Abstract

Hydro-geochemistry of samples collected from both surface and subsurface regimes were studied from different locales of Damodar river basin. The primary aim was to assess the quality and suitability of these water resources for irrigation, potability and other ancillary uses by local inhabitants. The analytical findings were plotted in geochemical facies diagrams to find out the variability in water quality over this hydro-geographic province. It is found that calcium and bicarbonates are the dominant ions in all the samples analyzed, with concentrations increasing from surface to subsurface environment. The TDS of subsurface water is substantially higher than surface regime which may be due to its long residence time within the host rock. The Piper trilinear diagrams reveal that Ca-Mg-HCO₃ is the dominant hydro-chemical facies in surface water while Ca-Na-HCO₃ is common in subsurface samples. The Wilcox diagram, which shows the plot of percent sodium with the total ionic abundance, indicates that surface water chiefly falls within excellent-to-good quality class, while the subsurface samples bear good-to-permissible quality standard. Gibbs variation diagram shows that rock weathering plays the key role in controlling the hydro-geochemistry of the Damodar river basin. Comparison of water quality parameters with prevalent environmental standards indicates that, with few exceptions, the raw water is fit for drinking and irrigation use and is free from alkali and salinity hazards.

Key words: Damodar river basin, geochemical characteristics, hydrochemical facies diagrams, surface and subsurface waters, water quality parameters
2. Environmental Isotope Hydrogeochemical Investigation for Characterisation of Groundwater in Tiruvanmiyur Coastal Aquifer, Tamil Nadu, India

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Abstract

Environmental isotope techniques ($\delta^{2}H$, $\delta^{18}O$, $^{3}H$ & $^{14}C$) have been used along with geology, hydrogeology and hydrochemistry for characterising groundwater of Tiruvanmiyur coastal aquifer. This aquifer has been developed along the coast of Bay of Bengal in the southern part of Chennai Metropolitan Area. The main objectives of the investigation were to understand the hydrodynamics and geometry of the multiaquifer system, interconnection between aquifers, source of groundwater salinity, dating of groundwater and source & origin of groundwater recharge. Water samples collected from different aquifers, surface water bodies and precipitation were analysed for major & minor chemical species as well as environmental isotopes $\delta^{2}H$, $\delta^{18}O$, $^{3}H$ and $^{14}C$. The combined interpretation of hydrogeology, hydrochemistry and isotope data suggests that the investigated area is characterized by two-aquifers system, viz., top sandy unconfined aquifer and weathered & fractured semi-confined aquifer. In general, the quality of groundwater in unconfined aquifer is fresh and is brackish in semi-confined aquifer. In the northwestern part groundwater in unconfined aquifer is fresh and is brackish in semi-confined aquifer. In the northwestern part groundwater is saline in both unconfined and semi-confined aquifers and their chloride values are in the range of 9,900mg/L to 10,500mg/L. Saline groundwaters are highly depleted in stable isotopic content compared to modern seawater and they have negligible tritium content. Groundwater salinity in these aquifers is due to mixing of entrapped old seawater as well as water – rock interaction. The brackishness of groundwater in the semi-confined aquifer is due to contribution of recharge from Buckingham canal and marshy land and leaching of salt from the formation. The two aquifers are interconnected in the eastern part of the study area, where as in the other parts they are not interconnected. The unconfined aquifer receives precipitation as the only source of recharge, except western part of the study area, where, the recharge is from both precipitation and surface water bodies. The semi-confined aquifer receives recharge from rainwater collected in the depression on the western side of canal and lateral flow across the study area. The existing surface water bodies also contribute recharge to this aquifer. Carbon – 14 results indicated that the fresh groundwater in unconfined & semi-confined aquifers are modern, except the saline groundwater in the northwestern part, where the uncorrected age is 6900 years old and brackish water is 11000 years old.

Key words: Environmental isotopes, coastal aquifers, Chennai, salinity, groundwater, semi-confined aquifer.
3. Problems and Perspectives of Projecting the Artificial Drainage in Arid Zone of Central Asia

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Abstract

In Central Asian Region (CAR) water is one of the most important factors defining the possibility for life and development in an arid zone. New Independent States of CAR acquired independence in 1991, namely the Republic of Kazakhstan, Kyrgyz Republic, Republic of Tajikistan, Turkmenistan and Republic of Uzbekistan. General area of region territory is about 3882 thousand square kilometers with the population of more than 53 million people.

Arid climate and irrigated nature use contribute to land and pasture land degradation, which leads to significant decrease of agricultural productiveness. Significant parts of irrigated areas are subject to salinization, which is 16% and above in Tajikistan, up to 30% in Kazakhstan and about 70% in Turkmenistan. Therefore, today the decision of tasks in the field of melioration and obtaining the supplementary sources of irrigation water has great importance. In every individual case the possible complex of measures and their mutual combination must be defined in view of natural conditions, technical economic purpose orientation. Surface and underground water-carrying horizons, vertical drainage, open and closed horizontal drainage, ant-filtering covers, machine irrigation and biotechnical drainage should be used widely in the complex of engineering constructions and measures in irrigation-melioration building. Often, while conducting meliorative hydrogeological works, the proper attention is not paid neither to water balance and the balance of territorial groundwater nor to possible changes in position of level and mineralization of groundwater. For irrigated lands the main components of subterranean water balance are filtration loss of irrigation waters, total evaporation from the soil and artificial drainage throw of water. In Tajikistan the underground waters for irrigated lands are spent mainly on natural and artificial drainage flow and the total evaporation from the ground surface. The very fact of evaporation from the ground surface is the cause of that there are still great areas of salinized lands. At the first stage of developing the virgin lands with the shallow soil the main part of filtration losses is to fill up the volume (static) store of underground waters, thus causing the corresponding rise of their level. The surface and underground waters in Tajikistan are characterized by the considerable variety in mineralization degree and chemical composition. The least mineralized groundwater is observed near the filtration river sites and irrigation canals. The most marked difference in chemical composition of republican irrigation waters is observed in chloral ion contents, on the base of which the evaluation of ground salinization degree is given for the areas with sulfate and sulfate chloride salinization. It should be mentioned that in Tajikistan the land salinization does not result in falling of free soluble salts into solid sediment. This is explained by the fact that lands in
Tajikistan, which are subject to salinizing, are characterized by the running of groundwater. At the same time sulfate and other more hardly soluble salts fall into solid sediment, right up to forming the independent layers in soil grounds. Lands, irrigated for the long time, are characterized also by comparatively broad development of ground salinization. The part of these lands in the republic is over 116,000 ha. This situation is caused by the scanty development of drainage or its neglected condition, and as well by the insufficient depth of horizontal drains. As to amelioration, the only thing is poor – in conditions of two-tier geological structure of these lands the main part of salts is focused in the most upper layer of soil grounds. At the same time limited salt store and broadly developed bedding pebbles, which easily absorb water, with fresh subterranean and forceful waters are potentially favorable factors for relatively fast ameliorative improvement of these lands, if vertical drainage is possible to apply.
Abstract
Asundi Nalla Watershed (ANW) is 5th order basin. The hard, compact, less weathered/fractured greywackes are the litho units in the watershed. The watershed experiences very heavily scattered rainfall and has experienced mild drought for last 15 years. The hypsometric analysis shows that ANW is in its mature stage. The groundwater occurs under phreatic conditions. The uncertainty in water bearing aquifers is due to complicated nature of aquifer characters. The bore wells close to lineaments yield more than those away from the lineaments. The depth and yield relations of 306 bore wells are studied. The depth of bore wells range from 70 to 110 meters and their yield varies from 1 to 4 lps. The study reveals that central and northeastern parts of ANW are suitable sites for future groundwater development with optimum depth of drilling is 120 meters. Topography and aquifer characters control the yield of bore wells in ANW.
Abstract
Groundwater in coastal regions is usually deteriorating by seawater intrusion. The towns and villages of Krishna delta are facing fresh groundwater problems because of transforming fresh groundwater to brackish/saline. Hydrochemical study has been carried out for the identification of hydrochemical parameters, which can be used for demarcating the fresh groundwater zones and identify the seawater intrusion processes. Groundwater samples were collected and analyzed, and indicate that (1) $\text{HCO}_3/\text{Cl}$ and TDS are fairly reasonable indicators for the identification of fresh groundwater in coastal aquifers, (2) Sr and B are found to be indicators for such delineation, and (3) Na vs. Cl, Na vs. EC, Cl vs. EC and Mg vs. TDS have been found reasonably good for the estimation of the intensity of seawater intrusion and their space time variations.

Keywords: Krishna delta, Trace elements, TDS, Seawater Intrusion, India.
ABSTRACT: The availability of ground water is non-uniform in space and time. Hence precise estimation of ground water resources is essential for planning its development. National Water Policy, 2002 of India also stresses the need for periodical assessment of ground water resources on scientific basis.

In India, extensive and intensive studies on evaluation of ground water resources were undertaken through multi-disciplinary ground water balance projects in varied hydrogeological conditions across the country. The first systematic approach for state-wise estimation of the ground water resources was made in 1979. The methodology was subsequently modified based on the findings of the water balance projects and improvement in database and was known as GEC’84. The present methodology being used for ground water resources assessment of the country is GEC’97. This paper discusses various methods for assessment of ground water resources adopted in India and suggests future refinements in the assessment methodology.
7. Assessment of Groundwater Reserves: A Case Study

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Abstract
Assessment of groundwater reserves to a basin in granite, having an area of 6100 Square Kilometer in Andhra Pradesh, India, has been measured by artificial tritium tagging method. Tracer was injected at 46 selected locations before the onset of monsoon covering various soil types. Annual replenishment of groundwater reserves of the drought prone area, due to percolation of fraction of the annual precipitation, has been quantitatively estimated. Vertical soil profiles, down to a maximum depth of 330 cm were collected. Soil moisture content and tritium concentration (T.U.) were measured for every 10 cm section of the soil moisture profile. Moisture content and tritium concentration of the soil cores collected after monsoon were measured in the laboratory. Tracer displacement was estimated by using the variation in tritium concentration vs moisture with depth and the same is measured for estimation of recharge. The recharge values calculated from moisture content and displacement of the tracer peak in the study basin were found to vary from 2.90 cm to 17.9 cm. The mean recharge value for the entire basin was computed as 2.60 cm i.e. 4.2% of the average annual precipitation. This gives an annual groundwater reserves in the study area of about 140 MCM.

Keywords: Tracer, Recharge, Groundwater Reserves, Drought Prone Area, India.
Abstract
The present water policy in Qatar is to use groundwater resources primarily for agriculture and construct desalination plants for provision of drinking water. In the time being, groundwater resources in the Rus and the upper Umm Er Rhaduma aquifers are devoted for agriculture. The average annual recharge for these two aquifers, from the year 1971/1972 to the year 2002/2003, is about 58 Million Cubic Meters (MCM) while the total abstraction increased steadily from 42.6 MCM in 1971/1972 to 215 MCM in 2002–2003. Obviously, the main problem facing groundwater management in Qatar is the provoked discrepancy between demand that is in upsurge and replenishment that is in short supply.

A groundwater quality monitoring network was established in the year 1971 to observe the aquifers under use in order to continually follow up with water quality status as a consequence of groundwater abstraction or recharge.

The purpose of this paper is to describe the existing groundwater quality monitoring network, assess groundwater quality deterioration in the last thirty years of operation and suggest the needed development for such a network in order to overcome its noticed shortage and perform its main and original function.

The results of the assessment demonstrated groundwater quality declination to a serious extent that can reach irreversible level in few years in case of not taking suitable measures in the very near future. Some applicable suggestions were identified. In addition to that, the monitoring network deficiency was recognized and a program for potential development is proposed.
Abstract
The Bayalish Mouza basin within Kathajodi River basin of Orissa is a typical river island surrounded by the Kathajodi River and its branch Surua. Agriculture is the main occupation of the inhabitants and groundwater is a major source of irrigation. Ample water is available in the monsoon season and even some area remains waterlogged during this time. But farm ponds dry up towards the end of February and groundwater is not enough to meet the agricultural water requirements during the post-monsoon and summer season. The present study focuses on the hydrologic and hydrogeologic analyses of this basin to explore the possibility of enhanced and sustainable groundwater supply. The streamflow analysis showed that the river flow is highly seasonal and it reduces very much during summer season. The hydrogeologic analysis indicated that a confined aquifer exists comprising medium to coarse sand. The aquifer depth ranges from 20 to 40 m below ground level with its thickness varying from 12 to 56 m. Overall groundwater flow is from north-west to south-east direction. The groundwater level drops by 3 to 6 m during dry periods, with April-May being the most critical months. The daily groundwater-level data show a good correlation with the rainfall, suggesting significant groundwater recharge from rainfall. Apart from rainfall, groundwater aquifer has good interaction with the Kathajodi River also. Construction of a series of check dams with spillways along the main natural drain, construction of a few more water harvesting structures in the upper portion of the basin and numerical analysis is recommended for exploitation and sustainable use of water resources in the basin.

Key words: Checkdam, groundwater, hydrogeology, streamflow, Kathajodi River basin, Orissa
10. Delineation of A Ground Water Zone Using Airborne and Ground Magnetic Data in a Part of Basement Complex West of Cuddapah Basin-A Case Study


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Abstract

Total intensity aeromagnetic maps of hard rock terrenes provide useful information in isolating fault/shear/lineament patterns, lithological variations, shallow and subsurface inhomogeneities with in the crustal rocks. Aeromagnetic data collected over a part of exposed granite-gneiss basement complex west of Cuddapah basin (14 30 N 14 35 N lat. And 77 40 E and 77 50 E long.) has been analyzed in conjunction with the drainage pattern and well information to locate potential ground water zones.

Ground magnetic data has also been collected along a north- south profile of length 2500 m with a station interval of 20 m across an inferred fault/shear zone. Analysis of this ground magnetic data indicated a concealed thin dyke with in the shear zone traversing in approximately east - west direction. This dyke seems to have been acting as a subsurface barrier for the ground water to flow towards north. This structural barrier appears to have been helped for the formation of a good drainage net work and aquifer zone towards south near Battulapalle in the study area.
11. Demarcation of water filled voids and Identification of Old Workings in Coal Seams – Geophysical Approach

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Abstract
Exploration of water filled voids of old workings is an important problem for coal mining industry in India. Due to this problem, disaster like inundation may occur. Experimental geophysical investigations have been carried out in one of the coal mining areas of Bharat Coking Coal Limited (BCCL), Dhanbad to find the feasibility of finding the barrier thickness of coal seams in underground mining area. The area under study forms the southern part of East Basuria Colliery located in northern part of Jharia coalfield in Dhanbad district, Jharkhand State. The coal bearing rocks of Barakar formation of Lower Permian age (Gondwana) occurs in the area under a thin cover (10 to 15m) of soil and or alluvium. Coal bearing Barakar formations consist predominantly of sandstone of varying grain size, intercalation of shale and sandstone, grey and carbshale and coal seams.

Water filled formations and empty old coal workings are expected to have significant resistivity contrast with surrounding host rock. Hence, experimental studies were carried out using high-density resistivity survey (resistivity imaging) and mise-à-la-masse technique to find out if these old workings can be detected from the surface measurements. A 2-D resistivity section was obtained up to about 30m depth with Pole-Dipole configuration and up to about 70m depth using Pole-Pole configuration with an inter-electrode spacing of 2.5m.

The resistivity imaging has clearly indicated the water-bearing zone along the profile. At the same time resistivity imaging did not indicate the size of the coal pillar and gallery (empty voids), which might be due to the small size of the voids (i.e. about 3m x 2m) below a depth of 15m and more.
12. A Comparison of Ground Water Quality in Two Agricultural Dominated Districts of Punjab, India

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Abstract

Patiala and Muktar districts are two major agricultural districts of Punjab in India. The consumption of fertilizer is maximum in Punjab among the all-Indian states. Present study focuses on the quality parameters and is carried out for the pre-monsoon and post-monsoon seasons in 2003. Comparison of the concentration of the chemical constituents with different standards, Geochemical classification and classification for agriculture utility shows that present status of ground water in Patiala is better for irrigation purpose and drinking purposes (except a few location) but it may become deteriorated in future. While in case of Muktsar it is unsuitable for drinking in the entire districts. It is also not suitable for irrigation purpose. This water can be used after soil treatment or soil having sufficient permeability or leaching and also excess of irrigation water is required.

Salinity in the study area is related to: a) dissolution in aquifers, b) mixing of ground water, and c) irrigation return flow. Initially weathering process controls the chemistry of ground water and later dominated by secondary leachate fertilizers and other anthropogenic activities. Due to abnormal concentration of ions in ground water nature of water is brackish to salty in the study area. In the study area natural recharge is minimum due to the presence of impermeable alluvium (clay) that may not allow the major portion of rainwater to percolate and recharge the ground water. Results provide a baseline for the ground water quality.
Abstract
Locating favorable groundwater zones in granitic terrain is difficult task, as the groundwater in such terrain is controlled by the secondary features such as faults, fractures, lineaments and dykes. Although these features can be identified from photogeological or satellite imagery maps, their nature of occurrence is highly variable. Therefore, there is always a need for locating and pin-pointing the favorable location.

To identify such linear features for further groundwater prospects in granitic terrain, profilings with different electrode separation across the known lineaments followed by vertical electrical sounding (VES) with 100 to 200 m current electrode separation were conducted along the lineaments in granitic terrain for pin-pointing the groundwater potential zone. Vertical Electrical Soundings with Schlumberger configuration and profiling were conducted in Nalgonda District, Andhra Pradesh, India. The entire area is underlain by granite and gneissic complex. The VES curves were interpreted with conventional curve matching techniques and then by Inversion Method to know the resistivities and thickness of different sub-surface layer.
14. Groundwater Resource Quantity and Quality Assessment in Khudiya nadi watershed, a part of Damodar River Basin, Jharkhand, India


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Abstract

Damodar River Basin is a repository of 46% Indian Coal reserve. Exploitation of coal and related industries in this area has exerted a great impact on the water environment of the area. The Basin is spreaded over an area of 23,170 sq.km. falling into two states Jharkhand and West Bengal. It comprises of six coalfields and more than 100 major industries including of thermal power plants, coke ovens, coal washeries, steel plants, fertilizers and other coal based industries. Khudiya nadi watershed in Dhanbad district, which is a part of Damodar river basin, has been selected for detail study.

Coal mines in the basin have caused significant impact on ground water both in terms of quantity and quality. Huge pumping is being done to facilitate safe mining in underground mine. Opencast mines lower the water table of the area and also deteriorate the ground water quality prominently in terms of TDS, SO_{4} and hardness. The water table fluctuation studies clearly illustrate the gradual depletion of water table in the area. However water balance studies shows that the watershed area is still at present under “White category”. The study reveals that there is no dearth of groundwater potential in the watershed area.

Thus, the paper highlights in brief the geological, geomorphological, and landuse pattern of the Damodar river basin area and detail groundwater quality and quantity assessment in the watershed region which is being affected by various mining and industrial activities.
15. Artificial Recharge Methods of Groundwater

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Abstract
Ground water is the largest source of fresh water available on earth, which is exploited to satisfy our needs for domestic, agricultural and industrial purposes. Surface water sources are limited in nature and open land for natural recharge is also decreasing day by day. More abstraction of groundwater in comparison to natural recharge results in depletion of groundwater storage. More storage of water behind dams and especially in aquifers via artificial recharge is necessary to save water in times of water surplus, for use in times of water shortage. Limited natural rainfall-recharge and increased water usage throughout the country calls for conservation as well as augmentation by artificial recharge. Variety of methods have been developed to recharge the groundwater such as direct surface recharge, direct subsurface recharge, combination of surface and subsurface recharge, indirect recharge.
Abstract
Groundwater constitutes a major national resource providing fresh water supplies not only in remote locations but also in the areas where surface water sources are being exhausted due to recurrent failures of monsoon. Consequently location and exploitation of the aquifer system for domestic or agricultural demand is crucial in water management system.

Several geophysical techniques viz. resistivity, frequency and time domain electromagnetics have been developed and are being extensively used by the scientists to solve the groundwater problems.

Self-Potential methods are rarely used in groundwater exploration, though they are used in mineral exploration quite extensively. Self-Potential effects caused by fluid movements in porous materials are also known as Streaming Potentials (Simon S. Baker and James P. Will, 2004) may be measured and used as the indicators of groundwater movement in favourable geological conditions. The variations in the amplitudes of the Self-Potentials in the Khondalitic terrain of Orissa and Granitic terrain around Hyderabad and their possible relation with groundwater movement have been studied and presented in this paper.

It is observed that the potential aquifer systems in Khondalitic terrain has yielded Self-Potential anomalies varying from 50 mv to 80 mv amplitudes and aquifers in Granitic terrain has given Self-Potential amplitudes ranging from 10 mv to 25 mv. It is also observed that the Self-Potential anomaly amplitudes in Khondalitic terrain are as high as 160 mv when the groundwater is contaminated with tailings of the graphite mines. However, before establishing the effectiveness of the Self-Potential method, calibration process of the streaming potentials is required to link hydrological models with geophysical data in complex situations.
17. Floodwater Infiltration - Results from a Multi-Tracer Experiment

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Abstract
Floodwater infiltration and groundwater recharge in arid and semi-arid zones is studied intensively world-wide. Scientific efforts to understand the processes involved in floodwater infiltration and groundwater recharge arose from the realization that groundwater in shallow alluvial aquifers is the only renewable water source in arid environments. Moreover, in recent decades population growth and a tremendous increase in agricultural activities, due to convenient climatic conditions, have dramatically increased the water demand in arid environments.

In this study the process of floodwater infiltration was investigated using a novel technique that allows complete monitoring of percolation through a set of probes designed to detect and sample the percolating water all along the vadose zone, from the surface to the groundwater. The experimental set-up used special flexible TDR probes to monitor the infiltration process, and special sampling ports designed for continuous sampling of the percolating water.

The study site is located in a hyper-arid area in the central Arava Rift Valley of Israel, where a shallow alluvial aquifer is infrequently replenished by floodwater percolation. The monitoring system in this site consists of five sampling ports and five flexible TDR probes that were installed at different depths from the surface to the water table (4 m b.s.l.). The probes and sampling ports were installed in a slanted borehole drilled underneath the center of the stream channel. A controlled percolation experiment designed to simulate a typical flood event was performed in a large pond (7x9 m) specially constructed for the experiment. Five infiltration rings were installed at the bottom of the pond, one on top of each sampling port. Two tracer tests were conducted at different stages of the flooding. Ten different chemical tracers were injected into the ring infiltrometer. Five fluorinated derivatives of benzoic acid were used in the first tracer test and five other chemical tracers (Br-, Li+ and 3 fluorescences: Eosin, Uranine and Sodium Naphthionate) were used in the second test.

The results show quick infiltration with a complex percolation mechanism that involves spreading of flow lines and preferential flow mechanisms in a dual porosity system. The
results reflect the effect of heterogeneity of alluvial sediments on the infiltration process, emphasizing the vulnerability of those aquifers to pollution processes.

**Key words:** tracer tests, groundwater recharge, unsaturated zone, soil water sampling, floodwater infiltration.
Abstract
Mechanisms and rate of groundwater recharge has been assessed in near Tombouctou, Republic of Mali, by the use of chloride budgets. The area has a Sahelian climate and receives a rainfall of 225 mm. Two clusters of wells and three soil water profiles were sampled for the purpose. For the well cluster away from the river Niger near the town of Tombouctou a mean recharge of 3.7 mm was found while the soil profiles showed recharge rates of 2.1, 3.8 and 4.2 mm, respectively. The recharge occurs preferably in depressions between dunes due to channelling by soil crusts on the slopes of the dunes (Ribolzi et al., 2000) (Fig. 1). The scanty vegetation is transpirates about 50 mm while thus most of the rainwater goes for evaporation. During the dry season gypsum needles can be seen in the surface sand in the depressions. Occasional contents of high nitrate in soil and groundwater may be due to the N-fixation by cyano-bacteria found on the soil surface (Garcia-Pichel et al., 1996).

Fig. 1. Lateral flow and recharge in dune sand areas near Tombouctou

The groundwater recharge satisfies the water use by the local population. The main threat to their livelihood is the availability of grazing and browsing for their herds of camels, cows, sheep and goats.

References
19. Estimation of Natural Recharge to Phreatic Aquifers in a Granitic Basin

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Abstract
The natural recharge to the phreatic aquifer of a river basin in granites is estimated. Tritiated water was injected before the onset of monsoon rains at 45 selected sites in this basin having an area of 8650 Square Kilometer covering different soil types. Moisture content and tritium activity of the soil core profiles collected from the injected sites after the monsoon rains were measured. The variation in tritium activity and moisture content with depth is used for studying of tritium movement and estimation of natural recharge. The recharge values were found varying from 2.6 cm to 9.4 cm with the mean value of recharge as 2.9 cm corresponding to the rainfall of 61.5 cm. The quantum of natural groundwater recharge to phreatic aquifers through vertical infiltration using injected tritium technique has been estimated as 211 Million Cubic Meters (MCM).

Key words: Natural Groundwater Recharge, Tritiated Water, Phreatic Aquifers, Granites, India.
Abstract
Kallugotla Watershed in Kurnool district of Andhra Pradesh, located in semi arid region, experiences scarcity of water for drinking and irrigation. The Watershed (25 km²) covered by limestone-quartzite terrain of Upper Precambrian age, receives an average annual rainfall of 550 mm. Integrated Geohydrological investigations comprising resistivity surveys, Hydrogeological surveys, bore hole pumping tests, natural recharge studies were carried out in the Watershed for selection and design of artificial recharge strategies for sustaining the yield of irrigation bore wells. Based on the investigations, few Watershed specific artificial recharge strategies were suggested and implemented in this Watershed.

Natural recharge rate due to combined effect of rainfall and applied irrigation was measured at 6 sites in the Watershed area during 2000 monsoon using tritium tracer technique. The result indicates average recharge of 105.4 mm for the seasonal rainfall of 585 mm and irrigation input of 377 mm. The natural recharge and water level fluctuation data obtained in this Watershed with the recharge measurements made in the adjacent Watershed was used for estimating natural recharge due to rainfall and return flow due to applied irrigation independently. Dye and chemical tracers were used in tracer experiments for delineating flow pathways during the time of groundwater recharge through the artificial recharge structures. The tracer data obtained was used for determining the influencing zone and beneficiary wells due to artificial recharge structures. The tracer studies indicated that the recharge is taking place through dipping (3° - 5°) dipping planes towards south and moving against the topographic slope and stream flow direction.
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Abstract
Delhi quartzite ridge, the northern most tip of Aravalli range, acts as the most potential recharge zone for the aquifers underlying not only the ridge area but also underlying the surrounding alluvial areas. Ground water regime in quartzite terrain is in hydrological continuum with that of adjacent alluvium as inferred base on the detailed ground water flow patterns and depth to water levels in the study area. Moreover, because of the continuous recharge from the ridge, the fresh/saline water interface is pushed to deeper levels near the ridge, which rises to shallow depths away from the ridge. The aquifer in quartzite terrain, highly fractured/jointed in nature with substantial thickness of overburden material, provides good recharge environment for aquifer underlying the surrounding areas.

Detailed watershed pattern in the area has been studied. The area can be divided into 26 watersheds of different dimensions. Out of these, 17 watersheds fall in NCT, Delhi and 9 watersheds in Gurgaon and Faridabad districts of Haryana. It is estimated that about 6.875 MCM of rainfall runoff is available in a normal rainfall year from the 17 watersheds of NCT, Delhi. Though the runoff available in these watersheds is being completely harnessed through check dams and bundharas constructed during the historical period which created open ponding for recharge purpose, the desired impact on ground water regime is not being observed as the sites for construction of check dams and bundharas were not selected based on the proper scientific studies and filtration characteristics of an area. Check dams constructed recently by Central Ground Water Board and Delhi Development Authority in JNU-IIT-Sanjay Van-Vasant Kunj-II and Kushaknala watersheds, which are having the recharge efficiency of about 90 to 95%. An attempt has been made to identify a few more sites for construction of nalabunds and check dams, which can have high efficient recharge rates. Apart from these nalabunds and check dams, recent urbanization of the ridge area has resulted into generation of lot of runoff from the urbanized environments which can also be utilized for recharging the depleted aquifer through cost efficient structures like recharge shafts and trenches associated with recharge tubewells. Attempts has been made to standardize the designing characters of recharge structures in urbanized environments through a few case studies and filtration rates of their recharge structures and recharge tubewells.
22. Artificial Recharge in Hard Rock Areas of Coimbatore District- A Case Study

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Abstract

Water is a basic human need and a precious national asset. Groundwater is the basic source of water supply in many semi-arid developing countries. In some areas, water withdrawals are so high, relative to supply that surface water supplies are shrinking and ground water reserves are being depleted faster than they can be replenished by precipitation. Agriculture is by far the biggest user of water, accounting for over 70 per cent of water and over 90 per cent in the case of low income countries. The phenomenon of ground water exploitation is much more pronounced in the state of Tamil Nadu, which depends heavily on ground water for domestic, industrial and irrigation purposes. This is mainly because of uneven distribution of rainfall. It has been observed from many studies that there has been a continuous decline in ground water table in the state. It necessitated the importance of augmenting groundwater resources particularly by artificial recharge structures. With this view the study was undertaken to test the effectiveness of AR structure in hard rock areas of Coimbatore district.

Coimbatore district is located in the western part of Tamil Nadu state. The district is bordered to the west by the mountains of the Western Ghats but is dominated by the plains to the east. Kodangipalayam watershed is in the middle portion of the Noyyal river basin. The study was undertaken in this watershed covering two villages namely Karanampettai and Kodangipalayam (Latitude 11°02’00” to 11°04’00” N Longitude 77°01’00” to 77°14’00” E) of Palladam block of Palladam taluk of the Coimbatore district. The watershed covers Karanampettai micro watershed with the area of 1.408 sq.km. The elevation ranged from 307.7 to 325.0 m above MSL. The study area underlined by a wide range of high grade metamorphic rocks of the peninsular gneissic complex. The geological formations found in the area are charnockite overlying migmatite and banded gneiss cut by fractured pegmatite. Climatically, the area belongs to semi-arid climate. The annual rainfall is about 524±100mm with bimodal distribution of summer (March to May) and north east monsoon (October to December).

Topographic survey was carried out to identify the surface water catchment of the recharge structure, to obtain the geodetic heights (datum) at observation points, to know the stage volume relationship of recharge structure. Automatic weather station was installed to record the weather parameters. Automatic water level recorder installed in the recharge structure to record daily water level in the pond. Nine bore wells (NBW 1 to 9) were drilled and twelve open wells (KP 1 to 12) were also selected to monitor the water level data in the micro watershed. Water sampling for quality assessment was done from August 2003 to October 2004 for seven times and analysed for pH, EC, cations and anions using the standard procedure. The sampling periods also cover both before and
after monsoon periods to explore the impacts of artificial recharge on ground water quality.

The results of the ground water level variations in the monitoring boreholes (NBW 2 to 9) showed that in all bore holes the influence of recharge started on 29th days after the start of recharge structure filling. The influence of recharge continued up to three months from the start of recharge structure filling. The maximum water level rise found to be varying with the distance from the recharge structure. The nearest (64 m) bore well (NBW 9) from the recharge structure, recorded maximum water level rise on 48 days after the start of filling. In the far away (more than 400 m) bore wells NBW 3 and NBW 7, recorded maximum water level rise on 91 days after the start of filling the recharge structure. Bore wells situated in the radius of 165 to 217 m from the recharge structure, namely NBW 2, NBW 5, NBW 6 and NBW 8, takes about 60 to 65 days to record maximum water level rise. Cross-section groundwater levels in the study area indicated that the influence of recharge was much more higher in the closer wells (NBW 8 and 9), followed by NBW 2, 5 and 6 and lower in distanced wells (NBW 3 and 7). This is supported by minimum water level fluctuation in the nearby wells and maximum fluctuation in distanced wells.

The EC and chloride concentration affected with distance from the recharge structure. Very high salinity in far away wells, high salinity in medium distanced wells, medium salinity observed in hand pump (nearest monitoring point) which receive maximum benefit from the recharge structure leads to reduced salinity. On farm employment has increased due to the AR structure induced recharge of aquifer. Well failure percentage brought down to five percent and the hours of pumping increased from less than 2 hours to 3 hours, this makes farmers to go for relatively high value crops.
Abstract
The groundwater is not only an important component of water resources but also the major water supply source in hard rock area. The increasing population and demand for water and lack of sufficient safe surface water are causing over-exploitation of groundwater resources. Thus there is a need for sustainable development and management of the groundwater resources, which need to tap the surface run off water and enhance the recharge to groundwater resource.

Present study deals with Bairasagara watershed, Karnataka, India, where severe groundwater scarcity has occurred. Hydrogeological, geophysical and tracer studies have been carried out and found well corroboration among electrical resistivity, SP, water level fluctuation and tracer results. It helped in identifying the suitable sites for construction of artificial recharge structures for development of groundwater resources. The study also suggest that the combined application of different investigating tools particularly in hard rock areas will reduce the ambiguity, boost the result quality and the confidence level.
24. Sustainable Lei-Drainage Groundwater of Rawalpindi-Islamabad (North Pakistan), and the Potentials of Recharge

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Abstract
The Lei-Drainage-System of Rawalpindi-Islamabad in North Pakistan is about 210 km². Aquifer depletion, pollution, floods, droughts, urbanization, variability of rainfall, evaporation losses are the main challenges. Monsoon yields about 60 % of the total annual. Annual average is about 1,200 mm/a, 30 % flows off, 56 % evaporates and 14 % recharges the groundwater. Basin is recharged with 36 Mm³/a and about 35 Mm³/a of groundwater flows into it from the neighboring Kurang basin. Water-table drop is 1.40 m/a and more than 44 Mm³/a of groundwater is being over-mined annually.

In case of Islamabad, new environmental techniques can still be applied in the areas still under planning. The naturally sealed areas can be used for the construction of houses and buildings, etc. Since evaporation losses in dry period would be high, methods of recharge would be restricted to involving little surface exposure to sun and wind. Surface water spreading is fit for direct recharge in the periods of low evaporation. Small check or diversion dams can also contribute towards groundwater recharge. The remaining old ancestral village irrigation areas should be retained for groundwater recharge. Recharge system could integrate dried-lined-dug-wells. Broadly conceived measures would improve groundwater both qualitatively and quantitatively.
25. Groundwater recharge and management - A Case study from Coca Cola India

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Groundwater Balance Studies: Need to Investigate Scope for Increased Recharge – A Case Study

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Abstract
A detailed groundwater balance study was carried out in Suganadhi watershed, Tamil Nadu for understanding the level of groundwater utilization. The area is underlain by hard crystalline rock formations and groundwater occurs both in the weathered rock zone as well as the fractures in the unweathered bed rock. Groundwater levels are quite shallow, ranging from about 1 to 8m below ground level in the post-recharge period. Maximum groundwater level fluctuation is of the order of only 5 m (ave.3.5m). Large diameter dug wells form the most common way of groundwater abstraction for irrigation in the area, though borewells are almost exclusively used for supplying protected water for domestic use in the urbanized areas. The average depth of dug wells is about 10m while the average depth to bed rock is 14m in the area.

Water balance study was carried out using the methodology suggested by the CGWB. The area was divided in to 72 polygons with a monitoring well as the reference point for each. Specific yield for the weathered rock aquifer, estimated using the amplitude of groundwater level fluctuation in the dry season and the groundwater draft in the same period, varies from 0.01 to 0.1. The total available recharge estimated is 91.6 Mcm while the gross groundwater draft is 101 Mcm, giving a level of 95% groundwater utilization for the entire area.

However, it is observed that the groundwater fluctuation is quite small compared to the weathered and partly weathered rock aquifer thickness and thus there is scope for significantly increasing the quantum of available groundwater. This can be achieved by creating additional abstraction by increasing the well depth as well as abstraction per well. Considering the average specific yield of this aquifer zone, average aquifer thickness and current groundwater level fluctuation, it is estimated that an additional 21.5 Mcm of groundwater recharge can be added by creating favourable conditions during non-monsoon season – that is by increasing current abstraction. This is justified by the fact that at present, the groundwater levels recover to their original levels after recharge and there is no secular decline in them. This will change the classification of this watershed from critical to semi-critical, and thus amenable for further safe groundwater development.

Thus, it is necessary, while making a groundwater budget for a watershed to consider this aspect for achieving optimum development.
27. Influence of Artificial Recharge on Water Quality Parameters in Hard Rock Areas

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Abstract

Groundwater is the main source for rural water supplies in many developing countries. Over recent years, increasing abstraction to meet rising demand for domestic supplies and irrigation has raised concerns for the sustainability of the resource and the livelihoods it supports. Consequences of over-exploitation include declining water levels and increasing competition for scarce water resources between domestic and agricultural users and rural and urban communities.

Agriculture is by far the biggest user of water, accounting for over 70 per cent of water and over 90 per cent in the case of low income countries. The phenomenon of ground water exploitation is much more pronounced in the state of Tamil Nadu, which depends heavily on ground water for domestic, industrial and irrigation purposes. This is mainly because of uneven distribution of rainfall. It has been observed from many studies that there has been a continuous decline in ground water table in the state. It necessitated the importance of augmenting groundwater resources particularly by artificial recharge structures. With this view the study was undertaken to test the effectiveness of AR structure in hard rock areas of Coimbatore district and the impact of AR on water quality and livelihood trends.

Coimbatore district is located in the western part of Tamil Nadu state. The district is bordered to the west by the mountains of the Western Ghats but is dominated by the plains to the east. The district is underline by crystalline basement rocks, typical of much of peninsular India. Kodangipalayam watershed is in the middle portion of the Noyyal river basin. The study was undertaken in this watershed covering two villages namely Karanampettai and Kodangipalayam (Latitude 11°02’00” to 11°04’00” N Longitude 77°01’00” to 77°14’00” E) of Palladam block of Palladam taluk of the Coimbatore district. The watershed covers Karanampettai micro watershed with the area of 1.408 sq.km. The elevation ranged from 307.7 to 325.0 m above MSL. The study area underlined by a wide range of high grade metamorphic rocks of the peninsular gneissic complex. These rocks are extensively weathered and overlain by recent valley fills. The geological formations found in the area are charnockite overlying migmatite and banded gneiss cut by fractured pegmatite. Climatically, the area belongs to semi-arid climate. The annual rainfall is about 524±100mm with bimodal distribution of summer (March to May) and north east monsoon (October to December).

Nine bore wells (NBW 1 to 9) were drilled and twelve open wells (KP 1 to 12) were also selected to monitor the water level data in the micro watershed. Water sampling for quality assessment was done from August 2003 to October 2004 for seven times and analysed for pH, EC, cations and anions using the standard procedure. The
sampling periods also cover both before and after monsoon periods to explore the impacts of artificial recharge on ground water quality.

Water quality assessment revealed that Electrical Conductivity (EC) was very high (>2.25 dS/m) in far away wells namely KP 9, KP 7 and KP 8. Since the recharge water has to travel longer distance to reach these wells (roughly 90 days) leads to higher salinity level because of high interaction with aquifer material for substantially longer time. High level (0.75-2.25 dSm⁻¹) of salinity observed in medium distanced wells namely KP 1, KP 3, KP 4, KP 5 and lateral wells KP 10, KP 11 and KP 12 because of medium level of recharge structure influence. Medium level (0.25-0.75 dS/m) of salinity observed in hand pump, KP-HP (regularly pumped for bathing and washing cloths), since this is the nearest monitoring point (60 m) which receive maximum benefit from the recharge structure leads to reduced salinity. Recharge structure (KP- PP) and KP 2 (which collects only the rainfall run-off water) were of low (<0.25 dS/m) in salinity hazard. The chloride concentration also followed the same pattern with distance as Electrical Conductivity. Before and after recharge comparison of water quality showed that the quality has improved due to the artificial recharge.

The EC and chloride concentration affected with distance from the recharge structure. Very high salinity in far away wells, high salinity in medium distanced wells, medium salinity observed in hand pump (nearest monitoring point) which receive maximum benefit from the recharge structure leads to reduced salinity. On farm employment has increased due to the AR structure induced recharge of aquifer. Well failure percentage brought down to five percent and the hours of pumping increased from less than 2 hours to 3 hours, this makes farmers to go for relatively high value crops.
28. Role of Soil in Ground Water Protection

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Abstract
Pesticide contamination of ground water resources has become a major problem today as this water is used for drinking by more than 50 percent of the national’s population. Ground water especially of the agricultural areas is susceptible to contamination, as certain groups of pesticides are mobile in soil. Under certain conditions, some pesticides may leach to ground water from normal field applications. A key to protecting groundwater is understanding the role of soil in removing the contaminants. The study related to the role of soil in ground water protection is very important as the pesticides that readily leach beyond the root zone of the soil are suspected to have the greatest potential to pollute ground water. A work was initiated to study the role of soil (acidic soil from tea farm, organic carbon content 0.87-1.74%, loam to sandy clay loam) in ground water protection. Four pesticides representing different properties were included in the analysis. Among the pesticides under study dimethoate showed the highest vertical leaching while fenazaquin, quinalphos and deltamethrin showed negligible vertical leaching. The horizontal leaching in each case was negligible or not observed. High water solubility and low K_{oc} value of dimethoate might have enabled it to move through the soil profile but due to its degradation by microorganism the leaching was less than as expected. High K_{oc} values of fenazaquin, quinalphos, dicofol and deltamethrin showed low potential for leaching due to their high ability to bind with the organic matter present in the top soil. Thus, besides the acidic and loamy nature of the experimental soil, the presence of rich soil organic matter (SOM) might have offered more protection to ground water. Further, comparative study of the field soil and the autoclaved soil has confirmed the degradation of these pesticides by the soil microorganisms further reducing the chances of ground water contamination. Based on the experiment it was observed that the soil leaching potential (SLP), pesticide leaching potential (PLP) was responsible for the ground water contamination potential (GWCP). This study proved that the experimental farm selected here for the study will have lower probability that the above pesticides will leach and impact the ground water.

Key words: Ground water contamination, soil, pesticide, leaching
Abstract
Water is an essential basis for life. It is of utmost importance for health and dignity and without continuous access to clean water, social and economic development is simply not feasible. Production of food and industrial goods as well as human well being in social communities are highly dependent on this resource, which became a key issue of international development strategies in the last decades. The challenge is obvious. The dynamic growth of both the global population as well as the economic development has simply absorbed these achievements. At the beginning of the new millennium 1.1 billion people are without access to clean water and 2.4 billion people have no access to sanitation (UNEP 2000). The overexploitation of water resources has caused a direct threat to agricultural production in a number of regions and polluted water impacts industrial production negatively.

More than half of the world’s major water bodies are seriously depleted and polluted, degrading and poisoning the surrounding ecosystems and threatening the health and livelihood of the people who depend on them. One of the most significant effects of poor water supply and water sanitation are severe health hazards. For instance, approximately 4 billion cases of diarrhoea annually cause 2.2 million deaths, mostly among children under the age of five for instance. Water and hygiene interventions would be able to reduce diarrhoea on average by between one-quarter and one-third. On Global water budget, only 0.69% is available as fresh water in the form of rivers, lakes and groundwater. In the present day environment, good quality of water is becoming increasingly scarce. This problem can be tackled in many ways i.e., optimized use, waste reduction and reuse of waste water etc. In India most of the used water is untreated and allowed to drain through rivers, streams, canals, lakes and finally to ocean. These scenarios urge us to understand and respond with immediate necessary steps to follow water treatment and re-use. This paper focuses on optimum method and reuse of domestic and certain industrial wastewater through natural treatment and their working procedures. Treatment of the domestic wastewater is aimed at removing organic material, pathogens and toxic chemicals. Primary water treatment involves physical separation like removal of suspended solids through the use of settling tanks and it removes the BOD from 30% to 40%. Secondary treatment uses microbial degradation to reduce the concentration of organic compounds further; it involves microbial processes, which can be aerobic and anaerobic. The combined use of primary and secondary treatment reduces approximately 80% to 95% of the BOD. Finally, depending on the usage point and regulatory requirements, the optional tertiary treatment using chemical oxidants to remove residual organic compounds and pathogens can be employed.
Abstract
The importance of ground water to meet the growing demand of our nation for its ever-increasing agricultural, industrial and domestic growth needs little emphasis. Though the overall extraction of ground water is only about 35% in India, it is more than 80% in southern states and in Tamil Nadu the ground water level is more than 300 m in many parts and the water mining is continuing as there is no law to control the extraction.

Watershed development program is taken up by the states and central governments in a big way in order to augment the ground water for the last three decades on watershed basis. Soil and water conservation and water harvesting measures are implemented by various departments and NGO’s under this program with the objective to use the land and water resources to get maximum benefit with the involvement of people living in the watershed mainly to recharge the ground water in order to maintain the water table for sustainable agricultural production. In India thousands of crores of rupees are spent every year by various agencies for watershed development, but still we have to go a long way to achieve the objectives.

In this paper, the impact studies carried out by the researchers / scientists on watershed development works mainly in recharging the ground water in different parts of the country are analysed. The following are some of the results in brief, how it is helped in augmenting the ground water in all the places.

The study conducted at Tamil Nadu Agricultural University, Coimbatore, by construction of percolation pond and check dam enhanced the storage capacity and the ground water levels in the wells have increased from 0.5 m to 5 m and the cropping intensity in the area has increased from 100% to 134%. From the trace techniques, it is found that the zone of influence due to percolation pond and check dam extend to about 750 m to 1200 m. It was also reported by the farmers in this area that about 3 m raise in water level and pumping has been increased considerably due to watershed development.

The studies conducted by the ICAR centres for soil and water conservation research in various watershed have demonstrated the water table rise, increased irrigated area, increased recuperation, increased irrigation intensities and crop diversification etc. Studies conducted in Kallambella watershed in Karnataka, Kandi watershed area in Punjab, National Institute of Hydrology, Roorkee Uttarakhchal, Minor irrigation department of Andhra Pradesh have indicated the impact of watershed development works in ground water augmentation especially in drought affected areas.

This paper gives the results of case studies for about ten locations in various parts of the country.
Agriculture has always been an important part of the economy and cultural heritage of our country. Although the number of farmers has declined over the last fifty years, food and fiber still accounts for a large percentage of the gross national product. Because of the scientific and technological advancements occurring, farms have become more automated, specialized, productive and increasingly dependent on off-farm inputs. Among these commercial fertilizers and pesticides have been widely used to save time and labor.

However, environmental concerns about agrichemicals, especially pesticides are growing. These concerns revolve around long-term hazards to the consuming population, the wildlife and to the environment, generally including surface and groundwater. Agriculture is one of the most, if not the most, pervasive contributors to non-point source pollution of surface and groundwater.

The paper aims at reviewing the status of agrichemical contamination of groundwater in our country. Whether the widespread occurrence of agrichemicals in groundwater implies chronic mismanagement of these substances or reflects the consequences of normal, label specified field use is not clear, nor is the full extent of the problem known with the current crop of technology available. Historically, agricultural policies and programs have played major emphasis on increasing production. However in the future, protecting environmental and public health could be considered as important as enhancing agricultural production. The tone is set for increased legislative and executive attention to agriculture’s impact on the environment.
Abstract
Nilgiris hills are situated in the north western corner of Tamilnadu, bounded on the north by Karnataka on the west and the southwest by Kerala and on the east and the southeast by Coimbatore district. The Nilgiri hill consist of a well defined plateau situated at the junction of the two great ranges of hills of the Deccan peninsula viz, the Eastern and the Western ghats. The network of stream rising from the Nilgiri plateau resolves it self into the following principle river systems. Pykara river which rises as the Mukuruti stream on the grassy slopes of the Mukurti peak, receives water from the west the Kurmund and Parson’s valley stream drains the extensive west of the plateau and plunges down a steep valley by a series of falls into the low country near Gudalur Hydro-electric power constituted 25.2% of the total power generation in the state (of the total installed capacity of 7905 MV). There are seventy five watersheds in Nilgiri district. In that seven silt monitoring station were installed. The one at Mynaly shows highest run off and rate of silt accumulation is also high. The total area covered 1977 Hectares and the name of the catchments is Lower Bhavani. The slope range is 4% to 39%.

The average rate of sedimentation was 0.6326525ha.m/100sq.km(s).analysing the four year silt data indicates that in the year 2001-2002, the rate of sedimentation was higher 1.19648 Ha.m/100sq.km (s).The reason for the highest rate of sedimentation may be higher rainfall or the slope range of the particular area. On the other hand, in that silt monitoring station at Moyar have been lowest run off water and the rate of siltation was also less. The total area covered 810 hectares and the name of the catchment is Lower Bhavani. The slope ranges from 3% to 48%. The average rate of sedimentation is 0.6326525Ha.m/100sq.km(s) in the Moyar region.

Key words: Silt Load, Water Shed, Monitoring, Niligiri District, Tamilnadu, India
Abstract
Salalah is situated on a fresh water aquifer that is replenished during the annual monsoon season with an average precipitation of 252 mm/year in Al Qara Mountain and 114 mm/year in the Salalah plain. Salalah plain aquifer is the only source of water in the city for a population of more than the 134,000 currently inhabitants living in the city. Rainfall recharge in the Al Qara Mountain supplies the plain with significant renewable fresh groundwater resources that have allowed agricultural and industrial development to occur. In Salalah city where groundwater is used extensively since the early 1980s for agricultural, industrial and municipal purposes, groundwater is withdrawn from the aquifer more rapidly than it can be replenished by natural recharge. The heavy withdrawal of large quantities of the groundwater from the aquifer leads to the encroachment of seawater. Agricultural activities usually utilize over 80% of the groundwater.

For the last 10-15 years the aquifer is facing acute challenge due to the over-extraction that has taken place since the 1980s and led to salinity intrusion problems. The water budget presented in this paper shows that the renewable groundwater resources meet only the 65% of the present demand. The water budget for coming years is predicted and shows that the deficit will increase. The prediction shows that the shallow on-farm wells will virtually lead to abandon the farming activities if no solutions are implemented since excess salinity in many wells will occur. The paper suggests a number of recommendations to be taken into account in order to protect the aquifer from further deterioration. A very urgent suggestion of this paper is to take an immediate action to relocate Garziz farm and the fodder production farm of MAF. The two farms located on the freshwater zone and pump currently almost 24% of the total discharge for irrigation on the plain. Another measure is to conduct the reuse of the treated wastewater in Salalah plain in order to halt seawater intrusion. These measures would improve the water supply situation for Salalah.

Key words: Salalah coastal aquifer, over-extraction, salinity, Garziz farm, treated wastewater reuse, water budget.
34. Evaluation of Groundwater Development Prospects in a Typical Watershed of Humid Tropics

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Abstract
The first step in the development, conservation and optimum management of groundwater resources is a regional appraisal of the hydrogeologic condition. Drainage basins or watersheds should be the unit of study area for the better understanding of the hydrologic system and for accurate quantitative estimation of the resources. It is in this context this study has been carried out in the Karimpuzha watershed, which falls within the highland region of Malappuram district of Kerala State, India. All the available data on geology, hydrogeology, rainfall, etc. were collected from various reports and agencies. A hundred percent well census was carried in one sq. km area, to know the type of groundwater extraction structures, density of wells, usage purposes, etc. All this information has been analysed to understand the groundwater development scenario in the study area. Charnockites and Gneiss of Precambrian age, laterites of Pleistocene age and alluvial formation along the stream course of recent to sub-recent age characterize the area. In this watershed groundwater occurs predominantly under phreatic condition in laterites, weathered and fractured rocks.

In deep-seated fractured rocks, groundwater occurs under phreatic, semi-confined or confined condition. Groundwater is extracted mainly from the lateritic formation through dug wells. The depth to water level below ground level during peak summer ranges between 3.60 and 20.00 m depending on the topography. The net annual groundwater availability is 16.6 MCM. The annual groundwater draft is estimated as only 28% of the annual available groundwater in this watershed and hence there is scope for future groundwater development.

Key words: Groundwater; Watershed; Development Prospects.
35. Investigation of Drip Irrigation Under Low Pressure

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Abstract
The main objective of the experiment is to determine the field emission uniformity and manufacturer coefficient of variation of the supplied Derecoil emitting system (newly introduced by one of the irrigation company in Gujarat) at various pressures and slopes. The result were obtained, that there was no significant change in the emission uniformity by changing the small variation in pressure as well as slopes. So we conclude that this Derecoil emitter can be used in various pressure and various slopes.
Study on Age Old Non-Conventional Adit/Tunnel Wells in the Lateritic Terrain of Kasargod District, Kerala.

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Abstract
Kasargod, the northern most district of the Kerala State has an areal extent of around 1961 square kilometers. Most part of the district is marked by rugged topography with steeply sloping hills separated by deep cut valleys. Though the district receives very high annual rainfall of around 3294 mm, it experiences severe water scarcity in summer months. Southwest monsoon contributes 85% of the total precipitation, most of which flows to ocean as overland and base flow during and just after the rains. Laterite serves as the main aquifer system in the area. Dug wells at the summit and slope of the hills and plateau are deep (15 to 25 m) below ground level. Most of them either go dry or need frequent deepening at regular intervals to fetch sufficient water during summer months. Moreover adjacent dug wells showing contrasting water levels and their fluctuations, add another dimension to the problem. Thus to avoid such gamble and to take advantage of the Inhomogenity and Anisotropism of the lateritic aquifer system, Tunnel wells are of common practice. Known popularly as “Surangam” in Malayalam, they are rectangular wells driven horizontally into the lateritic plateau and hills for tens of meters. No lifting device like bucket and rope or pump is necessary for harnessing ground water as it drains under gravity. Each Tunnel well is unique in its structure as the availability of ground water leads to its modification and specialization. Most of them yield 0.1 to 0.3 L/s (lps) during summer which is sufficient for the domestic requirement. However few good yielding wells of 1 to 3 L/s discharge are being used for irrigation. In general the rainy season discharge is 10 to 15 times that of the summer yield. Though these structures are the best feasible in the area, they lead to the excessive draining of the aquifer which render it unproductive during summer seasons. This necessitates the need for ground water conservation by suitably modifying these structures.
Abstract
Kalahandi, one of the western districts of Orissa, is having the dubious distinction of frequent occurrence of drought due to erratic monsoon and rainfall pattern. Physiographically the district can be divided into three natural divisions i.e. Eastern Ghat hills; Pediplain along with residual hills/inselbergs and lateritic upland. River Tel constitutes the major drainage system of the district. Only 32% of the net area sown has irrigation facilities and the crops in the rest of the area are rain fed. The district receives a normal annual rainfall of 1378 mm, more than 80% of which is received from the southwest monsoon during June to September. Major parts of the district are underlain by rocks belonging to Eastern Ghats group comprises of granite gneiss, khondalites, charnokites and quartzites. The Consolidated Formations (hard rocks) form the main hydrogeological unit which lack primary porosity and are rendered porous and permeable by weathering and fracturing which also holds the key to their water yielding capability. Ground water occurs under phreatic condition in the weathered zone and under semi-confined to confined condition in the deeper fracture zones. Dug wells and deep bore wells are the feasible ground water structures in the consolidated formations. Granite suites of rocks are more promising aquifers having yield between 3 to 18.6 lps with moderate drawdown. Quaternary alluvium occurs as discontinuous patches in the flood plains of major rivers. Ground water occurs under phreatic condition in these unconsolidated formations. Yield of the shallow tube wells in the alluvium varies from 5 to 10 lps for a drawdown of 5 to 10 meters but dug wells are most favoured ground water abstraction structures. In plateau areas lateritic capping is developed on the weathered residuum. The depth to water level is shallow in most part of the district. The quality of ground water barring a few exceptions is generally good. The total replenishable ground water resource of the district is estimated to be 89520 ham but the stage of ground water development is only 12.83% leaving a huge amount for further utilization. Optimal utilization of ground water holds the key to counter the age-old natural problem of frequent draught in the district. Judicious utilization of ground water through properly designed abstraction structures constructed at suitable locale can mitigate the problems of water scarcity faced during summer. Rain water harvesting and run off management through the construction of percolation and storage tanks, check dams, check and diversion weirs are to be taken up for the conservation of rain water and for augmenting recharge to ground water. Construction of suitable ground water conservation structures like sub surface dykes and cement plugs in specific locations can curb the base flow during post monsoon period. Few well designed check dams with proper arrangements for flood control can be
constructed in some of the major rivers flowing in the district which will facilitate the use of base flow in lean season and reduce base flow from the aquifers.

**Key words:** Hydrogeological unit, aquifer, ground water resource, Rain water harvesting.
Conjunctive use of surface and ground water resources-A Necessity for Water Resources Management in the Command Areas with Special Reference to Orissa State in India

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Abstract
Conjunctive use increases the flexibility of overall water management, improves efficiency and assists in development of creative solutions to potential problems within the command areas of the irrigation projects. The conjunctive use of surface water and ground water, which takes advantage of the interaction between the different sources of water, offers a vast scope for mitigating the problems generally faced in the major and medium irrigation projects. The command areas of the major and medium irrigation projects of the state are characterized by inequitable distribution of water resources in the head and tail reaches. The head reaches are endowed with abundant surface water sources that suffer from water logging, whereas the tail end areas suffer from water scarcity with deeper water level.

In the state of Orissa, there are mainly about six major irrigation projects, which suffer from problems of water logging, scarcity of water due to inequitable distribution of water in space and time. The Hirakud command area (with an aerial extent of 3000 sq. km), has a permanent waterlogged area of 160 sq. km that increases to 1500 sq. km during post-monsoon. The Rushikulya command area has a geographical area 1200 sq. km, with 43 sq. km waterlogged area during pre-monsoon (May 2004) that increased to 834 sq. km during post-monsoon (November 2004). The other irrigation commands are also having patches of waterlogged area in larger proportions. Water quality problems have also been detected in the command areas with prolonged period of irrigation. In the Rushikulya command area, about 32% of water sample (total 143 samples) have been found to belong to C4S1 to C4S3 of USSL irrigation classes and in case of Hirakud it is 35% water samples (total 128 samples) belong to C3S1 and C4S1. Other irrigation commands are also no exceptions.

All these command areas have a potential for increased cropping intensity after improvements in the water logging and water quality problems, through conjunctive use of surface water and ground water in suitable proportions. An attempt has been made to determine the optimal cropping pattern in Hirakud command area for the maximum use of available surface water resources in conjunction with ground water to get the maximum financial return from irrigation and to get rid of the water logging and water quality problems. Linear programming has been adopted to design an optimal developmental pattern in the command area. Keeping in view the socio-economic conditions, paddy has been allotted 98% and sugarcane for 2% of the CCA during kharif and crop diversification has been attempted for Rabi using both surface and ground water. It is also found that conjunctive use of surface and ground water can increase the cropping intensity to 200%. Conjunctive use plan may thus be formulated for the other
command areas for higher cropping intensity and get rid of the problems associated with prolonged surface irrigation.

**Key words:** Conjunctive Use, cropping intensity, optimisation, water-logging, Rushikulya Command Area, Hirakud Command Area
Abstract
GWQM is a tool, which enables governmental authorities to set objectives to achieve and maintain clean water and reduce the impacts on human health and the environment. Environmental regulatory enforcement and compliance continue to be the main problems in controlling the rapid depletion and degradation of segments on environment (water, etc) in Nigeria.

The paper discuss the statutory responsibilities and initial functions of the Federal Environmental Protection Agency (FEPA) of Nigeria towards the overall protection of the environment including the priorities and the policies for achieving sustainable development in Nigeria i.e. the national policy on environment. Also FEPA is initiating a monitoring programme to ensure that the set standards are met.

The objective of this paper therefore aims to facilitate law enforcement, to inform, educate and strengthen stakeholder participation in all aspects of ground water quality management in order to prevent and reduce the impacts of water pollution also to include or strengthen the concept of water quality management in relevant policies and legislation in cities in Nigeria.

The paper presents the overall recommendations that include policies standards and regulation that is a strategic framework for ground water quality management in Nigeria.

In conclusion, Clean Water Implementation Plans (CWIPs) in Nigeria are a means of improving urban water quality and are a convenient way of reporting on the different activities in ground water quality management.
Abstract

A study was conducted on the impacts of three landfill practices on the groundwater quality in Kuwait. All three landfills are receiving liquid and solid waste of different origins. Among the objectives of the study was to provide real-time information on the operations, hydrogeological conditions and the effects on groundwater quality that would enable the evaluation and amendment/overriding of the current guidelines regarding land filling practices in Kuwait. A total of 16 test holes and nine monitoring wells were constructed and sampled. Though land filling in Kuwait uses abandoned quarries, which provide no protection for groundwater, contamination was limited to the total petroleum hydrocarbons (TPH) and total coliform bacteria (TCB). These results highlighted the effectiveness and spatial variability of the natural protection provided by the unsaturated zone. This paper provides a set of guidelines that covers the different stages of landfilling practices, that is, selection of location, design, operation and closure. Reviewing the current local regulations for landfilling (EPA and Municipality in Kuwait) and international guidelines, and building upon the experience gained in the three landfills study, a set of guidelines were developed and herein recommended to ensure the quality of the groundwater. The essence of the recommended guidelines is the need for site-specific landfill design based on comprehensive, mostly field, assessment of hydrogeological conditions.

Key words: Landfill practices, groundwater quality, total petroleum hydrocarbons, guidelines, Kuwait.
41. An Ecologically Sustainable Watershed Management Approach to Inter-Basin Water Transfer in India

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Abstract
Many rivers in India are shared resources, flowing through or between more than one province and one country. The combined effect of climatic stochasticity, rapid population growth and inefficient water infrastructure is increasing the stress on the river basin ecosystems. As stresses on river basins continue to increase, re-distribution networks are rapidly assuming the status of a ‘growth industry’, but they have a distributing and unaddressed potential for intra-and international conflict and for severe ecosystem perturbation. Despite their high coast and ‘high profile’ in terms of complex engineering and technical inputs that they require, the ecological and social implications of such schemes have been, and continue to be, inadequately addressed.

Healthy freshwater ecosystems provide a wealth of goods and services for society, but our appropriation of freshwater flows must be better managed if we hope to sustain these benefits and freshwater biodiversity. This paper will offer a framework for developing an ecologically sustainable watershed management approach, in which human needs for water are met by storing and diverting water in a manner that can sustain or restore the ecological integrity of affected watershed ecosystems. The framework includes: (1) developing initial numerical estimates of key aspects of river flow necessary to sustain native species and natural ecosystem functions; (2) accounting for human uses of water, both current and future, through development of a hydrologic simulation model that facilitates examination of human–induced alterations to river flow regimes; (3) assessing incompatibilities between human and ecosystem needs with particular attention to their spatial and temporal characteristics; (4) collaboratively searching for solutions to resolve incompatibilities; (5) conducting watershed management to resolve critical uncertainties that frustrate efforts to integrate human and ecosystem needs; and (6) designing and implementing an adaptive management program to facilitate ecologically sustainable watershed management for the long term. Drawing from case studies to illustrate the framework, this paper will suggest that ecologically sustainable watershed management is attainable in a vast majority of the watersheds.

Key words: Ecological sustainable watershed management, Interconnecting rivers, ecological problems, Indian river system.
Abstract
Groundwater in Kenya is under threat of pollution by the increased abstractions and excess use for different purposes and disruptions of the recharge areas. In the coastal region for example, excessive abstraction induces sea water intrusion rendering most boreholes unusable. It is thus necessary to improve our understanding of the groundwater systems for better management of the ground water resource. This paper gives an overview and outlook of the groundwater status, regional aquifers and unique problems including the Nairobi Conservation area and the coastal region in Kenya. Policies on groundwater contamination monitoring and control are stipulated as desirable by the water sector reforms in Kenya. Groundwater management and consumption, conjunctive water use, modelling and rainwater harvesting for enhanced groundwater in Kenya's arid and semi arid lands (ASALS) are discussed. Drinking water supplies need protection through watershed management (WSM). Water resource supply must be protected, especially near urban areas. Approaches to develop and implement WSM strategies to protect the groundwater supplies from contamination and the current constraints in Kenya's developing economy are presented. The strategies focus on different scale systems for ground water protection. The factors considered are presented. The measures discussed include; protection of conservation areas, legal aspects of waste management and permits for water abstractions and waste management. Measures to protect the vulnerable watersheds from pollution require stakeholder involvement, such as farmers using pesticides, industries, urbanisation etc.

There is need for greater attention for developing watershed management plans in Kenya, and this is particularly important for the urbanised watersheds and coastal areas. The WSM practices and techniques need to be implemented to protect the groundwater resources especially the recharge areas. Disposal of hazardous waste, waste management, ground water monitoring and ground water supply development in vulnerable zones and associated problems are of concern to water users and management agencies at all levels.
43. Relevance of Community Mobilisation for the Success of Arsenic Mitigation Programme in West Bengal, India

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Abstract
There is an increasing emphasis in recent times on implementing water supply programmes through active community participation. In India, the newly launched Swajaldhara programme is rooted in this approach where implementation of the physical scheme will follow the process of demand generation, indicated by the willingness of the people to participate in the implementation, management, operation and maintenance and also by the proportion of capital cost they contribute. The relevance of community participation gains greater importance in situations of water quality problems such as high arsenic in drinking water, an ever-expanding problem in the state of West Bengal. Though several options for mitigating the problem and supplying of arsenic-safe water to the people are being put in place, there are merits and demerits of each, besides the issues of considering community perceptions and their level of association with the project.

This paper presents the case study of arsenic removal plants as one of the latest measures, highlighting the relevance of community mobilisation in use and management of these plants. Actively involved in the process of implementing the arsenic mitigation programme through installation of arsenic removal plants in the local communities in the state, the author presents his first hand experiences with the approach and delineates its problems and prospects along with suggestions about how community mobilisation and continued participation can be effectively achieved. It is suggested that efforts made at community mobilisation should heavily rely on Information, Education and Communication (IEC) materials, proper awareness campaigns, Human Resource Development (HRD) and training activities, that would help initiate behavioural change on one hand and, equip the villagers to plan, implement, manage, operate and maintain the schemes, on the other.

Key words: Water supply programme, implementation, community participation, Swajaldhara programme
44. Ground Water Management Study In Shillong Urban Agglomeration, Meghalaya

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Abstract
Greater Shillong Water Supply Scheme (GSWSS) is the only major water supply scheme which supply treated surface water to Urban Agglomeration of Shillong. There is no major ground water supply scheme. About 80% of the total households are dependent on supplied surface water for their domestic purpose. Recent valley fills (in Polo area) and Quartzites constitute the major aquifer system in the study area. Two sets of fractures are observed within 100 m depth. The average seasonal water level fluctuation is around 1.19 m whereas the long-term water level does not show any significant trend. Most of the bore wells drilled in the area yield 5 m³/hr to 10 m³/hr. The depth at which water struck lies between 2.43m to 100 m. The high yielding bore wells are generally associated with NE-SW trending lineaments and the intersection of NE-SW & NW-SE lineaments. Most of the springs in the study area are of gravitative type with discharge varying from 8100 lpd to 187488 lpd (lpd = Liters per day). The springs at Umkdait, Lengkarding, Pynther, and Madanrting indicate a very close correspondence to rainfall. The low yielding springs are least affected by rainfall. The stage of ground water development is 69.25% and qualitatively the ground water is potable.

Key words: Ground Water Management, Shillong, Urban Agglomeration, Water Supply
Management of ground water in India fundamentally rests upon the principle that a landlord is also a water lord, and thus entitled to abstract unlimited amounts of groundwater from the aquifers. The Indian Constitution distributes the legislative power between the Centre and the 28 federal States, and ‘water’ is a subject under the authority of the latter (enumerated on the State List). No uniform ground water regulation can thus be enacted, but a Model Bill was proposed in 1992. Only a few states have so far opted to implement it, and to various extents. Calls for a thorough reform of the system have been heard for a long time, and are growing stronger with the rapid and urgent decline of the water table as well as the deteriorating ground water quality.

A case that has received a great deal of attention during recent years includes two main actors; the Coca-Cola Company (hereinafter referred to as the Company) and the elected village council, the Panchayat, to which the function of local water supply is delegated from the state level. The Company set up a factory for manufacturing bottled beverages at a site in the state of Kerala in 2000, but was soon alleged of causing, i.a., severe water shortage in the vicinity. The Panchayat, under pressure from the indigenous village community, decided in 2003 not to renew the Company’s licence. According to a High Court decision taken by a single Judge a few months later, ground water is a ‘common pool resource’ that belongs to no-one. It was furthermore declared that the Panchayat did not have the authority to cancel a granted licence in such a manner, and the Company should be allowed to draw water from its land – though merely an amount equivalent to what a normal farmer in the area, with the same size of land, would.

The Company appealed to the Court’s Division Bench, which decided in April 2005 to overrule the previous outcome. The Judges stated that the Panchayat had no ownership rights to private water sources. Based upon a ‘scientific’ investigation into the causes of ground water depletion, and a ground water budget model for the area, it was found that of the annual available ground water resources, the Company could safely be allowed to draw the 500 kL/day required for its production. It was however also ordered to provide the local people with drinking water.

At the end of August 2005, the Kerala State Pollution Control Board ordered the plant to shut down because of the Company’s inability to explain cadmium levels in the sludge effluents being 400-600 times above the permissible limit, and because the plant did not have an adequate waste water treatment facility. The story is not likely to end here, since the Supreme Court has been moved and a precedent is needed in relation to issues such as the allocation priorities in the National Water Policy, the Constitutional Right to Life provision (Art 21), and the power decentralised to local ‘self-government’ bodies (the Panchayat Institution).
The aim of this paper is to highlight and discuss several questions that emerge from the case. First, it is still not clear whether a local Panchayat Institution is legally mandated to cancel a valid licence as done here. Second, the scattered and loop holed system for issuing permits seems to be in a need of an overhaul – and subsequently be put in force – but it can also be contested to what extent the ‘Rule of Law’ doctrine applies when a legal person’s licence can be withdrawn in a rather arbitrary way by a political body. Last, in the absence of clear, integrated, and not least updated provisions regarding the ground water situation, effective implementation is unattainable. However, the mixed legal system that India has developed since Independence does not, per se lack the proper means or principles to deal with the problem. At stake, we rather find a weak enforcement machinery; political intervention, nexus between implementing administrators and concerned private actors, and too little of stringent will to take preventive action.

**Key words:** Ground water rights, Coca-Cola case, Panchayat Institution, Kerala, implementation.
Abstract

On the 29th of November 2005 a seminar “The Hidden Language” was held at Delft University of Technology, the Netherlands, in association with AMRF Society, NGO Forum for Drinking Water and Sanitation, Bangladesh Rural Advancement Centre (BRAC) and sponsored by Inter Church Organization for Development Cooperation (ICCO), the Netherlands. It reviewed conscious attempts to implement participatory and rights based approaches to development in rural water supply of Bangladesh. Such approaches entail a change in cultural codes and values in rural Bangladesh. In that among other things, it suggests the need to introduce ‘alien’ concepts i.e. cooperation across family lines, the emancipation of women and poor, and new and democratic decision-making procedures. One may doubt whether transfer of cultural norms should occur anyhow. It reflects too much like introducing the old-fashioned western idea of cultural supremacy. But in the meantime change of culture does occur and seems almost inevitable; even in Bangladesh, and for that reason it might be better done consciously, wisely and with respect for the receiving culture.

In their efforts to do so, donor organisations tend to overlook the fact that transfer of codes and values occurs often implicitly and unconsciously. This enables miscommunication and deficiencies in the participatory process that should lead to the fulfilment of programme goals. Therefore, it is important to make the tension explicit between the project goals (mostly stated in terms of technical results) and the process that should lead towards these goals (participatory development, rights based approach). Yet many technical solutions fail due to lack of taking social aspects into account. Infinite examples in that respect can be mentioned e.g. sense of ownership (who is taking responsibility) and social hierarchy (low status and female villagers being excluded from water supply or services). From socio-technological viewpoint, a technological device has to be unified with its social environment in which it is supposed to perform its function. In addition to the technological, institutional and human component of community water supply programmes, Singh et al. rightly stress the urgent need to integrate socio-cultural factors as a fourth dimension in designing such programmes, Singh et al., 2005, Women and community water supply programmes: An analysis from a socio-cultural perspective, Natural Resources Forum. Hence, it is impossible to transfer a particular technology without interfering in the tissue of culture, habits, codes and values of the receiving society. Hidden meanings transferred in project criteria and project implementation unconsciously have to be exposed to the open in order to make the participatory process more efficient. These ‘hidden’ values to be uncovered are:

- Cooperation across the lines of family loyalties
- Women in public life
• **Opposition, criticism and pluralism**
• **Drive for fundamental change**
• **Instrumental time and planning.**

These are the values at work generally in project proposals and project implementation in development aid. If indigenous development would mean non-interference in the receiving culture, it would be a contradiction in terms, in that any form of development would contaminate the "indigenous" character of a particular culture. Though interferences in indigenous culture seem almost inevitable, transfer of technology, policy and values should take place in a respectful way. It stresses the need to seek for ways to integrate the "transplant" in the older layers of culture and institutions of the receiving society. To do so, donors do not underestimate or neglect the capabilities of society to develop itself. Additionally, a society should have the ultimate judgement on whether this process of integration truly contributes to its development.
47. Groundwater Resources Development in the Western Ghats, India

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Abstract
The Western Ghats (hills) region of the Indian Peninsula in western India is bestowed with heavy precipitation (4000-6000 mm/yr), but the headwater basins that coalesce runoff from these hills retain very small quantity of groundwater due to poor surface slope conditions. The narrow valleys in these hills offer ample scope for surface water development, and several medium to major irrigation projects have already been constructed in these areas with well-defined canal network. These developments have truly boosted agricultural productivity in the region, but at the same time they have also brought an economic disparity between the command (areas irrigated by these canals) and non-command areas. Water logging problems are also increasingly seen in low-lying areas. These problems are mainly due to poor groundwater management strategies in the region, and call for implementation of suitable measures for a uniform groundwater development. As a first step in this direction, several measures have been suggested as a case study for the groundwater resources development in the Koyna River basin, a headwater basin on the east of the main ridge of the Western Ghats. Artificial recharge measures have been suggested in the water-scarcity areas in non-command areas, and also for the development of springs at higher elevations. Conjunctive use of surface water and groundwater has been suggested in the command areas of the lift-irrigation schemes. Suggestions have also been given for the development of existing dugwells and construction of new dugwells and borewells in both command and non-command areas.

Key words: Western Ghats, Deccan terrain, conjunctive use, artificial recharge, groundwater resources development
Abstract

Tamilnadu state is one of the groundwater over-drafted states in India. Using the Gamma distribution, it is concluded that rainfall is the major factor that had contributed for the shifts in area from source to other over years, where the probability of getting the mean South west and North east monsoon rains will be only 30%. The variability in rainfall is one of the main reasons for abandonment of the rainfed agriculture by the farmers, which ultimately resulted in the intensification garden land agriculture where wells are the primary source of irrigation. The results of the study conducted in Coimbatore district in the state during 2003-04 have indicated 49 percent well failure. The total cost of over-draft is varying from Rs 2999 per ha to Rs 19789 per ha. Energy consumption varies from 0.30 kwh per M$^3$ of water lifted in critical regions to 0.62 kwh per M$^3$ in over-exploited regions with a resulting energy cost of Rs 0.92 per M$^3$ and Rs 1.93 per M$^3$ respectively. The average net return from maize crop with free electricity varies from Rs 0.14 per M$^3$ for marginal farmers to Rs 0.92 per M$^3$ for large farmers. Benefits due to groundwater management with free electricity will be ranging from Rs 40015 per ha in over-exploited regions to Rs 4792 per ha in safe regions. In spite of the declining groundwater table and well failures, farmers still prefer to invest in wells to augment the groundwater supplies mainly to minimize the cost of uncertainty (of not having additional wells) which is as high as Rs 45450 or 59 percent of the net income of an average farmer.

Groundwater availability also influenced the farm input use and overall farm efficiency. Data Envelopment Analysis (DEA) has been used to quantify the level of technical efficiency in different groundwater extraction regions. The average efficiency had varied from 92 percent in groundwater over-exploited regions to 77 percent in less exploited (safe) regions. The weights of different inputs and outputs derived as part of the results are useful in rationalizing the input and output levels at farm level.

Suggested policy options include change in cropping pattern towards less water intensive as well as less risky crops, investment in watershed activities and adoption of well spacing norms. Also, implementation of participatory educational and crop management programs in different water extracting regions to benefit the farming community is recommended.

Key words: Gamma distribution, well failure, technical efficiency, cost of uncertainty, watershed programs.
49. Driving Forces in Depletion of Groundwater Quantity and Quality in Punjab and Haryana States, India.

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Abstract
Punjab and Haryana are the “Green Revolution” states of India. In these two states the contribution to total national food grain production increased from 3 percent before the green revolution to 20 per cent at present, contributing 50 and 85 per cent of government procurement of rice and wheat, respectively. Agriculture intensification has increased with a significant expansion in the area with more than one crop sown per year. As land use intensity has increased, the area of land under irrigation has also increased. Also the total area under irrigation has almost doubled since 1960-61. The main sources of irrigation in these two states are canals and tube wells. However, this green revolution, as it appears, is not so green. There have been adverse ecological impacts as well. The increases achieved by the green revolution have created several environmental problems, viz. water logging, salinity, alkalinity, soil erosion, and decline and rise of the ground water table linked to brackish water etc. In the areas where tube well irrigation is practiced, there has been tremendous decline in the ground water table. This is mainly because of the continuous lifting of water throughout the year. Approximately 95-98 per cent of the area under rice and wheat in this region is irrigated. Irrigation from ground water accounts for 60-65 per cent of the total irrigation requirement and the remaining 35 to 40 per cent is met through canals. This intensive exploitation has caused the ground water problems. While in many areas the ground water table is rising, many districts in the rice growing area of Haryana show a water table decline in range of 3-10 meters. These districts are Kurukshetra (10 m), Ambala (3m), Yamunanagar (3m), Kaithal (3m), Karnal (5m), Panipat (5m).

A study shows that if the tubewell irrigation continuous for the supply of the moisture to the crops, the underground water table may not be in a position to recharge. In the tube well irrigated areas the underground water table has fallen by more than 2 meters in majority of the districts. Many of the farmers have to lower and re-drill their tube well owing to the lowering water table. Contrary to this, in the areas where canal network is extensively practiced, the underground water table is rising significantly. This rise in the water table is resulting into capillary action and leading to the development of saline and alkaline formation. Owing to the capillary action, the soils are becoming either saline or alkaline in character. The saline and alkaline affected tracts, locally known as kaller in Punjab, have expanded and increased in area. According to one estimate about 50 per cent of the total arable land in Punjab and Haryana have been harmed by soluble salts. Major driving forces include changes in cropping pattern due to green revolution, use of HYV seeds require more water than the indigenous seeds, over irrigation, Over use of fertilizers (Chemical) and pesticides, Impact of agro based industries, Impact of rapid growth of industrialization. This has resulted in over-exploitation of groundwater in many blocks leading to decline in groundwater table. Decreasing the price of land is another implication due to decreasing quality of water.
Abstract
Without going into the rationale for sudden stimulus to ground water mining in last quarter of a century in certain water stressed areas of South Asia that has led to universally acknowledged plunging ground water (GW) levels - it may be noted that the situation has raised serious concerns about the livelihoods of communities dependent on GW – very often as the only source of water. The paper will focus on implications of developments as above, for influencing the dynamics of poverty in a drought prone region in Southern India.

It has been argued that people are better off with GW irrigation than without and this is an indication of the positive contribution of GW development for poverty alleviation. Taking the experience of a rural community in drought prone area - where GW is the only source of water for agriculture and domestic use – we try to bring out differential consequences of the excessive use of GW for livelihood status of households and critically evaluate the hypothesis that GW irrigation has been a source of increasing livelihood security for all members of community, with clear reduction in poverty levels.

   It is argued that while *private* exploitation of groundwater was perceived as *positive opportunities for productive agriculture*, in the absence of any effective regulatory framework in place either by state agencies or communities, aggregative consequence of such anarchy of decision-making was an over drawl of water out of proportion to avenues of recharge. This sets in motion a self reinforcing process of increasing extraction - greater the depletion, more the desire to drill deeper that again spurs a further cycle of decline of water levels – creating further incentives for deeper drilling and so on till limited by physical or economic considerations.

   While *potential* for using a source of water e.g. bore well - under the personal /private control of the user offers tremendous possibilities of efficient and productive use for more secure livelihoods, operational modes to actualize this potential raises concern about precisely the *opposite* eventuality.

   Potential and constraints of using GW based strategy of rural development and livelihood security is assessed from the perspective of what options are feasible under the existing bio-physical and socio-economic parameters. Policy options such as use of pricing strategies, groundwater recharge through watershed strategy, incentives approach to regulate extraction of ground water are examined to point out conditions of their efficacy. Limitations of supply side measures and potential of demand management strategies are noted. It is argued that there is need to design suitable set of *integrated* policy packages that reinforce each other to give productive support to small producers while discouraging (by creating disincentives) ecologically damaging practices such as over exploiting GW.
Abstract
The concept of sustainability in urban scenario means protection of ground water quality, while in the rural scenario, it means the protection of the quantity of ground water available from wells and bores, so that adequate yield is available for irrigation. Occasionally, one also comes across instances when the urban piped water supply is highly inadequate and the residents over-exploit ground water. Recharge augmentation by roof water harvesting is then necessary. In rural areas where ground water is threatened by saline ingressions or by arsenic/fluoride contamination, the quality aspects also assume importance.

The efforts for sustainability have to be made at three levels: (1) Technical aspects of ground water management & capacity building at Government Departments & Institutions (2) Educating the public through media and village meetings (NGOs and Universities play an important role in achieving public participation.) and (3) Legal aspects: Enacting and implementing ground water protection laws. However, in low-income countries these efforts are only partly effective and there is a need to create a database for successful practices.

The UNESCO-IUGS-IGCP Project no 523, approved in April 2005, is titled as ‘Grownet’ Ground water network for best practices in ground water management in low-income countries”. The Author of this paper is the Convener and Project leader for Grownet. Under this project best practices in various aspects of sustainable ground water management will be assessed from the projects in low-income countries and posted on a Website for global dissemination. Best practices like (a) Watershed management for soil and water conservation leading to increased natural recharge and (b) Recharge augmentation through artificial processes, are followed in some of the watersheds in the semi-arid basaltic terrain in western India, under Government programs, with active participation of dedicated NGOs and local self-help groups. The urgent need for recharge augmentation is explicit in semi-arid regions due to over-exploitation in several watersheds, thereby affecting the survival of millions of farmers. Sustainability of ground water development in these regions is totally dependant upon successful augmentation of recharge. The Paper describes an outline of the best practices in recharge augmentation, which need to be replicated elsewhere in India and also in other low-income countries. ‘Grownet’ welcomes participation of international community of hydrogeologists for achieving its goal of collecting and disseminating best practices in ground water management.
Abstract
Groundwater systems are dynamic in nature and adjust continually to short term and long-term changes in climate, groundwater withdrawal and land use. Water level measurements from observation wells often called ‘groundwater monitoring’ provide vital and much needed information about the hydrologic stresses, the aquifer undergoes and how these stresses affect groundwater recharge, storage and discharge. A groundwater-monitoring network is a system of dedicated ground water monitoring wells in a geohydrological unit at which ground water levels and water quality are measured at pre-determined frequency. The design of an optimal network layout reflects the entire hydrogeological system of the area under consideration. The network provides long-term information on the different aquifers being developed. Information on shallow aquifers tapped by open wells, deeper multi-layer aquifers tapped through open dug wells/dug cum bore well /bore well/tube wells and ground water development issues (declining water levels, rising water levels, coastal salinity, water logging in irrigated areas, ground water pollution etc) should be considered in the network design. Balasore district of Orissa is represented by 34 monitoring stations. Out of these hydrograph stations, 29 are open dug wells and 5 are purpose built piezometers. The effectiveness of the existing network was evaluated and the evaluation of the network was carried out independently of different hydrogeological units. The criterion was that an optimised network should represent full range in variation in Geology (Hard Rock / Soft Rock), geomorphology and administrative units like blocks. Existing hydrograph stations were plotted in maps block-wise, geomorphology-wise and geology-wise. Finally all the data have been synthesized in a tabular form and optimised number of network stations arrived at after taking into consideration all the factors like categorization of blocks on the basis of net annual draft, geomorphologic units and Geology (Hard rock /Soft rock). The yardstick for the evaluation was: (1) How well does the data emanating from the existing network permit an estimation of the mean water level elevation in a specified area? (2) How well does the data emanating from the existing network permit interpolation of the water level in areas having no monitoring structure?

Number wise no additional monitoring stations are required. However flood plain of Bahanaga block and lateritic upland of Nilgiri block are not represented by any Hydrograph station. So two new monitoring stations are proposed in these two geomorphologic units having area of more than 50 sq. km each. Further the blocks of Oupada and Bhograi (both ‘Safe’) are represented by one Hydrograph station each. So two more hydrograph stations (one in each block) are required to be established in the district.
Abstract
In this paper we present the software and computing agent role and use in ground water management and public policy making. Agents has been using for the information processing, decision-making, and many social issues. Agent-based models are an increasingly powerful tool for simulating social systems because they can represent important phenomenon difficult to capture in other mathematical formalisms. By using this agents based on mathematical formalisms, we can model a hybrid system which deals with different issues relating to social and economic domain. But, agent-based models have provided only limited support for policy-making because their distinctive abilities are often most useful in situations where the future is unpredictable. The effective policy making and decision making is very important in developing countries/lesser developing countries. We extends our work based on traditional agent system to multi hybrid agent system to deal with the problems relating to social and economical issues which is a main concern in developing countries. The traditional analytic methods for applying simulation models to support decision-making are least effective. Fortunately, new analytic approaches for decision-making under conditions of deep uncertainty—emphasizing large ensembles of model-created scenarios and adaptive policies evaluated with the criteria of robustness, rather than with optimality or efficiency—can unleash the full potential of agent-based policy simulators. This system will help policy makers a scientific tool for policy and effective decision-making. Hybrid system can be used which integrates the application of tradition methods like neural nets, chaos, genetic algorithms, fuzzy logic in a agent based model to provide the better policy model and help the policy maker to take the decision. System also deals with the Simulating the Timing Effects of Public Policy Interventions.

Key words: Hybrid system, Multi agent system, Social agents, policy model, AOPM, Artificial agents, policy simulators.
54. Status of Groundwater Development and Management in Bangladesh: A Critical Analysis

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Abstract
Groundwater plays very important roles in socioeconomic developments of Bangladesh as two of the countries major achievements, viz. access to safe drinking water and self sufficiency is rice production, are associated with the use of this often unrecognized natural resource. Though groundwater plays vital roles in Bangladesh’s socio-economic development yet the resource is used rather carelessly. Although good policies, rules and regulations exist there is very little implementation on the field. Overexploitation of the resource, indiscriminate disposal of industrial and municipal wastes, lack of understanding between surface and groundwater are the major areas of concern for sustainable groundwater resources. Adverse impacts such as lowering of water level, degradation in water quality, saltwater intrusion, reduced base flow to rivers, etc. are evident from various parts of the country including the national capital Dhaka City. Exposure of more than 30 million people to high arsenic in drinking water can be linked to lack of management and monitoring. Groundwater protection is not considered in implementing major engineering projects. There is a general shortage of relevant expertise in the field of hydrogeology in the country.

To ensure sustainable groundwater development in Bangladesh and in order to make sure that the large population of the country continues to have access to safe drinking water and have enough supply of food, groundwater development has to be properly planned. And implementation of existing policies, rules and regulations has to be ensured along side introduction of new legal instruments such as Groundwater Protection Law. Capabilities in various organizations dealing with groundwater has to be increased has to be increased substantially along side enhancement of research and training facilities locally.
Abstract

Ground water is of major importance in providing water supply to the fields in the command areas in terms of the economic and social health of population, especially in the developing world. The subsurface water also plays an important role in water management, notably the provision of water supply, distribution of water into different canals and drainage. The initial benefits like possible staged development, initial water quality better and private and public supply can develop separately, low capital cost perceived from such use of the subsurface environment need to be balanced against the long term costs like reduced efficiency of walls, saline intrusion risk and subsidence risk, which are rarely taken into consideration because of lack of vision or concern about the processes involved. No comprehensive statistics exist on the proportion of water supply derived from ground water.

In result, there are widespread indications of degradation of the ground water resource base caused by excessive exploitation. The objective of this paper is to raise awareness of hydro-geological processes among irrigation policymakers, to highlight the interdependence of ground water and irrigation to provide a framework for systematic consideration of the ground water in water management through remote sensing and Geographical Information System (GIS) techniques.
Abstract
The Lower Okavango Delta is made of several and mostly seasonal anastomosing distributery channels. The Gomoti Valley, where this study is focused, is one of the several distributery channels developed in the lower Delta. In the semi-arid Botswana, groundwater recharge in the aquifers associated to the channels is mainly through the Delta annual floods. Groundwater recharge is one of the parameters considered for sustainability of groundwater and with the ample annual floods, the lower Delta has always been considered a viable groundwater resource. Villages and other localities in the lower Delta mainly rely on groundwater for potable use. The increased water demand due to population growth, saline water intrusion and highly variable surface water flow in the lower Delta necessitated assessment and development of new groundwater resources. It was during the implementation of such a project that high levels of arsenic were confirmed in groundwater of the Gomoti valley.

Laboratory analysis for the boreholes sampled in the Gomoti valley have arsenic levels (0.01 – 0.38 mg/L) exceeding the Botswana drinking water standards (0.01 mg/L). This study is using the limited data to map the spatial distribution of arsenic in groundwater in the Gomoti valley using GIS and geostatistics techniques.
Abstract
Nowadays the world is in a deep environmental crisis. Environmental pollution, global warming, depletion of forest and water resources, etc have crippled the world. The Delors Commission had rightly pointed out “We have a moral responsibility to save the earth and hand it over to the future generations.” The UNO, UNCED, etc are seriously devising ways to save the earth from the current crisis. Saving forests, water harvesting, etc are a few to mention. But people, particularly the younger generation neither have a clear-cut idea about the present menace nor the solutions. To educate the masses and change their cold attitude towards the environment is the first and foremost duty of every Government. In this aspect, media comes into the forefront. It is well known that the media enhances the knowledge, awareness, change the attitude and modify behaviour. In the present study, some environmental programmes from Discovery and National Geographic channels were shown to the children in the age group 10-17 and their effect on the environmental awareness and behaviour were found out.
Agriculture intensity has increased the amount of water used per unit output. Change in cropping pattern towards cash crops along with free electricity has further raised the demand of water for agricultural purpose in the coastal region of Gujarat. As a result, the rate of withdrawal of ground water exceeded the rate of recharge. Over withdrawal of ground water has made water table lower. This lowering of water table has resulted in saline water intrusion due to reverse hydraulic gradient and capillary action in the coastal region.

The level of ground water development in Saurashtra coastal talukas have remained more than 85% since 1991 indicating the alarming situation of declining water table in the coastal region. This decline in ground water table has further accelerated the process of salinity ingressition.

Implementing regulatory and economic reforms to control ground water use is rather difficult for the state. In this situation, community based regulatory approach are the most appropriate approach. This paper presents a case study from the Gujarat coastal region in which community based regulatory mechanism has facilitated local people to maintain their livelihood by using ground water in an efficient manner. The case study has looked into the community-based approach adopted by village level institutions namely; Kharash Atkao Juth (KAJ) and Kharash Atkao Sankalan Samiti (KASS) supported by AKRSP (I). Two major strategies namely; use of drip irrigation and promoting horticultural crops, are studied in detail for their implications on ground water resources. The study has shown that community based strategies have drastically reduced withdrawal of ground water in the coastal villages of Mangrol Block in Gujarat. This has also improved the livelihood of local people, who were otherwise vulnerable and exposed to frequent droughts.

**Key words:** Ground Water Resources, Coastal Salinity, Community Participation, AKRSP (I)
India is water stressed and both rural and urban sectors reveal gross deficiency of surface water and for easing the situation of shortage rely on ground water aquifers. Ground Water being decentralized is used widely for agriculture and for human habitats. Tube wells are used country-wide causing depletion of sub-soil water which in turn is becoming vulnerable to pollution with adverse impacts.

Appropriate technologies for sustainable development and the mantra of “4Rs – Reduce, Reuse, Recycle and Recharge – to get the most from available water” are propagated through awareness and participation programs to communities and others.

Apt Implementation, Operation and Maintenance of Rain Harvesting Systems in both rural and urban sectors are vital and the communities are made aware. Recycling of once used water for secondary uses is also propagated. Inputs are provided to Research Institutions viz. IIT Delhi, JNU, IIT-BHU on Hydro-geo-chemical aspects based on NGO’s work and for arriving at sustainable solutions for water secure future. On our study in association with CGWB Delhi, NIH Roorkee and others has revealed an alarming scenario of rapid depletion of sub-soil water in many parts of the country. Optimum strategy for replenishing the aquifers is through feasible Community Based Rain Water Harvesting and inter river-basin links. India has enough surface and sub-soil water for present and future needs, it is just that communities and others need to be made aware to manage and use water judiciously.

Key words: Water stress, Aquifers, RWH- Rain Harvesting, 4R- Mantra,
60. Managing arsenic-safe water supply options in West Bengal, India: Problems and prospects from gender perspective

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Abstract
While about a decade ago, developing appropriate hardware for mitigating the arsenic menace in West Bengal was the prime concern, today, safe water supply options almost abound in the affected local communities. The government has drafted a detailed program for mitigating the problem and international development agencies are actively supporting the various available options. However, the plight of the people does not seem to have been contained.

It needs to be increasingly realized that management of the available safe water supply technologies is the critical issue that will determine effectiveness as well as sustainability of the alternatives in the long run. So far, either centrality of the issue has been evaded or else the government has taken over the burden in relation to its own interventions. The community has been largely kept at bay or else involved in a piecemeal approach, without realizing that linkages between technology and society can be complex and intricate and that without effective participation of the users in planning and implementation, mere installation of technologies in the community cannot deliver the goods. The complexity of the linkages is furthered by the gender-based differences between women and men as water users. It is also aggravated by the level and nature of the technology, the major categories being community-level arsenic removal plants, deep tubewells, and treated surface water pipelines on the one hand and domestic water filters on the other. Community level rainwater harvesting is being developed as an additional alternative.

Based on an ethnographic study conducted in the state, this paper aims at identifying the problems concerning management of the various kinds of safe water supply technologies introduced in the affected villages in West Bengal. The problems are first analyzed from gender perspective and then suggestions made for an appropriate gender-based approach to ensure effective community participation in the process of managing these alternatives. The recommendations aim at developing a model, which can help promote effectiveness and sustainability of technological options available for arsenic mitigation in local communities.

Key words: ethnographic study, local communities, safe water, technology, arsenic removal plants, gender based approach.
61. **Ground water Assessment in Indian Tradition With Special Reference to Sanskrit Literature**

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**Abstract**

Water is very essential for human life and vegetational world. Without it life is not possible on the earth. That’s why human being all over the world settled around the water resources. Indian common man as well as specialized people so to say having scientific mind recognized the need and essentiality of water right from unknown day to our one day of human history. The study of our scriptures reveals that ancient Indian thinkers such as Sarasvata, Manu etc. with scientific bent were not only interested in exploring the means of storing the rain- water but also exploring the methods to find out the ground water resources. There are descriptions in many sanskrit works i.e. Brihatsamhita of Varahamihira, Arthasastra of Kautilya etc. that interior of the earth are full with water channels, like the veins in the human body, further subdividing into hundreds and thousands of minor streams at different levels causing lives of different plants, trees etc. on this earth. These works claim that on the basis of certain plants and trees, ground resources of water can be searched in the areas where water in not available on the surface of the earth. There are other methods like the smell of soil of a particular region and the character of rocks through which water can be searched underneath the ground. Not only this, on the basis of the character of the trees and rocks of particular kind water whether it is sweet, saline, pungent, bitter and acidic can also be specified. Through such descriptions from our ancient literature we can know that Indian thinker had a concern as well as specialization of both restoring the rein water as well as exploring the ground water, the most essential for life on the earth.
62. Hydrogeochemistry of Ground Water in vicinity of Bhalswa Landfill, Delhi, India

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Abstract

Hydrogeochemical investigations were carried out in three landfill sites selected out of many in Delhi, India, to assess leaching effect of pollutants on to the groundwater quality for its suitability to domestic and irrigation purpose. All three are located on the bank of the river Yamuna and are dominated by alluvium. The groundwater hydro-geological and hydro-chemical aspects of these landfill sites were studied from May 2003 to Jan. 2005. About 83 groundwater samples were collected from shallow and deep aquifers about 28 km² around each landfills. Total six times sampling were done for pre-monsoon (May), post-monsoon (September) and winter (January) continuous for two years.

Very high conductivity reported in all most all samples. The oxidation-reduction potential shows minor changes (149 to 172). Almost all sample shows pH higher than 7.0. Average value of dissolve oxygen (6.3 mg/L) was reported while; some samples reported very less dissolve oxygen (4.2 mg/L). This represents possible contamination of groundwater.

The groundwater quality is very poor around 1 km radius from the land fill sites. the concentration ranges from: iron (6.98 mg/L), manganese (1.613 mg/L), copper (0.071 mg/L), lead (1.5 mg/L), nickel (0.25 mg/L) and zinc (3.1 mg/L) all of them much higher than WHO standard drinking water. Chloride (max 1267 mg/L), bicarbonate, sulphate (156 mg/L), phosphate (2.6 mg/L), nitrate (40.23 mg/L) and fluoride (3.2 mg/L) were much higher than USPH and WHO standards. In the inland samples very close to landfills concentration of all parameter increases excessively. A very high concentration of heavy metals and anions are found in Bhalswa Dairy village. This shows that this landfill is a point source of pollutant. As geology of study area is mainly alluvial, it shows high probability of leaching of pollutant due to high hydraulic gradients. This study suggests that landfill should be modified with lining, etc., or be abandoned in phases and alternative suitable landfill sites should be developed.
Abstract
The present study has been carried out to assess and understand nutrient behaviour (nitrate, phosphate and potassium) and its spatial and seasonal variations in the groundwater of National Capital Territory of Delhi, India, in 2003. The concentration of nutrients in groundwater in general acts as an indicator to identify the nature and influence of agricultural and urban runoff on the shallow subsurface environment. Results of our study indicate that the agricultural activities, including application of fertilizers, soil mineralization processes and irrigation return flow, are major processes regulating the nutrients chemistry in the groundwater of this region. Groundwater in the alluvial formation has comparatively higher concentration of nutrients than the groundwater in hard rock formations, which seems to be due to the adsorption of nutrients by the weathered rock materials. The seasonal water level fluctuation shows that rising water level increases nutrients concentration in groundwater due to the agriculture related activities. The result also indicates a multiple source of origin for the nitrate and potassium and not a single source as it was thought earlier. Few ground water samples in the northern part and eastern part of the study area exhibited very high phosphate concentration. This may be due to local factors such as discharge of agriculture runoff or due to mixing of sewage with the shallow ground water table and Leachate from the landfill sites. The study brings out a over all scenario of the nutrient behavior and their variation in space and time in the Delhi region.

Key words: Groundwater, Nutrients, Agricultural runoff, Delhi, India
64. Physico-Chemical Characteristics and Determination of Cu (II), Mn (II), Fe (II), Zn (II) Ni (II) and Pb in the Water from Electroplating Sites of Agra City, India

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Abstract
Wastewater from four electroplating sites of Agra city was assessed for physico-chemical characteristics and heavy metal concentration. A comparative study revealed that each sample was highest in particular metals concentration and some samples were higher in organic pollution than the others. Site AB1 sample was highest in organic pollution (BOD 285.14 mg/l and COD 580mg/l ). AB2 sample was highest in iron (46.70 mg/l) and zinc (10.79 mg/l) levels. AB3 sample was least organically polluted and was the second highest in copper, manganese, iron and nickel concentration and AB4 site sample was highest in copper (3.68 mg/l) and manganese (56.80 mg/l) concentration. All these heavy metals have severe adverse effect on human, plant and animal when present beyond tolerance limit. As these waste water finally reaches river Yamuna, the paper draws attention towards the contribution of electroplating industries and units in contamination of this river and need of more adequate and efficient treatment of waste water let off from such industries before it get finally discharged in to natural resources.

Key words: Electroplating Industry, Waste water, Heavy metals.
Abstract
Ground water near chromite mines is usually contaminated by the release of chromate ion from the weathering of chromite ore. Mafic and ultramafic bed rocks at the Boula-Nuasahi and Sukinda chromite mines of Orissa show a lateritic soil profile. The uppermost horizon contains a group of Hydrated Ferric Oxide (HFO) compounds both in crystalline and amorphous state. Under natural water pH range, the HFO particles have a positively charged surface. Therefore, the goethite-rich overburden material is an efficient sink for the chromate anion. Leaching experiments using a saline (NaCl-NaHCO₃) solution showed that the material at the Sukinda mine had retained a higher amount of this ion compared with the nearby Boula mine. This difference can be attributed to the higher proportion of poorly crystalline goethite in the Sukinda sample. Mineralogically, the Boula laterite contains higher amount of crystalline goethite, kaolinite and less maghemite compared with the Sukinda laterite. Experiments on further adsorption of arsenate and phosphate by the chromate-contaminated samples indicated that the Boula sample had a higher uptake capacity for both anions. This is apparently because this sample had retained less chromate at the mine. Removal of arsenate decreased with increase in initial concentration and increased with time of contact. The effect of solution pH was different for arsenate and phosphate. For example, arsenate adsorption was maximum at an intermediate pH of 7.5 whereas phosphate removal steadily decreased with increase in pH. These differences are controlled by the relative influence of outer sphere and inner sphere complexing. The results of this investigation can be useful in evaluating natural attenuation of fertilizer-derived pollutants near chromite mines.

Keywords: Chromite mine, ground water, weathering, natural attenuation, fertilizer-derived pollutants, Orissa.
Abstract

Water is a prime natural resource, a basic human need and a precious asset, in the absence of which no socio-economic developmental activities can sustain. Agricultural development, urbanization and industrialization are the major causes for all modifications on the quality of water. The chemical quality of groundwater in Phalgu and Morhar river plain of Gaya region has been studied in detail in this work in order to demarcate the potable groundwater zones without any deterioration by pollution.

A total of 40 ground water samples and 8 surface water samples (Phalgu and Morhar river) have been collected from Gaya district of Bihar, during 2005. In Gaya district, granites, gneiss and schistose rocks are highly weathered and groundwater occurs under water table conditions.

Each groundwater has its own characteristic chemical signatures produced as a result of the meteoric water recharging the system. It depends on several factors, such as interaction with solid phases, residence time of groundwater with pockets of saline water and anthropogenic impacts. Groundwater is in general slightly alkaline in nature ranging from 7.19 to 8.31. The range of ORP is from 134 to 172. EC ranged between 296.25 to 2985. Very few samples are crossing acceptable limit of EC (1400 µs/cm) prescribed by WHO. Value of TDS varies between 165 to 843 mg/L.

The major cations follow trend, Ca2+ >Mg2+>Na+> K+. The calcium ion in the groundwater is due to weathering of the rocks. The Ca2+ ranged between 9.9 mg/L to 83.1 mg/L, and except one sample all comply within the desirable limit. The K+ ranged between 0.2 to 48 mg/L i.e. most of the samples are found below desired limit but some were found to be above permissible limit. The major anions varied in order HCO3->Cl->SO4^2->NO3->PO4^3- and their concentrations were below desirable limit. Iron is one of the less toxic pollutants in water and its presence has been observed in natural water in appreciable quantities. Its value is below the desirable limit. Cu and Zn both are in below desired due to non-industrial area. Arsenic is also found in few samples but value is below the permissible limit, its source may be the weathering process taking place in upper catchments of the rivers.

The ground water quality of Phalgu River and Morhar river basin around Gaya, Bihar in term of parameter like EC, HCO3-, PO4^3-, SiO2, NO3- are within permissible level recommended by WHO and the Bureau of Indian Standards (BIS), has good water quality of water without any pollution threat.
67. Assessment of Heavy Metals and Organochlorine Pesticides Concentration in Sediment of River Yamuna Agra, India

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Abstract
Pesticides and heavy metals are ubiquitous in the environment. They are accumulative and non-biodegradable compounds which affects not only animals and plants but humans also. The information about the distribution of pollutants in the sediment can be valuable for assessing the potential impact of sediment suspension upon water quality. Indeed sediment shows a high capacity. Indeed sediment shows a high capacity to accumulate and integrate pollutants on time. Hence the enrichment rate of pollutants reflects the upstream contamination sources. Depending on their physico-chemical environment, the contaminants trapped on the sediment, can leach out to the ground water as well as overlying water. Therefore, the information about the distribution of pesticides in sediment can be significant in assessing water quality of Agra region.

Hence, a study was conducted to determine the level of pollution in river. For this aim, organochlorine pesticide and heavy metals were collected from seven different sites and the concentrations of organochlorine pesticide were measured by Gas Chromatograph (GC-ECD) and heavy metals by Atomic Absorption Spectrophotometer. The results shows that Yamuna river is highly contaminated and the water of Yamuna has turned black and the concentration were not with in permissible limit as prescribed by WHO.

Key words: Heavy Metal, Pesticide, Sediment, ground water River Yamuna, Agra.
Abstract
Nitrate contents have been quantitatively estimated in the groundwater samples of Krishna Delta (Longitude: 80°10'- 81°15'E, Latitude: 15°40' - 16°45'N). Hydrochemical data indicate a large variation of nitrate from 5-135 mg/l. In 144 groundwater samples, about 32% have shown high nitrate contents (> 50 mg/l), which is more than the permissible limits of drinking water. In north Krishna delta 22% and in south Krishna delta 10% water samples were found to exceed the permissible limits. Nitrate pollution level is found more in dug wells compared to hand pumps/bore wells. This study indicates that groundwater of north Krishna delta is more polluted than south and in this region 24% dug wells and 18% hand pumps have exceeded the desirable limits. The possible sources for the high nitrate level in groundwater have been identified as excessive utilization of nitrogenous fertilizers, insecticides and pesticides for agricultural purposes.
69. Acid Mine Drainage: Effects of Sulphide Ore Mineralisation and Mine tailing on Groundwater – A Case Study

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Abstract
The effects of sulphide ore mineralization and mine tailings on groundwater quality were studied in Kalyadi (Lat.13°14’N and Long. 76°9’E; toposheet No.57C/4) located about 20 km SW of Arsikere town in Hassan district of Karnataka State. The lithounits of Kalyadi formation belong to Sargur Group of rocks (3.0-2.9 Ga in age) and include quartzites and quartz-chlorite-biotite schists. The quartzites and associated quartz-chlorite-biotite schists contain the cupriferous sulphide mineralisation. Some of the quartzitic bands carry pyritic and also cupreous sulphide mineralisation. The ore occurs largely in disseminated form consisting of pyrite, chalcopyrite, magnetite and pyrrhotite. The percentage of sulphides in ores range from less than 10% to about 70%.

The chemical parameters were measured employing various standard methods of analysis. The result indicates the enormous amount of heavy metal ions budged in the samples. The present study analyses water-inorganic sulphide interaction in a metalliferous terrain and its impact on the groundwater.
Abstract

The area under investigation lies 20 km north of Hyderabad city commonly known as Jidimetla, Balanagar, Sanathnagar and Bolarum Industrial Belt, which are endowed with number of industries, mostly chemical, distilleries, paint, steel re-rolling mills, plastic, brick and large number of metal based industries. Several of the inorganic and organic constituents present in the industrial effluents are toxic. The quality of groundwater regime are deteriorating due to diversion of sewage water and industrial effluents into the near by stream courses, water bodies and tanks. Hence, the people residing in these areas are facing serious problems with the contaminated water resources.

Geochemistry of groundwater of the Jidimetla industrial area has been studied on 100 representative samples for pH, electrical conductivity, total dissolved solids, total hardness, calcium, magnesium, sodium, potassium, carbonate, bicarbonate, chloride, sulphate and nitrate. The concentrations of most of these ions are present in more than the permissible limits. Correlation matrix is prepared to find out the relation between different parameters. The shaded contour maps for various elements and scatter plots are generated to know the distribution pattern of the different parameters. In the present study the methods such as Piper, Back and Hanshaw, Wilcox, Eaton, Todd and U.S salinity Laboratory classifications are used to critically study the geochemical characteristics of the groundwater. The degradation of quality of groundwater can be controlled by improving the sanitary and drainage system and adopting safe domestic and industrial waste disposal system.
Abstract
Conventional and unscientific clay mining poses severe threat to the environment, public property and life. Incompatible land uses, large scale land transformation and huge waste dumps have resulted high negative impact on landscape, loss of topsoil, ponding, depletion of groundwater resources, surface and groundwater contamination, loss of aesthetics, health and safety hazards in the clay mining site at Mangalapuram Panchayath in Trivandrum district. The huge excavation has resulted in deep trenches. Active mine sites and abandoned pits dot the area throughout. Further, lack of vegetation, high waste generation and clay dusts during dry season cause air and aesthetic nuisance.

In order to assess the impact on hydrogeoenvironment, both domestic well water samples from the mining area and surface water from the abandoned mine pits were collected and analysed for detailed physico-chemical characterization. The attributes like pH, turbidity and DO of all groundwater and surface water samples indicate that they are highly acidic, turbid with low DO, and fall well outside the permissible limit. Other dominant water quality parameters fall within permissible limit. Anion chemistry has shown that chloride is the dominant ion, followed by sulphate, nitrate and phosphate in the decreasing order of abundance. The major cations in the decreasing order of abundance are Na, Mg, Ca and K. Heavy metals like Fe, Mn and Zn also lies within permissible limit. No significant site-wise variation in the major physico-chemical attributes of groundwater is seen in the study area.

Compatible land uses, partition of dumps, stabilization of slopes after mining, re-establishing soil profile, prohibiting mining below water table are some of the suggested measures for reclamation and restoration of degraded land.
Abstract

Pesticides stand out as one of the major developments of modern agriculture. They are widely used on crops to increase yields, save energy and labour, and make crop production efficient and profitable. However, their use and or misuse may lead to serious water quality problems that could impair the use of water for crop and animal production or even human consumption. The impact of agricultural chemicals on surface water and ground water quality has become an issue of national importance. Fish kills, reproductive failure of birds, and acute illness in people have been all attributed to the ingestion of pesticides or exposure to pesticides usually as the result of misapplication, careless storage and careless disposal of unused pesticides and pesticide containers. In addition to potential health and environmental threats, pesticide losses from fields and contamination of non-target sites (such as surface water and ground water) represent a monetary loss to farmers. This paper reports recent data on pesticide residues in surface water, ground water and wastewater.

Key words: Pesticide, solid-phase extraction, GLC, HPLC, water.
Abstract

Environment contaminated with heavy metals pose serious risk to the ecosystem and human health and thus an issue of global concern. The determination of metal ions concentration in natural water systems has received increasing attention for monitoring environmental pollution is due to the fact that metals are not biodegradable and find their way in food chain through a number of pathways and may accumulate in different organs of human beings or animals. It is already reported that Zn, Cu and Cr in combination are many times more toxic to fish, compared to their individual toxicity. So, presence of such persistent pollutants in the watercourse not only creates unfavorable environment for fish but also causes paucity of fish feeding organisms, fish eating birds and human population.

The aim of the study was to evaluate the chances of heavy metal toxicity in aquatic food chain. To generate the data water samples were collected from three sampling locations along Delhi segment of Yamuna river: i) site I Wazirabad (in western Delhi); ii) site II (near I.T.O. in Central Delhi) and iii) site III (Okhla in south east Delhi). The selection of these sites also indicate the changes in water quality as enters and leaves the city. For the same, Quantification of heavy metal concentration in water and soil samples were carried out and compared with the heavy metal concentration data analyzed by Central Pollution Control Board (CPCB) during the last 5 years period (1999-2003). In-situ analysis was undertaken for few physico-chemical parameters whereas, composite samples were taken for other analysis. Sedi ment samples were taken randomly across the river using a dredge. Physico- chemical parameters of water samples were analyzed according to the laboratory standard methods. The heavy metal concentrations were determined using Atomic Absorption Spectrophotometer.

The reported and the present analytical data on the heavy metal concentrations in Yamuna water samples indicate that the concentrations of Fe was dominantly higher in all the three sites. Interestingly, at site III concentration was comparatively lower (4.5-6.1 mg/L) than site I and site II (4-12 mg/L) zone. The concentration of Pb, Cu Cr and Zn were low at the three sites of river Yamuna but exceeded the environmentally safe concentrations as per the standard guidelines of CPCB. Similar trend was observed in the soil samples with higher concentration of metals like Pb (0.014 µg/kg) and Zn (0.565 µg/kg) as compared to 0.029 mg/L and 0.012 mg/L in water respectively. Bioaccumulation patterns of toxic metals in fish tissue was also reported by CPCB which shows presence of higher concentration of zinc and nickel in the fish tissue samples. This
can be utilized as effective indicator of environmental contamination. Presence of such heavy metal pollutants in the water course not only creates unfavorable environment for fish but also causes paucity of fish food organisms and fish eating birds.

**Key words:** Bioaccumulation, heavy metals, toxicity, aquatic food chain, Yamuna River, Delhi.
74. An Assessment of Distillery Spent Wash for its Possible Pollution Potential in Dry Land Areas

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Abstract
Spent wash is a liquid waste from distillery industries. Being originated from plant source, it is rich in nutrients and organic matter. The distillery spent wash is recommended as a liquid manure for improving soil fertility particularly in drylands. Being acidic and rich in calcium, it is also recommended for ameliorating the sodic soils. Though the beneficial effect of the distillery spent wash on soil and crops has been well documented, information is scarce on its pollution potential. In this study, the distillery spent wash was characterized and assessed for its possible pollution potential through laboratory experiments.

The spent wash used in the study was very much concentrated and was reddish brown in colour with unpleasant odour. It was highly acidic (pH < 4.0), but loaded with organic and inorganic salts recording high EC (48 dS/m) and TDS. The spent wash had exceptionally high BOD, COD and other components like phenols, lignin and oil and greases.

Soil column experiment had shown that large amounts of soluble cations (Ca$^{2+}$, Mg$^{2+}$, Na$^+$, and K$^+$) and anions (Cl$^-$, SO$_4^{2-}$) were found leached from both black calcareous and high pH sodic soils amended with spent wash. Remarkably, greater amounts of Na$^+$, Cl$^-$ and SO$_4^{2-}$ were leached from high pH sodic soil due to exchange reactions of Ca$^{2+}$ with Na$^+$ on the soil exchange sites and revealed the potential of spent wash in ameliorating the sodic soils. The application of organics (FYM, green leaf manure and bio compost) was also found beneficial in this regard.

Leachates from both soils had exceptionally high BOD and COD reflecting its pollution loads. The conjoint application of spent wash and organics resulted in buildup of salts in soil even after seven leaching events. The accumulation of cations followed: K$^+$ > Ca$^{2+}$ > Na$^+$ > Mg$^{2+}$ in black calcareous soil and K$^+$ > Ca$^{2+}$ = Na$^+$ > Mg$^{2+}$ in high pH sodic soil. This resulted marked suppression on seed germination and vigour index of ragi grown of the leached soils. However, organics, particularly green leaf manure (daincha) were found effective in mitigating such salt effect.

The biotoxicity study showed that a concentration of spent wash as low as 0.5 per cent was found as a lethal dose for 50% mortality / survival (LC$_{50}$) of fingerlings of a fresh water fish species. Field observation on quality of ground water, collected from well, nearby spent wash applied fields in Theni district of Tamil Nadu, had shown no pollution due to spent wash application, contradicting the results of the laboratory leaching experiment. Therefore, long term field experiments, involving piezometer studies, are needed to confirm the field level pollution of soil and ground water due to the application of distillery spent wash in dryland areas.

Key words: Distillery industries, spent wash, soil fertility, drylands, biotoxicity, Tamil Nadu
75. Biosorptive Removal of Cadmium from Contaminated Groundwater and Industrial Effluents

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Abstract
This paper reports the results of a study for the search of a locally available and novel biomass in Chhattisgarh. The removal capacity of biomass was investigated for removing cadmium from industrial effluents. Sorption studies using standard practices were carried both in batch and column experiments to study the factors influencing and optimizing the biosorption of cadmium. The parameters investigated are the effect of biomass dosage, contact time, metal concentration, particle size & pH. The study revealed that on an optimum pH of 5.0 this biomass can remove up to 85% of cadmium from solutions containing Cd as high as 250 ppm and hence this biomaterial could be an efficient biosorbent for cadmium. The kinetics of the adsorption was fast with more than 85% of adsorption taking place within 30 minutes at a concentration of 250 mg Cd/L. The effect of various anions (SO₄²⁻, Cl⁻, F⁻, PO₄³⁻) and cations (As, Mg, Ca and Fe) on the equilibrium uptake of cadmium was studied under laboratory conditions (28-33°C). Adsorption isotherm analyses for the adsorbent were investigated under similar conditions.

Based on the results it appears that this biosorbent possesses extremely high affinity for cadmium and thus it can be successfully used in controlling the cadmium pollution in various industries and contaminated groundwater.

Key words: Biosorption, Biomaterial, Cadmium, Groundwater, Contaminated water.
Abstract
Dykes are commonly believed to act as barriers against groundwater flow in areas underlain by hard rocks. Consequently the zone on one side of the dyke is supposed to have high-yielding wells/borewells while the wells are poor-yielding on the other side. Investigations of the hydrogeological conditions around a dolerite dyke in Melpatti village of Rasipuram taluk, Tamil Nadu has brought out some interesting facts which do not support the above belief. The study area, about 5km² in extent, has seventeen deep borewells, 11 dug-cum-borewells and 45 large diameter dug wells. The depth of the dug wells varies from 11 to 43 metres while that of the borewells ranges from 60 to 193m. The potentiometric map for the area does not show any effect of the dyke, in that there are no sharp changes of the hydraulic heads on either side of the dyke. The average water levels of wells located on the north of the dyke is 21.6m (24 wells) while it is 23.6m for wells present on the southern side (21 wells). The yield from dug wells varies from very low to as much as 96,000 lpd (litres per day) in the month of October, with an average of 32,000 lpd. In the case of borewells, the yield varies from 15,000 to 72,000 lpd with an average of 45,000 lpd. For wells located to the north of the dyke, the average yields are 40.3 lpd (borewells) and 38 lpd (dug wells) while it is 34.7 lpd (borewells) and 50.5 lpd (dug wells) for wells located on the southern side of the dyke. Thus the yields of dug wells/borewells do not show any appreciable variations on either side of the dyke. Two groundwater samples were analysed for their major ionic constituents, one on either side of the dyke. From the results of the chemical analyses (Table-1) it is seen that the groundwater to the north of the dyke is more brackish with higher TDS and total hardness as compared to the southern side. This may be due to relatively restricted groundwater movement in the northern side as the area is bounded by the BIF on the north and the dyke to the south. This indicates that there is possibly some barrier effect on groundwater movement caused by the dyke in the south and by the banded iron ore formation to the north. The high level of total hardness in the groundwaters of the area has resulted in the problem of encrustation of the delivery pipes when air-lift pumps are used for pumping water from the borewells. The pipes have to be replaced every 2-4 years as the pipes tend to get almost fully blocked by the deposits with in this period. Electrical resistivity investigations show that the area around the dyke shows higher apparent resistivity values indicating that sub-surface dykes could be identified from resistivity investigations.

The study thus shows no clear-cut indication of the dyke acting as a barrier in this area, though some reduction in hydraulic conductivity of the dyke formation is indicated by the groundwater chemistry. It may be that the post-dyke emplacement tectonics has induced fracture systems, which cut across the dyke, thus providing hydraulic continuity. In any case, the large scale exploitation of groundwater and the prevalence of several pumping troughs are not likely to encourage much lateral recharge in the area leading to predominance of vertical recharge from precipitation. Under such circumstances, the dyke, even if it is massive formation is not likely to affect the well yields on either side.
Problem of Selenium Toxicity in Nawanshahr & Hoshiarpur Districts of Punjab State, India

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Abstract

Selenium toxicity in ground water, soils and plants has been observed in parts of Nawanshahr & Hoshiarpur districts of Punjab State in India. The problem is prevalent only in about 1000 hectares of area covering about 5-6 villages namely: Mehadpur, Jainpur, Barwa, Rakkar, Simbli & Nizarpur. Selenium content of soils from toxic regions ranges from 0.23 to 4.55 mg/kg/-1 and is present upto 180 cms depth of soil profile. Concentration of selenium in ground water ranges from 2.5. ug/L to 65.5 ug/L. Maximum permissible concentration of selenium in water for irrigation use is 20 ug/L. Ground water pumped from shallow tubewells (upto 50 m) contains 2-3 times more selenium than that from deep tubewells (more than 100 m depth). Higher concentration of selenium has affected the human and animal health. According to house-to-house survey carried out by Health Department, Punjab; in Nawanshahar district 59 humans were found to be affected out of total of 4159. In Hoshiarpur district, about 50% of population above the age of 40 years suffers from problems caused by selenium toxicity. In the present paper, effects of selenium toxicity on human & animal health and the remedial measures to tackle the problem are discussed alongwith the possible causes of selenium toxicity.
Local Groundwater Supply and Sanitation in Suburban Dhaka, Bangladesh

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Abstract
Coverage by improved sanitation in Bangladesh is 25\% in rural areas and 75\% in urban areas (WHO, 2004). Awareness of the importance of proper sanitation is high (Hoque et al., 1996). Suburban areas in Dhaka are growing fast. The authorities cannot supply the suburban blocks with piped water supply and sewers. NGOs have helped people to construct local water supply and sanitation in the form of wells with depths of 15-25 m and pit latrines. The house plots are small and wells and pit latrines are often placed as close as 10 m apart. This has caused serious bacterial and nitrate pollution elsewhere (Jacks et al., 1999).

Two suburban blocks, Dattapara and Keraniganj have been investigated what concerns bacteriology and chemistry of the groundwater. In general the water quality is satisfactory both from bacteriological (Mcdonald et al., 1999) and chemical point of view. This is due to the favourable geological situation consisting of a 10-15 m clay layer on the top of the sandy sediments from where groundwater is extracted. Dattapara, the most densely populated settlement with house plots of around 200-300 m\textsuperscript{2}, have an input of 1500 kg/ha into the pit latrines out of which about 30 kg/ha are leached into the groundwater by a recharge of 1300 mm. Most of the nitrogen is denitrified while a small fraction, around 10 kg/ha is removed in the form of ammonia and about 20 kg/ha is taken up by sparse stands of trees. The nitrate concentration in the groundwater is 10 mg/L. The only parameter that is excessive is chloride at 300-500 mg/L. Another concern is the content of ammonium in the clay pack which is high, 70 000 kg/ha. However, with the high moisture content and anoxic conditions in the clay, this poses no immediate problem.

The house plots in Keraniganj are larger and vegetation is more abundant but the groundwater quality is similar due to the same sedimentary sequence. Thus, largely due to the geology, local water supply and sanitation is a viable alternative for these suburban areas.

References


79. Assessment of Impact on Groundwater due to Mine Discharge in Talcher Coalfield Area, Orissa, India

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Abstract
Groundwater is being deterioted due to many activities such as industrial pollution, man-made activities and mining activities etc. The mining activities causes degradation of land surface and ground water quality, degradation of habitat, springs, wetland habitat and lowering of water table due to continuous abstraction from the mining areas for extraction of ore.

In order to assess the impact of groundwater in Talcher Coalfield Area, Orissa, India, due to daily mine discharge water, a mathematical model has been prepared which has also been used to assess the groundwater budget in the area. The modelling study suggest that in some part of the area the lowering of water table in shallow aquifer is pronounced. Proper groundwater management and development has to be given priority to arrest the lowering of water table caused by mining.
Abstract
In developing countries many people are forced to drink turbid water and as a consequence many children are dying related to water borne diseases. Hence there is a need for inexpensive and easy methods to purify drinking water. *Moringa oleifera* seed contain an active coagulating compound that can be extracted and used as a natural coagulant. This paper describes the purification and immobilization of coagulant protein for water treatment. The coagulant protein from *M. oleifera* seeds were extracted with ammonium acetate buffer and studied its coagulation properties in synthetic clay solution. The crude extract has the same coagulation activity as alum. The active component was purified to homogeneity with fast flow Sepharose ion exchange chromatography and characterized the properties of the purified protein. The coagulant protein has also been purified using magnetic beads. The purified component is a cationic protein with a molecular mass less than 6.5 kDa. The magnetic beads have six times higher adsorption of the crude extract than the ion exchange matrix. The proteins immobilized to magnetic beads are active and have coagulation property in synthetic clay solution. The coagulated particles can be removed from immobilised protein by washing without disturbing the protein. The possibilities of using immobilized protein to magnetic beads are discussed. The immobilized beads or purified protein can be used in water treatment in developed and developing countries.

**Key words:** *Moringa oleifera*, coagulation activity, purification, ionexchange, magnetic beads, immobilization
Abstract

Intensification of agriculture is believed to be one of the major causes of contamination of both surface and ground water, especially in the regions where large quantities of inorganic nitrogenous fertilizers are used. This results in an increase in the level of nitrate in the water. A high level of it (> 45 µg g⁻¹ NO₃ or > 10 µg g⁻¹ NO₃-N) in the drinking water can cause methemoglobinemia or blue baby syndrome in infants and stomach cancer in adults. In the present study we have made a survey of NO₃ content in surface and ground water systems in the Hooghly district of West Bengal, one of the districts having highest fertilizer consumption rate in the country.

Water samples were collected during the premonsoon season of 2005 from ponds, khals, canals etc. (for surface water) and from dug wells, shallow, mini deep and deep tube wells at 70 odd sites spread over in 17 blocks of the district following appropriate statistical design. While selecting the wells, priority was given to those which are used as sources of water both for irrigation and drinking purposes. Data on soil types, cropping pattern, quantity of fertilizer used and depth of aquifer at the sampling sites were also collected. pH and EC values of the samples were measured on the spot immediately after collection while NO₃-N was measured in the laboratory following phenol disulphonic acid method with the help of a spectrophotometer.

pH and EC of the samples ranged from 6.2 to 8.6 and from 0.0113 dSm⁻¹ to 0.8240 dSm⁻¹ respectively. On an average, the values of pH were higher in the surface than in the ground water but reverse was the case for EC. The NO₃-N content both in surface and ground water also varied significantly in different blocks ranging from 0.10 µg g⁻¹ to 3.24 µg g⁻¹, showing that the content in all the samples (both surface and ground) were below 10 µg g⁻¹, the threshold limit fixed by WHO for drinking purpose. Samples from Khanakul-I, Pursura, Khanakul-II, Dhaniaakhali, Haripal, Tarakeswar and Pandua blocks were, however, found to contain a higher content compared to the other blocks. Of the 108 samples analyzed, only 3.7% of them contained NO₃-N higher than 3.0 µg g⁻¹, 5.6% higher than 2.0 µg g⁻¹ and 17.6% higher than 1.0 µg g⁻¹. The concentration of NO₃-N in the surface (pond) water was higher than in the ground water which varied from 0.27 to 3.12 and 0.10 to 3.24 µg g⁻¹ with mean values of 0.96 and 0.81 µg g⁻¹ respectively. The NO₃-N concentration in different sources of ground water followed the order: dug well > tube well > shallow tube well > mini deep tube well > deep tube well showing that the concentration decreased with increase in depth of sampling. Statistical analysis of the data showed a significant negative correlation (-0.29*) between NO₃-N concentration in water and depth of sampling. It was also observed that the concentration both in surface and ground water increased with the increase in the rate of application of fertilizers especially nitrogenous ones. It attained maximum with a mean value of 3.1 µg g⁻¹ and a...
minimum with a mean value of 0.23 µgg⁻¹ when the rate of application was > 200 kg ha⁻¹ and < 100 kg ha⁻¹ respectively. It was further observed that the NO₃-N concentration in ground water in areas where shallow rooted crops are cultivated was more than where deep-rooted crops are grown. Again, the same was lower in the areas where lowland rice was cultivated rather than the other crops; possibly because of increased denitrification under the anaerobic condition and decreased leaching of nitrate under rice cultivation. A significant negative correlation was observed between NO₃-N concentration in water and water pH (-0.22*) and EC (-0.24*).

Results thus indicated that although relatively higher accumulation of NO₃-N is mainly restricted to shallow aquifers and its level is still below the permissible limit in all the 17 blocks of the district (Hooghly), there is a clear indication of its possible build up in ground water particular where the use of nitrogenous fertilizer is higher and shallow rooted upland crops are grown. Hence it calls for immediate necessary steps for rationalization of use of chemical fertilizers particularly nitrogenous ones and also the cropping pattern so that the situation does remain under control in future.
82. Isotopic Analysis of Ammonium ($\delta^{15}$N), Nitrate ($\delta^{18}$O and $\delta^{15}$N) and DOC ($\delta^{13}$C) at Trail Road Landfill Plume, Ottawa, Canada

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Abstract
Both ammonium ($NH_4^+$) and nitrate ($NO_3^-$) are common contaminants found in shallow groundwater (Smith et al., 1991; Korom 1992) and are known pollutants recognized. Although there are multiple sources of ammonium and nitrate such as agricultural fertilizer, septic systems etc., it also can enter groundwater reservoirs from landfill leachate. In this research several samples were taken from leachate and groundwater at Trail Road Landfill (TRL) site, located at about 25 km West of Ottawa City. The ammonium concentrations of samples have been measured using Ion-Selective Combination Electrode method (ÔTM 390 Ph/Temp/mv/ISE Meter; Beckman Instruments, Inc.) for the low concentrations of ammonium and a simultaneous distillation and titration method, the traditional Kjeldahl distillation method with a few modifications, for the high concentrations of ammonium. Ion chromatography (IC model DIONEX – DX-100) was used to measure nitrite and nitrate concentrations. For the $\delta^{15}$N of ammonium, the collected homogeneous powder of ammonium sulfate salt ($(NH_4)_2SO_4$) were weighed into tin capsules and then were flash combusted at 1800 °C in an elemental analyzer (EA). Resulting gases were carried via helium through the EA to purify and separate the N$_2$ gas. N$_2$ gas was carried from the EA into an isotope ratio mass spectrometer (IRMS) for isotope analysis. For the isotope values of nitrate ($\delta^{18}$O and $\delta^{15}$N), the denitrifier method using the bacteria Pseudomonas chlororaphis has been applied (e.g. Casciotti et al., 2002). During the isotopic analysis, N$_2$O from samples (20 ml vials) were frozen into trap for 15 min, released then run in continuous flow via GasBench peripheral (Thermo Finnigan) interfaced to an Isotope Ratio Mass Spectrometer Delta XP (Thermo Finnigan). Dissolved organic carbon (DOC) was characterized using a Total Carbon Analyzer (TCA) and a continuous-flow IRMS. All measurements have been made in the geochemistry and the G.G. Hatch Isotope Laboratories of Department of Earth Sciences at University of Ottawa.

High concentration of NH$_4^+$ in leachate pipes (average amount of 210.8 mg/l, n = 7) and in M32 (337.4 mg/l) in comparison to groundwater samples shows that leachate environment is free of oxygen (anoxic condition) and low concentrations of NO$_3^-$ in leachate is due to natural attenuation of nitrate over the denitrification process which take place under this sufficiently anoxic environment. This can be confirmed by the enriched isotope values of nitrate ($\delta^{18}$O and $\delta^{15}$N) in the leachate sample (LP2B) and $\delta^{13}$C values.
Abstract
Kiltan Island is one of the 10 inhabited islands in Lakshadweep. Built on the ancient volcanic formations is the Lakshadweep, the tiniest Union Territory of India. The major problem experienced by the islanders is the acute scarcity of fresh drinking water. Groundwater is the only source of fresh water and the availability of the same is very restricted due to peculiar hydrologic, geologic, geomorphic and demographic features. Hence proper understanding of the groundwater quality, with reference to temporal and spatial variations, is very important to meet the increasing demand and also to formulate future plans for groundwater development. All the available information on water quality, present groundwater usage pattern, etc., were collected and analyzed. Total hardness and salinity are found to be the most critical water quality parameters exceeding the permissible limits of drinking water standards. Spatial variation diagrams of salinity and hardness have been prepared for different seasons. It is also observed from these maps that the salinity and hardness is comparatively better on the lagoon side compared to the seaside. Majority of the wells are bacteriologically contaminated, as most of them are very close to the leach pits. Considering the present status of groundwater, strategies for conservation and management of fresh groundwater sources have been suggested for the Kiltan Island.

Key words: Lakshadweep Island; Groundwater Quality; Management Strategies.
Abstract
The characteristics of the wastewater from the Industrial Estate of Ankleshwar (South Gujarat) were studied in order to provide an optimal solution to the treatment of wastewater. The wastewater from the industrial estate of Ankleshwar could be classified as medium strength consisting mainly pharmaceutical and chemical industrial effluent from over 50 units. A relationship between the BOD (Biological oxygen demand) loading and the treatment efficiency provided in the lab scale biotower was studied. The entire treatment was given keeping COD (Chemical oxygen demand) and BOD as main criteria though wherever necessary TSS (Total Suspended Solids) and pH were also analyzed. The trend in the efficiency observed was that, with an increase in organic loading there was a decrease in COD% and BOD % reduction. The reduction in decrease was more or less linear. However for a loading of 1.92 kg/m3/d the COD, BOD and TSS reductions obtained were higher than at lower loadings which may be because of higher acclimatization or due to lower strength of BOD during that period. The TSS reduction after settlement of the effluent of biotower were very encouraging and were on an average 45% thus a very important result concluded was that primary sedimentation can be omitted if proper screening facilities are provided which screen the incoming solids which may clog the nozzles of the distribution system. The remaining micro suspended solids can be settled in the intermediate clarifier provided after biotower reactor. An attempt is made in the study to reduce the cost of the entire project of common effluent treatment plant using two stage biological treatment (Biotower followed by activated sludge process) instead of using conventional activated sludge process. The results, not only will reduce the operational cost but will reduce the shock loads on the activated sludge process.

Key words: Trickling filters, Biotower, Activated sludge process, BOD, COD, TSS.
85. New Role of Subsurface Colloids in Groundwater Contamination

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Abstract
Until some two decades ago, it was believed that only the soil liquid and gaseous phases were mobile and could facilitate the transport of chemicals and nutrients in subsurface flow. It is now generally accepted that also part of the soil solid phase is mobile under different geochemical conditions and that mobile organic and inorganic soil particles, colloidal in nature may facilitate or retard the contaminant transport.

The mobility of contaminants in subsurface zone is dependent on their distribution between the immobile solid phase and the mobile aqueous phase. Many contaminants readily sorbs to immobile aquifer media and therefore considered to be virtually immobile in the subsurface, thus presenting little danger to, e.g., groundwater supplies. Therefore, most predictions of contaminant transport were based on two-phase equilibrium adsorption models (a dissolved phase and a sorbet immobile phase). The greater the extent to which a contaminant partitions onto the immobile phase, the slower is its average transport velocity in the groundwater. This is the case of contaminant transport in the absence of mobile colloidal fines in subsurface environment.

The unexpected appearance of low-solubility contaminants some distance from known source or sooner than would be expected from their solubility, led to examination of the possible involvement of nonaqueous, mobile colloids in contaminant transport. The presence of mobile colloidal fines can explain such observations and led to the thinking of three phases in contaminant transport models i.e. mobile liquid phase, mobile colloidal phase and the immobile solid phase. It is a complex phenomenon in porous media involving several basic processes such as adsorption, colloidal fines release, migration and fines entrapment / plugging at the pore constrictions. The effects of these basic processes on the contaminant transport are studied in this work.

Key words: Subsurface Colloids, Groundwater, Contamination, transport, adsorption models.
Abstract
The provision of water-supply, sanitation and drainage are key elements of the urbanization process. Substantial differences in development sequence exist between higher-income areas, where the process is normally planned in advance, and lower-income areas, where informal settlements are progressively consolidated into urban areas, but common factors are impermeabilization of a significant proportion of the land surface and major importation of water from outside the urban limits, with subsequent disposal of large volumes of wastewater. Sanitation of drainage arrangements, are thus also fundamental to consideration of the urban hydrological cycle. They generally evolve with time, but very widely with differing patterns of urban development. In most developing towns and cities installation of mains sewerage systems lags considerably behind population growth and water-supply provision.

Distinction between point and non-point sources of pollution is essential to deal with groundwater quality problems. Point sources deal with identifiable activities causing soil and groundwater pollution, such as domestic and industrial wastewater. Non-point sources represent poorly characterized diffuse sources, such as stormwater – runoff pollution and sewage leakage. In the arid regions, until recently, most of the studies were aimed at quantity aspects of groundwater, as they are faced with problems of water shortages. However, in the last few decades, the importance of quality aspects in conjunction with quantity is being recognized due to groundwater pollution vulnerability.

Warangal, headquarters of a district is not a well-planned township. The entire town falls under ribbon development pattern along the sides of the main road, which connects Kazipet and Warangal. The town is situated far off from the seacoast and its attitude is about 100 MSL. The climate is almost dry and without much variation in the temperature. Rainfall occurs mostly during the monsoon period following hot summer months and average yearly rainfall is about 900 mm. Unfortunately, the town is without an underground drainage system till now. There are many drains both open and closed, mainly intended to drain off wastewater and stormwater. On most of the occasions, sewage enters the storm drains that lead ultimately to Bhadri tank, polluting the waters. Secondary effluents from septic tanks are often let off into these drains without proper treatment. In addition at some places, the water closets are directly connected to the drains, which causes groundwater pollution due to seepage of wastewater.

Abandoned wells represent another major source of groundwater pollution. Most domestic wells have no casing to prevent surface water contamination from leaking directly into acquires that they penetrate. These become direct routes for drainage of
surface contaminants into the aquifers. Though most of the town is supported with treated water by the municipal corporation, public still depends on private groundwater sources due to water shortages. Because of the traditional assumptions that groundwater is always safe for consumption, the water from private wells are generally used without any treatment. The use of contaminated, untreated groundwater causes waterborne diseases in the town. Sorting out the source of pollution and suggesting appropriate measures to control the source is very essential in the present situation. The present paper presents the results of such an attempt to identify the sources and origin of groundwater pollution through extensive water quality survey and systematic laboratory analysis.
Abstract
Though the incessant rain lashed the whole Tamil Nadu during October and November 2005 filling almost all the lakes and reservoirs, still we depend on ground water during summer due to poor conservation of surface water. The chemical quality of groundwater is essential for evaluating its usability for domestic and agricultural purposes which depends on chemical, physical and bacteriological properties. Thus the hydrogeochemical investigations were carried out in the Thiruvalangadu area, a pilgrim town located in the Palar river basin of Tiruvallur district of Tamil Nadu. Nagari, Nandhi and Kusastala are the three major rivers which drain the study area. The area falls under a semi-arid climate and consists of Archean Granites and Proterozoic Dolerite with other metamorphic and sedimentary rocks. Representative groundwater samples were collected from dug and bore wells to study the water chemistry of various ions comprising calcium, sodium, potassium, magnesium, bicarbonate, chloride and sulphate. The laboratory analysis and the interpretation of the samples are systematically carried out and the results are represented numerically and thematically. The study area is dominated by Bi carbonate followed by chloride and sulphate. The study area falls under fresh to brackish types of water. In most of the area, groundwater is not well suitable for irrigation purpose.
88. Models and Their Role in the Assessment and Management of Groundwater Resources and Pollution (Key Note Paper-TS-4)

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Abstract
One can infer the past behavior of an aquifer system from the available earlier field records, but there is no way of computing the future behavior of the regional aquifer system unless it is actually subject to the stress. A full-scale experiment would be prohibitively costly and time consuming. The only feasible recourse, therefore, is to be appropriately simulate the aquifer and study its response to several input/output schemes and thereby evolve the optimal management schemes. A groundwater model is thus a simplified version of the real system that approximately simulate the input – output stresses and response relations of the system. One has to understand here that normally the real system is simplified to model the system as such there is no unique model for a given groundwater system. Normally, models are classified as predictive, interpretive and generic models. Predictive models are used to predict the future response of the aquifer, which needs a calibrated and validated model. Interpretive models are used for studying system dynamics and it is generally used for optimal data network design. Generic models are used to understand the flow dynamics in hypothetical situations.

H. Skibitzke and J. Karplus during sixties introduced the analogy between groundwater flow in porous medium and flow of electric current in resistance-capacitance (R-C) network and simulated the groundwater flow system. Since then there has been a considerable advancement in the modeling tools for a better understanding of the flow dynamics in complex aquifer systems. Early eighties witnessed the era of the numerical simulation techniques in replacing the time consuming electric analog modeling techniques. The time old Hele-Shaw physical model to simulate density dependent flow was replaced by a powerfulnumeric model. Numerous numerical methods (Finite Difference, Finite Element and Integrate-finite Difference, etc.) were developed during the eighties and nineties to simulate the realistic condition of groundwater flow system in porous medium. Though, a good perfection could be achieved in simulating continuous porous medium, we have no answer for non-continuum medium such as weathered fractured zone. Future attention needs to be focused on the
development of easily workable non-continuum models and apply them to assess the regional groundwater potential and contaminant migration through fractured medium. Another area of modeling technique that needs to be perfected is the simulation of soil moisture and contaminant migration in the vadose zone and the simulation of interactions between surface water and groundwater. Two case studies will be discussed on the application of flow model in evolving pre-development management schemes and mass transport model in the quantification pollutant migration.

**Keywords:** Modeling tools, Groundwater management, Fractured system, Non-continuum models, Contaminant migration, Vadose zone, Surface water-groundwater interactions.
89. Modeling Long Term Effect of an Aquifer Storage Recovery Well on Ground Water Situation under Cotton Wheat

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Abstract
Ground water situation was projected of a farm of 81.7 hectares in semiarid region having brackish under ground of EC = 8dS/cm growing cotton wheat with and without an ASR well operation for 5 year using Hydrus 2D model. Before using Aquifer Storage Recovery (ASR) well, the farm had canal irrigation of 0.61m/ annum and no ground water irrigation facilities. After installing an ASR well of recovery rate of 15 L/s and recharge rate of 20 L/s, ground water irrigation of 0.4m/ annum was added at the farm. Actual daily field measured evapotranspiration values using SWAP model with remote sensing technique from well irrigated; and water and salt stressed wheat cotton fields were used for with and without ASR facilities farm. Daily rainfall of normal year 1992 of the region was taken as one of the input parameter. Recharging of fresh water in ASR well decreased the salinity of the ground water and its use for irrigation decreased water table at all distances. Water table showed a rising trend without the ASR well creating water logging situation where no crop could be grown. The effect of changing the rainfall and irrigation has been shown on water balance and other water management indices on long term basis using the model. The study has shown that artificial ground water recharge through an ASR well having brackish native ground water could be a viable technology for encouraging the conjunctive use of brackish ground water and excess
fresh rain water in high water table areas for lowering the water table and increasing crop productivity at a large farm over the years.
90. Groundwater Flow Model in the Mangrove Forest

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Abstract

The ability to predict groundwater fluxes with a minimum of effort and measurement is an important objective. Numerical modeling is one approach to obtain such a prediction. Predictions of groundwater fluxes can be used to determine fluxes of other materials such as salt and nutrients provided the concentrations of these materials are known independently. In this paper an analytical model is developed to predict the flow of groundwater from mangrove forest to the creek. The model uses the geometry and hydraulic conductivity of the mangrove forest sediment, which is inundated by tidal water from day zero to day five, with the flux ranged from 0.026 to 0.007 m³/(m² day) with the average error is about 10 %. The solution for the groundwater flow is written in terms of an analytic series solution, based on two dimensional potential flow. The approach is basically to solve the hydraulic potential flow for steady state conditions using the Laplace equation. The advantages of this method are that it is simple but accurate, and the error in the computation can be readily calculated. The result of this model is then compared to the result of the field measurement from also day zero to day five after inundation, which ranged from 0.030 to 0.013 m³/(m² day) with the average error is about 40 %. From the above results, it is concluded that the series solution model can be used to calculate the flux of the groundwater, especially in the mangrove forest area.
91. Stochastic Algorithm for Simulation of NAPL Dissolution and Degradation Reactions in Porous Media

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Abstract

The kinetic approach is suitable for solving complex reactive transport processes in ground water. If the transport scale is faster than the reaction time scale, the kinetic formulation of reaction modeling can be studied by two different approaches. The time behaviour of the homogenous chemical reaction system can be described either by the deterministic approach or by the stochastic approach. The deterministic approach considers the time evolution as continuous, which is governed by a set of coupled ordinary Differential Equations (ODEs). The stochastic approach considers the time evolution similar to a random walk process. It is governed by a single differential equation, which is called the master equation. This paper deals with the conventional way of modeling geochemical reaction systems using a deterministic approach with its limitations and clarifies the necessity and application of stochastic algorithms (Gillespie’s Algorithms) to PCE\textsubscript{NAPL} dissolution degradation reaction. The simulation of PCE\textsubscript{NAPL} dissolution degradation reaction was done using Gillespie’s Direct Method, a stochastic. The next reaction to be occurred and time of occurrence of reaction are obtained through generation of two random numbers. An example of the concentration profiles of PCE\textsubscript{NAPL} dissolution degradation simulation using ODE and Stochastic Algorithm is presented in Fig. 1.

![Fig. 1. Comparison of concentration profiles of PCE\textsubscript{NAPL} dissolution degradation simulation using ODE and Stochastic Algorithm](image)

From the above results, it is concluded that Stochastic Algorithm can be better
approach for reaction involving low concentration species.

**Keywords**: Deterministic approach, Gillespie Algorithms, NAPL dissolution, degradation, Ordinary Differential Equation, Gillespie Direct Method.
92. Investigation of Aquifer Remediation Strategies by Using a Coupled Finite Element Model for Ground Water Flow and Contaminant Transport

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Abstract
Ground water is one of the important sources of drinking water for many countries in the world. Long-term withdrawals of ground water resources has created a need to predict its effect on future water quality and sustained availability. With the increasing water demands, growing agricultural and industrial activities, the protection of ground water resources has become a major challenge. Remediation of contaminated ground water is complicated, time consuming and expensive practice. Identifying the source of ground water pollution is an imperative before a specific ground water pollution remediation strategy can be applied.

This paper describes the contaminated aquifer remediation alternatives using a coupled model for ground water flow and contaminant transport by finite element method. The study investigates a problem of cleaning up the aquifer, which has been contaminated due to leachate entering the ground water from a pond and also combination of pond and recharge well for 25 years. Four remedial alternatives of cleaning up the aquifer were simulated. These include a no-action, flushing, pumping and combination of flushing and pumping alternatives. From the simulation results obtained for the four decontamination strategies, it is observed that maximum initial concentration in the aquifer is reduced to drinking water standards within three years by self cleaning, while it took two and half years approximately to reach this level in the second alternative. Third and fourth alternatives were found to reduce the cleanup time to nearly one and half years to attain this level. However the last two options demand more financial resources and their suitability depends upon the water necessity in a particular locality.

Key words: Aquifer remediation, Flushing and Pumping. Groundwater pollution, Finite element simulation
Abstract
As urban, industrial and agricultural water use grows, the effective and cost efficient
development and management of limited water resources is quickly increasing in
importance. The firm supplies of non-perennial rivers are limited in absence of storage
facilities such as reservoir. In such situations, a careful design of intake structure is
required to ensure supply of water for specified needs. In alluvial river, a Radial Collector
(RC) well is appropriate solution to satisfy large demand under low-flow condition.
Another advantage of RC well is that it provides naturally filtered water and save the
treatment cost.

As the RC well comprises of horizontally placed screen pipes in riverbed aquifer,
the complete structure behaves like well with large effective radius. However, due to
asymmetry of radials and position of recharge channel, no analytical solution exist to
exactly provide discharge drawdown relationship. The discharge and design of radials
are governed by saturated thickness of aquifer, position of river channel with
reference to RC well, hydraulic conductivity of riverbed aquifer, gradation of aquifer
material and depth of scour. An appropriate methodology to design RC well is; to
decide radials orientation as per site condition and then to verify the design discharge
by constructing riverbed aquifer flow simulation model.

A radial collector well was proposed to be constructed at confluence of river
Kanhan and Jam near Borgaon of Madhya Pradesh, India for supplying 22.5 Mgd
water to an industrial area of M.P. Audhyogic Kendra Vikas Nigam. Necessary field
data were collected and pump tests were carried out. The arrangement of radials were
decided. A finite difference method based MODFLOW model and Analytic Element
Method based model were used to simulate stream aquifer interaction process under
steady state. Using MODFLOW, aquifer is divided into seven layers. 301m x 301m
area was descritised into 113 cells in rows and columns. Radial locations were
modeled by head dependent boundary cells. Recharge channel was introduced using
constant head boundary cells. A steady state simulation was carried out for different
positions of recharge channel and under different drawdowns.

Simulation results indicated that 17 Mgd of water can be drawn from RC well
even in absence of surface channel in summer. The actual discharge may increase
considering depletion of storage in riverbed aquifer. 14 radials of total 380 meters length in two tiers were proposed.

In absence of analytic solution that represents site condition of RC well, numerical modeling is essential for design which leads to economical viability and provide safe yield. Finite difference based three-dimensional model, MODFLOW and Analytic element method based two-dimensional model were used. Results of Analytic Element Method are comparable with MODFLOW model. AEM is found to be very simple to construct the model for design purpose. Initial trials can be done using AEM by varying radial lengths, numbers and orientation with different surface water channel location. A final design can be checked by three-dimensional MODFLOW model. This approach saves considerable time during design process. The riverbed aquifer flow model was found to be useful to finalize the design of RC well.

**Key words:** Riverbed Aquifer, Radial Collector Well, Stream Recharge, Modflow, Analytic Element Method, Madhya Pradesh.
Abstract
Onitsha metropolitan Area (300 sq. km.) is located at the confluence of river Niger and river Anambra, in the Anambra basin, Nigeria. It is a highly populated centre and includes the present Onitsha Townsi, located between latitude 60 04’N and 60 15’ N and longitude 60 45’ E and 60 53’ E in the southeastern part of Nigeria. The aim of this study is to produce a detailed predictive model for the aquiferous units and the quality of underground water from boreholes in Onitsha metropolis in south Eastern Nigeria. It included the use of borehole lithologic logs, GPS and GIS software and geochemical analysis of trace elements in underground water from 10 boreholes.

The components of the aquiferous units and depth to water table were characterized using lithologic logs and GIS. Also the ground water distribution and flow pattern, topographic driving force and water table were produced in 3D models. Geochemical analysis of 36 trace elements in 10 water samples was also carried out.

Results shows that the area comprises of three aquifer systems, flow pattern of the ground water is of east-west direction and indicates effect of topography on the flow pattern. Also the water table of the area was seen. It also shows that most of the boreholes samples in Onitsha metropolis are in bad conditions except Boreholes 1, 2, 3 and 9, which are situated in clean environments. Geochemical analysis shows that most of the ground water is not potable because of high level of Ba, Ca, Cu, K, W, Si, and Zn. The lack of planning in this area and awkward sitting of wells close to roads, drainage system, waste disposal sites, sewage tanks and latrines, which have aggravated the level of contamination. This study shows that in as much as the borehole is drilled to a great depth to avoid contaminants, the environmental condition is very important to be considered before boreholes are to be sited.

Key words: Predictive Model, Aquiferous Units, Quality, Ground Water, Anambra Basin, Nigeria.
95. Computer modelling of point and non-point source pollutants and nutrients discharge from coastal watersheds to coast

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Abstract
More than half the world’s human population lives within 100 km of the coast, and that number is expected to increase by 25% over the next two decades. Consequently, coastal ecosystems are at serious risk. Larger coastal populations and increasing development have led to increased loading of toxic substances, nutrients and pathogens with subsequent algal blooms, hypoxia, beach closures, and damage to coastal fisheries. Subsurface Water Discharge (SWD) into the coastal zone is recognized as a potentially significant pollutant pathway from the land to the coast. This interaction affects the water quality and quantity in both surface water and subsurface water. Subsurface water and surface water interaction affects chemistry, especially acidity, temperature, dissolved oxygen, and reduction-oxidation potential. There are a wide range of reasons and applications for the study of subsurface water relationships in the coastal zone. This diversity, in combination with the range of disciplines and of time and space scales involved; complicate the use of data for purposes other than those envisioned by the investigator. As land and water resource development increases in the coastal watersheds, it is becoming readily apparent that subsurface water and surface-water interaction must be considered in establishing water management policies.

In this paper, the roles of hydrologic processes and hydro-biogeochemical processes are investigated through development, modification, and application of models for addressing point and non-point source water quality modelling of
receiving waters: surface water, subsurface water and seepage water to the coast and
with some examples.

**Key words:** Hydrologic and hydro-biogeochemical processes, nutrients, coastal
watersheds, subsurface water discharge (SWD), modeling, water quality.

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Abstract
Contaminant transport with significant density contrasts is of increasing interest in many subsurface hydrology problems like seawater intrusion, saltwater upconing in coastal aquifers, and dense contaminant migration. Several numerical codes have been developed to simulate those systems. Results from these codes are found to be sensitive to grid and time step sizes, and to the numerical schemes used to approximate the solution. The 3-D Finite Difference Method code, SEAWAT has been tested over a wide range of problems, but the sensitivity of the computed results to spatial and temporal discretization levels for different numerical schemes supported by the code has not been studied in detail yet. This study aims to: (1) provide an approximate guide for SEAWAT users to ensure proper selection of grid and time step sizes for a particular numerical scheme in order to minimize the numerical error (in 2-D) and (2) to investigate the ability of SEAWAT code to simulate more complex 3-D systems.

The Elder-Voss benchmark problem was selected for the study. Different degrees of spatial and temporal discretization were found to produce significantly different results. A grid size of around 0.4% of the total length of the domain is found to be fine enough to produce results with acceptable accuracy for most of the numerical schemes when the Courant number (Cr) is around 0.1. Some numerical schemes produce accurate results with a coarser mesh while other schemes produce similar accuracy only with an extremely fine mesh. A higher Cr number (around 1) was found to reduce the accuracy of the computed salinity-spread patterns significantly for all schemes compared with the case when Cr is 0.1 or 0.5. To ensure a high level of accuracy when using SEAWAT, Cr should be \( \leq 0.1 \) when the Peclet number (Pe) is \( \leq \) about 1.
SEAWAT using a coarse mesh was able to capture the main physical features of the Elder-Voss convection pattern in 3-D when compared with that produced by a Finite Element Method code “FEFLOW” at a very fine mesh (Diersch and Kolditz, 1998). The 3-D modeling requires a large numerical effort compared with that of the 2-D case. Using the same computer, run-times for 2-D problems with a very fine mesh were up to 70 times as long as those for a coarse mesh; run-times for the 3-D problem with relatively coarse resolution were normally at least 150 times those for the 2-D problem with a coarse mesh. The 2-D and 3-D results showed similar convection patterns in terms of fingering, and up/down welling behavior. Other factors like the level of accuracy required, computational expense and storage memory requirements should be considered along with the spatial and temporal resolution levels.
Abstract

The paper deals with the development of numerical model for inverse modelling of groundwater systems based upon simulated annealing (SA) global optimization method. Galerkin's finite element technique is developed for computing the head distribution in a confined aquifer domain. The developed numerical model is applied to the synthetic aquifer involving a set of boundary conditions, source and sink terms to compute the system parameter (transmissivity) within the chosen nine zones of the aquifer.

Different data sets involving, both, steady and transient head values are used for these estimations. The results show that the developed model can be successfully used to obtain optimal estimates of the aquifer parameters. Based upon these information optimum model structure is also identified later from five different initial models.
Abstract
Groundwater modeling techniques have been proved to be a powerful tool to understand the hydro-dynamics of any complex groundwater system and also to assess its groundwater potential for the effective management of an aquifer system. But modeling a hard rock aquifer poses a numerous problem because of its heterogeneity nature. Of course many researchers have attempted to model the weathered part of hard rock aquifer (crystalline rock) system by assuming the saturated part of the unconfined aquifer as porous one. One such attempt was made in Kodaganar river basin a hard rock region in Dindigul district, Tamilnadu. The study area covers about 1752 km² excluding the hilly part and it falls in the rain shadow part of western ghat. Groundwater in this basin is heavily exploited for domestic, irrigation and industrial purposes. The indiscriminate exploitation of groundwater coupled with erratic rainfall has lead to continuous decline of water level over a long period of time. The consequence has been deepening bore wells, depletion of water resources and deterioration groundwater quality in many parts of the study area.

A mathematical model representing weathered part of aquifer system was conceptualized based on the hydrogeological data collected by NGRI, Hyderabad, Public Works Department (PWD), Govt. of Tamilnadu and Central Groundwater Board, Chennai. Numerical model was constructed by considering the realistic field condition, various boundary conditions and initial conditions prevailing in the system. The model was then calibrated for steady and transient conditions and it was used for predicting the future behavior for various input and output stresses. The model study clearly has brought out the fact that unless good rainfall recharges the system there is no possibility of increasing the abstraction in the basin. It also indicated that the dewatered weathered aquifer system can bounces back with good rainfall. The assumptions used and the uncertainty involved in the model has been explicitly brought out.
**Key words:** Weathered aquifer, Numerical simulation, hard rock aquifer, Kodaganar basin.
Numerical Analysis of Tide-Aquifer Interaction Data For Estimating Aquifer Parameters

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Abstract  
The analysis of tidal effects on aquifer systems plays an important role in coastal aquifer management. Adequate knowledge of the hydraulic properties of aquifer systems such as transmissivity (T) or hydraulic conductivity (K), storage coefficient (S) and/or hydraulic diffusivity (D) is crucial for almost all the studies concerning groundwater quantity and quality, including the modeling of subsurface flow and transport processes. In this study, the tide-aquifer interaction data of unconfined and confined aquifers have been numerically analyzed for estimating aquifer parameters by the Levenberg-Marquardt technique considering two approaches: without tidal data resolution (Approach I) and with tidal data resolution (Approach II). In addition, the effect of tide-aquifer interaction data corresponding to Spring and Neap tides on parameter estimates has also been investigated. The tide-aquifer interaction data for two unconfined sites and three confined sites were used in this study.

The analysis of the results indicated that the aquifer parameters S and T, and hence hydraulic diffusivities (D) based on Approach II are more reliable and accurate for both the aquifers than those based on Approach I. Therefore, Approach II is strongly recommended for the estimation of aquifer parameters by the tide-aquifer interaction technique. Sensitivity analysis of the Levenberg-Marquardt technique revealed that it is
very sensitive to the choice of initial guess values, but the algorithm converges even for very poor initial guess values. Furthermore, the Spring and Neap tide-aquifer interaction data significantly affected the aquifer parameter estimates. It is concluded that a judicious use of the tide-aquifer interaction technique is indispensable for the reliable estimates of aquifer parameters.

**Key words:** Tide-aquifer interaction, Numerical analysis, Levenberg-Marquardt technique, Aquifer parameters, Coastal aquifer.
100. Modeling of ground water flow induced by time varying recharge and/or withdrawal from multiple sites

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Abstract
Recharging and pumping are the essential components of groundwater resource development scheme. Both processes significantly affects the dynamic behavior of the water table. Leakage is another hydrological process which influences the nature of water table variation. Artificial recharging and pumping are intermittently applied when needed and their rates are known to vary with time. Therefore, an accurate prediction of water table variation in response to time varying recharge and/or withdrawal (which include pumping and leakage) are essential to achieve the preset objectives of ground water resource development. Mathematical models are widely used for the prediction of water table variation. The present work deals with the development of a mathematical model to predict the water table variation induced by time varying recharge and/or withdrawal from any number of source and sink, respectively of different dimensions. Application of this model in prediction of water table variation is demonstrated with the help of a numerical example. This model can be used for judicial selection of an appropriate scheme of recharging/pumping out of many proposed schemes for sustainable development of a ground water system. Accurate estimation of time varying recharge rate is a difficult task. If water table variation at some observation points is known, then this model can be also used for estimation of recharge rate by using trial and error method such that the computed water table variation at the observation point for the considered rate of recharge is in good agreement with the observed water table variation.
101. Assessment of Geochemical Processes Regulating Groundwater Chemistry in a River Basin in Southern India

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Abstract
An investigation was performed to understand the geochemical processes and its contribution to groundwater chemistry in a hard rock and sedimentary formations, south India. For this study, groundwater samples were collected monthly once from 43 wells (in total, 641 samples) from January 1998 to June 1999, and analyzed for major ions. Results indicate that major ion chemistry of the groundwater samples varies with respect to space. Groundwater occurring near the Palar River has high concentration of major ions except calcium due to the absence of river flow, where as lower concentrations of major ions were observed in the central part of the study area due to the recharge of fresh water from number of reservoirs. The groundwater chemistry in the study region is controlled by both mineral dissolution and anthropogenic activities, especially agricultural activities. Weathering of silicate minerals is the major processes regulate the major ions concentrations in the groundwater of this area. Further, the activity plots indicate that the groundwater is in equilibrium with kaolinite, smectite and montmorillonite. The relative contributions of mineral dissolution and anthropogenic contamination are estimated by reaction stoichiometric approach, and suggested that mineral dissolution is the dominated processes in both the formations. However, the contribution of anthropogenic activities is slightly higher in the sedimentary formations. Thus, groundwater chemistry of this region is largely influenced by mineral dissolution and anthropogenic activities.
Abstract
Little information is available regarding the water resources systems of Abaya and Chamo lakes, which are found in Southern Rift Valley Region of Ethiopia. In this paper, modelling of the water balance components and there by impact of water use, sediment transport and deposition are highlighted. In order to be able to develop the water balance model, the watersheds of the lakes system are developed under GIS and the watershed characteristics are derived. The optometry of the Lakes is investigated by undertaking bathymetry survey. Developing relevant database and information system and establishing regional relationships as well as rainfall-runoff model have also investigated the hydro-meteorological component of the system. These information systems have been integrated to model the water balance of the Lakes, which simulates the water level. Based on the simulations result and computation of life expectancies, it is found that sediment inflow and deposition threaten the two Lakes.

Key words: GIS, Rift Valley, Bathymetry, Sediment Depositions, Water Balance Modelling.
103. Simulating Affects of a “Tsunami event” on Density Dependent Flow and Transport Ground Water Model for Pine Rivers Shire, Australia

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Abstract
On December 26th 2004, a catastrophic tsunami devastated many countries of South East Asia. The inland saltwater surge impacted upon the coastal soil and groundwater quality in low lying areas. The groundwater resources along the coastal aquifers were affected through contamination and destruction to existing freshwater wells. Although most of the saline flood water eventually drained back to the sea and the period of flooding appeared short but the sea water nevertheless infiltrated or remained on the land and appeared to leave a considerable salt load in the soil. For example, Pondicherry in India and Bande Aceh in Indonesia have both been severely impacted by salt contamination. These areas and many others around the world rely on groundwater for their domestic and agricultural needs. This paper investigates the effects of a Tsunami event on the Australian coastal aquifer system. To simulate saltwater inundation inland a 3-D density dependent flow and solute transport model is developed using the FEMWATER code. The study simulated a short Tsunami event for the Pine Rivers Shire aquifer in Queensland (Australia). The results of the analysis are presented together with discussion of possible impacts on the ground and surface water quality.

Key words: Saltwater intrusion, GMS-FEMWATER, Coastal aquifer, Freshwater, Saltwater.
A Study On Groundwater Chemistry in and around Ariyalur Region, Tamilnadu, India

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Abstract
Surface water that percolate into the ground eventually becomes ground water. It further reacts with the surface and subsurface soil/sediments or rock. The hydrogeochemical composition of ground water can also be indicative of its origin and history of the underground materials that the water has been in contact with shallow and deep-seated conditions. The study reveals information about the geochemical reactions responsible for change in water chemistry. The area chosen for study is in and around Ariyalur near contact of Archaean and Tertiary. The study area has three distinct geologic formation namely, Archaean, Gondwana and Cretaceous. The present study is aimed in determining the factors influencing the hydrogeochemistry of the region. Thirty six samples were taken to broadly cover the three different major geological units in two seasons as, post monsoon - (August 2003) and premonsoon (December 2003).

The hardness of the sample indicates that most of the sample fall in the very hard category and requires softening before use. The sodium concentration in majority of the samples falls from permissible to doubtful range. SAR shows that samples fall from excellent to poor category. EC ranges from permissible to unsuitable both the seasons. The study classification indicates water quality from fresh to brackish salt. The major water facies is represented by Calcium-Sodium facies; Calcium-Magnesium facies; Chloride - Sulfate -Bicarbonate facies and Chloride facies. The study significantly reflects the impact of the lithology in the study area.

Key words: Groundwater Chemistry, Ariyalur Region, Tamilnadu, Water Quality.
105. Estimation of Aquifer Parameters from Large-Diameter Wells in Basalts

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Abstract
Dugwells are termed as large-diameter wells, because their diameters are typically more than a metre and go up to 10-15 m. These wells are the most prevalent groundwater extraction structures in the irrigation sector in India in basaltic terrains. Finding aquifer parameters from these structures has always been a matter of great approximation. An attempt has been made in this contribution to estimate aquifer parameters from these wells by the conventional methods, such as those of Papadopulos and Cooper (1967), Boulton and Streltsova (1976), Mishra and Chachadi (1985) and Singh and Gupta (1986), in the Deccan terrain of the Koyna River basin, India, and compare their advantages and limitations. Papadopulos-Cooper method (1967) relies more on long duration pumping, while the Mishra-Chachadi method (1985) emphasizes on long duration recovery. Both these methods are meant for confined isotropic aquifers, and take well storage into consideration. Boulton-Streltsova method (1976) has been envisaged specially for the unconfined aquifers that take partial penetration of wells, aquifer inhomogeneities and well storage into consideration, but due to greater degree of freedom, this method is very complex and time-consuming. Singh-Gupta method (1986) considers decreasing abstraction rate (discharge) into consideration, a characteristic inherent in all large-diameter wells in India. But, in many a case, a perfect match between the observed drawdown and the modeled drawdown is not possible, which limits the applicability of this method. Despite limitations, these four methods give enough options to the users to use any of them depending on field constraints and the type of data collected in the field.

Key words: Aquifer parameters, large-diameter wells, transmissivity, storativity, Deccan terrain.
Abstract

Study of aquifer geometry is essential for proper development and utilization of groundwater resource. In this study a systematic approach has been made for the analysis of aquifer geometry in parts of Muzaffarnagar and Meerut Districts, U.P, India, by integrating well log data and remote sensing data. The present study includes mapping of neotectonic lineaments from remote sensing LISS III data, determination of aquifer geometry from the well log data and generation of three dimensional aquifer models. Sub-surface geological sections have been developed to determine the actual aquifer geometry and identification of buried faults. The aquifers show a wide variation in nature and geometry from place to place. The region has varying thickness of alluvium composed of alternating sand/kankar and clay strata. The subsurface features of importance in the groundwater exploration such as buried channels have been identified. This has facilitated identification of the areas with favorable aquifer disposition and subsurface geomorphic features that are potential sites for groundwater development. In addition to the fence diagram various section diagrams have been generated to understand the spatial variations in the aquifer geometry. Moreover, the palaeo-channel aquifer is unconfined in nature with depth varying from 50 to 100 m and mainly consist of coarse to medium sand, gravel, pebbles and kankar. The lateral continuity of the paleo-channel aquifers with the adjacent aquifer is being investigated.
Abstract
Quantification of pollutant migration was carried out in the upper Kodaganar river basin in Dindigul district, Tamilnadu (India). The groundwater in and around Dindigul Town was contaminated due to heavy discharge of untreated tannery effluents from about 85 tanneries situated in the neighbourhood of Dindigul Town. About 100 km² agricultural land had become barren land and many villages have no potable drinking water and more over the rural folks are suffering from unknown skin diseases. After Supreme Court of India’s order, one treatment plant was installed for the treatment of effluents. However the total dissolved level (TDS) at many places are in the range of 6000-10000 mg/l. It was therefore decided to study the migration of contaminants for the present and future events.

A mathematical model of groundwater flow and mass transport was therefore constructed to study the present and future migration of pollutant in the upper Kodaganar basin. Groundwater flow model was constructed to evolve the velocity field and it was used as the input to mass transport model, which in turn is used to predict the pollutant migration. The preliminary model study has brought out that pollutant migration is dominated by advection phenomenon and also indicated that no migration takes place across the river Kodaganar. Sensitivity analysis was also carried out to understand the influential parameter on the migration of TDS and chloride. The impact of artificial recharge on the reduction of pollutant concentration level was also studied. Remedial measures to contain the pollutant migration have been suggested.

Key words: Upper-Kodaganar, hard rock aquifer, Mass transport modeling, contaminant migration
Abstract
Conjunctive use is defined as operation of surface and groundwater in such a way, which enhances their combined output. Since long, researchers and planners are trying to recommend the concept of conjunctive use in canal command as well as salt affected areas and many theoretical studies have been conducted in the past, but so far there is hardly any evidence about wide adoption and acceptance of conjunctive use practices among water users due to many constraints and mainly due to tremendous difference in cost of canal water and ground water. Since canal water is available at much cheaper rates, water users don’t prefer ground water utilization unless they feel that their production will reduce drastically in the absence of water.

In order to convince the farmers about concept of conjunctive use and its economical benefits, a decision support tool is developed both in Hindi and English using Visual Basic platform. This interactive tool calculates (i) annual fixed and operational costs of irrigation from tubewell and canal, (ii) yield and total cost of produce, (iii) excess expenditure incurred in tubewell irrigation over and above the canal water charges, and (iv) required yield increase needed to compensate for the additional cost of irrigation from tubewell.

The tool was demonstrated to water users in the command of RP Channel V of Patna Main Canal in Sone command. Data was collected through the specified format in participatory mode. Users were found capable of making the required analyses and were convinced of making decisions about ground water use under their prevailing constraints. Alongwith canal irrigation the economic viability of tubewell irrigation under three situations (i) own tubewell, (ii) renting pumping sets to run tubewell for irrigation, and (iii) purchasing water from tubewell owners, were analyzed to understand the constraints and possibilities of conjunctive use in the area.

The results reveal that conjunctive use of tube well and canal water has tremendous scope in canal command and it can be propagated in the area provided water users are convinced about yield improvement resulting in economic benefits, which compensate the additional cost of irrigation. Analysis showed that compared to owning tubewell, water purchasing is the most economical option followed by getting only pumping sets on rent basis to run tubewells for irrigation.

Key words: Canal, Groundwater, Conjunctive use, Decision support tool, Economic benefits
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Abstract
Development of groundwater resources to meet the increase demand for drinking, industries, irrigation and other purpose are ever growing in developed and developing countries. The over development of groundwater resources leads to the decline of water level causing socio-economic and environmental degradation. It is, thus, imperative to manage the groundwater resources in an optimal manner. Management schemes can be evolved, only if the groundwater potential is assessed in more realistic manner. Mathematical manner in conjunction with detailed field investigations have been proved to be a potential tool for this purpose. Evolving pre-development management schemes is still works out to be better choice. One such study was carried out in Kunyere River valley, Okavango Delta, Botswana. Kunyere River valley has three tributaries viz. Marophe, Xudum and Matsibe Rivers. The valley falls in the southeastern fringe of Kalahari Desert (Botswana), which tends along the Kunyere fault in a northeast to southeast direction. The materials in the valley system are saturated between 7 m to 9 m below ground level (bgl), where a fresh potable groundwater reserve is present to a maximum depth of 50 m to 70 m (bgl) and below this depth groundwater is brackish one. The department of Water Affairs, Govt. of Botswana, has quantified the groundwater resource in the valley through exploratory drilling, test pumping, and hydro-chemical analysis of groundwater samples.
A model with six layers of flow regime was conceptualized by making use of available data. Fourth layer of the model is the main fresh water bearing aquifer and the bottom layer is brackish one. Long duration pumping test carried out in this area indicated the leaky nature of the aquifer system. Mathematical model of the basin was constructed and calibrated for steady state condition by using Visual Modflow computer software. Two prognostic runs were made and an optimal one was identified which will ensure minimum upward leakage from the bottom saline unit to the pumping aquifer. This simulation study indicates that substantial development of groundwater potential is possible in this area.

**Key words**: Kunyere River Valley, Sedimentary aquifer system, Okavango Delta, Mathematical modeling, Management schemes, Botswana.
110. Influence of Hysteresis in Modeling of LNAPL Migration through Non-Homogeneous Binary Porous Media

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Abstract
The influence of soil heterogeneities and hydraulic Hysteresis as two natural phenomena on simulation of migration and redistribution of heptane’s as a Light Non-Aqueous Phase Liquid (LNAPL) is demonstrated in this paper, using a hysteretic three-phase Water-LNAPL-Air numerical k-S-P model named “NAPL”. The 2D simulations are conducted in a number of dissimilar granular porous media, which consist of a homogeneous medium, and four non-homogeneous binary media that have different characteristics regarding the assignment of divergent soil hydraulic properties and spatial configuration of heterogeneities for each one. In all considered cases vertical and horizontal dimensions of the modeling domain are set respectively to the value of 0.7m and 0.35m where a constant spatial step of 1.25cm used in spatial discretization of both directions. Boundary conditions are imposed specifically to investigate hysteretic k-S-P path behavior. Analysis of the acquired data shows that connivance of hysteresis or soil heterogeneities through numerical modeling process may lead to significant discrepancies among output results, especially when phase imbibition-drainage history is more sophisticated however hysteretic modeling of multiphase flow in porous media considering soil heterogeneities needs much more computational requirements and storage regarding the high degree of non-linearity which is accompanied with hysteresis.

Key words: Light Non-Aqueous phase liquid (LNAPL), multiphase flow, hydraulic hysteresis, soil heterogeneities, numerical simulation.
111. Analysis of Water Table Rise in a Finite Aquifer

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Abstract

Water tables in most of the canal commands are rising due to continuous seepage of water from unlined or partially lined canals and recharge from the land surface in the form of excessive irrigation or rainfall. In order to evolve operational policies for ground water management it is necessary to know accurate temporal and spatial distribution of ground water table. Mathematical modelling is one of the important techniques used to represent the physical situation in mathematical terms and predict the water table rise due to canal seepage with constant recharge. In the present study, a numerical solution of nonlinear one dimensional Boussinesq equation was obtained using fully implicit finite difference scheme for transient water table rise due to seepage from two canals located at different elevations and constant recharge from land surface in a homogeneous, isotropic, unconfined horizontal aquifer. Spatial and temporal water table rise predicted by the proposed numerical solution was compared with the water table rise computed from existing analytical solutions of linearized Boussinesq equation by considering a numerical example. L² and Tchebycheff norms were used to estimate the average and maximum deviations of water tables obtained through approximate analytical solutions with those computed from the numerical solution, for different values of space and time.

The study revealed that analytical solutions overestimate water table elevations compared to those obtained from the numerical solution, and difference in water table in the middle region decreases with increase in time. For practical purposes, the accurate solution as obtained by numerical approach may be used for computation of water tables.

Key words: Water table, Aquifers, Seepage, Boussinesq equation, Modelling, Analytical solution, Numerical solution
Abstract
The study area Mettur lies in northwestern part of Salem district, Tamilnadu, India. The area is entirely underlined by Archean crystalline metamorphic complexes. Rocks of this group is highly weathered, jointed and covered by recent valley fills. A total of 46 groundwater samples were collected at the rate of 23 samples per season (pre monsoon and post monsoon) widely covering the entire lithology of study area. The geochemical reaction simulation model WATQ4F has been used to determine the distribution of aqueous species and saturation state of the samples. Almost all the species of SiO₂ (Quartz, Chalcedony, and Cristobalite) show change with seasons. Carbonate results shows Calcite, Dolomite and Magnesite are under saturation to equilibrium. Thermodynamic plotting for groundwater is plotted on stability diagram as a function of [H₄SiO₄]. Seasonal variation plays a major role for determining the stability of Silicates rather than rock types. Dilution effect is well noted during post monsoon seasons. Water in study area is in equilibrium or near equilibrium. The greater degree of chemical evolution in litho units is attributed to longer contact time between the water and the aquifer materials. The difference in contact time is probably the result of deeper and longer flow paths and lower flow velocities in the aquifers, along with water draft for various domestic and agricultural purposes.

Key words: Groundwater chemistry, hard rock terrain, simulation model, WATEQF, saturation index, Salem District, Tamilnadu.
Abstract
Tritium tagging technique and environmental tritium measurements has been integrated to determine groundwater recharge due to precipitation, recharge zone and possible groundwater flow direction in Pathri-Rao watershed of Himalayan foothills region, Uttaranchal, India. On the basis of soil type four sites were selected for the recharge estimation due to monsoon precipitation using tritium tagging technique. Groundwater recharge due to precipitation is estimated by monitoring the vertical movement of injected tritium. The method is based on the assumption that the soil water in the unsaturated zone moves vertically downward as discrete layers. Water added on the surface either as precipitation or irrigation will move downwards by pushing the older water beneath and this in turn will push the still older water further below, thereby the water from the unsaturated zone is added to the groundwater reservoir. This flow mechanism is known as piston flow. The estimated recharge varies from 9% to 29% in the area. A linear relationship is obtained between the sand content and estimated recharge at these sites. Environmental tritium dating of six groundwater samples collected, from the shallow and intermediate aquifers, has indicated the relative age of shallow and intermediate aquifer in the area and possible recharge zone. The results have been used to define the interconnections of shallow
and intermediate aquifers, and their possible recharge zones. The study is useful in understanding the aquifer system, their possible interaction and groundwater flow direction.
Abstract
A methodology is developed for the precise determination of Li, Be, B, Al, V, Cr, Mn, Fe, Ni, Co, Cu, Zn, As, Rb, Sr, Mo, Ag, Cd, Sb, Ba, Pb and U directly in groundwater samples by inductively coupled plasma–mass spectrometry (ICP-MS). Sampling strategy, collection, preservation and storage of groundwater samples for semi-quantitative and quantitative determination of trace and ultra-trace elements by ICP-MS have been discussed in detail. Certified reference materials procured from National Institute of Standards and Technology (NIST), USA and National Research Council (NRC), Canada were used to calibrate the instrument and also to check the accuracy of the analysis. Detection limits (2σ) calculated are found to be in the range of 5 to 400 ng/L. Spectral and non-spectral interferences were minimized and in some cases totally eliminated by means of calibrating the instrument with matrix matching standards, sample dilution, use of an internal standard, blank subtraction and mathematical corrections wherever possible. Polyatomic interferences caused during the analysis of some trace elements like Cd, Ni, As, Se etc., and the correction procedures adopted for eliminating these interferences are also discussed.

Key words: trace elements, groundwater, Inductively Coupled Plasma–Mass Spectrometry, certified reference materials, interferences
High-Resolution Electrical Resistivity Tomography (HERT) for Sub-Surface Scanning: A Methodology

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Abstract
Vertical Electrical Sounding (VES) technique in Resistivity methods can not measure the signatures from sub-surface in lateral directions. Further, the depth-wise resistivity changes are not possible being measured with the Resistivity Profiling / mapping technique. Both these conventional techniques commonly employ a four-electrode set-up where the signatures from a singular depth level of the subsurface can be measured on the surface. Resistivity variations, both in lateral and vertical directions, can be measured concurrently by using Multi-electrode systems (Griffiths and Turnbull, 1985; Griffiths et al. 1990; Barkar, 1992) connected to multi-core cable (Griffiths and Barker 1993). The number of electrodes with the multi-electrode systems can be, for example, 48, 72 or 96 etc with specified inter-electrode spacing. The inter-electrode spacing can be varied from the specifications as per the available area and topography. In any case, a traverse of length from half a kilometer to one kilometer horizontal distance can be covered in a single-run depending upon the size of the array. Conventional Electrode Configurations namely, Dipole-dipole, Three-electrode, Two-electrode, Wenner, Schlumberger etc. can be applied for sub-surface data acquisition. To cover horizontal traverses in a phased manner, ‘role-along’ and / or ‘move-on’ techniques as per the situation are applied in which case the set of electrodes are moved forward in a systematic ‘pre-set’ manner. The depth down below the traverse can be increased by increasing the array size sequentially.
depending upon the ‘depth of investigation ’ of the corresponding array. Each array has got its own investigation depth, depending upon the theories like ‘maximum contribution concept’ (Roy and Apparao, 1971) or ‘median depth concept’ (Edwards, 1977). Some are following the data presentation method as proposed by Hallof (1957).

High-resolution electrical surveys play an important role in data acquisition especially in noisy areas. This is achieved by overlapping data levels with different combinations of Dipole lengths and Dipoles’ separations, as a whole, when Dipole-dipole array is applied. Similar combinations are possible with Wenner-Schlumberger and Three-electrode arrays also. The number of data points produced by such High-resolution survey is more than twice that obtained with a conventional array in routine application, and hence a better area coverage and resolution can be achieved.

After analysis and processing of the measured data in the field, pseudo-depth sections are constructed (Hallof, 1957, Edwards, 1977, Apparao and Sarma, 1981, 1983 and 1993) with overlapping data levels. By having such redundant measurements using the overlapping data levels, the effect of more noisy data-points will be reduced. Finally, High-resolution resistivity (HERT) surveys play a significant role especially for scanning the subsurface in noisy areas for better data coverage so that the sub-surface architecture can be studied with reasonable precision and faster survey.
Abstract
Development of groundwater resource of an area largely depends on the aquifer characteristics, such as storage, transmission and yield capabilities represented by its porosity, transmissivity, specific yield etc. Therefore, serious consideration has to be given to understand these parameters in order to determine the hydraulic potential of an aquifer and the production capability of wells. The conventional methods, such as pump tests, have inherent problems pertaining to assumptions and data collection especially in small coral atolls, where the fresh groundwater body occurs as fragile lens in hydraulic continuity with sea water. It warranted a study to find out whether aquifer properties can be deduced from the response of the water table to tidal wave propagation in island aquifers.

The tidal wave propagation in an island aquifer constitutes a measurable stress reflected by the water table fluctuation. The rate of propagation of change in the hydraulic head, therefore, indicates the hydraulic diffusivity, which is the ratio of transmissivity to storage. An attempt was made at Kavaratti, one of the islands of Lakshadweep, to collect tidal response data from 21 observation wells and deduce the tidal efficiency (TE) and tidal lag time (T_L). The TE, on an average, increased from 0.16 to 0.21 and T_L decreased from 270 to 210 minutes depending on the hydro-physical nature of the locations. The transmissivity (T) and specific yield (S_y) estimated from these values indicated that they are comparable with that obtained from pump tests and formation factor analysis. The experiment extended to eight other islands of Lakshadweep also indicated comparable results.

Key words: Aquifer Characteristics, Tidal Propagation Data, groundwater, Lakshadweep Island, India
Abstract

Ground water is the principal source for both irrigation and domestic water supplies in many areas of semi-arid and tropical countries. In many of these areas the groundwater consumption is more than its availability and because of this over exploitation has also lead to the deterioration in water quality. The Chennai city is facing such a problem due to the over exploitation of groundwater. An attempt was made to study the supply and demand for the present population in Chennai city. The Chennai area is forming part of a coastal plain with hills in the West and gentle slope towards the East on the shore of Bay of Bengal. The average annual rainfall is 1200mm/annum of which 60% of contribution comes from North East monsoon (October to December). There are four rivers namely, Araniyar, Korataliyar, Coovum and Adayar, flowing through the study area and these are grouped together as Chennai basin. These rivers are flowing from the West to the East. The main surface water sources for Chennai city are Poondi, Redhills, Cholavaram and Chembarambakkam reservoirs along with supply of water from Telugu ganga project. New Veeranam scheme which brings water from Veeranam lake has also augmented the supply of water to the city. The average contribution of the surface water sources to the city water supply is about 350 Mld. Apart from the surface water sources there are also groundwater sources of 60Mld, from 6 well fields such as, Poondi, Tamaraipakkam, Panjetty, Floodplains, Minjur and Kannigaiper. The major contribution goes to industrial water supply during normal rainfall periods which in turn is used for the city water supply during the deficit rainfall periods. The urban growth rate from 1991 – 2001 has increased by 13% in the city. The increase in population, development in industrial and agricultural activities in these region resulted in increasing water demand and thereby making the situation more complex to support the present population of 6 million people in the city. Adding to this severity the frequent failure of monsoon and increase in need lead to the development of RO plants, reuse of sewage water, hiring of private agricultural wells, desalination plants and leak detection and rectification measures. The average water supply is 350MLD but the present demand calculated based on 165 lpcd for the existing population of 6 million is 990 MLD. It is very difficult to meet the gap of 640 MLD (the gap between demand and supply), by identifying any new source so this has to be done only by water management techniques such as

1. Rain water harvesting
2. Reuse of grey water
3. by fixing water meters in the residences
4. construction of check dams
5. interlinking of Araniyar and Korattaliyar
The above management techniques will help in the judicial usage and sustainable management of the water resource.
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Abstract
The present paper develops a formulation for seepage flow in a soil stratum with a random hydraulic conductivity field. A two-dimensional vertical slice through a soil stratum is taken. The superficial seepage velocity components in this vertical plane are \( v_x \) and \( v_y \), where \( v_x \) and \( v_y \) are the velocity components in the horizontal and vertical directions respectively. If the velocity potential is denoted by \( \phi \), then

\[
\begin{align*}
  v_x &= \frac{\partial \phi}{\partial x} \quad \text{and} \quad v_y = \frac{\partial \phi}{\partial y}
\end{align*}
\]

satisfies Laplace’s equation.

\[
\frac{\partial^2 \phi}{\partial x^2} + \frac{\partial^2 \phi}{\partial y^2} = 0
\]

In a homogeneous aquifer, the hydraulic conductivity, \( K \), is the same at all points in the flow domain. In actual practice, due to non-homogeneity of soil properties like void ratio, mean grain diameter etc., \( K \) varies from point to point in a manner that is not deterministic. Because it is difficult to solve for the velocity potential analytically in a vast range of situations, numerical methods like the Finite Element have been employed to compute the velocity potential. In the above two works, three-noded triangular finite elements with Lagrangian Interpolation have been used. This has been extended to six-noded triangular finite elements with Lagrangian Interpolation. Whatever be the exact nature of the element being utilized, ultimately the matrix equation developed can be expressed as

\[
\{\phi(K)\} = [G(K)]^{-1}\{P(K)\}
\]

where \([G(K)]\) is the global constitutive matrix, \( \{\phi(K)\} \) is the matrix of the nodal velocity potentials, and \( \{P(K)\} \) is the equivalent of the load matrix in solid mechanics.

If the hydraulic conductivity is deterministic, a definite pattern of equipotential lines is obtained for a definite flow geometry. If the hydraulic conductivity at different points is not deterministic, the
equipotential lines become uncertain. The present work addresses this situation.

\[ \{ \phi (K) \} = [G(K)]^{-1} \{ P(K) \} \tag{3} \]
or,
\[ [G(K)] \{ \phi (K) \} = \{ P(K) \} \tag{4} \]

Now, differentiating equation (4) with respect to \( K \), we get
\[ [G(K)] \frac{\partial}{\partial K} \{ \phi (K) \} = \frac{\partial}{\partial K} \{ P(K) \} - \frac{\partial}{\partial K} [G(K)] \{ \phi (K) \} \tag{5} \]
or,
\[ \frac{\partial}{\partial K} \{ \phi (K) \} = [G(K)]^{-1} \frac{\partial}{\partial K} \{ P(K) \} - \frac{\partial}{\partial K} [G(K)] \{ \phi (K) \} \tag{6} \]

where \( \frac{\partial}{\partial K} \{ \phi (K) \} \) is the sensitivity of \( \phi \) with respect to \( K \).

Equation (6) can be written as
\[ \{ \xi (K) \} = [G(K)]^{-1} \{ P(K) \} \tag{7} \]
\[ \{ \xi (K) \} = \frac{\partial}{\partial K} \{ \phi (K) \} \tag{8} \]
and
\[ \{ P^* (K) \} = \frac{\partial}{\partial K} \{ P(K) \} - \frac{\partial}{\partial K} [G(K)] \{ \phi (K) \} \tag{9} \]

Now, undertaking a Neumann expansion,
\[ [G(K)] = [\bar{G}(K)] + [G'(K)] \tag{10} \]
where \( [\bar{G}(K)] \) is the deterministic component of \( [G(K)] \) and \( [G'(K)] \) is the residual component.

\[ [G(K)]^{-1} = ([\bar{G}(K)]^{-1} + [G'(K)]^{-1}) = ([I] + [H])^{-1} \bar{G}(K) \tag{11} \]
\[ = ([I] - [H] + [H]^2 - [H]^3 + \ldots) \bar{G}(K) \]

So,
\[ [G(K)]^{-1} = \left( \sum_{n=0}^{\infty} [-H]^n \right) \bar{G}(K) \tag{12} \]
\[ [H] = \bar{G}(K)^{-1} [G'(K)] \tag{13} \]

Therefore, the velocity potential matrix can be written as
where $\{\bar{f}(K)\}$ is the mean of $\{f(K)\}$.

This can be written as

$$\{\phi(K)\} = \{\bar{f}(K)\} - \{\phi_1(K)\} + \{\phi_2(K)\} - \{\phi_3(K)\} + \ldots$$  \hspace{1cm} (15)

$$\{\bar{f}(K)\} = \{g(K)\}^{-1} \{P(K)\}$$  \hspace{1cm} (16)

The stochastic nature of the $\{v_x\}$ and $\{v_y\}$ matrices is introduced through the presence of the matrix:

$$\{\phi(K)\} = \{f(K)\} - \{\phi_1(K)\} + \{\phi_2(K)\} - \{\phi_3(K)\} + \ldots$$

Localised changes in point velocity do occur and these are likely to have a major impact on, for example, the discharge into a pumping well.

The work has great ramifications for groundwater flow during earthquakes. During earthquakes, the ground gets shaken and the original pattern of equipotential lines gets disturbed and thus the original groundwater flow pattern also gets disturbed. The change in groundwater movement pattern can either act as a stabilizing agent or as a destabilizing agent depending on local circumstances.

**Key words:** Seepage flow, random, hydraulic conductivity, earthquakes
Abstract

Electrical resistivity imaging survey has been conducted to define the geometry of aquifer configuration in Pathri-Rao watershed situated in the Piedmont zone of Himalayan foothill region, Uttaranchal, India. Resistivity image profiling data at 9 sites were recorded using IRIS imaging system with 72 electrodes deployed at 10 meter spacing in each site. The profile length at each site was 710 m, oriented in different directions in field as per the survey design and accessibility of space. After initial data processing, 2D inversion of each profile data was carried out with topography information using RES2DINV code. Interpreted 2D resistivity image were analyzed in terms of geological formation and geometry of aquifer system in the area. Geologically the area is characterized as the Bhabhar zone with top unsaturated surface layer resistivity range 100 – 800 Ohm-m. Clay formation is characterized by low resistivity (10-25 Ohm-m). Resistivity of aquifer zone in the study area varies from 40 – 150 Ohm-m. Depth and thickness and surface elevation of shallow and deeper aquifer were delineated from the interpreted resistivity image. The possible groundwater flow direction and the interaction of shallow and deeper aquifers were also inferred from resistivity image. The results are in general agreement with the results obtained from isotope technique and other hydro-geological data obtained from the area.
120. Aquifer Vulnerability Mapping in Aizawl City of Mizoram, India

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Abstract
Due to scarcity of potable water, groundwater quality is becoming an acute concern in the Aizawl city. In this study, the basic groundwater chemistry of the region was studied using statistical analysis, spatial distribution of major ions and vulnerability to pollution of the groundwater was assessed using DRASTIC. For statistical analysis Principal Component Analysis (PCA) was used, which is one of the favourite tool in environmetrics for data compression and information extraction. The groundwater composition of the Aizawl city was found to be of relatively immature composition of Calcium bicarbonate (CaHCO₃) type. Arc-GIS was used in plotting the spatial distribution of ions in the region using kriging. As the main groundwater quality problem was identified as to be due to excess nitrate, vulnerability assessment to delineate areas that are more susceptible to contamination from anthropogenic sources was considered an important element for sensible management and land use planning.

The present work aims at estimating aquifer vulnerability by applying the DRASTIC model and utilizing sensitivity analysis to evaluate the relative importance of the model parameters for aquifer vulnerability in the Aizawl city. An additional objective was to demonstrate the combined use of the DRASTIC and geographical information system (GIS) as an effective method for groundwater pollution risk assessment. The DRASTIC shows highest vulnerability in the Aizawl west region, where the depth to water table parameter inflicts largest impact on the vulnerability.

Key words: Sediment, Brahmaputra, Nutrient, Anthropogenic Change, Biogeochemical Flux
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Abstract
During last 18 years we had analyzed 1,75,000 hand tubewell water samples for arsenic from Ganga-Meghna-Brahmaputra (GMB) plain having an area and population of 569749 sq km and more than 500 million, respectively and found a good portion of the states and countries [Uttar Pradesh, Bihar, Jharkhand, West Bengal, Assam and Bangladesh] is arsenic affected (>50 µg/L). So far from our own study we have identified 200, 250, 11, 3500, 27, 2000 villages, respectively, where groundwater contains arsenic more than 50 µg/L (Figure 1). In average about 50% water samples contain arsenic above 10 µg/L and 30% above 50 µg/L. With our medical team we have screened more than 1,50,000 villagers from affected villages, registered about 15000 patients with arsenical skin lesions. People were suffering from many
Figure 1. Magnitude of arsenic contamination in groundwater, and its related health effects, in the Ganga-Meghna-Brahmaputra (GMB). Types of arsenical skin lesions. Bowens, skin cancer were also noticed among those having arsenical skin lesions. Other internal cancers like lung, liver, bladder etc were also noticed among the arsenic patients. Arsenic neuropathy as well as adverse pregnancy outcomes such as spontaneous abortion, still birth, preterm birth and low birth weight was also recorded. About 50,000 biological samples analysis from arsenic affected areas showed elevated level of arsenic to both patients and non-patients indicating many people are subclinically affected. Progress towards resolution of this crisis in the GMB plain will require proper watershed management, economical utilization of available surface water, and the participation of all who live in or have influence over the region.

**Key words:** GMB Plain, groundwater, arsenic contamination, arsenical skin lesions, arsenical neuropathy, adverse pregnancy outcome, sub clinical effect, watershed management.
Arsenic contamination studies, in Nepal, have been consolidated only in the Terai region.

Realizing the extensive use of groundwater resources for drinking water by the people, the present comprehensive study, the first of its kind inside Kathmandu valley was undertaken to know the arsenic contamination levels and seasonal variation on arsenic concentration in Kathmandu and Lalitpur Municipality Areas. This study was conducted in two different seasons: Post Monsoon (Phase I) and Dry Season (Phase II). Water samples were collected from 160 shallow tubewells, 91 dugwells and 56 deep tubewells and analyzed for arsenic concentration by AAS-HG technique. Three water samples in between total water extraction hours in a day from six deep tubewells were also collected for two consecutive days in both seasons to know the effect of groundwater pumping on arsenic concentration. In Phase I, 50.0% of deep tubewells, 14.3% of shallow dugwells and 6.3% of shallow tubewells were found with arsenic concentration above WHO guideline value of 10 µg/L, while it was 68.6%, 11.5% and 11.4% in Phase II, respectively. In consideration with Nepal Interim Standard (50 µg/L), 8.9% and 9.8% of deep tubewells in Phase I and Phase II, respectively had high arsenic concentration and none of the shallow tubewells and shallow dugwells exceeded the national limit. Arsenic concentrations in Phase I and Phase II significantly correlated for deep tubewells (r=0.90,
p<0.001), shallow tubewells (r=0.78, p<0.001) and shallow dug-wells (r=0.27, p<0.02).

In present study, significant correlation between arsenic concentration and age or depth of water sources was not observed. The results of arsenic fluctuation monitoring suggested that the level of arsenic in groundwater fluctuates with the time period though a definite trend of increase or decrease in arsenic concentration with the groundwater pumping was not observed. Fluoride concentration for 10.7% of deep tubewells, 1.9% of shallow tubewells and 1.1% of shallow dug-wells was above WHO guideline value for drinking water. The present study showed arsenic contamination in groundwater in Kathmandu and Lalitpur Municipality areas, suggesting spatial distribution and variation in arsenic concentration at different times.

**Key words:** arsenic, fluoride, groundwater, Kathmandu, Lalitpur, Nepal
123. Isotope Hydrological Study of Groundwater of Southern West Bengal: Implication to Erratic Spatial Distribution of Arsenic

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Abstract
Arsenic pollution of groundwater poses a serious threat to millions of people of West Bengal and Bangladesh. The microbial reduction of iron-oxyhydroxide coating over the sand grains of shallow aquifer is the most plausible mechanism for release of arsenic into groundwater. However, in many areas spatial distribution of arsenic within closely spaced shallow wells show extreme variability. Systematic study of sub-surface lithology, identification of the sources of groundwater and monitoring the seasonal variation of groundwater chemistry can be useful for understanding such variability. Present study has been carried out in a small area of ~200m x 200m area of Southern West Bengal. Three piezometer nests were installed to observe the vertical variation of sediment chemistry and understand subsurface sedimentary packages. Stable isotope of oxygen and hydrogen of water were used to identify the sources of groundwater and estimate the amount of recharge from source to aquifer. The piezometer nests are closely spaced but show a wide range of arsenic concentration (from below detection level to 950 µg/L). Subsurface lithology shows that the thickness of the clayey aquitard above the shallow contaminated aquifer and concentration of organic matter in the clay are different in three piezometers. It seems that these two factors may control the arsenic concentration of the individual nest (McArthur et al., 2001). Arsenic shows peak at a particular depth in two of the nests. The similar trend is also observed in stable isotope profiles of these nests. To identify the possible recharge area, surface water samples from nearby ponds have also been collected seasonally and analysed for stable isotopes and major ions. The two contaminated piezo-nest shows appreciable surface water component in aquifer. However one piezo, having arsenic concentration BDL, does not show any signature of surface water mixing. Thickness of clayey aquitard in this piezo is maximum which possibly hinders the flow of water from organic rich clay layer to aquifer and inhibits microbial reduction. Seasonally groundwater chemistry is invariant though surface water chemistry show considerable change. Exact quantification of groundwater budget requires stable isotope analysis of local precipitation.
Abstract
Daudkandi Upazila under Comilla district of Bangladesh is severely affected by elevated concentration of arsenic (As) in groundwater. More than 80% of the shallow hand tube wells in Daudkandi Upazila yield water with As concentration above WHO guide line (>10 µg/L). The study area lies east of the river Meghna and is characterized by a thick sequence of fluvial sediments. The vertical lithofacies sequence in the Meghna Flood Plain (MFP) prepared from borelogs and collected undisturbed core samples show complete or truncated cycles of fining upward sequence- finer over bank deposits of silty clay and coarser sandy channel fill deposits.

The aquifer sediments, in general, are composed of 50-65% quartz, 7-15% feldspars, 5-15% micas with predominance of biotite, and 7-20% lithic grains. The percentage of heavy minerals (specific gravity > 2.9) which includes assemblages of both non-opaque and opaque varieties, range between 2-10%. The non-opaque heavies are mostly hornblende followed by epidote, garnet, kyanite, sillimanite and others. Preparations of polished section to identify the opaque species are in progress. However, X-ray diffraction (XRD) analysis of heavy mineral fractions shows presence of magnetite, pyrolusite, alunite and jarosite(?). Carbonate minerals, in the form of siderite, dolomite and ankerite, are also identified from XRD traces. Scanning electron microscopy (SEM) studies also reveal the presence of secondary authigenic Fe-sulfides on the coatings on framework silicate grains, that are formed under strongly reducing in micro-environments within the shallow aquifers. These observations are in conformity with earlier studies and the mobilisation of As in the groundwater by reductive dissolution/desorption of FeOOH.

X-ray fluorescence (XRF) analyses of total arsenic show concentrations vary between 7 mg/kg to as high as 175 mg/kg in a peaty layer. Total organic carbon (TOC) contents of the sediments are in the range 0.33% to 1.45% with a maximum of 45.7%
in the peaty layer. Sediments with relatively high TOC are generally enriched in As. The sediments of light yellow to yellowish brown in colour are usually low in As and TOC but grey to dark grey sediments are rich in As and TOC. Sequential extraction analyses were carried out to estimate the exchangeable, reducible and oxidisable fraction of As and other related elements in the sediment at different depths. Exchangeable fraction that estimates As in exchangeable phase as well as bound to carbonate phase ranges between 1.04 –1.68 mg/kg where as the reducible fraction of As i.e. bound to oxide/hydroxide phase varies between 0.33 mg/kg to 13.43 mg/kg. Oxidisable fraction which indicates As bound to sulphide and organic matter are in the range of 1.31 mg/kg to 4.79 mg/kg.

**Key words:** Aquifer, groundwater, arsenic, Meghna floodplain, SEM; XRF, Sequential extraction.
125. Arsenic and Fluoride in Groundwater: An Emerging Problem in North Eastern India

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Abstract
In North East India, with large human settlements in rural areas and villages, provision of safe drinking water is a real challenge. Few decades ago, it was generally assumed that groundwater, drawn from 90-110ft depth, can be considered as safe water, as it was generally devoid of microbial contamination. This led to the installation of millions of hand pumps and tube wells all over the region as a means to provide bacteriologically safe water to rural population. It is now known that ground water can have high levels of few chemical constituents such as fluoride and arsenic, in certain locations leading to chronic health effects like arsenicosis, dental and skeletal fluorosis and carcinogenic diseases.

Groundwater quality survey was conducted for North Eastern States (India) in the year 2003-05. Concentrations of fluoride, arsenic and other substances have been exceeded the BIS/WHO drinking water limits. In these areas, such waters are the primary or sole water resource that will cause massive degradation of population health.

Arsenic concentration at elevated levels (above 0.05 mg/L) are encountered in groundwater of alluvial aquifers in Assam, Tripura, Manipur, Nagaland and Arunachal Pradesh. Arsenic concentration was found higher in the area adjacent to foothills bounded by Himalayan mountains in parts of Jorhat, Lakhimpur, Nalbari, Nagaon, Barpeta, Dhemaji, Dhubari, Darrang and Golaghat district of Assam; West Tripura, Dhalai and North Tripura district; Thoubal district of Manipur; Mokokchung and Mon districts of Nagaland, and Papumpare, East Kameng, West Kameng, Lower Subansiri, Dibang Valley districts of Arunachal Pradesh. The study indicates that the affected aquifers are generally shallow (15-40 m deep). Hydrogeochemical information of Assam suggests that elevated arsenic concentrations in groundwater is governed by the presence of organic matter in the sediments and reduced alluvial aquifers with high iron, low sulphate and nitrate concentrations. Special care need to be taken to avoid oxidation of the sediment in reduced aquifers. However, no report of arsenocosis from any area of the region has been known till date.

In the area under investigation, fluoride concentration in groundwater is well above the permissible limit of 1.5 ppm in the districts of Karbi Anglong (Lumbajong, Hawraghat), Sivasagar (Nazira), Tinsukia (Gujiyan, Margherita), Goalpara (Rangjuli), Kamrup (Dimaria), Nagoan (Kandura, Nilbagan, Dabaka), Cachar (Udarbond) Golaghat (Podumoni) of Assam, and Lower Subansiri (Hapoli), Dibang Valley (Chatin Village, Midland Block) district of Arunachal Pradesh causing threat in the ground water occurring at deeper depth. The behaviour of fluoride in ground water from Karbianglong and Naogaon districts of Assam show high sodium associated with fluoride. Assam falls in moderately endemic zone with very high fluoride-groundwater occurring in pockets in
certain areas. Granites, Granitic gneisses and phyllitic quartzite are the main hard rock aquifers that contain fluorine bearing minerals such as fluorite, biotite and muscovite. The highest fluoride concentration in groundwater is found near intrusive granites and near a fault/lineament trending along NW-SE direction.

These water quality problems arising from natural conditions and are linked to local characteristics of a humid climate. In contrast to other arsenic and fluoride affected regions of the world this area receives high rainfall and has got high ground water table. A long-term environmental planning is essential to mitigate this emerging pollution in North Eastern India.
Abstract

In different countries of Latin America as Argentina, Chile, México, and Peru at least 4 million of persons are permanently drinking water with elevated arsenic concentrations in a magnitude, which converts the issue in some of the countries as in Argentina and Mexico into a public health problem. So e.g. in Argentina and Chile over 1% of the population is exposed to the problem, whereas in Bolivia, Brazil, Ecuador, Costa Rica, El Salvador, and Guatemala, arsenic in drinking water is proved, but the numbers of persons affected are yet unknown. In other Latin American countries, the existence of the groundwater arsenic problem is not yet known. This was for example the case of Nicaragua where the arsenic exposure of population from groundwater and related severe health effects, was detected just two years ago. Additionally it must be taken into account that with advances in the modern analytical methods for arsenic at low levels of concentrations, and with the introduction of new national arsenic limits of 0.01 mg/L, as already introduced by Nicaragua and being planned to be implemented Mexico, it is expected that in future arsenic will be detected also in several countries with elevated concentrations, where it was presumed until now to be arsenic safe, and that numbers of people exposed will significantly increase.
Although that the arsenic drinking water problem is already solved in most urban areas by installing corresponding treatment plants, practically no action was performed by the authorities or international and bilateral cooperation agencies to mitigate the arsenic problem for the rural population, making especially the dispersed living rural population, which drinks arsenic-contaminated water —often without being aware of its toxicity — to the most disadvantaged group and to an emerging target for further actions to reduce the arsenic exposure.

In most of these countries, the problem is of natural origin, related to arsenic occurrence in groundwater containing up to several mg As/l, used for drinking water. In decreasing order of importance, it is either related to (1) the presence of arsenic in the aquifer sediments, related to volcanism (Argentina, Bolivia, Chile, Peru, Nicaragua, Mexico, El Salvador), (2) mining activities (Chile, Bolivia, Peru, Mexico), (3) electrolytic metal producing processes (Brazil), and (4) agricultural activities (arsenic containing plaguicides).

This paper comprises a 3 parts: First it gives a country-by-country state of art overview on the occurrence of arsenic in the groundwaters and surface waters used for drinking purposes in Latin America, including the respective arsenic sources, the numbers of persons exposed and affected, and the respective already observed and future possible health effects. In each case the need and the possibilities of mitigating the impact are discussed.

The second part discusses the experiences from the until now applied remediation methods for both, applications in urban and rural areas, and the third block deals with future needed measures to mitigate the drinking water arsenic problem of "Rural
"Latin America". Therefore remediation methods as well as the identification of safe water resources free of arsenic are addressed as possible solutions.

Special emphasis is drawn on the fact, that —at first— it is not a technological problem to be solved. First, the local, national authorities of the affected countries and the bilateral or international cooperation agencies must recognize groundwater arsenic in the rural areas of Latin America as one of the most important natural health risks of the present century. They must recognize that groundwater arsenic is an issue and a problem that would challenge the UN Millennium Development Goals of sustainable development on a global scale, and therefore consider doing its utmost to better equip people for life in those parts, where groundwater arsenic affects population and their sustainable development.

In order to mitigate the groundwater arsenic problem in rural areas, it must be considered, that the most sustainable strategies for the management of water supply systems are executed by the communities itself. Such is especially applicable in rural areas with small communities. It requires participatory development strategies comprising community consultation for problem definition, involvement in investigation and planning and in the execution and maintenance of the constructions. This needs a strong technical assistance or expertise. Often with little education and assistance, communities can be highly motivated to take action to develop and manage local water infrastructure in a sustainable way. If this is not achieved, even successful arsenic remediation programs may be abandoned soon by the local users, as it could be recently observed in the case study of Nicaragua
Abstract
Groundwater in the shallow aquifers comprising fluvial and aeolian sediments of Tertiary and Quaternary age in the Chaco-Pampean Plain (CPP) of northern and central Argentina, contain levels of arsenic (As) exceeding the limits of the national drinking water standard (0.05 mg/L) and the WHO guideline value of 0.01 mg/L. Nearly 1.2 million population depends on shallow groundwater are at a risk of potential exposure to inorganic As which is known to be carcinogenic and cause other detrimental health effects. The origin of As is thought to be related to the leaching of volcanic ash, present as distinct layers or dispersed within the sediments. Three possible sources have been postulated within the alluvial cone of Rio Dulce, such as the Holocene volcanic ash layer (about 6 mg/kg As); the volcanic glass component (nearly 20 %) of the sand sediments; and sediments originating from metamorphic and acid magmatic rocks. In the present paper we present some of the results of the salient chemical characteristics, distribution of As and its speciation, and the possible mechanisms of As mobilisation in groundwater in the shallow aquifers of the Rio Dulce alluvial cone in La Banda county of the province of Santiago del Estero in north-western Argentina.

Groundwater sampling has been carried out from 56 shallow domestic and public wells spread over an area of ca. 300 km² in part of the Banda and Robles Counties during autumn 2002 (April-May). Groundwater pH, redox potential (Eh), temperature and electrical conductivity (EC) were measured in the field. Water samples were collected for analyses of major anions (filtered through 0.45 µm online filters), cations and other trace elements including As (filtered and acidified with suprapure HNO₃). Speciation of As(III) was carried out in the field using Disposable Cartridges®. As(V) was calculated as a difference between total As and As(III) in the water samples.

The water samples were generally near neutral to alkaline (pH 6.67-8.95) and moderate oxidizing conditions (Eh=0.177 to 0.362 V). The water samples were predominantly Na-Ca-HCO₃ and Na-HCO₃-SO₄ type. EC values of groundwater varied between 880-4600 µS/cm (maximum 9600 µS/cm) and revealed considerable variation in the concentrations of HCO₃⁻ (250-1000 mg/L), Cl⁻ (50-1900 mg/L) and SO₄²⁻ (90-3000 mg/L) in. Levels of NO₃⁻ (0-4.3 mg/L, maximum 30 mg/L) and PO₄³⁻ (0.1- 2.4 mg/L)
were generally low, with exception of some shallow wells influenced by anthropogenic contamination. Levels of Ca$^{2+}$ (2-215 mg/L, maximum 500 mg/L), Mg$^{2+}$ (0.6-132 mg/L), Na$^+$ (100-900 mg/L, maximum 2600 mg/L) and K$^+$ (2.5-110 mg/L) were high but varied considerably.

Concentration of total arsenic (As$_{tot}$) ranged between 11-850 µg/L, although levels in 3 wells were extremely high (up to 13494 µg/L), and dominated by the As(V) as the aqueous species, representing from 53-92% of the As$_{tot}$ in 29 sampled wells (only 34 were analyzed for their As(III) content). Levels of total Fe (Fe$_{tot}$), Mn, V and Mo ranged between 2-1400 µg/L, 0.1-1500 µg/L, 9-666 µg/L and <10-809 µg/L respectively. Dissolved organic carbon (DOC) concentrations in water ranged between 1-12.7 mg/L, while NH$_4^+$ levels ranged up to <3.2 mg/L. Fluoride (F$^-$) levels, in general varied between 0.75-6.96 mg/L, but concentrations as high as 16.7 mg/L are found in some wells. Low As$_{tot}$ levels characterize the Na-Ca-HCO$_3$ or Na-Ca-SO$_4$ type waters, while high As$_{tot}$ (>150 µg/L) levels correspond to alkaline Na-HCO$_3$-type waters. As$_{tot}$ shows positive correlation with Na$^+$ and HCO$_3^-$ and a moderate to low negative correlation with Ca$^{2+}$ and Mg$^{2+}$. The latter can be explained in terms of cation exchange on clay minerals (Ca$^{2+}$ and Mg$^{2+}$ for Na$^+$) with increasing residence time of groundwater. Definite trends of positive correlation were noted amongst As$_{tot}$ and F ($R^2=0.58$) and As$_{tot}$ and V ($R^2=0.77$). Even if a clear correlation was not found with Mo, it is clear that the highest As$_{tot}$ values correspond to the peaks of Mo as well as F and V at pH around 7.5. Hydrogeochemical modeling using the Visual MINTEQ code revealed supersaturation with respect to minerals such as amorphous Al(OH)$_3$ and gibbsite.

The present study indicates that elevated concentrations of As are prevalent in shallow groundwaters of the Chaco alluvial aquifers of Rio Dulce Cone. Most of the groundwaters are alkaline, suggesting that mobilization of As in Chaco aquifers is influenced by: i) hydrogeochemical variability, ii) distribution of As and its speciation in the sediments; iii) groundwater flow pattern and recharge characteristics. Arsenic may be leached from the volcanic glass and transported into the aquifer through: i) infiltration of rain and irrigation water through the unsaturated zone, and ii) leaching by groundwater if the layer is at least temporarily located below the groundwater table. Further studies are however in progress to understand the mechanisms of arsenic in the sedimentary aquifers of the CPP region and the possible means to remediate the high-arsenic groundwaters for drinking purposes.

**Key words:** Arsenic, groundwater, mobilisation, shallow aquifers, volcanic ash, hydrogeochemical modelling.
Assessment of Arsenic Contamination in the Ground Water Sources of Ganga Floodplain of Bhojpur District, Bihar


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Abstract
Arsenic in drinking water poses the greatest threat to public health. Arsenic is highly toxic carcinogen (Category I) and also a mutagen / teratogen (harming foetus). Long-term oral exposure via drinking water can cause cancer of the skin, lungs, urinary bladder, and kidneys. As it is a bio-accumulative toxin, symptoms of chronic arsenic poisoning can take 5 to 15 years to appear and are apparently influenced by nutrition and general health standards. According to the Third World Water Forum of the World Bank, “The most devastating truth is that arsenic poisoning in our water supply has no effective treatment.”

Bhojpur District in west Bihar is a thickly populated agrarian area, which draws heavily on ground water sources for drinking and irrigation purposes. This UNICEF-sponsored research is based on systematic testing of all the public hand pump sources, within a 10 km. belt along the southern flank of River Ganga in Bhojpur District. The arsenic hotspots were detected between December 2004 to May 2005. Barhara, Shahpur, and parts Behea, Ara, Koilwar and Udwantnagar administrative blocks were surveyed.

Testing of the water samples were done at each hand pump site by Field Test Kits [FTK] supplied by N.C.L. [Pune]. Trained Field Technicians having adequate knowledge of lab. procedures conducted on-site tests. Field procedures involved flushing out of stagnant water, collection of water samples for FTK testing and preservation of samples for further confirmatory tests. All the tested hand pumps were marked with a distinctive ID. The FTK can test for arsenic levels in the range of 10 – 100 ug/L, and have a relatively small random error at 50 ug/L. The efficacy of FTK results vis a vis AAS tests were confirmed, and FTK results could be safely relied upon as an economical and a rapid preliminary indicator of serious arsenic contamination of ground water sources. Simultaneous G.P.S. Readings of arsenic hotspots were obtained for mapping.

The purpose of this study was to gauge the spatial extent and intensity of arsenic contamination of ground water in the study area, through statistical and cartographic interpretation of generated primary data. This would provide the base for appropriate mitigation techniques.
The results showed over 47% of public drinking water sources being contaminated, of which over 60% had more than 40 ug/L. arsenic content. Only 9% of all the villages were free from arsenic contamination. Barhara and Shahpur blocks had diffuse spread of contamination, while the intensity of arsenic content [over 50 ug/L.] was highest in Udwantnagar and Behea blocks. In Bhojpur, information of the depths of public hand pumps, gathered from the villagers, suggests that arsenic occurs at almost all aquifer levels. Also, locations of the Bhojpur contaminations varied from the DIARA lands to the older alluvial beds southward away from the Ganga, beyond the study area limit. The contaminations were unevenly spread over the entire area, thereby destroying the other myth that arsenic manifestations are confined to areas of new alluvium in the Ganga Basin.

**Key words:** Arsenic, carcinogen, mutagen, Bhojpur, Field Test Kits, A.A.S. spatial, intensity, population.
Groundwater Arsenic in the Central Gangetic Plain in Ballia District of Uttar Pradesh, India: A future concern

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Abstract

Arsenic (As) contamination in the groundwaters has recently been envisaged as a major crisis in India. In recent years, As has been reported in groundwaters in several sectors of the Indo-gangetic plain, mostly in the Holocene aquifers of the states of Uttar Pradesh, Bihar and Jharkhand. The present paper reports about the As contamination in groundwater and surface water in the Ballia district of Uttar Pradesh in northern India. Around 29 groundwater samples and 6 surface water samples were collected in the flood plain of the two rivers Ganga and Ghagra river during November 2003. The water samples are collected from shallow (<20m) and deep aquifers (80-100m). Hydrochemical parameters like pH, redox potential (Eh), electrical conductivity (EC), total dissolved solids (TDS) and alkalinity (HCO₃⁻) were determined in the field itself. The samples were analyzed for major anions and cations, and dissolved trace elements.

Arsenic concentrations in the surface water ranged between 1.9 and 12.3 µg/L, whereas in the groundwaters the concentrations varied between below detection limit up to as high as 80 µg/L. The concentration of As was very high in the Reoti, Sohow and Bairiya which are located close to the river basin. The concentration of As near an inland lake was also very high. Concentration of As were found to be moderate to low in the interior flood plains between these two basins. The surface water showed high concentration near the confluence of the two rivers. The Ghagra seems to contributing more As. The groundwater in the intermediate and deeper aquifers has more As compared to As in Shallow aquifers. The correlation between Fe and As was low (R²< 0.5). The sulphate concentration in groundwater was low as compared to surface waters. This may be due to the river bound suspended sediments get deposited in the regions and undergo reduction in the deep layers, the solid phase capable of removing the dissolved As species when condition changed from oxidized to reduction the rate, which is generally influenced by microbial processes. Under reducing conditions, most of the dissolved Fe occur as Fe²⁺ species and these may precipitate as Fe-sulfides under reducing conditions. The trivalent As (III) species might get incorporated into the sulfides if present in sufficiently high
concentrations. These aquifers seem to be particularly in risk, due to the prevailing geochemical conditions in which oxidized and reduced waters mix, and where the amount of sulphate available for microbial reduction seem to be limited. This is a preliminary study and the detailed study is under progress to assess exactly the processes controlling the As concentration in surface and ground waters.

**Key words:** Arsenic, India, Uttar Pradesh, groundwater, Holocene aquifers, redox conditions.
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Abstract
In two districts of Uttar Pradesh screening testing has indicated that 350 villages in 18 blocks are affected by arsenic in groundwater above the prevailing upper limit of 50 µg/L. Blanket testing in the affected areas and mapping of the arsenic distribution with GIS has further elucidated the scale of the problem. Well-switching, i.e. use of arsenic-safe handpumps in preference to arsenic-contaminated ones, is one option available to people living in the affected areas. Alternative water sources relying on source-substitution to rainwater, deep groundwater and very shallow groundwater are also planned on a pilot basis in some areas. Twenty-six deep handpumps have already been installed and these are providing drinking water with substantially reduced arsenic content. Experience from these two districts has been used to develop a large-scale project to test and mitigate arsenic in groundwater throughout Uttar Pradesh. The strategy developed is also detailed here.
Abstract
Botswana is a semi-arid country with low and highly variable rainfall patterns both in space and time. About 80 % of the country is covered by Kalahari sediments and the only perennial surface waters are restricted to the Okavango Delta and Chobe River to the north of the country. The Lower Delta is notable for its seasonal floods and the aquifers developed in the valleys associated with these channels are mainly recharged during the annual Delta floods.

Villages in the Lower Delta mainly rely on groundwater for household purposes. The increased water demand due to population growth, saline water intrusion and highly variable surface water flow in the lower Delta outflows necessitated assessment and development of new groundwater resources. It was during such a project implementation that arsenic was confirmed present in groundwater of the Lower Delta. It is not routine to test for arsenic in groundwater and the analysis were started after reports of high arsenic concentration in a number of deltaic environments around the world. The reason for this constituent’s presence in alluvial groundwater environments is not entirely clear, but it seems to be concentrated by the presence of organic material in anaerobic conditions.

This paper is confirming the elevated arsenic content in the groundwater of the Lower Delta. Laboratory analysis for the boreholes sampled in all the project areas have arsenic levels between <10 and 400 µg/L, values exceeding the Botswana drinking water standards of 10 µg/L.
Abstract
Ground water contamination, in excess of the World Health Organization (WHO) guideline value of 0.01 mg/L, has been observed in many parts of the world including India, Bangladesh, Thailand, Myanmar, Nepal, China, Taiwan and Vietnam among others. In the South East Asia Region of WHO, it is currently estimated that about 40 million persons may have been exposed to contaminated ground water at various concentrations of arsenic and almost a quarter of a million exposed subjects are already showing overt symptoms of chronic arsenic poisoning. A review of the epidemiological data shows that there is a need for internationally accepted criteria documents based on evidence in the following areas: Environmental Technology Verification (ETV) for arsenic removal, exposure assessment, case-definition and case management. This paper reviews the existing epidemiological evidence for the formulation and validation of standard regional criteria documents including case definition and management and presents WHO strategic goals to meet these objectives. Sharing of these documents on a regional basis will provide consistency in arsenic mitigation strategies and avoid duplication in a resource limited environment.
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Abstract
In lowland Nepal, located in the Indian border along the Gangetic Plain, arsenic contamination in tubewell water has been detected recently. Based on fieldwork in three communities of the hot spot area, the villager’s exposure to arsenic through tubewell water and its effects on skin manifestations and nutritional status were investigated. Of all tubewell water samples (n = 146), 97.9% and 87.6% had arsenic levels above the WHO and Nepal Interim Standard limits of 10 $\mu$g/L and 50 $\mu$g/L, respectively. The mean arsenic intake from water exceeded 10 times the provisional tolerable daily intake (PTDI) of 2.1 $\mu$g/kg body weight/day. Urinary arsenic concentration (adjusted by creatinine) for 106 married pairs was correlated, for either sex, with water arsenic concentration.

Examination of arsenic-induced skin manifestations for 1,343 villagers revealed 6.9% as arsenicosis prevalence, with higher level in males (9.3%) than in females (4.4%). Of the identified patients, 79.6% were in mild and 20.4% were in moderate stages, according to the criteria for Bangladeshis. Lower prevalence and milder situation were attributable to short duration of tubewell use. Dose-response relationship between urinary arsenic level and skin manifestations was significant for only males. Assessment of nutritional status by body mass index (BMI) revealed that about half villagers were underweight (BMI < 18.5). Correlation between arsenic intake and BMI was inversely significant for either
sex and the underweight subjects of both sexes pooled had 1.65-fold higher arsenicosis prevalence, suggesting that arsenic exposure worsens nutritional status and modifies occurrence or development of arsenicosis.

**Key words:** arsenic, tubewell water, skin manifestations, arsenicosis prevalence, dose-response relationship, underweight, Nepal
Groundwater is the main source of drinking of rural households in Tarai region, the southern part of Nepal. The communities depend on water of dug wells and tube wells. Analysis of arsenic contaminated groundwater of 289 tube wells and nutrition level consumed by the rural communities of Bagahi village, Rautahat District of the Tarai region, Nepal has been performed. Altogether 35 households (average 6.0) consume water of these tube wells. This is a cross sectional study.

The average quantity of water consumed by a person ranged from 1.5 liter to 5 liters per day. According to the Nepal Interim standard (50 ppb), about 6% of the total tested tube wells are risk population, as compared to about 50% according to WHO guideline (10ppb). The average age of contaminated tube wells is 10 years. Among the risk households, 63% have consumed about 2 liters of arsenic contaminated water, followed by households consuming 3-4 liters/day and households consuming 5 liters or more per day. Approximately 3% of the total risk population of 210 has been identified as arsenicosis patients, which however has been identified as the first level of arsenicosis symptom. Further, the arsenicosis patients were not aware about the symptomatic effects of arsenicosis.

More than 20% risk groups found without adequate nutrition in terms of calorie content. The risk of arsenic is high because the contaminated water has been continuously used for cooking and irrigation since the last 10 years. This alarming situation therefore calls for a serious development measure to mitigate the arsenicosis patients in the country.

**Key words:** Groundwater, Tarai, Arsenicosis, Nutrition, Risk-group
Abstract
Seasonal variation of water availability forces Bangladesh to depend more on
groundwater use both for agricultural and domestic use. Present irrigated area of the
country is about 60% of its cultivable area and out of the 60% irrigated area, 63% is
irrigated with groundwater. About 90% of household water supply depends on
groundwater. Water quality issues during dry seasons, especially the recent problem of
arsenic contamination of groundwater, have added another adverse condition for water
management. Some areas in 60 out of 64 districts are affected by arsenic contamination.
High concentrations of arsenic are found in water from thousands of tubewells across the
country and about 30 out of 130 million people are affected. Therefore, Bangladesh
cannot afford to leave almost 25% of her population under arsenic hazard. Moreover, it is
suspected that there will be possible reductions of crop production due to arsenic
contamination if unattended. The country cannot afford these adverse affects since it is
already struggling to meet food requirements for her increasing population. Therefore,
utilization and management of groundwater and especially arsenic contaminated water
has become essential. It has become more important for increasing agricultural
production and its sustainability and for providing safe drinking water, especially during
the dry season, November to May.

During the dry months, the groundwater table goes down and in several places
beyond suction limit (>25 feet or 10 meters), coastal area water becomes saline and
unsuitable for irrigation purpose, arsenic content in groundwater become high and cross safety limits (>0.05 ppm). Therefore, the country faces various water related problems and demands better management of water resources for crop production and human consumption.

During June to October the country receives plenty of surface water from catchments area within and outside Bangladesh and through rainfall. Combined effect of these accumulated water resources, often create floods of different magnitude and duration. Only fortunate part of situation is that groundwater is fully recharged during this period of the year with exception of Dhaka city area where groundwater withdrawal rate is higher than the recharge capacity. The recharged water body is used subsequently for irrigating dry season crops and for household purpose. Floods and standing water in major areas of the country during May to October limits crop diversification and improved crop production to during the months November to April/May. Rainfall during these months is scanty and surface water unavailability is also a problem as most of the smaller rivers and low lying areas become dry during this period of the year. Access to good quality water and its proper management are therefore, very important for agricultural development and assured supply of drinking water during these months. Management strategies will be suggested in this paper for sustainable use of groundwater resources and with especial emphasis on use of arsenic contaminated water.
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Abstract
Arsenic contamination in the groundwater of the Bengal-Delta plain is affecting millions of people. However, it is reportedly found that the surface waters like ponds, canals, lakes etc. are effectively free from arsenic. It seems that the soil, contaminated with arsenic loaded irrigation water, is acting as a sink for arsenic. The present study was undertaken to examine arsenic retention behaviour in some surface soils of arsenic affected zones of West Bengal as affected by organic matter application and to correlate them with different soil properties and crop uptake by boro rice. Two surface soils (clay loam, Inceptisol) (S1 and S2) from arsenic contaminated area were studied for the changes in arsenic content in soils as affected by organic matter application (0,1% and 2% by weight of soil).

The results show that the amount of arsenic content has been found to be significantly decreased with the application of organic matter. The magnitude of such decrease, however, varied with levels of organic matter, being highest decrease with 2% organic matter. The results of field experiment on rice during Boro season using arsenic loaded irrigation water show that the distribution of arsenic in rice followed the order: root > stem > leaf > grain. The arsenic uptake increased with the progress of crop growth and maturity.

Key words: Arsenic, organic matter, rice.
An unfortunate combination of several different factors has contributed to the high arsenic concentrations (10-1,400 µg/L) found in ground waters near Fairbanks, Alaska. Major ions, trace elements, and redox species were determined for 17 ground waters extracted from residential wells before any online storage or treatment systems. The waters are all circumneutral in pH (6.0 – 7.8) calcium-bicarbonate type with a wide range of specific conductance, dissolved oxygen, and dissolved iron, manganese, nitrate, and phosphate concentrations. Redox speciation indicates expected trends. As(III) dominate in ground waters with the highest As concentrations; Fe(II) dominates in ground waters with the highest Fe concentrations. Although total dissolved As does not correlate well with total dissolved Fe, the ratio of As(III):As(T) does correlate with the ratio of Fe(II):Fe(T). Arsenic originates from arsenopyrite and arsenian pyrite found in mineralized portions of linear zones thought to be northwest-trending shears. Arsenic concentrations increase during downgradient flow from oxic recharge zones to anoxic discharge zones. Arsenic is kept soluble by high carbonate concentrations from dissolution of hydrothermal calcite and possibly dolomite and from organic matter (and possibly graphite) decomposition that causes high partial pressures of carbon dioxide (up to $10^{-0.6}$ atm). The well containing ground water with the highest arsenic concentration (1.4 mg/L) also contains the highest phosphate concentration (1.1 mg/L). Phosphate effectively competes with arsenic for sorption sites and keeps arsenic in solution. Another well water contains extremely high nitrate concentration that can oxidize arsenic-bearing sulfides in the absence of dissolved oxygen. The source of the phosphate and the nitrate appear to be anthropogenic, but natural processes including arsenic-rich sulfides exposed in oxic recharge zones, high-carbonate ground waters, and reduction by organic matter in discharge zones would still mobilize high concentrations of arsenic in these ground waters.
138. Global Arsenic and Antimony Flow through Coal and their Cycling in Groundwater Environment

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Abstract

The world bituminous coal production has increased from 3,358.80 Mt (Million metric tonnes) in the year 2000 to 3,688.43 Mt in 2003 (USGS 2004). Over 64 trace elements and metalloids have been detected in coal, and concerns on related environmental contamination have been raised. Exposure pathways differ significantly from one element to another. While pathways of arsenic (As), mostly from drinking water and from food, grown using As-contaminated irrigation water, are fairly well-known, experience with antimony (Sb) is rather scant, although most humans are now exposed to low levels of Sb in food, water and air. For the last three decades, As-related problems with groundwater, soils, and wastes have been in the focus of many countries around the world. In South-East Asia, e.g., in Bangladesh and West Bengal (India), many people suffer from groundwater-related As-problems which have emerged as the single largest social and environmental problem of the present century. Besides, the U.S. Environmental Protection Agency (USEPA) and the European Union (EU) have classified Sb and its
compounds as a highly toxic elements. Both elements toxicity depend upon the oxidation state.

Arsenic and Sb are metalloids belonging in the group 15 (previously VA) of the periodic table. Their speciation and mobility are governed by redox conditions and pH. The concentrations of As and Sb in coal vary strongly from one region to another. For example in South African coals, concentrations lie in the range of 0.9-8.2 mg As/kg and 0.47 mg Sb/kg respectively. In coals of the United States, concentrations are up to 24 mg As/kg and 1.2 mg Sb/kg respectively. In the Raniganj coalfield, India, As-concentrations of 3.41 to 6.36 mg/kg have been reported, whereas in the Sohagpur coalfield, North-Central India, values were between 0.29 and 40 mg As/kg. In Indian coal combustion products (CCPs), As varied between 5-68 mg/kg. In the latter coalfield, Sb concentration was reported to be 0.63 to 1.6 mg/kg.

The widespread occurrence of As and Sb in coal suggests the necessity to pinpoint the fate of these elements in the environment, especially in soils, waters and sediments. These two environmentally sensitive elements are important due to their chemical and toxicological properties. It has been cited that Sb exists as Sb(V) in waters with only minor levels of Sb(III). The Sb in sediments may be mobilized, and thus presents a potential environmental hazard.

Arsenic is a very coalphilic element, with its affinity to organic and inorganic matters in coal. Antimony is a chalcophile element entering the atmosphere with aerosols from sulphur bearing mineral deposits and their related smelting processes, and from the combustion of fossil fuels (coal and oil). Prior to exporting and importing coals, it is necessary for national and international policy makers to have accurate information on the trace metal-related quality of coal.

In this study, we have divided the globe in seven regions: North America, Central and South America, Western Europe, Eastern Europe & Russia, Middle East, Africa, and Asia plus Oceania. An attempt has been made to establish the flow (export and import through coal) of these two elements from one region to another for 2003. We have also tried to explain how these elements behave in the groundwater and their effects on the importance of water in global economic development.
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Abstract
The South West district of NCT Delhi is one of the larger districts having considerable dependency on groundwater for drinking purposes. It has been notified by central groundwater Authority for regulated development of groundwater resources on account of rapid decline in the water levels of the district and because of the fact that the majority of the groundwater resources available in the district is saline and has poor quality. The groundwater of the district has considerable fluoride contamination (fluoride concentration > 1.5 mg/L) to the extent that more than 50% of the groundwater samples collected randomly in the district showed fluoride concentration beyond permissible limit. The fact being known that anomalous fluoride concentration (fluoride concentration > 1.5 mg/L) in groundwater can have adverse effects on human health, it becomes important to study the pattern of variation in the concentration of fluoride in groundwater of the district and think of the reasons thereof.

The predominance of fluoride contamination is found in the samples collected from the older alluvium areas underlain mostly by saline water and lithologically predominated by clay, Kankar and silt deposits and in the northeastern part of the hard rock areas of the district. The groundwater samples from the rest of the hard rock areas and the mid eastern part of the district just adjacent to the hard rock areas have shown concentration of fluoride below permissible limit. The probable reasons for the distribution of fluoride contamination have been put forward on the basis of residence time of the groundwater.
140. Arsenic Pollution in Chhattisgarh

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Abstract
In several Asian countries, i.e. India, Bangladesh, Cambodia, China, Nepal, Pakistan, Taiwan, Thailand, Vietnam, etc., the situation of arsenic toxicity is alarming with reports of severe health problems among the populations. The arsenism has been spreading due to weathering of the bed-rock and geothermal exploitation of natural resource materials, etc. The arsenic contamination in surface and ground water of the most mineral rich and industrialized state i.e. Chhattisgarh is investigated. It is situated between 17º – 23º 7” N latitude and 83º 38” - 84º E longitude with area of ≈ 1.35 x 10^5 km². The technique i.e. HG-AAS is used for the determination of the total arsenic in water samples using sodium borohydride for generation of arsine as prescribed in the literature. The arsenic contaminated environments, situation of the contamination and anthropogenic sources are explored.
141. Recent Developments in Analytical Techniques for Monitoring Inorganic Pollutants in Ground Water Samples

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Abstract
Nearly 97.5% of the water on the earth’s surface is salty. Of the remaining 2.5%, glaciers constitute 68.5% and about 30% is fresh groundwaters. Once, groundwater reserves acted as standby resources for overcoming drought. With the tremendous increase in human population and its activities there has been unforeseen depletion of groundwater reserves. Increased use of water for agricultural purposes, urbanization and demand and demand for supply of drinking water through public utilities, ever growing industrialization accompanied by increased power production, mining and other activities have greatly depleted the groundwater resources. Increase in population and climate changes will raise the water demand by about 50% by 2025. This will increase the population under water stress to about 3.4 billion and most of them will be in the developing countries. Demand for irrigation water will grow most in Asia since the largest percentage of irrigated land lies in this continent. Continued drawing of groundwater has already depleted the water table. Besides, the use of fertilizers and pesticides, discharge of industrial effluents, domestic and industrial landfills have caused the infiltration of several potentially dangerous heavy metals and other pollutants into the already scarce groundwater reserves.

Therefore, monitoring and protection of ground water resources from pollution has become a high-priority area of research in recent years. Ground water monitoring for various pollutants is a complex undertaking requiring the application of time tested sampling and analytical procedures resulting in the collection of high quality data. Maximum permissible levels to different elements in drinking water have been legislated and accepted by the relevant national and international environmental protection agencies. The application of isotopic data in the monitoring of ground water is also extremely important. For instance, boron isotopes can be used to track and measure pollution and contamination pathways in the investigation of sewage pollution in ground water. Therefore, it is necessary to analyse several batches of ground water samples on routine basis for inorganic pollutants (for both elemental and isotopic, cations and anions) in the monitoring programmes.

Several modern analytical techniques have attained capability of measuring most of the elements in the Periodic Table at sub-ng/g levels in the ground water samples. Some of the more popular analytical techniques that are being applied to the analysis of ground water samples are spectrophotometry, flame photometry, flame atomic absorption spectrometry (F-AAS), graphite furnace atomic absorption spectrometry (GF-AAS), ion chromatography (IC), X-ray spectrometry (XRF), inductively coupled plasma atomic emission spectrometry (ICP-AES), inductively coupled plasma mass spectrometry (ICP-MS), high resolution inductively coupled plasma mass spectrometry (HR-ICP-MS) and
inductively coupled plasma time-of-flight mass spectrometry (ICP-TOF-MS). Mass spectrometric techniques offer the capability of precise estimation of isotopic concentrations / ratios in addition to sensitive detection of different elements. XRF which was widely accepted as a technique for the estimation of metals in a variety of solid samples, is now being used for the analysis of ground water samples using a micro-droplet method. The technique is good for the analysis of Pb, As, Cr, Se and Cd and especially effective for low Z elements such as Na, F and B. Ion chromatography is now a well established technique for the precise estimation of common anions like chloride, nitrate fluoride, etc., in ground water samples. Though there have been some spectacular advancements in the field of ICP-MS by the development of HR-ICP-MS and ICP-TOF-MS, the original quadrupole based ICP-MS has revolutionized the inorganic analysis of ground water samples. Currently it has been widely accepted as a powerful tool for trace and ultra-trace (< pg/g) elemental as well as isotopic analyses.

In light of the difference in the toxicity and physiological behaviour between the chemical forms the need to determine individual chemical species instead of total element contents is now widely recognized. Once the toxic elements have entered into the environment, their physical and chemical properties, toxicity, mobility and biotransformation are controlled to a large extent by their physicochemical form. Particularly for those in contact with living organisms, it is necessary to determine not only the total content of the element but also to gain an indication of its individual chemical and physical form. The knowledge of speciation is necessary for estimation of biological availability, reactivity and toxicity of the element.

One of the most common approaches adopted by many laboratories for obtaining information on different species of elements has been by coupling the separating powers of chromatographic techniques with the element-specific detection capability offered by atomic and mass spectrometric techniques. The specific advantages of ICP-MS and HR-ICP-MS techniques, such as extremely high sensitivity, limited interference effects, wide element coverage and speed would make them powerful analytical tools in future for speciation analysis of ground water samples.

In the ground water monitoring efforts, accurate and precise results only enable valid conclusions to be drawn about the different types of ground water and the risks related to human consumption and other specific applications such as agriculture, aquaculture, etc. This can be best assured by the implementation of quality assurance (QA) and quality control (QC) measures.
Abstract
This topic is a part of a project sponsored by EC in the Asia Pro Eco Program dealing with innovative treatment of drinking and industrial water (INNOWA). The aim of the project is to establish a European – Asian network on innovative water treatment technologies with focus on membrane technologies. This represents the steps required to find out an appropriate, reliable, simple and cost-effective technology for removal of arsenic from ground water. A clear glass of well water, once as welcome in Bangladesh as anywhere in the world, has in recent years become a symbol of controversy and fear. Dangerously high levels of naturally occurring arsenic, a colourless, odourless, tasteless poison, have been found in the water in underground wells, putting an estimated 35 million people—nearly one fourth of the population – at risk. This problem is also occurred to other countries of the world and threatened human being to death. To get rid of this naturally occurring maniac a promising technology was searched for. This topic focused on low energy RO membrane technology for elimination of arsenic from ground water. Low energy RO membranes have been justified in the lab scale unit under different operating conditions to face the challenge of arsenic elimination. This work was supported by company DOW from technical and financial point of view. After performing a lot of experiments through this work the appropriateness of this technology was verified at the end depending on the quality of arsenic spiked water.
143. Removal of Arsenate Anions from Groundwater Using an Anion-exchanger Derived from Tamarind Fruit Shell

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Abstract
The removal of arsenic from groundwater and aqueous waste streams is one of the most important environmental problem. Although the problem has been addressed for many years, an effective treatment option is still limited. The objective of this study was to increase the anion exchange properties of the agricultural by-product, tamarind fruit shell (TDF) by chemical modification. The TDF was treated with epichlorohydrin and dimethylamide in the presence of pyridine and N,N'-dimethylformamide. To convert into it into an anion-exchanger (TDF-AE), the above product was treated with HCl solution. The infrared spectroscopy results were used to confirm the presence of spacer group and –CH2-NH(CH3)2 functionality in TDF-AE. The surface modification of TDF improved the thermal and chemical stabilities of the adsorbent. X-ray diffraction pattern and scanning electron microscopy studies were carried out to investigate the crystallinity and morphology of the adsorbent. The decrease in crystalline domains in TDF-AE results in the loss of tensile strength of the back bone chain and consequently enhances the free mobility of the chain to catch the arsenate anions from solution. The adsorption of arsenate ions onto TDF-AE was studied in a batch system with respect to the initial pH, initial concentration of arsenate adsorbent dose, ionic strength, diverse ions, and temperature. The adsorbent exhibited the highest uptake capacity (>99.0%) for an initial concentration of 15.0 µmol/L at the initial pH value of 8.0. The adsorption equilibrium time for arsenate was reached within 3 h. Adsorption process was found to be concentration dependent and exothermic in nature. Adsorption capacity decreased from 99.7 to 82.5% with an increase in temperature from 10 to 40°C at an initial concentration of 60.0 µmol/L.

Kinetic aspects were studied in order to develop a model that can describe the process of adsorption onto TDF-AE. The surface mass transfer coefficients were determined for the process under the influence of varying concentration and temperature. Arsenate adsorption was found to decrease with increase in ionic strength due to the expansion of diffuse double layer. Anions such as silicate, chromate, sulphate, bicarbonate, nitrate and fluoride were antagonistic towards the uptake of arsenate by TDF-AE. To evaluate the theoretical number of stages for the removal arsenate ions from the groundwaters, operational lines were also generated with a slope of solution/mass of fixed adsorbent (V/m) with different initial concentrations. The L-type adsorption isotherm obtained in the adsorbent indicated a favourable process and fitted the Langmuir equation model well. The thermodynamic parameters for adsorption process were calculated to predict the nature of adsorption process. The adsorption efficiency towards arsenate removal was also tested using simulated groundwater samples. Adsorption isotherm experiments were
also conducted for comparison using a commercial chloride form, Duolite A-7, a weak base anion-exchanger. Acid regeneration was also tried for several cycles with a view to recover the adsorbed arsenate ions and also to restore the adsorbent to its original state. The results obtained point towards viable adsorbent, which is both effective as well as economically attractive for arsenate removal from aqueous solutions and groundwaters.

**Key words:** Arsenate anions, removal, groundwater, anion-exchanger, Tamarind fruit shell.
Abstract
The global significance and human health impact of heavy metal pollution have become major issues of public concern only in the last few decades. Arsenic has received a great a great deal of attention due to its toxicological effects on human system. Arsenic is a commonly occurring toxic metal in natural ecosystem. It enters the aquatic environment in the dissolved form through industrial discharges such as from metallurgical industry, glass and ceramic pesticide manufacturing and petroleum refining industries etc. beside being proven carcinogenic, inorganic arsenic can lead to gastrointestinal, cardiovascular, dermal and respiratory disorders, hyper pigmentation and peripheral neuropathy as it gets deposited on or bound to tissues.

Most of the treatment techniques available in literature are at the experimental stage with regard to arsenic removal, and have not been demonstrated at full scale. Although some processes may be technically feasible, cost may be prohibitive. Several studies have addressed the issue of arsenic removal from natural and synthetic water by adsorption. This paper reviews the different adsorbents used in literature for arsenic removal.

Most of the adsorbents used for the removal of arsenic can be classified into three major groups of compounds comprising namely aluminum, lanthanum, and iron. Several studies are available in the literature on goethite, hematite, manganese greensand, iron oxide coated sand, Fe loaded coral limestone, granular ferric hydroxide, pyrite, ferrihydrite, activated carbon, hydrotalcite, ferruginous manganese ore. However the arsenic specie present in water limits the performance of most of these adsorbents, as most of the available adsorbents are more suited for As(V) removal than As(III). Efforts are also being made to develop a suitable adsorbent for the removal of As (III) from groundwater. Iron (III) oxides have been effectively used for removal of both As(V) and As(III) from aqueous solutions. But the occurrence of ferric oxides in form of fine
powder limits the use of ferric oxide in column operations. Iron oxide impregnation/coating on different materials such as activated alumina, sand, granulated activated carbon, MnO₂ coated sand has been reported in the literature. The mechanisms of adsorption-based process along with its safe disposal were also reviewed. Various adsorbent-based treatment technologies used in the field have also been discussed in this paper.

**Key words:** Arsenic, Adsorption, Iron oxide, Drinking water, Treatment
Abstract
It is well-known that anion adsorption (e.g., arsenic) by metal oxides in water depends on the pH, oxidation state, and other common anions. The objective of this study was to examine removal of arsenic species from surface water, groundwater, and waste water samples using ARTI-64 particles. Samples were reacted with ARTI-64 particles for 30 minutes. The suspensions were filtered and analyzed for arsenic and other anions. Results of this study suggested that ARTI-64 particles, unlike other sorbents (e.g., iron and aluminum oxides), effectively adsorb both arsenite and arsenate from different samples, in the presence of other anions (e.g., sulfate/phosphate) without requiring change in the pH of the samples. This process is rapid, simple, and reversible. These findings could offer opportunities to develop practical arsenic removal methods and help solve a serious worldwide arsenic health and environmental problem in underdeveloped and developed nations.

Key words: Arsenic, removal, groundwater, adsorption process, ARTI-64.
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Abstract
The growing groundwater contamination by arsenic in West Bengal Delta (WBD), India is posing a serious threat to mankind as the drinking water supply, particularly rural water supply for domestic consumption, is at the stake of great hydrogeological risk because of associated health hazard resulting from arsenic dose by indigestion. This is becoming complicated because of the increased unplanned exploitation of groundwater in this region and accelerated shrinkage of freshwater resources due to various reasons. In fact, arsenic is used to be presumed either secondary or trace elements in the past, has become now major contaminant and lots of investment have been already made in various studies, alternate safe drinking water supply and health measures in this region by government and various NGOs. However, the problem is still persisting with same degree of vulnerability, if not more, and is posing a serious threat to the mankind. In this paper, the hydrogeological conditions, arsenic distribution and level of arsenic contamination has been investigated for parts of the WBD, and an innovative insitu technique is conceived and suggested to mobilize arsenic concentration in groundwater and to remove arsenic from the drinking water supply wells.

The technique, termed as well head protection, utilizes the scientific findings of hydrogeological subsurface characterization and flow regime investigation to design arsenic trap zones for arsenic removal from the groundwater moving towards a well. This activates natural filtration process through hydraulic control. Such technique can be utilized effectively as low cost water treatment technology for safe drinking supply. This may prove a new dimension in drinking water supply schemes, especially in rural areas.
where infrastructure facilities for safe drinking water supply are either nonexistent or severely adequate. Since such zones can be easily constructed from local available materials, it may prove to be economical and viable for safe drinking water supply. However, there is need of further research and evaluation at the field level for its viability and performance.

**Key words:** Arsenic, groundwater, well head protection, natural filtration, hydrogeology, safe drinking water.
147. Newly Developed Adsorbent for Arsenic Removal from Groundwater

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Abstract
This topic is a part of a project sponsored by EC in the Asia Pro Eco Program dealing
with innovative treatment of drinking and industrial water (INNOWA). The aim of the
project is to establish a European – Asian network on innovative water treatment
technologies. This topic represents the appropriateness of a reliable, simple and cost-
effective technology for removal of arsenic from ground water. Dangerously high levels
of naturally occurring arsenic, a colourless, odourless, tasteless poison, have been found
in the water in underground wells, threatening thousands of people to death. A promising
technology was looked for to face this naturally occurring maniac. The newly developed
adsorbent focused on elimination of arsenic from drinking water. This technology has
been justified in lab scale unit under different conditions to face the challenge of arsenic
elimination. The results found from different experimental set ups have been compared
with the results of available adsorbents found in the market. One part of this work also
discusses about the disposal criteria of waste arsenic residue. For this purpose all the
activities were supported by a Germany company from technical and financial point of
view. Based on the lab oriented experimental results the appropriateness of this
technology was verified at the end depending on the quality of arsenic spiked water.
Arsenic and Fluoride in Groundwater: A Comparison of Conceptual Models

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Abstract
Globally, arsenic and fluoride are the two naturally-occurring chemical constituents of groundwater that are most harmful to human health. Both occur in excessive concentration over widespread areas, affecting the groundwater-based drinking water supplies of large populations. The modes of occurrence of arsenic and fluoride in groundwater may be compared by reference to their mineralogical sources and host rocks, release mechanisms and hydrochemical constraints, and the hydrostratigraphic and hydrogeological contexts that govern transport to wells and determine concentration at the well-head. These are the constituent elements of conceptual models required to explain the patterns of occurrence of arsenic or/and fluoride in pumped groundwater, and to direct the development of possible solutions. Conceptual models of arsenic in groundwater will be presented for the Bengal Basin and the Argentinian Pampas, both containing regionally extensive arsenic-bearing aquifers yet in contrasting hydrogeological and hydrochemical environments. The models are firmly based on field observations of spatial distributions and hydrochemical associations. In the case of the Bengal Basin, the conceptual models have been further developed into numerical models of representative tubewells. The numerical models quantify the rate of arsenic transport in tubewell catchments, and simulate the changes in well-head arsenic concentration with duration of pumping. The models emphasise the scale and rate of likely increases in arsenic concentration in the long-term, with important implications for monitoring, treatment, alternative abstraction strategies and applications in epidemiology. The usefulness of these conceptual and numerical models in the case of arsenic in groundwater can be contrasted with those proposed for fluoride. In general, fluoride presents the greater complexity and therefore, hydrogeologically, a greater challenge than arsenic. Fluoride has a multitude of potential mineral sources and rock hosts, and affects groundwater across a wider range of geological environments than does arsenic. A variety of weathering regimes and other release mechanisms transfer F from host rock to groundwater solution. Furthermore, the hydrogeological context for fluoride is commonly the complex ‘fractured aquifer’ environment of igneous and metamorphic terrain, rather than the sedimentary environments that host regional occurrences of arsenic in groundwater. With the notable exception of southern India (Jacks et al., 1993 onwards), studies of fluoride hydrochemistry and groundwater flow have not been linked successfully on a catchment scale. Examples of the complexity and uncertainty of fluoride sources and hydrogeological contexts will be presented from studies in the Arusha region of Tanzania, and in the Bhandara region, Maharashtra District of central India. Requirements for further research on fluoride in groundwater will be emphasized. These programmes should combine studies of the geochemistry of the source mineral(s) and release mechanism(s) of F from the host rocks, with the hydrochemical constraints
and the patterns of groundwater flow and mixing imposed at catchment scale.
High fluoride groundwater of Karbi-Anglong district, Assam: Source characterization

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Abstract

India is one among 30 countries, where people consume ground water with more than 1.5 ppm of fluoride, which is the upper permissible limit prescribed by WHO(1993). Although high fluoride in groundwater is very common in arid and semi-arid parts of India. Assam, which receives highest rainfall, falls in moderately endemic state. Many cases of dental and skeletal fluorosis have been reported from several small pockets of Assam. In order to delineate the root cause of fluoride in ground water, a small area (Long: 92°56’ – 93°20’E; Lat: 26°10’ – 26°24’N), in and around Dokmuka town comprising about 100 km² was chosen for the present study. The area consists of three geomorphological units, denudational hills, piedmont zone and alluvial plain, drained by Dikharu nadi, a tributary of Jamuna River. This area experiences humid tropical climate with annual temperature varying from 6 to 32° C with annual of 1250 mm. Granites and micaceous quartzite are the major rock type exposed in the area. Several alternate layers of clay, silt, gravel and sand define the aquifer system. Artesian wells are quite common in this area.

Fifty two groundwater (from deep, shallow tube wells and open dug wells) and surface water samples (from stream and natural springs) for three seasons (premonsoon-monsoon and post monsoon for the year 2003-2004) were collected during the present study. A large spatial and minor temporal variation with respect to fluoride is noticed in the samples. The concentration of fluoride in groundwater decreases from foothills towards the river channel. Such variation could be due to mixing of river water and increasing in the depth of the bedrock. The tube well water is of Na⁺-HCO₃⁻ type with a small shift towards Ca²⁺-HCO₃⁻ field in pre-monsoon period. Dug well water shifts from Na⁺+Ca²⁺-HCO₃⁻ field in pre-monsoon to Ca²⁺-HCO₃⁻ fields in monsoon and post monsoon, indicating a different source of recharge water for both deep and shallow aquifers. Tube well water sample has higher TDS compared to dug well and surface water samples. The pH varies from 6.4 to 8 in tube well, 5.8 to 7.6 in dug well water samples and in surface water samples. Total fluorine in Pink Granite is 590 ± 30 ppm and in quartzite it is 260 ± 20 ppm. The soil sample is acidic with fluorine amount being between 230-440 ppm. Anhedral fluorite was identified using microscope and SEM in the Granite sample. Mica being the other fluorine bearing mineral identified.
Abstract
In semi-arid and arid regions, water scarcity is already a crucial problem. The growing groundwater contamination problem in these regions is making the problem further acute and complicated. In turn, availability of safe drinking water is becoming major challenging task at the state and national level. The present study reveals alarming level of fluoride in many villages of Dungarpur district located in Rajasthan, India, where groundwater is the main source of the drinking water supply, and thus is at the stake of fluorosis risk. High fluoride water is of concern for drinking water supplies, as fluoride concentration has surpassed the permissible limit of 1.5 mg/l (Indian Standard) in many wells. Hydrogeochemical investigations are carried for the shallow as well as deep wells of Dungarpur district, Rajasthan. The hydrochemical data were analyzed and saturation states of various minerals are computed using PHREEQC geochemical code to investigate prevailing hydrogeochemistry in the study area.

Fluoride concentration ranges from 1- 6 mg/l. It is observed that twenty one percent of the shallow wells have fluoride concentration more than the prescribed limit of 1.5 mg/l and thirty four percent of the deep wells have fluoride concentration above 1.5 mg/l. The fluoride concentration is also correlated with the concentration of certain major dissolved constituents. It is observed that fluoride is inversely related to dissolved calcium in the groundwater, and solubility of calcium and fluoride containing minerals control the fluoride concentration in the groundwater. Results obtained in the present study will be useful to water resources managers and planners in chalking out strategic measures to control fluoride contamination in groundwater and to abate the fluorosis problem.

Key words: Hydrogeochemistry, Fluoride, Groundwater, Dungarpur District, Rajasthan, PHREEQC.
151. Hydrogeochemistry of fluoride in groundwater of Wajrakarur mandal of Anantapur District, Andhra Pradesh

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Abstract

Fluoride occurrence in groundwater is a natural phenomenon influenced by the local and regional geological setting and hydrological region. It is unique substance for which there are both lower and upper limits of concentration in drinking water with identified benefits.

Wajrakarur revenue, mandal, Anantapur District, Andhra Pradesh is one of the severe affected regions, where higher concentration of fluoride identified in drinking water used by the people. Keeping in view, thirty representative groundwater samples are analyzed for fluoride and other associated chemical parameters. It is found that fluoride concentration varies from 0.5 to 6.0 mg/l. Calcium, magnesium and bicarbonate concentrations are varying from 87 to 585 mg/l, 45 to 454 mg/l and 13 to 326 mg/l respectively. The pH values of all the samples are within the desirable limits and all the samples of groundwater is alkaline in nature.

It is observed that the onset of fluorosis and severity of symptoms are governed by various factors such as nutritional deficiencies, high ambient temperature, high alkalinity and low calcium and magnesium contents in drinking water in the study region. It is also observed that in the study region low groundwater movement in drinking water is a hydrodynamic condition in which fluoride concentrates in groundwater. Arid and semi-arid climate causes high evaporation of groundwater, which is an important factor in concentrating salts (including fluoride) in groundwater. In the investigation area high fluoride groundwater is generally associated with high bicarbonate values and low
calcium content. In general, basic hydro carbonate-sodium (HCO$_3$- Na) water with higher pH value is advantageous to the concentration of fluoride.

**Key words:** Hydrogeochemistry, fluoride, wajrakarur, Anantapur
152. Occurrence of High Fluoride in Ground Water of Orissa and Fluorosis Problem

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Abstract

Fluoride above the permissible limit of 1.5 mg/L occurs in ground water of both hard rock and Mahanadi alluvium of Orissa. Out of the 1100 borewells drilled in hard rock terrain of Orissa 8.5% of the borewells show fluoride above 1.5 mg/L. Recently fluoride above the permissible limit has been reported in Mahanadi alluvium also. Fluorite, fluorapatite, micas and amphiboles are the main fluoride bearing minerals. In alluvium fluoride occurs in clay minerals like montmorillonite, illite and vermiculite etc. In alkaline condition, OH⁻ from ground water replaces F⁻ from the minerals and fluoride content of ground water increases.

Four endemic fluorosis zones have been delineated in the hard rock terrain of Eastern Ghat. These are: i) Balasingi–Singipur area of Khurda district; ii) Hiradeipur-Deuli area of Nayagarh district; iii) Karlakot grampanchayat of Nawapada district; iv) Gohirapadar village of Sauntpur grampanchayat of Kalahandi district. Impact of fluorosis on human health is in three forms such as dental, skeletal and non- skeletal fluorosis. In Karlakot problem is devastating. More than 90 % of the children, in the age group 0-15, in Karlakot and its surrounding villages have dental fluorosis, while more than 40% of the adults has skeletal fluorosis leading to acute pain in their bones. Most cannot straighten their backs and get exhausted very easily.

In fluorosis affected areas both dug well and bore wells are having high fluoride. Fluoride reaches as high as 16 mg/L. Fluoride bearing minerals occur in granite, gneiss, pegmatite, hornblende syenite, nepheline syenite and amphibolite etc. The Karlakot area where fluorosis problem is severe occurs in the boundary between Eastern Ghat Mobile Belt and Bastar craton. The area exposes a host of granite gneiss of Bengal Supergroup, which are intruded by syenite, hornblende syenite and pegmatites. Fluoride content of various rock types are hornblende syenite (4240-7480 ppm), nepheline syenite (612-888 ppm), granite gneiss (460-1560 ppm), amphibolite (1568 pm ), khondalite (816 ppm), pegmatite (472 ppm ), quartzite (324-448 ppm).

In the Mahanadi alluvium high fluoride occurs in some restricted patches in phreatic aquifer underlain by clay. Clays are potentially good absorbers of anions since they contain crystalline minerals such as kaolinite, smectite and amorphous minerals such as allophane and other metal oxides and hydroxides which would absorb anions such as F⁻. The adsorption of fluoride is maximum at pH 5.5. In alkaline condition the OH⁻ from water replaces F⁻ in the clay minerals and fluoride concentration of the water increases. The ground water is high in Na, Cl, SO₄, and K which clearly indicates the influence of sea water. The water type is (Na+K) –Cl and (Na+K) –HCO₃.
As in the alluvial areas people use tube well water and high fluoride occurs in dug wells which is having high electrical conductivity no health hazard is reported. All the bore wells and dug wells having high fluoride should be delineated and abandoned so that there is least impact on human health. In the fluorosis affected areas alternative source of water supply is the only solution. With increase in utilization of ground water peoples awareness against fluorosis is also important to reduce its impact.

**Key words:** Fluorosis, Fluorite, Fluorapatite, Montmorillonite, Illite, Vermiculite.
Abstract
Surveillance on the fluoride problems of Alappuzha town was done through dental fluorosis survey and water quality monitoring. Drinking water supplied to the town of Alappuzha by the Kerala Water Authority from tube wells placed in Warkali aquifer is found contain fluoride concentrations above the drinking water standards. Warkali aquifers comprises a sequence of alternate layers of fine to medium grain sand with clays and thin bands of lignite. Dental fluorosis survey indicated that 14 % of the surveyed school children have fluorosis problems. The high concentration of bicarbonate, high pH and low calcium is found to correlate positively with high fluoride concentration.

The correlation of fluoride with other water quality parameters was determined from a correlation analysis. It was found that, high fluoride concentration is associated with a high bicarbonate ratio generally above 10. It was also observed that the ratio of calcium to fluoride is generally below 10, wherever high fluoride concentration is noted.

The calcium rich water moving northward release sodium by ion exchange from clay minerals, which had become sodium rich. This results in Na- HCO₃ type water, which also explains the higher fluoride content. The alkaline water is effective in releasing fluoride from the minerals like fluorapatite since hydroxide and fluoride have same charge and nearly equal ionic radii.

Fluoride removal experiments were attempted using various brands of charcoal, alum, various types of alumina and medicinal plant materials. The experiments indicated that aluminium sulphate is the best material available in the market in terms of removal efficiency, quantity of material to be used and cost. The materials can be used as a coagulant for which technology is robust and implemented locally.

The removal efficiency of different medicinal plant materials from a solution contaminated with 5 mg/l fluoride is: clove (Eugenia carryophyllata) (82%), pomegranate (Punica granatum) (73.3 %), nutmeg (Myristica fragrans ) (68 %), gooseberry (Phyllanthus emblica) (64 %) dried ginger (Zingiber officinale) (66.2%)
sathavari (*Asparagus racemosus*) (44%) kozhinjil (*Tephrosia purpurea*) (42%) karinochi (*Vitex negundo*) (34%) ramacham (*Vetiveria zizanioides*) (26%). Different types of domestic filters were fabricated using tested materials and their details and efficiency are also reported in the paper.

**Key words:** Groundwater, Fluoride, fluorosis, Alapuzzha, Kerala, removal efficiency, medicinal plants.
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**Key words:** Groundwater, Fluoride, fluorosis, Alapuzzha, Kerala, removal efficiency, medicinal plants.
155. Sustainable Arsenic Mitigation: A case of Community Initiative in Bangladesh

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Abstract
In the last decade, Bangladesh has achieved immense coverage in ensuring safe drinking water for its rural areas than any of the South East Asian countries. 98% people had access to safe drinking water source but due to arsenic contamination in ground water layer the achieved coverage has become threatened and created tremendous health hazards in rural areas of the country. Meanwhile, the Government of Bangladesh has developed arsenic mitigation strategy involving other national and international agencies working on arsenic issue. Most of the organizations including the government has taken special initiatives to address the arsenic issue through undertaking different types of projects and activities such as, people’s awareness, capacity building and installation of alternative water technologies in the arsenic affective areas. This discussion paper explores community participation and selection process of alternative water technology, which is an essential factor for ensuring sustainable arsenic mitigation. Being a national level service delivery networking organization in water supply and sanitation, NGO Forum has been implementing an action research project on Integrated Arsenic Mitigation project in Jinaida district of the southern part of the country. This paper analyzes the important lessons in connection to community participation during
installation of new water technologies and their sustainability. It is concluded that community involvement linked with local institutions and changing communities perception in regard to water point installation are the essential factors for sustainable arsenic mitigation. Finally, this paper emphasizes the urgent need to integrate capacity building of community groups and institutions and changing peoples mind set to shift new safe, appropriate and affordable technologies in the arsenic contaminated areas.

**Key words:** Bangladesh, safe drinking water, Arsenic mitigation strategy, Community perception, sustainability
156. Sustainable Arsenic Mitigation: A case of Community Initiative in Bangladesh

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Abstract
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**Key words:** Bangladesh, safe drinking water, Arsenic mitigation strategy, Community perception, sustainability
Adsorptive Removal of Arsenate and Arsenite Anions from Groundwater Using Iron(III) Adsorption Sites Immobilized by Cation-exchange Resin

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Abstract
Arsenic is a toxic element that can be found in natural waters as well as in various industrial wastes, solid or liquid. Leaching of arsenic into the groundwater may cause significant contamination. Investigations and the development of new techniques are required, as well as improvements to known ones, for purification of arsenic rich drinking water sources. The aim of the present study was to develop a suitable method for preparing a hydrated iron(III)-oxide loaded cation-exchange resin in a granulated form (HFOLR) and to examine its usability to remove arsenite [As(III)] and arsenate [As(V)] anions present in water by batch technique. Iron(III) was loaded onto the sulfonic acid sites of Duolite C26, a commercial cation-exchanger, and was then converted into hydrated ferric oxides (HFO) disbursed throughout the macropores of the ion exchanger beads. A combination of macroscopic and microscopic techniques like FTIR, SEM, XRD, TG/DTG and EDAX was utilized to describe the sorbent properties as well as adsorption mechanism of arsenate and arsenite ions. X-ray diffraction analysis confirmed that the HFO in the prepared adsorbent was amorphous. The surface area and the pore size distribution were determined as well. Maximum removal of arsenite and arsenate anions onto (>99.0 %) HFOLR occurred at a solution pH range 7.0 – 8.0 and 3.0 – 4.0 respectively. This observation is well correlated to the surface properties of the adsorbent and to the existence of the different species of As(III) and As(V) at different pH values. Dependence of adsorption on ionic strength and FTIR studies enabled to explain the mechanism of adsorption on the basis of surface complexation models. FTIR spectra of the adsorbent, before and after adsorption, demonstrated that M–OH groups play an important role for arsenic removal in the adsorption mechanism. Intraparticle diffusion model was used to understand the sorption kinetics of As(III) and As(V) ions onto HFOLR. Results indicate that equilibrium was established in about 8 h. Kinetic profiles showed three distinctive parts, consisting of an initial curved portion corresponding to the external surface adsorption, a second linear portion corresponding to the slow rate-controlling intraparticle diffusion process, and a third portion corresponding to the final equilibrium. The intraparticle diffusion rate constant, $k_p$, was found to be increasing for As(III) as well as As(V) when the initial concentration was increased from 10 to 100 mg/L.

To establish the most appropriate correlation for the equilibrium curves, isotherm studies were performed for both As(III) and As(V) ions using four different isotherm equations namely, Langmuir, Freundlich, Temkin, and Dubinin-Radushkevich. The pattern of adsorption of As(V) by the adsorbent fitted well with Freundlich model. The
maximal adsorption capacities of As(V) and As(III) were 36.24 and 25.79 mg g\(^{-1}\) at 30\(^0\)C, comparable to that of other adsorbents reported in the literature. The groundwater samples were treated by HFOLR to demonstrate its efficiency in removing As(III) and As(V) ions from aqueous solutions. More than 97.0\% of the arsenic adsorbed to the HFOLR was desorbed by 0.1 M NaOH in less than 3 h suggested the recyclability of the adsorbent. The present system is appropriate and advantageous to small communities, especially in developing countries because of the high arsenic removal efficiency, simplicity, and easiness of construction, operation and maintenance and promises to be a competitive choice amongst the treatment systems available for arsenic removal.

**Key words:** Adsorptive Removal, arsenate, arsenite, groundwater, Iron(III) adsorption sites, cation-exchange resin
Abstract
Arsenic in shallow wells is a well documented risk to the population in the large deltas in Bangladesh and India (West Bengal). Large resources are spent on providing clean drinking water to affected regions. Despite this, large segments of the affected population are not benefited due to the high costs of mitigation e.g. drilling for uncontaminated ground water 100-300m down. This may help initially on drinking water habits but may not affect the cooking water habits. However, in the longer perspective people may start using their own shallow well both for drinking and cooking due to difficulties in fetching the borehole water if the distance is too far.

Arsenic concentrations in shallow wells are often alarmingly higher than the WHO's guideline value of 10 µg/l with 6*10⁻⁴ as estimated life time risk of getting skin cancer with 2 l/d drinking water. Even higher risk is expected in Bangladesh and India, because of a higher intake of drinking water and a lower average body weight. Despite this, affected families are not always having signs of expected arsenicosis probably due to beneficial behaviour leading to reduced intakes.

Our research has shown that high natural iron concentrations reduce the arsenic concentrations in the drinking water to much lower levels if left to precipitate before consumption. This happens often inadvertently due to bad taste of iron which is often present in proportion to the arsenic content. Based on the results simple precautionary measures as aerating the raw water and leaving it to precipitate will reduce the risk of arsenicosis. If iron is absent or low, cheap mitigation could still be attained adding ferrous iron to the raw water before aeration.

Thus, as an alternative to waiting for unaffordable mitigation measures, reaching too few, building public awareness towards exploiting the presence of natural or added iron would help many more against getting arsenicosis. This may be combined with advocating use of arsenic free surface water in cooking.
Role of Social Factors as Determinants and in Distribution of Chronic Arsenicosis in India

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Abstract
Arsenic contamination of ground water has emerged as a major public health problem in India. Thousands of people are suffering from arsenic related skin and other manifestations. Most of the existing studies linked health impacts with arsenic level in groundwater. However, studies dealing with the social factors of arsenic problems are very few in number. The present study explores the role of social factors as determinants and in distribution of arsenic exposure and clinical manifestations.

The whole populations living in five arsenic affected villages were screened, based on the presence of pigmentation (melanosis and leucomelanosis) of skin, the earliest diagnosable clinical manifestation. The social epidemiological approach was adopted to examine the social determinants influencing the extent and distribution of chronic arsenicosis. Socio-economic status (SES) was constructed on the basis of participatory assessment in the local context. All water sources were identified and tested by using field test kits. Measurement of average arsenic exposure (milligram of arsenic per litre of water per day) was done by testing arsenic levels both from domestic sources and the workplace of every individual and calculating the average daily intake of water from each source in the past year. The nutritional status of individuals was assessed by measuring Body Mass Index (BMI).

After screening, 410 people were found with dermatological and other manifestations and they were taken as cases for the study. Association between arsenic exposure level and severity of manifestation was found significant (p<0.05). Manifestations were more severe, and mortality and prevalence rates were higher among people belonging to lower SES (p<0.005 to 0.05). Lower age group was mostly found among poorer section of the community (95%CI, 17.8–25.7 & 36.3-48.9 years, lowermost and uppermost SES respectively). Households from higher SES could afford to shift to alternative arsenic free water source and many of them experienced an improvement in symptoms. Landless agricultural labourers were exposed to higher levels of arsenic. Severe form of manifestations was found to be associated with low BMI (p<0.05). Low BMI was associated with lower SES (p<0.005), which was in turn associated with quality and quantity of food intake. Males had higher - exposure levels, prevalence rate, mortality rate, and severity. Younger age group was mostly found among males (95%CI, 33.5-37.8 & 37.1-39.4 years, males & females respectively) and also duration of manifestation longer (95%CI, 4.1-6.8 & 2.8-4.3 years, males & females respectively). Marriage was found to be another important determinant of the gender differential in arsenicosis. Higher SES had easier accessibility to treatment facilities. There was a gender disparity regarding treatment seeking.
The study of chronic arsenic poisoning unfolded a number of issues which have either not been highlighted before or never been articulated at macro level. The study shows that apart from level of arsenic exposure - socio-economic status, occupation, gender relation, nutritional status are the major determining factors in distribution of chronic arsenicosis and the severity of manifestations. The research revealed multidimensional perspectives, apart from mainstream epidemiological issues.
159. Arsenic-safe water for local communities in West Bengal, India: A technological issue or a management challenge?

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Abstract
In recent years, the arsenic menace has come to threaten the lives of several millions in a number of states in India. Of these, the earliest to be reported and perhaps the worst to be affected are the populace living in the state of West Bengal. Until the middle of the 90s, the concern was with developing appropriate ‘hardware’ that can supply arsenic-safe water to the affected communities. By the second half of the 90s, a number of technological options were developed, promising to supply water containing arsenic well below the permissible limit set by the WHO. These various technologies can be conveniently clubbed under the rubric ‘arsenic removal plants’ (ARPs). Other alternatives lately promoted as safe water sources include deep tubewells, treated surface water supply through pipelines and rainwater harvesting. While each of these alternatives has its own strengths and weaknesses within the technological framework, this paper argues that a common challenge facing them and the users is their management. While the government had commissioned evaluative studies of the ARP technologies quite early, an understanding of the management issues underlying their sustainability and adoption is yet to be developed.

Based on detailed first hand observations made in a sample of 45 villages in the state, this paper outlines the major ‘software’ issues confronting the adoption, access, maintenance and sustainability of the different technology options introduced in the local communities of West Bengal for supplying arsenic-safe water. It argues that neglect of...
the software dimension of the problem has resulted in inadequate attention to interventions that should have otherwise constituted critical components in the arsenic mitigation programmes designed and executed by different agencies in the state – namely, government, non-governmental organizations and international development agencies. The core of the software dimension is identified as lying in the notion of real and effective ‘community participation’.

**Key words:** Arsenic-safe water, local communities, mitigation programmes, software dimension, community participation, West Bengal.
Mitigation of arsenic contamination in groundwater-West Bengal

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Abstract
The problem of arsenic contamination in the ground water of West Bengal and Bangladesh has wide aerial extent and around 90-100 million people are at risk due to higher intake of arsenic through drinking water and food. A lot of attention has given to stop migration of arsenic to human body through drinking water. The Government, NGO’s and different International bodies put enormous efforts to check this (migration of arsenic from groundwater to human) by placing arsenic removal plants throughout the area. This has off course solved the issue (problem) to some extent. However, considering the socio-economic status of the rural population of West Bengal, this may not be a viable long term solution. Since arsenic has entered the food chain in West Bengal, even taking filtered water may not control arsenic related diseases in rural population.

The crops especially the rice crop, cultivated throughout the year, is the integral part of the food habits of the people in the area. The rice crop needs huge amount of water and most of the water due to evapo-transpiration processes goes in to the atmosphere which leads to further increase in the concentration of arsenic in remaining water. When the plant uses this water in photosynthetic reaction, the arsenic gets incorporated into the food chain, poising problem not only to human but also the other components of ecological system. 13 plant samples (rice) were analyzed for arsenic concentration in different parts of plant body. The arsenic concentration is found to be ranging between 190-215 mg/kg in the root, 9-13 mg/kg in stem and leaf, 3-5 mg/kg in husk while in grain it varies from .45-70 mg/kg. In author’s opinion the best way to eliminate arsenic from the food chain is to change the crop pattern and the government should encourage local people to grow Jute and export it in exchange of rice. In this way not only arsenic will be eliminated from the food chain but also from the sediments of the affected area.
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Abstract
Environmental contamination by arsenic is a serious threat to human health in many parts of the world since arsenic can enter the human food chain. Arsenic is the second most common inorganic constituent after lead on the US EPA national priority list. Long-term use of arsenic contaminated groundwater to irrigate crops, especially paddy rice (*Oryza sativa* L.) has resulted in elevated soil arsenic levels in Bangladesh and in some parts of India. There is, therefore, concern regarding accumulation of arsenic in rice grown on these soils. Arsenate containing irrigation water reduced plant height, decreased rice yield and affected development of root growth. Phosphate application neither showed any significant difference in plant growth and development, nor in arsenic concentrations in plant parts. In paddy fields arsenite has also been found as the predominant arsenic species (36–63%). The arsenic accumulation in the straw of up to about 200 mg kg⁻¹ was reported. Cattle fed with highly arsenic contaminated straw could be a direct threat to their health and also, indirectly, to human health via ingesting arsenic contaminated meat and drinking milk with elevated arsenic concentrations. Plants may detoxify arsenic unless the concentration of arsenic is high enough to inhibit the detoxification mechanisms such as (i) complexation of arsenite and arsenate (production of thiol rich peptides phytochelatins [PCs] (ii) reduction of arsenic influx by suppressing phosphate/arsenate uptake systems and (iii) enhanced production of antioxidants that detoxify free reactive oxygen species (ROS) produced in response to arsenite and arsenate.

Arsenic accumulation by plants, toxicity and tolerance, As-phytochelatin complexes, Arsenate and phosphate influence on plants, rhizospheric processes - root exudates and arsenic accumulation in plants and emerging phytotechnologies related to arsenic management are covered in this
Abstract
We conducted a human trial on the efficacy of a potentized homeopathic drug, Arsenicum Album, in amelioration of arsenic (“As”) toxicity and characteristic symptoms of arsenicosis, both mild and acute, in random populations of two high risk arsenic villages in West Bengal. Both “controlled” and “uncontrolled” experiments were performed for certain valid reasons. In the short-term controlled group, the “As” contents of blood and urine and various toxicity biomarkers like acid and alkaline phosphatases, alanine amino transferase, aspartate amino transferase, lipid peroxidation and reduced glutathione, and hematological parameters like total count of RBC and WBC, hemoglobin content, erythrocyte sedimentation rate, blood sugar level, ANA test etc. were examined before and periodically after administration of the homeopathic remedy (“verum” fed group) and the data were compared with the “placebo fed” group (positive control) and another group of people (negative control) from a village not contaminated with groundwater arsenic. In the uncontrolled group, the subjects were fed only “verum” and long-term effects were studied. Initial results are highly encouraging and further research by other groups in this direction is recommended.
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Abstract
The major Tsunami of Dec. 26, 2004 that hit many South Asian countries bordering the Bay of Bengal severely devastated the coastal regions of Sri Lanka. A key concern is the nature and extent of the Tsunami impact on the water supply and, in more general, the water resources of these areas. In the coastal areas of Eastern Sri Lanka, the majority of the population, which is rural or semi-urban, is relying on groundwater for their domestic and agricultural activities, most predominantly through traditional private shallow open dug wells in the sandy aquifers. As the Tsunami destroyed practically all wells within the reach of the flood waves, access to freshwater for these people was suddenly cut off and interim alternatives had to be sought urgently in the form of freshwater trucked in from unaffected areas. With the aim to assess and document the extent of the damages and the long term impacts of the Tsunami on groundwater and associated water supply, a field monitoring program was initiated in March 2005 (2.5 month after the Tsunami) in three areas of the east coast. A total of approximately 150 wells were selected within 1.5 km distance from the coastline covering both affected and non-affected wells. Salinity, groundwater level, turbidity, and occurrence of mosquito larvae were monitored on a regular basis, with from 20 to 40 days interval. In addition, salinity levels in sea and lagoon water were measured.
Results indicate that 38% of the wells had been flooded by the Tsunami, with the flooding being more severe in the two most northern sites (48% in Kallady and 47% in Kaluthavalai), as compared to the last site (21% in Oluvil). This pattern could be explained by the way the waves had come in and had been received by the land complex. Salinity levels in wells decreased significantly from the estimated levels at the time of the Tsunami till the start of the monitoring. At this latter point, only 55% of the flooded wells had salinity levels above an acceptable level for drinking (here defined as 2000 µS/cm), as opposed to 100% initially. This can be explained by the rainfall that occurred shortly after the Tsunami and the rapid dissipation and mixing of intruding seawater with pre-Tsunami fresh groundwater. As time passed, average salinity levels in flooded wells decreased more slowly, until middle of July, when 43% of flooded wells were not suitable for drinking. The slower decrease can be attributed to the onset of the dry season and the slower mixing and dissipation mechanisms as concentration gradients decreased. Non-flooded wells showed an opposite trend with salinity levels slightly increasing during the dry season, a generally encountered phenomenon. One half year after the Tsunami, flooded wells had higher mean salinity levels than background, non-flooded wells, indicating that the groundwater still had not recovered fully from the Tsunami.

Key words: Tsunami, shallow groundwater, salinity impacts, water supply, East Coast, Sri Lanka
Abstract
The impact of earthquake and tsunami on people, livelihoods and landscape has led to a need for rehabilitation. In Nanggroe Aceh Darussalam (NAD) province, Indonesia, agricultural land has degraded through three major processes including (a) salinization of soil and water, (b) de-surfacing of landscape due to deposition of sand to clay sediments and destroying the dike of paddy fields, and (c) destroying irrigation/drainage infrastructures and roads.

The Ministry of Agriculture of Indonesia has collaborated with FAO to assess the magnitude of the damage and come up with the four classes of damage including (a) class A (low damage area), (b) class B (medium damage area), (c) class C (high damage area) and (d) class D (lost area). Several types of damages have recognized including (a) direct crop destruction by wave, salt poisoning, uprooting etc., (b) de-surfacing of the landscape due to erosion and sedimentation, (c) deposition of salted sediment, (d) trash and debris accumulation, (e) salt infiltration and groundwater salinization, (f) fertility depletion when the top soil is eroded, (g) biological destruction and (h) infrastructure damages. The estimated affected agricultural areas of NAD was about 61,816 ha including wetland and dry land. The affected areas of west coast were about 45,755 ha and of east coast were about 16,061 ha. About 50% of affected areas of east coast belong to low damage and other 50% was medium damage. Out of the total 45,755 ha damaged 10% with low damage (4,575.5 ha), 20% with medium damage (9,151 ha), 60% with severely damage (27,453 ha) and 10% was lost (5,575.5 ha). In the class C areas, salinity of surface water in the paddy rice area may reach a value of >100 mS/cm, while in the class A areas, the lowest value may reach of about 0.3 mS/cm. Salinity of the sediment which has been deposited in the paddy field was as high as 7-12 mS/cm.

There is an urgent need to rehabilitate the agricultural land with aim to improve it productivity and to facilitate farmers in (re)using their land. Land rehabilitation is significance to recover damages through salt leaching, tillage and civil works. Since salt and salted sediment are the major problems, rehabilitation is based on the principle of salt leaching and tillage by puddling. The level of salinity in agricultural land can be depleted by a proper rehabilitation strategy through the leaching. Rehabilitation provides a direct benefit for farmers through cash for work. The strategies of land rehabilitation are described according to the class of damages as follow (FAO,2005):

**Class A:** Recovery of this area is obtained without major intervention. The salinity level is normally in the level of tolerable to crops. Net water balance between January and April, will be enough to flush out the salt from the field. The irrigated rice area is
generally belongs to this class. The availability of surface water to flush out the salt is the key factor. Restart cropping can be done in March and April 2005.

**Class B:** Recovery will take some more time and more specific interventions, at least one full cropping season and/or a full monsoon season will be required to recover. Net water balance between January and June is required for flushing out the salt. Restart cropping can be done in June 2005. FAO proposed several strategies for this class including salt tolerant varieties of usual crops to allow cropping in not fully cleaned soils, delayed start of the season with varieties having shorter period of growth, temporary changes in the production system to compensate for the expected losses of food production and incomes in the coming seasons.

**Class C:** Major works of rehabilitation are required either within the field or in the nearby infrastructures. For the major part of these fields return to cultivation cannot be reached immediately and solutions must be found to allow farmers to temporary cultivate in other un/less affected lands; and to diversify land and natural resources management in order to provide them with alternative means of production and food security.

**Class D:** FAO described these areas where massive erosion or land subsiding has occurred and these fields are no longer part of the land domain but of the sea domain and must be considered that has been lost permanently for agriculture. There is no remediation except that compensation of land owners and relocation of activity elsewhere. The rehabilitation plan is summarized in the following Table.

<table>
<thead>
<tr>
<th>Situation</th>
<th>Crops/Farming</th>
<th>Agronomic support required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class A “Low damaged area”</td>
<td>Return to normal expected for the next season starting in April 2005</td>
<td>Usual crops</td>
</tr>
<tr>
<td></td>
<td>Monitoring salinity</td>
<td>Seeds and inputs supply, equipment supply if needed</td>
</tr>
<tr>
<td>Class B “Medium damaged area”</td>
<td>Delayed return to normal to allow enough time for specific interventions</td>
<td>Cultivation of salt tolerant rice varieties recommended.</td>
</tr>
<tr>
<td></td>
<td>Support for seeds and inputs</td>
<td>Compensation for reduced yields</td>
</tr>
<tr>
<td>Class C “Highly damaged area”</td>
<td>No return to normal this year. Major rehabilitation works needed Possible reorientation of land uses</td>
<td>Major temporary or permanent diversification of farming system</td>
</tr>
<tr>
<td></td>
<td>Compensation for land abandon</td>
<td>Support for diversification</td>
</tr>
<tr>
<td>Class D “Permanently lost land”</td>
<td>No longer part of the land domain but of the sea domain.</td>
<td>Relocation of farmers/owners elsewhere</td>
</tr>
<tr>
<td></td>
<td>Support for relocation and diversification</td>
<td></td>
</tr>
</tbody>
</table>

Source: FAO (2005)

**Key words:** Rehabilitation Strategies, Tsunami, Agricultural areas, Nangroe Aceh Darussalam, Indonesia, FAO.
Abstract

In the east coast of Sri Lanka, Kirankulam is a dry zone coastal village which extends as a narrow strip of land about three km in width and running approximately in NS direction between the sea in the East and a lagoon in the West. The area is underlain by a sequence of unconsolidated dune and beach sands followed by occasional marine clay and coral formations. The crystalline bed rock is present at a depth of between 25 and 30m below the ground level. The unconsolidated sedimentary sequence forms a highly productive unconfined aquifer with transmissivity of around 2500m²/day, where static water level is found at a depth of about 2.5m. Highly permeable sands in the topmost horizons facilitate direct infiltration during monsoon rains allowing good recharge and good quality groundwater with Electrical conductivities around 200 µS/cm.

On the December 26th 2004, tsunami water flooded into the village to a distance of about two km inland, destroying most of the properties and a large number of traditional dug wells. Direct infiltration of flooded sea water caused wells and most parts of the aquifer unsuitable for drinking or other domestic purposes.

A hydrogeological and geophysical survey carried out 10 months later, shows a gradual lateral and downward movement of saline water plume towards the sea and the lagoon. In addition, the slow vertical sinking of the highest saline zone of the plume has reached a depth of about 20m at present. The water quality of the uppermost horizons of the aquifer is recovering slowly and comparatively low salinity water is becoming more dominant in the upper part of the saturated zone. Spatial distribution of Electrical conductivity of the dug well water too, indicates the lateral retrieval of saline water front towards the sea. It is expected that infiltration of precipitation of the oncoming monsoon rains will further improve the quality of water through flushing and dilution in the uppermost horizons of the aquifer.

Key words: Tsunami, coastal aquifers, groundwater, resistivity imaging, salinity.
Abstract
On 26 Dec. 2004, Tsunami was triggered due to the earthquake that rocked Sumatra Island. This Tsunami has affected Indonesia, Sri Lanka, and the entire southeastern coast of India. East coast of Tamilnadu had experienced severe environmental devastation such as erosion and deposition of sediments, disturbances in the environment of microbes and water quality deterioration both in surface and groundwater resources. This study is aimed to evaluate both surface and groundwater quality changes due to Tsunami. The study area is bounded by the river Coleron in north, southern boundary of Karaikal (Union Territory of Pondicherry) in south, Bay of Bengal in east and 5 km stretch perpendicular distance from the coast in west. Water sample collection and conduction of Vertical Electrical Sounding (VES) have been carried out from the pre determined 24 locations that are equally distributed in the study area. These water samples were analysed for major cations and anions and processed with a computer programme. This computer programme classifies the water with reference to several standard water quality classifications. With the output of this computer programme, various ground water quality maps have been prepared in GIS environment. These output maps indicate the changes in the water quality along the coast due to Tsunami. The VES field data have been processed both manually and digitally. With the geophysical output, resistivity maps for different layers and isoapparent resistivity maps for different depths have been
prepared. Hydrogeochemical output matches with the findings of the geophysical investigation.
Abstract
A large number of more or less empirical methods have been developed over the last 50 years by numerous scientists and specialists worldwide to evaluate the coastal groundwater resources from different climatic variables. Relationships were often subject to rigorous local calibrations. Testing the accuracy of these methods under global scale is laborious, time-consuming and costly because of the necessity of calibration for many variable data. To overcome these restrictions and to achieve an improved assessment of future coastal groundwater simulations, the global evaluations of fresh groundwater resources should be carried out using methodologies which need only few climate data. To accommodate users with the limited available climate data, a method has been presented in this study. It helps to calculate the groundwater recharge based on precipitation and temperature as measured climate data. Also the proposed methodology will be useful in ungauge basins and in areas where limited hydrological data is available.

In order to introduce the consequences of land use change on hydrology and coastal groundwater resources a numerical model has been developed based on the sharp interface assumption to evaluate the saltwater intrusion in coastal aquifer systems. This model helps to study the coastal aquifers for proper understanding of the functioning of the hydro geological behavior of the aquifer systems regionally as well as globally. To further investigate the factors affecting groundwater recharge, a water balance technique has been employed in order to establish the groundwater recharge as a function of annual precipitation, mean annual temperature, land use pattern and hydrologic soil condition.

The aridity index has been introduced to represent the variations in precipitation and temperature. Results show that when the aridity index is less than 22, groundwater recharge will be zero in all land use patterns. Combined climate and land use scenarios show that when aridity index is less than 60, the agricultural lands give higher groundwater recharge than other land use patterns. It concludes that with respect to groundwater recharge, agricultural lands are the best land use pattern in arid and semi arid areas. Calculated recharge was then used to estimate the freshwater-saltwater interface and percentage of freshwater loss due to salinity intrusion. We found that in arid areas, fresh groundwater loss increases as the percentage of forest cover increases. Combined effects of deforestation and aridity index show that, deforestation causes to
increase the recharge and to increase the existing fresh groundwater resource in areas having less precipitation and high temperature (arid climates).

The outcome of this research would assist the planners and decision makers to come up with control measures for ongoing land use practices and groundwater development activities ensuring its long-term sustainability in coastal groundwater systems.
A Study on Coastal Ground Water from Parangipettai to Pumpuhar-Tamilnadu, India

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Abstract
The ground water in the coastal aquifer system is a complex hydro geochemical environment. The problem of sea water intrusion, saline connate water, recharge from brackish waters, like back waters, estuarine waters, aquaculture activities, urban sewage etc., adds more complexity to the problem. The study area falls from Parangipettai to Pumpuhar area lies in between 79°46'E to 79°51'E longitudes and 11°07' N to 11°30' N latitudes. The Vellar and Coleroon are the major rivers flowing in the study area they form a an Estuary with marshy mangrove environment at Pichavaram. The Cuddalore sandstone formations are exposed in major part of the district and are characterized by laterite cover at exposures. The sandstones are variegated in color (whitish, reddish or mottled) and are friable. The Quaternary formations in the district consist of sediments of fluvial fluvio-marine and marine facies. It includes various types of soils, fine to coarse grained sands, silts, clays, latrite and lateritic gravels. The fluvial sediments occupy the flood plains, the Vellar and the Coleroon rivers. It consists mainly of sands, sandy loams or clayey loams. Irregular mounds of 10 to 15 m height are the prominent feature due to wind action near Porto Novo. 11 parameters are analyzed for all these samples, namely EC, pH, TDS, Na, K, Ca, Mg, HCO₃, Cl, SO₄, and H₄SiO₄ for the hydro geochemical interpretations. Totally 46 samples were collected, 32 samples representing shallow groundwater, 7 from surface and 7 samples from vadose zone.

The sodium concentration of majority of the bore well samples fall from permissible to doubtful class and most of the surface samples fall from unsuitable to good class and most of the vadose zone samples fall in unsuitable class of sodium percentage classification of Wilcox.1955. The major representations of SAR shows that the groundwater samples fall from excellent to good category and the surface water samples fall from excellent to poor category and the vadose water samples fall in the poor category of Richards classification. In the EC (Wilcox, 1955) classification, most of the samples fall in unsuitable category .In the Sawyer and McCarty Hardness classification, most of the samples fall in very hard category and requires softening before use. The Stuyfzand classification indicates water quality from fresh to fresh brackish in the bore water samples and brackish-salt to salt in the surface water samples and salt to brackish salt in the vadose water samples. The major water facies is represented by chloride-sodium facies, chloride-sulfate –bicarbonate facies in the groundwater samples and calcium-sodium facies, chloride facies in the surface water samples and calcium-sodium facies, chloride facies in the vadose water samples.

Key words: ground water, coastal aquifer, Tamilnadu, Quarternary sediments, hydrogeochemistry.
Interrelation between Saline and Fresh Water in Costal Region of North Western Region - Sri Lanka

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Abstract
Focus of the study area is on the Puttalam lagoon bank, which situated in the northwestern region of Republic of Sri Lanka. The main and basic water supply of Puttalam area is ground water exploring through Quaternary and Miocene aquifers. The centerline batch water intake in study region is not available therefore groundwater is to explore through tube wells and dug wells. Three types of favorable saline intrusion aquifer systems identified in the study area and its distribution in the areas of river delta, lagoon belt and shore line.

The interrelation of saline and freshwater in northwestern region of Sri Lanka is being studied and preliminary results demonstrate, seawater intrusion take place in the wells adjacent area close to Lagoon and region river delta. Analyzing the forming of seawater intrusion to water intakes with the pumping and off pumping, considering different densities of salt water, on the basis of analytical solutions. By the analytical method determine the length of "lens" salt water in different values of saline and fresh water density. For the theoretical solutions, values of the natural flow gradient are obtained by results of simulation. The calculations Indicate, for the definite ground water gradients being polluted due to sea water intrusion. Therefore, the ground water computer model does not contradict all collection of the available correct hydro-geological information’s. The analytical solutions can be used for forecasting the seawater Intrusion in the coastal aquifer areas if correct hydro-geological information being available.
Abstract
Saltwater intrusion is one of causes that threatens quality of groundwater in coastal aquifers. In this study, eastern part of Mazandaran Province in north of Iran, in southern shorelines of the Caspian Sea is the area of interest. Uncontrolled exploitation of groundwater decreases quality of groundwater drastically in recent years due to the salt water intrusion. To estimate the effect of groundwater exploitation on this phenomenon in this area and to aid the operation management system, salt water intrusion is modeled by SHARP model. On this purpose all field data were presented in GIS format. These data include topography, groundwater table, aquifer layer, precipitation, surface water, sea level, water discharge, geotechnical information, etc. For lack of data on some fields, SHARP model was chosen which needs less data and it assumes a non-dispersive interface between salt and fresh water.

According to the hydrological system, area of interest was divided into 5 parts and existing rivers were determined as lateral boundaries. In addition upper boundary was determined based on different conditions with different spans to select an optimum boundary with the least potential of calculation capacity.

The field measurements showed that selection of non flow boundary for lateral boundaries can not be harmful for model integrity. After compiling the model different scenarios were considered that can include future view. In addition to the case-study dependent results of this study that can be very helpful for groundwater operation management, an innovative approach for estimation of discharge rate was considered. As a result of sensitivity analysis, sensitive parameters were determined that should be emphasized in modeling procedure.
Abstract
Bangladesh is a part of one of the largest deltaic plain of three mighty rivers, namely the Ganges, the Brahmaputra and the Meghna (GBM). These rivers carry huge amount of water from upper riparian countries to the Bay of Bengal in the south and subjected to dynamic actions due to natural conditions in the Bay of Bengal. Bangladesh is the 8th most populous country in the world. Population is about 130 million (2001 census) in a land area of 147,540 km2 with density of 876 person/km2. Agriculture is the mainstay of livelihood system in Bangladesh and is essentially linked with the water cycle and arable land. About 50% land of Bangladesh is hardly 3 m above the mean sea level and 30% land is under tidal bore. The central region is the most active one and continuous process of accretion and erosion is going on there. The eastern region is covered by hilly areas and it is more stable and has a long beach there. The approximate population in the coastal area is 40 million and they are very much vulnerable to the natural disaster along the about 720 km coastline. Saline water intrusion is the main problem in the southwestern zone. Saline water intrusion is temporal phenomenon in Bangladesh and minimum during the monsoon (June-October) by push back of the rivers discharge at the salinity front in estuarine and floodplains. Saline water intrusion increases in inland coast from the month of November due to the reduction of fresh water flows and intrude up to
150 km inland in the lower Meghna in the South East and up to 290 km up the Passur River in the south-west of the country. Maximum salinity levels occur during March-April.

In the south-western coast of Bay of Bengal, 60 percent of arable land of Khulna and Patuakhali districts are affected by salinity in the dry period. About 15 percent of the arable land of Noakhali and Chittagong districts of the south-eastern region are saline during the same period. Total 1.0 mha croplands are affected by salinity in the winter months. This salinity is caused by cyclone and storm surges, high spring tide inundation and capillary actions. Its affect the soil surface and root zones, which decreases the crop production about 0.13 M.T. each year. The increase of salinity intrusion and decrease of arability will be prevailing due to climate change effect and reducing of flood plain. Some investigations indicate that one third of the country will be inundated by greenhouse effect, which may propagate the saline water intrusion all over the country and the total trans-boundary sources of potable water in ground water aquifer will be affected. The accurate assessment can be needed to encounter these future problems of the habitat.
Environmental Isotope Investigation on the Recharge Processes to the Coastal Sedimentary (Cretaceous) Aquifers of Tiruvadanai in the State of Tamilnadu

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Abstract
Environmental isotopes (2H, 18O, 3H, 13C & 14C) are used in conjunction with hydrogeology, hydro-chemistry and in-situ physio-chemical parameters (EC, Temp., etc) to understand the recharge processes of the coastal sedimentary aquifers of Tiruvadanai in the state of Tamilnadu located in South India.

From the investigation, it was observed that the modern day natural recharge to the aquifer is a slow process with a given year’s rainfall reaching water table after several years and recharge through artificial means appears to be very low and also slow. Thus the significant rise in water levels of the tube wells located near the recharge area or an increase in yield of the artesian flowing wells located at the discharge area seen during each rainy season is the result of pushing down of many previous year’s soil moisture by the current year’s soil moisture. From the isotopes analyses of various water samples from the aquifer area, differences in the aquifer recharge processes occurring at the recharge areas lying near-to and far-way from the two (bounded) ephemeral rivers could be fairly understood. Suitable river for planning large-scale artificial recharge structures could be north bounded ephemeral river (Manimutharu) rather than the south bounded ephemeral river (Sarugani). The waters in the confined zone of the potential and fresh water bearing aquifer appear to have recharged during a different period and climate, mostly in an arid phase. The distribution of various hydro-chemical species along the general groundwater flow direction of the aquifer showed a decreasing trend in some of the species along the general groundwater flow direction.

Key words: Environmental isotopes, hydrogeology, hydrochemistry, groundwater recharge processes, Cretaceous aquifer
Abstract
Discharge of groundwater to the sea along the coastal zone normally takes place as overflow through the unconfined aquifer apart from the natural mechanism of freshwater release from land to sea as base flow with the streams. Further, deeper or confined aquifers forcefully conduct groundwater to the offshore segments, depending on the hydraulic gradient available, which is common in Karst terrain. Open and interconnected joints/fractures also induce submarine discharges at favourable sites. There cases of appreciable freshwater leakages to the sea through the thick sandy layers of sedimentary origin, due to the presence of intervening impervious clay layers. All these groundwater movements fall within the category of Submarine Groundwater Discharge (SGD). The phenomenon of Submarine Groundwater Discharge, however, received less attention as a potential medium of groundwater release and also for nutrient/contaminant transport in the Indian context.

This paper reports two zones of SGD from the SW coastal zone of India falling between two prominent coastal promontories, which include a coastal length of about 5km in the Thiruvananthapuram district of Kerala state (Pulluvila region) and about 4km in the Kanyakumari district of Tamil Nadu state (Manavalakurichi region). The purpose of understanding and characterizing such zones is (a) to determine optimum exploitation
levels of coastal groundwater; (b) to locate feasible waste disposal sites in the coastal zone areas; (c) to estimate pollution transport levels. IRS-IC digital data (Middle IR), temporal microlevel field observations, physico-chemical water quality indicators from forty observations wells and resistivity data from twelve shore-parallel and shore-perpendicular profiles have been depended to understand the nature of groundwater movement in the study area. Geologically the coastal area under consideration comprises of Tertiary sedimentary layers unconformably overlying the Precambrian basement. It is postulated that the configuration of surface topography of crystalline basement coupled with the intense neotectonic disturbances took place in the area have resulted the development of potential subsurface groundwater discharge zones. The Pulluvila region represents an accreting shore, where more than 100m of sand accretion has been noticed during the last two decades. On the other hand, the Manavalakurichi segment has been subjected to intense mining of mineral sands for more than three decades, which ultimately resulted into a non-eroding and non-accreting area. These observations indicate that there is probable seaward extension of aquifer layers, which are also getting reworked and offers better beach stability. Modelling of coastal aquifers offer good scope for estimating the water budget and the quantity of SGD.
Abstract
In constructing water budget and mass flux estimations for coastal margins, submarine ground water discharge is often overlooked. The ground water discharge influences oceanic chemistry through discharges of nutrients. The coastal waters of Arabian Sea had indications of ground water seepage through the narrow strip of submerged porous lime shell beds running almost parallel to the coast. This supplies considerable quantities of nutrients and precondition the coastal waters for rich primary production. The long-term chlorophyll trend showed a “greening” of the near-shore waters. The poor sanitary facilities of the coastal belt are the main source of nutrients to ground water. The ground water fluxes depend on factors such as: climatic (Monsoon) variability—which controls the fresh water discharge into backwaters providing the necessary force to overcome the frictional resistance of the porous lime shell deposits; human factors (land use mosaic, socio economic and sanitary conditions) and the tidal factor - controls the hydraulic difference between sea and brackish water. The significant quantity of ground water flow occurs during the monsoon months when water level in the backwater is high and the sea level remains at its annual low. With the heavy rains and flash floods linked with climate variability, such situations can occur in other seasons and at similar oceanic locations. Though the coastal nutrient enrichments, primary productivity boosting and a slow change in biodiversity were identified at few coastal pockets along west coast of India; the details of the exchange of coastal water and groundwater across the sediment-water interface deserve more attention.

Key words: Nutrient enrichments, Ground water fluxes, primary productivity
POSTER PRESENTATIONS
1. Causes and Challenges of Surface Water Pollution in India

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Abstract

Natural system and social system are complex systems in themselves, furthermore many of our resource and environmental problems involves the additional complexity of interactions between natural and social systems. Sustainable development and management of global and regional resources has to balance ecological, economical and social goals. In India water pollution poses an unprecedented challenge to its large population. While provision of safe drinking water is the immediate concern of the country but it is also crucial to recognize that (especially for a developing country like India) there are a number of other priorities that affect human welfare as well—such as hunger, poverty, population growth, health, malnutrition, local environmental damage, conflicts and governance. The economic factors like growth of industries, urbanization, agricultural activities are important causes of water pollution in India but social factors like poverty, population growth, corruption, unawareness, also cannot be overlooked. As a result of very complex interrelationships between socio-economic factors and environment a pressing need has emerged for comprehensive and accurate assessments of trends in water quality.

The paper aims to shed light how human activity leads to surface water pollution in India. More specifically the paper aims to study the effect of socio-economic and institutional factors on human activities and associated water pollution in India. To estimate the link between surface water pollution (BOD) and per capita income a simple linear regression model is first used. This reduced form estimate will give us the net effect of state’s income on water pollution. Then by including the additional explanatory variables the study will analyse their effect on water pollution.
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Abstract
Bangladesh occupies an area of 14.47 million hectares (ha) of which 13.46 ha area land surface and only 0.94 ha are rivers and other inland water bodies. The country is bounded to the west, north and east by India and to the extreme south-east by Myanmar, the Bay of Bengal lies to the south. Almost the entire area of Bangladesh is still an active delta formed by the three major rivers are the Ganges, the Brahmaputra and the Meghna that constitute one of the largest river systems in the world. Most part of these river basin consists at quaternary alluvial deposit lain down by these three big rivers and 700 rivers including its tributaries and distributaries. About 80% of the total land area of the country’s land formations is riverrine floodplains. The principal wetlands comprise of rivers and streams, fresh water lakes and marshes including water storage reservoirs, fishponds, seasonally flooded cultivated plans and estuarine system with mangrove swamps, covers about 7-8 million ha. The country is facing tremendous degradation of wetland ecosystem, water and environmental pollution due to infiltration of toxic industrial effluents, urban sewerage and saline water. Bangladesh is the most densely populated country; total population is estimated 123.1 million in January, 2001 and growing at a rate of 1.47 per cent. Average population density is about 834 per square kilometer (BBS, 2001). More than 95% of urban municipal sewerage sludge and industrial effluents are discharging directly into surface water or river without any treatment are polluting wetlands and water all over the country. Only Dhaka city currently produces 3,200 tones of municipal garbage of which Dhaka City Corporation (DCC) could only collect and dump 12000 tones everyday in a crude manner in lowland area and polluting water bodies (DCC,2005). Thus, water is polluting by bacteria, virus, parasites or other serious water born diseases, threatening life of aquatic biodiversity, reproductive abnormalities in fish and aquatic mammals, human life as well as polluting surface and ground water through the recharging process. The IUNC has enlisted 23 species of wildlife as endangered species in its Red Data Book.
Among 30,000 industrial units of Bangladesh, Department of Environment (DOE) identified 1176 major polluting industries. The hazardous wastes and effluents, especially heavy metals are generally discharged in low-lying areas, rivers, along the road sides or in the vicinity of the industrial installation. The main heavy metals discharges are Cd, Pb, Cr, Hg, Zn, As and in few cases Cu and Mn. These metals and toxic substances are polluting soil, water and environment causing health hazards (DOE, 1992). Bangladesh government and NGO’s are views strategy of sustainable use of water resources to satisfy the needs of all groups of people and conserving water resources. The precious fresh water resources are scarce in the world as well as in Bangladesh. Unsustainable use of water resources has dried up many international rivers of the Asia-Pacific region. Integrated water resource management is only solution to resolve such conflicts arising out of water use.

**Keywords:** Wetland, Water Pollution and Environment.
Abstract
The quality and underground water table depth in Pakistan is highly variable and it varies with distance from the rivers. About 70% of waters are marginal or brackish. According to another estimate, two-thirds of this water is not usable directly and requires special management practices or prior amelioration. Farmers must combine various crop management strategies to cope with water deficit resulting from soil, weather or limited irrigation: drought escape, avoidance or tolerance, crop rationing, irrigation (supplemental, deficit). This situation necessitates the development of unconventional sources of water in addition to the efficient use of the existing ones. A field experiment was conducted to study the interactive effect of Canal Water/Drainage Water with alternate application of Canal, and Drainage water with the addition of Farmyard Manure and Gypsum. The experiment lasted for three years. Rice variety KS-282 was taken as test crop, cultivated in field in completely randomized block fashion with four repeats. Paddy (rice) yield indicated that the rejuvenation of Canal and drainage water alone and in combination with gypsum resulted to better yield as compared alone drainage water application.
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Abstract
Nagapattinam district is one of the eleven eastern coastal districts of Tamil Nadu in South India and has an areal extent of about 4600 sq.km. The area is irrigated with the water from Mettur dam constructed across River Cauvery. In the recent years, since the storage situation at the Mettur dam has been poor, the ground water resources are being harnessed without determining the quality of ground water that is deteriorating due to the lateral movement and upconing of saline water in the coastal parts of Nagapattinam district. Isotope hydrogeochemical investigation was carried out in Sirkazhi area of Nagapattinam district to study: i) the source of salinity; ii) the inter-relation between Quaternary and Pliocene aquifers iii) the source and origin of ground water recharge and iv) the age of ground water.

Ground water, surface water and rain water samples were collected from the study area to analyse for environmental isotopes namely ²H, ¹⁸O, ³H and ¹⁴C and major ion chemistry. In addition, their E.C. and pH were also measured in-situ. Major ion chemical data show that mainly there are three different groups of waters. They are Na-Cl type, Na-Mg-Cl type and Na-Mg-HCO₃-Cl type. The δ²H and δ¹⁸O values vary from –40 ‰ to –5 ‰ and –6.5 ‰ to –0.8 ‰ respectively. The ³H values range between 0 to 6.5 T.U. Nine intermediate (50m to 174m) aquifer samples were found to be saline (EC values 6600 to 35800 µs/cm) and their ages vary from 6000 years to 36000 years B.P. and they are not interconnected with shallow aquifer. The source of ground water salinity could be due to the interaction of ground water with marine sediment in the sub surface. The shallow aquifers are getting recharge from local precipitation as well as Mettur reservoir water, which is used for irrigation purposes.

Key words: Ground water resources, Coastal districts, Tamilnadu, Isotope Geochemistry, salinity.
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Abstract
The over exploitation of water from the coastal environment, results in reduction and salt water intrusion of groundwater resources which a reflected in quantity and quality changes of water level. Pondicherry is one such region with recent alluvium as the major litho unit. A study has been attempted to calculate the extraction of water and to estimate the amount of recharge into this alluvial aquifer. The monthly water level fluctuation was observed for the study period in eighteen locations (2000-2002). The study area receives 1205 mm of rainfall annually. The highest water level observed during 2000 was taken as the initial water level for the study and the subsequent decline in water level up to 2001 was monitored monthly until the rising trend was noted. This was taken as the fall in water level due to extraction. Keeping this as the initial value increasing trend was studied until there was a notice of decline in water level. This was taken as the rise in water level due to recharge. The spatial representation of these datas in the above said eighteen locations were carried out by using GIS and the area occupied by different water level contours were calculated and the amount of water withdrawn was estimated. The maximum discharge and recharge was noted in the Kodukkur region. The rate of discharge and recharge is 1.9957/month and 1.1825/month. The minimum rate of recharge is noted at Sompet region. Similarly the minimum rate of discharge is 0.0234/month noted in the Vambupet regions.
Key words: Recharge, Discharge, Alluvial Aquifer, GIS, Pondicherry, water level fluctuation.
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Abstract

The effects of sulphide ore mineralization and mine tailings on groundwater quality were studied in Kalyadi (Lat.13° 14’N and Long. 76° 9’E; Toposheet No.57C/4) located about 20 kms SW of Arsikere town in Hassan district of Karnataka State. The lithounits of Kalyadi formation belonging to Sargur group of rocks (3.0-2.9 Ga) include quartzites and quartz-chlorite-biotite schists. The quartzites and associated quartz-chlorite-biotite schists contain the cupriferous sulphide mineralisation. Some of the quartzitic bands carry pyritic and also cupreous sulphide mineralisation. The ore occurs largely in disseminated form consisting of pyrite, chalcopyrite, magnetite and pyrrhotite. The percentage of sulphides in ores range from less than 10% to about 70%.

The chemical parameters of groundwater were measured employing various standard methods of analysis. The result indicates an anomalous concentration of heavy metal ions budget in the samples. The present study analyses water- inorganic sulphide interaction in a metalliferous terrain and its impact on the groundwater.
Infiltrate Characteristics at Different Depths from Kale Plots Irrigated by Domestic Wastewater, Primary Effluent and Groundwater

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Abstract

Wastewater reuse and reclamation in many countries have been increased due to the water shortage problem. The past research results from the wastewater reuse and reclamation projects in agricultural irrigation show technically and economically feasible. However, the groundwater contamination nearby the wastewater irrigation area might be occurred. This study had been conducted in order to investigate the quantities and characteristics of infiltrates from the vegetable plots irrigated by raw wastewater and primary effluent.

Four crops of kale plantations with different irrigation rates at 400, 300, 200 and 100 m3/rai/month had been conducted. Each crop consisted of 3 plots irrigated by raw wastewater (RW), primary effluent (PE) and groundwater (GW). The dimension of each plot was 1.5 m x 8 m and had 3 stainless steel plates with a dimension of 1.2 m x 2.5 m x 0.15 m under the plot at depths of 0.3, 0.6 and 1.0 m from soil surface. The plot had a transparent plastics roof with height of 2.2 m in order to prevent the effects of rainfall on the plantation. Kale used in the study was Brassica oleracea var. algoglabra.

For kale cultivation, the seeds were grown in green house for 30 days prior to planting in the plots, at the 0.3 x 0.15 m row. The growing periods ranged from 24 to 36 days. Grab samples of irrigated waters and 1 day composite samples of infiltrate waters at 3 different depths of plots irrigated with RW (0.3RWI, 0.6RWI, 1.0RWI), PE (0.3PEI, 0.6PEI, 1.0PEI) and GW (0.3GW1, 0.6GW1, 1.0GW1) had been collected and analyzed. The quantity and characteristics of infiltrate were determined every day and 2 times per week, respectively. The parameters that were analyzed are pH, conductivity, total phosphorus, suspended solids, total dissolved solids, COD, BOD, NH4-N, TKN, NO2,-N, NO3-N, total coliforms and fecal coliforms.

The following results are obtained from this study. The infiltrates from kale plot using the rate of 400 m3/rai/month were investigated at 0.3, 0.6 m depths and a few sample at 1.0 m depth. Their quantities were in the ranges of 0-18.8 % of the irrigated water. Their quantities were in the ranges of 0-18.8 % of the irrigated water. The infiltrates from kale plot using the rate of 300 m3/rai/month were found at 0.3 and 0.6 m depths and their quantities were in the ranges of 0-10.5 %. The infiltrates from kale plot using the rate of 200 m3/rai/month were found at 0.3 m depth only and their quantities were in the ranges and 0-4.1 % of the irrigated water. There was no any infiltrate from plot using the rate of 100 m3/rai/month. In general, the highest quantity of infiltrate generated from GW plot was observed and followed by RW and PE, respectively. The results of pollutant loading in the irrigated water and infiltrates from plots at 0.3, 0.6 and 1.0 m depths indicated that very high loading from irrigated waters in RW and PE.
plots had been observed compared with GW. However, higher loadings of almost pollutants in the infiltrates from GW plots have been found due to the higher volume of infiltrate generated and the leaching process of the substances from soil in GW plot.
8. Nitrate Contamination Estimation from Domestic Septic Tanks to Groundwater Table: Combination of Vulnerability Assessment and Lump Parameter Method

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Abstract

Groundwater resource of Tehran is the main resource supplying water demand of Tehran with population of more than 8 million. It is vital to preserve the quality of groundwater due to the great population and water crisis. More than 50% of Tehran water demand is supplied by groundwater resource that is mainly contaminated by domestic cesspools.

For lack of sanitary wastewater disposal system, cesspools are the main cause of different biological and chemical contamination such as nitrate contamination in groundwater. This study can be reviewed in two different sections that were carried out in GIS system: Qualitative and Quantitative estimation.

For qualitative estimation, basis of DRASTIC vulnerability assessment method which is applicable for rural areas is used and modified according to urban conditions. Major factors considered in DRASTIC are as following: i) Depth to water: in this special study it was considered as the distance between the bottom of cesspool and groundwater level; ii) Net recharge: this factor includes rainfall discharges to cesspools and wastewater as the main cause of pollution transport. Since the ground surface is covered by asphalt or other impermeable surfaces, the only way of rainfall discharge to groundwater is the roof collectors which convey water from roof to cesspools. And this factor is estimated based on the roof area; iii) Aquifer media: it is produced according to the geotechnical boreholes in GIS system; iv) Topsoil: it is considered as the top 2m-layer of soil under the bottom of cesspool tank; v) Topography: this factor is not included in this study as it has no effect on unsaturated zone transport; vi) Impact of vadose zone: This factor is considered as the soil layer in the vicinity of groundwater table; and vii) Hydraulic Conductivity: this factor is estimated based on geotechnical relations or experimental tests.

To control the integrity of vulnerability map, values were compared with data of nitrate in groundwater. For quantitative assessment of nitrate contamination it was impossible to use sophisticated models because of the great lack on data and field measurements as well as large study area (more than 600 km²). Therefore a one-dimensional lump parameter model and mass balance model was developed in GIS system simultaneously to quantify the nitrogen total loading, nitrate contamination and fate of transport.

This combination of vulnerability assessment method and lump parameter model shows a good correlation as well as application in large areas such as Tehran which suffers from lack of field data. As a result of study in south region of Tehran, in which groundwater level is too high, nitrate contamination is high. This contamination is produced mainly by domestic wastewater (more than 90%) and air pollution and agricultural activities. In addition population density as the main source of contamination duplicates the problem.
Maximum nitrification rate occurs in depth between 2 to 3 meters. In depth between 20 to 30 meters, denitrification rate will be almost constant. According to the mass balance method, nitrogen loss rate in unsaturated zone will be about 55%.
Abstract

It is from the depths of this arid tribal belt of Jadugada that India’s nuclear programme had its inception which is still continuing. Located in the mineral-rich Singhbum district of east Bihar, Jaduguda is the principal and almost only source of Uranium in India and provides the major nuclear fuel for the 10 existing nuclear reactors. Now the overall processing capacity of the Uranium Mill is 2090 MTPD. The operating units under UCIL at present are: Underground Mines at Jaduguda, Bhatin Narwapahar; Ore Processing Plant at Jaduguda for producing Uranium concentrate, and Plants for uranium mineral recovery from copper tailings at Mosaboni and Rakha. All the units are located in Singhbum (East) Dist. Bihar.

For each ton of Jaduguda uranium oxide (yellowcake) extracted for processing, between 1000 and 40,000 tons of tailings remain behind, waste that can hold up to 85% of the ore’s original radioactivity. These tailings are dumped into tailing repository ponds. The principal danger for people living near Jaduguda, say environmentalists, is a 40-hectare “tailing” pond used to hold liquid and solid waste produced in the processing of the ore into yellow cake. India’s Atomic Energy Act states that there should be no habitation within five kilometers of a waste site or uranium-tailing pond. Even though Jaduguda has been in operation for more than 30 years, seven villages yet stand within one and a half kilometers of the danger zone, which is perhaps unavoidable. For e.g., one of the villages called, Dungardihi, begins just 40 meters away from one of the tailing ponds.

Due to long active life of radioactive waste that remains in the tailings pond, even after closure of the mines and processing plant, proper design for impoundment of tailings of 80 lakh tons over 20 years life time of the project is essential. Environmental impact assessment hardly gives any details about the pond design except saying that lining can be provided. Linings are effective only for chemical waste, which gets detoxified in a much shorter time comparatively. Radioactive waste takes more than 100,000 years to reach low safe radiation levels. No lining can be effective over such long periods. The claim that the tailings pond is located over a hard granite rock area and hence no seepage is possible is not supported by hydro-geological evidence. Without clear specifications for the type and design of the tailings ponds the risk of contaminated water due to seepage in aquifers, surface water bodies appears very high. Also, accidental issues such as breach of the tailing dams (e.g., 1986 tailing pond dam burst and radioactive water flow in Dungardihi); periodical flooding of local road due to leakage of during transportation of tailing material; over flooding of tailing pond due to heavy precipitation, etc. may cause contamination in the local aquifers. UCIL needs construction of more repository tailing ponds due to increasing extraction of uranium ore (e.g., Stage III, new shaft for work up to 905 meters). Therefore, a detailed study of the permeability, porosity and other hydraulic properties of the entire area of the proposed sites for tailing pond together with the nearby areas, which may be affected due to
accidental events, should be assessed before finally deciding on the site for construction of the repository-tailing pond.
10. Groundwater quality around the Pirana Landfill site of Ahmedabad, India

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Abstract

Like other Asian countries, in India too most of the waste is landfilled. The methods followed in Asian countries are not in keeping with modern practices of sanitary landfilling. The wastes are largely dumped in landfill areas without proper segregation and treatment. These landfill areas are not well designed for this purpose. This leads to ground and surface water contamination. These low-lying dumping areas are also prone to flooding and polluting adjoining areas.

Present study is carried out with the objective to monitor impact of these landfill on groundwater through leaching in Ahmedabad. Pirana, the only landfill site of the city is of 84 acres area which is receiving municipal waste since 20 years and nearly 95% of total solid waste i.e around 1045-1140 tonnes/day generated from the city is being dumped here. Sampling was done for the both season of pre and post monsoon and were analysed by following standard methods from APHA (1995). To match with the characteristics of the water with that of solid waste, four samples of MSW were also collected and analysed for the heavy metal concentration and some other parameters too.

Different types of chemical & statistical analysis of water samples show that groundwater exceeds the permissible limit of Fe, Cu, Zn and Cd for drinking water. A good number of samples are also showing higher values for NO₃ and Pb than that of WHO drinking water regulation. Predominance of Fe and Zn in both water and solid waste samples are due to iron and tin based industry as well as Zinc based waste in the area.

A detail modeling work is going on in order to trace contaminant transport in the area with the help of MODFLOW for better understanding of leaching and its impact on groundwater quality in the city.
11. Trace Element Geochemistry in the Groundwater of Patancheru Industrial Area, Andhra Pradesh, India

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Abstract
Patancheru Industrial Area located about 40 km from Hyderabad is one of the most contaminated region identified by central regulatory body in India. About 250 small and large scale industries manufacture pharmaceuticals, paints, pesticides and chemicals apart from steel and metallic products in this region. Several small streams drain through the area to join the main Nakkavagu stream which merges into Manjira river, after percolating into the subsurface. A preliminary study was undertaken in an area of about 65 km² in and around Patancheru to determine the spatial distribution of trace elements in groundwater and to assess the extent of pollution, and its impact on human health.

Several groundwater samples were collected from bore wells for the determination of minor and trace elements (Li, Be, B, Si, V, Cr, Mn, Fe, Co, Cu, Zn, As, Se, Rb, Sr, Mo, Ag, Cd, Sb, Ba and Pb) by ICP-MS using the standard reference material NIST1640 (Standard for trace elements in natural water) for calibration. Major ions (Ca, Mg, Na, K, Cl, SO₄, total alkalinity and NO₃) were also estimated to classify and characterize the groundwater. Fe (409 to 1848 µg/L) and Pb (34 to 209 µg/L) was found to exceed the drinking water permissible limit by about six and two times respectively. As (3 to 13 µg/L), Se (4 to 41 µg/L), Cr (33 to 69 µg/L), Cu (20 to 86 µg/L) and Mn (2 to 142 µg/L) vary significantly in some places indicating heterogenetic characteristic of trace element transport in groundwater. Contour maps for several trace elements was prepared and mass balance calculations were performed to identify the source and transport of the contaminant.
Abstract
Ground water in Sri Lanka is essentially the rainwater that percolates through the over burden and limestone belts and eventually formed into a variety of aquifers different in size and nature. They are also further nourished through seepage from rivers and man-made water bodies. Apparently, the chemical composition and their relative concentrations of ground waters are lithogenic, but anthropogenic activities also influence them to a greater extent. Temporal and spatial patterns of ground water chemistry in Sri Lanka were not analyzed yet in relation to topology, geology, vegetation and soil type of the landscape, and climate and drainage pattern, although the resource is largely being exploited for quality based beneficial uses such as drinking and irrigation. Available scattered information on the composition and their relative concentrations of ground water in Sri Lanka is diagnosed and review with a view to shed light on the present status highlighting the gaps to be filled for meaningful use and sustainable management.

Ca$^{2+}$ and HCO$_3^-$ dominant ground water in the wet zone shows low concentrations of macro chemical constituents with narrow seasonal changes whereas Na$^+$ and Cl$^-$ dominancy occurs in the dry zone with high concentrations and large seasonal changes. Concentrations of major ions (except for dissolved Si) decrease progressively from the coast to the hinterland, but trends vary from headwater to downstream along the river basins perhaps due to geological formations. Nitrate ion, which is primarily anthropogenic in origin, is high in densely populated urban areas and agricultural lands underlain by karst limestone beds in Jaffna peninsula and Kalpitiya area (> 100 mg 1$^{-1}$). Certain stretches of lowland dry zone contain a higher amount of fluoride (> 3 mg 1$^{-1}$) whereas in central highland and southwest coastal region area relatively free of fluoride. A bulk of elements in micro levels have been reported in ground water (Fe, Cu, Cr, Co, Mn, V, Zn etc..,) in variable concentrations and their occurrence have been interpreted in relation to both lithogenic and anthropogenic attributes.

Keywords: Ground water, Chemical Composition, temporal and spatial variations, Sri Lanka.
13. Trace Element Profiles in the Drinking Water of Mysore District.

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Abstract

Element concentrations found higher in drinking water are a major cause for health hazard reported in many parts of India, since drinking water is one of major sources for human exposure. In the present study, the various samples of drinking water were collected from bore well, hand pump and municipal water tap in and around Mysore District. A questionnaire relevant to the exposure assessment of resident who had consumed water continuously for more than 10 year was obtained while sampling water. The levels of trace elements such as Cd, Pb, As, Ni, Hg, F, Fe, Cr, Cu, Zn, Se and Mn were measured in the drinking water with use of AAS/ICP and quality control samples.

The results were discussed for significance of the source of water elements whether natural or man-made, the admissible level of elements, various influencing factors and health related implication mainly high blood pressure, coronary heart disease and diabetes. It is observed that further studies required for element levels in biological samples of the residents for assessing relationship between body burden of elements and element levels in water.
Abstract
In the Nyamandhlovu aquifer, groundwater monitoring dates back to 1970s but continuous monitoring was initiated from 1989. Monitoring was found to be necessary because the aquifer is important for its agricultural potential and setting which makes it the breadbasket of the City of Bulawayo. Moreover in 1992 about 100 production boreholes were drilled in the aquifer to augment the City of Bulawayo’s dwindling water supply by up to 27 000 cubic metres of water per day. The monitoring frequency is once every month and the data is archived in the Department of Water’s database. An assessment of the water level data shows that groundwater flows towards the northwest.

Groundwater levels have been declining to date and the drawdown ranges from about 2m to 8m depending mainly on the proximity of monitoring wells to pumping wells. The fear now is that if pumping is not controlled and this trend continues, the aquifer might dry up resulting in loss of investment and destruction of the natural habitat. Monitoring of groundwater levels is crucial for the proper planning, sustainable development and management of groundwater resources. Changes in water level infer changes in groundwater storage and hence the amount of water available.

Two methods were used, the hydrogeological approach and kriging. The hydrogeological method assumes that physical and human phenomenon like rainfall and land use influences groundwater level fluctuations hence must be considered when designing network density. This assessment gave a high network density in the cultivated area where fluctuations are expected to be high due to abstractions.

Kriging is an interpolation method that predicts unknown data from data observed at known locations using variogram models, which express the spatial variations. Its main advantage over many interpolation methods is that it also gives the standard deviations of
the estimation errors, which are related to network effectiveness. Annual average groundwater data for 1997 was used. The variogram model for residuals was therefore used during network design.

The resultant redesigned network has 25 new wells and 45 existing monitoring wells. This was arrived at after considering kriging results and the network density zones generated by the Hydrogeological approach. The current monitoring frequency of once per month was also found to be adequate for the study area.
Abstract
The Haldia industrial region, situated in the east Midnapore district of West Bengal, has started developing into a major industrial hub of eastern India for the past few decades. With the setting up of Haldia Petrochemicals Limited (HPL) and declaration of the new industrial policy by the government, the area offers unique infra-structural advantages for industrial rejuvenation to take place in diverse ways and dimensions. Various units have already come up, and a lot more are expressing their interests to set up downstream- and allied- industries at Haldia, to avail the facilities of the Haldia port and port-based activities. The increased spate of industrial growth and related urbanization has cast its pollution load on the hydro-geochemical regime of this region, that forms the near-coastal inter-fluvial zone of Hooghly and Haldi rivers.

The present work assesses the geochemical characteristics of groundwater in the Haldia industrial region with respect to its suitability for drinking and irrigation uses.

Water samples representing the shallow aquifers were collected from various pollution zones during the pre- and post- monsoon seasons of the year 2004. The data were analyzed in conformity with BIS and WHO standards, based on which the ionic relationships, hydro-chemical facies and water types were determined. A strong correlation was established between certain water quality parameters which could be suitably utilized to predict the concentration of these constituents in other parts of this industrial belt. The usefulness of applying regression equations in such prediction is also emphasized in this paper.

Key words: Correlation coefficient, groundwater, hydrochemical facies, Haldia industrial belt, regression analysis.
Development of Geographic Information System (GIS) for Water Resources of the Republic Tajikistan

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Abstract
In conditions of a dry and hot climate of the Central Asia the basic role is played with water resources. They provide an opportunity of steady development of economy and stable existence natural and anthropogenous ecosystems. The basic sources of pollution of superficial waters in territory of Republic Tajikistan are objects and the enterprise of system housing-and-municipal, an agriculture and the industry. The greatest influence occurs on the part of housing-and-municipal sector and makes 80-90% from total volume of waste water into waterbodies. It in many respects is connected by that existing capacity and efficiency of clearing constructions is insufficient for processing and clearing of all acting sewage. The project intends to carry out inventory of the objects having discharges in water objects by creation of an electronic cadastre of water-users, similarly existing before system of the account of water use 2-TPI “Vodkhoz” and system of the account used at present in the countries of the European Union. Quality of superficial and underground waters of Tajikistan in separate regions has tendencies to deterioration. Within the framework of the project it is provided to execute on the basis of use of GIS-techniques the developed (unwrapped) analysis of the data of quality of water in water objects of these territories and on available hydrochemical and hydrobiological given to define priority actions and recommendations to improvement of quality of water.
Water management is one of key economic branches which successful functioning provides a basis of stable development of all industrial and social infrastructure of the state. Water resources on volumes of their consumption by mankind now surpass all other kinds of natural resources taken together and consequent fresh water in the majority of the countries of the world carry to a category of strategic resources. The water delivered to the consumer and prepared for use, is not so simply a natural resource, and a product of the enclosed work and means for its (her) preparation and can be referred in concrete cases to the enriched raw material, semifinished items or an end-product, and in some cases and to waste products of manufacture.

World experience testifies that the crisis situation with drinking water supply is characteristic practically for all countries of the world. Therefore economic development of new water objects should be integrated with protection ecosystems which plays a determining role in the nature where water is the vital factor maintenance of necessary balance anyone ecosystem. The basic responsibility for the practical decision of problems of protection of water resources is usually assigned to regional bodies, organizational structures which in the different countries essentially differ. Regional bodies develop programs of water use, supervise a condition of water resources in region, are engaged in regional planning and coordination of municipal plans, render the financial help to local authorities, etc.

Structural units of a control system of water resources (regional and municipal) should have system of a supply with information of the branch focused not only on reception, but also on processing of the information and representation to its (her) users as, providing an opportunity of acceptance of administrative decisions.
Abstract

Stochastic models that have been developed for modeling and forecasting seasonal time series are very useful within the field of water resources planning in arid and semiarid regions. As demands for additional water continue to increase, the need for greater efficiency in the modeling and forecasting of water availability becomes increasingly important. However, sophisticated forecasting systems are used to plan dam operations, water supply planning, groundwater management and conjunctive use of available surface and groundwater resources. Modeling and understanding of temporal variability of groundwater discharge is important regarding to efficient water resources management, especially in low flow seasons. Base flow, which is a major component of streamflow can be considered as groundwater inflow or discharge. To model the temporal variability of groundwater discharge at the basin scale, base flow data series can be applied. With respect to computation of base flow data series in monthly basis in some basins in southwestern of Iran, stochastic modeling can be applied to model the groundwater discharge and prepare forecasting ability of base flow in the region. In this study two stochastic modeling approaches, seasonal autoregressive moving average (SARIMA) and Thomas-Fiering models were used. In this paper the background theory of these two techniques was explained. For construction of SARIMA model, the identification, estimation and diagnostic check stages of model development were mentioned. The Akaike and Bayes information criterions were used to select the best fit from the candidate set models. One-step-ahead forecasts for the test portion of data series were generated using the selected set of candidate models. The major objective of this research is to study forecast accuracy improvement by choosing the most reliable model. The results have shown that SARIMA (1,0,0)(0,1,1) and SARIMA (1,0,1)(0,1,1) models provided the most accurate forecasts for particular basins. The methodology proposed in this paper can be used for forecasting of base flow time series in similar basin during drought seasons. Improvement of the skill of base flow forecasting dramatically affects water management efficiency, crop production, hydropower production, drought forecasting and environmental sustainability of arid regions.

Key words: Stochastic process, time series analysis, groundwater, base flow forecasting.
Abstract
Estimating the monthly and annual volume of groundwater contributions to runoff within a watershed is a critical aspect of many hydrogeologic investigations including water supply, irrigation planning, wastewater dilution, navigation, hydropower generation and aquifer recharge and characterization. This is particularly useful for numerical groundwater-flow modeling researches. In this study, groundwater contributions to total runoff as Base Flow Index (BFI) were estimated at some stream gaging stations throughout the Dez Basin in south western of Iran. Local minimum and recursive digital filter with range of 0.9-0.975 filter parameters were used to separate daily runoff data into direct runoff and base flow. Discharge records for nine gaging stations, with about thirty complete water years of daily mean streamflow data, were used in this study. Correlation analysis between the two methods has shown the very close results. A visual inspection of results of these two different approaches indicated that digital filter method has more reliable base flow values. On the other hand, local minimum seems to have underestimation of base flow contribution of the total runoff. Monthly variability of BFI through the region extracted using filter parameter of 0.925 was investigated regarding to importance of low flow seasons with viewpoints of water quality and environmental consequences of drought periods. This study is intended as an early step toward improving our understanding of the temporal and spatial base flow characteristics of
southwestern basins of Iran, which is crucial to prevent groundwater depletion and pollution and to define a rule for establishment of conjunctive use in the region. Some possible applications of the results of this study were discussed regarding to regionalization of low flow data series and base flow estimation at the ungaged basins in study area.

**Key words:** Ground water discharge, Base flow separation, digital filter, BFI.
19. Regional Groundwater Chemical Modelling: A Case Study in Kodaganar River Basin, Tamilnadu, India

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Abstract
Groundwater quality is the main concern for its use either for domestic or irrigation. All groundwater contains minerals carried in solution, the type and concentration of which depends upon the surface and subsurface environment, rate of groundwater movement and source of groundwater. Man can adversely alter the chemical quality of water by allowing untreated polluted water in to subsurface. The chemical composition of groundwater evolves during regional flow due to in-situ reactions. This evolution can be generalized by considering the water types that are typically found in different zones of flow systems, weathering, ion exchange, salt dissolution, and/or seawater intrusion tend to cause water to evolve from a dilute calcium bicarbonate type in recharge areas towards a more concentrated sodium chloride or calcium chloride type in the discharge area. Presentation of geochemical data in the form of geophysical charts such as Schoeller’s diagram, Piper-Hill diagram and Durov’s diagram help us in recognizing various hydrogeochemical types in a groundwater basin. Analysis of the chemical constituents of groundwater also shed light on the geochemical evolution of groundwater as well as identification of recharge areas.

Chemical modeling study was carried out in Kodaganar river basin, which covers an area of about 2000 km² in Dindigul District of Tamilnadu, India. Groundwater in and around Dindigul town and its surrounding area has been polluted due to the discharge of untreated effluents from the tanneries situated around Dindigul town. It was noticed in many wells that TDS concentration level is more than 10000 mg/l. The area affected by tannery pollution is around 100 km² and the agricultural land has become barren. It is in this context, a detailed hydrochemical modelling study was carried out by NGRI during 2000 and its findings are reported in this paper. Historical data of chemical analysis of water samples at about 56 locations were perused and some conclusions were drawn.

The effects of tannery pollutant sources on the groundwater system were evaluated in the Dindigul town and environs. The quality of groundwater in the region has been affected negatively due to the discharge of effluents on open lands and into ponds, tanks and streams. Water samples from surface-water bodies, dug wells and bore wells were analyzed for their major ion concentrations. The high values of electrical conductivity (EC) and concentrations of Na⁺, Ca²⁺, Mg²⁺, Cl⁻, HCO₃⁻ and SO₄²⁻ indicate the impact of tannery effluents. Based on the hydrochemistry, the groundwater has been classified into different types such as sodium chloride, sodium bicarbonate, calcium chloride, calcium bicarbonate and magnesium chloride and magnesium bicarbonate. The groundwater suitability for drinking and irrigation has been assessed. Graphical representation of the chemical data on the USSL diagram shows that most of the area has high salinity-low sodium (C3S1) water that may be useful for irrigation. These areas are located away from the influence of tanneries. Around Dindigul and nearby places very high salinity-medium
sodium (C4S1; C4S2) waters are present which need adequate drainage to overcome the salinity problem.

**Key words:** Chemical modeling, Kodaganar river basin, tannery effluents, groundwater suitability.
Abstract
Unstructured waste disposal system, which results in the potential problem of
groundwater and surface water contamination due to production of leachate, is still now
very common practice in most of the developing countries. In this context, this current
study focuses on investigating the prevailing landfill contaminant spreading phenomena
in the lake Kiyanja watershed which is again considered as the potential water supply
source in the surrounding community of the Masindi district of Uganda. Attempts were
first made to develop a conceptual model considering all possible factors involving in the
hydrogeological processes of this watershed. Analysis of Groundwater boundaries,
aquifer system, existing boreholes, recharge and discharge sources and the associated
water balance were performed in developing the conceptual model. Using this conceptual
model numerical model was then developed with the help of Ground Water Modelling
System (GMS). The specific solute transport model MT3DMS was used in simulation of
this numerical model. It has also been used the software FEMLAB to study the transport
of contaminants through the soil. The results of the FEMLAB gives an idea of
understanding the multiphysics involved in pollutant movement in the subsurface system.
A further study of bedrock fracture analysis was suggested for developing of appropriate
conceptual and numerical model.
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Abstract
The paper embodies a study of depositional environment and aquifer condition of Barind area of Bangladesh using conventional gamma log data and this sort of study is thought to be first of its kind for this area. The study also attempts to scrutinize the potential aquifer either single layer or multi-layer considering the thickness, depth of occurrence and its viability of groundwater development.

The available subsurface lithology and interpretation of gamma ray well log data in the Barind area indicate that sedimentation occurred in floodplain to point or channel bar environment. In the sandy layer, coarser and less matured sediments are transported from shorter distance that prevailed in the western part of the study area. Hydrogeologically, the area is covered by semi-impervious clay-silt layer of Recent-Pleistocene age having thickness of 3.0-47.5 m; and is characterized mostly by single aquifer within the depth range of 9.0-51.5 m; but that of eastern, south-eastern, southern, north-eastern and northern parts by multiple layered (two-four) aquifer system of Plio-Pleistocene age having thickness ranges of 5.0-42.5 m at different depth levels. The northern and southern parts of the Central Barind Tract and the Atrai valley exhibit potential horizons for groundwater exploitation at shallow (depth up to 30.0 m from ground surface) and intermediate (depth between 30.0-50.0 m from ground surface), and deep (depth more than 50.0 m from ground surface) depths respectively. The aquifer potentiality for groundwater exploitation in the south-eastern part of the area is noticed at greater depth than other parts.

Key words: Barind, depositional environment, gamma ray log, aquifer, Bangladesh.
Abstract
In recent decades, groundwater resources have become increasingly threatened by the leaching of contaminants from uncontrolled landfill, containing industrial and/or household waste, infiltration of pesticides and fertilizers from agricultural areas and leakage of a wide range of organic pollutants from petrol stations, refineries, pipelines. Simulation of contaminant leached from landfill shows that the movement is towards the river Yamuna along the direction of lineament density. The software used for this study was Visual MODFLOW/MT3D provided by Waterloo Hydrological Inc. The study area is almost triangular in shape surrounded by Arravali ridge on North, northwest and west while east as well northeast by the River Yamuna. The River Yamuna is considered as constant head for this study. Eleven-year data (1992 to 2002) was used for calibrating this constant head. These data for constant head was collected from Okhala Barrage (source: U.P. Irrigation Department), Railway Bridge, Harayana Irrigation Department, Delhi Jal Board, and Central Flood Irrigation Department, Govt. of NCT, Delhi. Okhala landfill found to be a major source of groundwater pollution in South Delhi.

The model area was oriented parallel to major lineaments and the commend area has been discretised into 800 cells (25 columns and 32 rows). However there were only 348 active cells. Each side of cells measures about 860.74 m (North-South) in width and 912.28 m in length (East-West).
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Abstract

In this study we have developed an infiltration model for safe fly ash disposal in the compound of IB thermal power plant. This study is based on detailed fieldwork carried out in the study area sample collection and laboratory investigation. We have also carried out detailed literature review on the subject and proposed most appropriate model for the investigated sites as Explicit Green-Ampt Model. The major findings of this research are: At a constant geological and topographic condition infiltration rate will increases with increased in ponding height. Hydraulic conductivity or permeability of soil at saturated condition shows linear relationship with infiltration rate i.e. more is the permeability greater will be the infiltration rate. It has been observed that for course grain soils having coefficient of curvature varies between 0.13 to 1.15 infiltration rate increases with increased in coefficient of curvature. Assessing infiltration based on soil types will not give correct result. The developed model is used as a tool for appropriate site selection in the compound of the IB thermal power plant keeping leachate infiltration in ground water in mind.

Key words: Infiltration Model, Fly ash, Ground Water Contamination, Thermal Power Plant
24. Accumulation of Arsenic in Common Food Stuffs in Contaminated Environment

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Abstract
Arsenic contents in surface water, well water, tube well water, soil and rice grain of village, Kaudikasa was investigated and found to be contaminated with arsenic at elevated levels. Arsenic concentration in the soil of Kaudikasa is several folds higher than in the soil of Bangladesh and West Bengal, India. A wide variety of food species are grown and used for food. The common cereals, seeds, and spices i.e. pulses, gram, pea, green gram, black gram, lentil, kidney bean, ground nut, onion, garlic, turmeric, ginger, mint, chilies, etc. grown from the contaminated soil of Kaudikasa (Ambagarh Chauki block Rajnandgaon district, Chhattisgarh,) were collected using established methodology. The samples were dried, crushed, sieved out and digested with acids. The analytical techniques i.e. ICP-OES, HG-AAS, etc. are used for monitoring of arsenic and other metals. The accumulation pattern of arsenic in the edible plants grown in the contaminated environment is discussed.
25. Redox characteristics of the shallow groundwaters of Inner Mongolia, Peoples Republic of China and their implications on the mobilisation of arsenic

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Abstract

Elevated arsenic (As) concentration in groundwater is becoming a worldwide problem. In Huhhot Alluvial Basin (HAB) in Inner Mongolia, People’s Republic of China, a population of over a million is exposed to severe health risk due to the consumption of groundwater with high As concentration. In some arsenic seriously affected areas, As concentration reach 1491 µg/L, 149 times over WHO’s drinking water guideline value for As and exceed the Chinese drinking water standard by a factor of 30 times. Due to the acute shortage of safe water supply and inefficient water management system, people are compelled to drink groundwater with high As concentration. Long period ingestion of water with high As concentration have lead to chronic arsenic poisoning among the residents of the region. This present work deals with the hydrogeochemical characterisation of the groundwater of the shallow alluvial aquifers and their implications on the chemistry and its relation to the mechanism of As mobilization in the HAB.

Groundwater samples were collected during October 2003, from 29 sites in the village of Tie Men Jing, located about 100 km from Inner Mongolia’s capital Huhhot. The pH, redox potential (Eh), temperature and electrical conductivity were measured at sites while major ions, trace elements including As total and As (III) were analyzed in laboratories at the Royal Institute of Technology and Stockholm University in Sweden. Groundwater is generally neutral to alkaline and the pH varies from 6.67 to 8.7. The redox potential (Eh) lies between 74 and 669 mV. The electrical conductivity (EC) range varies from 581 to 5200 µS/cm. Temperature ranges from 9.1 to 13.5 °C. Depths of wells are from 4 m to 75 m. Groundwater is mostly of Na-Mg-HCO\textsubscript{3}-Cl-type and dominated by HCO\textsubscript{3} and Cl\textsuperscript{−} as the predominant anions. The concentrations of SO\textsubscript{4}\textsuperscript{2−} ranges between 0.3 and 172.8 mg/L and there is a trend of decreasing sulfate concentrations with increase in well depth. The levels of NO\textsubscript{3} are lower than the WHO’s acute guideline value of 50 mg/L in 27 wells. However, two wells concentration are revealed above the WHO’s limit. These high NO\textsubscript{3} concentrations could have been caused by anthropogenic contamination due to the sanitation practices. The PO\textsubscript{4}\textsuperscript{3−} concentration ranges between 0.04 to 2.6 mg/L.
Arsenic concentration ranges from below detect limit (5.2 µg/L) to 140.5 µg/L. Among them, As concentration in 28 wells exceed WHO’s guideline value 10 µg/L and 17 wells exceed Chinese standard 50 µg/L. Among the 42 groundwater samples of the shallow aquifers only three complied with the WHO drinking water guideline value for As. As (III) was the dominant species in the groundwater. In the 29 wells of Tie Men Jing, the concentration of Fe and Mn exceeded the WHO’s guideline value by a factor of 10.

The aquifers are composed of Quaternary (mainly Holocene) fluvial and lacustrine sediments. High As occurring in anaerobic groundwater in low-lying areas are associated with high concentrations of dissolved Fe and Mn. Improved water supply system, employment new water and energy resources, poverty fighting and expertise cooperation are recommended to solve Huhhot basin rural area’s drinking water problem.

**Key words:** Redox characteristics, shallow groundwaters, Inner Mongolia, arsenic, mobilisation.
26. Arsenic in the groundwater of the Bengal Delta Plain: Hydrogeochemical studies from the districts of Nadia and South 24 Parganas, West Bengal, India

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Abstract

Bengal Delta Plain (BDP), an integral part of the world's largest delta, is a major natural storehouse of high groundwater arsenic, where millions of people are now suffering from serious health hazards including arsenic induced cancer. The unconsolidated alluvium of Pleistocene-Recent age is the source horizon that rests upon Tertiary rock sequence. In this pericratonic basin, various near-shore paleogeomorphic terrains have been identified widening towards south/southeast resulting from shifting of delta front/coastal plain. In the present study, we tried to investigate the occurrence and mechanism of arsenic release to ground water in alluvial aquifers of BDP. We sampled ground waters from two different areas (Chakdaha, Nadia and Baruipur, South Pargana district in West Bengal) and tried to compare the governing geochemical processes leading towards arsenic contamination.

The major groundwater chemistry in both areas are almost alike whereas their scale is largely dependent on the geospatial signatures of the affected areas. The result shows that high concentrations of As (average: 293 and 116 µg/L) are accompanied by high concentrations of Fe (average: 3.8 and 4.7 mg/L), PO₄ (average: 3.2 and 3.7 mg/L) and Mn (average: 0.49 and 0.37 mg L⁻¹) for Baruipur and Chakdaha, respectively. The groundwater quality reveals that the waters are in general Ca-HCO₃⁻ or Ca-Mg-HCO₃⁻ type with elevated levels of chloride (average: 125 and 30 mg/L) and sulphate (average: 11 and 2.1 mg/L). The aquifer is anoxic in nature (Eh < -0.07 to -0.34 V) with high load of bicarbonate (average: 498 and 408 mg/L), respectively along with redox sensitive species (Fe, Mn). However, the abundance of As-traps and orthodox redox traps playing an important role in mobilizing arsenic into groundwater. Statistical evaluation of the geochemical data suggests Fe bearing silicates (such as chlorite and biotite) and clay minerals as the main carrier mineral phases for arsenic in the aquifer sediments. Results from this study further strengthen that the competitive exchange with fertilizer-phosphate as well as over-extraction of groundwater by irrigation does not contribute to arsenic pollution. Nevertheless, the redox-sensitive mobilization of As from disperse distributed Fe- and Mn-oxyhydroxides is likely to be considered as the main driver for the enrichment of As in groundwater. The release of arsenic in groundwater is due to microbial reduction of sedimentary Fe(III) phase (arsenic traps) under local reducing conditions (redox traps).
27. Factors affecting groundwater arsenic mobilization occurring in Chakdaha block in West Bengal

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Abstract
We sampled 107 shallow (9-48m) wells, 7 deep wells (>100m) and 11 wells from intermediate depth (60-90m) in a well-demarcated 4km x 4km area in Chakdaha block, an arsenic contaminated area in West Bengal. High arsenic ([As]T = 0.2-0.5 mgL⁻¹) in groundwater is associated with 37-87% (average-64%) ferrous iron and 45-70% (average-59%) was found for safe ([As]T < 0.05 mgL⁻¹) water. XRF analyses showed that 8-14 mgkg⁻¹ As, 5-9.6% Fe₂O₃, 0.07-0.15% MnO found in silty clay particles whereas fine to medium sand have a typical range of < 5 mgkg⁻¹ As, 1.15-3.9% Fe₂O₃, 0.02-0.06% MnO. High Fe(III)ₐm oxy-hydroxide (10-12 gkg⁻¹) was obtained by CBT extraction in safe zone. Speciation of Fe(II)T, MnT, HCO₃⁻ and AsT in groundwater samples were done by using MINTEQA2. Batch arsenate adsorption study was made with bulk sediment from riverbank reflects slow adsorption kinetics and low adsorption capacity. XPS studies on biotite, a Fe(II) containing mica frequently found in BDP sediment, showed that reduction of arsenic preferentially occurs at the edge of biotite and thus contribution of this mineral towards arsenic mobilization has been established.

Key words: arsenic, mobilization, speciation, edge, XPS
28. Arsenic Accumulation in Edible Plants Irrigated with Arsenic-Rich Groundwater

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Abstract
The lethal effects of arsenic have been known for centuries. This tasteless toxin is slowly poisoning people in different regions of the world through their drinking water and the situation in Bangladesh is considered as the biggest mass-poisoning case of the history that exposed approximately 35–77 million people. Use of underground water resources for irrigation is a common practice in the rural areas of Bangladesh and people used to rely on homestead garden production for daily vegetable requirement which are usually irrigated with arsenic-rich shallow tubewell water. Edible vegetables, medicinal and aromatic plants grown in arsenic contaminated soil may uptake and accumulate significant amount of arsenic in their tissue. Present work include study on some common plants grown in the homestead gardens, e.g., Lablab niger (Bean), Lycopersicon esculentum (Tomato), Solanum melongena (Brinjal), Cucurbita maxima (Sweet gourd), Amaranthus gangeticus (Red amaranth), Carica papaya (Green papaya), Capsicum sp. (Chilli), Lagenaria siceraria (Bottle gourd), Momordica charantia (Bitter gourd), Mentha viridis (Mint), Vigna sesquipedalis (String bean), Abelmoschus esculentus (Okra), Trichosanthes dioica (Palwal), Basella alba (Indian spinach). Mean and maximum arsenic content in those plants as well as the average dietary-arsenic intake due the plants were estimated. Correlation with the groundwater arsenic status and statistical significance of variations has also been discussed.
Arsenic (As) contaminated groundwater is being extensively used in Bangladesh to irrigate rice fields during dry season. The element accumulates in the paddy soils and enters into food chain through crop uptake. This investigation reports the levels of As in irrigation waters, soils and boro rice (grain and straw) from 100 shallow tube well (STW) areas over the sadar upazila of Chapai Nawabganj. The As concentrations for all samples (soil, water, grain and straw) varied widely between locations. The STW water As concentration ranged from 0.015 to 0.352 µg ml$^{-1}$ with a mean of 0.075 µg ml$^{-1}$, the concentration being lower in shallow well depth, reaching to a maximum about at 25 m depth and then decreased with increasing depths. The levels of total As in soils over the locations ranged from 5.8 to 17.7 µg g$^{-1}$ with a mean of 11.2 µg g$^{-1}$. Total As content in soils was positively correlated with irrigation water-As indicating a possibility of As build up in soil with time. The rice grain-As concentration was in the range of 0.241 to 1.298 µg g$^{-1}$ having a mean of 0.759 µg g$^{-1}$. Eleven percent of the grain samples had As level <0.5 µg g$^{-1}$, 37% in the range of 0.50-0.75 µg g$^{-1}$, 40% 0.75-1.0 µg g$^{-1}$ and the rest 12% more than 1.0 µg g$^{-1}$. The grain-As was poorly correlated with soil-As as well as irrigation water-As, however it was positively correlated with straw-As concentration. Rice straw-As concentrations ranged from 1.48 - 17.6 µg g$^{-1}$ with a mean of 5.88 µg g$^{-1}$. Higher concentration of As in rice straw fed to cattles may be a threat to cattle health. About 89% of the rice grain grown in Chapai Nawabganj irrigated with As contaminated water may lead to an intake of more than 100% potential maximum tolerable daily intake (PMTDI) for an adult of 70 kg body weight.

**Key words:** Arsenic, STW water, soil, rice grain, rice straw
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Abstract
The process of electrocoagulation (EC) is a good alternative because it can remove the disadvantages of the classical chemical destabilization. Therefore EC has been applied successfully to treat various wastewaters. The available methods in general, have quite low efficiency for As(III) removal and thereby chemical oxidation of As(III) followed by adsorption is suggested. Electrocoagulation offers possibility of anodic oxidation and in situ generation of adsorbents such as hydrous ferric oxides (HFO). In the EC process with iron electrodes, As(III) gets oxidized to As(V) and gets adsorbed on to the metal hydroxides (HFO) generated in the process. Therefore, electrocoagulation seems to be a better choice for arsenic removal from water. Electrocoagulation laboratory scale set up has been used for arsenite removal. The arsenic laden water is passed through a container (volume 2 L) in which electrocoagulation (current: 0.2 amp) is done and then it passes through filter medium at flow rate 44ml/min. Experiments were carried out with initial arsenic concentration of 1 mg/L and 2 mg/L with varying current flow. Results show that arsenic levels below 50 µg/L could be achieved, which is the drinking water standard in India and Bangladesh.

Key words: Arsenite, removal, electrocoagulation, laboratory scale set up, water
Abstract
This study examines users satisfaction with piped water system for arsenic-free safe water and also examines the management mechanism of rural piped water systems. Data were collected in October 2004 using structured questionnaire from 106 households in Sonargaon, 140 households in Barura, 98 households in Daudkandi, and 100 households in Godagari upazila. All the households who were using piped water during the survey were included in the study. The findings show that almost all the users were satisfied with the piped water system. About 86% of the users were paying monthly water bills on regular basis while more than 50% of the users had good economic status. Majority of those who were irregular in paying their bills claimed to be of poor economic status. The study findings would be useful to design sustainable rural piped water scheme in Bangladesh.

Key words: Sustainability, Arsenic, Mitigation, piped water supply, management.
32. Bioremoval of Arsenic by Green Algae (*Oncorhynchus mykiss*)

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Abstract

Removal of heavy metals from the water has been a long term-challenge. During the recent era environmental protection, the use of microorganisms for the recovery of metals from contaminated water has generated growing attention. Many studies have demonstrated that both prokaryotes and eukaryotes have the ability to remove metals from contaminated water. The behavior of green algae *Oncorhynchus mykiss*, an eukaryote, against inorganic arsenic dissolved in media was studied. *Oncorhynchus mykiss* was shown to have capabilities of endurance against a high concentration stress and accumulation of arsenic. The algae were grown for 90 days receiving full sunlight during the day to get a substantial biomass, arsenic application rates were 0.0, 0.05, 0.25, 0.5 and 1.0 mg/L. After 90 days the algae were chemically analyzed for As. Algae possessed the ability to take up high concentration of arsenic and other heavy metals from the contaminated water.

Key words: Arsenic, Biomass, Bioaccumulation, bioremoval, green algae
Abstract
Fluoride contamination in drinking water pose great problems viz; skeletal fluorosis and dental fluorosis. There are many means of treatment of fluoride containing water. Of these, electrochemical treatment of fluoride is more advantageous since this involves no chemical addition. Treatment of water is done in electrolytic cell fitted with anode and cathode, where the anode dissolves in water and react with the fluoride for the removal. Aluminium is widely used in defluoridation. The passivation of aluminium decreases the efficiency of dissolution. Aluminium alloy overcomes the problem of passivation. Aluminium alloys (Al-Zn-In) containing various amount of Zn (1 to 4%) and In (0.006 to 0.025 %) were prepared. The corrosion behavior of pure aluminium and the alloys in water containing fluoride (5 to 25 ppm) were investigated using weight loss measurement, potentiodynamic and galvanostatic polarization measurements. The OCP of aluminium was found to increase with the addition of Zn in the negative direction. The addition of indium to Al-Zn alloy also was found to increase the OCP to the negative values. The pattern of dissolution of these alloys were also investigated with SEM and discussed.
34. Electrochemical Defluoridation of Drinking Water: Part II

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Abstract
The contamination of fluoride in drinking water from ground water sources has become major problem in thousands of villages in India. By taking active steps through scientific technological approaches, this problem can be eradicated. This paper presents the results of our study relating to the electrochemical removal of fluoride from drinking water with various type (Tank type and flow type) and different capacity (100 – 300l/hr) electrolysers. The electrode materials and other parameters viz., effect of initial fluoride concentration, anode current density, pH, flow rate and additives on removal efficiency were studied and optimized. The electrochemical method can be applied for the effective treatment of higher (≥50ppm) and lower (≤5ppm) concentration of fluoride from drinking water. The rate of removal of fluoride is faster when the initial concentration of fluoride is more than 5ppm. At high current densities the dissolution of anode is not uniform, causes loss of anode without effective use. Whereas at lower current densities the dissolution of anode is uniform resulting higher efficiency of utilization. When aluminium is used as anode, the anode is getting passivated after certain duration of operation resulting voltage increase leads to higher energy consumption. Aluminium alloy (proprietary) gives lower energy consumption. The flow rate of water depends on the current passed and initial concentration of fluoride. When the concentration of fluoride is 5ppm the flow rate of water would be 10litter per ampere hour.
35. Use of GIS as a planning tool for arsenic testing and mitigation in Uttar Pradesh, India

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Abstract
Global Positioning System (GPS) units have been used to locate arsenic-contaminated handpumps, along with safe sources, in affected areas of two districts of Uttar Pradesh. Data obtained has been mapped using ArcGIS software. This revealed an association of arsenic-contaminated groundwater with flood plains and riverine terraces of major rivers and thus sediments deposited in the recent geological past. This information has been used to focus arsenic testing in 289 selected blocks which coincide with these geological units throughout the state, thereby reducing the overall requirement for testing and leading to a substantial saving of time and money. In time, all government installed handpumps in the state may be tested for arsenic, however, this strategy has meant that with the financial and human resources currently available, the areas most at-risk can be tested on a priority basis. Block and village level mapping of the arsenic data for the original two districts in currently underway and this will provide an awareness raising and planning tool for the local administration and communities living in affected areas.
36. Arsenic and Fluoride Contents of the Aquifers Located within the Crystalline Basement Complex Rocks of Southwestern Nigeria

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Abstract
In the basement complex area of the southwestern Nigeria, the depth of the aquifers are mainly 50m with the water table existing mostly in the weathered layer portion of the crystalline rock. The water yield is usually 50 l/min or less and sometimes even difficult to obtain. The water are classified as moderately hard to hard with a pH range of 7.10 to 7.30 which characterizes the aquifers of the basement complex. The occurrence of arsenic and fluoride in the groundwater systems of Nigeria are not known with certainty due to paucity of data. However, it is believed that arsenic occur naturally in trace form within the aquifers. The available data on the occurrence of total arsenic in aquifers located within the basement complex rock units of southwestern Nigeria revealed a concentration range of 0.02 to 0.04mg/l. The occurrence of fluoride within the basement complex aquifer has been found to be at a higher concentration with a range value of 0.95 to 1.20 m/l. The values of the arsenic metals in the aquifers are slightly higher than the recommended levels of 0.01mg/l by World Health Organization (WHO) in some locations and are generally within the recommended values of 0.05mg/l by the United State Environmental Protection Agency (USEPA) and Federal Environmental Protection Agency (FEPA) in Nigeria. Also, the concentration level of fluoride in the aquifers are within the USEPA and FEPA permissible range level of 0.8 – 1.7mg/l. Other possible trace element constituents of the aquifers located in the basement complex of southwestern Nigeria include manganese (Mn), copper (Cu), lead (Pb) and zinc (Zn). Both the arsenic, fluoride and these trace elements require close monitoring since their presence even in minute quantity / concentration will affect the water quality of the aquifers.

Key words: Arsenic, Fluoride, Aquifer, Basement complex and Southwestern Nigeria
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Abstract
The removal of arsenic from drinking water with the help of chemically activated fly ash bed has been presented. The preparation and characteristics of the bed material has been described. The effects of different parameters like pH and the presence of other constituents have been studied. Various arsenic compounds in synthetic mixtures as well as drinking water samples containing arsenic have been investigated. The effectiveness of the modified fly ash bed for the control of arsenic has been effectively demonstrated taking different quantities of As(III) and As(V) salts. The feasibility and cost effectiveness of the process in pilot plant scale has been studied. The scheme and flow sheet diagram of the model plant has been submitted to NTPC, Farakka for the removal of arsenic in the nearby locality. The utilization of the bed material after use has also been discussed. The results of using fly ash bed filter was found to be satisfactory and could be used as low cost treatment method for the removal of arsenic with improvement of the quality of drinking water.

Key words: Chemically activated fly ash bed, arsenic removal, pilot plant scale.
Abstract
Kerala Rural Water Supply and Sanitation Agency of Government of Kerala State, India, with the assistance of World Bank, has planned a community based safe drinking water supply scheme in the rural sector. The project aims to provide safe drinking water with groundwater as the main source. However, identification of potential groundwater sources is essential for the success and sustainability of the project. It is in this context this study was carried out in Koothaly Grama Panchayat in Kozhikode district. Physiographically the area is characterized by undulating topography. The main rock type in this area is Hornblende Biotite Gneiss of Pre-Cambrian age. Hydrogeological data on depth to water table, depth to bedrock, sub-surface lithology, water quality, perenniality of the source, etc., were collected and analyzed. All the available secondary data on geology, hydrogeology, borehole lithology, rainfall, etc., were also collected and processed. The geomorphology, land slope characteristics and lineament distribution were also studied. All these information have been integrated to delineate the Grama Panchayat into a number of zones suitable for different types of wells. Annual groundwater availability in this Grama Panchayat is estimated as 3.53 Mm$^3$ as against the current domestic water requirement of about 1.16 Mm$^3$. This clearly confirms that groundwater can be a very promising source for community drinking water supply schemes in this Grama Panchayat. Dugwells or ponds are found to be better suitable in
this area as compared to borewells. The experience gained in this study can be profitably employed for planning a sustainable development of water resources with beneficiary participation in other Grama Panchayats.

**Key words:** Hydrogeological Investigations, Rural Community Participation, Drinking Water Supply, Kozhikode.
39. Management of Groundwater and Arsenic Issue in Bangladesh

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Abstract
Seasonal variation of water availability forces Bangladesh to depend more on groundwater use both for agricultural and domestic use. Present irrigated area of the country is about 60% of its cultivable area and out of the 60% irrigated area, 63% is irrigated with groundwater. About 90% of household water supply depends on groundwater. Water quality issues during dry seasons, especially the recent problem of arsenic contamination of groundwater, have added another adverse condition for water management. Some areas in 60 out of 64 districts are affected by arsenic contamination. High concentrations of arsenic are found in water from thousands of tubewells across the country and about 30 out of 130 million people are affected. Therefore, Bangladesh cannot afford to leave almost 25% of her population under arsenic hazard. Moreover, it is suspected that there will be possible reductions of crop production due to arsenic contamination if unattended. The country cannot afford these adverse affects since it is already struggling to meet food requirements for her increasing population. Therefore, utilization and management of groundwater and especially arsenic contaminated water has become essential. It has become more important for increasing agricultural production and its sustainability and for providing safe drinking water, especially during the dry season, November to May.
During the dry months, the groundwater table goes down and in several places beyond suction limit (>25 feet or 10 meters), coastal area water becomes saline and unsuitable for irrigation purpose, arsenic content in groundwater become high and cross safety limits (>0.05 ppm). Therefore, the country faces various water related problems and demands better management of water resources for crop production and human consumption.

During June to October the country receives plenty of surface water from catchments area within and outside Bangladesh and through rainfall. Combined effect of these accumulated water resources, often create floods of different magnitude and duration. Only fortunate part of situation is that groundwater is fully recharged during this period of the year with exception of Dhaka city area where groundwater withdrawal rate is higher than the recharge capacity. The recharged water body is used subsequently for irrigating dry season crops and for household purpose. Floods and standing water in major areas of the country during May to October limits crop diversification and improved crop production to during the months November to April/May. Rainfall during these months is scanty and surface water unavailability is also a problem as most of the smaller rivers and low lying areas become dry during this period of the year. Access to good quality water and its proper management are therefore, very important for agricultural development and assured supply of drinking water during these months. Management strategies will be suggested in this paper for sustainable use of groundwater resources and with especial emphasis on use of arsenic contaminated water.
Groundwater Resources Sustainability in Qatar: Problems and Suggested Solutions

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Abstract
The State of Qatar has no surface water and the only accessible and renewable conventional source of water is groundwater that is being recharged from the sparse rainfall within Qatar. The abridged groundwater balance explains that the abstraction by the Qatari farms is always greater than recharge from rainfall apart from few exceptional years and the accumulated deficit is estimated to be more than 2180 MCM by the year 2003/2004.

The aim of this paper is to identify the existing pressing problems that cause groundwater deterioration in Qatar and suggest a set of applicable technical solution to protect and develop the on-hand groundwater resources and advocate new non-conventional ones that could be unswervingly used in agriculture or used as a source of water for artificially recharging the groundwater aquifer, so as to fulfill current and future demand of the agricultural sector.

Nevertheless, the foremost problems are identified and summarized as follows: Severe climate conditions, Very limited water resources, inefficient use of water in most of the Qatari farms existing technical and institutional obstacles, ambitious agricultural and industrial national development plan, Urbanization, and High rate of population increase.

The main elements of the proposed set of solutions are: developing the institutional and administrative structure of the organization responsible for groundwater resources management, intensify the water awareness campaigns, fully utilizing treated municipal and industrial sewage effluent in agriculture, the use of either the economically viable desalinated water or the imported freshwater in agriculture and increasing the recharge rate of rainfall to the groundwater aquifer.

Results showed that the gap between resources and demand can be bridged and sustainable use of groundwater can be achieved in case of taking these proposed solutions into account.
Abstract
Open wells in the coastal regions are inapt for drinking purpose mainly due to series of contamations from seawater, household sewage, agricultural residues and coir industry waste. The well water quality decline is due to continuous accumulation of suspended and dissolved components in the aquifer. The quality problem is a major concern and incremented over the past 10 years, given the rise in population. However, open wells are the main source of domestic water supply in coastal and backwater dotted households. These open wells are shallow ranging from 1.50 to 2.80 meter deep and less than 2 meters diameter. The density of wells is approximately 250 nos. /square km. and these areas receive an average of over 3000 millimetres rainfall annually.

The objective of this participative experimentation is to improve the safe water availability in the household wells, being the most common and easy accessible water source option. PLANET KERALA in partnership with Kerala Rural Water Supply and Sanitation Agency was selected under the World Bank India Country level Development Marketplace 2004 competition. Two Coastal Panchayaths were selected - Kadalundi and Chengottukavu in Calicut District, Kerala State, India.

The process is a simple technique, which involves collection of rainwater from rooftops and feeding directly to the wells. The rise in water level causes seepage into the surrounding aquifer thus replacing the existing high dissolved solids contained water with soft rainwater. The rise in water level in the well, results in reverse flow of water concentrically and cleansing action (Fig. 1). This process enables a speedier measure for replacing existing contaminated ground water with soft rainwater. Once the water column in the wells is filled, the excess rainwater slowly seeps into the surrounding aquifer. Thus continuous backwashing enables exchange of contaminated hard water with soft rainwater.
Essentially, backwashing of well is a ground water exchange process whereby quality of the ground water is improved through initial diffusion and a displacement process. Over a continuous period, it is noticed that the excess accumulation of chemical and other contaminants declined and regaining the water quality.

The material used for installation comprises of locally available PVC pipes and gutters and can be easily fixed with minimum skills of a local Plumber. Along with technical guidance and with the help of community volunteers and partner households, the pilot demonstration units were installed. A functional backwashing system does not incur any monetary operational and maintenance cost, except for occasional cleaning.

Continuous participation of the problem household in the technological development and social appropriation from the beginning of the experimentation is the basic philosophy applied here. Each individual household is initially appraised over the water related issue and then placed options by the facilitators, which could be tried out. The essence of this approach is to facilitate ownership building among the households and to set them as interested partner in the process development initiative and to improve the post operational sustainability.

Participatory community experimentation is a continuous process, and this is a humble and small beginning towards addressing water issues through local tailor made solutions in the coastal regions.
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Abstract
This paper presents a study attempts to determine groundwater inflow and outflow along Gombak River in the upper Klang River Basin. The study is increasingly recognized as it contributes important implications for the nearby groundwater flow with respect to quantity and quality. It involves hydrological and geological analyses that include the study on seepage rate, lithology and physical properties of sediment beds. The research was carried out since September 2004 during low flow conditions of the river. Investigation on seepage rate was conducted using river discharge and seepage meter measurement. Both methods show a significant view that groundwater influx occurs along the river. This scenario is explained based on geophysical exploration results that indicate a shallow water table as well as granite composition below the sediment beds. The investigation on grain size distribution (sieve analysis) shows that the sediment particle is finer as moving down the river. It causes hydraulic conductivity and permeability that affects the seepage rates at the study area. Overall, it is observed that river-groundwater interaction depends on hydrology and geological setting of the area.
Abstract

The significant area of dispersing powerful pebble water – bearing horizon provides an opportunity of creation in them practically of unlimited adjusting capacity. Preliminary in them operating a level of underground waters on 5-10 m and more can ensure adjusting capacity, in most cases quite sufficient for use water – bearing pebbles of horizon as underground reservoirs for seasonal and of many – years regulation of a drain of yet not used part of superficial waters (plenty of flood waters and not vegetative the period).

Water – bearing horizon in pebbles, described raised water – permeability, large square spreading and significant total powerfulness, practically provide an opportunity of development of wide network of high-efficiency chinks of vertical drainage and centralized economical drinking water supply. Debit of them can make from tens up to 100-200 l/sec and more, and effect drainage many tens and hundreds hectares. On the basic objects irrigation of Northern Tajikistan and Kizilsu – Yakhsu valleys the network of such chinks can supply the most economic joint decision (in comparison with machine irrigation in a combination with horizontal drainage) tasks on melioration of irrigated grounds and covering of deficiency in irrigated to water.

On the water – supplied objects of irrigation, requiring in land improvement of the salted grounds the chinks in pebbles can ensure more economical decision of ameliorative task with passing use of basic weight pumped out fresh and concerning
fresh underground waters for irrigation and washings, and also for centralized of economical drinking water supply having here and important ameliorative meaning (at the expense of the termination winter water serving for this purpose on irrigating network). Marked debit from cases is possible at downturn of a dynamic level on 10-15 m (specific debit from 35 up to 10 l/sec and more) and depth of chinks about 50-100 m. Deposit of chinks of a considered type, in the volume number by a diameter up to 800-1200 mm, is provided already with available self – propelled machine tools high – speed rotor drilling with direct and return washing. The large diameters of drilling simplifying a task of creation of the powerful grave – sandy filter around stronger of a chink, sharply reduce at the end specific cost of pumped out underground water. The rather small productivity existing horizontal drain in cover small-ground is conditioned sometimes not only lowered filtered ability the last, but also small dip of drain is direct under a level of underground waters. In particular, it is caused also by that in already wetted and strongly becoming swollen small-ground practically was not presented possible to put in pawn deeper drainage.

Taking into account this phenomenon, on again mastered virgin grounds the drainage should be pawned still in dry well steady small-ground. At pumping out is superficial (0-1-2 m) deposit of underground waters from a single chink or their small group, when they do not cover completely file subject land-improvement, in an external contour already on small distance from a chink the depth up to a water mirror can be of less design norm of drainage. Here, alongside with outflow to a chink, earth waters will be spent and for total evaporation from a soil cover.
Abstract
The UN (1992) projects that world population will, under the most likely scenario have increased from the 5.3 billion of 1990 to 6.3 billion by 2000, growing there after to 8.5 billion in 2025, 10.0 million in 2025, and 11.2 billion in 2100. The World Bank’s project are very similar. Nearly all of this growth is anticipated to occur in today’s developing countries, increase in world population would mean increase global demand of energy, which with current energy technologies, would result in increase in green house gases (GHG). Nigeria’s natural environmental resources and the quality of water is severely threatened, according a 2002 U.S Agency for International Development (USAID) study of the challenges and possibilities facing the Nigerian environment. The report found that increasing poverty, high population growth and migration, especially into urban area and political/institutional constraints are the underlying causes for environmental degradation in the country.

The paper therefore aims to emphases that when making plans for long term ground water quality management in Nigeria, dispersion modelling is important top project trends in ground water quality, which include what to monitor, how to monitor, where to monitor and the data collected from ground water quality monitoring systems may be used for a variety of purposes.

The paper concluded that in Nigeria, ground water quality management aims to maintain the quality of the water that protects human health and welfare but also provides protection of animals, plants (crops, forest, natural vegetation), ecosystems, materials and aesthetics, such as natural levels of visibility was also discussed.
The multifarious beneficial use of water is well recognised by policy makers. Its scarcity makes the different uses competing with each other for primacy. Water is essential for development and industrial use, as for domestic purpose and sanitation as also for agriculture. Which of these should be given priority would be the teasing question facing a policy maker.

In a writ petition\(^1\) before the Supreme Court by a resident of Delhi against Haryana for release of water of Yamuna to Delhi, an argument was advanced that among different uses of water right to drinking water would prevail over other uses. The argument was attractive to the court also. But, because of a memorandum of understanding among the riparian states the legal question was not gone into. Again in Sardar Sarovar Project\(^2\) case the Supreme Court specifically adverted to the beneficial effects of the dam that it would alleviate drinking water scarcity in parts of Rajasthan. These dimensions add to the complexity of the problem.

The sharing of river water relates to irrigation and linked to food security. The state of Tamil Nadu has an agreement with the state of Andhra Pradesh for bringing Krishna water to the city of Chennai, as a solution to its drinking water scarcity. Even within States, the sub-regionalism prevails. These aspects should be seriously addressed by the water managers for the purpose of allocation of water and the existing legal framework has to be critically examined.

Chennai, the capital of Tamil Nadu, is prone to water scarcity. Drinking water is a constant issue to be addressed. A solution to it has evaded successive governments. One of the projects to solve this was bringing water from Veeranam lake to Chennai. This has been a non-starter for a long time. A new Veeranam Project was proposed whereby it was planned to draw sub-surface water from Kollidam and bring it to Chennai. The agriculturists around the area objected and filed a writ petition\(^3\) in the High Court challenging the government decision. A strong reliance was placed on T.N. Ground Water (Development and Management) Act, 2003. Host of other issues such as locus standi, scope judicial review of policy decision, and governmental privilege to maintain confidentiality of its files was considered. The paper seeks to highlight the issues.

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\(^1\) Delhi Water Supply & Sewage Disposal Undertaking And Another V. State Of Haryana And Others, 1996-(2)-SCC -572  
\(^2\) Narmada Bachao Andolan, V. Union Of India And Others. 2000-(10)-SCC -664  
\(^3\) S.Ramamirtham V. State of Tamil Nadu, 2005 Writ LR 451
involved in the matter, including the provisions of the above Act, as in future water disputes would attain complex dimensions involving competing rights over its use.
Abstract

Ground water is of special importance and interest in the development and improvement of agriculture and is of great significance in the economic uplift of small and marginal farmers in the rural areas. Wise use and management of ground water for irrigation give the farmer security and sustainability. It is all the more important in hard rock zones since the porosity of the rock is about 3%, the thickness of the weathered zone is about 3-20 m and only about 8 to 12% of the rainfall is entering into the ground and form ground water resources. In most of the hard rock areas especially in the southern peninsula, the ground water is depleted due to over exploitation / mining and in TN, many districts the water table has gone beyond 300 m due to over exploitation. Under these circumstances, the ground water management is very critical in hard rock areas for sustainable agriculture. This paper gives in detail various ground water augmentation methods and water management practices for various crops including use of water saving method of irrigation in surface irrigation and introducing advanced methods like micro irrigation etc.

The various augmentation methods to increase the recharge of ground water from 8-12% to 15-20% are construction of percolation ponds, check dams, providing barriers across nallas, taking soil and water conservation measures like contour bunding, contour trenches, contour stone walls, farm ponds, recharge pits etc on watershed basis. The pumped water from the well should be taken to the field for irrigation through lined channels or pipes which can save about 20-25% and providing distribution and control structures after the land / field is leveled and shaped to use the water efficiently.

The water management practices like water saving method or SRI method for paddy cultivation will save 40-50% of water and increase the yield by 30%. By practicing paired row, alternate furrow irrigation for all row crops, about 20-30% of water could
be saved without affecting the yield. Advanced method like sprinkler, for closely spaced crops and drip irrigation with fertigation for all row crops and wide spaced crops can be introduced in a big way since it is hardly 1% of the irrigated areas in the country to save water about 30-50% and to increase yield.

Selection of crop which gives more profit per unit of water/ unit time/unit area is important in well irrigation which will also help to maintain the water table at a reasonable level. High water consumption crops like paddy, sugarcane, banana should be prohibited/ banned to grow in well irrigation areas.

This paper gives in detail the various technology with case studies for augmentation of ground water and research information for the economic use of water for various crops with economics. If we follow these methods, ground water level can be maintained at a reasonable depth in a sustained manner.
Abstract
The groundwater in Bangladesh is severely contaminated with arsenic and about 35 million people are at risk of arsenic toxicity. A total of 53 districts out of 64 is arsenic affected having concentration beyond Bangladesh Standard. Nearly 10,560 cases of Arsenicosis patients have been identified and in the most cases they are experiencing socio-cultural impacts. Considering importance of arsenic contamination, Bangladesh Government has prepared and enacts National Policy and Action Plan for Arsenic Mitigation in 2004 Providing safe drinking water to the affected people is essential and treatment of arsenic contaminated water is one of the options to do this. Among the available methods of treatment, adsorption on activated alumina is a promising one for implementing on a small-scale rural community or household levels.

The objectives of this paper is to delineate the level of arsenic concentration in groundwater, present scenario of public health and socio-cultural impacts, existing regulation and policies of Bangladesh Government for arsenic mitigation and performance study of activated alumina adsorption process as a treatment option.

Arsenic victims of some villages of Narayanganj and Sylhet districts were selected as the primary source of information on public health and socio-cultural impacts of arsenic. Media coverage on arsenic victims, research reports and articles were the basis of secondary source of information. Column study was conducted in the laboratory to evaluate the performance of activated alumina in removing arsenic from water under different conditions such as different oxidation state of arsenic, iron and pH of water.

It has been found that arsenicosis is hampering the physical development, proper psychological as well as socialization of a child. Arsenic patients of all age groups are often identified as patient of leprosy and remain ostracized. In different parts of the country divorce is occurring due to arsenicosis. It is obvious that arsenic is more prevalent among the poor, who are forced to take contaminated tube well water.

Laboratory experiments for arsenic mitigation show that As(V) is removed efficiently than that of As(III) by activated alumina adsorption. A negative correlation was found between the volume of treated water and arsenic concentration for both cases of As(V) and As(III). Iron has a significant negative effect on As(V) removal and some positive effect on As(III) removal efficiency. As(V) removal efficiency is better within the pH range of 5.0 to 6.0, whereas, As(III) removal increases at higher pH values.
Abstract

Most of the current research in relation to the arsenic issue is directed to the technical aspects of the problem. Very few have seriously looked into the development of the organisational and institutional structures that are essential in the successful implementation of any solution. Because the underlying processes in setting up these structures tend to have large time constants there is an inevitable tension between the need to solve the immediate problem and the sustainability of their supporting organisational and institutional institutions on the longer term. Contrary to social changes, pure technical developments and installations can be done relatively quickly. Reasons for the lengthy character of the social process are found at various levels. Within the rural system there are direct social, institutional and economic limitations that inhibit the local communities to solve their problem. Nevertheless, in a broader context there are influences from outside the system, which further restrict the local communities to take matters in their own hands in their search for endogenous solutions. The questions are about the source of these constraints and how they influence local drinking water supply systems?

In this paper we present an approach to streamline the technical and social processes and their inherently differing timing. In short, scientific work and field implementation activities can be linked by using so-called ‘triggers’. For example a water-testing programme can be used to spark off the participatory dialogue in the villages. In the same way geological data acquisition, the construction of a social map, a risk analysis, or other research input can be used as triggers. At the other hand, a short-term solution for the immediate problem might create room for further research on long-term solutions and the use of endogenous knowledge and information from the local people is an essential ‘trigger’ for this. The approach presented here incorporates attention to internal as well as external factors, as both will have their impact on any future solution.

Key words: Drinking Water Institutions, Arsenic, Social Processes, Implementation, Participatory dialogue, Rural Bangladesh
49. Limitation of Remote Sensing and Geophysical Techniques to Explore Groundwater Resources in Indian Himalayas

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Abstract

History of groundwater exploration and its development in Indian Himalayas is a very old affair. Records of historical data suggest that systematic exploration of groundwater in Himachal Himalaya to provide 24 hours water throughout the year for the troops stationed at the forts, on the top of the mountains, at an altitude of 2000 meters above the mean sea level took place in the early 18th century. The traditional knowledge to explore groundwater resources in the past, was based on the simple geological observations which were combined with the spiritual knowledge (emphasizing on use of intuitive power of mind developed by practicing meditation) scientifically developed by the ancient hydrogeologists/ Pani wala babas/ water diviners as they were usually called. The hydrogeological development and groundwater exploration was at its peak at that time. Contrary to this the modern techniques are still unable to locate sites with conformity to develop groundwater resources in the peaks.

With the arrival of Britishers in early 19th century in the mountain kingdom of Himachal the traditional knowledge was lost, as the western science was based more on instruments and not intuitions. Hydrogeological knowledge thus paved way for the geophysical methods and remote sensing techniques later engulfed the basic hydrogeological observations. These methods have been unquestionably used to explore groundwater resources in all the terrains but with only 60-70% success rate in Himalayas.

Present paper highlights the limitations of these modern techniques in exploring groundwater resources and strongly objects to its unconditional use, which has literally no application, particularly in Himalayas and all mountain ranges in general.

Based on the data of more then 8000 borewells drilled in different hydrostratigraphic zones identified by Arya,(1996) in Himalayas, the author suggests that the success rate to develop groundwater resources by drilling borewells is 100% guaranteed using the simple geological observations and the traditional scientific wisdom practiced by our ancestors in the past in comparison to the modern techniques propagated by the west.

Keywords: Groundwater exploration, Remote sensing, Geophysical methods, hydrostratigraphic zones, Himalaya.
Abstract

In 1981 at the age of six years, I drew a bucket of water from my village public well without any rope or mechanical help and quality of the water drawn was good enough to drink. Whereas in 2005, my villagers use forty to fifty feet long rope to draw water from the same well and quality of the water is not safe enough to drink. Now in India, one fifth of the urban population and three quarters of rural population do not have access to safe drinking water.

The object of this paper is to examine factors responsible for this problem although much of the problem stems from overwithdrawal and pollution of groundwater. What is the Indian Constitutional law pertaining to groundwater and why it has failed to safeguard quality and quantity of groundwater by not resorting to old known techniques like water harvesting.
51. Water Quality in the Western Ghats Rivers in between Goa and Mangalore

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