COMPENDIUM OF RURAL WATER SUPPLY AND SANITATION RESEARCH PROJECTS

VOLUME I

RAJIV GANDHI NATIONAL DRINKING WATER MISSION
DEPARTMENT OF DRINKING WATER SUPPLY
MINISTRY OF RURAL DEVELOPMENT
GOVERNMENT OF INDIA

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CHAPTER – III: SANITATION AND POLLUTION ABATEMENT

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Foreword

The rural water supply programme faces a number of challenges which include: deterioration of water quality, depleting water table and drying of wells due to over-exploitation of water resources, pollution of drinking water sources due to indiscriminate disposal of solid waste and effluent from municipalities and industries and limited financial and human resources.

The presence of high fluoride in groundwater sources in 19 states has put nearly 60 million people at health risk. Nearly one million people have been adversely affected by high arsenic concentration in groundwater in the eight districts of West Bengal. Bacteriological pollution of water sources due to environmental degradation is not uncommon. Several blocks in the country are water stressed due to over exploitation of water sources, making even supply of drinking water difficult.

It is recognized that supply safe and adequate water to rural communities is not possible by conventional implementation and technology interventions. To tackle these sectoral problems, it is necessary to continuously improve technologies and implementation approaches to respond to the emerging challenges. This objective can only be achieved through continuous research and development.

Recognising the importance of R&D in the national rural water supply programme, RGNDWM has been supporting Indian educational and R&D institutions and non-government organizations to undertake specific research and development projects to respond to the emerging sectoral needs. The areas of research cover a wide range of subjects including groundwater recharge, community based water resource planning and management, pollution and its prevention, low-cost and appropriate water treatment technologies, role of nutrition and importance of IEC programmes.

I am happy to note that RGNDWM has brought out the Compendium of Rural Water Supply and Sanitation Research Projects providing an insight into the R&D efforts by various institutions in projects funded by RGNDWM.

I am sure that this compilation will provide much needed information to sector partners on past R&D efforts and help in identifying new research areas that need to be explored.

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Preface

The Indian rural water supply programme is the largest water supply programme in the world, serving over 600 million people in nearly 1.4 million habitations. The challenges in the rural water supply programme include deterioration in water quality due to anthropogenic or natural causes, depleting water tables, drinking water sources becoming dry in summer season and/or drought period, lack of awareness about health and hygiene practices among users and supply driven implementation approach followed by the government in the past.

There is a need for a concerted and holistic programme implementation approach including IEC, human resource development, community participation, R&D, health and hygiene education and cost effective and environmental friendly water supply and sanitation facilities to meet the challenges.

Keeping in view that resources are limited, it is necessary to develop low-cost effective and innovative technologies and implementation approaches to ensure optimal utilisation of resources. The research and development, therefore, is an integral part of the Rural Water and Sanitation Programme.

In late 1980s, the Rajiv Gandhi National Drinking Water Mission (RGNDWM) launched Mini-Missions to evolve models that could be replicated in other parts of the country. Simultaneously, it also undertook an important step to liberally support educational and research and development (R&D) organizations and NGOs to undertake R&D projects in diverse areas such as water recharge practices, water resources management with community participation, development of water treatment and water testing technologies, pollution and its control, impact of nutrition on health particularly in areas affected by water quality problems such as fluoride and arsenic, and effect of heath and hygiene awareness programmes.

This first volume of the compendium is a compilation of thirty-eight R&D projects funded by RGNDWM in the rural water and sanitation sector. The remaining projects will be covered in the second volume of the compandeium which will be brought out later in 2003. It is heartening to note that institutions from all regions of the country have participated in this important effort covering wide range of topics.

The compendium is divided into four chapters namely groundwater recharge, water quality and water treatment, sanitation and pollution abatement, and impact of water quality on health and role of nutrition and awareness campaigns. This publication will help in assessing the potential use of various R&D outputs in the field and identifying new areas for future R&D.

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Abbreviations

AAS	Atomic Absorption Spectrophotometer
APHA	American Public Health Association
BCT	Bhoruka Charitable Trust
BOD	Biological Oxygen Demand
BMI	Body Mass Index
CAZRI	Central Arid Zone Research Institute
CEP	Community Education and Participation
COD	Chemical Oxygen Demand
CWRDM	Centre Water Resources Development & Management
EC	Electrical Conduction
EPA (USA)	Environmental Protection Agency
ESP	Exchangeable Sodium Percentage
EWS	Early Warning System
FRP	Fibre Reinforced Plastic
GFAAS	Graphite Furnace Atomic Absorption Spectrophotometry
GI	Galvanised Iron
GIS	Geographical Information System
GOI	Government of India
IEC	Information Education and Communication
IICT	Indian Institute of Chemical Technology
INRECA	International Rural Education and Cultural Association
MCM	Million Cubic Meter
MMC	Multi Monitoring Cards
MPN	Most Probable Number
NCHS	National Centre for Health Statistics
NEERI	National Environmental Engineering Research Institute
NGO	Non Government Organisation
NGRI	National Geophysical Research Institute
NML	National Metallurgical Laboratory
PHED	Public Health Engineering Department
PRI	Panchayati Raj Institution
PVC	Polyvinyl Chloride
PWD	Public Works Department
R&D	Research and Development
RGNDWM	Rajiv Gandhi National Drinking Water Mission
SAR	Sodium Adsorption Ratio
SDDC	Silver Diethyl Dithiocarbomate
SPRERI	Sardar Patel Renewable Energy Research Institute
TDS	Total Dissolved Solids
SMR	Standardised Morbidity Ration
WHO	World Health Organization

Introduction

To meet the challenge of providing universal access to safe and adequate water and sanitation to rural communities the use of conventional implementation and technology interventions is not enough. Therefore, it is necessary to continuously improve technologies and implementation approaches to respond to the emerging challenges.

Recognising the importance of R&D in the national rural water supply programme, RGNDWM has been supporting Indian educational and R&D institutions and non-government organizations to undertake specific research and development projects to respond to the emerging sectoral needs. The areas of research cover a wide range of subjects including groundwater recharge, community based water resource planning and management, pollution and its prevention, low-cost and appropriate water treatment and water quality testing technologies, role of nutrition and importance of IEC programmes

This is the Volume-I of the Compendium of Rural Water Supply and Sanitation Research Projects covering 38 projects sponsored by Rajiv Gandhi national Drinking Water Mission over the last fifteen years. The reports of the remaining projects will be incuded in the second volume which is expected to be brought out later this year.

The compendium is divided into four chapters as under:

Chapter I	-	Groundwater recharge
Chapter II	-	Water quality and water treatment
Chapter III	-	Sanitation and pollution abatement
Chapter IV	-	Impact of water quality on health and role of nutrition and awareness campaigns.

This publication will provide a brief account of the progress made by various projects and their out puts. This will help sector partners in selecting a potential technology or implementation approach for trial in their projects. Some partners may pick up potential developments for further research and development.

To obtain detailed information, the reader is advised to contact the relevant research institutions.

1 - Water Resources Inventory and their Conjunctive Utilisation for Drinking Water Supply

Study by Bihar College of Engineering, Patna

Introduction

Surface water and groundwater being two distinct sources of water, usually, any one of them is used for drinking purposes. Conjunctive use of surface and groundwater sources for drinking water purposes, however, has not been specifically and systematically planned so far. Realising that conjunctive use will render drinking water supply both techno-economically efficient and sustainable, this project experiments with the same.

Conjunctive use of surface and groundwater for irrigation is now widely accepted as suitable strategy for irrigation development and watershed management. Such conjunctive use, however, is planned on a river basin, command area or macro watershed basis. Allocating different areas in the basin or the command area to be irrigated exclusively by one or both the sources can be planned. Temporarily, conjunctive use can be adopted by irrigating the same area by different sources at different times or in different seasons. Also, conjunctive use can take place by using one source while augmenting its supply by the other source. In any given situation, one or a combination of these methods of conjunctive use can be planned and implemented for optimum and sustainable irrigation, depending on the hydrology of the two sources and the nature of demand.

Objective

The primary objective of the study is to facilitate the development and exploitation the potential of surface and groundwater for drinking purposes. This was done by taking advantage of the complementary hydrology of the two sources in a given watershed. As the two sources have different spatial and temporal patterns of quality, and the technology and economics of their exploitation is also different, their conjunctive use will facilitate integrating the complementaries of their features. This would enhance reliability, adequacy and sustainability of providing drinking water in the given region.

The study aims at developing a model and methodology for understanding the complementary hydrology of the two sources as well as their hydrologic interaction. This will result in a model of general applicability for planning water resources for drinking water purposes through conjunctive utilisation of water sources in mini watersheds. The study area consists of a mini watershed of a river called Khudia, which lies in Damodar Barakar basin, and the sub-area comprises Rajauli and Akbarpur in Nawada district, which is the watershed of river Job, a tributary of river Khuri.

Methodology adopted

Conjunctive use of surface and groundwater combines the advantage of groundwater storage with surface water system and serves as a remedial and corrective measure of efficient water management. Our National Water Policy states that both surface and groundwater should be viewed as integrated resources, and should be developed conjunctively in coordinated manner. Their use should be envisaged right from the project planning stage.

The process of conjunctive use takes advantage of the interactions between the surface and groundwater phases of the hydrological cycle, and also the natural movement of groundwater. To elaborate, planning conjunctive use does not mean optimised development of surface water resources and groundwater resources to serve the same general objectives. Rather, it means complementary use of many natural sub-resources of both systems to allow more cost-effective development. The objectives of water resources development include making optimal use of the complimentary aspects of both the sources of water and their related natural resources. Thus, the principles of conjunctive use of water resources can be expected to be different from those of both surface water systems and groundwater systems considered independently. Obviously, conjunctive use must include the principles involved in both the systems considered independently, but they must also include principles to guide the optimal development of the complementarity of both the systems with respect to storage, transport, energy, water quality and time-responsivity requirements imposed by uncertain rate of growth of actual demand for the resource.

The techniques for integrating surface and groundwater use for drinking purposes are:

Option I: Allocating separate area (conglomeration of population) to surface or groundwater

Option II: Integrating surface water and groundwater in time

Option III: Space and time integrations (combination of options I & II)

Option I: Allocating separate area for surface and groundwater: This is the most cost-effective methodology, specially where the population is scattered. In such cases, individual distribution network for groundwater is usually small. Covered dugwells or tubewells could directly supply water where needed in these low order networks. However, under these circumstances conjunctive use would be effective only if the distance from the major recharge area (that is, surface water storage) and the well is less so that the groundwater flow is sustained by the available gradient. The exact position of the areas marked for groundwater and surface water development depends on the local topographic and geohydrologic conditions. In hard rock areas, groundwater movement would be slower and would require larger gradients. If separate areas are to be planned for groundwater and surface water, the population to be catered to may have to be kept small. Clay soils with low permeability would require much larger gradient. In these areas, the strategy of assigning separate habitat for conjunctive groundwater use may not be successful.

Option II: Integrating surface water and groundwater: This involves allocating surface and groundwater in time so that in a particular season surface water is used and in another season only groundwater is used. Normally, when the same population is to be supplied with surface water at one point of time and with groundwater at another point of time, it would be costlier to have two separate distribution networks. Therefore, a feeding point will have to be identified in the surface network and linked with the groundwater source. Tubewells, openwells and borewells may be allowed to use the same network, which carry the surface water.

Option III: Space and time integration: In many cases, the mixed strategy may have to be used in practice. In option I, where regions are to be divided source wise, exactly similar pattern of withdrawals may have to be followed for both surface and groundwater. This comprises of proper operation and management of surface and groundwater reservoirs for optimum efficiencies by re-adjustment, that is, groundwater levels would be lowered during dry spells and raised during the ensuing wet period. The optimum rate of transfer from

surface to groundwater storage must be large enough so that surface reservoir will be drawn down enough to retain the next high runoff. Artificial recharge by wet year surface flow into the groundwater reservoir may be done through combination of one of the techniques; spreading of water in ponds or basins for infiltration and percolation to the groundwater,
recharge pits,
recharge wells;
construction of underground dykes, etc
intra-annual regime of the uses may vary from year to year in order to take advantage of the stable regime of groundwater.

Transfer of surface water and groundwater from existing areas with sufficient water to more needy areas where one or both the water sources are scarce may be worked out in option III. The distribution network can either be separate and distinct or could be common. In a common network, the groundwater would be pumped into surface water network. In such cases, either the surface and groundwater can be physically mixed or certain rotations can be on surface water and others on groundwater.

Study findings and recommendations

The study has served to consider the conjunctive use of surface and groundwater for the purpose of drinking in a reliable, adequate and sustainable manner in a given watershed. The study has been conducted on existing groundwater and surface water sources, specially for the purpose of drinking. Exclusive application of only surface water or groundwater is not feasible and sustainable in the study area.

A dam of about 20 m high is proposed to create a gross storage capacity of 26.88 mcm in order to serve both irrigation and water supply needs of the pilot study area. Presently, the water supply needs of the area are served though inadequately from both surface sources as well as groundwater sources through tubewells and pumps. About 75 per cent dependable monsoon rainfall of the catchment amount to 85.90 cm and 75 per cent dependable monsoon yield estimated from the study area will be 45.2 mcm. Groundwater availability in the pilot area works out to be 10.8 mcm. The depth of tubewells drilled in the area range between 25 m and 45 m. The diameter of the tubes used are generally 10 cm to 12.5 cm and the yield from each tubewell varied between 0.8 to 2.2 litres per second. Although tubewell sinking is inadvisable and uneconomical from the viewpoint of yield from the irrigation purposes, presently there are more than 11,500-drilled tubewells in hard rock terrains of Chotanagpur and Santhal Paragna regions. Geologist has recommended openwells with lateral holes of tunnels as community wells.

As surface water is not utilised for drinking purposes, efforts should be made to accelerate the recharge of groundwater in Rajauli and Akbarpur in Nawada district. However, at present, groundwater balance in Rajauali and Akbarpur blocks are 769 ha m and 179.8 ha m, respectively. There is a reservoir on river Job with a storage capacity of 9,695 acft, which is used mostly for irrigation purposes. The annual rainfall in the study area is 1,100 mm.

Inventory of water resources of both the pilot areas were prepared and feasible studies were carried out. The other part of the study is to formulate a strategy for meeting the requirements of drinking water supply of the area in techno-economic and sustainable basis through conjunctive utilisation of both surface and groundwater. Further studies are required to develop a methodology for understanding the complementary hydrologies of the two sources as well as their hydrologic interaction, which may be applicable and helpful for other mini watersheds.

2 - Natural and Artificial Recharge Studies

Study by National Geophysical Research Institute, Hyderabad

Introduction

Natural recharge study was carried out in six districts, selected by the Rajiv Gandhi National drinking Water Mission using tritium tracer technique. The districts covered are Bankura, North 24 Paraganas and South 24 Paraganas of West Bengal, Koraput district of Orissa, Nalanda district of Bihar, and East Godavari district of Andhra Pradesh. The project comprises research and development work aimed at achieving sustainable drinking water supply in areas having seasonal scarcity or poor quality of drinking water. Quantitative assessment of the annually replenishable groundwater potential is essential to know about the safe rate of groundwater withdrawal. Natural recharge was measured in some of the districts of the study area for intensive studies. The selected districts are located in agro-climatic zones, where such data is not available. Before the present study was done, studies on natural recharge were carried out mainly in regions of south India covered with hard rocks. The study in the selected six districts would, therefore, bridge the data gap.

Hard rocks cover 66 per cent of the area of the country. Basalts and granites are the main hard rock types. Villages in low rainfall areas of the hard rock region often suffer from drinking water scarcity in the summer months. The study, therefore, proposes to develop a methodology for artificial recharge and retrieval (ARR), which comprises transfer through a borewell of filtered and chlorinated surface water during the monsoon months of surplus, and pumping of the same in the summer months to meet the shortfall in drinking water supply. This methodology can be used for reducing the level of fluoride, iron or total dissolved solids in a localised groundwater source.

Objective

The main objectives of the study were to calculate the annual replenishable groundwater potential for the areas studied and to bridge the data gaps in different agro-climatic zones. This study was done to find the relationship between recharge and rainfall for four major geological provinces of India, namely granites and gneisses, basalts, sediments and alluvium.

The study also aims to develop artificial recharge methodology for hard rock areas in order to augment drinking water sources of some villages in Nalgonda and Ranga Reddy districts of Andhra Pradesh and also to reduce fluoride content of groundwater by artificially recharging the aquifers with surface water containing less fluoride and abstracting the mixed water after a time gap.

Methodology adopted

An injected tritium technique for measurement of natural recharge, based on piston flow model concept for movement of moisture in the unsaturated zone has been developed and was carried out in several basins. Thousands of percolation tanks have been constructed by various Government agencies. However, the percolation efficiency of these tanks has not been quantified. The project aims at using injected tritium technique for quantifying the deep percolation from the tank storage. Efficiency of a percolation tank can be evaluated using this methodology.

Tritium was injected at representative sites in a basin of a mini-mission district before the onset of monsoon. Soil cores were collected from the injection sites after cessation of monsoon. The soil moisture content and tritium content of each soil core was measured in the laboratory and a spot recharge value calculated for each site. The average recharge value obtained from spot values for several scores of sites was used in calculating the annual input to the phreatic aquifers of the basin. Water level data in observation wells selected near tritium injected sites was monitored and compared with recharge rate obtained.

The artificial recharge programme comprised the following activities:

Activity 1: Study of percolation tanks: Selection of two percolation tanks; monitoring of their water levels and water levels of the command area wells; monitoring of conductivity levels of groundwater in command area at periodical intervals; delineation of the zone of influence of the percolation tank (sub-surface command area); and, assessment of quantum of recharge from the percolation tank.

Activity 2: Borehole injection experiments: Under borehole injection experiments, two borehole injection sites, close to two minor irrigation tanks were selected after hydrogeological and geophysical surveys and the following works were carried out:

- drilling of injection and observation borewells;
- erection of filtration and chlorination facility;
- gravity transfer of measured quantity of clean, chlorinated surface water into injection well during the monsoon months;
- retrieval (abstraction) of water from the same well during the summer months next year and supply of this water to the local population;
- monitoring of water levels, fluoride, total dissolved solids etc, throughout the experiment;
- Conduction of tracer tests to determine the velocity of injected water
- calculation of the amount of recovered water as a fraction of the amount injected.

Research findings

Natural research studies: A summary of the results of measurements of natural groundwater recharge in various study areas is given in Table 1. The natural recharge data was used for calculating the input to phreatic aquifers of the study areas in the six districts, which is given in Table 2.

Table 1: Assessment of natural recharge

Selected districts	Study area	Main rock type	Year of study	Seasonal rainfall recorded (mm)	Mean Recharge (mm)
Bankura district, West Bengal	Saltora block Bishnupur block Joypur block	Granite Laterite Alluvium	1995 1995 1995	1240 1147 1147	179 181 137
North 24 Paraganas	Rajgarh block	Alluvium	1995	1454	198

District, West Bengal					
South 24 Paraganas district, West Bengal	Baruipur & Sonapur block	Alluvium	1995	2328	34
Koraput district, Orissa	Putra watershed Parlijhori watershed	Granite Gneiss Granite Gneiss	1996 1996	1250 1100	166 159
Nalanda district, Bihar	Rajgir, Biharsharif, Girihat blocks	Alluvium	1996	750	83
East Godavari district, Andhra Pradesh	Rajhamundry area Sudhagadda Watershed	Sandstone, Basalt Granite Alluvium	1997 1997 1997 1997	863 863 850 850	136 91 41 105

Table 2: District wise input to pheratic aquifers

Mission District (Annual rainfall)	Area (Km^2)	Input (MCM)
Bankura district (1300)	0890	1126
North 24 Paraganas district (1525)	4094	809
South 24 Paraganas district (1775)	8128	213
Koraput district (1520)	27020	4392
Nalanda district (990)	2367	259
East Godavari district (1140)	10818	1090

Natural recharge values show a wide range. This wide range is due to variation in hydraulic properties of soil, rainfall pattern and intensity and hydrogeological conditions. The estimate on natural recharge, arrived at by the tritium injection method, represent the minimum quantity due to rainfall percolation, and they do not account for seepage from river beds, stream channels, tanks or canals.

The annual input estimates can be considered to represent the safe yield or permissible groundwater draft for sustainable development of groundwater resources in the six selected districts. The data for natural recharge in these six districts was used with the other existing data for deriving a rainfall-recharge relationship in four major geological provinces of India, namely granites, basalts, sediments and alluvium.

Artificial recharge studies: The studies about efficiency of percolation tanks, carried out in hard rock areas, identified the factors mentioned below, which affect the efficiency of artificial recharge strategy.

- Shallow water table conditions after monsoon is a common feature in many parts of the hard rock terrain and especially significant in areas adjacent to surface storage. Development of shallow water table conditions below the tank and in downstream side with increase in seasons of ponding and a significant reduction in water table gradient was observed over the years. As a result, groundwater movement becomes sluggish.

Groundwater utilisation should be encouraged in the downstream. Groundwater development should be programmed along with artificial recharge, otherwise, lift irrigation programme should be implemented to pump out the augmented groundwater from the influence area to other areas of non-influence at cost-pricing.

- The impounding height of water column may play a role in increasing the infiltration rate. Most of the percolation tanks are much wider compared to its depth. More lateral spreading of impoundment causes considerable evaporation loss. During planning stage, it is necessary to consider the geophysical nature of the sub-surface over the ponding area and consider the dimensions of percolation tanks and also the level of expected exploitation on the downstream. In general, it would be better to go in for lesser length and more depth. If the geographical conditions are not favouring, then it would be better to go in for cascading system of smaller tanks along the drainage.
- Silting is a serious problem with tanks. Efficiency studies of percolation tank conducted using environmental chloride method in a newly constructed percolation over a granite area indicated a recharge efficiency of 35 per cent during the first ponding season which was reduced to 22 per cent in the second year. The cause for the reduction is attributed to silting. It is impossible to prevent the incoming silt from the catchment area, but adapting a cascading chain tank system (smaller capacity) might prevent the siltation of tanks down below the first one, which is of bigger dimensions.
- Evaporation loss from tank storage is very significant in semi-arid areas. Nearly 4 to 6 mm/day of storage water gets evaporated from the tank. The infiltration is maximum in the beginning of ponding and reduces to the minimum within 10 to 15 days of ponding. The storage is for a maximum period of 2-3 months during the lowest infiltration rate, allowing most of the water to evaporate. A twin-tank strategy should be followed for artificial recharge in the semi-arid hard rock covered region. The storage is released from the tank on the up-stream to other tanks on the downstream in cyclic manner to facilitate more infiltration and percolation efficiency of the total water harvested in the area. This increases the beneficial area.

Influence area of a percolation tank: The zone of influence area of a tank can be inferred from the water level variations (temporal and spatial). Attempts have been made to delineate the zone of influence of a percolation tank using water levels, well performance index and tracer studies. A study was initiated to use a natural indicator, which reflects the effect of infiltrating water over the water quality in the command area of two percolation tanks. The conductivity of runoff water collected in the tank is much lower than the natural conductivity levels of groundwater in the command area. When the low conductivity water in the percolation tank travels sub-surface towards the command area, it is expected to change the conductivity of the water in the zone of influence. Periodical monitoring of water levels and groundwater conductivity in selected observation wells were done for a hydrological cycle (pre-ponding to post-ponding) period. The conductivity of surface water (storage water in the tank) was also measured fortnightly during the ponding period. The relation between the conductivity and distance was studied. The relation revealed that the influence extends up to 550 m from the bund in both the studied percolation tanks. Based on the hydrogeological boundary conditions of the command area and the distance of influence inferred, an area of about 82,000 m^2 or 8 hectares is estimated to be influenced by the percolation tank. The analysis of temporal and spatial variations in conductivity of samples helped in grouping the beneficiary wells into strongly, moderately and weakly influenced categories. The results of this study suggest that a simple tool like conductivity can be effectively used in demarcating the influence of an artificially recharged structure.

In-situ fluoride reduction through borehole recharge: A field experiment conducted near Malkapur village in Nalgonda district of Andhra Pradesh for two years resulted in a reduction of fluoride content in the aquifer area of 22.5 m radius by 40 per cent. The field experiment demonstrated the feasibility of alternate technology for solving the problem of fluoride contamination in drinking water. The pilot scale experiment attempt indicated that for replicating the borehole recharge technique for reducing the fluoride content, the following measures are necessary to be considered before implementation:

- The catchment area for collection of surface water to be used for artificial recharge should be smaller in size so as to avoid the fluoride content in the surface water source;
- Filtering of surface water before recharge is very necessary and it is recommended that a two-stage filtering (a rapid sand filtering, followed by a slow sand filtering) to be followed;
- Chlorination is to be followed by using a liquid chlorine injection by drips.

Utilisation of research findings

Results obtained through natural recharge in different agro-climatic zones were utilised for validating and refining rainfall vs recharge relationship established for four geological provinces (granites and gneisses; basalts, sedimentaries and alluvium). State Governments can also utilise the findings for knowing the safe yield of a region/watershed for development of water resources.

The artificial recharge studies on percolation tanks clearly indicated that nearly 50 to 60 per cent of the volume of harvested water is lost through the process of evaporation and soil-moisture. It is necessary to minimize the non-potential loss and utilise the resources for development of region. Different measures like optimal desilting are being tested through the support of various agencies. The artificial recharge and recovery test conducted in fluoride-affected area demonstrated the potentiality of this tool for tackling the quality problem. The methodology is under testing in other areas of fluoride-rich groundwater pockets.

The natural recharge studies carried out over the last 25 years brought out a solution to have a first order estimate of dynamic groundwater potential of an area through the established rainfall-recharge relations. The States can use it for planning their activities. Further, data generation may help in preparation of annual recharge contours of India, similar to that of rainfall, evaporation, etc.

In the case of artificial recharge, the percolation tanks are simple. But there is a scope for further research on increasing the potential utility of these harvesting structures like optimal designing of tanks, utilisation of percolation tank water during lean percolation period, utilising the soil-moisture in the tank bed area during receding of storage, etc.

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3 - Artificial Recharge of Groundwater by Enlarging Voids, Fissures and Joints

Study by Natural Resources Development Cooperative Society Limited, Andhra Pradesh

Introduction

Prakasam district of Andhra Pradesh is a drought-prone region with vast upland areas. Although it receives 500-600 mm of rainfall annually, rainfall is quite erratic in this region, with temperature shooting up to 45 degree C in the summer months. Due to adverse conditions, the possibility of raising dry crops is also uncertain, though soil is fairly fertile.

The entire area in the district, except a few parts along the coast, is covered by crystalline rock strata, and is not amenable to easy percolation from the little available resources. Generally, the weathered zone extends up to 10-15 m deep. It is porous and rocky beyond 15 m, and have minor voids, fissures, cracks and cavities with little scope for infiltration of water. It is, therefore, necessary to exploit groundwater resources like borewells in this and similar other areas, to face adverse conditions.

In the absence of sufficient recharging facilities and increase in voids, fissures and cracks at depths beyond 15 m, there is a decline in the water table and gradual reduction in discharge in the borewells in this region, and other drought-prone areas. With the reduction in discharge of borewells, there is corresponding reduction in ayacuts, too. The old irrigation wells have also become dry. As a result, many villages are faced with severe drinking water scarcity. Hence, augmenting the groundwater by artificial recharge within the joints and fissures of fractured rocks is the only possible way to increase aquifer storage capacity and the water level in the borewells.

Objective

The main objective of the study is to identify the regions, where groundwater potential is less, but at the same time, the area is under imminent threat from water crisis. It seeks to monitor groundwater level of these regions, and study the fractures developed before and after the experiments done on 20 observation wells in the project area of Santhapet, Ongole and Prakasam districts of Andhra Pradesh. The study also ascertains the enhancement of fissures, joints and cracks in different geological formations to assess the impact of blasting. The data thus generated would facilitate other regions with similar problems to follow the same procedure for enhancing groundwater level as per the suitability of the area. The rural mass can also utilise the facility in their existing wells with nominal expenditure.

Methodology adopted

Experiments were conducted in the project area of Santhapet, Ongole and Prakasam districts of Andhra Pradesh, and the results were quite encouraging. The project studied the depth of voids and fractures, the characteristics of the joints and fissured rocks and assessed the groundwater potential. Groundwater was analysed as per the standards in the laboratory along with the following operations:

- Static water level before experiment;

- Assessment of yield of borewell by pumping method;
- Geophysical survey to ascertain the depth of fractures;
- Post blasting static water level to know the impact
- Assessment of yield of borewell in the post-blasting period

Research findings and its significance

Artificial recharge of groundwater assumes great significance in Prakasam district, where different geological formations like cumbum shares, metavolcanics and meta sediments of dharwards, granites, charnockites and precambrian exist. Augmenting of borewells by controlled blasting in agricultural fields has proved successful in this region. Deep fractures have openings and increased the water level in the shaly. A well to be used for drinking purposes was identified, where yield cold be increased by 20 per cent. The rate of increase in water is more than 80 per cent in five cases, more than 60 per cent in three cases and 20 per cent in one case.

This technique could be applied at a low cost on unutilised borewells for irrigation as well as drinking purposes. In large-scale operations, the cost of blasting material and inputs range between Rs 1,000-2,000. Yield in about 1,800 borewells and 3,000 in-well bores in Prakasam district can be increased, if implemented properly. The scheme would also benefit lakhs of people throughout the State. In fact, this technique could be used across the country to augment yield in borewells by enhancing voids, cracks, fractures and fissures through controlled blasting for artificial recharge. This would put the unutilised wells into use, and would also help in rejuvenating drinking water resources in problematic regions.

4 - Development of a Replicable Model for Drinking Water System Through Improved Groundwater Recharge

Study By Society for Rural Industrialisation, Bariatu, Ranchi

Introduction

Piped drinking water is an index of "quality of living". In urban area, where public facilities are managed by organised technical departments with other infrastructure supports, it is easy to install, operate and maintain drinking water supply system and ensure reliability in quality and supply. In rural area there is no public body to take charge of such a system, as there is no organisation and the economic status of the users is low. The users lack will and capacity to maintain such systems. The sense of ownership is absent, and therefore, even if the system is installed with outside support, it will not be sustainable.

Management of ground water and surface drainage are vital for a dependable source of water. In order to address these issues a package of technology, which the villagers can implement, operate and maintain was developed as part of this study. The study was conducted in a Micro-catchment of a watershed in Angara block of Ranchi district, Jharkhand with a population of 40 families (Tribal). It has two characteristics

(a) Data based recharging plan.
(b) Creation of awareness and capability of the users to manage drinking system.

Objective

The objective of the study was as under:

(a) To improve availability of potable drinking water to each family by enriching ground water potential through watershed development.
(b) Organising and training of village group in the implementation of technology and its management.
(c) Dissemination of developed package of Technology to grassroots organisation.

State of Knowledge

Technical: There are two faces of technical knowledge, namely:

(a) About hydrogeological phenomena.
(b) Cost effective, affordable and treatment techniques for construction of surface structures.

Hydrogeological: Satellite photo interpretation technique, analysis of toposheet, soil and geographical map, study of crop pattern and their correlation technique are known procedures. This knowledge provides information about relatively larger area without providing a method of pinpointing locations of water source for development. This method can be adopted by villagers after necessary training.

Treatment Structure: Normal land and water management in a treatment structure in a watershed requires rudimentary knowledge of soil conservation and run off control. In some

cases, appropriate technology for construction using local material and skill may be available. When it comes to recharging groundwater for drinking water purpose, additional knowledge is required to tackle pollution (filtration- physical and bio), hygiene etc.
Social: So far potable drinking water system management is linked with the organised sector and sophisticated techno-economic management. It presumes certain social habit of users for maintenance of hygiene etc. In case of rural water supply, the above management system is not financially viable. And therefore, the system is designed, implemented and operated by external agencies without consideration of the social habits, attitudes of the users and their capability to pay makes the system unsustainable. It is therefore necessary to conduct a study to understand socio-economic factors governing the tribal community behaviour.

Research methodology adopted

Selection of study area is based on following criteria:

(a) No. of households and distribution.
(b) SC & ST population.
(c) Accessibility to drinking water source.
(d) Existing water harvesting structures.
(e) Area accessibility.
(f) Hydrogeological investigation:
    (i) Sub surface geological mapping/flow net analysis and correlation with contour.
    (ii) Determination of potential for vertical drainage and storage.
    (iii) Determination of possible location of peculation well following resistivity and flow net analysis.
    (iv) Determination of W.H.T. for rainwater harvesting and recharge.
(g) Engineering and system study for feasibility, construction, operation, maintenance and replication:
    (i) Survey for detail engineering data
    (ii) Analysis, design and estimate
    (iii) System design and validation by users.
    (iv) Group formation and training of selected youth for various functions.
    (v) Implementation by trained youth.
(h) Socio-technical intervention to create a conducive environment to develop drinking water supply systems in hamlets through:
    (i) Audio visual media and demonstration.
    (ii) Construction and use of wells, tube wells (hygiene & environment).
    (iii) Construction and use of pond- biological method of cleaning and plantation around.
    (iv) Use of pre-filters before storage in the pond.
    (v) Planning for water supply system with users participation.

Research findings and their application

(a) Evolve a water budget for the area: The average per capita water demand for drinking, cooking etc. is 150 L/day. This was compared against the net receivable water, which was found to be almost 100 times. The present demand Hydrogeological survey was conducted to correlate the surface feature with respect to subsurface geology depicting present groundwater status and subsurface weathered layer. This helped in establishing relation with respect to extraction.

Based on the above, adequate measures to conserve the surface run off was planned.

(b) The Hydrogeological survey of the area revealed the following:
- Considering the surface contour, resistively contour, subsurface flow outcrop, the location of the main subsurface fracture zone could be identified.
- The resistivity contour indicates that, there is granite barrier on either side of the existing surface drainage, contributing to subsurface flows.
- Control of the subsurface recharge can be affected by increasing the retention time of the surface precipitation in identified zones through water harvesting tanks, plantation, check dam etc.
- The extraction potentiality of the available surface water can be developed by improving the permanent moisture zone, spring and water harvesting structure in identified zones.
- Based on the above, following treatments at various locations were undertaken:
  - Moisture conservation pits.
  - Check dam.
  - Vegetative hedge and bound side plantation.
  - Plantation on wasteland.
  - Social fencing for protection of existing forest etc.

(c) Infiltration well with filter, developed as the water utilisation structure is used as source for supply of drinking water. The recharging was ensured by the treatment techniques described above.

(d) The steep slope of the catchment of the well was treated with vegetative hedge, random barrier and moisture conservation pits.

(e) The villagers have constructed a separate platform near the well for utensil cleaning etc. in order to protect the water from any kind of contamination.

(f) People's Committee at hamlet level (Tola Committee) was organised to conduct weekly meeting to execute the approved plan (by the villagers) and solve the operational problems immediately.

(g) The study has given an occasion for the people to organise and form a committee. This committee has initiated various other development activities in the hamlet.

(h) Identification of operational difficulties and solutions- Technical and social: During the course of study, number of technical and social difficulties due to specific topographical features and land ownership issues came up. The alternate solutions were evolved by participatory discussions with the villagers.

(i) People's organisation: Right from the initiation till completion of the study, villagers were organised and trained for various functions to transfer the technology package for recharging and utilisation (of drinking water) through a reliable hygienic system.

Utilisation of Research findings:

Under the watershed development programme, the TSP area of Jharkhand has been identified as the priority zone. The preliminary works have been initiated in some of these areas by NGOs and Grassroot organisations. Owing to similar geographical and socio-cultural characteristics, the system developed under the present proposal has an enormous scope of replication. Foreseeing the this need, preparation of training package for NGOs and Grassroot organisations has been included as part of this study.Linkages for that purpose has already beern established with Pani Chetna Manch, Daltanganj, Jharkhand.

Once the system is standardised, the flow-net analysis technique can be extended to the entire area of Tati Singari Watershed for assessment and exploration of ground water. Following preparation of Tati Singari Watershed Plan, DST has sanctioned the implementation of plan, which is going on.

Scope of further Research

In highly water scarce area where the statiographical character is unfractured granite rock, the recharging will not help creation of subsurface storage. Further study and research will be needed for identification and location of appropriate sites and special cost effective concrete or polythene structures for underground storage. The research will involve study of differential permeability criteria of the area, subsurface flow, drainage and several alternative structures for ground water storage using modern appropriate technologies.

5 - Investigation into the Geohydrological Profile and Groundwater Level in Relation to Rainwater Harvesting Structures

Study by International Rural Education and Cultural Association, Dediapada district, Gujarat

Introduction

The study area consists of two tribal villages of Dapada and Pati in Dadra and Nagar Haveli. The terrain of the area is hilly and undulated, with a number of small rivulets and valleys. The daily consumption of water, particularly for drinking purposes and other domestic uses, is quite less compared to other parts of the country. Yet, these villages face drinking water crisis during the summer months, as rainfall is erratic. Groundwater movement in this area is controlled by hydrological formation and structures.

Objective

The study, undertaken by International Rural Educational and Cultural Association (INRECA) in Dapada village of Dadra and Nagar Haveli, investigates the geohydrological profile and groundwater level of Dapada village of Dadra and Nagar Haveli to ascertain the possibilities of constructing rainwater harvesting structures like check dams, and also to determine the water consumption from handpumps in the village. The project also aims to estimate the percolation or infiltration rate from check dam. Under the study, the handpumps of the village and their location was surveyed and two check dams and three handpumps were constructed in Dapada and Pati villages.

Methodology adopted

Geohydrological survey of the two villages was conducted for the installation of handpumps and selection of areas for the construction of the two check dams. Soil and rock formation was collected to study the preliminary information regarding the local soil formation. The beneficiaries of the villages were given awareness training about the benefits of the check dams, the water from which can be used for minor irrigation, for bathing and washing clothes and for other purposes. Training programmes for masonry works were also organised.

Day-to-day survey was done to study the domestic water consumption of the two villages. The habits of the tribal people were studied. It was found that much of the water was used for drinking purposes and for other domestic purposes. Washing of clothes and utensils were done with the water from the rivolutes.

Water infiltration rate of the area was measured by concentric cylinder infiltrometer and the measuring jar was studied for accuracy. Water was added to the inner cylinder in between using the local available black and fractured rock in order to determine infilteration rate of area.

Findings of the survey

Average consumption: The average per capita water consumption for drinking and other domestic purposes was found to be 6-7 litres per day (Ipd), which sometimes reaches to 10 litres. The average per capita water consumption for all purposes was estimated to be about 30 litres, including livestock requirements.

Availability of drinking water sources: Both the villages are depended on handpumps as no other water resources are available.

As may be seen from Table 1, infiltration rate of black cotton soil is .45 cm/day. Infiltration rate considerably decreased with the depth of the soil, depending on the texture. Infiltration was higher in the upper layer as compared to hard soil beyond it. Thereafter, gravel and finally fractured and joint rocky portion are found. Chronologically, infiltration rate is – Upper layer soil> hard soil> gravels > fractured and joint rocks. Various experiments have been carried out by infiltrometer through with the help of the aforementioned soil texture.

Table 1: Details of infiltration rate depth wise and formation wise

Texture of the soil	Reading Time (hr)	Distance of water surface from reference point		Infiltration during period		Average infiltration rate (cm/ day)
		Before filling (cm)	After filling (cm)	Depth (cm)	Average rate (cm/day)	
Black cotton and brackish soil	0 12 24	- 10.71500 10.83500	11.00 11.00 11.00	- 0.28500 0.16500	- 0.570000 0.330000	0.450000
Clay soil	0 12 24	- 10.96450 10.97250	11.00 11.00 11.00	- 0.03550 0.02750	- 0.071000 0.055000	0.063000
Hard soil	0 12 24	- 10.99795 10.99895	11.00 11.00 11.00	- 0.00205 0.00105	- 0.004100 0.002100	0.003100
Murhum/ gravel soil	0 12 24	- 10.99930 10.99980	11.00 11.00 11.00	- 0.00070 0.00020	- 0.001400 0.000400	0.000900
Fractured rocks	0 12 24	- 10.99996 10.99998	11.00 11.00 11.00	- 0.00004 0.00002	- 0.000075 0.000045	0.000060
Joint/ lava rocks	0 12 24	- 11.00000 11.00000	11.00 11.00 11.00	- 0.000000 0.000000	- 0.000007 0.000003	0.000005

The average of the infiltration rate worked out as 0.086 cm/day (mean through the infiltro-water experiments carried out.). Taken 150 x 100 m fetch area of constructed check dam (catchment area and storage has been taken into account on normal conditions)

Rainwater is stored for at least 240 days in a year
So 0.086 x 240 days
= 20.64 cm or 0.21 m

Now considering total wetted perimeter for check dam (height @ 1.5 m but due to filling up say 1 m) is 150 m in length with its average width of 100 m.

So, total area = 150 x 100 = 15000 m^2
So, total infiltration = 15000 x 0.21 = 3150 m^3
Converting 3150 m^3 into litres i.e. 31,50,000 litres of water.

Note: Construction of check dam, which has fetch area (150 x 100) m under specific conditions in Dadra and Nagar Haveli. So the total water infiltration has been calculated 31, 50,000 liters in a year by one check dam of its fetch area.

Total percentage of water infiltrated out of the accumulated water.

Total water accumulation in one check dam of size
(100 m x 150 m x m height) = 100 x 150 x 1 mts = 15000 m^3

Total water = or 1,50,00,000 litres
Infiltrated water = 31,50,000 litres

Percentage of percolated water = 21%

Total water consumption through single handpump installation

Permissible distance coverage for one hand pump

That is, 150 m to 200 m radius or say Rs 200 m
No of population dependent on single handpump =150
That is, 25 families @ of 6 member per family
Maximum water consumption by one person 30 litres during a day
So, the total water consumption during the year = 30 x 150 x 365 = 16,42,500 litres.

Note: If one can install one handpump in the vicinity of the constructed check dam, water accumulation underground through infiltration is rather high as compared to the consumption of the local water requirement by installing handpump.

6 - Land Water Resource Mapping and Micro-level Planning for Recharge and Rational Use of Water

Study by Madhya Pradesh Vigyan Sabha, Bhopal

Introduction

Natural water resources are an important factor for the development of the region. Hence, efforts should be made for their proper development and management. This study envisages to analyse three broad components of water management:

- To map the characteristics of land and water resources, which ultimately depict the status of the two basic resources;
- To prepare micro-level plan for better recharge and rational use; and,
- To intervene through voluntary organisation and people's participation.

Ashta block is one of the five development blocks of Sehore district of Madhya Pradesh. The Indore-Bhopal State highway cuts the block into two parts. The total geographical area of the block is 1,454 sq km, with 298 villages and two towns having 2.32 lakh population. A part of the Malwa plateau, Ashta block has gentle slope and flat table land, with rugged topography. The contour of 500 m above the mean sea level divides the block into southern plateau and northern plain. Geologically, the region is part of the Deccan trap with basaltic rocks and generally black cotton soil.

Astha block is drained by two main seasonal rivers – Parvati and Nevaj, with a clear water divide passing through the middle from northeast to southwest. The Panas and Dhamini are the tributaries of Parvati. The rainfed river basins receive 1,052 mm of annual rainfall during the monsoon. Runoff is very high because of steep slopes.

The net sown area of this region is 67 per cent of the total geographical area, and 82 per cent of the net sown area is unirrigated. Commercial crops like soybean and wheat are usually grown in this area, which uses up most of the groundwater of the area. The rural areas of the block face acute shortage of drinking water during the summer season as most of the wells, tanks and rivers dry up.

With this as the background, the project was conducted to map the surface water resources of the Astha block and study the micro-level planning for recharge and rational use of water. Rainwater harvesting and rational use of water can improve the situation. The study analyses the availability and use of water for Astha block.

Objectives

Issues related to water resources are investigated in isolation providing limited answer to the problem, and in absence of a comprehensive and integrated approach, the gaps in research and development may be observed. To deal with the subject in an integrated manner and bridge the gaps, the present study intends to provide the conceptual and theoretical base for micro-level planning for water resources. The study, therefore, aims

- To assess the land and water resources available at the village level;
- To depict the spatial distribution pattern of land and water resources;
- To analyse the pattern with reference to hydro-geological characteristics;
- To identity the main chemical quality and other characteristics of groundwater

resources and the current use; and,

- To suggest possible strategy for better recharge and rational use with feasible interventions.

The scope of the study is much wider and refers to physiographic configuration, geology, soil texture, and rainfall behaviors, along with socio-economic composition of the population of region. The study is basically of interdisciplinary nature, as each of the above characteristics of the region determine the availability and use of water resources. Physiography relates to the slope and rock formation beneath the earth surface and determines the porosity. The characteristics of the region are the determinants of surface and groundwater availability and its recharge with reference to rainfall occurrence.

The study attempts to provide an insight into proper management of water resources through micro-level planning by analysing the status of the surface and groundwater resources of the area. It also deals with the availability, use and future strategy for better recharge and rational utilisation of water.

Methodology adopted

The study is based on simple methods and techniques of research. Secondary and primary data have been used for analysis; land use and cropping pattern have been collected at the village level for two years – 1980-81 and 1994-95. Data for demographic characteristic such as population, number of households, settlement size and occupational structure were also collected from the villages of the block. These data were then converted into percentages and ratios to make them comparable and to calculate the mean and growth rates to find the status and change in the variables.

Availability of rainfall was measured in terms of rainfall during the year showing monthly variations. Maps were prepared for each component like physiography, geology, hydrogeology, soil, drainage pattern, distribution of population and settlements. Random sampling techniques were used for collection of primary data. About 50 villages were selected for a sample survey to collect primary information about various parameters of water quality, both at the village and household level. Water samples were collected from wells of 50 villages for the pre-monsoon and post-monsoon period.

Chemical analysis of the water samples were done to measure temperature, pH value, alkalinity, chloride, calcium, magnesium contents and hardness. All parameters of land and water resources of the area was mapped to show the spatial distribution and seasonal changes.

Research Findings and action that can be taken

It was found that land resources are adequate to support the development process of the region. Two-thirds of the area is under cultivation. However, forest area, cultivable waste and fallow land are quite low. Agricultural production can be increased through intensive use of land by increasing the area sown more than once. The double-cropped area can be increased and productivity can be enhanced by bringing more area under irrigation. The area under irrigation is very low, and the only possibility of increasing irrigation is through better water management practices of both surface and groundwater.

Availability of water resources depends on the geology of the area, gradient of topography, texture of soil, vegetation cover and rainfall. Astha block is a part of the Deccan trap, covered with basaltic rocks.

Groundwater of this area is not very deep as it ranges between 3 to 9 m from the surface. In the post-monsoon period, the water table rises and gradually recedes. Water bodies and wells get dried during the summer, leading to acute water scarcity.

The quality of groundwater has normal pH value ranging between 6.5 and 8, which is suitable for drinking purposes. Alkalinity in post-monsoon period is relatively high up to 700 mg/litre, which comes down to 500 mg/litre during pre-monsoon. Magnesium content in the water ranges between 0 to 80 mg/litre. Chloride content is found up to 250 mg/litre, but generally it is 100 mg/litre. Magnesium and calcium content increases as the summer approaches. Likewise, hardness also increases with the receding water table. Magnesium and total hardness also show an increase as the water table goes down.

Physiography, geology and drainage pattern, which have been collected, can provide the basis of water and soil conservation. These findings can be used for long-term policy planning for water use. It may help in carrying out watershed programmes and identify the sites for check dams, construction of water tanks and for bunding of soil.

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7 - Drinking Water Quality Management with Concomitant Development of Agriculture and Prawn Culture in a Coastal Rural Habitat

By Institute for Ocean Management, Anna University, Chennai

Introduction

Land-use change is currently very rapid and its consequences are more evident in tropical regions, in part because human population growth there is the most rapid of all geographic regions. In India, nearly 70% of the population is dependent directly on agriculture for sustenance. Of the total 320 Mha of the area, nearly 180 Mha is cultivable. From 1970 to 2000, non-agricultural land use in India has expanded from 16.2 to 26 Mha, an increase of about 60%. This study focuses on the change in groundwater quality due to land-use change in the Sirkazhi region (Lat 11° 14′ N 79° 44′ E) of the Cauvery delta (Fig.1). The Sirkazhi region primarily depends on the Cauvery River for irrigation. Recently, farm-cultured shrimp and other commercially important fishes have grown rapidly in this region. The continued inter-state water dispute, which deprives the Cauvery delta of its share of freshwater for agriculture, has resulted in decreased agriculture as farmers have either sold their prime agricultural land or converted it for aquaculture. This paper investigates a few key drinking water parameters, emphasizing the occurrence, land-use change pattern, concentrations, and spatial distribution.

No extensive and systematic studies have been conducted on the quality of drinking water (ground water) in this region. A detailed hydro chemical study needs to be carried out with respect to major ion concentrations, their source, seasonal variation and distribution. Also, the spatial variation of various forms of inorganic nutrients needs to be assessed to understand the impact of agricultural and aquacultural activities in this region. The present study gives an insight towards the understanding of various natural and anthropogenic processes influencing the ground water of the coastal area of Sirkazhi region and is a step towards the development of effective management strategies for drinking water

Objectives

- (i) Assess the spatial and temporal variation of major elements in the drinking water of Sirkazhi region and the process controlling the variation of these elements.
- (ii) Measure the spatial variation of various forms of inorganic nutrients in ground water to assess the impacts of agricultural activity
- (iii) Estimate the variation in concentration of toxic trace metal pollution and the levels of coliform bacteria in water samples, to highlight the current status of trace metal and bacterial pollution.
- (iv) Classification of ground water with respect to various hydro chemical parameters to determine the suitability of water
- (v) Sociological evaluation of rural habitat based on water quality and availability
- (vi) Evaluate the spatial and temporal variation of major elements using geographical information system (GIS).

This study is an effort towards the understanding of the various natural and anthropogenic processes influencing the ground water of the coastal area of Sirkazhi region. Due to the complex nature of the processes occurring in ground water system, a multidisciplinary effort is necessary to understand the ground water quality scenario and this study is a step forward in this direction.

State of knowledge

Chemical analysis of water has been a routine for more than a century; however the successful correlation of water chemistry with hydrologic and geologic environments is a more recent development. A study conducted by El-Baruni (1995) in Tripoli, Libya revealed that the over exploitation of ground water of the Miocene-Quaternary aquifer resulted in seawater intrusion thereby increasing the TDS content to about 10,000 mg l^{-1}. Studies conducted on the chemical quality of ground water of Mangalore, Karnataka and Madras have observed that ground water quality has deteriorated due to sea water intrusion into the fresh water aquifer because of over exploitation of ground water (Narayana and Suresh 1989, Ramesh et al 1995a). Anthropogenic activities and improper management of natural resources have led to the unequal distribution of major and trace elements in nature (Ramesh et al 1995a). Ground water analysis by Ramesh et al (1995a and b) of Madras city, have indicated that the major and trace metal concentrations have increased several fold indicating that the polluted overlying water is influencing the quality of ground water.

Research methodology adopted

Groundwater samples were collected from 22 locations (Fig. 1) in 14 villages for a one-year period during pre-monsoon (July-September), monsoon (October-December), post-monsoon (January-March) and summer (April-May) seasons. Acid washed 1-L polyethylene bottles were used for sample collection and storage. Water samples were collected from both bore and open dug wells. Electrical conductivity and pH were measured *in situ*. Water samples were filtered immediately after collection in the laboratory using 0.45 μm Millipore filters and analyzed for major ions including Cl, SO_4, HCO_3, Ca, Mg, Na, and K, and nutrients including NO_3, NO_2, and H_4SiO_4 using standard methods (RAMESH & ANBU 1996). The ion balance, difference between the sum of cations and anions is within ± 5%.

(This matter is not in the hard copy) Research findings and their application

Groundwater quality: The movement of inorganic and organic chemical species underground is partly governed by their occurrence as free ions, complexes, or molecules, and partly by the physical, chemical, and hydrogeological features of the groundwater environment. The study of such a complex system requires the acquisition of several types of information such as hydrogeological, geochemical, and human influences on the landscape (BENCINI ET AL. 1993). The average groundwater major ion and nutrient concentrations of the Cauvery delta (Sirkazhi region) are listed in Table 1. The groundwater of this region is generally colorless and the pH ranges from 6.3 to 9.2. Groundwater can be classified based on the TDS concentration as: freshwater 0 - 1000 mg l^{-1}; brackish water 1000 - 10,000 mg $l^{-1;}$ saline water 10,000 – 100,000 mg l^{-1}; and brine water >100,000 mg l^{-1} (FREEZE & CHERRY 1979). Most samples are freshwater except at locations 14, 20, 21 and 22, which may be due to the seawater intrusion into the aquifer system (Fig.2 and Table 1). The seasonal distribution of TDS and Cl was evaluated to determine the extent of salinity encroachment into the inland basin (Fig.2). The Cl in the two-groundwater samples of the Cauvery delta region exceeds 1000 mg l^{-1} during pre-monsoon and monsoon seasons, indicating seawater intrusion. A Cl content of 600 mg l^{-1} is the highest acceptable salinity level for human consumption (ROSENTHAL 1994, RAMESH ET AL. 1995). In other parts of the basin, the Cl concentration is less than 1000 mg l^{-1} indicating marginal mixing. Similarly, the maximum concentration of Na occurs along the coast and Cl concentrations gradually decrease inland. Overexploitation of groundwater in areas adjoining the coastline and pumping of seawater for aquaculture may be major factors affecting the migration of seawater inland. In contrast, *Penaeus monodon* culture requires a lower salinity than that of seawater. Large amount of freshwater are pumped into shrimp farms to decrease the salinity of seawater, which is used as the growth medium. The annual water used in semi-intensive and intensive shrimp culture is 11,000 - 21,000 m^3 t^{-1} and 29,000-43,000 m^3 t^{-1}, respectively (SONAK 2000), which results in a large-scale depletion of groundwater. Because most of the aquaculture farms are located in coastal areas within 500 m of the high tide line, a decrease in groundwater level will result in seawater intrusion of the aquifer (ALAGARSWAMI 1993; BEVERIDGE ET AL. 1997). Groundwater flowing through a normal and active hydrological gradient is characterized by Na/Cl ratios of 0.86-1 (ROSENTHAL 1994). The Na/Cl ratio of the Sirkazhi aquifer is 0.29-0.71. The lower than normal ratio indicates mixing of seawater and freshwater within the aquifer.

Nitrate (NO_3) is the main inorganic N species in groundwater. The average concentration of NO_3 and NO_2 were 5-48 mg l^{-1} and 0.23-2.13 mg l^{-1}, respectively (Table 1). The average NO_3 concentration exceeded the permissible health limit 45 mg l^{-1} only in two groundwater samples (WHO 1984). During monsoon and pre-monsoon, the NO_3 concentration exceeded the permissible limit in 27% and 14% of the samples, respectively (Fig.2). The consumption of water with high NO_3 concentration can decrease the O_2 carrying capacity of the blood, which is particularly important for the health of infants (MCNEELY ET AL. 1979, WHO 1984; RAJAGOPAL & TOBIN 1989). NO_2 is much more toxic to humans and animals than is NO_3. Drinking water guidelines of the WHO specify that the NO_2 concentration should not exceed 3.3 mg l^{-1}, as NO_2 (WHO 1984). NO_2 concentration in the groundwater samples in this study did not exceed the recommended maximum concentration limit. A few trace metals like Cu, Fe, Zn and Mn were analyzed and from the present study, it is clear that the concentrations of Cu and Fe in the ground water samples were below the detectable limit. The concentrations of Zn varied from 0.007 to 0.276 mg l^{-1} well below the maximum acceptable limit of 5 mg l^{-1}. The Mn concentrations were below the rejection level except at the agriculture dominated areas at locations 9, 10, 14, 15 and 21. The presence of faecal coliforms in drinking water is an indicator of faecal contamination. In the present study, except one sample at location 16, all other locations are within the MPN index of 10 per 100 ml for untreated water.

Land-use Change: Development of aquaculture in the coastal areas has led to the destruction of vast areas of mangroves. The total area of the wetland of the Vellar-Pichavaram-Colleroon estuarine complex (Cauvery delta) is about 2335 ha, of which only 241 ha are presently occupied by dense mangrove vegetation (Pichavaram mangroves). KRISHNAMOORTHY (1996) calculated the total loss of mangrove extent in this mangrove using satellite data. His study showed that the mangrove cover has decreased from 650 ha in 1971 to 495 ha in 1987; to 477 ha in 1998 and to 241 ha at present. However, the rate of decline in mangrove-cover is slowing down in recent years, due to the extensive replantation measures. Nevertheless, nutrient concentrations have increased in the mangrove waters (PURVAJA & RAMESH 2000) over the past decade. This increase is due to the untreated effluent discharges from the aquaculture farms surrounding the mangrove area.

Status and potentiality of utilisation of research findings

The heterogeneous distribution of elements in the Sirkazhi region of the Cauvery delta, India is mostly due to indiscriminate use of ground water in aquaculture farms, which causes ground water levels to decline and salinization of fresh water aquifers. In the present study, it is very clear that salt-water intrusion is the main reason for water quality deterioration. The intrusion of seawater is found to be maximum in the south of Uppanar river compared to the intrusion of seawater north of Uppanar. Prawn farms have been found to have impact on drinking water quality at some of the locations found south of Uppanar river. The land use change associated with intensive aquaculture activities results in ground water abstraction and pollution due to effluent discharge. Socioeconomic survey conducted, revealed that agricultural practices caused by changes in the crop pattern and area have decreased due to inadequate water supply for irrigation from the Cauvery river and salination of ground water. Health problems were also prevalent from some locations due to contamination of ground water used for drinking.

Suggested follow up action / scope for further research

Ecological security can be ensured through judicious use of land and water resources, conservation of ground water resources and planned and regulated development of coastal aquaculture zones. The suggested follow up action for the management of drinking water resources include:

(i) Identification of special zones for aquaculture.
(ii) Buffer zone of about 500 m to avoid seepage of saline water from prawn farms to nearby agricultural lands and drinking water resources.
(iii) Indiscriminate use of ground water resources should be avoided to conserve aquifers and prevent land subsidence.
(iv) Aquaculture has a self-polluting effect and untreated farm and hatchery effluent may cause environmental degradation. Treatment of effluents is necessary and environmental impact monitoring studies must be carried out.
(v) Salt tolerant crops may be introduced in the regions where the soil is saline.
(vi) Pollution control boards must be strengthened to cover monitoring, analytical and technical aspects of water and other types of pollution.
(vii) Artificial recharge of aquifers with rain and treated water may be helpful in preventing the negative effects of lowering of ground water table and salt water intrusion.
(viii) Community desalination plants must be installed in coastal rural habitats as coastal aquifers are depleting rapidly and turning saline due to intrusion of seawater.
(ix) Public awareness on environmental degradation should be emphasized.
(x) Development and management of water resources should be based on participatory approach involving users, planners and policy makers.
(xi) Development of database is needed on drinking water quality in coastal rural villages.

Pollution and land-use change is of concern and because environment, development, and public health are interlinked, it is essential to adopt sustainable utilisation of the available water resources.

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Note: To insert Figure 1 & 2 and Table 1

8 - Assessment and Development of Groundwater Resources in Midland Regions of Thiruvananthapuram

Study by CWRDM, Kerala

Introduction

Although the midland region of Thiruvananthapuram in Kerala receives an average of 1,800 mm of rainfall annually and has 98 rainy days in a year, most of the water is lost as runoff. This leads to scarcity of drinking water, particularly in the summer months. As a result, it calls for an urgent need for studying the groundwater resources of the region, especially in the Thiruvananthapuram district.

Objective

The study aims at assessing the groundwater potential of the midland region of Thiruvananthapuram, and suggests groundwater development schemes based on large diameter wells, borewells and springs for the study area. It looks into the occurrence and movement of groundwater in different geo-morphological units. The study also assesses the extent and pattern of groundwater utilisation to establish spatial and temporal variations of water quality. It also studies the aquifers, sub-surface information, recovery characteristics of openwells and various sources of water.

Methodology adopted

One borewell, one spring and 14 dugwell-based water supply schemes were implemented in the midland as part of the investigation. Available information on groundwater and data was collected from Government departments, agencies and CWRDM. Investigations were carried out and network of permanent observation wells were established in Thiruvananthapuram. Data for two years have been generated and processed on groundwater levels; one year's data on groundwater quality have also been procured. Pumping tests and exploratory drilling coupled with geophysical investigations were carried out in selected areas of the midland. The data, which was generated, was then used in evaluating hydrogeological situations of the area.

Research findings and recommendations

In the midland, groundwater occurs in laterites, sandstones and in weathered and fractured khondalite rock formations under the water table. Besides, dugwells and borewells, which are common groundwater structures in this region, springs, ponds and tanks are other sources of water. Investment on borewells in this region is not economical due to poor yield and high cost of construction. Digging an ordinary dugwell in this area is difficult due to deep water table (56 m), the risk involved in digging and the high labour cost. To meet the domestic requirement in areas like Kanjiramkulam and Uchakaa, it is recommended that rainwater harvesting may be practiced.

There are caving problems in a few borewells of central midland and parts of northern midland. In order to avoid this problem, fracture zones that have been identified in borewells may be cased with slotted pipes with packing gravel around the borewell. This enhances the lives of the borewells.

Well density and use pattern: It was found that the well density of dugwell varies from 100-150 well per km^2. Table 1 shows the well use pattern in the midland belt of Thiruvanathapuram.

Table 1: Well use pattern in the midland belt of Thiruvanathapuram

Name of the area	Domestic purposes	Domestic & irrigation	Irrigation
Southern midland	80%	15%	5%
Central midland belt	80%	10%	10%
Northern midland belt	70%	10%	20%

The average withdrawals from these wells were observed to be 900 litres per day per well. The average draft for domestic and irrigation wells are estimated to be 2,000 litres per day per well from the sample survey and 3,000 litres per day per well for irrigation.

Groundwater levels and fluctuation zones: The depth of groundwater level varies in the midland. In the northern midland, the groundwater level is 4 m-30 m below ground level (between Korani and Pallickal); in the central midland, groundwater level is 4 m-30 m below ground level (between Vellayani and Korani); in southern midland, groundwater level is 4 m-56 m below grundwater level (between Parasala and Vellayani).

It was found that the presence of clay formation and thicker overburden are the causative factors for deep groundwater level and poor recharge, resulting in less dependence on groundwater by the people in the southern midland. The present study indicates that the midland area can be divided into six groundwater fluctuation zones, with an average yearly mean fluctuation of 1.50, 2.50, 3.50, 4.50, 5.50 and 6.00 m, respectively. Pumping tests were carried out at 12 wells and the discharge, and time for maximum recovery of wells was computed. Wells tested at Sreekaryam, Nemom and Navaikulam have low permeability and poor recovery due to clay formation.

Sub-surface geology and water quality: Analysis of borehole data shows that the midland comprises of laterite, sandstone, weathered and fractured rock formations. Its bedrock depth varies from 20 m in the north to more than 60 m in the south. The discharges of borewell vary from 1.83 m^3/hr in the midland. The transmisivity of fractured aquifer ranges from 0.93 m^2/day to 9.03m^2/day. The groundwater is generally hard in most of the borewells. Borewell at Vamanapuram shows high content of fluoride (3.9 ppm). Analysis of water samples from openwells shows that there are three major water quality problems in the openwells — low pH, high Fe and high hardness. Borewells could be dug in the valley fills of the study area, but the actual site should be confirmed by geophysical investigations.

Groundwater availability and utilisation: Groundwater availability in the midland is estimated as 188 million cubic metres (MCM) based on groundwater fluctuation method, and utilisation is 56 MCM. This shows that 30 per cent of groundwater is utilised and 70 per cent is available for future development.

Springs, tanks and lakes: Eleven springs have been identified in the midland, the discharge of which ranges from 6-540 lpm. The study shows that development of spring-based water supply is economical as compared to borewell-based water supply schemes. A comparison of schemes is given in Table 3.

Table 3: Comparison between borewell and spring water supply schemes

Drinking water schemes through springs	**Drinking water supply schemes through borewells or borewells fitted with handpumps**
Total cost of schemes vary between Rs 18,000 and 26,000 Safe and good quality of drinking water Annual maintenance minimum Gravity flow, pumps not needed No caving problem Storage tank can be cleaned any time and is cost-effective	Total cost of borewell scheme through handpump is Rs 30,000. The cost increases on drilling depth and casing pipe etc. Local people do not use borewell during the monsoon season, leading to break down and increase in iron content Annual maintenance cost is more Yield of the wells are found poor. During summer months, the water level goes beyond the level of settings pumps. Hence, in most of the borewells, there is no water during the summer, resulting in pump disorder High discharge borewell-based water supply schemes costs more than Rs 50,000. Occasional cavings are noticed, which become detrimental to the borewell life Borewell servicing is more time-consuming and expensive

Investigations revealed that there are 51 tanks in the midland region of Thiruvananthapuram; 40 per cent of which are used for irrigation, 50 per cent for domestic and washing purposes and 10 per cent for drinking purposes. Recognising drinking water problem in Anathazhchira, it was suggested that tanks could be developed for resolving drinking water crisis. Deepening of tanks and ponds is risky due to clay deposit. It is, therefore, necessary to ascertain the exact depth of the tanks by geophysical investigations.
Vellayani is the only freshwater lake in the midland belt of Thiruvananthapuram. Mini water supply scheme from this lake could be developed to meet water scarcity during the summer months.

It is essential to preserve the traditional water resources of this area from pollution and silting.

Similar studies that exist: A systematic study of similar nature for Thiruvanthapuram coastal belt was attempted by CWRDM in 1983, which identified the problematic area of the coast, and studied the extent of seawater intrusion, availability, distribution and utilisation of the groundwater in Thiruvananthapuram. It also studied the sub-surface information of the area.

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9 - Enhancement of Runoff to Traditional Water Harvesting Structures in Thar Desert

Study by National Geophysical Research Institute, Hyderabad
Indian Institute of Chemical Technology, Hyderabad

Introduction

Low seasonal rainfall, deep and brackish groundwater and extreme climatic conditions give rise to scarcity of potable drinking water in major part of the Thar desert. The main source of drinking water in this area is runoff water collected in traditional water harvesting structures like *kunds, tankas*, *johads* and *nadis*. However, runoff collection in these rainwater harvesting structures is poor due to high permeability of catchment sandy soils. Tracer experiments in the dune area of the Thar desert indicates that about 70 per cent of the infiltrated rainwater returns to the atmosphere through soil evaporation amounting to poor replenishment to the aquifer. Traditionally, the surface of the catchment areas of these rainwater harvesting structures are made less permeable by using lime, surakhi and kankar. These do not serve as efficient impermeable material and, as a result, substantial part of the rainwater is lost through infiltration. Significant runoff is generated only at some places having high intensity of rainfall. Due to meagre rainfall and poor runoff collection, the existing *kunds* fail to collect water and meet the annual requirement of drinking water. It is, therefore, necessary to make scientific attempts to enhance the runoff quantum generated even from a low intensity and low rainfall year.

Objective

The main objective of the study is to develop suitable non-toxic water-based polymer formulations for treating sandy soil of catchment area of traditional water harvesting structures. This is mostly done in low rainfall areas like the Thar desert of Rajasthan for enhancing the runoff collection and providing adequate supply of potable water to the rural people of the Thar desert.

Methodology adopted

The present approach of the project involves catchment treatment, using a polymer liquid (hydrophobic chemical in combination with binder) spray, which permeates the highly porous sandy soil. The polymeric material on treatment reduces permeability and consequently the infiltration rate of the sandy soil. This, in turn, increases the runoff generation from the chemically treated surface. The chemicals selected for this purpose have the following properties:

- since the objective of the study is augmentation of drinking water supply, the material selected was non-toxic;
- the chemicals work as soil (sand) stabiliser or binder and the treated surface have hydrophobic (water repellant) properties;
- the capital and recurring costs is less than that of the costs involved in providing daily tanker water supply or by installation and operation of a desalination plant or a piped water supply;
- the methodology of treatment in catchment area is quite simple.

Various activities of this experiment in the laboratory and field are:

- Surface and augered core samples of sandy soil from the Thar desert were collected for chemical analysis; mineral facies were identified; soil moisture was determined; grain size was analysed to select suitable polymer formulation for treatment;
- Suitable water-based non-toxic polymer formulations were selected through laboratory column experiments using sand samples brought from experimental sites. The nature of binding was developed, depth of penetration of the polymer formulation in the soil column was ascertained, water was retained over the treated surface for some time to test its effectiveness as water repellant and for toxicity;
- Selected polymer formulations were tested in the laboratory perspex box models (surface area 0.1 sq m), which had provisions for measuring runoff and infiltration. Soil samples collected from field sites were used in these experiments. Data on runoff was generated under simulated rainfall and actual rainfall conditions;
- Various polymer formulations selected on the basis of tubular and box models were tested on small, open to sky plots (2 sq m) with 1 to 2 per cent slope, specially prepared in the institute campus in Hyderabad. Testing was carried out on soil samples brought from experimental sites;
- Polymer formulation was tested in the deserts of Churu district of Rajasthan (treated area 50-500 sq m) with 1 to 2 per cent slope condition. Data on runoff was monitored for various rainfall events occurring during the monsoon season and the results were compared with the runoff results from untreated catchment surfaces.

National Geophysical Research Institute (NGRI), Indian Institute of Chemical Technology (IICT), and Bhoruka Charitable Trust (BCT) were involved in formulating, execution and completion of the project work. IICT was responsible for development of various water-based non-toxic polymer formulations. NGRI was responsible for hydrological studies and for testing the chemicals used in various treatment techniques in laboratory models, small-scale campus plots and field sites. Field experiments were conducted at various existing *kind* sites constructed by BCT in the Rajgarh tensile of Churu.

Research findings and suggested actions

The samples brought from the experimental sites were analysed for physical properties, chemical constituents, mineralogical composition, clay mineral identification, grain size distribution and moisture content. The results of the chemical and physical analysis were the following:

Chemical analysis: Loss on ignition (2.3-8.6 per cent), silica (62.3-69.5 per cent), aluminium oxide (12.5-17.9 per cent), iron oxide (4.1-5.5 per cent), calcium oxide (3.9-12.1 per cent), magnesium oxide (0.7-1.1 per cent), water soluble salts (0.1-0.4 per cent), conductivity (131-224 micromhos), pH (7.9-8.1), organic carbon-low.

Physical and mineralogical analysis: Soil type was loamy sand (sand-78 per cent, silt-15 per cent, clay-7 per cent), clay mineral-illite and chlorite (less than 5 per cent), moisture percentage unto 2.8 m depth (2.6-3.4 per cent). Infiltration test using double ring infiltrometer carried out near experimental site indicate a steady state of infiltration rate of 17.8 cm/h.

A number of water-based polymeric formulations were prepared and were tested in tubular glass columns in the laboratory. The experiments have resulted in selection of various polymer formulations (aqueous sprayable formulations with conditioners) for further laboratory and field experiments.

The various polymer formulations identified after column experiments were tested in box models fabricated especially for this purpose under simulated and actual rainfall conditions. Runoff was measured for various polymer treated surfaces ranging from 70-90 per cent for the chemically treated surfaces, under simulated rainfall condition. The experiment resulted in selection of a particular polymer formulation for small plot experiments in the campus of the institute. The polymer formulation selected was prepared from a commercially available product based on polyvinyl alcohol.

The selected polymer formulation, which was tested successfully in box model, was selected for small plots (2 sq m) in the institute campus. The plots adjacent to each other and having provision for runoff collection were used in the experiments. The sample of the sand brought from experimental sites in Rajasthan was used for the experiment. The polymer formulation was sprayed over the sandy surfaces of the experimental plots. Experiments were conducted for different rainfall intensities and for different time periods under simulated and natural rainfall conditions. The results indicated that runoff collection from the chemically treated surfaces were about 8-10 times more compared to runoff generated over untreated surface. Experiments were also carried out within a mixture of top layer of sand, fly ash, and sand, cement in the ratios of 10:1. After the satisfactory results of the campus trials, using sand and cement mixture as a base for application of polymer, field scale catchment treatment was carried out at selected sites in Rajgarh tehsil of Churu.

The polymer tested in small plots in the institute campus was also tested at six field sites during the monsoons months. Four newly constructed *kunds,* with capacity of 60-100 cubic metres, were used for the experiment. The experiment involves leveling of the catchment area with 2 per cent slope, spreading sand and cement mixture in the ratio of 10:1 as top layer, spraying of water using mechanical sprayer and spraying of polymer solution using rose cane and mechanical sprayer. The quantity of polymer solution used for treatment was about 2.8 liters per sq m. Runoff was monitored for various rainfall events during 1997 and 1998 monsoons. The field results indicate that average runoff efficiency obtained at treated and untreated sites varies from 40-82 per cent of the rainfall (for the treated sites) and 1-2 per cent from the untreated bare topsoil plots. The laboratory and field scale experiments carried out showed that the catchment treatment technique is technically feasible for enhancing runoff from the catchment surfaces and, thus, it is possible to improve the efficiency of rainwater harvesting structures. The developed and tested technique for runoff generation is cheaper than the traditional method and it is also socially acceptable.

The experimental data indicate that runoff generation could be achieved even for 10 mm rainfall at actual desert conditions. Hence, the technique can be used for harvesting rainfall even in low intensity areas of Rajasthan. The technology can be used for providing drinking water in problem villages, and in areas where groundwater has excess fluoride or higher salinity.

The field observations at the chemically-treated surfaces, carried out at the end of the monsoon, shows that the treated layer gets destroyed at several places due to development of cracks. This is due to the fact that some of the species of the polymer formulation used are biodegradable. Polymer penetration was also found to be only a few millimetres. As a result, laboratory and field-testing are necessary for development of improved polymer formulation, which is 100 per cent non-biodegradable and improve the depth of penetration of polymer liquid in sandy surfaces.

Table 1: Observations of runoff enhancement experiments carried out at selected sites in Rajgarh tehsil, Churu district

Site	Treatment	Observation Period	Total rainfall (mm)	Total runoff (mm)	Average runoff (%)
BCT	March 1997	97 Monsoon	295.1	215.8	73.0
		98 Monsoon	166.0	128.0	38.0
Gwalisor	March 1997	97 Monsoon	158.4	130.1	82.0
		98 Monsoon	256.4	102.5	40.0
Kyali	March 1997	97 Monsoon	276.0	113.8	41.0
Mithiredu	March 1997	97 Monsoon	254.0	124.6	49.0
Chalinabs	May 1998	98 Monsoon	221.6	117.3	53.0
Chotinangal	May 1998	98 Monsoon	234.4	111.6	48.0

Similar studies carried out

Runoff to water harvesting structures can be increased if the permeability of the soil of the catchment area is reduced. Work on road surface used as catchments and treatment of catchment surfaces with different chemicals or sheets or other materials have been carried out in Australia, United States and Israel. However, these projects were aimed at providing irrigation or for cattle farms. The Central Arid Zone Research Institute (CAZRI) has tested several materials such as mud plaster, bentonite, cement and soil, lime concretion, sodium carbonate and Janata emulsion as materials for treating the catchment surface in their campus on an experimental basis. However, field trails on the effectiveness and durability of these materials have not been carried out.

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1 - Development of Low-cost Filtering Medium for Removal of Arsenic from Groundwater

By National Metallurgical Laboratory, Jamshedpur

Introduction

Majority of the arsenic removal processes involved oxidation of total arsenic to As(V) followed by the coagulation-precipitation of the As(V) with Fe(III) salt or alum. However, this technique has its own shortcomings. The removal operation involves one additional pre-treatment step in the form of oxidising As(III) to As(V). This affects the quality of drinking water. The coagulation process further deteriorates the water quality as external salts are being added.

There are also some low-cost materials for removing arsenic from groundwater. However, they were mostly theoretical and were never visualised visa-vis the present need and constraints. Based on this background, National Metallurgical Laboratory, Jamshedpur conducted research work for development of a low-cost filtering medium for removal of arsenic from groundwater.

Objective

The objective of the project was to develop a filtering medium, which could remove arsenic from groundwater by a single filter operation. The operation does not involve any pre-filter or post-filter treatment of groundwater. The filtering medium is made available in the form of candles, pellets or powder.

Methodology adopted

A number of low-cost, naturally occurring minerals were selected and characterised mineralogically. These materials were then studied in the laboratory for their arsenic trapping capability in both the oxidation states of arsenic using synthetically spiked arsenic samples through batch adsorption. The prospective materials were short listed and subjected to rigorous investigation for optimising operational parameters, namely, dose, contact time, agitation frequency, effect of pH, heat treatment etc.

Analytical protocol for analysing arsenic: Arsenic was analysed by either silver diethyl dithiocarbamate method (SDDC) Spetrophotometric method or by graphite furnace atomic absorption spectrometry (GFAAS).

Batch adsorption study: 100 ml of a synthetic arsenic solution, which is referred as mother solution in the tables that follow, was mixed with a definite amount of adsorbent and shaken for a fixed period of time in a wrist shaker. The mixture was allowed to settle and the water was filtered and analysed for arsenic. The difference in the arsenic concentration before and after adsorption is a measure of the arsenic removed by the adsorbant.

Research findings and their significance

The results and discussion has been organised in two sections. First section deals with the mineralogical characterisation of low-cost materials by X-ray powder diffraction and optical microscopy. Table 1 gives the X-ray powder diffraction and corresponding mineral phases for the selected materials. The second section describes removal of arsenic using the low-cost materials and subsequent treatment of these materials to obtain an arsenic filter candle.

Mineralogical characterisation of low-cost materials: Following materials were chosen for mineralogical characterisation by X-ray powder diffraction and optical microscopy: bauxite, blue dust from Kudremukh, kayanite, pyrolusite, mica, chalcopyrite. Table 1 gives the X-ray powder diffraction data and corresponding mineral phases for the above minerals.

Table 1: X-ray diffraction data for kyanite, bauxite, blue dust, pyrolusite, mica, chalcopyrite

Kyanite		Bauxite		Blue dust		Pyrolusite		Mica		Chalcopyrite	
d(A)	Phase	d(A)	Phase	d(A)	phase	d(A)	phase	d(A)	phase	d(A)	Phase
4.26	Quartz	4.73	Dsp	4.86	Mgt	4.96	Gth	3.22	Musco	2.71	Pyrite
3.77	Kya	3.99	"	3.68	Hmt	4.75	Mgt	3.11	"	2.64	Pht
3.55	"	3.22	"	3.34	Quartz	4.17	Gth	3.04	"	2.60	Chalc
3.19	"	2.56	"	2.97	Mgt	3.69	Hmt	2.64	"	2.45	Quartz
3.03	"	2.32	"	2.70	Hmt	3.12	Pyro			2.27	Quartz
2.95	"	2.13	"	2.53	Mgt	2.69	Gth			2.21	Pyrite
2.70	"	2.08	"	2.43	Mgt	2.51	Hmt				
2.51	"	1.81	"	2.21	Hmt	2.44	Gth				
2.46	Quartz	1.71	"	2.10	Mgt	2.41	Pyro				
2.36	Kya	1.63	"	1.84	Hmt	2.11	Pyro				
2.28	Quartz	1.61	"	1.71	Mgt						
2.24	"	1.57	"	1.69	Hmt						
2.31	"	1.52	"	1.62	Mgt						
1.96	Kya	1.48	"	1.48	Mgt						
1.93	Kya	1.42	"	1.45	Hmt						
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Kya = Kyanite, Mgt = Magnetite, Hmt = Haematite, Gth = Goethite,
Pyro = Pyrolusite, Musco = Muscovite, Pht = Pyrrhotite, Chalc = Chalcopyrite

Study on arsenic removal through batch adsorption: Table 2 gives the data for probing study of selected materials with synthetically prepared As(III) and As(V) solution.

Table 2: Probing study for the removal of As(III) and As(V) from spiked Water using different naturally occurring minerals

Wt. of the adsorbent = 1.0g volume = 100 ml Mother As(III) = 0.118 ppm Mother As(V) = 0.172 ppm		
Adsorbent	**Arsenic concentration after adsorption (ppm)**	
	As(III)	**As(V)**
Chalcopyrite	0.040	0.036

Mica	0.076	0.130
Pyrolusite	0.026	0.036
Kayanite	0.070	-
Magnetite	0.096	-
Haematite	0.085	0.16
Bauxite	0.076	0.116

It may be seen from the above data that for As(III) and As(V) pyrolusite and chalcopyrite are the most prospective adsorbents. On the basis of the study, a number of parameters like heat treatment, shaking time, mesh size, etc were studied. In this report, pyrolusite and chalcopyrite will be referred to as ANALPRO and ANALCO, respectively.

Tables 3 and 4 represent the weight variation study of ANALPRO and ANALCO with synthetically prepared As(III) and As(V) solution.

Table 3: Weight variation study for ANALPRO and ANALCO with As(III) spiked water

Volume = 100 ml		**Shaking time = 30 min**	
Adsorbent	**Wt. (g)**	**Arsenic concentration (ppm)**	
		Before adsorption	**After adsorption**
ANALPRO	0.2	0.124	0.034
ANALPRO	0.4	0.124	0.036
ANALPRO	0.6	0.124	0.032
ANALPRO	0.8	0.124	0.032
ANALCO	0.1	0.164	0.126
ANALCO	0.2	0.164	0.104
ANALCO	0.4	0.164	0.072
ANALCO	0.8	0.164	0.052

Table 4: Weight variation study for ANALPRO and ANALCO with As(V) spiked water

Volume = 100 ml		**Shaking time = 30 min**	
Adsorbent	**Wt. (g)**	**Arsenic concentration (ppm)**	
		Before adsorption	**After adsorption**
ANALPRO	0.2	0.122	0.124
ANALPRO	0.4	0.122	0.058
ANALPRO	0.6	0.122	0.070
ANALPRO	0.8	0.122	0.068
ANALCO	0.1	0.2	0.0.072
ANALCO	0.2	0.2	0.042
ANALCO	0.4	0.2	0.038
ANALCO	0.8	0.2	0.042

The optimised parameters obtained for ANALPRO with 100 ml of 0.2 ppm As(V) and 0.12 ppm As(III) are given below.

		As(V)	As(III)
Weight of ANALPRO required	:	0.2g	0.4 - 0.8g
Mesh size(μm)	:	200	200
Heat treatment	:	Not required	Not required

Shaking time	:	5 min	5 min

The optimised parameters obtained for ANALCO with 100 ml of 0.2 ppm As(V) and 0.12 ppm As(III) spiked water are given below.

		As(V)	As(III)
Weight of ANALCO required	:	0.2g	0.8g
Mesh Size (μm)	:	60	200
Heat treatment	:	Not required	Not required
Shaking time	:	5 min	5 min

It may be concluded from the parameter optimisation programme that ANALPRO is equally effective for both As(III) and As(V). ANALCO is slightly better for As(V) than As(III). This may also be noted with caution that though ANALCO serves as a good adsorbent for As(III) and As(V), it is not possible to heat treat the material. In that case, the material itself acts as a source of arsenic.

Application of ANALPRO and ANALCO on real life arsenic contaminated groundwater samples: ANALCO and ANALPRO were used for the purpose of removing arsenic from some real life groundwater samples containing arsenic, collected from Baruipur areas in West Bengal. The results have been tabulated in Table 5.

Table 5: Test of ANALPRO and ANALCO on real life groundwater samples containing arsenic.

Sample.	**As conc. (ppm)**
Water sample (A)	0.168
A + 0.4gm ANALCO	0.04
A + 0. 4 gm ANALPRO	0.014

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2 - Assessment of Arsenic in Groundwater in Sahebganj District

By National Metallurgical Laboratory, Jamshedpur

Objective of the R&D and its scope

The objective of the present study was to assess the groundwater quality of Sahebgunj district with respect to arsenic and associated cations. The assessments were based on the limits of these metals in drinking water as laid down by WHO.

Justification for the study

Arsenic contamination of groundwater is not a new phenomenon and has been reported from all over the world. The latest of the arsenic outbreaks have been observed in Bangladesh and India. In West Bengal, India, groundwaters of eight districts covering an area of more than 3000 sq. Kms, affecting about 6 million people have been found to be contaminated with arsenic.

Maldah is one of the eight districts of West Bengal, which is severely hit by the arsenic contamination of groundwater. Maldah is situated on the bank of river Ganga, while Sahebgunj district of Jharkhand is situated exactly on the other side of Ganga facing Maldah. Both Maldah and Sahebgunj are topologically and demographically similar. Looking at the serious arsenic situation in West Bengal in general and Maldah in particular, it was decided to undertake a thorough survey of the water quality of the entire Sahebgunj district with special reference to arsenic. Well and tubewell waters of all the nine blocks of Sahebgunj district were assessed with respect to their arsenic contents and other associated cations. The entire programme was financially supported by Rajiv Gandhi National Drinking Water Mission, Ministry of Rural Development, Government of India.

State of knowledge

Arsenic in groundwater has been reported from various parts of the world. High levels of arsenic in groundwater was reported from New Hampshire (1), United States(2) and New Maxico(3). A massive outbreak of arsenic in groundwater spread over a large area of West Bengal has attracted serious international concern. This is the biggest ever reported case of arsenic contamination in groundwater in the world(4, 5, 6). The arsenic contamination of groundwater in Bangladesh has been estimated to be even of greater magnitude than West Bengal(7, 8, 9).

Consumption of arsenic contaminated drinking water causes serious problems in human health(10,11,12, 13, 14). Hyperpigmentation, depigmentation, keratosis and peripheral vascular disorders are the most commonly reported symptoms of chronic arsenic exposure.

Research methodology adopted

Experimental: Collection of water samples has been carried out during Sep, 99 to March 2000. The district Sahebgunj has 9 blocks, namely, Mandro, Sahebgunj, Taljhari, Rajmahal, Udhwa, Barharwa, Pathna, Barhait and Borio. From each block, water samples were collected from wells and tubewells

Monitoring parameters:

Parameters monitored in the present study were, pH , As, Fe, Cu, Mn, Zn, Ca and Mg concentrations. Arsenic was analysed by hydride generation and graphite furnace atomic absorption spectrometer. Fe, Cu, Mn, Zn, Ca and Mg were determined by flame atomic absorption spectrometer. Water pH was measured by portable pH meter at the time of collection.

Instrument Used:

Flame Atomic Absorption Spectrometer.
Graphite Furnace Atomic Absorption Spectrometer
Hydride generation Atomic Absorption Spectrometer
UV-VIS Spectrophotometer
Digital pH meter

Research findings and their application

A total of 1539 water samples were considered in the present study of which 1321 and 218 were tubewell and well waters respectively.
Attachments:

Table 1. WHO standards of pH, As, Fe, Cu, Mn, Zn, Ca and Mg in drinking water

Parameter	**Highest desirable (ppm)**	**Maximum Permissible (ppm)**
pH	7.0-8.5	6.5-9.2
As	0.01	0.05
Fe	0.1	1.0
Cu	0.05	1.0
Mn	0.05	0.5
Zn	5.0	15.0
Ca	40	200
Mg	30	150

Table 1 lists WHO standards of pH, As, Fe, Cu, Mn, Zn, Ca and Mg in drinking water. It may be seen in Table 1 that for all the parameters there are two levels as denoted by highest desirable level and maximum permissible level. In the present discussion water samples bearing metal values less than the highest desirable level are marked as “safe” with respect to that metal while values lying between highest desirable and maximum permissible are marked as “alert” and values above maximum permissible level are marked as “toxic”. Based on these criteria all the Sahebgunj water samples were labelled as safe, alert and toxic with respect to As, Fe, Cu, Mn, Zn, Ca and Mg. A summary of this labelling exercise for all the water samples in percentage has been shown in Table 2.

Table 2. Safe(S), alert(A) and toxic(T) status of the groundwaters of Sahebgunj district with respect to As, Fe, Ca, Mg, Mn, Zn and Cu.

		Tubewell			Well		
Element	**Block**	**S (%)**	**A(%)**	**T (%)**	**S (%)**	**A (%)**	**T (%)**
As	Barhait	100.00	0.00	0.00	100.00	0.00	0.00
	Barharwa	100.00	0.00	0.00	100.00	0.00	0.00
	Borio	100.00	0.00	0.00	100.00	0.00	0.00
	Mandro	100.00	0.00	0.00			
	Pathna	99.26	0.74	0.00	100.00	0.00	0.00
	Rajmahal	82.42	13.74	3.85	84.62	12.82	2.56
	Sahebgunj	83.44	7.28	9.27	94.44	5.56	0.00
	Taljhari	99.26	0.74	0.00	100.00	0.00	0.00
	Udhawa	83.33	14.29	2.38	86.36	13.64	0.00
Fe	Barhait	8.06	22.58	69.35	16.67	33.33	50.00
	Barharwa	1.67	4.67	43.33	29.03	41.94	29.03
	Borio	25.84	69.66	32.58	27.12	47.46	25.42
	Mandro	64.71	170.6	33.33			
	Pathna	11.85	13.33	25.93	12.50	62.50	25.00
	Rajmahal	23.08	31.87	31.32	30.77	33.33	35.90
	Sahebgunj	25.83	56.95	25.17	27.78	61.11	11.11
	Taljhari	22.06	61.03	24.26	53.85	38.46	7.69
	Udhawa	35.71	46.03	23.81	13.64	54.55	31.82

Arsenic

It may be seen in Table 2 that out of the nine blocks studied, in four blocks, namely, Barharwa, Borio and Mandro, all the water samples irrespective of tubewell and well, were found to be safe with respect to arsenic. However this study revealed that the situation in Sahebgunj, Rajmahal and Udhawa was quite alarming as a number of tubewells and wells were found to be contaminated with arsenic.

It has been found from our observation that Sahebgunj waters are highly contaminated with iron in general. The next most predominant contaminant is Mn followed by Zn. The occurrence of zinc and manganese in groundwaters of Sahebgunj district is probably related to geological formation of the region. In some places copper contamination was observed through the source of copper in the groundwater of Sahebgunj district is apparently unknown and needs to be investigated.

Present study has generated an extensive database on the metal contents of the tubewell and well waters of Sahebgunj district. It gives a comprehensive picture of the groundwater quality of Sahebgunj district with respect to metals in general and arsenic in particular. This study also underscores the need to carry out more rigorous survey of the region. The study further highlights the need to undertake remedial measures on urgent basis to arrest further spread of the problem.

Status and potentiality of utilisation of research findings

- An extensive database on arsenic contents of well and tubewell waters of Sahebgunj, Rajmahal and Udhawa blocks of Sahebgunj district has been generated. This database can be used to mitigate the arsenic related problems of the people of Sahebgunj district.
- Identification and tagging of arsenic contaminated water sources may be done with the help of present database.

Suggested follow up action

The database generated on the water quality will be shared with the state PHED for necessary action. This may be noted that the report of our earlier programme has already been sent to the state PHED for necessary action.

NML may also provide remediation in arsenic affected areas for getting safe drinking water. The local population needs to be educated about the arsenic menace and how to get rid of it. State government may take up the job in collaboration with NGOs. NML may participate in this programme if its participation is sought for.

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3 - Electrochemical Defluoridation And Deferation

**Study by Central Electrochemical Research Institute,
Karaikudi, Tamil Nadu**

Introduction

The potability of water from natural sources has become questionable owing to various types of contaminations. The contamination of groundwater with fluoride and iron has been identified in many parts of India. Excess fluoride, over 1.5 mg/l, in drinking water causes flourosis (dental and skeletal). Intake of excess iron, above the limit of 0.3 ppm, causes constipation and stomach problems. This study looks into development of a suitable process to remove fluoride and iron from groundwater.
Control of fluororsis is a major problem due to the extremely large population, wide land area and enormous volume of water being used. The best and foremost option is to supply safe water drawn from an alternative source not affected by fluoride. This approach is not practicable in many places, which do not have access to river water supply. Thus, the next best logical choice is to adopt suitable water treatment technologies to remove fluoride.

Technologies for defluoridation can be categories as precipitation and adsorption. Addition of lime is the only precipitation method, in which, fluoride is precipitated as calcium fluoride. This method has been found suitable in reducing the fluoride concentration of even 1 gm/litre. However, additional process is also necessary to make the water potable.

The adsorption process is of two types. The first involves adsorption of fluoride by hydroxides of aluminium, magnesium, iron etc, of which, aluminium hydroxide adsorption is more effective. The second adsorption method involves the use of activated alumina, activated carbon, ion exchange resins, etc. Adsorption is done by bringing the fluoride-contaminated water in contact with the adsorption medium in a contact bed column to generate defluoridated water.

Among the possible defluoridation methods, only a few have become technologies, viz., alum precipitation, adsorption on activated alumina and electrochemical defluoridation. The alum precipitation process was developed by NEERI, Nagpur and is known as Nalgonda technique. The activated alumina adsorption process, known as Prashanti technique, was developed by Sri Sathya Sai Institute of Higher Learning.

Electrochemical Defluoridation

This project was undertaken with the objectives of investigating the electrochemical removal of fluoride and iron and to work out the economics of the process.

Central Electrochemical Research Institute has developed the Electrochemical defluoridation process, which is a combination of electro-precipitation, electro-coagulation and electro-flotation. The basic principle of the process is the same as in alum precipitation, where the effectiveness of fluoride adsorption by the aluminium hydroxide is favourably utilised. But the difference between these two methods is the source of the aluminium hydroxide. Electrochemical route offers a versatile way of generating aluminium hydroxide by employing soluble aluminium electrodes.

The electrochemical defluoridation and deferration was initiated in 1988. The preliminary studies indicated that fluoride can be conveniently reduced to acceptable level by employing aluminium electrodes. The removal of iron was done with graphite anodes.

Methodology and findings

Flouride is removed by defluoridation by precipitation and adsorption processes utilising alum and different types of alumina, respectively. Aluminium hydroxide has the capacity to adsorb fluoride irreversibly and this is the basis for many of the fluoride removal processes. An electrochemical cell is utilised to generate the required aluminium hydroxide by anodically dissolving aluminium in the water to be defluoridated. The earlier laboratory experiments used aluminium electrodes and indicated the usefulness of this route.

Based on these data, the electrolytic cell was scaled up to 400 litre capacity (100 Amp.) through an intermediate stage of 100 litre (25 Amp) cell. The process in these cells are as efficient as in the lab cell. The conclusions drawn from the operation of these higher capacity cells are as follows:

- The electrochemical defluoridation is technically feasible under the conditions:

Concentration of fluoride up to which applicable	Even up to 100 mg/l
Final concentration of fluoride attainable	< 1 mg/l
Electrode material	Aluminium
Optimum current density	$0.5\ A.dm^{-2}$
Duration of electrolysis	15 min *
Energy consumption	0.5 kWh(DC) / kl *

(*: Depends on the initial fluoride content. The data are for a concentration of 3 mg/l).

- The continuous operation of the cell repeatedly with the same electrodes under the optimised conditions revealed that the aluminium anode gets passivated due to oxide growth on its surface. Due to this, the efficiency and rate of fluoride removal progressively decreases and the cell voltage continues to increase batch after batch leading to higher energy consumption.

- Similarly, a white coating was observed on the cathodes, which was due to the calcium and magnesium content of the inlet water. The first two observations are a serious disadvantage that will considerably affect the commercialisation of the technology and require regular cleaning of the coatings formed on the electrodes. The coating formed on the anode was difficult to be cleaned and in field installations frequent replacement of the anodes may have to be done.

- To obviate the disadvantages encountered in the batch type electrolysers, flow cells with aluminium electrodes were fabricated and operated. Though this design improved the performance of the cell, continuous operation was not possible beyond 50 to 60 hrs due to the formation of adherent coatings on the anode, due to passivation, and on the cathode, due to the calcium and magnesium present in the water.

- The passivation of the anode was overcome by employing aluminium alloy anodes, which have good anodic dissolution characteristics. The flow cells fitted with these alloy anodes were fabricated and operated in capacities ranging from 0.1 to 30 Amp. and evaluated at different current densities and flow velocities.

Following conclusions were drawn from the operation of the semi-pilot defloridators of 30 and 20 Amp capacities:

- The rate of fluoride removal and final fluoride content depended on the flow rate. The fluoride level decreased to a lesser extent at high flow rates, even though lower cell voltages were observed.

- The fluoride removal efficiency decreased with increasing anode current density, probably due to enhanced passivation of the anode as current density increased.

- The design of the cell must be favourable for free flow of water through the inter electrode gap at sufficient velocities to remove the aluminium hydroxide from the electrolysis zone and to provide adequate mixing of the precipitate for higher fluoride adsorption.

- Employment of aluminium alloy anodes is a must to realise better dissolution efficiency.

- The alloying elements do not contaminate the defluoridated water as all of them are precipitated as their hydroxides at the operating pH. This has been verified by analysis of the defluoridated water.

- The electrochemical defluoridation as per the above process requires the other unit operations such as settling and (sand) filtration as employed in the conventional chemical treatment.

- The electrochemical process also helps in the reduction of the total hardness to an extent of 10-15 per cent, owing to the removal of calcium, magnesium etc as cathodic deposits.

- The electrochemical process improves the coagulation of any suspended colloidal matter because of the electrical charge present between the electrodes. Also the aluminium hydroxide helps in the adsorption of other impurities like arsenic.

- The constant and continuous efforts spent on the development of the electrochemical defluoridator resulted in the design, fabrication and operation of a semi-pilot scale cell and the optimum operating conditions are:

Anode	:	Al alloy
Cathode	:	GI sheet

Current Density, A, dm^{-2}	:	0.1 to 1.0
Flow Rate, l/A.hr	:	5 – 20 (depends on fluoride content)

A patent application has been filed on the composition of the aluminium alloy and its preparative method.

- The above optimum operating conditions were used to make a pre-design cost estimate for a 10,000 litre per day defluoridation plant. The capital investment for one such plant works to about Rs. 4.00 lakhs that can deliver defluoridated water from a source containing 5 ppm fluoride at a cost of Rs. 35/- per kilolitre.
- Graphite is used along with aluminium for combined defluoridation and deferration unit. Using this data, iron removal was scaled up to 400 litre capacity and later combined with defluoridation in a single cell fitted with both aluminium and graphite anodes.

While treating both iron and fluoride it was observed that the rate of settling of the precipitate was quicker. This is due to the mutual coagulation effect of the two precipitates, viz. $Al(OH)_3$ and $Fe(OH)_3$.

The experiments on combined defluoridation and deferration led to the following conclusions:

- The continuous operation of the cell for both these pollutants in a single cell with graphite or even titanium substrate insoluble anodes will not be feasible because the presence of fluoride causes a high disintegration rate of graphite and the presence of fluoride is not recommended with titanium anodes.

- Under this condition the only alternative is to have two separate cells for defferration and defluoridation and circulate the contaminated water in series flow through these two cells. Further, developmental work is necessary in this direction and experiments have to be taken up employing titanium substrate insoluble anodes in the near future.

4 - Deflouridation Of Groundwater By Herbal Exracts

Study by Natural Resources Development Cooperative Society Limited, Praskasam district, Andhra Pradesh

Introduction:

The defluoridation of well water by herbal extracts is the need of the hour. The Prakasam district of Andhra Pradesh, which has been selected for the study, is affected by fluoride. The reaction of herbs vis-à-vis the different soils and strata has been ascertained and studied for replication of treatment elsewhere in the country. This project emphasises the use of herbal extract for defluoridation and analyses the effectiveness of the technique at laboratory level.

Objective

The main objective of this project is to ascertain the reaction of herbal extracts on fluoride water and geo-chemical phenomenon in different geological terrain by using the data that already exists. The project involves tests to study the veracity of the herbal defluoridation as envisaged in ancient texts. The findings are then applied to find out the limitations of the techniques in different geological settings. A detailed sample survey and analysis of water from about 25 openwells under treatment was done to verify the efficiency of herbs for reduction of the fluoride ions in the water. The findings were also applied elsewhere to evolve a methodology and to verify the efficiency of the herbs in different coastal areas to generate the data on the lines of modern science and technology.

Methodology adopted

Water samples were collected from 25 openwells representing different geological formations in Prakasam district. In addition, fluoride solutions of different concentrations were analysed for fluoride estimations. Material used for defluoridation are Cyperus Scariousus, Vetiveria Zizinoides, Luffa Acutangula, Enbilica Officinalis and Strychnos Potatorium.

The herbal plants were shredded, dried and powdered and mixed in equal proportions. The powder mixture was boiled six times in water for about one hour, until the extract reduced to one fifth of its volume. The hot water extract was used for defluoridation of well water. Samples were collected at regular intervals for estimation of the fluoride reduction by using Specific Fluoride Ion Electrode (BIS 3025). The samples were analysed for other parameters such as pH, EC, Calcium, Magnesium, by using standard analysis method (BIS 3025 & APHA Methods).

Research findings and their application

Treatment with herbal extracts directly in the wells has shown considerable reduction of fluoride content. The values of the fluoride content were observed to have reached tolerable limits. This was maintained for few months till the on set of monsoons. The monsoons or natural calamities in the months of September, October, November and December has risen the water levels in the wells, thereby leading to dilution of the herbal extract aqueous solution. This has again changed the phenomenon.

The different herbal extract combinations show a considerable reduction in the fluoride concentration in the groundwater as well as in the laboratory. Among all the ingredients used for treatment, only the five ingredients mentioned above worked more effectively in the wells, and in the laboratory. Total extracts of the above medicinal plants were also used for treatment in the laboratory with different combinations.

- The mean value of fluoride samples treated with 2.5 ml of herbal extract for 12 to 24 hours were observed, and finally found that 12 hours contact is sufficient for the reaction;
- The material used for aqueous solution is 0.43 grams of the combined herbal mixture, for 1 litre of sample water. Total material required for treatment with five ingredients is to be worked out in reference to each well.
- Different herbal combinations show a considerable reduction with synthetic fluoride water/standard solutions of 1 mg/ltr to 5 mg/ltr. The combination of five ingredients appears to be more appropriate among others.

The experiments were conducted in the laboratory on water drawn from wells in different areas. It was not possible to conduct experiment at the site for the second time because of the short project period. Further, research work may be carried out with different combinations of fluoride water, by using the above five herbal ingredient combinations in wells before monsoon period. In order to have a proper assessment of the experiment without the water levels rising, it is necessary that the experiment be carried for a period of six months prior to the commencement of the monsoons, which would rise the water levels in the wells.

The present study was limited to laboratory testing of the well water samples. However, if the study needs to be elaborated to the field level, it is necessary to standardise the herbal aqueous solution to treat the specific well water before the monsoon. The experiment is feasible only for open well water and not for borewells.

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5 - Flouride Problem in Groundwater of Ajmer District, Rajasthan

Study by Jawaaharlal Nehru University, New Delhi

Introduction

While defluoridation plants based on alum are widely used for tackling the problem of fluorosis in Ajmer district, this study attempts to assess fluoride content in groundwater in the district and examines the locally available soils in scavenging the excess fluoride in the groundwater.

In order to understand this aspect, several experiments were designed in the laboratory with a number of variables that are likely to influence the interaction between fluoride and soil particles. Extensive fieldwork was done in the district and adjoining areas. The observations clearly show the heterogeneity of soil in this region, and reveals potential sites for storing excess fluoride at the sampling sites. Using local soil as potential fluoride scavenger was also successfully demonstrated.

Objective

The main objective of the study is to understand the various sources of fluoride and related toxic elements in fluoride and also to study their distribution and fractionation in several environmental sample.

The other objective is to evolve a technique based on laboratory work to remove the higher F levels using locally available source materials, such as soils, rock type and aquifer materials.

Methodology

Water samples were collected in polyethylene bottles between the year 1994-99 and analysed for pH, EC, F^-, $C1^-$, NO_3^-, PO_4^{3-}, SiO_2, HCO_3^-, SO_4^{2-}, Ca^{2+}, Mg^{2+}, Na^+ and K^+ as per standard procedures (APHA, 1995). The F-, C1- and NO3- ions were determined by ion selective electrode; PO_4^{3-} by ascorbic acid method and SiO_2 by molybdo silicate method in spectrophotometer; HCO_3^- by potentiometric titration; SO_4^{2-} by modified titration method after Fritz and Yamamna (1955) and Haartz et al. (1979); Ca^{2+} and oMg^{2+} in absorption mode while Na^+ and K^+ in emission mode of the atomic absorpition spectrophotometer. Chemical standards and blanks were run and replicate analysis of each sample was done for each parameter and variations were $\pm$5-10%.

Along with water analysis, on the soil samples collected from various sites, following laboratory analysis were carried out –

- i) Soil Fluoride – Water Extraction (Fswe)
- ii) Soil Fluoride – Acid Extraction (Fswe)
- iii) Rock Fluoride – Acid Extraction (Frae)
- iv) Fluoride in Soil Fraction
- v) Uptake of Fluoride by Soil
- vi) Uptake of Fluoride by Activated Charcoal
- vii) Uptake of Fluoride by Lake Sediment

Research findings

As the relationship in groundwater and soil depend on other ionns present such as bicarbonate (hardness), phosphate, calcium, etc and hence fluoride problem requires understanding the overall chemistry of the water-soil system and not just fluoride alone. The mean fluoride concentration varies from lake water (0.2-0.8ppm) through river water (0.6ppm) to well water (0.1-11.6ppm). Seasonal variation of fluoride and other major chemicals was in the following order, Post Monsoon <Monsoon < Pre Monsoon. Fluoride showed a significant positive correlation with alkalinity, and a moderate correlation with exchangeable sodium percentage (ESP) and sodium adsorption ratio (SAR). Coupled with the high sodium content, these correlation's reveal that weathering is the major source of fluoride in groundwater. In general, relatively high pH conditions have a tendency to displace fluoride ions from the mineral surface. From the above it is clear that relatively high alkalinity favours high fluoride concentration in groundwaters of Ajmer district.

Solubility of fluoride shows that 30% of the samples were over saturated with the mineral fluorite. Considering a reversible reaction involving hydroxylapatite to fluorapatite it was found that the possibility of conversion from hydroxylapatite to fluorapatite with the increasing concentration of fluoride was found negligible while the possibility of conversion from fluorapatite to hydroxylapatite was very high with increasing pH.

To understand the influence of fluoride in groundwater with other parameters, under the performed factor analysis HCO_3, F, and pH were grouped. Thus, when the water is alkaline in nature the fluoride tends to come out from its complex mineral assemblage.

The relationships between water extractable (0.5 to 21μg/g) and acid extractable soil fluoride (0.2 to 122μg/g) was found good. Various fluoride extractions on rock/soil in different depth and their relation to groundwater concentration shows the available source of fluoride very near to surface.

The fractionated soil fluoride from bulk soil clearly shows fluoride domination in clay fraction. About 21% accounted groundwater fluoride, which depends on the amount of clay, presents in soil. If the amount clay decreases the value of fluoride present in groundwater also decreases.

The fluoride release or uptake was found non-linear when a series of soil samples with fluoride solution containing 0-2.0ppm were kept from 15 minutes to 120 minutes. Fluoride release rate relatively slow initially, increased at 60 to 90 minutes and kept up to 120 minutes.

Effect on time versus fluoride release in zero concentration and fluoride negative release in 0.5, 1.0, and 2.0ppm was found with the sample from Deuli.

The relationship between water soluble and acid extractable fluoride in soil versus fluoride in groundwater was found moderate. Thus ~15% of Ajmer district groundwater fluoride source may be soil bound.

Results show that the efficiency of cation uptake by activated charcoal was enormous comparing to fluoride. But a non-linear relationship was observed between groundwater initial pH value and uptake of fluoride by lake-sediment. The lake sediment absorbed a minimum of 0.2 to a maximum of 112μg/g of fluoride whereas from 0 to 50μg/g fluoride was taken by activated charcoal.

It could not be made possible successfully to apply the lab model in the field because of time factor and the late release of funds in this project. Even though a detailed fluoride area map and hydrological studies for existing water sources show low lines and hydrogeochemical survey in areas where fluorosis is endemic in Ajmer district. In the affected areas the government should apply firm guidelines for the utilisation of groundwater so that tube wells/hand pumps in high-fluoride zones could be discouraged. The short-term solution to minimize the fluoride level in drinking water could be the use of Pushkar lake sediment in domestic defluoridation. The work should be quantitatively extended to field conditions for demonstrating the viability of this model to real life conditions.

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6 - Evaluation of Effectiveness of Domestic Defluoridation Techniques in Rajasthan

By SARITA, Udaipur

Introduction

In arid and semi-arid areas of Rajasthan, groundwater is mainly used for drinking and agricultural purposes in the absence of perennial rivers or surface water sources. Groundwater, however, contains high fluoride contents. The problems of fluoride becomes more complex in areas where groundwater contains high total dissolved solids, more than 1,500 ppm, making the water brackish. The contents of fluoride in ground water are increasing due to heavy withdrawal of water for agricultural purposes and poor recharging.

Aspur tehsil of Dungarpur district, Rajasthan is faced with widespread skeletal and dental Fluorosis. About 150 villages of three panchayat samiti (Aspur, Dungarpur and Sagwara] of Dungarpur district of Rajasthan [study funded by **RGNDWM**]. Besides, substantial animal population is also suffering from the disease. The micro-level study reveals that the dental fluorosis is pronounced in those areas where fluoride content in ground water is above 2.00 mg/l. But the skeletal fluorosis symptoms were observed only where the water contained more than 5 mg/l of fluoride. The non-skeletal manifestation are however, commonly complained of by people living where fluoride is above 1.5 mg./l.

Dental fluorosis and non-skeletal manifestations among the tribal population. Considering the high cost and associated problems in supplying water from safe sources, domestic defluoridation was recommended in four villages of Aspur tehsil with 100 % coverage. In two villages, Nalgonda techniques was promoted and in the remaining two villages, the Activated Alumina defluoridation technique was field tested.

According to the survey conduced in Rajasthan by the Public Health Engineering Department (PHED) from 1991-93, drinking water sources in 9,741 (25.7 per cent) out of 37,889 villages and 6,819 (15 per cent) out of 45,311 habitations were found to contain fluoride more than 1.5 ppm (the permissible limit according to the World Health Organisation).

Objectives of the R&D study :

The objectives of R&D project are:

(i) to break the generally held spiritual apprehensions about the disease and create awareness about causes of the disease;

(ii) to create awareness among the villagers about the importance of the domestic defluoridation through demonstration, education and people's participation;

(iii) to distribute both AA-filters and Nalgonda based filters on a pilot scale and validate their feasibility;

(iv) to correlate pH, alkalinity with fluoride content to suggest most appropriate domestic delfluoridation technology for its replication in other affected areas; and

(v) to educate and motivate the beneficiaries to self-sustain the use of these household technologies.

Research methodology adopted:

The programme is an action-oriented approach therefore, lot of primary data was collected and analysed. There was active involvement of community, PRIs, Govt. teachers and other staff to make the programme sustainable.

Although four villages in a cluster in Aspur Block were initially selected on the basis of reported data, yet **Baseline survey** was planned and executed to ascertain the fluoride levels in potable water sources of the villages. During the initial **CEP** [Community Education and Participation] meets, the issues like sharing of recurring expenses on chemicals, constitution of a village level committee to collect the annual recurring expenses, opening of saving accounts at local post office were organised and implemented. The **PRIs** [Sarpanchs, Up-sarpanchs, ward Panchs] were apprised about the importance of the kits [filters] before the initiation of the programme. Then these representatives were oriented to motivate the local population of four villages to actively participate in the programme.

The '**Key-components**' [variables] of the programme are :

(i) Public awareness activities;
(ii) Community based training;
(iii) Baseline survey;
(iv) Water analysis;
(v) Hardware [distribution of defluoridation kits];
(vi) Supply of chemicals;
(vii) Filed testing of treated water for determination of 'F' content;
(viii) Medical examination of fluorosis patients;
(ix) Cost sharing by the users;
(x) Concurrent monitoring and evaluation; and
(xi) Periodic documentation and report submission.

Research findings and their application :

The analysis revealed that the situation is alarming and the problem of high fluoride contamination in drinking water sources in Dungarpur district has to be tackled immediately. SARITA, therefore, propose following short-term and long-term measurers to minimize the ill-effects :

a. **Inculcate awareness** among the villagers to make aware about the real cause of the disease.
b. Popularise simple and handy domestic defluoridation techniques. This shall put a halt in further spread of disease of fluorosis among the local population. **Activated Alumina technique** be replicated till some other reliable technique is being established through R&D studies as it is simple and technically feasible.
c. **Urging villagers** to use water from safe water sources.

d. Popularisation of physio-therapic exercises under desired medical attention; through there is no permanent treatment of fluorosis; recent researches has shown that continuous intake of calcium doze prevents spread of disease in human body.
e. Geophysical surveys be attended to locate non-contaminated [fluoride free] aquifers which could supply polluted free water in the villages.
f. Installation of community based defluoridation equipments in affected localities and ensure about their proper maintenance by 'Local Village Group'.
g. Research and documentation work in gap areas of the district be attended urgently.

Status and potentiality of utilisation of research findings :

a. This programme may be considered as a model for replication in the adjoining 100 No. of affected villages of the Aspur tehsil, district Dungarpur.

b. Leaching experiments on various rocks and minerals to ascertain geochemistry of fluoride be attended to establish correlation between fluoride content, pH, alkalinity, hardness, TDS etc.

c. R&D work on popularisation of some other less expensive defluoridation technique be attended.

The results of our study can be of great use in formulation and implementation of an action-oriented programme by various departments and agencies. The suggestions made in this report can be of immense help to state PHED to re-orient drinking water supply strategies.

Suggested follow-up action/ scope for further research :

Following actions are suggested:

(i) PHED should take-up adequate measurers for maintaining the quality of supplied water as per international norms and should ensure that water supplied contains less than 1 ppm of fluoride.
(ii) The State Medical and Health Department, its subordinates district level hospitals and PHC's should be advised to maintain record of fluorosis affected patients. All patients should be examined as per WHO norms and stage of fluorosis of each patient be determined and recorded.
(iii) Central government should sponsor R&D work for proper treatment of fluorosis through research institutions and their findings be popularised for cure of diseased persons.
(iv) R&D works be further attended to introduce most reliable, simple and cheap domestic/ community based defluoridation system of polluted water.
(v) International donor agencies should be requested to donate funds for popularization of domestic defluoridation programme as at number of villages, fluoride free regional water supply could not be executed because there is not a single safe source. Moreover in the hilly terrain of Dungarpur, number of fluoride affected villages lie over undulating topography in remote and interior areas. In such areas, domestic defluoridation programme only appears suitable and sustainable.

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7 - Field Study Of Decentralized Drinking Water Supply Using SPRERI Solar Still In Needy Villages Of Gujarat

Study by Sardar Patel Renewable Energy Research Institute
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Introduction

Solar still is a simple device used to produce demineralized water from saline water with the help of solar energy. It has been observed that in many locations where shortage of safe drinking water exist, saline or brackish water is available. In order to produce safe potable water from the backish water at a household level, solar stills can be utilized. As solar still can be used in a decentralized manner, individual users can own the stills and hence can be expected to properly maintain them.

Conventional solar stills have been in use since over twenty years. These are difficult to maintain, clean and operate. Also it had glass as glazing material which often broke resulting in non use of solar stills. SPRERI had developed a new design of solar still which was easy to operate and maintain. The output from the new still was similar to conventional stills. Upscaling, optimization of specifications and selection of materials were the major activities that were needed to be undertaken. Though the still was technically superior to conventional stills, its user acceptability had to be evaluated

Objectives

Primary Objectives:

a) Scale up the existing 0.5 m^2 solar still developed by SPRERI to 1 m^2 and field test for supplying drinking water in needy villages.

b) Evaluate the utility of solar still in supplying safe drinking water and thereby improve the quality of life.

c) Optimize the design of the solar still for large scale field application.

Secondary Objectives:

a) Study the utility of solar still in controlling fluoride and other harmful chemicals in drinking water and its effect on health of people.

b) Determine the target groups where decentralized solar stills can be economically and technically viable.

c) Evaluate the potential of solar still in reducing the drudgery of village women and their health improvement.

This Institute had developed laboratory models of solar still which are easy to maintain and use. SPRERI solar still have to overcome many problems faced on conventional solar stills. Photograph of the first model of solar still is shown in Fig. 1. The current project has been undertaken to develop models appropriate for field evaluation. The scope of work included optimization of certain parameters and production of ten prototypes and their field-testing in a needy village.

Fig. 1 : First model of SPRERI solar still developed prior to the project

The following parameters for optimization were included in the study.

(i) Design of scaffolding to hold glazing
(ii) Optimization of height of scaffolding
(iii) Selection of glazing material and its fabrication
(iv) Design of stand for solar still

After optimization, ten solar stills were prepared and a village where available water was saline was to be selected for the field study. Suitability of SPRERI solar still for supply of drinking water in affected village was studied through field testing.

Research methodology adopted

Optimization of specification and material	: Through market survey and experimental evaluation
Selection of target voltage	: Village survey
Evaluation of product	: Through installation and monitoring at evaluators residence in an affected village

Research findings and their application

The solar still developed in the project consists of a FRP basin of 1 m^2 area with circular channels on the periphery. A scaffolding made of PVC pipes was fixed to the tray on which a cover made of UV stabilized plastic was supported. Saline water kept in the basin would get heated and the vapour generated would condense on the plastic cover and flow down to be collected in the channel. Condensate from the channel would flow into a bottle. On a clear sunny day three to four litres of salt free water would be available from each still. Fig. 2 shows the basin along with the scaffolding and Fig. 3 shows a complete solar still. Salt free water available from the still can be mixed with available saline water so as to prepare potable water. Three stills each were installed in three houses for the evaluation. The house members were trained in proper operation and maintenance of the stills. The output from the three stills, after blending with saline water was found adequate for each family for drinking and cooking purpose. Food that were hard to cook with saline water could be cooked well with solar still water.

Solar still developed under the project can be used in affected villages for providing potable water provided saline water is available in the village.

Fig. 2 :   FRP basin and scaffolding of SPRERI solar still

Fig. 3 : Fully assembled SPRERI solar still

Status and potentiality of utilisation of research findings

Limited field studies have been completed. A large-scale study involving a few villages representing different problem areas need to be taken up. The current solar still costs about Rs. 4500/-. It is essential to take up a study to bring down the cost mainly by using alternative materials. The single most expensive part in the solar still is the FPR basin which costs Rs. 3000/-. More economical materials like HDPE could be used to prepare the basins provided the numbers are large. If a project to field test about 450 to 600 covering 150 to 200 families in about 10 to 12 villages is undertaken, the above objectives can be achieved.

Suggested follow up action/scope for further research

A much large field study and efforts to bring down the cost are the major areas of future work. This would also help in technology transfer to one or more industries so as to develop suppliers for the product.

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8 - Development of low cost technology for the removal of pathogens and Pollutants from drinking water system

By Durga Seva Sadan, Bulansharhr

Introduction

Safe potable water is the necessities of life. A significant percentage of ground water a large percentage is biologically and/or chemically contaminated due to climatic,geo-chemical and anthropogenic factors. Excess fluoride, iron, lead, salinity, arsenic, nitrate and pesticides in the potable water are the cause for water borne diseases like fluorosis, blue baby disease, hemosiderosis, cancer etc.

A survey conducted by Government of India also revealed that 70 percent drinking water sources were biologically contaminated and 30 percent were chemically contaminated. Durga Sewa Sadan, Bulandshahr assessed the seriousness of the problem and drew attention for the development of this filter which is effective in remove of pathogenic bacteria and harmful chemical pollutants. The study focuses on the use of heavy metals for the purification of domestic water supplies.

Many metals like mercury, silver, copper and rare earth metals have antibacterial and antifungal properties. In water treatment systems both the metals (Silver and Copper) were used since ancient time and recently during the second world war these metals were incorporated by dissolving their compounds in to a filter media during electrolysis process by applying a reverse low voltage. In addition to heavy metals, several materials such as aluminium salts, zeolites, calcined alumina, sulphonated carbonaceous materials, ion exchange resins, alum, calcium phosphate bone char have been found to have purification capability. These materials have limitations and cause environmental problems. The defluoridation method like Nalgonda technique developed by NEERI, Nagpur and activated alumina technique were popular but failed in field operations.

To overcome all shorts of problems, studies have been undertaken for the development of filter material to disinfect existing water systems along with reduction of fluoride, iron, lead by the immobilisation of metal ions like silver and copper on the porous solid support.

Objective

(i) To design and develop cheap zero bacteria pollutants free water filter for best durability, decent flow rate for supplying safe potable drinking water.

(ii) Extension of developed technology to suit requirement of community.

State of Knowledge

In the past chlorine, ozone, chlorine dioxide, iodine, bromine, hydrogen peroxide, silver, ultra violet radiation and electro-physical processes were used for disinfection. The filtration technology has been used since ancient time to purify water viz. coarse and fine sand filter with grinded coal. In the present time slow sand filtration technology has been used to remove suspended particles along with chlorination to make water potable. With increased cases of water borne diseases candle filters were introduced in the market and it attracted attention of consumers. Now a days along with candle filters other water purifiers based on iodine, ultra violet radiation, activated carbon and silica gel etc. have been introduced in the market by the private sector to make water potable which is popular only in urban areas due to high cost. Iron, fluoride and nitrate is major problem in our country.. In case of iron and fluoride contamination in drinking water, NEERI, Nagpur developed technologies which failed in field operations and more effective technology is awaited. Durga Sewa Sadan, Bulandshahr developed a water filter for disinfection of drinking water along with reduction of fluoride, iron and lead. The water filter is mixture of some immobilised oligdynamic metal ions on the porous solid support. The filter has been tested in a laboratory with water samples of known concentration of E.Coli bacteria, iron, lead and fluoride.

Research Methodology Adopted :

To develop low cost water filter, experiments were conducted by immobilisation of oligodynamic metal ions like silver and copper on naturally occurring materials like Zealots, Activated Alumna, Activated Carbon, Silica gel and others for the removal of pathogenic bacteria like E. Coil and hazardous inorganic chemicals like iron, lead and fluoride from the drinking water .

Thermotolerant E.Coli bacteria strains were isolated from Kali Nadi on brain heart infusion broth (BHI) and cultured at 37 ^{0}C for 24 hours. Disinfection experiments were conducted in chromatographic columns at different bed depth of silver and copper immobilised on porous solid support at different concentrations from 500 to 10,000 microbes/ml. Bacteria strains in unfiltered water and filtrate were examined by MPN and plate count method.

Experiments were also conducted for the removal of hazardous inorganic chemicals like iron, lead and fluoride in chromatographic columns (1 - 5 cm.). Batch experiments were conducted by varying weight (0.5 - 5.0 gm/l) of filter material of different concentrations. In batch reaction studies the concentration of pollutants was kept 100 mg/l. Experiments were also conducted to examine continuous reduction of pollutants on filter material and at different pH. and temperature on which maximum reduction may take place. Gradient composition experiments were also conducted to finalise best suitable filter material for best efficiency. Disinfection durability experiments were also conducted for 96 hours, and lastly, a module of filter was designed and developed for the water filter.

Research Findings and Their Applications

The complete developed water filter was attached to the filter container (Steel, plastic and earthen pitchers) of 10 - 15 litre capacity each. The upper container was filled with nonpotable water and filtrate is potable water which may be used for drinking purpose. The application of water filters are as follows :-

(i). It is newly invented filter, totally non-hazardous to health.
(ii). The principle of disinfection is based is based upon physico-chemical methodology.
(iii). It removes micro-organisms like E. Coli.
(iv). It also removes iron, lead,fluoride, sulphate and suspended matters from drinking water sources .Other mineral contents remain unchanged.
(v). To fix the filter in the container(Earthen pitcher, steel and plastic)

remove the nut from the bottom of the filter. Fix the filter in the upper container and tight the nut.The filter may be fitted or removed according to the consumer need.

(vi). Generally filter provides 12 - 15 thousands litres safe potable water i.e. two and half year, if 15 litres water per day consumed.(vii). The filtered water has been tested for 96 hours, thus Disinfection property persist.Although reported data about the constituents of filter material revealed that disinfection property should persist for more than a year.

(viii). The rate of filtration of each filter is 1.00 - 1.50 litre per hour. *Presently our government is sanctioning water supply schemes to all of those areas where available water sources are not fit for drinking purposes due to fluoride, iron and other contaminants. The cost of each water supply scheme is not less than 80 lakhs. The electricity supply in our rural areas is not regular. The established water supply schemes are generally useless. Even then the water quality is not the surety. If in case we provide such type water filters to each family. The cost will be very less and in future beneficiaries may purchase its own.*

(ix). Filter water does not contain any hazardous material. The filtered water is free from any health risk

Status and Potentiality of Utilization of Research Findings :

The developed water filter has been tested in laboratory for fluoride, iron, bacteria etc.by nationally reputed R & D organisations i.e. Centre for Water Resource Development and Management (CWRDM), Kozhikode and Sanjay Gandhi Post graduate Institute of Medical Sciences (SGPGIMS), Lucknow. On the basis of two national laboratories findings about the filter, U.P.Jal Nigam (Agra Zone) established around 25 water filters in one fluoride affected village Patti Pachgai. The test report about fluoride removal from U.P.Jal Nigam revealed the fact that the water filter is fully suitable to convert contaminated drinking water in to potable water and due to its low cost it may be provided to the villagers for field trials for their better health.

Suggested Follow Up Action/ Scope for Further Research:

In future follow up action and further research may be as follows :-

a) The filter has to be tested nationally in the naturally water field conditions for the effectiveness in water borne affected areas;
b) It is low cost water filter. Government has to made efforts by UNICEF,
c) RGNDWM,CAPART or by some other agency to distribute among villagers to aware them for its use and utility;
d) Efforts should also be made to search problems and technology development for arsenic in West Bengal which may be given to each and every family of its use;
e) In future efforts should also be made to develop low cost on line water filter assembly, development of non-chlorinated water disinfectant product.
f) Efforts should also be made to control level of pollution in ground water which is still the best water source for drinking purpose.

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9 - Development of a water purification technology based on ceramic pre-filters and micro-filtration membrane modules

Study by Central Ceramic Research Institute, Kolkatta

Introduction

Measures for water treatment by several methods such as coagulation and sedimentation used for removal of suspended impurities, although separates considerable amount of particulate matters, relatively finer colloidal particles still remains as contaminants requiring removal by suitable techniques. Filtration by slow or rapid sand filters, pressure filters are not only very inefficient (due to slower filtration rate, usually of the order of 80-1000 lpm/sq.m) but also requires large space requirement and recurring maintenance cost. Use of membrane filtration for water purification has the following advantages:

a) Tailor made porosity and pore size of the membrane filter.

b) Suitable for producing higher flow rate at higher operating pressure.

c) Resistance to microbial attack and degradation of the filtering media.

d) Resistance to corrosive chemicals and stability of the membrane material.

e) Ease of cleaning and regeneration of the membrane material.

f) Higher durability and longer life with lower maintenance cost of the membrane module as a whole.

Objectives

The objectives of the study are:

i. Development of simplified and more efficient water purification technology based on ceramic prefilters and microfiltration membrane modules for treatment of water from open dug wells, ponds, rivers and canals.
ii. Improvement in the quality of drinking water through removal of microorganism/ bacteria through the use of membrane technology.

State of knowledge

Membrane may be defined as thin microporous devices which permit selective separation of some specific components present in a homogeneous medium under the action of pressure/ potential gradient. Membrane process encompasses wide applications such as clarification of suspended particulate matter or colloidal impurities for clarification/ purification of liquid media, removal or recovery of microorganisms for sterilization or purification purpose, fractionation/ removal of macromolecular, molecular and ionic species. Membrane separation thus implies removal of undesirable materials/ impurities by size exclusion mechanism, i.e. by seiving the desired components. The pore size of the membrane medium determine the level of separation that can be achieved. Control of pore size, porosity, microstructure and thickness as well as configuration of the membrane module determines the efficiency of the system for removal of undesirable elements. According to the nature of impurities, i.e. suspended particles, microorganisms, macromolecular compounds, nano-sized molecules or ions, the membrane module is required to be designed and developed in a specific configuration such as disc/plate, tubular, cartridge, spiral, etc. The scope of application of membranes in water purification is given below :

a. Membrane filtration: Water is forced through prefilters and MF membranes with absolute diameter pores. Contaminants larger than the pore size are collected at the surface with some smaller substances trapped within the finer structure. Typical pore size for such type of membranes is 200-1000 nm. The advantage of this process is that it effectively removes all particles and microorganisms greater than the pore size and also requires minimal maintenance cost. The primary application of such type of membranes is removal of certain types of bacteria and particulate matters.

b. Ultrafiltration: In this process water flows tangentially across the membrane having a highly asymmetric pore structure. The membrane is strong enough to withstand higher water head pressure and retain contaminants and macromolecules at its surface while allowing water to pass through the same. Typical pore diameter is between 2-100 nm for such type of membranes. UF membrane has the advantage of removing almost all the particulate matters, colloidal particles, microorganisms and pyrogens effectively and producing quality water with much lower amount of energy compared to conventional separation process. The membrane is also regenerable and requires minimal maintenance cost. The main application for ultrafiltration membrane is for production of pyrogene free water and providing feed water input to DI and RO systems besides obtaining high resistivity semiconductor grade rinse water.

Literature survey reveals that there are three methods for preparation of membranes :

a) Solid State sintering

b) Phase separation and leaching

c) Sol-gel processing .

The solid state sintering process following suspended powder technique leads to the development of microfiltration membrane with pore size in the range of 200 - 1000 nm. Ultrafiltration membrane having pore diameter between 1-100 nm may be prepared by solid state sintering process following colloidal route or by phase separation cum leaching process. The pore size in the former method varies between 2 nm and 20 nm while the later method is generally used to develop pores in the range 2-100 nm. The Sol-gel process is an emerging technique for the development of ceramic oxide membranes with much finer pore sizes suitable for nano-filtration and reverse osmosis application. Presently developmental efforts are being carried out extensively for preparation of oxide membranes based on silica, alumina, titania and zirconium oxide layers primarily for gas separation applications.

Research methodology adopted

Under the above project, detailed investigations have been carried out to develop porous ceramic supports and membranes of controlled pore size. Attempt has also been made to increase the porosity of the ceramic tubes by incorporating pore forming agent in the mix composition. The effect of adding pore former on pore volume and pore size distribution shows that porous supports with desired pore structural characteristics can be achieved by controlling particle size of pore forming agent. Subsequently, tubular samples have been fabricated using the optimum mix composition. The permeability of slip cast tubular samples was determined with progressive period of filtration using different qualities of water

Based on the above findings, a multitubular module (about 0.05 sq. metre area) consisting of nine elements (7 mm I.D. X 300 mm length) has been designed and fabricated. A prototype unit including the membrane module, water pumping and regeneration facility has also designed for seperation of suspended particulate matter and water borne microorganisms from surface/ sub/ sub-surface water.

Research findings and their application

Dimensions of the porous tubes fabricated using different techniques like slip casting and extrusion are :

- 200 mm length x 25 mm internal dia. X 6 mm
- 300 mm length x 7 mm internal dia. 2 mm wall thickness .

The pore structural characteristics of these tubes have been evaluated and then used for studying suitability as membrane filters with or without applying metal coating and oxidation sintering. The modal pore size have been found to be about 1.5 and 3 um for smaller and larger dia. tubes respectively.

With a view to get an idea about the ease of regeneration, permeability of the disc samples after pore clogging and subsequent cleaning treatments have been measured. A comparative evaluation of the permeability characteristics before and after cleaning showed that the samples can be regenerated to their original efficiency both by back flushing and chemical treatment .

The performance of the porous supports has been evaluated before and after coating under varying conditions, viz. filtration time, feed pressure and quality of feed water samples (tap water, turbid water containing clayey and ferruginous impurities at a level of 300 ppm). The performance of the coated sample for filtration of turbid water have been found to be much better than the uncoated sample. The bactereological quality of water obtained after treatment has been analysed and is found to be free from all water borne microorganism. The performance of the porous supports has been evaluated before and after coating under varying conditions, viz. filtration time, feed pressure and quality of feed water samples (tap water, turbid water containing clayey and ferruginous impurities at a level of 300 ppm). The performance of the coated sample for filtration of turbid water have been found to be much better than the uncoated sample. The bactereological quality of water obtained after treatment has been analysed and is found to be free from all water borne microorganism.

Preliminary evaluation of the performance of the prototype unit has also been conducted in the laboratory and the filtration rate is found to be of the order of 5-6 litre/ hour using water from open dug wells and tap water.

Potentiality of utilization of research findings

The application of membrane filtration in water purification primarily aims at separation of mainly three types of impurities, viz. suspended particles/ colloidal matter, microorganisms and ionic solutes. The ceramic prefilters as fabricated under the proposed project may be used to remove suspended particulate matter from the surface water while ceramic microfiltration membranes can separate the water borne microorganisms.

Thus the following ultimate goal of the above investigations would be fulfilled :

i) Development of a simplified and more efficient water purification technology based on ceramic microfiltration membrane modules for treatment of surface water from various sources like ponds, rivers and canals.

ii) Improvement in the quality of drinking water using membrane technology for community supply.

The results of the above work may also be utilized for development of multichannel ceramic module for attachment to the hand pump units. The membrane modules envisaged to be fabricated under the proposed investigation are also expected to lead to development of technologies for pollution abatement and reuse of wastewater generated from location of specific sources/ industries .

Scope for further research

As an extension of the above activity, it is proposed to formulate a new project on “Field Trial of Prototype Unit of Ceramic Membrane Filter for Surface Water Treatment and Scaling Up Studies for Community Application “. The new project is being contemplated to develop a field demonstration model. It is proposed to undertake extensive laboratory and field trial using raw water from different sources. Performance evaluation of the prototype unit would also be carried out continuously for longer duration to determine the useful life of the membrane filters both before and after regeneration and cleaning. If necessary, furthur modification of the prototype unit would also be made for validation of the findings under field condition for continuous operation .

Based on the above results, necessary action needs to be taken to undertake scale up studies in order to fabricate modules for development of community model for supplying potable water. For this purpose, about 200 porous tubes (25 mm I.D. x 37 mm O. D. x 1000 mm length) is required to be fabricated and fired under controlled condition. The membrane preparation technique is also needed to be mechanized in order to obtain an uniform coating thickness. Finally, the efficiency of the “Community Model” would be tested under simulated laboratory condition prior to its field application . Detailed investigation on the multi-tubular modules (surface area 1.0 sq. metre) would be undertaken for evaluation of their performance during long term field trial at different operating parameters like feed pressure, flow speed, regeneration period, etc.

Finally, separate projects would be taken up in the next phase for fabrication and installation of field demonstration units at various location to study the adoptability of the same in rural areas.

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10 - Development of Water Purification System for the Supply of Safe DrinkingWater using Magnetic Carrier/Tag Technique

By Regional Research Laboratory, Bhubaneswar

Introduction

Water-the most precious gift of nature consists of 75% of earth's surface but we are endowed with only 4% of the world's fresh water supply. This most important resource for the existence of loves on earth cannot be taken for granted simply because it is seemingly abundant. It is not only the basic need for human existence but also a vital input for the development activities. Its availability in sufficient quantity and of right quality is a necessary infrastructure for promoting better quality of life. Safe drinking water and sanitation are the two basic needs in a developing country like ours. Provision of these facilities should help to improve the hygiene and thus raising the quality of the life and health of people. One of the most serious threats faced today by the mankind is the scarcity and availability of safe drinking water. It is expected that the per capita water requirement is around 320 litres per day.

Water is difficult to treat, costly to transport and impossible to substitute and the consumption is increasing day by day due to increase in population. Since the pure water is a low value product, the main problem is to remove the dissolved and suspended impurities economically from large surface water when general public uses it as safe drinking water. As such water for treatment must be presented with large surface area of reactive surface to promote rapid adsorption of hetro-coagulation of the impurities to be removed. In most of the Indian water works, alum and bleaching powder are commonly used in treatment process. Many polymers are used as coagulant aid in the drinking water system in several developing countries. In connection, Regional Research Laboratory, Bhubaneswar (PRLB), he developed of a the unique process for the purification of surface water to safe drinking water using magnetic carrier technique.

One of the latest technologies under development for the clarification of water is the use of magnetic particles in conjunction with some polymeric reagents. In this method raw water comes in contact with regent and magnetite, where upon the soluble ions, colour, turbidity particle like clay, bacteria or virus hetro-coagulate by bridging the loaded oxide. The process enhances the settling rate. The purfied water there on is safe for drinking purpose and as such a techno-economic process was needed to be developed in India.

Objective of the R&D study and its scope

a. Removal/separation of the suspended (colloidal) and dissolved impurities for purification of surface water with appropriate selection of polymer (gel) and the magnetic particles (carrier).

b. Separation and or minimization of biological impurities or the disease causing Bacteria present in the surface water using the above technology while specifically aiming for the portability of water supply.

c. To set up a 1-2 M^3/h on-line bench scale experiment for cleaning of surface water for rural water supply.

State of knowledge

Since the early 1900s several patents on magnetic separation have appeared describing devices for the separation and handling of magnetically susceptible solids for mineral applications. Process engineering applications using magnetic carrier technology originated in the early 1940s when magnetite was used to remove organic impurities from waste water via electrostatic adsorption. Later the use of magnetic carrier particles for the immobilization of enzymes and biologands in bioprocess reactors was proposed. In addition to these established applications, it is also evident that immobilization of macromolecules or colloidal solids onto magnetic support offers a means of selective separation which is likely to be amenable to efficient and large scale biological and effluent and drinking water other treatment operations.

Magnetic carrier technology

Recently there has been increased interest in the use of magnetic separation techniques in the treatment of the fine colloidal particles, which are slow and difficult to separate by classical separation techniques. However, applications have been limited to those involving magnetically susceptible particles. To overcome this problem magnetic carrier particles have been developed to enable the separation of small particles, which are not naturally magnetically susceptible. By varying the surface characteristics, selective recovery of colloidal and macromolecule species can be achieved by attaching the desired species onto the surface or entrapped within, a magnetic carrier particle.

A carrier system involves using one magnetic particle to carry a number of particles or molecular species on its surface, or entrapped within the carrier particle. The diameter of the magnetic micro sphere, Dp is generally larger than the diameter of the species to be separated dp. A number of particles bind to the surface for magnetic carrier particles the ratio of the diameters dp/Dp generally lies in the range of 0.1-0.001. An early example of the use of the magnetic support materials for selective separations was reported as consisting of beads of polyacrylamide gel containing magnetite with a surface bead coating of d-asparagines coupled on the surface. One of the most suitable magnetic materials is Fe304. Common gels used are; polyacrylamide, and alginate.

Either coating a magnetic particle or entrapping a magnetic particles in a polymer matrix can generally produce magnetic beads. However gels are generally less stable to temperature and solvents than polymer carriers and they most are hardened using an agent such as glutaraldehyde. Recently, the development of good quality magnetic carrier particles that can withstand temperatures up to 120^0 C and common solvents has been reported and the large scale of the production of magnetic carriers will undoubtedly result in their expansion into large-scale operations, such as effluent and water treatment.

Research methodology adopted

Quality of surface water used in the study: Water from river Kuakhai which flows parallel to Bhubaneswar city is being supplied as drinking water to the city after required treatment being done at Palasuni Water Works, a Govt. of Orissa undertaking. The unit operates on a conventional water treatment and uses alum and Polyelectrolyte for purification and chlorine as disinfectant in the final step. Since the river basin is alluvial in nature, the turbidity in the rainy season rises as high as 200-240 NTU. Therefore the purification of water in rainy season is quite a challenging job. The physico-chemical analysis of the Kuakhi river water sample collected in rainy season is presented in Table-1.

Table-1
Chemical Analysis of Kuakhai River Water Sample
(All values except pH and turbidity are in mg/l)

Constituents	**Parameters**	**Constituents**	**Parameters**
PH	8.05	Cu	0.00
SO_4^{-2}	331.0	Ni	0.04
Cl^-	13.99	Co	0.02
Alkalinity	73.2	Zn	0.00
Salinity	25.28	Fe	2.6
Total Hardness	54.04	Mn	0.0
Harness (pH)	9.15	Pb	.01
Harness (Ca)	40.04	Na	4.58
Harness (Mg)	14.01	Ca	10.04
TDS	143.0	Mg	6.54
TS	825	Cr	0.09
TSS	682.0	Turbidity	233.65

The table-3 above indicates that the Kuakhai river water during the rainy season is very muddy, has a turbidity of 233.65 6 NTU and is highly unsuitable for human consumption unless processed. Besides that it contains some of the heavy metal ions like Zn, Co, Ni, Cr, Mn, Fe, and Pb etc in small entities. The coagulated and flocculated materials present in the water were carefully taken out by thickening. The dried material thus obtained was subjected to chemical analysis and is presented in Table-2.

Table-2
Chemical analysis of the impurities present in Kuakhai river water

Sl. No.	**Constituents**	**Percent**	**Sl. No.**	**Constituents**	**Percent.**
1.	SiO_2	57.3	9.	Ni	0.003
2.	Al_2O_3	11.6	10.	Co	0.009
3.	Fe_2O_3	19.68	11.	Cu	0.0037
4.	LOI	19.8	12.	Mn	0.12
5.	CaO	0.05	13.	Pb	0.006
6.	MgO	0.691	14.	Cr	0.0037
7.	K_2O	0.625	15.	Cd	0.36
8.	Zn	0.036			

I can be seen that the turbidity of the river water is mainly due to the presence of SiO_2 Al_2 O_3 FeO, CaO, and MgO etc. The particle size analysis the above material show that 80% passing sizes – 15.3 micron size and the average diameter of the particle (d_{50}) is around 8 micron.

Purification of surface water: Alum is the most common coagulant used in India for the purification of surface water. Most of the water works in abroad are now using Polyelectrolyte along with the alum for better results. When Polyelectrolyte is used as coagulation aids with magnetite they enhance the settling of suspended solids and reduce the aluminium sulphate dosages. It has been stinted that in the clarification of water with a redeemable particulate coagulant such as magnetite, soluble colour ions, and turbidity particles like clays, bacteria, virus (1 to 10 micron) are being removed. The impurities with negatively surface charges hetro-coagulate with positively charged oxide.

Physico-chemical characterization: The physico-chemical analysis of raw and processed water for hH, Total Solids (TS), Total Dissolved Solids (TDS), Total Suspended Solids (TSS), was carried out by wet chemical analysis using APHA methods, Century Make CK 710 Water Analysis Kit and Atomic Absorption Spectrophotometer. The colour measurement of the raw and the clear water was carried out with the help of Beckman DU 640B UV spectrophotometer. The analysis of the heavy metals present in water was carried out by AAS techniques. The turbidity measurements were performed using a DRT Turbidity meter supplied by M/s H.F. Scientific Inc., Florida USA. The zeta potential measurements were carried out using a Zeta Meter supplied by Rank Brothers Mark II, England.

The coagulated and flocculated materials present in the water were carefully taken out by thickening. The dried material thus obtained was subjected to particle size analysis. Malvern Particle Size Analyses Model 3600 carried out the particle size analysis of the sample. The field strength measurement of the field coil and the permanent magnets used in the experiments was carried out with the help of a Gauss Meter manufactured by Control System & Devices, Bombay using a Hall Probe. The range of the instrument is 0.10 KG.

Reagents and Magnetic Material: Analytical reagent $Al_2(SO_4)_3$ of crystalline grade and potato and corn starch were used as the coagulant aid in the experiments. The starch was degraded by 10% NaOH at 70_0 C by conventional method. The potable Polyelectrolyte viz. Rishfloc, 950 C and 950 Cap manufactured indigenously by Rishabh Metal and Chemicals Pvt. Ltd. Bombay and Polyelectrolyte SN1, SN2, SN4 and SN64 manufactured by Suyog Chemicals Pvt. Ltd. Nagpur were used in the series of experiments.the other reagents such as Magnafloc LT-27, LT-31, LT-225 used in water treatment were potable, non-toxic and having high molecular weight Polyelectrolyte from Allied Colloids Minerals Processing Division USA. All the reagents were dissolved in distilled water as per the instructions laid down by the manufactures. For the preparation of synthetic water high quality clay was mixed with mineralized water in required proportions. Magnetite Sample being produced by M/s. Kudremukh Iron Ore Company Limited (KIOCL) was used in the present investigations. The sample crushed, ground and sieved to a, close fraction (-45+25) was selected for the studies. The iron content in it was found to be 71.98%.

Experimental Procedure: Water samples underwent a series of Jar tests by conventional methods. One litre of raw water was conditioned for 5 minutes at 300 rpm with the help of IKA German make highly precisions electronic speed regulator motor with an accuracy of +_1 rpm, followed by mixing of known quantity of selected reagent. The conditioning was further continued for another 5 minutes at 200 rpm. The entire water was then allowed to settle in the graduated cylinder and subjected to turbidity measurements. During the settling period supernatants were drawn from the Jar at a fixed level from the Jar. Initially the settling was carried out with synthetic water of known turbidity by mixing clay and demineralised water and subsequently the polyelectrolyte that can enhance the settling behaviour of the suspended solid particles. The magnetite was applied as carrier. Magnetite particles (1.0 g/I) were homogeneously mixed with the required amount of reagent before addition to the water sample. A permanent magnet of field strength 1200 gauss was applied to enhance the settling rate. The jar was kept on the bar magnet just before starting the settling studies.

Mechanism of water purification by Polyelectrolyte: The removal of turbidity and organics from water supplies involves contending with impurities that are negatively charged at natural pH levels, and have formed a stabilized dispersion. The first step is to destabilize the dispersion and coagulate the contaminants, which is generally done by the addition of positively charged species in appropriate quantities to neutralize the charge on the impurities. A flocculation step is the used to bring together the particles so that large flocs are produced. The best turbidity and colour removal occur when the mobility or zeta potential of the particles is close to zero, or the particles carry net zero charge. The impurities along with the magnetite settle after magnetization and the magnetite is regenerated with alkali at pH 11 to 12.

Research findings and their applications

The measurement of zeta potential showed that the particles are fairly negatively charged at all the pH values indicating the presence of quartz and clay type of materials in it. the results of the zeta potential indicate that the optimal pH for reducing the electrostatic charge on the colloidal particles is around 6.5 this has been also confirmed by studies carried out earlier by Lawrence et al. the effect of alum at two different dosages for the removal of turbidity from Kuakhai river water was tried at slightly acidic pH (6.5) because at alkaline pH the $Al_2\,(SO_4)_3$ precipitates as various hydroxides of aluminium. The results indicate that it is possible to obtain the turbidity of 12.5 NTU from the entail value of 236 NTU at 10 mg/1 of reagent concentration. Similarly the addition of degraded strach also did not prove to a good coagulant for purification of surface water containing negatively charged particles.

The minimum turbidity achieved with the combination of Rishfloc and Magnafloc (1:1) is 9.03 NTU at a reagent concentration of 40 mg/I and 100 mg/I of clay. The reverse effect was seen at higher dosage of reagent concentrations perhaps due to adsorption of a small amount of reagent on magnetite and the dispersion effect caused by the excess reagent. Magnafloc LT-27 is an anionic polyacrylamide and most of the particles responsible for turbidity in water are also negatively charged ions increases resulting in reduced electrostatic attraction. It has been seen that with the increase in reagent dosages, the turbidity also increases. The mangafloc LT-225 is a high molecular weight polyelectrolyte, especially used for potable and industrial raw water treatment. The optimum coagulant dose to remove the suspended inorganic matters was found to be advantage over the anionic polymer Magnafloc LT-27. The studies were carried out with a potable reagent namely 950 C on synthetic and actual water sample obtained from Kuakhai River. The results of settling of impurities in synthetic water with reagent 950 C with 1000 mg/l of clay as impurities indicate that a final turbidity of 16.9 NTU in 60 min was 11.3 NTU. Further, the settling of the impurities was also not so rapid. Similar studies as above with the reagent 950 C yielded good results. The results of purification of Kuakhai River water having a turbidity of 233.6 NTU with the reagent 950 C at different concentrations with and without magnetite was however better. The settling of the impurities was very rapid and the final turbidity achieved with a reagent concentration of 30 mg/l and 1g/l of magnetit was found to be 4.42 and 4.23 NTU in 20 and 60 min respectively.

The reduction in settling time is mainly due to the use of magnetite particles as carrier. The size of magnetite and its magnetic properties help in increasing the settling rate in many folds. The colloidal particles from flocs around magnetite and thereby settle faster in presence of a magnetic field. The combination of coagulation and magnetic attraction enhances the settling rate and reduces the turbidity. The final turbidity of the water was found to be 4.23 NTU and all the other parameters are also well with in the permissible limits.

Magnafloc LT-31 is a high molecular weight liquid polyelectrolyte liquid and has high cationic charge especially used for potable and industrial raw water treatment. Magnafloc LT-31 showed the highest activity on coagulation system. A turbidity value of 8.07 NTU could be achieved with a dosages of 1.25 mg/l of Magnafloc LT-31. The use of magnetite proved still better on the coagulation if impurities and settling rate improved with final turbidity of 6.0 the higher dosage however, produced reverse results. This may be due to dispersion of impurities in the presence of excess regent. Magnafloc LT-31 has been proposed by the manufacturer as an adjuvant for coagulation of suspended matter in water. It has been specially developed for the treatment of potable and industrial raw water. It is used as a coagulation aid along with the conventional coagulant such as alum, ferric alum, or poly aluminium chloride. In the present study it has been observed that the cationically charged polymers flocculate colloidal particles by the bridging mechanism. The bigger floc thus formed allow faster settling; better overflow clarity and thus more efficient filtration to improve overall performance of the process. Some tests were also carried out by using the Magnafloc LT-31 in combination with alum. It can be seen that the suspended particles were successfully removed by a mixture of 1.25 mg/l of Magnafloc LT-31 and 12.25 mg/l of aluminium sulphate. It was possible to get a clear water having a maximum turbidity of 3 NTU within 5 minutes, and there by greatly reducing the dosages of aluminium sulphate naturally required otherwise. The final turbidity achieved after 60 min was 1.4 NTU as seen in fig.

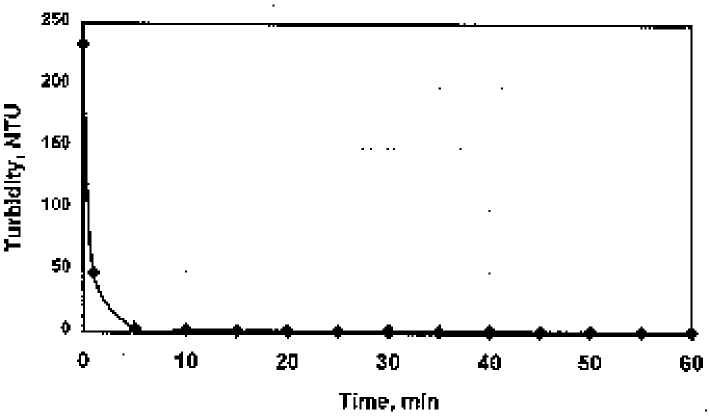

Fig. 1 Settling bahaviour of impurities in Kuakhai river water with 1.25 mg/l of magnafloc LT-31 and 12.25 mg/l of alum

Although the Magnafloc LT-31 has the advantages of decreasing the turbidity but it could not significantly bring down the total dissolved solids concentration in above conditions. However, it is able to reduce the total dissolved solids (TDS) from 105.3 mg/l to 95.1 mg/l. Kolarik found that soluble colour ions present in the water were adsorbed onto the magnetite surface and polymeric reagent during the process of coagulation by virtue of the protonated sites. The colour transmittance was also measured with fixed dosages of Magnafloc LT-31 (1.25 mg/l) at different settling times. It was possible to bring down the transmittance of the water from 80.2 to 97.5 The clarity of the processed water was also tested by recording the optical transmittance of the treated sample at different time intervals with help of UV spectrophotometer at 400 nm. The transmittance, which was 25.4% at the beginning of the treatment, increased to 97.6% after 60 min. This proves the complete settling of the impurities after the treatment with 1.25 mg/l of LT-31.

Further studies were undertaken with four different (SN1, SN2, SN4 and SN64) Polyelectrolyte to reduce the turbidity of water to an acceptance level. The effect of magnetite particles on the coagulation of the impurities was also studied during these studies. Among the above Polyelectrolyte, Surfloc SN4 yielded better results, as it was possible to bring down the turbidity to 2.11 NTU from a initial value 233.65 NTU by using 1.5 mg/l of

SN4. Further experiments using 12.25 mg/l of $Al_2(SO_4)_3$ and 1.50 mg/l of the reagent at 6.5 pH in combination with magnetite resulted further significant reduction in turbidity. It was possible to get a clear water of 0.22 NTU within 5 min of the settling time. The clarity of the supernatant and the reduction in settling time is due to the use of magnetic particles as carrier. The complete analysis of the water obtained by this technique is given in Table-3. The water however needs to be tested for its potability.

Chemical analysis of processed water by the combination of 1.25 mg/l of Surfloc SN4 and 12.25 mg/l of Alum
(All values except pH and turbidity are in mg/l)

S. N.	Constituents	Processed Water	S. N.	Constituents	Processed water
1.	PH	7.4	7.	Pb	0.001
2.	SO4-2	25.35	8.	Fe	.022
3.	Cl-	8.2	9.	Mn	0.006
4.	Alkalinity	43.22	10.	Cr	0.001
5.	Total Hardness	47.4	11.	Cd	0.008
6.	Total dissolved solids	95.3	12.	Turbidity	0.22

Laboratory Setup

An on-line laboratory set-up having a magnetic field strength of 4.500 Gauss has been designed, fabricated, installed and tested in the laboratory for purification of Kuakhai River water. A capacity of 2 litre per in was achieved with the above unit. Certain improvements are therefore necessary in increasing the output of the system. Other related studies like, determination of molecular weight of different polymers has also been carried out.

Status and potentiality of utilization of research findings.

Since drinking water is a low value product, the process for the purification of water has to be basically techno-economically viable. In a conventional water treatment plant, the treatment process is a time taking process because the settling of the impurities is a very slow process and it normally takes 4 – 5 hours to complete the whole process. As such the capital cost of the plant goes very due to large storage capacity. In the present investigation the results are very encouraging. Even water having turbidity 233.65 NTU collected during the rainy season could be converted to a clear water of 0.22 NTU with in 1 hour with the application of a small dosage of 1.5 mg/l of Surfloc SN4 and 12.25 mg/l of conventional alum. The quantity of the Polyelectrolyte, the alum the time will be very much reduced in normal days when the turbidity of the raw water varies between 5 – 10 NTU. Hence the above technique will prove to be a technology of tomorrow when the require of drinking water is going to increase a number of times. The present investigations a new technique for the purification of surface water to be used for drinking purpose has been well demonstrated which now needs to be converted to a technology by design the system and a large magnetic circuit. Hence, further exploration of the above technique is very much essential.

Suggested follow up action / scope of further research.

The research project could be invited for conforming the above finding and design and development of an online demonstration plant for purification and supply of drinking water using magnetic carrier technique. This is certainly going to be the technology of tomorrow which needs to be indigenously developed today.

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11 - Natural Products As Water Purifiers

Studies on the Adsorption of Organics and Inorganics from Aqueous Solution using Carbon Prepared from Natural Wastes

Introduction

In last three decades, National and International bodies responsible for public health have become increasingly anxious about trace constituents of food and water and their possible harmful effects on human health. As most industrial wastes contain toxic substances, their disposal into a natural body of water is objectionable. If the toxic specifies could be recovered from waste water it may bring high economic returns in addition to removing the pollution load from the waste water. Further, the water recovered from the segregated waste, if in good quality, can be reused resulting in the reduction in the consumption of fresh water. Such a reuse of water is often a necessity when supply from natural source is inadequate to meet the needs of the ever expanding population and industries.

The stringent discharge requirements of waste water coupled with the rising cost in the treatment of waste water with the convergence of diminishing supply of fresh water and the demand placed on that water has prompted many research workers to examine new avenues for treating water. Treatment with activated carbon has no doubt been found technically sound as the treated water is clean of suspended solids and toxic substances. However, the use of commercial activated carbon makes the treatment by adsorption expensive. Therefore in recent years, an upsurge in low cost / waste material as a source of activated carbon.

In view of this, it is worthwhile to pay attention to the preparation of pseudoactive carbons from an agricultural waste such as Pearl Millet Husk (PHMC) and from a forest residue, Eucalyptus leaves (ELC) and study its capacity to remove methylene blue dye, phenol, Cr (VI), Hg(II) and Cu(II) from aqueous solution.

Objectives

The project aim to optimize conditions like pH, carbon dosage and equilibration time for maximum adsorption efficacy of PHMC and ELC. These isotherm test variables along with the adsorption kinetics results will help in designing a waste water treatment process. From the practical view point, the recovery of the adsorbed species from the carbon surface and carbon was experimented which would indeed be of considerable value for repeated use of the carbon.

Justification for the Study

Among the various standard methods of water / waste water treatment, adsorption is generally preferred due to its high efficiency, easy handling, availability of different adsorbents and cost effectiveness.

Adsorption is a unique process useful for the removal of both organics and inorganics from water and wastewater. It is a process by which the concentration of solute is enriched at the surface or interface between two phases. It is capable of producing effluent free of suspended solids. Carbon adsorbents have attracted special attention on account of their well-developed porous structure, large active surface area, good mechanical and regeneration properties. Despite the prolific use of the commercial activated carbon for water / waste water treatment, carbon adsorption remains an expensive treatment process. This has prompted a growing interest for the production of low cost activated carbon from cheap, indigenous carbonaceous precursors. During recent years much emphasis is placed on agricultural wastes as source of carbon with a view to bring about a significant cost reduction in the treatment of water / waste water with concomitant management of the solid waste chosen as carbonaceous precursor.

Pearl Millet husk and Eucalyptus leaves are available as a waste agriculture product in plenty in India at a very low cost. It is an ideal agricultural mask production for the production of activated carbon.

The problems caused by the colour imparted by methylene blue dye and traces of phenol, Cr(VI), Hg(II) and Cu(II) and the harmful effects associated with their presence are well documented. Hence their removal from water / waste water using cost effective technology assumes importance.

State of Knowledge

Various feed stocks proposed for the preparation of activated carbon are adequately covered in the textbook of Hassler. Cost effective, non-conventional adsorbents like agricultural and industrial waste / by products, biosorbents and other sources such as ores, minerals, metal oxides, etc., are used as carbonaceous precursors for the preparation of low cost activated carbon. Pollard et al. and Namasivayam have reviewed low cost non-conventional adsorbents for the removal of heavy metals and dyes from waste waters. Mohammad and Mohamed reviewed different adsorbents used for the minimization of heavy metal content in water and waste water. Utilization of agricultural and forestry wastes as raw material for the production of energy, chemical and activated carbons has increased notably in recent years.

Research Methodology

Low cost carbon was prepared from pearl millet husk and waste eucalyptus leaves by sulphuric acid treatment method. Normally, carbon from agricultural materials is prepared by heating to high temperatures (700-1200^{0}C) to remove volatile matter followed by activation either physically or chemically. Carbonization of agricultural materials can also be performed by treatment with sulphuric acid or phosphoric acid. It is believed that while carbonizing these materials using sulphuric acid groups ($-SO_3H$) are introduced through sulphonation which are capable of exchanging cation present in the solution. The carbon, therefore, shows both adsorptive and ion exchange properties.

The carbon was prepared by treating each of Pearl Millet Husk (PMH) and waste Eucalyptus Leaves (EL) with conc. H_2SO_4 in 1:1.8 weight ratio. The resulting char was activated at 140-160^0 C for 24 hours followed by washing with water until free of excess acid and dried at 105±5^{0}C. The carbons obtained from PMH and EL was sieved to 100um size and was designated as PHMC and ELC, respectively. Characteristics of carbon such as moisture content, apparent density, ash content, pH, water soluble and acid soluble matter, decolourising power and surface area, each describing the property of carbon, were experimentally carried out by adopting standard methods.

The preliminary evaluation program for the adsorption efficiency of PHMC and ELC in the form of batch experiments was carried out systematically. Hundred milliliter of the solution containing predetermined concentration of the adsorbate under investigation was taken in 200 mL polythene bottles. After the addition of known amount of carbon, the bottles were equilibrated for a predetermined period of time at a constant temperature in a mechanical shaker. At the end of the equilibrium period, the solutions were filtered and the residual adsorbate in solution was determined. Copper was analysed suing Atomic Adsorption Spectrophotometer (AAS) and UV-Visible Spectrophotometer was used for the quantitative determination of methylene blue, phenol, mercury and chromium. Each set of batch experiment was carried out in duplicate and the results were reproducible within 5% deviation. All the calculations were performed in Microsoft Excel software package.

Research Findings and their Application

The characteristic of PHMC and ELC were systematically carried out and the results are summaries in Table 1.

Characteristics of PHMC and ELC

Characteristics	PHMC	ELC
Moisture (%)	22.95	9.96
Apparent density (g/cc)	0.68	0.74
Ash content (%)	11.29	8.58
PH	8.00	6.90
Water soluble matter(%)	0.91	1.19
Acid soluble matter(%)	17.65	5.92
Decolourising power (mg/g)	37.5	7.5
Surface area (m^2/g)	52.91	52.28

Optimization of Conditions

Optimum pH, Carbon dosage and equilibrium time for maximum adsorption of methylene blue, phenol, Cr(VI), Hg(II), Cu(II) by PHMC and ELC were determined by batch experiments.

- The results suggest that the range of pH between 5.0 – 6.5 is optimum for maximum removal of Hg(II), methylene blue dye and phenol. Hexavalent chromium was adsorbed efficiently by PHMC and ELC at pH 2.0.

- Taken an initial concentration of 10 ppm each of phenol, Cr(VI), Hg(II) and 20 ppm each of methlyene blue and Cu(II) solution, 0.5, 13, 1.0, 2.8, 0.4 g/L are required for the maximum removal (97, 77,100, 98%) of methylene blue, phenol, Cr(VI), Hg(II), Cu(II) by PHMC and 6, 14, 10, 3, 0.3 g/L are required for their maximum adsorption (100, 83, 100, 99, 76%) by ELC.

- The equilibrium time for the maximum efficacy n the removal of methylene blue, phenol, Hg(II), Cu(II) by PHMC was 30 minutes and that of Cr(VI) was 110 minutes. ELC required 60, 85, 90, 60, 30 minutes for their maximum removal.

Adsorption Isotherms

The Freundlich adsorption isotherm ($\log x/m = \log k + 1/n \log C_e$), the most widely used mathematical description in aqueous systems, gives a representation of the amount of solute adsorbed per unit weight of the adsorbent as a function of equilibrium concentration. It can also be used for calculating the amount of activated carbon required to reduce any initial concentration to a predetermined final concentration. A plot logx/m versus log C_e gave a linear relation for the all the system taken for study with slope (l/n) and value of k from the intercept (log k) indicating the adsorption intensity and adsorption capacity respectively. The values of ‘n’ obtained, ranging between 1<n>10 denote favourably adsorption.

The Langmuir adsorption isotherm ($C_2/q_e=1/Q_0b + C_e/Q_0$) which represents the monolayer saturation was investigated. The plot of C_e/q_e versus C_e gave linear relation, obeying Langumir isotherm model, with Q_0 and b obtained from slope and intercept indicating the adsorption capacity and energy of adsorption respectively. The essential characteristics of Langmuir isotherm can be expressed in terms of a dimensionless constant, separation factor or equilibrium parameter, $R_L=1/(1+bC_0)$ where b is the Langmuir constant and C_0 is the initial concentration. R_L values obtained for the adsorption systems taken for study, between 0 and 1 indicate favourable adsorption.

Freundlich and Langmuir Constants

Adsorbate	Adsorbent	Freunlich constants		Langmuri constants		
		N	k	Q_0	B	R_L
Methylene Blue	PMHC	3.00	46.77	157.14	0.17	0.23
	ELC	4.80	3.2	5.26	0.23	0.18
Phenol	PMHC	1.23	0.58	3.00	0.09	0.53
	ELC	1.13	0.50	2.33	0.15	0.40
Cr (VI)	PMHC	2.00	12.16	34.21	0.54	0.16
	ELC	1.65	1.45	5.48	0.18	0.36
Hg(II)	PMHC	1.50	70.79	157.89	0.81	0.11
	ELC	1.41	15.49	14.00	2.23	0.04
Cu(II)	PMHC	1.23	85.11	141.18	1.09	0.04
	ELC	1.17	47.86	26.67	0.18	0.22

Adsorption Kinetics

The rate at which a solute will be removed from dilute aqueous solution by the adsorbents is a significant factor for application purposes. The Lagregren equation ($\log(q_e-q)=\log q_e-(k_{ad}/2.303)t$) which predicts the overall rate of adsorption was determined for all the systems. The rate constant values (k_{ad}) obtained from the linear plot of $\log(q_e-q)$ versus time (t) for different concentration of the adsorbate, gives a measure of the rate of adsorption process for that concentration and also indicates that the adsorption process follows first order kinetics.

Adsorption rate constants

Adsorbate	Initial concentration mg/L	Adsorption rate constant $k_{ad}(min^{-1})$		Intraparticle diffusion constant $K_p(mg/g/min^{1/2})$	
		PMHC	ELC	PMHC	ELC
Methylene Blue	20	0.118	0.069	2.353	0.167
	50	0.069	0.053	2.286	0.159
	100	0.113	0.084	4.286	0.208
Phenol	10	0.077	0.020	0.040	0.018
	20	0.080	0.036	0.024	0.033
	30	0.109	0.028	0.084	0.046
Cr (VI)	10	0.021	0.038	0.714	0.078
	20	0.012	0.027	0.455	0.121

	30	0.022	0.054	1.333	0.233
Hg (II)	10	0.044	0.050	0.083	0.100
	20	0.037	0.015	0.125	0.077
	30	0.067	0.023	0.200	0.286
Cu(II)	20	0.118	0.096	1.600	2.500
	30	0.099	0.132	2.692	3.077
	40	0.092	0.112	3.333	2.609

Two important mass transport steps associated with the adsorption of solute from aqueous solution by porous adsorbents, are film and pore / intraparticle diffusion process. The plot of mass of solute adsorbed versus square root of contact time ($q=K_p t^{1/2}$) showed a linear relation (for all the systems) indicating that the rate limiting step in the adsorption process is intraparticle diffusion. The film diffusion (D_f) and pore diffusion (D_p) coefficients obtained also reveal the same.

Desorption Studies

Different acids and bases with varying normality were tried to desorb the adsorbed solute from the carbon surface. This would help to recover the solute form waste water and also allows to regenerate the carbon for reuse. Thee following Table presents a list of desorbing agents and percentage desorption established for each system with respect to PHMC and ELC.

Desorbing agent and percent desorption

Adsorbate	Adsorbent	Desorbing agent	Recovery (percent)
Methylene blue	PMHC	HCOOH	79
	ELC	CHOOH	52
Phenol	PMHC	5% NaOH	99
	ELC	5% NaOH	70
Cr (VI)	PMHC	1 M NaOH, 2 M HCl	79
	ELC	1 M NaOH, 2 M HCl	89
Hg (II)	PMHC	10% KI	94
	ELC	Conc. HCl	88
Cu(II)	PMHC	0.1 M of HCl	99
	ELC	0.01 M HCl	61

Status and Potentiality of Utilization of Research Findings

The work described has shown that carbon prepared from pearl millet husk (PMHC) and eucalyptus leaves (ELC) can form the basis for the removal of organics and inorganics from water / wastewater. The present study has clearly demonstrated that PHMC and ELC can be used for the treatment of water / waste water with contaminants such as methylene blue dye, phenol, chromium (VI), mercury (II) and copper (II). The experimental results furnished will be useful for water engineers and environmental technologists in designing treatment plants with batch experiment setup employing the adsorbate-adsorbent systems investigated.

Scope for Further Research

This work can be extended for the application of low cost carbon derived from pearl millet husk and eucalyptus leaves for the treatment of other toxic metals and organics. In addition, with the base line data obtained from this study, column studies can also be carried out.

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12 - Reclamation Of Drinking Water Polluted Due To Industrial Effluents In The Four Blocks Of Dindigul District.

Introduction

Among the villages of the four blocks of Athoor, Dindigul, Vadamadura and Vedasandur, those of Dindigul block are seriously polluted. The major polluting industries are tannery unites. All tanneries are adopting vegetable tanning methods at present through chrome tanning was employed earlier. Due to this, considerable amount of chromium had been discharged into the open lands along with high dosages of residual chlorine. All these have seriously contaminated the groundwater sources and the agricultural lands resulting in extremely high levels of pollution. The villages of the remaining blocks are also polluted to a large extent by the effluents let out by textile and other industries. The groundwater quality has been seriously affected by organic pollutants, organic dyes and also by trace metals which are used for dyeing of fabrics. The high levels of pollutants of different forms have made the groundwater sources of these villages unpotable and thereby, have become sources of several epidermal problems to the people of the area. Moreover, the people of these villages are put to hardships in procuring safe drinking safe drinking water from distance places.

It is therefore important that suitable treatment processes are developed so that the polluted water sources are reclaimed for domestic and agricultural use. The objective of this study is the development of suitable treatment methods for reducing the chemical contamination in the water bodies of the villages polluted by the industrial effluents, using eco-friendly materials.

Objectives

The major objectives of the study are,

- To carry out the analysis of water from 82 villages, which are severely polluted due to the effluents emanating from different industries like tannery units, dyeing units, textile mills etc., for the quality parameters.

- To develop suitable alternate technologies / revive or promote existing traditional technologies for the reclamation of drinking water, after identifying exact nature of pollutants, beside employing synthetic polymers.

- To create awareness among the people about the technologies developed or traditional technologies as applicable at the village level for implementation by villagers by preparing and circulating suitable literature, conducting periodic camps, PRA techniques, employing media, conducting health camps, etc.

State of Knowledge

The industries located in the four blocks include textiles, paper and pulp, food processing, chemical, metal, soap and detergent and small scale industries like coir, plastic, polymers and coconut products. A large number of leather industries are located in Dindigul block. These industries are mainly responsible for the environmental degradation and high level of water pollution in this region.

In all, 214 drinking water samples from different water sources (open wells, deep bore wells and ponds) from 43 hamlets of 11 village panchayats of Dindigul block were anlaysed for the quality parameters. The result reveal the presence of chloride in excess; of the order of 5480 mg/L in few cases. High levels of TDS is also noticed, indicating very high level of water pollution. The EC values of water samples are also high such that crop production in the affected areas are severally affected. Most of the villages are fluoride endemic and the water sources contain high level ranging upto 3 mg/L which is favourable for high prevalence of dental fluorosis. The chromium content of the groundwater sources are observed to be low due to adherence of vegetable tanning process by the tanning units currently. Few water samples from Dindigul block containing traces of copper.

Research methodology adopted

1. All polluted water samples from the area of study were collected and subjected to chemical analysis for colour, pH, total dissolves solids, conductivity, bio-chemical oxygen demand (BOD), chemical oxygen demand (COD), hardness, sulphates, chlorides and biochemical parameters like E. Coli by established methods of analysis as per Indian and International Standards.

2. Trace elemental and heavy metal determinations of water samples were done using AAS and Flame Photometer.

3. Traditional technologies, employing trunk of amala tree (Emblica officinalis), vettiveru (Vetiveria zizznodes), and vilamuchiveru (roots of two herbal plants), burnt coconut shells (activated carbon) and similar materials were carried out for purification of drinking water to remove toxic chemicals / vapours and to establish the employability of such materials on a firm scientific basis.

4. Propagation of the technologies developed / applicability of the traditional technologies are achieved by

    a. preparing literature / pamphlets, booklets, etc.
    b. Audio and video Software.
    c. Conducting camps in the villages and also carrying out field visits.

Research findings and their applications

Chitin and chitosan, both polysaccharide derivatives are found to form complexes with chromium. Both these materials are polymeric in nature and occur as a major component of shells of marine crabs, crustaceans etc. The ability of these materials to remove chromium in neutral medium make them good complexing agents which can reduce chromium pollution. Also included in this class are Oyster mushroom (Pleurotus sajor-caju), water hyacinth (Eicchornia crassips) and cabbage (Brassica oleraceae). In addition, activated groundnut husk carbon, paddy husk, fibrous materials like coirpith, dried banana stem (Musa paradisiacal) etc. commonly used as adsorbents are employed for removing chromium. The influence of pH, temperature and other ions present in water bodies have been experimentally verified. Important findings are given below :

1. The sorption kinetics show that about 90% of chromium is removed in the initial

stages.

2. The rates of adsorption of the metal ions remained unaltered by the changes in the medium and also by the presence of other ions.
3. The amino groups of the cell walls of chitin network act as the coordination sites of these materials.
4. The adsorption is governed by chemisorption as evidenced by adherence to Freundlich isotherm.
5. Adsorption occurs through a monolayer mechanism.

Defluoridation experiments were conducted using burnt clay. High defluoridation capacity is observed at low pH range and it decreases with increase in pH.

Status and potentiality of utilization of research findings

Water sources polluted by industrial effluents can be reclaimed by employing traditional technologies to a limited extent. Age-old practices adopted include the use of bark of trees like moringa (Moringa tinctoria), karuvelampattai (prosopis julifora) and Nelli (emlica officinalis) besides a few herbal products. Activated carbons and a variety of naturally occurring fibrous materials also are employed for such practices. Such traditional technologies have been helpful to a great extent in the reclamation of the polluted water.

However, such technologies have limitations, since they fail to bring down the level of toxic metals and several other organic pollutants. A large number of synthetic polymeric materials and organic compounds are successful in the removal of trace metals through compounds are successful in the removal of trace metals through complexation process, probably with the risk of residual toxicity. It is, therefore, necessary to identify eco-friendly complexing agents with considerable ability to remove toxic metals from water bodies as reclamation methods. Naturally occurring polymeric materials like chitin and chitosan remove toxic metal ions like chromium (VI) forming stable complexes. These scavenger molecules do not cause residual toxicity and hence are environment friendly. Drinking water sources contaminated with effluents from the leather industry have chromium (VI) above the tolerance limit. The polymeric materials remove the metal ions from the solutions forming metal complexes. Because of this property they can be used as successful scavengers for the reclamation of polluted waters.

Suggested follow-up action / Scope for further research

Industrial effluents are responsible to a large extent for the deteriorating quality of water sources in the vicinity of the industries.

The effluent let off by these chemical industries have high levels of pollutants which are extremely toxic. Trace metal present in the discharge to the surrounding areas are toxic pollutants and the excessive presence of these trace metals in drinking water cause serious threat to the health of the people. It is therefore important to identify techniques to reduce the metal pollution by trapping the toxic metal ions using environmentally safe complexing agents. Locally available, low cost and eco-friendly complexing agents with appreciable ability can serve as viable scavengers for reducing the level of trace metal pollution of the drinking water sources.

A few of the toxic trace metals which form part of common industrial discharge are chromium (VI), lead, mercury, manganese, cadmium, arsenic, cobalt, iron and zinc. Removal of these metals from water bodies using eco-friendly complexing agents will lead to their purification, besides being an efficient method of water resources management. Chitin and chitosan form stable complexes with chromium and a number of trace metals. Other polymeric, naturally occurring materials like oyster mushroom – a natural protein, water hycanith and cabbage have also proved to be successful in complexing with chromium. The favourable conditions for complexation reactions using these materials such as, the influence of pH, role of other ions present in water bodies etc., are to be established so that these materials can be effectively used for reducing metal pollution of water bodies. Such eco-friendly and indigenous scavenger materials can be of immense help in the reclamation of water sources polluted by industrial effluents.

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13 - Development of a Replicable And Cost-Effective Plant For Removal Of Iron From Drinking Water

By Government Polytechnic, Saharsa, Bihar

Introduction

The presence of excess iron in drinking water affects gradually or it is a slow poison whose effect can be visaulised after continuous use. The excess presence of iron in water is objectionable because the precipitation of this metal alters the appearance of the water, turning it a turbid yellow brown to black. In addition, the decomposition of these precipitates will cause staining of plumbing fixtures and laundry. The white colour of teeth is turned into black, the colour of platform becomes red and also the clothes are looking yellow in colour. The black hair becomes gray and the user seems older than his original age.

Another problem that has been associated due to excess presence of iron in water is the growth of micro-organisms in distribution systems which is highly objectionable for the clinical or medical view point. Accumulations of microbial growths can lead to reductions in pipeline carrying capacity and the clogging of meters and valves, Sloughing of the accumulations often leads to adverse consumer reaction including complaints of tastes and odours. Decomposition of iron precipitates in mains is frequently re-suspended by increased flow rates causing high turbitides. The precipitation of this metal may lead to difficulty with water-treatment processes such as ion exchange.

The continuous practice or drinking water containing excess iron, may lead to diarrhoea and dysentery. The physicians also say that when it becomes chronic, it causes stomach disorders. After initial deposit of more than 10 gms. of iron, stomach disorder is turned as Liver Cirrosis which is beyond the control of the doctors. Several patients of Carcinoma or carpogenic have also been detected due to regular use of excess iron containing water. These diseases are cancerous in nature and the users have to die at premature age. The doctors of this locality accept that in this area, there are 60 to 70% liver problem is due to regular use high iron water for drinking purposes.

Objective

The main objective of this study is to develop an eco friendly / cost effective and sustainable technology for removal of excess iron from drinking water. It should strive to harmonise man, materials, nature and principles of science and technology to address the problem of excess iron in groundwater without the use of electrical power or chemicals. Several R & D institutions have developed iron removal plants. However, most of them have some limitation. To overcome these limitations it is posed to develop an eco-friendly, cost effective and sustainable technology for removal of iron from drinking water.

State of Knowledge

The soluble iron is present in the Ferrous iron Fe++ when it is oxidized, it converts into ferric iron Fe^{+++} which can easily be filtered. Conversion of Fe^{++} into Fe^{+++} is performed by spraying the water from the fountain on trickling filter and cascades which precipitate in sedimentation tank.

$4\ FeO + O_2 – 2Fe_2O_3$

It is clear that the three processes are involved in the removal of excess iron from drinking water :

Oxidation or aeration.
Sedimentation
Filtration

Research Methodology Adopted

The following methodology has been followed to implement the project to achieve the objectives.

Hydrological investigation.
Selection of the project area.
Selection of technical expert team.
Details of consultants.
Identifying the quantity of iron in Drinking water.
Mechanism for the study.
Infrastructure created for the study.
Establishment of environmental laboratory for water testing.
Human Resource Development.
Orientation of project personnel.
Orientation of rural masons for cost effective, eco-friendly construction methodology of Iron Removal Plant.
Quality of Saharsa water.

Research Findings & Their Applications

In 1996, this institution was selected to carry out a R&D Project on “Development of a Replicable, Cost effective and adoptable plant for removal of excess iron from drinking water” with the financial support of Rajiv Gandhi Drinking Water Mission under Ministry of Rural Development, Govt. of India. The developed model was adopted in Koshi Amrit Peyjal Yojana under Public Health Engg. Department, Govt. of Bihar in a state level workshop, sponsored by UNICEF during 25 – 29th October 1997. The cost of this plant (attached to a hand pump) is Rs. 12,000/- (Rupees Twelve Thousand only) The filter bed needs to be replaced every three year @ Rs. 750/- per replacement.

Status & Potentiality of Utilization of Research Findings

The Koshi Amrit Peyjal Yojana was started in 1997 – 98 by the PHE Deptt., Govt. of Bihar in the nine iron affected districts of Bihar namely Saharsa, Madhepura, Supaul, Purnea, Katihar, Kishanganj, Araria, Khagaria and Begusarai to facilitate iron free water to the people of these area. The model, developed by Govt. Polytechnic, Saharsa was adopted for removal of excess iron from drinking water. The state Govt. sanctioned two such iron removal plants in each village of the above nine districts.:

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1 - Early Warning Systems for Hazardous Water Pollution Using Biomonitors

Study by National Chemical Laboratory, Pune

Introduction

The primary components of early warning system (EWS) are biological, physiological or biochemical dysfunction in plant or animal species. These biomonitors or bioindicators have to be developed indigenously for given situational (national/ regional) parameters. Existing physico-chemical and biological (quantitative, potentiometric) systems are rather antiquated, and in any case need to be integrated as follow-ups for the primary EWS. Identification and standardisation of animal bioindicators and monitors, and their use in *situ* in target waters, as contemplated here, is a totally new concept.

Paucity of suitable bio-indicators/monitors for water quality assessment practice is one of the crucial gap areas. Moreover, the rate at which pollutants are being dumped into the aquatic ecosystem is rather alarming. Hence, it is felt that observations and analysis of effects on biological systems (here, species directly and experimentally exposed to the test waters) must constitute the first and primary information report on suspected pollution hazard, so that an early warning can be given.

All outputs are indubitably specific measurable parameters, which could be used as specific monitorable outputs and would include identification of bioindicators/monitoring organisms and effects on particulate systems with respect to different classes of hazardous pollutants, especially the toxic synthetic insecticides.

Objectives

The study seeks to identify and select suitably sensitive biomonitor species from and for aquatic ecosystem. It aims at developing and standardizing response parameters based on observations of survival, growth, development, behavioural, physiological and biochemical responses of the selected biomonitor species. The study also builds an elaborate protocol for issuing Early Warning Advice of high risk based on laboratory base line data obtained.

The study coordinates the new biomonitoring protocol with existing physico-chemical ones and formulates a holistic multi-monitor system for water quality assessment. It tests the algorithm developed in actual field sites in tandem with chemical assays of the latter.

Review of studies

International studies: A survey of literature indicates that the utilisation of biological monitoring techniques for the purpose of protecting our waters has only recently come to be perceived as having special significance. The grouping of organisms into various broad categories in relation to their observed tolerance of pollution caused mainly by oxidizable organic waste, the saprobic system, was conceived in Germany by Kolkwitz and Marsson (1908 and 1909). This was developed extensively in Europe (Sladecek, 1973) and has been paralleled in America, for example, by Beck (1955) and in the UK with the development of the Treat Biotic Index (Woodwiss, 1964), in which the presence or absence of six categories

(Species of group of organisms) is taken into account. Biological monitoring is, therefore, now rapidly becoming an important means to establish presence, persistence and biological availability of chemical contaminants in the eco-systems (Bergman et al. 1986; Roop and Hunsaker 1985). The approach of using insects and other invertebrates to detect and quantify movement of contaminants in eco-systems has been used successfully at Oak Ridge National Laboratory (USA) in studies on radio nucleotide dispersal (Reichle et al 1970; Witkamp and Frank 1970; Crossley and Howden 1961).

Due to their large number and wide dispersal, insects have been recommended as biological monitors to detect radio nucleotides and heavy metals in biological monitoring programs (Bromenshenk et al 1985; Voshell et al 1985; Wallwork-Barber et al 1982). Benthic invertebrate communities can provide important information on toxic effects of discharges in the environment (Rosenberg et al 1986; Winner et al 1980).

In 1984, the office of water of the EPA (USA) issued a Policy for the Development of Water Quality-based Permit Limitations for Toxic substances to incorporate biomonitoring techniques for assessing water and wastewater quality. In 1985, the EPA published guidelines for conducting biological monitoring on wastewater and a technical support document for interpreting the results. Regrettably, however, actual work done on new biological parameters has been very restricted in the US also. The situation is singularly lamentable insofar as 'on line' or field work is concerned, although it is being increasingly recognised that more than laboratory, field applications are the imperatives of the day (Gruber 1989).

National status: Water quality assessment in India is mainly confined to the physico-chemical analysis of water. So far, a biological monitoring of water quality of the kind envisaged in the present proposal has not been attempted even in the laboratory in India.

Surprisingly, however abundant data now exists on the high level of pollutant (including pesticides) contamination of food, water, air and host of non-target organisms, including humans (Handa 1994). It is, therefore, now all the more essential and urgent to develop entirely new, radical and user-friendly as well as effective monitoring systems as proposed herein.

Methodology adopted

Six common metals and equal number of modern conventional synthetic organic insecticides closer as representative xenobiotics currently inundating various Indian water sources were selected for this study. Various organisms ranging from small invertebrates to vertebrates such as fish were initially experimented upon to investigate their potential to proposed biomonitoring. Based on results of the above studies, a simple score or monitor card was devised which would enable quantification of the bioresponses obtained so that the early warning issuance protocol can become objective.

Field studies entailed the following:

- Fabrication of special cages for *in situ* confinement of biomonitors in water;
- Biomonitor assessment of field samples of water obtained from different water sources in laboratory;
- Deployment of the model monitor cards for quantifying biomonitoring results in the above two.

Research findings

Effects on opercular beats: Effects of heavy metals on the operculum beats of fish, Poecilia reticulata were studied when exposed to different concentrations of heavy metal salt solutions as well as insecticides, which are generally used in agriculture and public health purposes at 25^0c water temperature. Heavy metals accelerate the pace of operculum beats in fish at the test concentrations. Highest acceleration was occurred in case of Hg followed by Pb, Cd, Cu, Co, Cr, Al and Fe respectively, while among insecticides Dichlorovos exhibited higher rate of opercular beat per 10 seconds.

The second observation in sequel was on acute toxicity to fish on exposure for 24 hrs duration to various concentrations to test heavy metals in order of lethality at Hg > Cd > Pb > Co > Cu > Cr > Al > Fe.

Effects on fin regeneration: Yet another study using fish, *Poecilia reticulata* was undertaken to examine the effect of various heavy metals and insecticides on fin regeneration. When the experimental fishes were exposed to chosen heavy metals (0.1 ppm to 10 ppm) and insecticides (0.005-0.05 ppm), it was observed that while in control, almost 95 per cent of the caudal fin was regenerated in 30 days, but in case of fishes exposed to heavy metals such as Cr, Al, Co, Fe, Pb, Hg, Cd and Cu, and insecticides such as cypermethrin and Dichlorovos exhibited different degree of regeneration with respect to length and width. In order of inflicting adverse effect on the intensity of coloration, Hg was found to be the most active and Fe the least.

Effects on mosquito larvae: Hg, Cd and Pb were also found highly toxic to *Aedes aegypti* larvae. At very low concentrations of Hg, almost 50 per cent population of mosquito larvae gets wiped off, suggesting serious physiological disorder during development. Mercury is followed by Cd, Na, Fe and Pb in the order of activity.

Effects on Cyclops: In cyclops, *Mesocyclops leuckarti*, it was observed that Hg and Cd alone and in combination inflicted heavy cyclops casualties within 24 hrs (acute) at higher concentrations and were also able to produce cent-percent cyclops mortality on continuous exposure ranging from 4-10 days at lower concentrations.

Effects on growth and development of housefly: The observations reveal that housefly larvae took 15-60 minutes for penetrating gel media treated with Pb, Cu, Cd and Hg. It was further observed that Pb, Cd and Cu permitted quick penetration as compared to Hg, but larvae came out of the gel media and moved away on the sides of the holding container and subsequently died. Some of the larvae died in the gel itself since they were unable to come out of the media.

Observations were also made on growth and development of housefly larvae till adulthood on exposure to heavy metal treated diet. Hg was the most toxic heavy metal causing 100 per cent larval mortalities in the initial stages itself at very low concentration ranging from 0.01 per cent to 1.0 per cent. As a consequence, this prevented any adult emergence from the exposed larvae. Same trend was not observed in case of Cr, Co, Pb, Cd and Al, in the early stages, but were successful in inhibiting almost 60-100 per cent normal adult emergence. At 0.01 per cent heavy metal treated diet least normal adult emergence took place from Co treated diet, followed by Cr, Cd, Al and Pb, as compared to about 90 per cent normal adult emergence from larvae released on untreated diet.

Studies on Chironomus larvae: It was found that Hg, Co, Cd were most toxic, Cr, Pb were moderately toxic while Cu and Al were the least toxic to the species at 1-10 ppm.

Cytochemical study: It is observed that specific puffing is induced in Chironomus salivary gland chromosomes by heavy metals. The phenomenon can be used for bioindicator of heavy metal pollution.

The model monitor card: Based on the foregoing results, a model monitor card incorporating the chosen biomonitors and their responses was developed.

Utilisation of research findings

During the course of the present investigations, it was found that major difficulties arise in attempts to simplify the protocols being developed. It is emphasised again that an important objective of the project design is to make it possible for just literate personnel to handle all details beginning fro m biomonitor rearing to observations of responses and making inferences. In actual situations, maintenance of even biomonitor species may pose an arduous task at the village level. Nominal infrastructure by way of elementary technical facilities, extension services to train executing personnel, and cooperation at both community as well as district authority levels would be a prerequisite for the success of this simple but ambitious venture.

Not only better and more convenient biomonitors are needed, the scope to increasing the number of common harmful pollutants is also essential to lend authenticity and meaningful utility to the work. For this, continuous work in different laboratories with different organisms and different toxicants must continue unabated. It is only through consulted action of a number of institutions and agencies that a sufficiently comprehensive lab data base of common xenobiotics can be built up, and used to predict or pinpoint suspect water sources. The potential of this undertaking is immense. The concept of biomonitoring as discussed is inexpensive, unsophisticated, informative and user-friendly enough to enable supplementation or even substitution of extent conventional chemical protocols of water quality assessment by such biological evaluations, as far as issuance of early warning is concerned.

Suggested follow up action

On the basis of studies conducted under the present project, it has been concluded that in the existing Indian conditions, the reasonably well organised method of primary healthcare, the panchayat, educational and community welfare (block development) infrastructure in the Indian rural and peri-urban sectors can lend itself to the adaptation of the EWS proposed by this study, and practice the same with minimum inputs in terms of facilities, equipment and personnel. Thus, school, dispensaries and Gram Panchayats' may be given this EWS. Elementary extension courses can impart skills of cultivation of selected biomonitors, and how to use the MMC for issuing risk warning when indicated. Possibilitiies must also be examined of developing monitor cards based on 2-3 species only. It is also necessary to examine some combinations of metals and pesticides to simulate field conditions and to authenticate and adapt database of actual realities that exists.

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2 - Pollution of Groundwater Due to Domestic Sewage

By Centre for Water Resources Development and Management, Kozhikode

Introduction

Palakkad district of Kerala experiences acute water scarcity problems during the summer. Incidences of water-borne diseases reported at a rate of about 46,000 people per year (1993-94), could be attributed to the impact of drought compounded with use of contaminated water. To protect the available water sources from further degradation and to reduce the incidences of water-borne diseases, it is essential to improve the water situation in the district. For this, field investigations should be attempted to locate the degraded water sources, identify the source of pollution and appropriate laboratory analysis has to be carried out to determine the pollutants for suggesting suitable methods to decontaminate and conserve the water sources. Hence, the present project was envisaged to carry out in-depth studies on contamination of groundwater sources of Palakkad district, with respect to domestic sewage.

It is estimated that there are around 45 lakh openwells in Kerala, of which 30 lakh are being used for domestic purpose. Almost 1.5 crore people of the State depend on openwells to meet their domestic requirements. Groundwater potential of the State is estimated as 8,000 mm^3. The groundwater is being rapidly contaminated by domestic, industrial and agricultural runoff. The domestic sewage composed of faecal wastes, kitchen wastes, wastes from hospitals etc, which pollute these water sources. Pollutants, which are of mineral origin like fluoride and iron, contribute to the severity of the problem. The use of this contaminated, untreated water has been the major cause for the outbreak of water-borne diseases in the State.

Most of the groundwater contamination incidents are local and affect only the uppermost aquifers. Although the specific volume of groundwater contamination may be small compared to percentage of groundwater resource, the impact of this contamination can be large. So it is important to identify and manage contamination sites both from the standpoint of protecting the public health and preserving the water resources. The project envisaged to investigate the source of pollution and determination of the specific chemical and microbial contaminants of the groundwater sources in Palakkad.

Objective

The main objectives of the study were to identify contaminated groundwater sources due to domestic sewage in Palakkad district; and, to determine and estimate chemical and microbiological contamination of the groundwater sources.

Similar studies that exists

Studies about groundwater sources of Kerala, especially in Kozhikode, Malappuram, Kasargode and Kannur districts, with special reference to physicochemical characteristics, salinity intrusion, geological investigations and sewage infiltration were carried out by the groundwater division of CWRDM. Investigations on groundwater sources of Palakkad district is found to be meager. The biological component of the groundwater sources of

Kerala, the main impact of which is the spread of water-borne and related diseases, are not yet attempted. The major projects executed and reports published are as follows.

- Salt water intrusion in the coastal aquifers of Kannur.
- Chemistry of groundwater in coastal aquifers of Malappuram district.
- Groundwater pollution in the Kozhikode city

Methodology adopted

The study area involved the five talukas of Palakkad district — Palakkad, Ottappalam, Chittoor, Alathur and Mannarghat. Investigations on groundwater quality of the district was based on both primary and secondary data.

Secondary data collection: Secondary data collection involved field visits, collection of data on water-borne diseases prevalent in the study area from primary health centres, local bodies, medical records and department of health services. Besides this, to identify the contaminated groundwater sources in the district, reconnaissance survey was carried out. The data on the socio-economic profile of the area, pollution sources, hygienic conditions, epidemiological aspects and other location specific details were collected by field visits. Interviews of the target group in selected villages by stratified random sampling methods were carried out. Survey data sheet was prepared to collect the details from the target group.

Based on the feedback obtained through the survey, the sampling network of groundwater sources was formulated. The baseline data collected involves physico-chemical and biological characteristics. The criteria selected for locating the basic sampling points were areas of frequent incidences of water-borne diseases; community wells used by large number of people; and, poorly located and constructed wells suspected to be contaminated by domestic wells.

Primary data collection: Based on the secondary data collected, groundwater sources were identified for analysis of physico-chemical and biological characteristics. The samples were processed and analysed for pH, conductivity, total hardness, calcium, magnesium, nitrate, potassium, phosphate, chloride, sulphate, fluoride, iron, and coliforms as per standard methods in American Public Health Association (APHA) 1995.

The auxiliary data on water levels in the wells, location of pollution sources like septic tanks, drainage, leach pits, hygienic status of the area, measures taken to protect and maintain the wells were collected, which served as baseline information to chalk out valuable conclusions.

The data on the physico-chemical and biological characteristics of the wells were processed and the contaminated water sources were identified. At selected critical areas of pollution, contour sampling was carried out to study the spatial variation relative to specific pollutants. Based on the data, contour mapping was carried out with the aid of Surfer computer software and contour maps for various parameters were prepared and classified according to the maximum admissible limits set by Bureau of Indian Standard.

Study findings and recommendations

For assessing the quality status of the study area, the observed value of physical, chemical and biological parameters were compared with the maximum admissible concentrations set by the Bureau of Indian Standards 1991. Sources of pollution of wells sorted out through sanitary survey included domestic drainage, animal feed loads, septic tanks, storm runoff and garbage. Sources of fluoride and chloride have been related to the geological status of the area. With regard to water quality, except fluoride, chloride, iron, calcium, nitrate and coliforms, the levels of all other parameters are within permissible limits. With respect to fluoride levels, the values ranged from 0.29-1.8 mg/l and the highest concentration being reported in Olavakkode. Fluoride concentrations were high in Kanjikode, Olavakkode areas in Palakkad taluka and Kazhani area of Alathur Taluka. A significant correlation was observed between fluoride and calcium (-1) in these areas. High fluoride is of mineralagic origin in these sites. Granite rocks and augen gneisses in these areas are also rich in fluorite and appetite, and were primarily responsible for the high fluoride in groundwater.

Chloride concentration was high in the dugwells of Chittur taluka and the highest concentration (660 mg/l) was reported in Kozhinjanpara. The high chloride concentrations may be due to the existence of chloride type water in the drainage course in these areas. Other sources of chloride imparted in the area may be contributed by atmospheric salt, rainwater, human and animal contribution and fertilizers. Iron content was high in the wells in Kuzhalmannam and Parali. Concentration of calcium was detected to be high (300 mg/l) in the well monitored in Kajikode. Microbiologically, the quality of wells subjected to study was detected to be in a degraded stage. High density of coliforms were found in areas like Karimba, Mannarkkad, Kannady, Kazhani, Vadakkanchery, Meenakshipuram, Chittur, Kozhinjanpara and Kollankode.

In Kozhinjanpara and Meenakshipuram, high chlorides, electrical conductivity, nitrate and bacterial density were found. A significant correlation was found between $NO_{3,}$ N and coliform density in these areas. This can be due to the effect of septic tank drainage and domestic sewer lines identified through sanitary survey in the area on underlying waters. The wells in the areas were found to be not sealed and are located down gradient of pollution sources. The required safe distance from the pollution sources is not maintained. As a result, pollutants infiltrate into the wells.

Spatial variations in groundwater quality: To study the spatial variations in groundwater quality and demarcate the areas with reference to pollutants, contour mapping was carried out using data on water quality characteristics collected through contour sampling. Location of sampling points in each study area is from 1:50000 scale. Since the number of topographic sheets of sampling locations in each study area was limited and unevenly distributed within the area, data grid of 100 x 100 size have been created using the available data, by interpolation using the ‘nearest neighbour method’.

Leaching of pollutants from septic tanks, cattle sheds and domestic discharges coupled with the hydrogeological characteristics of the area have affected the quality of groundwater sources of Palakkad district. Identification of the polluted sites relative to specific pollutants and their sources in the study area is critical for the protection and management of groundwater sources and, thereby, to reduce health problems in the area.

Geochemistry of chemical-soil-groundwater interaction can be studied in order to assess the fate and impact of chemicals discharged on the ground. Research studies can also be extended to study the virological quality of groundwater, adequacy of bacteriological indicators for judging groundwater quality and development of predictive models on microbial survival in groundwater.

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3 - Pollution of Drinking Water Sources Due to Textile Mill Effluents in Kannur District

By Centre for Water Resources Development and Management, Kozhikode, Kerala

Introduction

Industrial effluents are generally discharged into nearby water sources, either untreated or inadequately treated. This has created a problem of surface and sub-surface water pollution. Various constituents of wastewater are potentially harmful to the environment and pose as a health hazard. Drinking water sources are often threatened by increasing concentration of toxic chemicals disposed of by various industries. Thus, treatment of industrial effluents is of paramount importance.

Textile industries, one of the major industrial sectors in India, utilise large quantity of water for processing and discharge almost equal quantity of water as effluents. The characteristics of the effluents show vide variations, which are mainly characterised by intense colour and varying concentration of chlorides, sulphates and nitrates. The presence of hydrosulphate, sulphide and sulphur dyes causes depletion of dissolved oxygen in the aquatic system, and the soil where these industrial effluents are discharged become infertile. The effluents, if not treated properly before discharge, may contaminate the adjacent water sources such as streams, ponds and wells.

In rural areas, people mainly depend on groundwater sources for domestic purposes. The increasing population rate and dense establishment of small-scale industries in these areas with inadequate effluent disposal facilities create serious health hazards for the people. Protection of drinking water sources in these areas should be seen in a wider perspective to control indiscriminate discharge of pollutants on land and water. This requires research work and analysis of groundwater to assess the quality and thereby to ascertain the extent of pollution.

Kannur district in Kerala is an industrially backward area, with a population of over 20 lakh. The district has 12 medium-scale industries, which include textile, electronic equipment spares and plywood-manufacturing units. There are about 200 small-scale textile industrial units in the district. At present, none of these industries have full-fledged treatment system to treat the effluents, which are discharged through open drains or stone-ware pipes to nearby fields or streams. Most of the industries are located in the coastal and mid-land belt of the district, where the population density is very high. The industries located in these area indiscriminately discharge untreated effluents to the nearby land. There are, therefore, chances of contamination of groundwater sources in these areas by leaching of contaminants through soil. So far, no study has been conducted to identify the nature and extent of pollution caused by the textile industrial effluents in the district.

Objectives

The study was conducted to identify the pollution-prone areas through field survey; to assess the nature and extent of pollution of groundwater sources caused by effluents from textile mills; to identify the contaminants that are leaching through the soil from the effluents; and, to suggest remedial measures to mitigate pollution due to effluents from textile mills.

Methodology adopted

Sampling stations were selected on the basis of a preliminary survey conducted in the area. About 110 industries were visited and by considering the factors such as the capacity of the units, their location, the processes involved, mode of disposal of effluents etc, 12 sampling stations were identified for investigation. The industrial locations selected include Azhikode, Chirakkal, Chovva, Kakkad, Morazha, Perallassery, Sankaranellur, Payyanur, Pinarayi and Kanchirode .

Secondary data was collected by visiting industrial units. These data include details on the location of the units, raw materials used by them, chemicals used, sources of water intake, quality of water, effluent details, points of discharge, etc.

A network of 24 observation wells were selected, representing 12 industrial locations considering various factors such as problems raised by the local people, population, distance from the sea coast, etc. In order to understand the general quality of groundwater in these regions, three wells were selected at locations having similar hydrogeological conditions of the locations of the observation wells, but away from the effluent discharge points. These have been used as control wells. Water level fluctuations in the observation wells were also noted in an interval of a fortnight.

Water samples were collected periodically covering all the three seasons and were subjected to analysis for different physico-chemical characteristics. The analysis conducted covered pH , total dissolved solids, total hardness, chloride, sulphate, nitrate, iron, calcium and magnesium.

Research findings and recommendations

Usually, effluents are discharged to nearby fields or *nallas* through open drains without any treatment. These effluents are polluting the nearby groundwater sources of the study area. It has also been found that no industry has a full-fledged effluent treatment system. Only around 5-10 per cent of the industries treat the effluents to some extent and let them out through stoneware pipes to either open drains or to the agricultural fields nearby.

The major chemicals used in these textile industries are caustic soda, hydrosulphite, bleaching powder, hydrochloric acid, sulphuric acid and different types of dyes. The effluents from the industries are, therefore, highly alkaline and rich in chloride and sulphate concentration. The content of sulphate ranges from 100 to 3625 mg/l and that of chloride from 42 to 3750 mg/l. The high level of chloride and sulphate in the effluent can be due to the usage of sulphuric acid, hydrochloric acid, and hydrosulphites in these mills.

The physico-chemical analysis of the water samples from the observation wells has revealed that the predominant pollutants are chlorides and sulphates. The values of chloride ranges from 10 to 1,990 mg/l and that of sulphate ranges from 0 to 419 mg/l, depending on the nearness of the well to the discharge points.

The analyses of seasonal variations in the water quality have shown that during the pre-monsoon period, 8 per cent of the wells are highly polluted, 29 per cent of the wells are nearing the upper limits of the BIS for potability, and 63 per cent of the observed wells are within the permissible limits.

Analysis of soil samples indicates that there is build-up of salts around the discharge locations compared to control points. Majority of the units fall under small-scale sector and hence, they are not in a position to afford the heavy cost involved in the establishment of treatment plants of their own.

It is suggested that a group of industries can have a common effluent treatment plant to reduce the pollution hazards. Industries should also reduce the usage of water for yarn washing, and leaking and spilling from the conveyance system should be prevented.

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4 - Environmental Effects of Septic Tank Systems in Peri-urban and Rural Areas

By Bangalore University, Bangalore

Introduction

Septic tank disposal system discharge the entire water into the groundwater aquifer, resulting in contamination. Many of the septic tanks in use are not built as per standards. As a result, they fail to perform efficiently. However, properly installed and correctly functioning septic systems do not contribute to pathogen contamination of groundwater sources because of the soil, which serves as an efficient filtering and absorptive media. The theory necessary to explain the retention of bacteria and the background phenomenon is not well developed, although absorption mechanism is usually suggested. The spread of pollutants vertically and laterally in the unsaturated zone of soil (vadose zone) is yet to be clearly understood.

It is in this context, the present research project assumes importance and the problems cited above are to be resolved with field investigtion and through mathematical models. A pilot study was carried out in the southern districts of Karnataka for two-and-a-half years (September 1996 to March 1999). The criteria for selecting the study areas was based on different topographical and hydrogeological features, soil conditions and meterological aspects. Filed investigation was limited to the following three study sites – Bangalore peri-urban area, Chikaballapur taluk headquarters and Mandya district headquarters, where sewerage system was non-existents. The residents of the study area are depended on open dugwells, borewells and piped water supply. They have resorted to septic tanks, cesspools and pit latrines for disposal of domestic wastes. A majority of the disposal systems are faultily designed and their performance is far from satisfactory.

Objective

The research project studied and assessed the impact of septic tank and low-cost sanitation system on groundwater and soil environment in the unsaturated and saturated zones of the soil around the chosen septic tank, soak pits, pit latrines, cesspools, etc. Septic tank systems, cesspools and pit latrines are the low-cost sanitation systems used for disposal of domestic wastes. The existing septic tank systems, developed nearly a century ago, has many functional inadequacies. Their performance depends on design, construction, nature of wastes, climate, regional geology, topography, physical and chemical composition of the soil mantle, and care taken in period maintenance. Otherwise, these systems may contaminate ground and surface waters and result in sanitary nuisance and health hazards. Contaminants identified include bacteria, viruses, ammonia nitrates, chloride and phosphates because of their potential health hazard, that is, incidence of blue baby disease (methaemoglobinemia) and bacteriological contamination may result in diarrhoea, cholera, typhoid, etc,.

Methodology adopted

A reconnaissance survey of the study sites was carried out to have a glimpse of the water supply and sanitation conditions. A questionnaire was made use of for collecting technical and socio-economic data from the houseowners in the urban and rural areas. Samples of water from 19 wells (six wells each from Bangalore and Mandya and seven well from Chikballapur) located down gradient, were collected based on their nearness to the septic tanks, cess pools, soak pits, and pit latrines within the homestead.

Sampling and analysis of water and soil were carried out as per standard methods for chemical and bacteriological parameters. The undisturbed soil columns extracted from the three study areas were used in the soil column experiments to draw breakthrough curves and to assess dispersion coefficients. The tracers used were deionized water, artificial nitrate solution and tritium.

Research Findings

The permeability of soil in the study area varied from 0.14 to 0.38 m day^{-1}. The distance between the pit and the well varied from 1.5 to 9 m; the infiltration rte varied from 0.5 cm hr^{-1} to 32.7 cm hr^{-1}. The Horton's coefficient varied from 0.11 to 0.16. It is observed from the results of water analysis for years 1997 – 99 that nitrate concentration varied from 41 to 495 MGl^{1} during summer and 7 to 418 mgl^{1} during the monsoon season.

Elevated concentration of chloride was observed in the study area. Higher concentration of nitrates and chlorides in well waters show that the groundwater is getting contaminated with septic effluents and sewage from open drains. Since nitrate is highly soluble in water, it easily percolates through the soil and into the groundwater. It was observed that surface waters are more pronounced with nitrates during the wet season than during the dry season. It was also found that nitrate-rich polluted groundwater possessed increased hardness, which may be due to the presence of nitrification, producing hydrogen ions and dissolving more carbonate materials present in the soil. The microbiological investigations have shown positive results (presence of E. Coli) in 17 samples under different coliform test, and only two samples were free from contamination. Dugwells are prone to more pollution from different sources, especially if uncovered and not protected. Significant variations in the electrical conductivity, nitrate and chloride content in water samples were observed during the monsoon months.

Sampling and analyzing of soil for indicator bacteria and other chemical characteristics close to and around the septic tank system showed lateral movement of water and micro-organisms. Movement through the unsaturated zone is complex and although it is assumed to be vertical, significant lateral movement can also occur especially when the hydraulic loading is high. Seepage into the dugwell above the water table has been observed and significant number of feacal micro-organisms were detected in the soil and rock wall of the unlined open dugwells. The results revealed fairly high level of mobility in the social profiles around the study area up to a depth of 2 m as compared to the normal levels of nutrients matter in the surrounding soil and weathered rock from where the nitrate is leached intermittently by the infiltrating solute and decrease in contaminants within 10 m from the pollutant source. The dispersion coefficient when tritium was passed through the soil coloumn ranged between 66.56 and 85.51 sqm yr^{1} and for nitrate it was found to spread from 17.56 to 48.2 sqm yr^{1}.

Computer simulation was done using IA 2D PIT model to predict the pollutant concentration at any time at any distance, which was based on 2d finite time model. The predicated concentration of chloride and bacteria were compared with the observed depth averaged concentrations and the comparison showed that they are in good agreement. The time us concentration plots show that the concentration gradually increased till the time of use and thereafter decreased as the time increased. Sensitivity analysis reveals that when dispersion coefficients reduced, the concentration level increased and vice-versa.

Precautions and actions to be taken

The present rule thumb requiring safety distance depends on the prevailing onsite conditions. It is necessary to take into account the groundwater level. There is clear evidence that micro-organism spread is enhanced when they are introduced directly into the groundwater. A safety limit of at least 1 m but preferably 3 m should exist between the bottom of the septic tank and the groundwater table under the prevailing situation of congested settlement in pre-urban areas. The required safe distance from the septic tank to a nearby well in the runoff direction is 10 m in Bangalore peri-urban areas and Chikballapur and 12 m in Mandya town. In general, the minimum horizontal distance of 5 m for all other directions is to be maintained, if more septic tank system is to be installed in the study area.

The research calls for the development of such a system, preferably a community on-site waster disposal system or alternatively increasing the number of blocks and wards that are severed together in order to improve the final effluent quality. Appropriate legislation on zoning and other land management controls, specifications, sitting, design, construction and maintenance of septic tank systems and also awareness for the users are needed in the interest of high beneficial use so that groundwater aquifers and the nutrient status of soil are protected. Methods for removal of nitrates (gentrification and promotion of breast feeding for infants and babies), coliform removal (disinfections using bleaching powder and boiling) are suggested before consumption of water.

Research should be continued into the basic issues of the use of septic tanks to look into the questions like what is the movement and fate characteristics in the subsurface environment of pollutants from septic tanks, especially viruses and organics? What density of septic tank systems can be tolerated in an area before pollution problems necessitate sewers or septic system modifications?

Research should also be continued for the development of septic system modifications and for alternate individual sewage disposal systems. The basic design and operation of individual treatment units require additional study, particularly from the stand point of avoiding failure. Improved permeability tests, cleaning frequency, and dual lateral systems require specific emphasis. The social and economic consequences of converting from individual units to sewered and central treatment facilities must be studied with the consideration for the resultant loss or groundwater recharge.

It is envisaged that this type of research would be best undertaken as a series of pilot studies in representative hydrogeological and socio-economic environments. It is important that these pilot studies are to be combined with existing regional monitoring (possibly supplemented by additional monitoring where gaps exist) to ensure that a broader picture may emerge from more detailed studies.

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1 - Water Related Health And Nutritional Problems Of Women And Children

Study by University of Mysore

Introduction

Undernutrition in children is a common problem in India; the problem is best viewed as a 'syndrome of developmental impairment caused by a complex of multi-factors. Nationwide surveys have indicated that more than half of the children below 5 years are underweight and stunted and one in six is exclusively wasted indicating acute long-term malnutrition. Although many health and nutritional problems are recognised at the national level, regionwise data for rural population that have adopted standard methodologies with representative samples are scarce. Information on overall nutritional status (long-term and short-term malnutrition, micronutrient deficiencies) and health status, magnitude of problems, their causes, etc are lacking. Hence, an in-depth study with an integrated approach of identifying the problems, tackling through various approaches and arriving at applicable and specific preventive measures was undertaken. The study proposed to focus on some specific aspects of health and nutrition, which are identified as public health problems in India.

Five villages – Golur, Hebya, Veeragowdanahundi and Veeradevanapura from Nanjangud taluka and Kochanahalli from Mysore taluka were selected for the study with the help of officials of Department of Women and Child Development. A total of 557 households were surveyed, which constituted a population of 3376, of whom 200 women and 400 children were enrolled for the study.

Objective

The project aims to study the various dimensions of water-related health and nutrition problems of women and children in rural areas near Mysore city. It also seeks to assess health and nutrition situation of women and children; assess the quality of water consumed by the population; evolve and execute health and nutrition intervention programme; assess the impact of intervention strategy on health and nutrition situation; and, arrive at recommendations for health and welfare organisations.

Research findings

Initial assessment of health and nutrition situation is as under:

Water quality: Borewell water was the main source of drinking water in the study area and was consumed by 94 per cent of the families. Assessment of water quality by chemical method revealed that 42 per cent (range 25-100 per cent) of the water samples 'at source level' was contaminated and unsafe for drinking purpose. The same water samples 'at household level' showed a higher range of contamination (41 per cent vs 81 per cent), indicating unhygienic habits and contamination at household level. Microbiological method indicated higher range of contamination (67-100 per cent). Water supply was adequate, but majority of them were contaminated and unsafe for drinking.

Health status: Morbidity profile monitored on fortnightly basis for six months revealed a high percentage of morbidity in pre-school and school children (47 and 31 per cent), ARI and diarrhoeal diseases were the major diseases encountered. Heavy intestinal infestations were reported in 36-40 per cent of the children. About 27 per cent of the women reported to have body pain.

Nutritional status: Mean weights and heights of the children were below the National Centre for Health Statistics (NCHS) standards, Z score analysis revealed that majority of the children suffered from current (68 per cent), long-term (45 per cent), and acute (50 per cent) forms of malnutrition. About 66 per cent of the women were graded as energy deficient as per body mass index (BMI). Of the clinical manifestations observed, anaemia registered the highest in all age groups followed by protein energy malnutrition (only in pre-school children). Assessment of anaemia by hemoglobin levels in the blood indicated that 98-99 per cent of children and 73 per cent of women were suffering from various grades of anaemia.

Dietary assessment revealed that their dietaries were predominantly cereal based, frequency of consumption of protective food was low. Computed nutrient intake based on 24-hour recall method revealed that their diets met 45 per cent of energy and 36 per cent of protein recommended. Other micronutrient intake was grossly inadequate. Health and nutrition knowledge of women was satisfactory.

The emerging scene after analysis of health and nutrition situation was unsatisfactory and called for health and nutrition intervention.

Execution of health and nutrition intervention programme: The planned health and nutrition was dispensed for a period of six months. Each village was considered as a group that constituted 30-70 pre-school children, 30-90 school children and 30-50 women. Children of two groups received enriched biscuits, two groups received iron, calcium and vitamin A supplements and group with no nutrient supplements served as control. Women of four groups received iron, calcium and vitamin A supplements thrice a week. In addition, all the groups received general medicines and doctor’s service once a month. Nutrition education was given to women of four groups.

Assessment of intervention programme

Water quality: The unsatisfactory situation remained unchanged ‘at source level’, however education component in the experimental group showed a positive picture in decreasing the contamination of Coliform ‘at household’ level by 50 per cent.
Health: ARI and diarrhoeal morbidity showed a reduction in all groups. Medical care reduced morbidity to the extent of 13-60 per cent in all the groups, nutrient intervention showed marginal impact on the incidence of the illness.

Nutrition: Severe form of malnutrition showed a reduction of 3-11 per cent in pre-school and 0-5 per cent in school children. Clinical picture showed a drastic decline in anaemia in the experimental groups among pre-school children (63-96 per cent to 37-53 per cent). Haemoglobin status revealed a dramatic reduction in the prevalence of anaemia among the nutrient supplemented children (50 per cent) and women (14 per cent).

The education component of intervention showed awareness concerning hygienic habits and infant care. It is important to note that 73 per cent of women, who participated in the intervention programme, were illiterate. Numerically, the effect may be low, but it may have a long-term effect on the health and nutrition scene of the family.

Analysis of the findings on water quality in relation to health and nutrition of pre-school children revealed a triangular relationship. It was interesting to observe that children who consumed unsafe drinking water were more morbid, registered higher percentage of severe grades of malnutrition and anaemia than their counterparts who consumed safe drinking water. However, the percentage of normal children was similar in both the groups indicating the coexistence of nutrient inadequacy, infection and infestation.

The findings of the study clearly brought out the health and nutrition scenario of rural children and women and also the limiting factors in the prevailing condition. The results also have a reflection of the improper functioning of the existing health and nutritional welfare programmes that are currently functional. The results also provide a basis for planning advanced studies in the field.

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2 - Monitoring Water Quality and Educating the Rural Community in Maintaining Water Quality

Study by Avinashligam Institute for Home Science and Higher Education for Women, Coimbatore, Tamil Nadu

Introduction

Covering a stretch of approximately 60 km along the banks of river Bhavani in Mettupalayam taluka of Coimbatore district, Tamil Nadu, most of the villages located on the riverbank use river water for drinking purposes. Three villages – Kuthamandi, Alankombu and Bhadrakaliamman Koil, with 870, 1,645 and 2,140 population, respectively, were selected for the study. These villages use water from river Bhavani for drinking purposes, as they have no other water sources except a few borewells. Although these villages are gifted with natural water resources like the river, due to lack of planning and proper management of the local water bodies, the rural community face water scarcity. The usage of low quality river water for drinking purposes also leads to health hazards.

Objectives

It is, therefore, of utmost importance that the quality of potable water is checked at frequent intervals in these rural areas. Effective low-cost measures need to be devised, which the rural people themselves can practice to improve water quality. The study, thus, aims to check the quality of river water at frequent intervals; to improve the quality of water by using low-cost measures; and, to educate the rural community about these methods.

Methodology adopted and research findings

By interviewing the villagers of Kuthamandi, Alankombu and Badrakalliamman Koil, information was collected regarding availability of river water throughout the year, the quality of the river water, problems faced with respect to non-availability of potable water, prevalence of water-borne diseases, mode of water collection and storage. Information regarding number of industries located along the banks of Bhavani, nature of the industry, quality and amount of raw water used in the industries, amount of spent water released, and mode of disposal of each industrial wastewater were collected.

Bhadrakaliamman Koil was considered as station I, Alankombu village, 15 km downstream and Koothamandi village, 15 km downstream from Alankombu were selected as stations II and III, respectively, which discharged their effluents directly into the river. The study was divided into three phases. In phase I, the three target villages were selected and water samples of these villages were studied for four months for its physical and chemical characterisation. In phase II, bioremediation of the highly polluted station III water samples was done with activated carbon prepared from coconut shells, coir pith and sawdust. In phase III, treatment of low quality water sample was done using selected medicinal plant products namely ginger, fenugreek, cumin, vetiver, drumstick seeds and seeds of *Strychnous potatorum.* Health surveillance surveys and campaigns for awareness generation was carried out in the target area in phase IV and V.

Research findings:

During the survey, it was found that several industries located near the river discharge wastewater indiscriminately into the river. Frequent incidences of water-borne diseases among the villagers have been reported. It was also found that the villagers were totally unaware about safe potable water. Water samples of station III had higher levels of all physico-chemical parameters than the levels suggested by the National and International Standards (Table 1 and 2).

Table 1: Physical characteristics of the water samples of river Bhavani collected from three different stations

Parameters	Station I	Station II	Station III	Desirable Limits
Colour	Colourless	Colourless	Brownish orange	Colourless
Turbidity	Clear	Clear	Clear	-
PH	8.1	8.4	8.3	6.5-8.5
Electrical Conductivity (µS)	151.6	176	3490	Not Mentioned
Total Suspended Solids (mg/l)	10.4	22	155.6	Not Mentioned
Total Dissolved Solids (mg/l)	168.3	203.3	3315	500

Table 2: Chemical characteristics of water samples of river Bhavani collected from three different stations

Parameters (mg/l)	Sampling Stations			Desirable Limits
	I	II	III	
Dissolved Oxygen	7.8	7.4	3.9	Not less than 6.0
Biochemical Oxygen Demand	5.4	6.0	530	Less than 5.0
Biochemical Oxygen Demand	20.5	35	1600	Not Mentioned
Biologically Refractory Organics	15.1	29	1070	Not Mentioned
Total hardness	89.3	95.3	7900	300
Cations				
Calcium	34	41.3	3400	Not Mentioned
Magnesium	55.3	54	4500	50 if SO_4. Is

				200, unto 100 if there is SO_4
Sodium	4.7	4.3	278	Not Mentioned
Potassium	2.0	1.7	3.5	Not Mentioned
Iron	0.1	0.3	2.4	0.3
Zinc	0.7	0.7	1.2	5.0

Anions

Chloride	22.4	23.3	799	250
Sulphate	2.0	2.7	2063	200
Nitrate	-	2.4	20.5	45
Nitrite	-	-	0.1	0.1
Ortho phosphate	0.1	0.2	1.4	Not Mentioned
Total phosphate	0.2	0.3	3.4	Not Mentioned

Adsorption process using activated charcoal prepared from coconut shells, coir pith and sawdust was efficient in the removal of colour and reduction of chemical oxygen demand, biologically refractory organics, total suspended and dissolved solids, sodium, iron, chloride, sulphate, nitrite and nitrate in the polluted river water. Ion-exchange using clay resulted in the reduction of electrical conductivity, calcium, magnesium and total phosphate. Coagulation using drumstick seed powder was efficient in bringing down the levels of orthophosphate and BOD and increasing the dissolved oxygen content. Among the selected medicinal plant products, drumstick seed powder and *Strychnous potatorum* caused maximum colour reduction. Electrical conductivity, acidity, alkalinity, anions and cations were increased significantly after treatment with all the six medicinal plant materials. Scale formation in containers could not be solved by any of the treatments. Dissolved oxygen content of water was improved by ginger and vetiver. Bacteriological test of the potable water indicated that ginger, cumin, fenugreek, drumstick seed powder and *Strychnous potatorum can* be used as efficient antibacterial agents.

The ill-effects of the contaminated river water were proved by high incidence of skin allergies, diarrhoea, amoebic dysentery, typhoid, cholera, and jaundice and hair loss among the rural people in the target area. There was good response from the people for all types of awareness programmes. The findings of the study clearly demonstrated the need for proper treatment of Bhavani water. The treatment methods adopted in the study as mentioned above seemed to be efficient enough for cleaning the river water, which could be tried at field level and commercially viable fabrication of a suitable water purifier based on the utility of activated carbon from indigenous materials.

Utilisation of the findings

It is essential to set up water quality assessment laboratories at different stations in the course of a river to monitor the water quality and possible contaminants in various points. Low-cost potable water quality assessment kits can be formulated to assess the water samples in the field. The use of activated carbon prepared from indigenous materials for treatment of water should be familiarised among the villagers. Stringent action should be taken against industries that discharge their wastewater into the rivers without proper treatment. A tie-up on environmental monitoring among the researchers, industries and Government agencies like the Pollution Control Boards may help in protecting the natural water sources.

Assessment of the quality of Bhavani river water throughout the course of the river is essential to measure the impact of pollution. All the villages on the banks of the river should be studied for availability of pure and protected water. Health surveillance of these villagers will help in finding remedial measures. other treatment methods for the remediation of polluted water like use of water plants can be tried.

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3 - Effectiveness of Communication Media for Intervention on Water Resource Management Practices and Adoption of Hygienic Use of Water

Study by Punjab Agricultural University

Introduction

Drinking water is a valuable asset for the rural people of Kandi in Punjab, where quantitative and qualitative availability of water has multi-dimensional problems. This is because the Kandi area of the State is bounded by severely eroded Shivalik hills with sub-mountainous areas, causing scarcity of drinking water. The operational area of the project included 85 villages of four districts that are covered the Kandi area of the State. Sources of drinking water varied considerably in these districts, and this was a criterion for selecting the villages for the study.

Objectives

The project was aimed at identifying location-specific drinking water management practices of rural women to help develop a platform for preparing intervention strategies for promoting hygienic drinking water practices. The study was also conducted to determine knowledge, attitude and practices of the rural women through participatory approach regarding drinking water management practices (DWMP), and assesses the deviation from hygienic practices. It also aims at conducting bacterial contamination test for assessing the quality of water, and finally to use software communication media through participatory interventions for promoting hygienic water management practices.

Methodology adopted

The participatory approach like transect walk was adopted for generating baseline data on management practices of drinking water, assessing the level of knowledge and determining attitude towards hygienic drinking water management practices. The village mapping was also done to portray the source of water around the cluster of houses.

For the purpose of baseline data, one woman per household, who performed the major responsibility of water collection, was considered as a respondent. An interview schedule was developed for recording data that included time slot of water supply, number of trips and time spent for water collection, distance traveled, quantity of water collected per day, per capita consumption, collection, transportation and storage of potted water, and use of drinking water. A knowledge test and an attitude scale were used for ascertaining knowledge and attitude regarding hygienic DWMP. Participatory observation was carried out to ascertain the extent of use of hygienic practices.

The project being promotional, it was necessary to first determine the quality of drinking water and to find out the deviation in use of hygienic practices. For this, microbiological tests on water samples from different sources were conducted by the Department of Microbiology, PAU. The deviations in actual use of hygienic practices were worked out through scoring technique. Based on these information’s, the intervention strategies through participatory methods were used and appropriate communication materials were developed for intervention. The interventions were conducted in small groups either at water collection point or in cluster of households.

Research findings and recommendations

The overall status of drinking water was found to be unacceptable for human consumption due to bacterial contamination and the associated problems were alarming. This requires joint efforts of village Panchayat, State Water Supply Department and key village leaders in taking initiative for ensuring supply and management of safe drinking water for longitivity and sustainability of human health.

Multiple water supply sources: Location specific water supply sources prevailed in the villages of the study area. The primary sources of drinking water in the villages of Nawashahar district are the community taps and handpumps; in Hoshiarpur district tubewells and handpumps; but in the hilly terrain of Gurdaspur district, the main source is river or stream water that gets collected in open tanks. The covered wells as source of drinking water was common in Patiala district. Thus, the scanty and unhygienic water supply sources needs to be calls for the attention of the State Water Supply Department to improve the sources of water supply.

Quantitative availability a problem: To meet the daily requirements of drinking water, women make several trips a day to fetch potable water. This was necessary due to erratic water supply and lesser number of water sources. Moreover, the women face the difficulty in carrying potted water on their heads. The women were thus subjected to drudgery-prone activity as they collected minimum of six pots or maximum of 15 pots of water per day. This physiological burden of rural women is a constant problem and perhaps by installing taps in the vicinity of households, this problem can be reduced.

Qualitative availability – unsafe for drinking: The quality of drinking water was found to be unsafe for human consumption as 75 per cent of the water samples showed presence of *e.coli* bacteria. Since these bacteria can cause several gastrointestinal diseases, the water was not found to be potable. There is a need for the Panchayat to take initiative in chlorination of openwells and construct platform at water collecting points. The State Water Supply Department should ensure supply of clean water.

Drinking water management – multiple problems: Problems associated with DWMP showed that women, who depended on community water supply, had to adjust their household chores to be free for collecting water during the supply hours. At times, there was an increase in the waiting period due to disproportionate number of water dependent families at each collection point. Combined with this, the non-functional taps or handpumps near their households compelled them to go to distant sources for collecting water. The irregular and erratic water supply timing also created problem in adjusting their other household activities. The dried streams in the summer months and low water level in wells also caused numerous problems to women for collecting drinking water.

Water collection – a drudgery-prone activity: For collection of potable water, women traveled half to 1 km per trip. The cumulative distance increased with number of trips and accordingly the time spent for collecting potable water also increased. This implies that head-load of pots had to be carried several times a day, thereby, causing fatigue and as such this activity was safely labeled as drudgery-prone activity, which is a part and parcel of daily affair for the rural women.

Existence of unhygienic practices: The practices of collecting drinking water and storing it were found to be unhygienic. In some areas this deviation was due to ignorance, while in other cases it was due to lack of knowledge. This directed the need for prompting hygienic use of drinking water through intervention.

Cost-effective and user-friendly methods – a must: The participatory intervention based on cluster household approach with water dependent families proved to be effective in educating women on hygienic use of drinking water for safeguarding the health of their family members. A vast majority of the women expressed a desire that rural women needed education on simple user-friendly methods that are cost-effective and could be used at household level. These included double cloth filtration, boiling and chlorination. A favourable attitude was expressed by women for accepting hygienic water management practices subject to the condition that they get education through interventions on various aspects. It is recommended that interventions based on family approach can be the answer for prompting hygienic DWMP. Sustainability in use of these practices could be ensured by training local people, who can act as catalyst for persuading local families towards continued use of safe drinking water.

The Following are recommended for ensuring sake drinking water for the Kandi region:

- Repair and maintenance of non-functional community taps and pipelines;
- Increasing the number of community taps to be at par with water dependent population in the respective villages;
- Constructing cemented platforms around the community taps, handpumps, paving wells and installing pullies on wells for improving the sanitary conditions at water collection points and reducing contamination;
- Ensuring definite water supply timings and curtailing on erratic water supply to avoid inconvenience to user community;
- Covering the water collection tanks in Danera block of Gurdaspur district to protect water from getting contaminated with undesirable elements;
- Generating local resources both human and non-human for maintenance, care and repair of community taps and handpumps. The human resource should be used as watch and ward for protecting the taps as property of the village and especially of water dependent families. The local Panchayat must take active role in these directions and should generate local funds and train local people for repair and maintenance of taps and wells;
- Installing new supply lines for piped water in Saroya block of Nawashahar district to curtail acute shortage of drinking water;
- Promoting the knowledge of women regarding use of hygienic practices through non-formal education;
- Sharing the findings of the project with State Department of Water Supply, State Department of Health and Women and Child Development for promoting hygienic use of drinking water;
- Organising village level resource groups, who should be given back-up support through training on importance and use of hygienic drinking water management practices. These groups should be also trained to repair and maintain taps and tubewells so that they could act as caretakers of the community property

4 - Assessment of Mineral Quality and to Suggest Nutritional Intervention to Overcome Fluoride Toxicity through Drinking Water

Study by Central Food Technological Research Institute, Mysore

Introduction

Endemic fluorosis is a complex syndrome of varied severity caused by ingestion of toxic amounts of fluoride in drinking water. Toxicity is more severe in children and women. The biological response and severity of fluoride toxicity depends on several factors like concentration of fluoride, calcium nutrition, trace elemental composition of diet (Ca, Mg, P, Al etc), age and sex. Fluoride ions can alter the functional ability of essential ions. Fluoride also being essential trace element, play a dual role – at lower concentrations they have beneficiary action, where as at higher concentration they are toxic. Metal to metal inter-relationships play a crucial role in causing deficiency of essential metals. There is, however, no data inter-linking nutrition components and fluoride toxicity.

Nutritional pattern of rural population is a complex phenomenon, as available food resources influence it. Their knowledge about nutrition is very limited and economy plays an important role in their dietary pattern. The fluoride affected rural areas are mainly drought-affected areas and have limited crops.

This study was undertaken in Kadiri Taluka of Andhra Pradesh to develop database on mineral quality of drinking water in fluoride-affected rural areas, and to understand the nutritive quality of food consumed by these rural people. This may help to identify the nutritive intervention programme to over come fluoride toxicity.

Objective

The study mainly aims to develop database on mineral composition of water; assess the harmful effects of fluoride and other metals on human body through blood analysis; analyse mineral content in vegetables grown with the help of fluoride-rich water; and to develop nutritive quality database (vitamins, protein, amino acids) of food consumed by the people of the study area.

Methodology adopted

Drinking water and food samples from fluoride-affected areas were analysed for essential trace elements (fluoride, chloride, sulphate, calcium, magnesium, silicon, copper, selenium, chromium, zinc and iron) and toxic trace elements (arsenic, lead, aluminium, nickel and cadmium). Further, a dietary survey was conducted to understand the dietary pattern and diet composition with respect to protein, amino acids and vitamins, and a nutritive quality database was developed.

Water sample collection: Water samples from different villages around Kadiri taluka were collected. These villages are affected with fluoride. Water samples were analysed for both, essential and toxic elements, by inductively coupled plasma atomic emission spectrometer (ICPAES), and some elements like sodium and potassium by atomic absorption spectrometer (AAS).

Nutritive quality of food: The following food items are consumed regularly by the people of the study area: Rice (50 per cent), ragi (20 per cent) groundnut (10 per cent), tamarind pulp, amaranth tender, spinach, parapu, kerai, potato, brinjal, tomato, chilies, butter milk and banana. Based on this, a nutrition database was developed with reference to amino acids, vitamins and minerals.

Trace metal analysis in blood: A total of 10 ml of blood from the antecubital vein in forearm were collected from individual by qualified doctor from Kadiri. Blood was collected from 50 fluoride-affected areas and 25 samples from non-fluorosis area. The serum was separated from the blood samples and used for analysis of trace elements levels using ICPAES. Normal samples were collected from areas based on drinking water level of fluoride as recommended by WHO.

Fluoride detection kit: A colorimetric reagent for spot analysis of fluoride in potable waters was developed. The reagent contains a mixture of alizarin red S reagent and zirconyl chloride in acidic medium. To test the level of fluoride, one has to take 5 ml of this solution in a tube and make up to 50 ml with the test sample. A standard colour chart was developed for easy comparison by the rural mass.

Research findings and their significance

Mineral quality of drinking water: It was found that essential elements namely Ca, Zn, Fe and Cu are low in concentration in fluoride-rich water in these villages. The concentration of toxic metals like Pb, As, Cd are also very low. Most interesting finding is that nitrate levels in selected fluoride-rich water samples were high, while chloride levels in all these samples were low. Selenium was also very low. Fluoride levels in rainy season were 1.5-2.5 ppm, while in summer it was from 2.2-4.5 ppm. This data clearly indicated that there are low concentrations of Ca, Fe, Cu, and Se Zn in drinking water in these villages, which will affect the bioavailability of essential trace metals through drinking water.

Nutritive quality of food consumed: A nutritive quality database was developed based on the comparative evaluation of calculated and recommended dietary intake of essential minerals like Ca, P, Fe, Cu, Mn, Zn, Cr, vitamins like Thiamine, Riboflavin, Niacin, Folic Acid, Carotene and Vitamin C, and protein and fat based on the dietary survey.

The most significant results were:

- Children consumer a good amount of carotene, but less Fe, Zn and Se. Children also consume low levels of niacin, riboflavin and folic acid. The above data clearly indicates that both children and adults are not getting required concentrations of trace elements through their diet. It is likely to lead to deficiency of Fe, Zn, Cu, se, and Ca.

- Adult and pregnant women are deficient in vitamins like Riboflavin, Niacin, Folic Acid and minerals like Ca, P, Zn, Se, Fe, etc and also have low protein intake.

- Based on the findings, it is recommended that there is an urgent need to develop nutritional counseling along with mineral and antioxidant supplementation.

Clinical studies: The medical team visited the study area and assessed the neurological and bone problems. Many of the villagers had teeth and bone deformity. People at the age of 35 develop immobilization, spondilytic myopathy and angiome (swelling of tongue). Ageing process among these people is fast and maximum life expectancy is around 50 years. This is due to metal imbalance, hormones, oxidative stress and possible expected DNA damage.

There is an urgent need for de-fluoridation of water in these areas using de-fluoridation filters. The efficiency of these filters needs to be assessed by the rural people before they consume water. A simple colour test was developed, where a villager can test the water in his house.

It was also suggested that villagers should grow and consume vegetables rich in Fe, Ca, Zn, folic acid. Dietary pattern for children, pregnant women, aged persons were suggested, which included milk, leafy vegetables, lentils, butter milk, drum sticks, etc.

5 - Epidemiological Study of Chronic Arsenic Toxicity in 24 Parganas, West Bengal

Study by Institute of Post-Graduate Medical Education and Research, Calcutta

Introduction

Over the past two decades, groundwater in at least eight districts lying in the Gangetic plains of West Bengal, has been found to contain elevated concentrations of inorganic arsenic of geologic origin. On the basis of research carried out in the Department of Medicine and Gastroenterology at the Institute of Post-Graduate Medical Education and Research, Kolkata, since 1984, the clinical characteristics of chronic arsenic toxicity have been delineated.

Although current information on the extent of arsenic groundwater contamination in West Bengal suggests that hundreds of thousands of individuals may be exposed to elevated levels of arsenic, there is a dearth of epidemiological data that may be used to determine the impact of this exposure on the health of the exposed population. Collection of information on health effects by detailed epidemiological research may yield several benefits:

- Trends in arsenic related morbidity and mortality will assist public health programmes in planning future allocations of medical resources, such as funds for hiring and training of health professionals in primary and specialty fields, construction or expansion of medical clinics and public awareness campaigns.
- Epidemiological research that examines predictor and modifier variables associated with the expression of arsenic- related disease, such as nutritional factors or co-morbid conditions may identify steps that can be taken to avoid or mitigate adverse outcomes.
- Enhanced understanding of the epidemiology of arsenic-related diseases may provide broader insights into the pathogenesis of cancer and other medical problems.

With the above objectives in mind, this cross-sectional epidemiological study on chronic arsenic toxicity was conducted in 24 Parganas (South), one of the worst affected districts of West Bengal.

Methodology adopted

The study was carried out on 7,683 people (4,093 females and 3,590 males) out of a population of 1,50,457 in 57 villages of South 24 Parganas. Water samples were collected from private and public tubewells used for drinking and cooking purposes by each household. Arsenic levels were measured by flow-injection hydride generation atomic absorption spectrophotometery. A full history of water intake including source and duration of water intake were prepared to ascertain As-related clinical effect.

Each participant was asked questions about their socioeconomic status, their dietary habit, past history of major illness, etc. A thorough clinical examination of each participant was carried out taking special care to detect skin pigmentation and keratosis, enlargement of liver, respiratory diseases and neuropathy. Specific symptoms like weakness, pain abdomen or nausea (suggesting affection of alimentary system) cough, breathing difficulty, (respiratory disease), tingling and numbness (paresthesia, suggestive of affection of nervous system). Proper statistical methods were adopted to test the results.

Study findings

The epidemiological survey shows that the inhabitants are traditionally dependent on groundwater and the source are shallow tubewells varying in depths from 21.3 to 30.5 meters, some of which have been found to be contaminated with arsenic. Arsenic concentration in tubewell water in he villages ranges up to 3400 µg/L, but 88 per cent of the residents are exposed to levels less than 500 µg/l. Among 7,683 people surveyed, 3,467 drink water containing arsenic less than 50 µg/l and 4,216 people consume water containing high levels of arsenic.

Duration of water availability was collected from 3,393 out of 3,467 people, who consumed water with As level less than 0.05 mg/l. Out of these, 271 people drink water with As level less than 0.01 mg/l and 3,122 with more than 0.01 mg.l, but less than 0.05 mg/l. It was observed that all 12 people who had pigmentation and four people who had keratosis, had consumed contaminated water for 10 years or more. On the other hand, people drinking water with arsenic level less than 0.01 mg/l did not suffer from any skin infection.

It was observed that pigmentation (8.82 per cent) and keratiosis (3.64 per cent) were the most specific diagnostic parameters of chronic arsenicosis, as none of the people who were drinking water having an arsenic level less than 10 µg/l had these features. Keratosis prevalence was examined by arsenic levels in water. Of the 4,093 female participants, 48 had keratotic skin lesion. A clear relationship was apparent between arsenic levels in water and the prevalence of keratosis.

Of 2,320 females, 690 (30 per cent) were 20 per cent below the standard weight. Out of 2,123 males, 808 (38 per cent) were below the standard weight by 20 per cent. Compared to those with adequate nutrition, 20 per cent are below the standard weight had a higher **age-adjusted prevalence of keratosis.** The overall standardised morbidity ratio (SMR) for keratosis was 2.1 for females (95 per cent confidence interval: 0.8-4.6, p = 0.07) indicating that the age-adjusted keratosis prevalent among females with potentially poor nutrition was approximately twice that of females considered to have adequate nutrition. The overall SMR for males was 1.5 (95 per cent CI: 0.9-2.4, p = 0.08) the combined SMR for both sexes was 1.6 (95 per cent CI: 1.0-2.4, p=0.02). Weaker findings were found for hyper pigmentation. The overall SMR for females was 1.8 (95 per cent CI: 0.8-3.5, p = 0.09). Thus, women with poor nutrition status had an age-adjusted hyper pigmentation prevalence nearly twice that of females who have adequate nutrition. This increase was less apparent in males, where the increase in age-adjusted prevalence was only 10 per cent greater among those with poor nutrition (SMR = 1.1, 0.7-1.7, p = 0.39). Combining men and women, the SMR was 1.2 (0.8-1.8, p = 0.17). All prevalent odd ratios are elevated, but particularly so for shortness of breath among females and weakness in both sexes. The most striking finding was that in 12 cases, pigmentation was found among people who drink water containing less than 50 µg/l of arsenic.

Thus, the overall SMR for keratosis suggested that those with poor nutritional status had an age-adjusted prevalence that was 1.6 times greater than those considered to be adequately nourished (SMR = 1.6 per cent Cl: 1.0-2.4, p=0.02). Although the overall SMR for hyper pigmentation for both sexes combined was 1.2 (95 per cent CI: 0.8-1.8, p=0.17), rise in incidence of keratosis found among malnourished women suggest that some dietary factors affect the susceptibility of the population.

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6 - Epidemiological Survey of Endemic Fluorosis in Mandla District, Madhya Pradesh

**Study by Regional Medical Rsearch Centre for Tribals,
Jabalpur (Madhya Pradesh)**

Introduction

In 1995, an investigation carried out in Mandla district of Madhya Pradesh, brought to light the prevalence of severe forms of dental and skeletal fluorosis in endemic proportion in two villages of the district. The occurrences of fluorosis problem appeared to be recent in origin. A striking feature of the study is that it revealed the occurrence of genuralgunn to an extent of 50 per cent among children and teenagers. Though fluorosis is known to cause genuralgunn deformity in some areas of Andhra Pradesh, but there had been no such incidence reported from Madhya Pradesh earlier. Considering the above fact, an urgent need was felt to assess the health and nutritional status in Mandla district and to map out the endemic area of Fluorosis so that necessary corrective measures can be taken..

Five villages of Mandla block surrounding Tilaipani was taken as the study area, and two villages around Mandla, which were not affected by fluorosis was taken as control villages. The total population of the five study villages were about 3,000, and that of the control villages was about 1,200.

Objective

A house-to-house survey was conducted in five selected villages to assess the severity and magnitude of the fluorosis problem. The study also aims to assess urinary fluoride level in individuals living in the study area and estimate drinking water fluoride, Ca^{++} and alkalinity of all sources in five villages. It also seeks to assess the nutritional status through diet surveys; assess the fluoride burden in the body; and, assess trace element status of Cu++, Zn^{++}, and Mg^{++}.

Methodology adopted

House-to-house survey was conducted to collect information, which was recorded in a pre-coded and pre-tested proforma. The data emerged from the benchmark survey revealed the number of child/adult affected with dental fluorosis, genuvalgum, skeletal fluorosis, etc.

Analysis of drinking water was carried out focusing on fluoride, calcium and alkalinity. Precision and sensitive method for fluoride testing using ion selective electrode technology was adopted. Individual intake was assessed by trained nutritionist in every tenth household, using 24-hour recall method.

Laboratory investigations: Spot urine samples of those having skeletal changes and early warning signs (as per proforma) were analysed for fluoride, using lon specific electrode technology.

- Fluoride in water was estimated using lon-specific electrode;
- Fluoride in foodstuffs was estimated by SPADNS method;
- Trace elements analysis was done using atomic absorption spectroscopy (AAS);

- Limited number of affected persons, particularly children, were x-rayed.

Survey findings and recommendations

A total of 2,263 individuals from the study villages and 852 from the control villages were examined. Dental fluorosis was observed among 252 (11.1 per cent) individuals from the study villages, most of them below 20 years (21.2 per cent). Genuvalgum or knockknee was seen among 171 (7.5 per cent) individuals in the study area, and 5 (0.5 per cent) individuals in the control villages, more among children and young adults below 20 years (10.2 per cent). Skeletal fluorosis was observed among 303 (13.4 per cent) individuals from study villages and not a single case was seen from the control villages (see Table 1). A cumulative total of 244 individuals (10.7 per cent) were suffering from gastrointestinal disturbances, while only 6.7 per cent individuals suffering from these symptoms were from the control group. Other related symptoms are given in Table 2.

Table 1: Age and sex distribution of dental fluorosis, genuvalgum and skeletal fluorosis cases

AGE GROUP (n)	PERCENT PREVALENCE											
	Dental fluorosis				Genuvalgum				Skeletal Fluorosis			
	STUDY*		CONTROL*		STUDY**		CONTROL**		STUDY		CONTROL	
	M	F	M	F	M	F	M	F	M	F	M	F
0-5 (531)	6.7	4.0	-	-	16.6	5.2	5.6	1.4	2.2	3.5	-	-
6-10 (428)	42.2	37.1	-	-	22.3	20.7	-	-	8.6	2.8	-	-
11-20 (605)	26.6	18.9	2.7	1.2	17.1	8.2	-	-	12.3	4.5	-	-
21-30 (533)	2.4	-	-	-	1.2	-	-	-	11.5	10.7	-	-
31-40 (454)	1.8	-	-	-	-	-	-	-	20.6	21.3	-	-
40 + (564)	0.5	-	-	-	-	0.92	-	-	28.4	34.1	-	-
Total	13.26	9.09	0.49	0.22	10.00	5.19	0.98	0.22	13.62	13.33	-	-

Samples size Study Group (n) Male =1108 , Female = 1155
Control Group (n) Male = 406 , Female = 446

DF = Dental fluorosis * Z = 2.56 p < 0.05
GV = Genuvalgum **Z = 3.50 p < 0.05
SF = Skeletal fluorosis

Table 2: Village-wise distribution of gastro-intestinal manifestations and other symptoms

Name of village		G. I. Manifestations	Other Symptoms

		Population Surveyed	Loss of Appetite	Gas in Stomach	Pain in Stomach	Diarrhoea	Constip- ation (chronic)	Head ache (chronic)	Frequent tendency to urinate	Exten- sive Weak- ness
Study	Tilaipani	441	15	01	21	02	11	09	07	20
	Barbaspur	528	17	10	33	03	12	46	12	41
	Khamariya	321	11	01	09	06	23	25	02	27
	Padrpatpara	384	15	01	20	04	13	10	01	23
	Simariya	589	03	-	08	01	04	08	-	14
	Total	2263	61	13	91	16	63	98	22	125
Control	Gajipur	378	12	02	17	02	20	15	02	12
	Amatola	474	02	-	01	-	01	01	-	12
	Total	852	14	02	18	02	21	16	12	24

Radiologically, coarse trabecular pattern was the commonest presentation with 83.3 per cent and multiple growth arrest lines were seen in 48.1 per cent X-rays. Thickening of cortex, bowing of tibia and fibula was 42.5 per cent and 27.7 per cent, respectively. Osteosclerosis was seen in 22.2 per cent X-rays. Bony exostosis was seen in 5.5 per cent cases. Typical finding of skeletal fluorosis like calcification of interosseous membrane was seen only in 1.8 per cent cases. Bowing of humerus, radius and ulna, which is very rare, is also found in 1.8 per cent X-rays.

Distribution of fluoride level is shown in Table 3. Fluoride content ranged from 0.14 ppm to 10.6 ppm, though the level of fluoride seems to have no direct relation on the prevalence of disease. However, it is directly proportional to the severity of the disease. A total of 49 (40.8 per cent) samples of urine fluoride was more than 2 ppm (see Table 4).

Table 3: Distribution of fluoride level in different villages

Name of village		No.of Drinking Water sources	No.of sources With high fluoride	Fluoride in PPM (Range)	No.of Handpump dismentled by PHED
Study	Tilaipani	10	05	0.171 - 10.3	05
	Barbaspur	14	2	0.149 - 8.8	02
	Khamaria	07	01	0.20 - 5.7	01
	Padraripatpara	05	02	0.148 - 8.8	02
	Simariya	09	01	0.190 - 6.2	01
Control	Gajipur	18	Nil	0.6 - 1.1	Nil
	Amatola	15	Nil	0.15 - 0.4	nil

Table 4: Distribution of urinary fluoride level in study and control group

Group	No. of Urine sample collected & Tested	No. with high fluoride >2PPM
Study	120	49 (40.8)
Control	15	Nil
Total	135	49 (36.3)

*Figure in Parenthesis indicate Percentage

The average nutrient intake is shown in Table 5. Significantly, low intake of calcium, iron, fat and vitamin C were also found. Consumption of green leafy vegetables, milk and milk products, sugar and jaggery, fats and oil were much lower than the RDA in both the group of villages (see Table 6).

Table 5: Average nutrient intake per cu/day in study & control villages

Nutrient	Control Villages (n=26)	Study Villages (n=71)	RDA	t Value, RDA/ Control	Z value,RDA/ Study	Zvalue STUDY/ CONTROL
Calories (K cal)	1963.90±541.94	2009.50± 490.29	2400	4.10*	6.71*	0.38
Proteins (gm)	58.22 ± 22.55	56.58 ± 23.75	60	0.4	1.21	0.31
Calcium (mg)	287.84 ± 213.54	200.14 ± 106.58	400	2.67*	15.68*	1.45
Iron (mg)	14.83 ± 8.70	12.29 ± 8.07	24	5.37*	12.23*	1.30
Fat (mg)	12.50 ± 9.43	15.23 ± 10.74	20	4.06*	3.74*	1.22
Vit. C (mg)	23.93 ± 24.04	24.69 ± 31.73	40	3.41*	4.06*	0.13
Copper (ug)	2.2 ± 1.63	1.92 ± 1.01	2.2	0	2.34*	0.82
Zinc (ug)	8.9 ± 6.60	8.90 ± 4.71	15.5	5.09*	11.80*	0.00
Magnesium (mg)	768 ± 583.3	780 ± 413.4	350	3.65*	8.77*	0.096

* Significant at 0.05 Level

Table 6: Average consumption of food stuffs per cu/day /gram In Mandla district

Food stuffs	Control	Study	RDA	't' value	Z	Z value

	Villages (n=26)	Villages (n=71)		RDA/ Control	value RDA/ Study	STUDY/ CONTROL
Cereals	449.52 ±133.73	515.61± 147.18	460	0.39	3.18*	2.10
Pulses	59.01 ± 60.59	43.21 ± 40.86	40	1.60	0.68	1.23
GLV	27.49 ± 60.72	17.30 ± 42.60	40	1.05	4.49*	0.79
Other veg.	91.00 ± 113.56	63.74 ± 86.84	60	1.69	0.36	1.11
R & T	42.44 ± 51.13	46.90 ± 66.39	50	0.75	0.39	0.35
Fat & Oil	4.88 ± 4.77	8.74 ± 9.86	40	37.54*	26.71*	2.58
Milk	35.84 ± 77.14	17.76 ± 43.31	150	7.54*	25.73*	1.13
Sugar & **J**aggery	10.34 ± 9.65	7.48 ± 9.33	30	10.38*	20.34*	1.30

* Significant at 0.05 Level, G.L.V.= Green Leafy Vegetables, R.&T. = Roots and Tubers

Various foodstuffs were analysed for presence of trace elements like zinc, copper, magnesium, calcium and fluoride. There is no significant difference in the trace element contents of the study and control villages. The following findings were, therefore, observed:

- The prevalence of dental fluorosis, genuvalgum and skeletal fluorosis is significantly more in study villages as compared to the control villages ($p<0.05$). Males were more affected than females.
- Other gastrointestinal symptoms or early warning signs were also significantly more in the study villages as compared to the control villages ($p<0.05$).
- Prevalence of dental, skeletal fluorosis and genuvalgum was directly proportional to the number of contaminated sources (high fluoride).
- Though the prevalence of dental, skeletal fluorosis and genuvalgum was not directly proportional to the level of fluoride, clinical severity was directly proportional to the level of fluoride.
- Diet survey showed that there was significantly low consumption of calcium, iron and copper in study villages as compared to the control villages.
- Significantly, lower intake of cereals, was observed in the study villages as compared to RDA. Intake of other foodstuff likes pulses, green leafy vegetables, milk and milk products, sugar and jaggery was much lower in the study villages as compared to the control villages. Less number of fluorosis cases were seen in those villages where there was high calcium and magnesium in the water. This factor needs to be studied further.
- There is no definite pattern or changes seen among the trace element contents of different foodstuffs from the study and control villages.

- None of the locally grown foodstuffs were found to contain high fluoride. However, some habit-forming substances sold in the local market and consumed by the villagers do contain high fluoride.
- It seems that fluoride in water is the only reason responsible for the fluorosis in the area, aggravated by multiple nutritional deficiencies.

Since the study villages have other alternative drinking water sources, which are free from fluoride, villagers should be directed to use them. All contaminated sources (>1.5 ppm of fluoride) should be closed. As the villages are not covered under ICDS activities, it is recommended to include these villages for ICDS activities. This will help in reducing calcium and vitamin deficiencies. Rainwater harvesting is also highly recommended.

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