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# AN ANALYSIS ON THE POLLUTION/ CONTAMINATION OF GROUNDWATER AND THEIR QUALITY: A REVIEW

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# An Analysis on the Pollution/Contamination of Groundwater and Their Quality: A Review

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***Abstract – Groundwater is the foremost source of water for domestic, agricultural and industrial purposes in several countries. Due to human and industrial activities the ground water is contaminated. This is the serious problem now a day. Due to industrial, municipal and agricultural waste containing pesticides, insecticides, fertilizer residues and heavy metals with water groundwater has been polluted by leaching process. The effects of groundwater pollution are wide. In this paper the overview of ground water pollution due to industrial as well as anthropogenic activities. Water quality is affected by both point and non-point sources of pollution. These include sewage discharge, discharge from industries, run-off from agricultural fields and urban run-off. Analysis of the water quality is very important to preserve and prefect the natural eco system. The assessment of the ground water various technologies has been developed and management practices should be carried out periodically to protect the water resources.***

***Groundwater pollution due to anthropogenic activities may impact overall groundwater quality. Organic and inorganic pollutants have been routinely detected at unsafe levels in groundwater rendering this important drinking water resource practically unusable. Vulnerability of groundwater pollution and subsequent impact has been documented in various studies across the globe. Field studies as well as mathematical models have demonstrated increasing levels of pollutants in both shallow and deep aquifer systems. New emerging pollutants such as organic micro-pollutants have also been detected in some industrialized as well as in developing countries. Increased vulnerability coupled with ever growing demand for groundwater may pose a greater threat of pollution due to induced recharge and lack of environmental safeguards to protect groundwater sources.***

***In this review paper, comprehensive assessment of groundwater quality impact due to human activities such as improper management of organic and inorganic waste, and natural sources is documented. A detailed review of published reports and peer reviewed journal papers across the world clearly demonstrate that groundwater quality is declining over time. A proactive approach is needed to prevent human health and ecological consequences due to ingestion of contaminated groundwater.***

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## INTRODUCTION

The crucial role groundwater plays as a decentralized source of drinking water for millions rural and urban families cannot be overstated. According to some estimates, it accounts for nearly 80 per cent of the rural domestic water needs, and 50 per cent of the urban water needs in India. Groundwater is generally less susceptible to contamination and pollution when compared to surface water bodies. Also, the natural impurities in rainwater, which replenishes groundwater systems, get removed while infiltrating through soil strata. But, In India, where groundwater is used intensively for irrigation and industrial purposes, a variety of land and water-based human activities are causing pollution of this precious resource. Its over-exploitation is causing aquifer contamination in certain instances, while in certain others its unscientific development with insufficient knowledge of groundwater flow dynamic and geo-hydrochemical processes has led to its mineralization.

The purpose of this Thematic Paper is to review the trends in groundwater quality and pollution, taking into account the physical, environmental, institutional and social actors involved in groundwater quality governance. The final goal is to diagnose historical and current issues related to groundwater use under the threat of pollution, and to identify prospects for improved and sustainable aquifer governance through prevention and mitigation of the factors that may impact water quality. It is aimed at the macroview level, based on existing experience from real cases.

With the relatively recent development of centrifugal pumps, mechanized drilling means and energy accessibility, groundwater is seen as an easily-developable water resource, invisible to people and lacking in social experience on its use as a common good. It is linked to surface water, and is essential for nature and its services. Groundwater governance refers to the sustainable and efficient use of this key resource, which is essential for drinking-water supply, food production, human development and the environment (Ragone *et al.*, 2007; Bocanegra *et al.*, 2005), as well as for the resolution of conflicting situations.

Water is the most important in shaping the land and regulating the climate. It is one of the most important compounds that profoundly influence life. Groundwater is used for domestic and industrial water supply and also for irrigation purposes in all over the world. Water quality is influenced by natural and anthropogenic effects including local climate, geology and irrigation practices. In the last few decades, there has been a tremendous increase in the demand for fresh water due to rapid growth of population and the accelerated pace of industrialization. It is estimated that one third of the world's population use groundwater for drinking.

Ground water has excellent natural quality usually free from pathogens, colour and turbidity and can be consumed directly without treatment. Rigorous agricultural activities have increased the demand on groundwater resources in India. Water quality is influenced by natural and anthropogenic effects including local climate, geology and irrigation practices. Although global attention has focused primarily on water quantity, water-use efficiency and allocation issues, poor wastewater management has created serious water-quality problems in many parts of the world, worsening the water crisis. Human settlements, industries and agriculture are the major sources of water pollution. Globally, 80 percent of municipal wastewater is discharged into water bodies untreated, and industry is responsible for dumping millions of tonnes of heavy metals, solvents, toxic sludge and other wastes into water bodies each year. Farms discharge large quantities of agrochemicals, organic matter, drug residues, sediments and saline drainage into water bodies. The resultant water pollution poses demonstrated risks to aquatic ecosystems, human health and productive activities. Water quality is affected by both point and non-point sources of pollution. These include sewage discharge, discharge from industries, run-off from agricultural fields and urban run-off.

Water quality is also affected by floods and droughts and can also arise from lack of awareness and education among users. In recent years, the increasing threat to groundwater quality due to human activity has become the matter of great concern. The overexploitation of groundwater in some parts of the country induces water quality degradation. India accounts for 2.2% of the global land and 4% of the world water resources and 16% of the world population. It is estimated that one third of the world's population use groundwater for drinking. Both surface and subsurface water sources are getting polluted due to developmental activities. Contamination of drinking water may occur by percolation of toxics through the soil to ground water. Industries are responsible for water pollution. Waste water from industries includes sanitary waste and process water.

The rapid and unregulated growth of industrialization has led to an alarming deterioration in the quality of life and has given rise to a number of environmental problems. Safe drinking water is primary need of every human being. Rapid industrialization is also having a direct and indirect adverse effect on our environment. Several countries have different types of industries. There liquid and solid waste is directly dumped into the soil as well as river. Some industrial wastes are so toxic that they are strictly controlled, Making them an expensive problem to deal with some companies try to cut the cost of safety dealing with waste by illegally dumping chemicals.

Increasing vulnerability of groundwater pollution due to both natural and anthropogenic activities warrants that proactive measures should be initiated to protect and reduce the vulnerability of this invaluable resource. Across the world, increasing number of mathematical modeling studies has documented increasing vulnerability of groundwater resource. Groundwater pollution due to anthropogenic activities is well known, however in some instances natural processes also contribute to the mobilize pollutants. Variety of organic pollutants enters the environment due to improper disposal of industrial, municipal and agricultural wastewater. Poor waste management, storage, transfers and disposal of liquid, solid and semi-solid waste also contributes to the organic as well as microbial pollution load to groundwater.

Inorganic pollutants impact groundwater through variety of sources. Land use practices such as urban residential development, septic tanks and agricultural practices can impact groundwater quality as demonstrated by Carroll et al. (2013) in their study of Ningi Creek catchment located in the Caboolture region of Queensland, Australia. The authors concluded that urban areas compared to the non-urban areas contribute more pollutants to groundwater due to high density of on-site wastewater treatment systems. Effect of urban wastewater pollution load on groundwater pollution was also documented by Borst et al. (2013) in their study of partly sewered city of Nablus-East (Palestine). The authors concluded that untreated sewage significantly (as much as 50%) contribute to the urban groundwater recharge thereby increasing the nitrate concentrations in the groundwater of the City of Nablus.

## GROUNDWATER AND ITS QUALITY: BASICS ASPECTS

Groundwater development is relatively recent and rapidly evolving. It mostly started during the 20th century and, in many countries, only a few decades ago. Due to intensive groundwater development, aquifer functioning has been greatly modified and needs management to become sustainable (López Gun *et al.*, 2011). This development implies that direct and indirect benefits and costs are produced and often involves an impact on groundwater quality. Intensive aquifer use, in many cases, and especially in large confined aquifers, may involve the transient depletion of groundwater reserves. In some areas of the world, continuous and unrestricted use of groundwater reserves – known as "water mining" – has led to the physical depletion of aquifers, water quality impairment and the increase of abstraction costs.

For a correct evaluation of groundwater resources, a validated conceptual model on how the aquifer system functions is needed, including mass transport as the basis for water quality assessment. Also, information concerning aquifer recharge is very important, even if it is often rather uncertain. These are key issues for groundwater governance that must be addressed to control groundwater development in a coherent and consistent manner.

Three main aspects of groundwater governance have been identified (HJ, 2006):

1) its role in nature and the environmental services it provides;

2) its quantity to supply human needs; and

3) its quality with respect to human uses, including productive activities, and to the environment.

However, groundwater quality is deteriorating worldwide and a growing concern, often the result of past action. This means that in many areas, currently poorly addressed quality issues will become soon a dominant issue for groundwater governance. Unfortunately, existing experience is short and patchy, and has an important local component. Governance of groundwater quality is at its early stages and often considered as 'an issue for the future' in many countries. In addition, it is not easy to show groundwater quality evolution, worldwide or at regional level, not only due to data scarcity but also to the difficulty of using an index that is able to reflect the different points of view. The evolution on a chemical characteristic at a given point does not always show the general trends.

Poor groundwater quality is due to the presence of contaminants. The term 'contamination' is considered here in broad sense, including salinity, physico-chemical characteristics, inconvenient solutes at very different concentrations, biological components, radioactivity and temperature. Groundwater contaminants may be: (i) of natural origin, induced by aquifer exploitation; (ii) introduced as a result of human activity; or (iii) a combination of the two. Only contamination resulting as a direct consequence of human activity is here considered as pollution.

The main causes of groundwater pollution that should be tackled in groundwater governance arrangements, both at large and at small scale, are:

a) land-use activities, part of which are unrelated to groundwater development;

b) groundwater development, including the means of groundwater abstraction, such as well and borehole construction, operation and maintenance;

c) groundwater–surface water relationships, as in many cases groundwater contamination comes from surface-water infiltration, including seawater in coastal areas, saline lake water and polluted river water;

d) inter-aquifer leakage.

Necessary components of groundwater quality governance are laws, norms, institutions, direct groundwater users and other stakeholders that have interests in groundwater-related issues, such as the environment and its ecological services, surface water, springs and agriculture. Assessment and action depend on adequate monitoring and good understanding of aquifer-system functioning and behaviour, reflected in a validated aquifer-system conceptual model and supported, when appropriate, by numerical modelling and hydrogeochemical and isotopic studies.

## SUBSURFACE EXPLORATION AND GROUNDWATER QUALITY IMPACT

Search for environmentally safe energy sources has led to increased exploration of natural resources. Often the exploration of subsurface environment for valuable natural gas extraction is perceived as possible energy independence. However, in the blind pursuit of harnessing natural resources, the unintended groundwater quality impact is overlooked. For example, natural gas extraction in shale formation may affect regional groundwater quality through gas migration, contaminant transport due to induced fractures, improper management of wastewater and undisclosed use of chemicals used in fracking process (Vidic et al., 2013). A direct impact of on groundwater quality due to extraction of gas was documented by Jackson et al. (2013). The authors demonstrated that horizontal drilling and hydraulic fracturing in the Appalachian Plateaus in the northeastern Pennsylvania has contaminated groundwater sources where 82 % (of the 141 wells) of the drinking water wells were found contaminated with hydrocarbons such as methane gas. The authors concluded that homeowner living within <1 km distance from the gas wells have contaminated drinking with stray gases. The effect of shale gas extraction is not limited to groundwater alone, but also affects the surface water quality as documented by Olmstead et al. (2013). The authors reported that natural gas extraction in Marcellus shale in Pennsylvania has impacted surface water quality in the downstream areas.

Metallic pollution of groundwater due to oil exploration has been documented by various studies.

Afkhami et al. (2013) reported elevated levels of metallic pollution due to the oil exploration activities in the Ahvaz Oil Field located in Southern Iran. Radioactive isotope pollution of groundwater was also reported from areas that were mined during the early eighties. Arabi et al. (2013), in their study of the northeastern part of Nigeria reported that 5.7 % (total samples 35) of the groundwater samples had uranium concentration higher than the WHO recommended standards for safe drinking water. The authors concluded that the radiological contamination is not localized within the mineralized zones and groundwater acted as a medium to transport uranium to other parts Similar concerns were raised by Gordalla et al. (2013) in their study on hydraulic fracturing and toxicological threat of groundwater contamination. The authors suggested that hydraulic fracturing may mobilize geological salts, toxic and radioactive species thereby posing increased risk to human health. The authors further cautioned that reliability of safety measures during hydrofracking cannot be assured and recommended to include a competent water quality specialist in prior to hydraulic fracturing planning.

Post sub-surface exploration activities such as oil refineries can also pose serious threat to groundwater resources. Groundwater up to 20 m has been found contaminated with gasoline, kerosene and gas oil with varying thickness in the petroleum refinery in Tehran.

## MAJOR ISSUES OF GROUND WATER POLLUTION

**Contaminated Land-** Industrial activity has left land contaminated with a variety of inorganic and organic contaminants, frequently including heavy metals, hydrocarbons, and organic solvents, which can lead to serious groundwater pollution. In comparison with other countries, In the UK contaminated land is a major source of groundwater pollution. The legacy of contamination resulting from past and present anthropogenic activities has led and will continue to lead, to serious groundwater pollution incidences.

**Heavy Metals-** Heavy metals are commonly present in groundwater at trace concentrations. The most common sources of contamination include mining, urban and industrial effluents, agricultural wastes, sewage sludge, fertilizers and fossil fuels. Heavy metals are dangerous because they tend to bioaccumulation. Bioaccumulation means an increase in the concentration of a chemical in a biological organism over time, compared to the chemical's concentration in the environment.

Heavy metals can be extremely toxic to humans even at low concentrations. Heavy metals like Chromium (Cr), Mercury (Hg), Lead (Pb), Cadmium (Cd), Zinc (Zn), Arsenic (As), copper (Cu), nickel (Ni) are more toxic in nature.

**Landfill-** Landfills have been identified as one of the major threats to groundwater resources. Landfill leachate is potentially highly contaminative to groundwater. With over 4000 active landfill sites in the UK, some existing since the 1970s, there is concern over the pollution threat posed to groundwater. The impact of landfill leachate on the surface and groundwater has given rise to a number of studies in recent years.

**Microbiological Contaminants-** Microbiological contamination of groundwater is derived from sewage from either humans or animals. The large variety of pathogens that may be present in sewage includes pathogenic bacteria, viruses and protozoa. These contaminants can represent a potentially serious threat to public health if they are present in a water supply. Microbiological contaminants may enter the subsurface environment via leaking sewers, leaking cesspits, septic tanks, soak ways, mineshafts used as a disposal route, landfills, or horn sewage applied to the land as a fertilizer. The potential for the transmission of infectious disease by contaminated groundwater has been widely assumed and several individual contamination events have been reported.

**Pesticide-** Pesticides include insecticides, fungicides and herbicides, all of which are widely used by industry, public authorities and in agriculture. Pesticides are both toxic and persistent in the environment and can represent a potentially significant health hazard; especially given their capacity for bioaccumulation in the food chain. The pollution of ground water, related to nitrogen fertilizers and pesticides, from widespread, routine land application, as well as point sources has become a serious concern. The EC Drinking Water Directive set a maximum admissible concentration in drinking water for individual pesticides at a very low level (0. 1µs/cm).

**Sewers, Soakaways & Septic Tanks-** Sewers, soak ways and septic tanks can cause contamination of groundwater as a result of the discharge of waste water or sewage directly to the subsurface environment. The occurrence of sewage contamination is related to the operation and structure of the waste water containment and treatment system and local hydrogeology. Sewers are responsible for the unintentional discharge, via leaks, of large volumes of sewage to the groundwater below cities and lesser urbanized areas from which the sewage is initially derived. The most common contaminants found in groundwater below these systems include bacteria, viruses, and nitrates.

Several researches were done on ground water pollution. Various technical research papers on assessment of ground water quality for hand pump of different locations of different cities and countries. Reported work on assessment of ground water quality index is summarized below. Some countries have used and are using aggregated water quality data in the development of water quality indices. The study states that Water quality index (WQI) is valuable and unique rating to depict the overall water quality status in a single term that is helpful for the selection of appropriate treatment technique to meet the concerned issues. Initially, WQI selecting 10 most commonly used water quality variables like dissolved oxygen (DO), pH, coliforms, specific conductance, alkalinity and chloride etc. and has been widely applied and accepted in European, African and Asian countries.

## NATURALLY-OCCURRING GROUNDWATER QUALITY

**Groundwater composition and salinity -** Groundwater is generally fresh under natural conditions, although not always necessarily of good chemical quality. Chemical groundwater composition of recent groundwater is the result of climate-soil processes and lithological influences. Climate-soil processes dominate in arid areas, and lithological influences do in more humid environments. The mineral concentration in water due to atmospheric deposition is increased by evapoconcentration – the concentration of solutes by water evapotranspiration – in the soil. The more arid the climate is and the higher the capacity of soil to hold water is, the greater evapo-concentration is. What remains will be converted into groundwater recharge, which incorporates soil CO2 from root plant respiration and organic matter decay by oxidation. This favours the dissolution of soil and rock minerals.

**Groundwater quality and tolerance -** Natural groundwater quality is important for potable water but also for agriculture and other human economic activities, as well as for the environment and the services it provides. A groundwater discharge area may be linked to a characteristic habitat, and most living species are sensitive to water quality and its changes, both in land and in littoral waters.

Plants have a tolerance limit to salinity of the water that is available to their roots. When irrigation-water salinity increases, an increased irrigation water depth (volume per unit surface) is needed to keep salinity at the roots and flush out the excess of salts. Otherwise crop yield decreases. Moreover, the soil must remain aerated. When applied water has an excess of sodium ion (Na) over earth–alkaline ions (Ca+Mg), as happens for the sodiumbicarbonate- rich waters found in CO2-rich volcanic areas, the soil becomes less permeable and gets easily saturated; this hinders aeration, hence the plant is stressed and may die. Also when boron concentration in soil water is high, plants – especially the leaves – are poisoned. Water quality effects in irrigated agriculture depend on crop, irrigation frequency and depth, soil characteristics and the presence of some inconvenient components.

Salinity tolerance depends on how soil water characteristics can be controlled. Effects need some time to develop and thus tolerance should be considered in the long-term. There are many examples of soil spoiled by persistent application of poor quality irrigation water in Pakistan, India, Spain, Northern Africa and other regions, although they are often poorly documented.

**Impact of climate variability on natural groundwater quality -** Under natural conditions, aquifers are not static but evolving systems due to past climate variability, land erosion, large land-use changes, sediment accumulation, shoreline changes and other processes. Small aquifers in wellrecharged areas adapt rapidly to changes, but large aquifer systems, which have a large water storage, may evolve so slowly – particularly under semi-arid and arid conditions – that they may be considered as being under longterm transient conditions for planning and management purposes, especially in what refers to water quality. Even groundwater quality may not correspond to current recharge. To understand quality patterns, the transient situation has to be considered. Yet, it has to be taken into account that aquifer exploitation accelerates changes because of an enhanced groundwater flow due to greater head gradients. This may be regionally important, especially when referring to vertical water movements. However, existing natural head gradients may be decreased, cancelled and even reversed in some cases.

## EXTENT AND IMPACTS OF GROUNDWATER CONTAMINATION AND POLLUTION

The incidence of fluoride above permissible levels of 1.5ppm occur in 14 Indian states, namely, Andhra Pradesh, Bihar, Gujarat, Haryana, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh and West Bengal affecting a total of 69 districts, according to some estimates. Some other estimates find that 65 per cent of India's villages are exposed to fluoride risk.

High levels of salinity are reported from all these states except West Bengal and also the NCT of Delhi, and affects 73 districts and three blocks of Delhi. Iron content above permissible level of 0.3 ppm is found in 23 districts from 4 states, namely, Bihar, Rajasthan, Tripura and West Bengal and coastal Orissa and parts of Agartala valley in Tripura.

High levels of arsenic above the permissible levels of 50 parts per billion (ppb) are found in the alluvial plains of Ganges covering six districts of West Bengal. Presence of heavy metals in groundwater is found in 40 districts from 13 states, viz., Andhra Pradesh, Assam, Bihar, Haryana, Himachal Pradesh, Karnataka, Madhya Pradesh, Orissa, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh, West Bengal, and five blocks of Delhi.

Non-point pollution caused by fertilizers and pesticides used in agriculture, often dispersed over large areas, is a great threat to fresh groundwater ecosystems. Intensive use of chemical fertilizers in farms and indiscriminate disposal of human and animal waste on land result in leaching of the residual nitrate causing high nitrate concentrations in groundwater. Nitrate concentration is above the permissible level of 45 ppm in 11 states, covering 95 districts and two blocks of Delhi.

DDT, BHC, carbamate, Endosulfan, etc. are the most common pesticides used in India. But, the vulnerability of groundwater to pesticide and fertilizer pollution is governed by soil texture, pattern of fertilizer and pesticide use, their degradation products, and total organic matter in the Pollution of groundwater due to industrial effluents and municipal waste in water bodies is another major concern in many cities and industrial clusters in India. A 1995 survey undertaken by Central Pollution Control Board identified 22 sites in 16 states of India as critical for groundwater pollution, the primary cause being industrial effluents. A recent survey undertaken by Centre for Science and Environment from eight places in Gujarat, Andhra Pradesh and Haryana reported traces of heavy metals such as lead, cadmium, zinc and mercury. Shallow aquifer in Ludhiana city, the only source of its drinking water, is polluted by a stream which receives effluents from 1300 industries. Excessive withdrawal of groundwater from coastal aquifers has led to induced pollution in the form of seawater intrusion in Kachchh and Saurashtra in Gujarat, Chennai in Tamil Nadu and Calicut in Kerala.

There are no estimates of the public health consequences of groundwater pollution as it involves methodological complexities and logistical problems. Nevertheless, levels of toxicity depend on the type of pollutant. Mercury is reported to cause impairment of brain functions, neurological disorders, retardation of growth in children, abortion and disruption of the endocrine system, whereas pesticides are toxic or carcinogenic. Generally, pesticides damage the liver and nervous system. Tumour formation in liver has also been reported.

The presence of fluoride in water cannot be detected without the help of water quality testing equipment. High fluoride content is often detected from such symptoms on human beings as yellowing of teeth, damaged joints and bone deformities, which occur from long years of exposure to fluoride containing water. Due to this reason, by the time the community realizes the “menace”, a large section of the population is already affected. A recent survey by the International Water Management Institute (IWMI) in north Gujarat showed 42 per cent of the people covered in the sample survey (28,425) were affected; while 25.7 per cent were affected by dental fluorosis, 6.2 per cent were affected by muscular skeletal fluorosis and 10 per cent by both.

The potential biological and toxicological effects of using fluoride contaminated water are also dangerous. Study on fluorotic populations of north Gujarat revealed an increase in frequency of sister chromatic exchange in fluorotic individuals indicating that fluoride might have genotoxic effect. Fluoride had been reported to cause depressions in DNA and RNA synthesis in cultured cells. Another study on the effects of fluorides in mice showed significant reductions in DNA and RNA levels. Conditions including ageing, cancer, and arteriosclerosis are associated with DNA damage and its disrepair. Prolonged exposure to water containing salts (TDS above 500ppm) can cause kidney stone, a phenomenon widely reported from north and coastal Gujarat.

## REDUCING IMPACTS ON HUMAN HEALTH

Reverse Osmosis (RO) is a process to get rid of all the impurities in drinking water including deadly ions and organisms and pesticide/fertilizer residues. Under RO-systems, water is made to pass through a membrane having a pore size of 0.0001micron under high pressure. Only 5-10 per cent of the ions are able to slip across the membrane, which is well within acceptable levels as per all standards including WHO, BIS, etc. RO systems are suitable for removing several of the toxic substances present in water in dissolved form, including fluoride, fertilizer and pesticide residues, and heavy metals. But costs vary, depending on the plant capacity and level of utilization, the level of salinity and other impurities in the water and the distance from the source of water. Costs can range between Rs.0.03/litre (for brackish water) to Rs.0.10/litre (for seawater).

A household arsenic treatment method is the ferric chloride coagulation system. This involves precipitation of arsenic by adding a packet of coagulant in 25 litres of tube well water, and subsequent filtration of the water through a sand filter. Field experiments showed arsenic concentration in treated water was nearly 1/20th that of raw water. The cost of chemical (ferric chloride) for treatment is Rs.0.09 per litre of raw water to be treated. Another method for removing arsenic is based on "sorptive filtration based on iron coated sand bed". Water is first put in a bucket and stirred for some time to accelerate precipitation of excess iron. It is then allowed to pass through a sand filter where the excess iron is filtered out. Finally the water is passed through an iron coated sand filter. But, the efficiency of removing arsenic reduces drastically beyond a certain bed volume with the arsenic concentration of treated water crossing the permissible limit of 50 ppb. The third method involves filtration of arsenic from raw water by passing it through a gravel media containing iron sludge. An evaluative study showed the first two systems to be superior, with the first one found to be most acceptable to the villagers.

## CONCLUSION

Ground water pollution is becoming a greater threat to the environment, especially as populations and industrial economies expand the toxic elements and chemicals enter the body mainly through water, food and air. The first step towards evolving measures to prevent and cure groundwater quality deterioration is generating reliable and accurate information through water quality monitoring (WQM) to understand the actual source/cause, type and level of contamination. More research is needed to assess to effect on human health. Public awareness should be created. There should be monitoring and control over the concentration of harmful chemicals on drainage of effluents. Preventive and curative measures against pollution and contamination of groundwater may continue to receive low priority for years to come, Demineralization using RO system can remove all hazardous impurities from drinking water and would be cost effective in many situations where TDS, nitrate and fluoride in groundwater are above permissible levels. Low cost treatment methods are available for removal of heavy metals from groundwater. For operation of CETP plants, new technologies should be developed for treatment of industrial waste water.

Preventive and curative mea sures against pollution and contamination of groundwater may continue to receive low priority for years to come, and technological measures to prevent the ill effects on human health will get priority in short term. Demineralization using RO system can remove all hazardous impurities from drinking water and would be cost effective in many situations where TDS, nitrate and fluoride in groundwater are above permissible levels. The cost of demineralization is falling rapidly. Saudi Arabia meets 20 per cent of its total water needs from desalinated sea water, and Saudi technologists believe desalination costs would fall so rapidly over the coming decades that desalination will be cheaper than pumping coastal aquifers. Low cost treatment methods are available for removal of arsenic from groundwater.

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