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SPECIFICATION OF WATER TREATMENT TECHNIQUES WITH REFERENCE TO GROUNDWATER

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ABSTRACT

The main decision-making tool when selecting a groundwater remediation technique is an economic evaluation of all viable techniques. During the planning stage of any kind of remediation scheme the costs and effectiveness of the different techniques have to be compared. It is very important that long-term remediation costs are factored into these comparisons, although these are difficult to estimate. In general, the costs of remedial activities are classified as capital investment costs which stem from the construction of the remediation system and operation and maintenance costs which arise continuously or periodically during operation of the system..

An economic evaluation of a PRB scheme needs to take account of:

1. *Expenditure on the site investigation;*
2. *Costs of preliminary and feasibility studies;*
3. *Planning and engineering;*
4. *Construction costs;*
5. *Costs for reactive materials (including any recovery, replacement and disposal costs);*
6. *Maintenance;*
7. *Monitoring (to verify long-term performance and demonstrate remediation success).*

***PRB systems usually have relatively high capital investment costs** (planning and construction), whereas operation and maintenance costs are normally much lower than those of most active remediation techniques, although this depends on case-specific factors such as the type of contamination, the hydraulic conditions on site, etc. From both a performance and economic standpoint the long-term performance of a PRB system is a critical area in determining its viability. Before a decision on installing a PRB system can be taken, a reliable prognosis on the probable operational life-time of the system [1,2] has to be made. Indeed, lowering the expected operational and maintenance costs is the main motivation for research and development in the field of PRBs.A number of papers have been published dealing with costs of groundwater remediation by both active (pump-and-treat) and passive (PRB) systems However, the projects differ substantially in size and complexity. In a report of the US EPA the economics of 22 PRB systems were analysed. The volume of groundwater treated was between 1000 and some 400,000 m3 per year. The operating costs and capital costs in US$ per m3 water treated per year were highest for the smaller remediation projects and decreased significantly for large projects. Of course these costs also depend on the site characteristics and the type of contaminant. [3]*

INTRODUCTION

Worldwide, several regions suffer from water scarcity and contamination. The infiltration and subsurface storage of rain and river water can reduce water stress. Artificial groundwater recharge, possibly combined with bank filtration, plant purification and/or the use of subsurface dams and artificial aquifers, is especially advantageous in areas where layers of gravel and sand exist below the earth's surface. **Artificial infiltration of surface water into the uppermost aquifer has qualitative and quantitative advantages**.

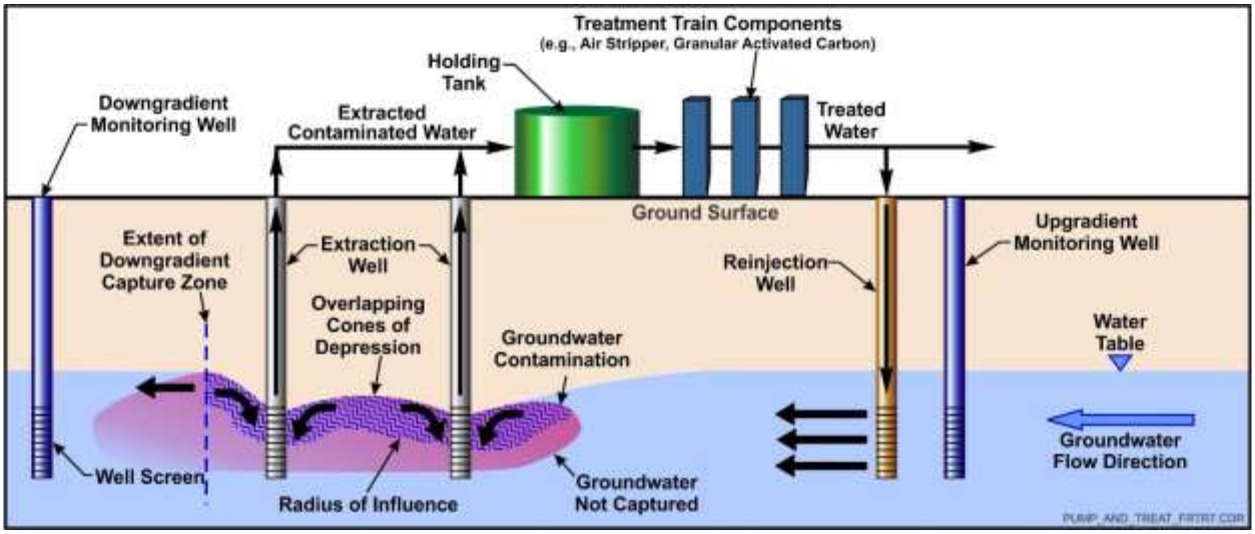

Fig.1.Groundwater Treatment

The contamination of infiltrated river water will be reduced by natural attenuation. Clay minerals, iron hydroxide and humic matter as well as microorganisms located in the subsurface have high decontamination capacities. By this, a final water treatment, if necessary, becomes much easier and cheaper. The quantitative effect concerns the seasonally changing river discharge that influences the possibility of water extraction for drinking water purposes. Such changes can be equalised by seasonally adapted infiltration/extraction of water in/out of the aquifer according to the river discharge and the water need. This method enables a continuous water supply over the whole year.[4] Generally, artificially recharged groundwater is better protected against pollution than surface water, and the delimitation of water protection zones makes it even more save. The growing population and an increase of industrialisation and agricultural production in numerous countries require more and more water of adequate quality. In many regions there is a lack of surface water and severe water contamination is to be found. Shallow groundwater resources are often of insufficient quality and over-exploited. Therefore, it is of high priority to take into consideration all the proved water techniques that could help to reduce the existing disaster.**Artificial groundwater recharge is an approved method that has been improved during the last decades**. It has been found that also the new kinds of polluting agents, especially organic compounds, can be minimized or even removed by natural purification processes in the subsurface.Artificial groundwater recharge is the infiltration of surface water into shallow aquifers to increase the quantity of water stored in the subsurface and to improve its quality by processes of natural attenuation .[5] It can be practiced especially in river valleys and sedimentary plains by infiltrating river or lake water into shallow sand and gravel layers. The infiltration technique is chosen according to the hydrogeological conditions, the available ground space, the water need, the composition of the infiltrated water, and the degree of purification to be achieved . In order to improve the efficiency of natural purification processes in the subsurface, artificial groundwater recharge can be combined with pre-treatment, bank filtration, plant purification, subsurface dams and artificial aquifers .

Contamination of ground water can result in poor drinking water quality, loss of water supply, degraded surface water systems, high cleanup costs, high costs for alternative water supplies, and/or potential health problems. The consequences of contaminated ground water or degraded surface water are often serious. For example, estuaries that have been impacted by high nitrogen from ground water sources have lost critical shellfish habitats. In terms of water supply, in some instances, ground water contamination is so severe that the water supply must be abandoned as a source of drinking water. In other cases, the ground water can be cleaned up and used again, if the contamination is not too severe and if the municipality is willing to spend a good deal of money. Follow-up water quality monitoring is often required for many years.[6]

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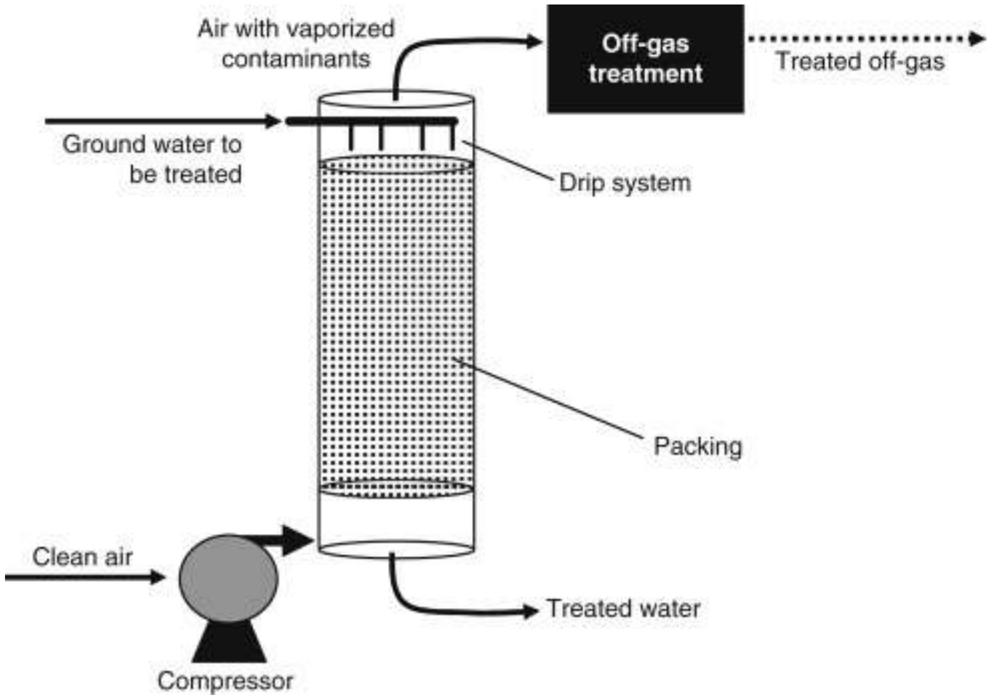
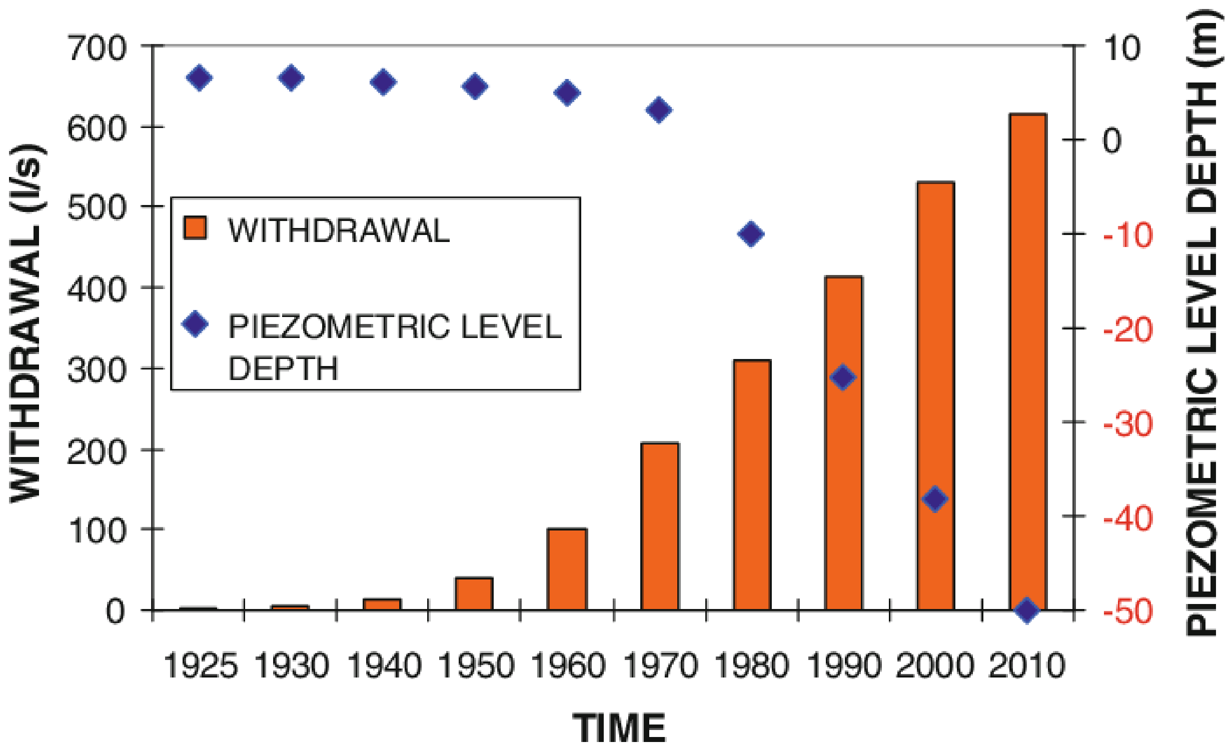


Fig.2. Groundwater Remediation Technique

Because ground water generally moves slowly, contamination often remains undetected for long periods of time. This makes cleanup of a contaminated water supply difficult, if not impossible. If a cleanup is undertaken, it can cost thousands to millions of dollars. Once the contaminant source has been controlled or removed, the contaminated ground water can be treated in one of several ways: • Containing the contaminant to prevent migration. • Pumping the water, treating it, and returning it to the aquifer • Leaving the ground water in place and treating either the water or the contaminant. • Allowing the contaminant to attenuate (reduce) naturally (with monitoring), following the implementation of an appropriate source control. Selection of the appropriate remedial technology is based on site-specific factors and often takes into account cleanup goals based on potential risk that are protective of human health and the environment.

The technology selected is one that will achieve those cleanup goals. Different technologies are effective for different types of contaminants, and several technologies are often combined to achieve effective treatment. The effectiveness of treatment depends in part on local hydrogeological conditions, which must be evaluated prior to selecting a treatment option. Given the difficulty and high costs of cleaning up a contaminated aquifer, some communities choose to abandon existing wells and use other water sources, if available. Using alternative supplies is probably more expensive than obtaining drinking water from the original source. A temporary and expensive solution is to purchase bottled water, but it is not a realistic long-term solution for a community's drinking water supply problem. A community might decide to install new wells in a different area of the aquifer. In this case, appropriate siting and monitoring of the new wells are critical to ensure that contaminants do not move into the new water supplies. [7,8]



Graph 1: showing variations in groundwater withdrawal

A number of microorganisms and thousands of synthetic chemicals have the potential to contaminate ground water. Drinking water containing bacteria and viruses can result in illnesses such as hepatitis, cholera, or giardiasis. Methemoglobinemia or "blue baby syndrome," an illness affecting infants, can be caused by drinking water that is high in nitrates. Benzene, a component of gasoline, is a known human carcinogen. The serious health effects of lead are well known—learning disabilities in children; nerve, kidney, and liver problems; and pregnancy risks. Concentrations in drinking water of these and other substances are regulated by federal and state laws. Hundreds of other chemicals, however, are not yet regulated, and many of their health effects are unknown or not well understood. Preventing contaminants from reaching the ground water is the best way to reduce the health risks associated with poor drinking water quality. [9]

DISCUSSION

Pollutants reaching the soil can pass through the surface just like the rain does. When it reaches the aquifer, it contaminates that water supply. Everything from pesticides to used motor oil can seep deep into the ground. Improperly sealed septic tanks may introduce human waste into this water, which is particularly problematic when it's part of the public supply. Gasoline storage tanks, which are typically installed underground, also threaten groundwater.The original water source, rain, could start out contaminated as well. Another primary source for pollutants comes from landfills. A well-managed landfill prevents any run-off, but unauthorized sites and a failure to adhere to best practices put the groundwater at risk.[10]

Several problems occur when pollutants get mixed into this water. The risk of disease is one of the biggest issues, although the specific ailments depend on the type of contamination. For instance, toxins can cause a variety of adverse health effects for humans and wildlife. Groundwater treatment neutralizes any problematic substances so you can use the water safely.

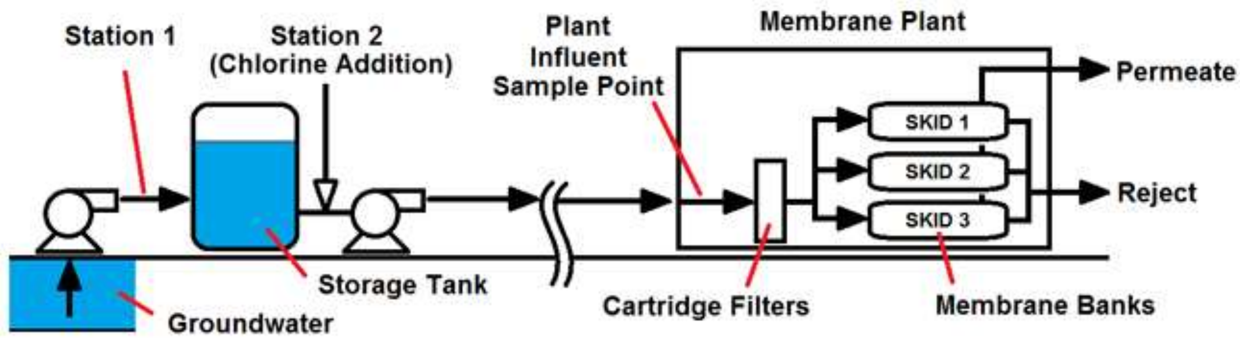


Fig.3. Membrane treatment of groundwater

This process handles pollutants with one of two methods. Either the contaminant gets removed entirely, or it goes through a conversion process to render it harmless. The treatment process varies based on the materials present in the water, but they fall into three broad categories: biological, chemical and physical. Water treatment plants typically combine multiple techniques like water treatment disinfection, iron and manganese removal from groundwater, and water treatment corrosion control to address a wide variety of problems.[11]

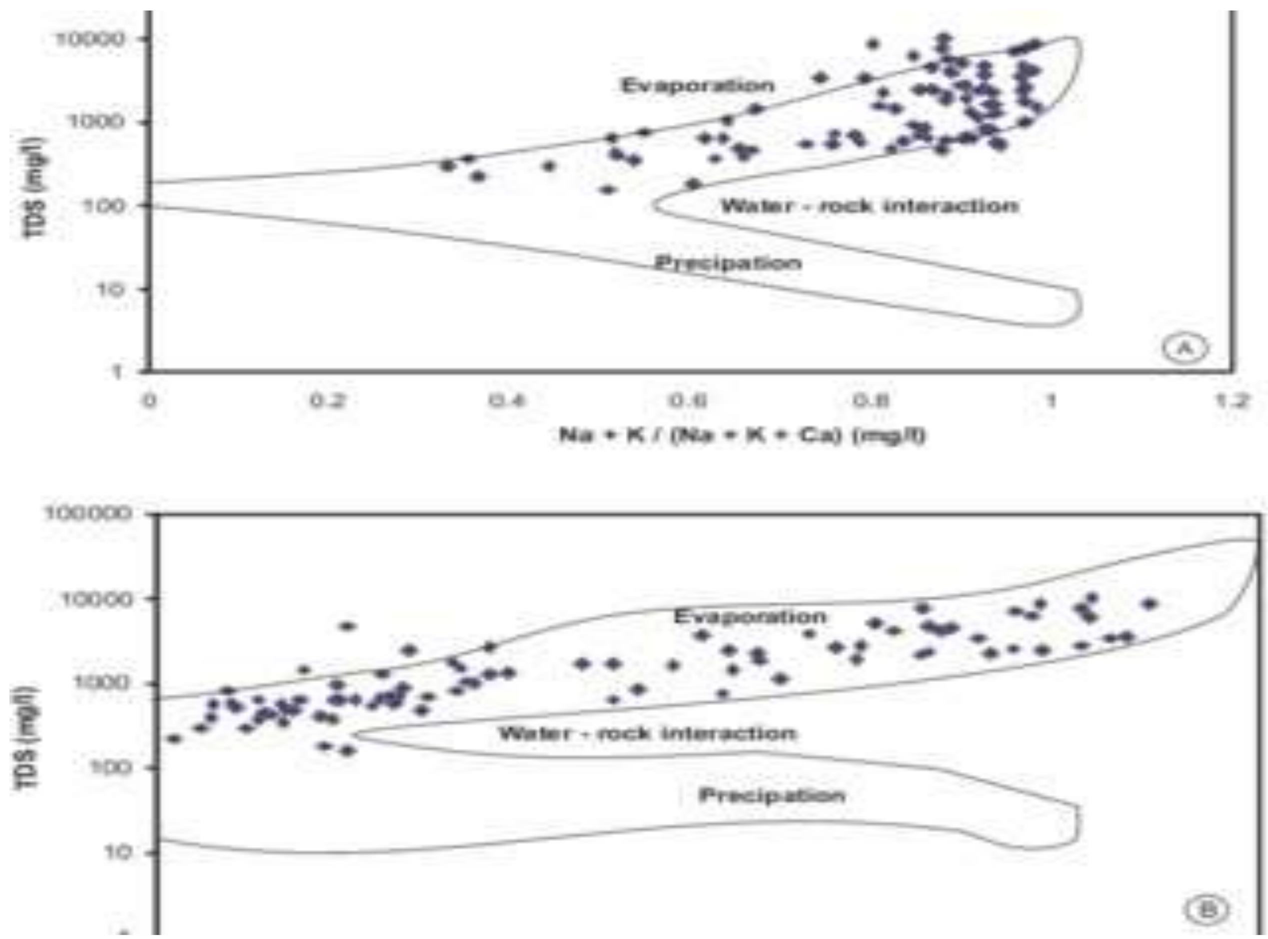


Fig.4 Hydrochemical Status Of Groundwater In Ajmer District

BIOLOGICAL GROUNDWATER TREATMENT

This method uses organic compounds to remove contaminants. Certain enzymes, microorganisms, bacteria and plants can remove harmful chemicals from groundwater. Think of the way a mountain stream gets filtered through rocks to create some of the best tasting water possible. Biological treatment operates with a similar concept that enhances the biological water quality parameters.(fig.5)

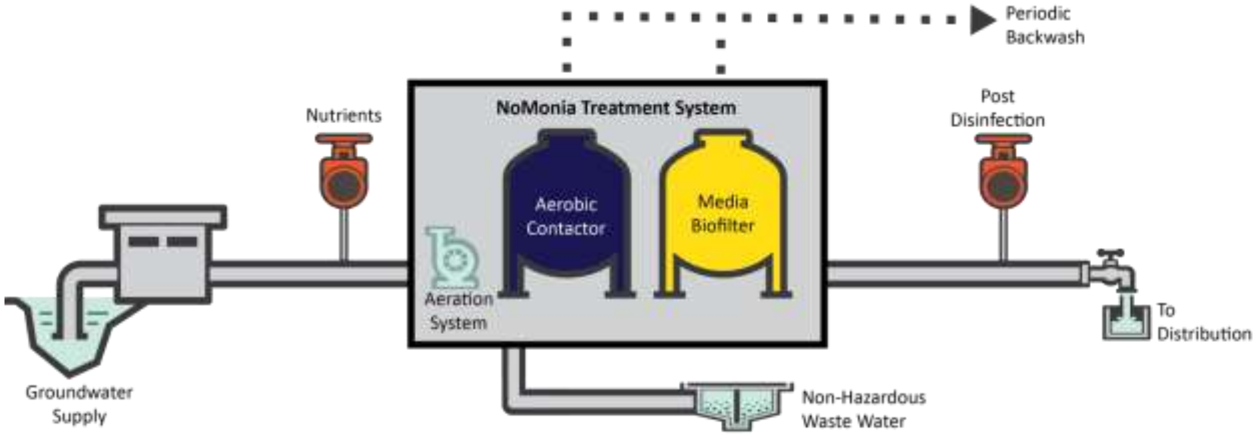


Fig.5. Biological groundwater treatment

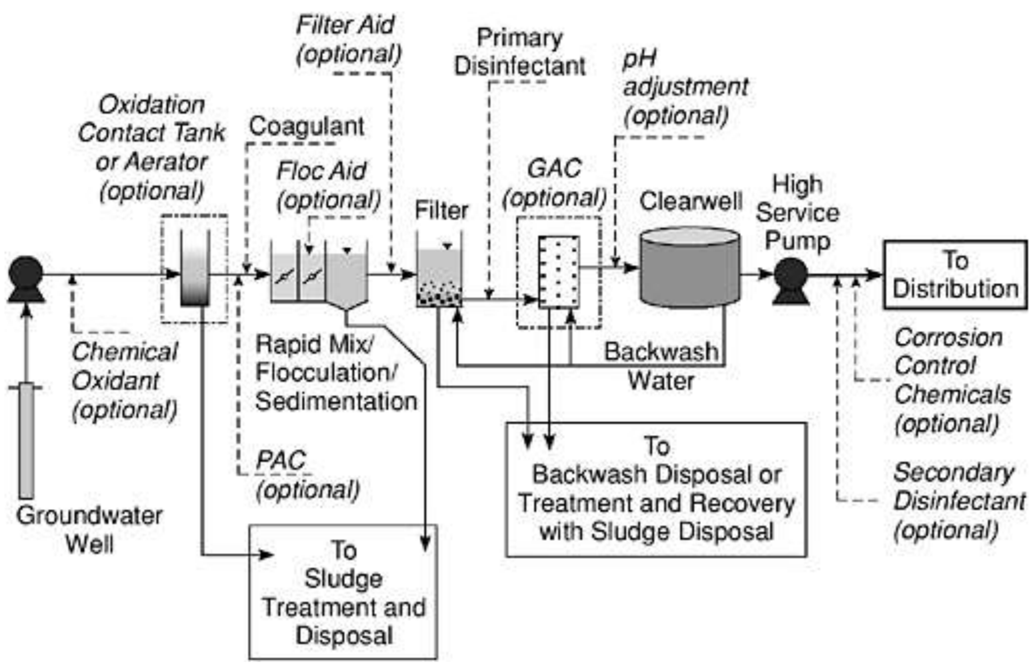


Fig.6: Chemical groundwater treatment

PHYSICAL GROUNDWATER TREATMENT

This practice relies on **machines to separate the contaminants** from the fresh water. Treatment plants combine physical techniques with chemical or biological, but you can reduce the amount of purification work required when you get rid of most of the material as the first step.

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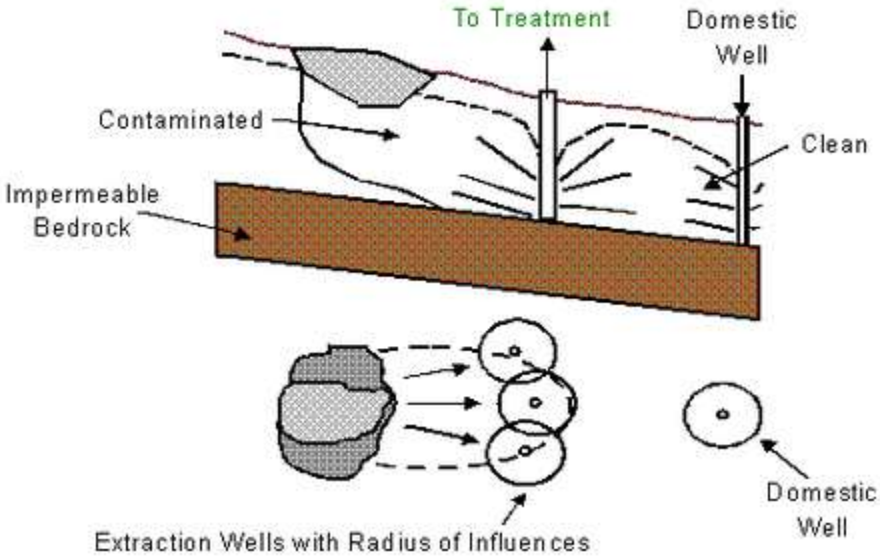


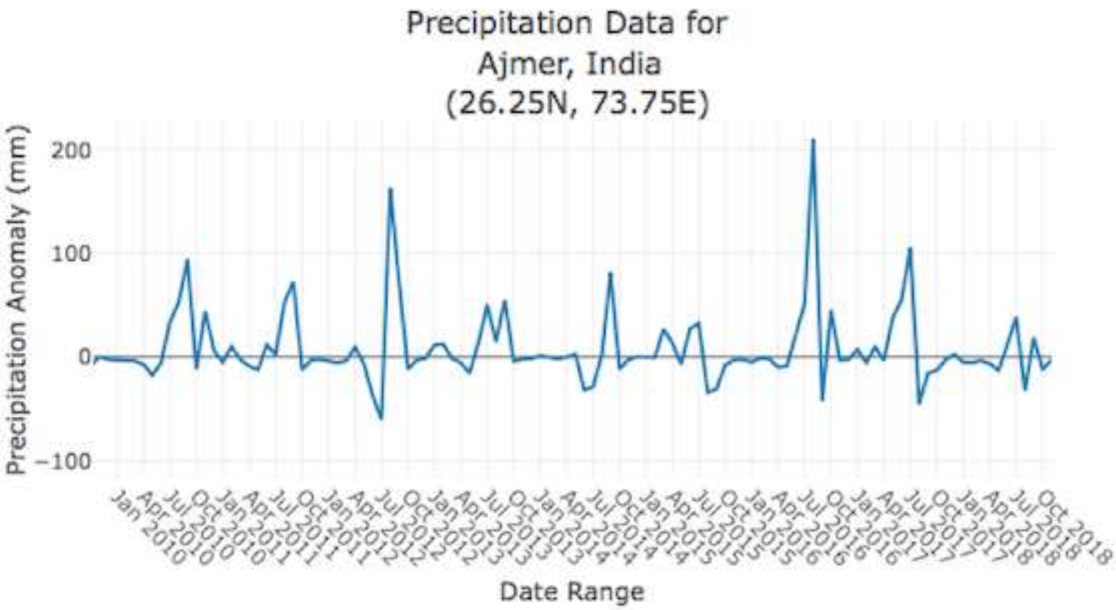
Fig.7. Physical groundwater pumping

Groundwater plays a critical role in everyday life, from the water you drink to the food you eat. Without this renewable water source, farmers wouldn't be able to keep crops watered, and drought-stricken cities would become ghost towns.

RESULTS

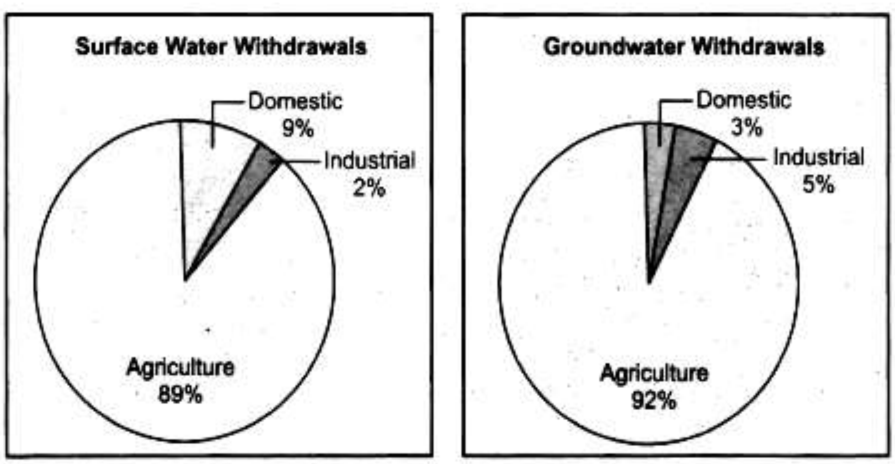
Ground Water Quality in India

Ground water in shallow aquifers is generally suitable for use for different purposes and is mainly of Calcium bicarbonate and mixed type. However, other types of water are also available including Sodium-Chloride water. The quality in deeper aquifers also varies from place to place is generally found suitable for common uses. Only in some cases, ground water has been found unsuitable for specific use due to various contaminations mainly because of geogenic reasons. The main ground water quality problems in India are as follows. Inland Salinity Inland salinity in ground water is prevalent mainly in the arid and semi arid regions of Rajasthan, Haryana, Punjab and Gujarat and to a lesser extent in Uttar Pradesh, Delhi, Madhya Pradesh Maharashtra, Karnataka , Bihar and Tamil Nadu. About 2 lakh sq.km area has been estimated to be affected by saline water of Electrical Conductivity in excess of 4000 µS/cm. There are several places in Rajasthan and southern Haryana where EC values of ground water is greater than 10000 µS /cm making water nonpotable. Inland salinity is also caused due to practice of surface water irrigation without consideration of ground water status. The gradual rise of ground water levels with time has resulted in water logging and heavy evaporation in semi arid regions lead to salinity problem in command areas. As per recent assessment about 2.46 m ha of the area under surface water irrigation projects is water logged or threatened by water logging.[12]



Graph 2: Precipitation Data For Ajmer District

Coastal Salinity Coastal areas represent zones where land and sea meet and comprises variety of complex environments including deltas, estuaries, bays, marshes, dunes and beaches. Coastal aquifers have boundaries in contact with seawater and are always under dynamic equilibrium with it. **Withdrawal of fresh ground water from these aquifers may result in inequilibrium resulting in intrusion of saline water in coastal aquifers**. The Indian subcontinent has a dynamic coast line of about 7500 km length. It stretches from Rann of Kutch in Gujarat to Konkan and Malabar coast to Kanyakumari in the south to northwards along the Coromandal coast to Sunderbans in West Bengal .The western coast is charactrised by wide continental shelf and is marked by backwaters and mud flats while the eastern coast has a narrow continental shelf and is characterized by deltaic and estuarine land forms. Ground water in coastal areas occurs under unconfined to confined conditions in a wide range of unconsolidated and consolidated formations**. [13]**



***Source** : Earth Trend 2001, World Resource Institute, as given in Govt. of India (200*

Fig. : Sectoral Usage of Surface Water Fig. Sectoral Usage of Groundwart

Normally, saline water bodies owe their origin to entrapped sea water (connate water), sea water ingress, leachates from navigation canals constructed along the coast, leachates from salt pans etc. In general, the following situations are encountered in coastal areas i. Saline water overlying fresh water aquifer ii. Fresh water overlying saline water iii. Alternating sequence of fresh water and saline water aquifers In India, salinity problems have been observed in a number of places in coastal areas of the country. Problem of salinity ingress has been noticed in Minjur area of Tamil Nadu and Mangrol – Chorwad- Porbander belt along the Saurashtra coast. In Orissa in an 8-10 km. wide belt of Subarnrekha, Salandi, Brahamani outfall regions in the proximity of the coast, the upper aquifers contain saline horizons decreasing landwards. Salinity ingress is also reported in Pondicherry region, east of Neyveli Lignite Mines.[14]

Some of the options available for removal of salinity from drinking water are – i) Electrodialysis ii) Reverse Osmosis iii) Ion exchange Fluoride Fluorine is the lightest member of the halogen group of elements. Fluorite (CaF2) is a common fluoride mineral. This mineral has a rather low solubility and occurs in both igneous and sedimentary rocks. Apatite (Ca5 (Cl, F, OH) (PO4)3,) commonly contains fluoride. Most fluorides are sparingly soluble and are present in natural water in small amounts. High concentration of fluoride in ground water beyond the permissible limit of 1.5 mg/L is a major health problem in India. Nearly 90% of rural population of the country uses ground water for drinking and domestic purposes and due to excess Fluoride in ground water [15]

Fig.8 Groundwater Well Shown

A huge rural population is threatened with health hazards of Fluorosis. To combat the growing problem of fluorosis, it is of utmost importance to understand the distribution and occurrence of fluoride in ground water and work out strategies for its mitigation and management. **Some of the options available for removal of fluoride from drinking water are – i. Adsorption (Activated Alumina) ii. Ion Exchange iii. Nalgonda Technique iv. Membrane (Reverse Osmosis) v . Electro dialysis vi. Alternate Fluoride free aquifer Arsenic Arsenic and its compounds are widely used in pigments, as insecticides and herbicides, as an alloy in metals and chemical warfare agents.** Though synthetic organic compounds have now replaced arsenic in most of the uses, arsenic is still an element of interest in terms of environmental quality. Arsenic is a metalloid. The common valancy of arsenic in unpolluted ground water of geogenic origin are +III & +V as hydrolysis species The dissociation constant of As(III) and As(V) acids are quite different The fact that dominant dissolved species are either uncharged or negatively charged suggests that adsorption and ion exchange will cause little retardation as these species are transported along ground water flow path. Organic arsenic compounds such as methyl arsenic acid and dimethyl arsenic acid are not common in ground water. The occurrence of Arsenic in ground water was first reported in 1980 in West Bengal in India. In West Bengal, 79 blocks in 8 districts have Arsenic beyond the permissible limit of 0.01 mg/L. About 16 million people are in risk zone. The most affected districts are on the eastern side of Bhagirathi river in the districts of Malda, Murshidabad, Nadia, North 24 Parganas and South 24 Parganas and western side of the districts of Howrah, Hugli and Bardhman. [16]

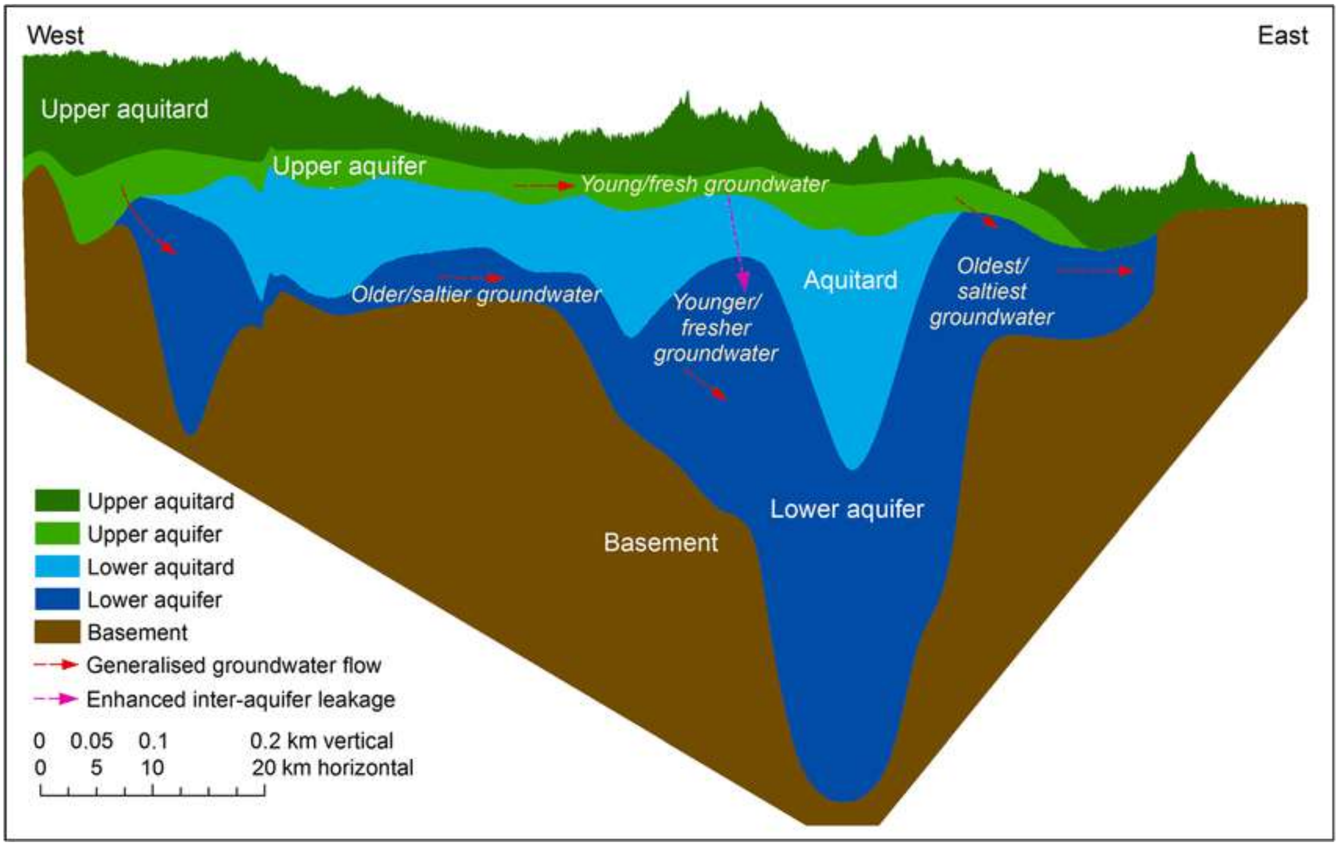


Fig.9. Hydrogeological Transect Following Generalised Groundwater

The occurrence of Arsenic in ground water is mainly in the intermediate aquifer in the depth range of 20-100m. The deeper aquifers are free from Arsenic contamination. Apart from West Bengal, Arsenic contamination in ground water has been found in the states of Bihar, Chhatisgarh and Uttar Pradesh &Assam. Arsenic in ground water has been reported in 12 districts In Bihar, 5 districts in U.P and one district each in Chhatisgarh & Assam states. The occurrence of Arsenic in the states of Bihar, West Bengal and Uttar Pradesh is in Alluvium formation but in the state of Chhatisgarh, it is in the volcanics exclusively confined to N-S trending Dongargarh-Kotri ancient rift zone. It has been reported in Dhemaji district of Assam. Table 2 shows the occurrence of Arsenic in ground water in some state of India. **The remedial options available for getting Arsenic free water are 1. Development of ground water from Arsenic free aquifers 2. Piped water supply from surface water sources. 3. Dilution of ground water with surface water 4. Treatment of ground water for removal of arsenic using adsorption (Activated alumina /Granulated ferric hydrated oxide) or precipitation and coagulation technique. 5. Rain water harvesting Iron Iron in an essential element for both plant and animal metabolism.** Both ferrous and ferric iron are wide spread minor component of most sediments. Soil development processes result in increase in iron content. The concentration of iron in natural water is controlled by both physico chemical and microbiological factors. In aqueous solution iron is subject to hydrolysis and iron hydroxides are formed during these reactions, especially the ferric form having very low solubility. The reaction of iron in aqueous solution is affected by redox potential and pH of the solution. In natural water, pH mostly ranges from 5 to 9 and as such is not low enough to prevent hydrolysis under oxidising conditions. Practically all the iron is precipitated as hydroxides. This ferric hydroxide may exist in colloidal suspensions in the range of 5 to 8. Organic rich water particularly those with humic acid, can contain dissolved iron over a large range of redox conditions. Organic compounds present in water consume dissolved oxygen which lowers the pH of water because of production of CO2 reducing both pH and Eh. An additional factor involved in the mobility in iron in ground water is the presence of bacteria. These bacteria are Gallionela, Leptothrix and Thiobacilhus. Decay of these bacteria produces unpleasant odour in the water. High concentration of Iron in ground water has been observed in more than 1.1 lakh habitations in the country. The highest value(49 mg/L) has been found in a hand pump at Bhubaneswar. Ground water contaminated by iron has been reported from Assam, West Bengal, Orissa, Chhattisgarh, and Karnataka. Localized pockets are observed in states of Bihar, UP, Punjab, Rajasthan, Maharashtra, Madhya Pradesh, Jharkhand, Tamil Nadu, Kerala and North Eastern States. The remedial methods available for removing Iron from drinking water are **i) Chemical Oxidation ii) Aeration iii) Ion exchange method**

Aqueous geochemical behaviour of nitrogen is strongly influenced by vital importance of the element in plant and animal nutrition. The most common contaminant identified in ground water is dissolved nitrogen in the form of nitrate (NO3). Nitrate in ground water generally originates from nitrogen sources on the land surface in the soil zone or shallow subsoil zones where nitrogen rich wastes are buried. In some situations nitrate that enters the ground water system originates as nitrate in wastes or fertilizers applied on the land surface. These are direct nitrate sources. In other cases nitrate originates by conversion of organic nitrogen. Ammonification and nitrification are processes that normally occur above the water table generally in the soil zone, where organic matter and oxygen are abundant. Though various nitrogen products are available in the nitrogen cycle, the content of nitrate in Ground Water is probably controlled by nitrification which is directly related to the capacity of soil microorganisms to convert ammonia to nitrate to provide growing plants with the assimilable form of nitrogen. Concentrations of nitrate in the range commonly reported for ground water are not limited by solubility constraints. It moves with ground water with no transformation and / or no retardation. Very shallow ground water in highly permeable sediment or fractured rocks commonly contains considerable dissolved oxygen and in these hydrological environment nitrate commonly migrates large distances from input areas. **Nitrate is a very common constituent in the ground water, especially in shallow aquifers.**[17]

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