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RESEARCH ARTICLE

In Situ Remediation Technique of Groundwater Contamination: A Review

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Abstract

Groundwater is primary source of urban and rural water supply. Due to urbanization, industrialization, agriculture and our modern life style has polluted this primary source of water. This article presents a review of In-Situ remediation technique of ground water and contains seven type of In-Situ remediation technique of ground water. As coin has two sides like that in- situ remediation has also some negative aspects.

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INTRODUCTION

This review focuses on In – Situ Remediation technique of ground water contamination. Millions of people worldwide especially over the last half century depend on groundwater which is a vital source of water (McCaffrey 2003) but over population have resulted in increases in soil and water pollution and growing pressure on our natural resources. Because the high expansion of industrialization and urbanization and improper environmental management (Kumar et al., 2011). Surface pollutants arising due to poor waste management pollute water table aquifer of lower Imo River basin (Nwachukwu and Osoro 2013). Not proper management of storm water pollutes surface water and polluted surface water pollutes ground water (Nwachukwu and Osoro 2013). Now a day's ground water contamination is a major challenging problem for us. Ground water is polluted mainly by these three sources i.e. urbanization, industrialization and agriculture (Nwachukwu 2014).A case reported in Libby, Montana that soil and two aquifers are polluted due to uncontrolled release of industrial chemical waste creosote and Pentachlorophenol (PCP) (Piotrowski et al., 2006). The typical sources of potential ground water contamination by land use category is mentioned in **Table:1**. As a result, at many places the surface aquifers are polluted and at that place shallow wellsproduce poor quality of water and consequently increases water related diseases, poverty and quality of life becomes poor. Treatment of aquifers is difficult, costly and sometime impossible due to slow movement of groundwater (Nwachukwu 2014).

Punjab, Haryana, Himachal Pradesh and Uttar Pradesh experienced first traces of arsenic contamination in India. Groundwater of lower Ganga plain of W.B experienced arsenic contamination in 1984. Three districts of U.P Ballia, Gazipur and Varanasi were on the hit list during October 2003-August 2005 (Chaurasiaat.el., 2012). Ground water of Gujarat, A.P, Kerala, Delhi and Haryana (India) were contaminated by heavy metals like Lead, Cadmium, Zinc and Mercury (Hazarika and Bhuyan 2013). Various problems arising due to groundwater quality degradation in India is mentioned in **Table: 2**.

Table 1. Typical Sources of Potential Ground Water Contamination by Land Use Category

Category	Contaminant Source	
Agriculture	Animal burial areas	Irrigation sites
	Animal feed lots Areas/pits	Manure spreading
	Fertilizer storage/Use	Pesticide storage /use
Commercial	Airports	Jewellery/ Metal plating
	Auto repair shops	Laundromats
	Construction sites	Paint Shops
	Car washes establishment	Photography
	Cemeteries	Railroad tracks and yards
	Dry cleaners	Research laboratories
	Gas Stations	Scrap and junkyards
	Golf courses	Storage tanks
Industries	Asphalt plants production/storage	Petroleum
	Chemical manufacture/storage	Pipelines
	Electronics manufactures sites	Seepage lagoons and sludge
	Electroplates	Storage tanks
	Foundries/metal fabricators	Toxic and hazardous spills
	Machine metalworking Shops	Wells(operating/abandoned)
	Mining and mine drainage	Wood preserving facilities
Residential	Fuel oil	
	Furniture stripping/refinishing	Septic system , cesspools
	Household Hazardous Products	Sewer lines
	Households Lawns	Swimming pools
Other	Hazardous waste Landfills	Recycling/reduction facilities
	Municipal incinerators operations	Road dicing

	Municipal Landfills depots	Road maintenance
	Municipal Sewer lines	Storm water drains/basins
	Open Burning Sites	Transfer Stations
Source: U.S. EPA, 1991a.		

Table: 2. States (in India) affected by various Groundwater Quality problems.

Parameter	Health Impacts	Affected States
Fluoride	Immediate symptoms include digestive disorder, skin diseases, skeletal Fluorosis.	A.P, Assam, Bihar, Chhattisgarh, Gujarat, Haryana, Jharkhand, Karnataka, Kerala, M.P, Maharashtra, Orissa, Punjab, Rajasthan, Tamil Nadu, Tripura U.P, W.B
Iron	Poisoning for child as it can damage blood tissue, Digestive disorder, Skin Diseases and dental problem	A.P, Assam, Bihar, Chhattisgarh, Gujarat, Haryana, Jharkhand, J &K, Karnataka, Kerala, Manipur, Meghalaya, Mizoram M.P, Maharashtra, Nagaland, Orissa, Punjab, Rajasthan, Tamil Nadu, Sikkim, Tripura U.P, W.B, A& N Islands, Pondicherry
Arsenic	Immediate symptoms of acute poisoning typically include vomiting, abdominal pain, and bloody rice water diarrhea. Long Term exposure to arsenic causes cancer of skin, lungs, urinary bladder and kidney. There can be possibility of skin change such as hyperkeratosis.	Assam, Bihar, Chhattisgarh, Jharkhand, Tripura, U.P and W.B
Nitrate	Causes Blue Baby Diseases where the skin of infants becomes blue due to decreased efficiency of hemoglobin to combine with oxygen. It may also increase the risk of skin cancer.	Bihar, Gujarat, Karnataka, Kerala, Manipur, M.P, Maharashtra, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh.
Heavy Metals	Damage to the nervous system, kidney and other metabolic disruption	Gujarat, A.P, Delhi, Haryana, Kerala.

In – Situ remediation technique

Many countries like USA, Europe and Australia are using In –Situ methods for treatment of polluted aquifers. In-Situ remediation methods destroys contaminants in same place without transferring to another environment medium (Nwachukwu 2014).

- **Pump – and – treat technique**

This process is simple and slow. In this process polluted ground water is extracted from aquifers, then treated and discharged in surface water body or again injected in aquifers (Nwachukwu 2014). This method of remediation is quite expensive (Mackay and Cherry 1989). This is illustrated in fig 1.

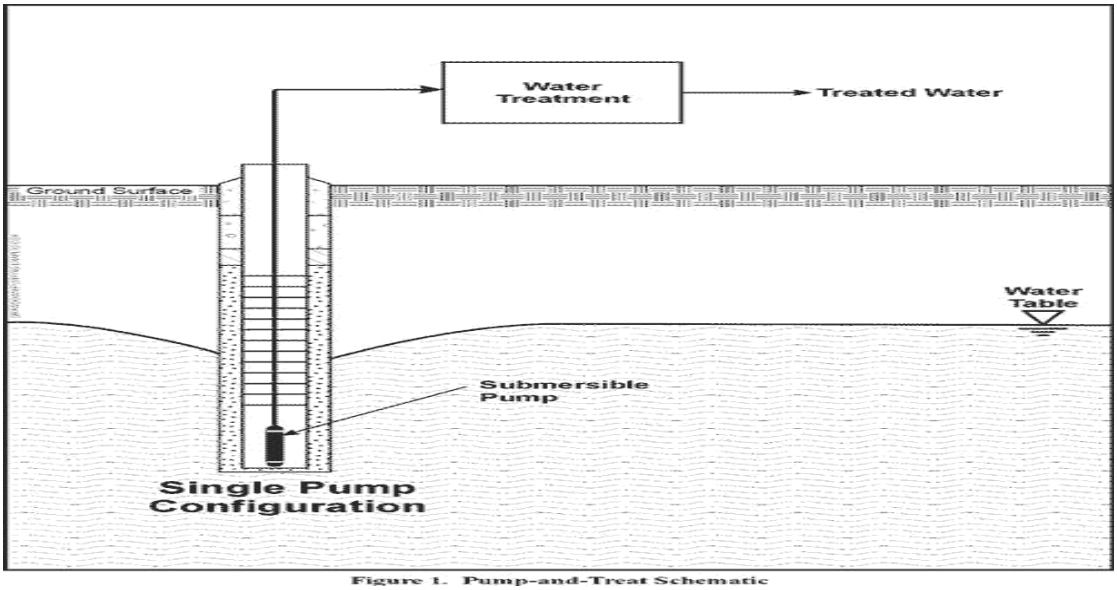

Fig 1: Pump and treatment technique of ground water contamination.

- **Nano – Treatment technique**

In this method reactive Nano – particles (10 to 100 nm in diameter) are used for transformation and detoxification of contaminants. Nano particles have characteristics of both chemical reduction as well as catalysis to mitigate the contaminants of concern. In Nano remediation there is no need to pump out the ground water and no need of soil transportation (Otta et al., 2008 and Nwachukwu 2014).Iron powder can be used as a nano-particle (Saleh et al.,2007,tratnyek and jonson 2006, US, EPA, 2008b).The reaction of Fe with chlorinated solvent effectively mitigate the chlorine. Laboratory test proved that 12 nm diameter particle of Fe remove 99% of As (Rickerby and Morrison 2007).Nano-technique is good approach for environmental remediation. Some manufactured nano-particles which potentially remediate contaminants are listed in **Table 3**.

For a comprehensive and there remediation application adopted from Theron et al., 2008, Zhang 2003 and Nwachukwu 2014.

Table 3. : List of manufactured nano-particles and the pollutants potentially remediated.

No.	Nano - particles	Application
1	Nanocrystalline zeolites	Toluene, nitrogen dioxide
2	Carbon nanotubes (CNTs)	Benzene, toluene, xylene, ethylbenzene, heavy metal
3	Activated carbon fibers	Benzene, toluene, xylene, ethylbenzene,heavy metal ions
4	CNTs fuctionalized with polymere and Fe	benzene, toluene, dimethy polymers and Febenzene, heavy metal ions.
5	Multi Walled CNTs	heavy metal ions, THMS, chlorophenols, Herbicides, Microcystin toxins.
6	Self-assembled monolayer on mesoporous support	Inorganic ions, heavy metal ions, Actinides, Lanthanides, Radionuclides TiO_2

7	Zero-valent iron nanoparticle	Chlorinated methanes, trihalomethanes, chlorinated benzenes, chlorinated ethenes, Pesticides, polychlorinated hydrocarbons, organic Dyes,Heavy Metal ions, inorganic ions, chlorinated Organic compounds
8	Photo catalysts	Heavy metal ions, Azo dyes, phenol, Aromatic Pollutents,toluene
9	Bimetallic: Pd/Fe nanoparticles	PCBs, Chlorinated ethane and methanes.
10	Ni/Fe nanoparticles Pd/Au nanoparticles	TCE, PCBs, Dichlorophenols, Trichlorobenzene, Chlorinated ethenes, Brominated organic c ompounds
Source:Adapted from Theron et al., 2008, Zhang 2003 and Nwachukwu 2014.		

- **In Situ soil vapors extraction treatment technique**

In- Situ vapors extraction is cost effective and successful remediation method for VOCs. This technique is applied for unsaturated zone (Reddy et al., 1995). This system has one or two extraction wells, a vacuum pump and a treatment system for vapors extraction (Nwachukwu 2014).This is illustrated in fig 2.

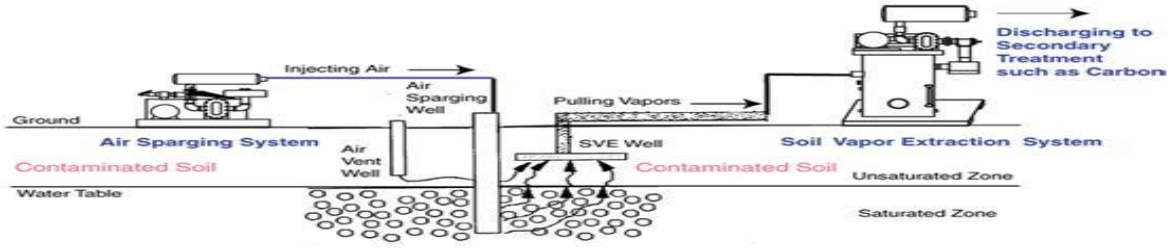

Fig 2: Soil vapors treatment technique for the ground water contamination.

- **In- Situ chemical treatment technique**

In this treatment chemicals are injected in subsurface to transform pollutants. This technique consists of series of well for delivering chemicals in the head of polluted area of ground water. These chemicals are reduced the pollutants, convert into less toxic and less mobile phase (Reddy et l., 1995). In this treatment sulphur dioxide, sulphide salts, ferrous sulphate metallic iron and zinc are used as reducing agents and hydrogen peroxide, ozone andpotassium permanganate used as oxidizing agents (Nwachukwu 2014). This treatment applicable in that where pollutants are well defined. This is illustrated in fig 3.

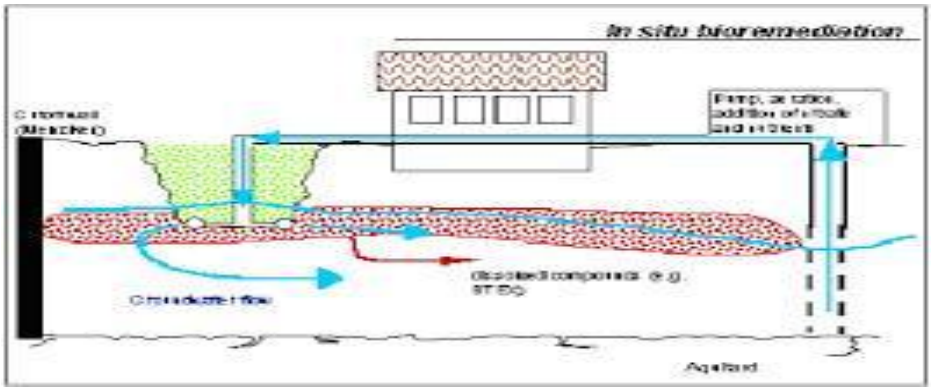

Fig 3: In situ chemical treatment technique for ground water contamination.

- **In-Situ thermal treatment technique**

In this technique we increase the temperature of subsurface after increasing the temperature the organic pollutants will mobilize more rapidly due to enhanced volatilization, desorption from soil, and increase water solubility and increased fluid flow rates (Nwachukwu 2014). This is illustrated in fig 4.

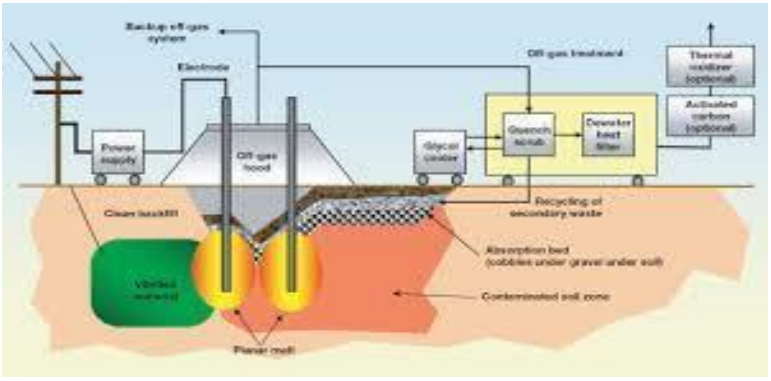

Fig 4: In - situ Thermal technique for the ground water contamination.

- **Permeable Reactive Barriers (PRBs) technique**

In PRBs treatment plume of contaminants are captures and pollutants are breakdown or removed after that treated water are released. In this technique barriers are install in the path of groundwater flow and barriers are contain reactive media (e.g., ZVI, solid phase organic carbon and oil coated sand). This is illustrated in fig 5.

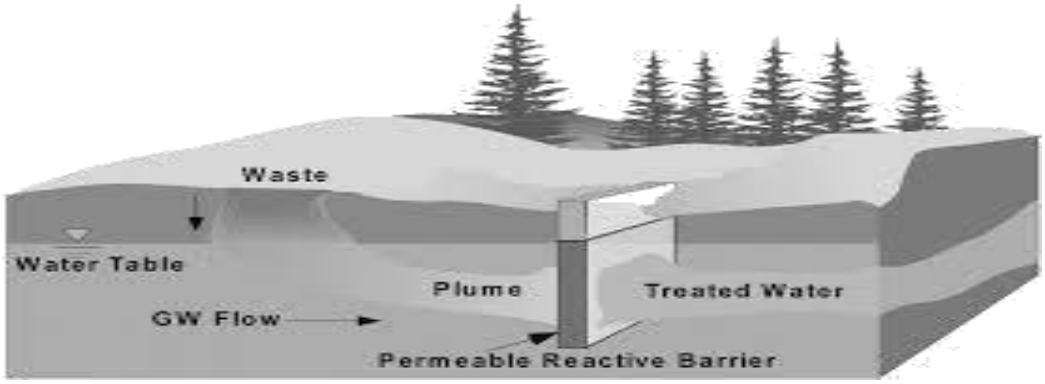

Fig 5: Permeable reactive barrier techniques for the groundwater contamination.

According to the U.S EPA (2001cp.2):

- PRBs work best at sites with loose, sandy soil and steady flow of groundwater.
- The pollution should be no deeper than 50 feet.
- Since there is no need to pump polluted groundwater above ground, PRBs can be cheaper and faster than other methods.
- There is no part to break, and there is no equipment above ground so that property can be used while it is being cleaned up.
- There is no energy cost to operate PRBs because it works with the natural flow of groundwater.

- **Bioremediation treatment technique**

Bioremediation is the intentional use of biological degradation process to remove or reduce the contaminants.

The most important bioremediation treatments are: o Bioventing

It is the most common in situ treatment and involves supplying air and nutrients through well to contaminated soil to stimulate the indigenous bacteria. Bioventing employs low air flow rates and provide s only the amount of oxygen necessary for biodegradation. This is illustrated in fig 6.

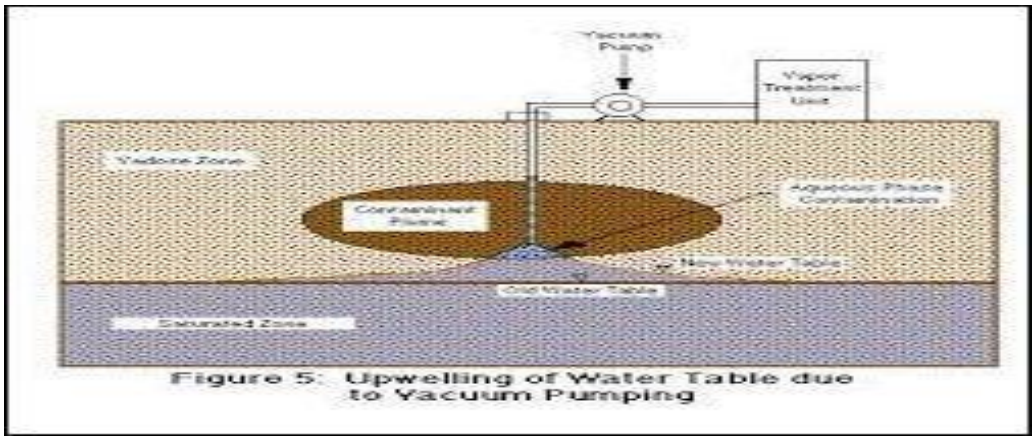

Fig 6: Bioremediation treatment technique (Bioventing) of ground water contamination.

- **Biosparging**

It involves the injection of air under pressure below the water table to increase ground water oxygen concentration and enhance the biological degradation of contaminants by naturally occurring bacteria. This is illustrated in fig 7.

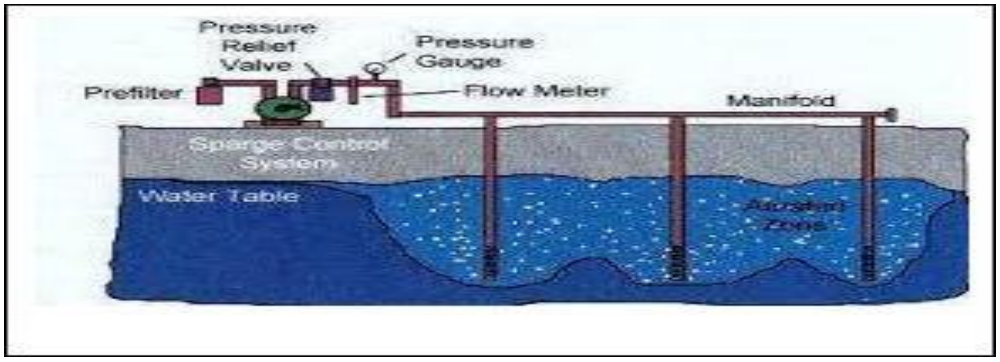

Fig 7: Bioremediation treatment technique (Biosparging) of ground water contamination.

Discussion and Conclusion

Groundwater of India is highly contaminated with arsenic, iron, fluoride, nitrate and load of heavy metals. There are many in situ remediation technique of groundwater contamination among which some are highly significant and very easily applicable but some techniques are not suitable for every contamination sites. As per the geographical and economic conditions of India some are not applicable for groundwater remediation. For pump and treatment technique: it is a slow process and an expensive also. In this process whole water is extracted from the aquifer and treated and injected to aquifers. In situ soil vapors extraction treatment technique is applicable only in unsaturated zone. In situ thermal treatment technique requires heavy energy consumption that's why due to power crisis not

effective in India. Permeable reactive barriers are very cheap as per Indian aspect. There is no any waste generated during this treatment. Apart from this PRBs can't work above 50 feet depth. It can be applied only on sites which has loose sandy soil and steady flow of ground water. Biosparging is readily available equipment to install easily. In this treatment contaminated groundwater site is treated for 6 month to 2 Years under favorable conditions. It can only be applied in environment where air sparing is suitable (e.g. uniform and permeable soil, unconfined aquifers, no subsurface confined space).

In Indian prospect the future aspect of in situ remediation techniques are Nano-treatment technique, Permeable Reactive Barriers, Bioventing and Biosparging which are highly suitable. These all four techniques are highly effective in Indian conditions to remove ground water contamination of As, F, Fe and Nitrate. The efficiency of these techniques is about 99% to remove groundwater contamination.

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