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Groundwater Contamination: Sources, Health Risks and Future Prospects

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Abstract

Groundwater quality is extremely important for people's health. Currently, there has been a global rise in growth of interest in environmental issues, including groundwater quality. Groundwater contamination constitutes one of the most important natural resources in drinking water supply in both rural and urban areas. With the coming of the new century, the serious deterioration of ground water quality has been observed in both developed and developing nations with the industrialized and densely populated regions being the most hit with the pollution. The extent of its damage is difficult to determine due to its complexities of contaminants, in predicting their movements and fate in the groundwater system.

The demand for drinking water supply has increased because of the global rise in population and food demand. This rise has further enhanced the call to better management of our groundwater aquifers by preventing any further pollution than remediating the already polluted ones. In this short article, groundwater problems and sources are described, health effects related to the pollution are briefly highlighted and lastly the future prospects with respect to groundwater mitigation and prevention are included. The onus to minimize the pollution and to confine and destroy the contaminants before they completely destroy our aquifers still remains on us. This is a battle that is very much achievable and it is our noble duty to see to it that our groundwater aquifers are rid of this pollution.

Keywords: Groundwater; Contamination; Industrialized; Demand; Aquifers; Health effects

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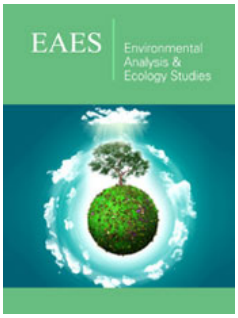

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Introduction

Groundwater purity and natural taste makes it the best water for human consumption and most systems are naturally well protected against contamination partly due to the filtration effect of the lower underlying layers and purification potential of the aquifer strata. Groundwater is the world's most extracted raw material with withdrawal rates currently in the estimated range of 982km^3/year.

About 60% of groundwater withdrawn worldwide is used for agriculture; the rest is almost equally divided between the domestic and industrial sectors. In many nations, more than half of the groundwater withdrawn is for domestic water supplies and globally it provides 25% to 40% of the world's drinking water [1,2].

If the negligence continues in contaminating the groundwater, we may be faced with a challenge of turning a renewable resource into something that cannot be recharged or used. It is a relief that most groundwater are still of very good quality but are unlikely to remain like this if current practices are unchecked. The frequent occurrence of groundwater contamination and poor quality of groundwater has become a major issue in these times of climate change and sustainability. Most of this is due to human negligence in disposing hazardous waste into the ground [3].

Before we can begin to address groundwater pollution or remediation, it is of utmost importance to understand how surface water and groundwater interrelate. Acknowledging the fact that groundwater and surface water are interconnected is the first step in understanding and intelligently managing the contamination. Aquifer and hydrogeological parameters, ground water flow, transport parameters of the contaminants, extent and characteristics of the contamination source, knowledge of the effects of possible remediate technologies is a prerequisite in dealing with groundwater contamination. For instance if near a water supplying well has a contamination source, that supply well runs the risks of becoming contaminated which trickles to the ground water which will transport its pollutants to the nearby streams, rivers and lakes.

Furthermore, contaminants may not necessarily move with the groundwater because of many factors in play like density and specific gravity. As you know the specific gravity varies greatly for different chemicals therefore the contaminant can float or sink to the bottom of the aquifer or better yet move in the opposite direction to the flow of water. Reasons why the extent of the groundwater contamination is not known is the very slow and complex movement it exhibits. It can only move faster if it is pumped or under a hydrological head [4-6].

Loading of contaminants into the groundwater occurs primarily via two routes

A. Point source pollution

B. Non-point source pollution. Point source pollution encompasses discrete sources whose inputs are clearly defined in a spatially explicit manner.

Examples include industrial effluents, sewage and combined sewage-storm water overflows, mining resource extraction and land disposal fills. Non-point source on the other hand is poorly defined, it usually occurs over broad geographical scales. Examples include agricultural run-off from pesticides and fertilizer storm water/urban run-off and atmospheric deposition of persistent organic pollutants like polychlorinated biphenyl's (PCB's) and mercury [5-8].

Sources of groundwater contamination

A simple visual review of the sources of groundwater contamination is given in Figure 1 and a brief explanation of the individual sources is provided.

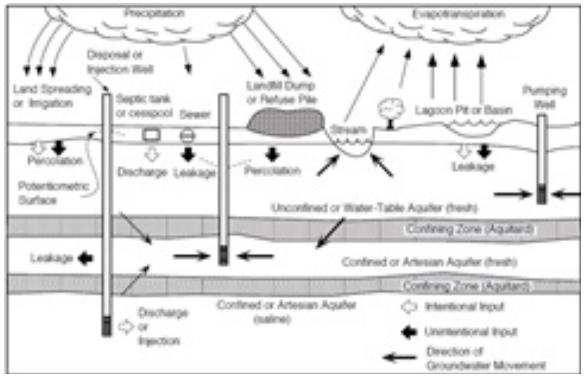

Figure 1: How waste disposal practices contaminates the groundwater system [3-6].

Landfill disposal of municipal and industrial wastes

Land disposal of solid waste is of utmost concern when it comes to groundwater contamination. Both developed and developing countries most common practice of dumping waste is through landfills which are generally engineered to contain waste. Landfills generally prevent exposure of solid waste at the land surface because the siting is based on the availability of undeveloped and inexpensive land requiring little modification rather than on hydrogeological suitability. These landfills have a direct connection with ground water and are mainly grouped into classes. Landfills that accept only municipal waste like heavy metals, nitrates and organic compounds are in class 3. Class 1 landfill contain hazardous waste and their designs mostly include liners.

Until recently, little attention was paid on how landfills operated or the true nature of contaminants it housed and what their connection to the groundwater system was. Populations which have a lot of industrial activity face serious potential health risks from solid waste disposal. So, the onus rests on the local authorities to responsibly manage and plan the solid waste by permitting, inspecting and enforcement of permit conditions. The permits should include conditions requiring waste analysis, record keeping, site monitoring and improvements, contaminant and closure procedures. Unfortunately, all landfills do leak, but if properly managed any harmful leakage can be quickly attended to before its eventual seepage to the groundwater.

Sewage intrusion and disposal

Apparently one of the main sources of groundwater contamination in the whole world is the effluent of septic tanks or cesspools. Almost every home relies on septic tanks to dispose of their human waste. In undeveloped countries, human waste can be directly applied to the ground. In all these cases groundwater contamination is at an all-time high because these disposed sewage contains pathogens, nitrates and organic matter which can directly through infiltration reach our groundwater aquifers. In addition, the use of solvents like methylene chloride to clean our septic systems can contaminate our water supply wells.

It is because of all this that local regulations require a safe separation distance between septic systems and drinking water wells to avoid contamination.

Storm water runoff

Storm water runoff is another serious source of groundwater contamination. It includes a variety of contaminants like household pesticides, heavy metals, volatile organic compounds (VOC's) and animal waste which can easily be discharged into streams/water bodies eventually getting into our groundwater system. The hydrologic cycle has groundwater and surface water. Ground water quality is largely influenced by surface water conditions, any contamination of the surface water body is also a contamination of the groundwater system because it is the surface water that recharges the groundwater. It is thus wise to consider the interaction of all environmental sources and pathways of pollution to effectively prevent groundwater contamination.

For instance an atmospheric pollution can lead to deposition of hazardous fallout to surface waters and soils hence leading to groundwater contamination.

Agricultural (Pesticides) Activities

Billions of tons of fertilizers and pesticides (herbicides, insecticides, fungicides and avicides) are applied as part of the common agricultural practice worldwide. These applications have entered and contaminated our groundwater even when following normal registered usage. Whether these become sources of

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contamination largely depends on the hydrogeological conditions, application methods and biochemical processes of the soil.

Another potential source is animal waste that percolates into the ground from farm feedlots. These feedlots should be properly sited and waste removed to avoid the contamination threat of sewage disposal briefly outlined above.

Mining activities

The construction and byproducts of mining activities can pose serious threats to groundwater. Mines both active and abandoned cause the same threat. Mining waste is broadly defined after the extraction and processing of ores and minerals as solid, semi-solid and liquid waste. Abandoned mines are mostly used as wells and waste pits, sometimes the drainage of materials from these mines can act as a contamination source for years after the mining operation ceases. Another interesting take on mines is the requirement of most mines to be pumped of the water to keep them dry, this practice causes an upward movement or better yet alter the flow field possibly inducing new contaminant sources.

Radioactive waste

The lethal and hazardous effects of exposure makes radioactive waste a burden of concern. The raw mining, processing, handling and final disposal of radioactive waste can create long term groundwater source of contamination. The disposal of these wastes has to have a very high accurate degree of isolation from groundwater systems. Even though most countries devote much work in engineering design of special waste depositories, a lot of uncertainties still linger because most radioactive chemicals half-lives remain a threat for thousands of years while in the process changes in geologic and hydrologic conditions come to play.

Contamination caused by wells

Wells improperly constructed are a source of groundwater contamination when the contaminated surface in groundwater is introduced into the well. Abandoned wells are mostly used as dumping sites by people. These wastes can reach aquifers that provide drinking water while poorly constructed water wells with construction problems like faulty casings, inadequate covers, lack of concrete pads can allow water or any other surface runoff contaminant to flow into the well.

Another source worth mentioning is the poorly constructed irrigation wells; these like all wells have the potential to allow contaminants like pesticides and fertilizers to enter our groundwater network.

Storage (Transportation) tanks spills and leaks

Storage tanks which can be above ground or underground are commonly used to store petroleum and other chemical products. Underground tanks have the habit of developing leaks as the tank ages and corrode due to the processes of nature. Its contents can easily migrate through the soil and reach our precious groundwater. Abandoned storage facilities on the other hand often cause problems as their exact location is unknown while above ground tanks can spill or leak if not properly designed and when adequate barriers are not in a place.

Tanker trucks and trains used for transportation together with pipelines leaks pose another storage hazard. When this hazard happens because of traffic accidents, corrosion, failure at connections, accidental damage by excavation, operation error or equipment failure the most common practice is to dilute the materials with water/sand and wash them into the soil thereby increasing the possibility of groundwater contamination. One could argue that the leakage from individual tanks is often insignificant, it is however quite enough to contaminant a large volume of groundwater. From this brief explanation, we can tell that above ground tanks pose less threat than underground tanks because leak detection and maintenance is easier and the connection with the ground system is less direct. The recent large scale introduction of Methyl Tertiary Butyl Ether (MTBE), an oxygenate in fuels which reduces carbon monoxide emissions has made the cleanup of leaks even more serious and urgent. MTBE is very mobile and miscible in water thus could easily contaminate our aquifers.

Careful identification of groundwater contaminant sources and characterization is the first step in the risk assessment process of groundwater. There are a number of other possible sources of groundwater contamination that were not included in this short article like seawater intrusion, salt and salinity, oil field brines, land application of liquid wastes etc. Hopefully this article provides a general framework for potential groundwater contamination sources [5-10].

Health effects

The general health effects of groundwater contamination are summarized in Table 1 below.

Table 1: Some major threats to groundwater [11,12].

Threat	Sources	Health Effects at High Concentrations
Nitrates	Fertilizer runoff; manure from livestock operations; septic tank systems	Suffocation and death in infants; digestive tract and other cancers, algal blooms and eutrophication in surface water
Pesticides	Runoff from farms, backyards, land fill leaks	Some linked to reproductive and endocrine disorders; nervous system damage and cancers
Petro Chemicals	Underground petroleum storage tanks	Benzene and other petrochemicals can cause cancer even at low exposure
Chlorinated Solvents	Effluents from metals and plastics degreasing; fabric cleaning; electronics and aircraft manufacture	Linked to reproductive disorders and some cancers

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Arsenic	Naturally occurring	Nervous system and liver damage; skin cancers
Radioactive Materials	Nuclear testing and medical waste	Increased risk of certain cancers
Fluoride	Naturally occurring	Dental problems; crippling spinal and bone damage
Salts	Seawater intrusion	Fresh water unusable for drinking or irrigation

Future Prospect, Recommendation and Conclusion

It has become evident that the global rise in population and food demand has become more and more dependent on ground water. With this development, all of humanity has to figure out ways of reducing the spread of toxins into our groundwater or prevent the contamination all together [11-14].

One thing which we know for sure is that it is 100% impossible to eliminate groundwater contamination due to its wide complex interaction between man and organisms that continuously produce contaminants which eventually find its way percolating to the groundwater. So, what are we to do to most effectively mitigate this ground water contamination? it has already been established that prevention is better than remediation in this fight against ground water contamination [13-16].

The following measures must be implemented;

A. A careful classification of aquifers and the restriction of their use to the intended purpose. Thus a comprehensive protection and control system must be developed for all aquifers, continuous monitoring and delineation of critical zones, controlling and eliminating sources of pollution and public awareness on the value and vulnerability of aquifers.

B. Restriction of unnecessary over pumping of wells as this system usually causes some water from one aquifer to move to the other thereby minimizing the transmission of contaminants between the two aquifers.

C. Chemicals and hazardous waste in landfills should be fixed prior to the leachate leaving the landfill.

D. Utilization of volatilization by injecting air into the dumpsite to drive off volatile organic compounds (VOC's) that are captured and destroyed at the same time.

E. Strict laws and policies should be imposed on industries which release their effluents directly into the water bodies. These effluents must be of acceptable standards before being discharged into the water bodies thereby reducing the purification processes of obtaining drinking water from the same water bodies.

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