International Journal of Research and Review
Vol. 10; Issue: 10; October 2023
Website: www.ijrrjournal.com
Review Paper *E-ISSN: 2349-9788; P-ISSN: 2454-2237*

Sources of Groundwater Contamination: A Review

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DOI: https://doi.org/10.52403/ijrr.20231016

ABSTRACT

Groundwater plays a vital role in sustaining human life and supporting public health. Numerous investigations into groundwater quality have been carried out on a global scale. Groundwater contamination is a widespread issue that adversely affects both ecological services and human health. Surface water contamination is different from groundwater contamination. Because contaminants are invisible and retrieving the resource is challenging with current technology. These contaminants in groundwater resources are usually colorless and odorless, making them difficult to detect. The main aim of this review is to focus on major sources of pollutants from natural and anthropogenic activities. Natural sources of groundwater contamination cause a wide range of problems with water quality problems, such as natural deposits of gypsum, minerals, salts, surface water with poor quality, seawater intrusion, and brackish water. Anthropogenic activities are industrial wastes (mining activities, solid and liquid wastes), agricultural sources (pesticides and fertilizers), urbanization (municipal wastes, land use practices, poor sanitary practice and landfill management), organic and inorganic components. This review revealed that it is necessary to generate and implement policies and regulations related to groundwater protection. This study also helps to understand contaminant sources better and reduce the effects of groundwater pollution for the public and governments.

Keywords: Sources, Groundwater, contamination, Natural sources, Anthropogenic sources

INTRODUCTION

Groundwater is the primary freshwater resource for the survival of the global population and is used for domestic and industrial demands, agricultural, and economic development.[1] Approximately groundwater accounts for 97% of the world's freshwater supply, serving as a significant source of drinking water and is essential for meeting households and the public water needs.[2] Additionally, irregular rainfall and limited surface water resources due to groundwater are valuable asset in arid regions. Springs, boreholes, and wells supply nearly 50% of the groundwater used in the urban areas in less developed countries.[3] Although the fact that demand for groundwater is increasing. Ensuring an uninterrupted and renewable supply of groundwater for drinking is one of the critical pillars in promoting the nation's sustainable development. However, urbanization, industrialization, agricultural practices, and climate change all cause threats to groundwater quality.[4]

Water naturally occurs in various dissolved inorganic components, including calcium, magnesium, sodium, potassium, chloride, etc. Besides, minor components like iron, manganese, and fluoride may be present in only a few micrograms per liter. The Earth's strata hold water control of these elements, which play a crucial role in water quality.[1] Nonetheless, when these substances naturally rise in concentration beyond permissible levels for particular uses, they transform into contaminants capable of posing risks to human well-being. These

contaminants are generated from rock materials through leaching or weathering, called geogenic contamination.[5] Over the last three decades, chemical contamination due to various human activities has been an ongoing issue in groundwater studies. The guidelines provided by the World Health Organization (WHO) specify that human health can be negatively impacted by any of the physical, chemical, or biological characteristics found in groundwater.[6] Groundwater contamination studies provide an excellent opportunity for researchers to discover the evolution of subsurface aquifers and for decision-makers to protect these water resources.[4] This article reviews some of the major sources of groundwater contamination.

Major contaminants

Surface water contamination is different from groundwater contamination. Because it is invisible, and retrieving the resource is challenging with current technology.[7] These contaminants in groundwater resources are usually colorless and odorless, making it difficult to detect their chronic negative on human health.[8] Once contaminated, groundwater resource remediation becomes costly due to its location in subsurface geological strata and long residence times and natural purification processes taking decades or even hundreds of years, even if the source of contamination is cut off.[9] These contaminants from both natural and anthropogenic sources can impact groundwater quality.

Natural/Geogenic sources

Natural groundwater contamination is a type of groundwater contamination not associated with any anthropogenic activities. The concentration of natural contaminants depends on the type of geological materials (rock or soil) through the groundwater moves and recharge.[10] Natural sources of groundwater contamination cause a wide range of problems with water quality problems, such as natural deposits of gypsum, minerals, salts, surface water with poor quality, seawater intrusion, and brackish water. Besides, radionuclides and decaying organic matter (OM) dissolved into groundwater sources. [2, 11] Warm weather elevates water temperature, reduces dissolved oxygen levels, and depletes shallow water bodies. Swamps that drain into streams have lower pH and dissolved oxygen levels due to low-flow conditions and tannic acids from decaying leaves. Groundwater flowing through sedimentary rocks and soils has the capacity to absorb various kinds of inorganic compounds, including magnesium (Mg), calcium (Ca), and chlorides (Cl). Several aquifers inherently possess higher dissolved constituents like Fe, Mn, As, F, SO_4, and B. Natural water may contain bacteria, viruses, parasites, and other microorganisms. In shallow wells, water near the ground surface is particularly vulnerable to contamination. Pollutants from wildlife and soils can be carried by runoff, which is especially common after flooding or monsoon. Radioactive elements such as uranium and radium may be present in the parent rock, which causes groundwater contamination through decay or erosion. Furthermore, radon, resulting from the natural decay of uranium in the soil, poses a significant threat to the health of living organisms, leading to serious health consequences. [12, 13]

Anthropogenic sources

Anthropogenic groundwater contamination is defined as the subsurface introduction of chemical pollutants caused by human activities. Several anthropogenic sources affect the quality of groundwater resources globally.[14] As a result of the rising economic activity coupled with industrialization, population growth and changes in land use patterns become crucial contributors affecting groundwater quality. Anthropogenic alterations significantly impact various aspects of the hydrological cycle, including altering the severity of current conditions and introducing new variables. [15, 16]

Industrial wastes

The primary source of groundwater pollution is mainly caused by industrial waste discharge from mills, factories, and mining operations, which pose a potential threat to water resources. These waste materials are released into the earth's surface and drain into the surface water that infiltrates into groundwater, either directly or indirectly.[17] Both developed and developing countries have made various efforts in recent years to identify these sources of water pollution and have subsequently put monitoring and cleanup activities. According to statistics, 35% of land surface is occupied by industrial wastes in urban areas, including minerals wastes, spills, and solid and liquid wastes.[18] In aggregate, manufacturing sectors generate a greater volume of waste compared to urban and agricultural activities, particularly highlighting mining as a significant global source of waste production. In recent decades, rapid industrialization in energy production, raw materials, and engineering applications has led to releasing a diverse range of waste products into the environment. On a global scale, more than 80% of wastewater from various industries is released into the environment without treatment.[19]

Agriculture sources

Agriculture, a widespread human activity, has the potential to impact both surface and sub-surface water. Major agriculture activities are fish farming, crop cultivation, livestock management, pesticides and fertilizers, and cattle and poultry farming.[17] Applying fertilizers, pesticides, herbicides, and animal waste in agriculture is a significant source of groundwater contamination, particularly when permeable soil formations allow the contaminants or elements from these substances to infiltrate the aquifer. Contamination can also result from pesticide or fertilizer spillage during handling, chemical substances upstream or near a well, runoff generated during the loading and cleaning pesticide sprayers or other application equipment, and storage of chemicals near wells.[20]

Pesticides are chemicals used to remove or kill undesirable organisms in agriculture. The beginning of the 1960s observed increased environmental pollution awareness concerning pesticides.[13] Chemical pest control techniques play a pivotal role in agricultural land cultivation and are also widely used in rapid urban expansion and industrial growth. Aside from safeguarding plants from insects, pesticides encompass herbicides (for controlling weeds), nematicides (targeting nematodes), insecticides (for insect control), rodenticides (to manage vertebrate pests), and fungicides (for combating fungi). These agents play a vital role in agriculture by promoting food production, protecting or boosting crop yields, and allowing for multiple cultivation cycles on the same land in a year.[21] The variations in pesticide breakdown and absorption rates (the two fundamental processes governing pesticide persistence of control) are different in the subsurface. These are complicated due to the function of individual pesticides and characterization in sediment and aquifer matrix.[22] Most pesticides can dissolve in water and are administered along with water, subsequently being ingested by their intended targets. Another contributing factor to water contamination from pesticides is the level of precipitation, as elevated precipitation rates increase the risk of pesticides contaminating water resources. Because groundwater moves slowly, it may require several decades to fully eliminate contaminated water from affected wells.[23]

Extensive fertilizer usage may contaminate the water bodies through field runoff or leach into water resources. Nitrogen and phosphorus are the major compounds in fertilization concerning the contaminating agent. Common nitrogen contaminants are nitrate, nitrite, ammonia, and Nitrogen, which have been widely reported in most regions of the world.[24] Nitrogen compounds are predominantly from agricultural sources and can move easily

from the unsaturated zone of the aquifer. When Nitrogen-contaminated water enters living organisms, it can cause severe health issues. The significant health impact of nitrate is methemoglobinemia or blue baby syndrome in children.[25] In some situations, the soil can easily transport phosphorous, another critical element in fertilizers. Improper storage handling and usage of fertilizers in farms can lead to phosphorus chemical pollution in water. Agriculture is also responsible for a significant portion of both surface and groundwater pollution caused by Nitrogen in most of developing countries.[26]

Urbanization

Substantial population growth and changes in Land use/land cover patterns cause the emergence of urbanization globally. Urbanization includes converting natural surfaces into impervious surfaces such as wetlands, vegetated areas, forests, waterbodies, and other land cover forms to commercial, industrial, and residential areas. Therefore, the artificial surface is closely correlated with a rise in polluted runoff sources, reducing water quality. Primary contaminated sources from urban activities are municipal waste, land use, poor sanitary practices, and landfill management.[27]

Municipal wastes are household or domestic wastes which are mainly derived from artificial activities. Black or grey colour wastewater released from domestic or residential buildings pollutes the groundwater system through surface runoff. Additionally, in highly populated urban areas, septic tanks can contaminate local groundwater supplies.[20] Drinking water is contaminated by domestic wastes, including various microorganisms that can result in severe human diseases like diarrheal, typhoid, and cholera.[4]

Inorganic and Organic contaminants

Inorganic pollutants, including nitrogen, fluoride, and heavy metals, are non-carbon-based materials naturally found in the environmental system. Various parts of the world, including developing countries, have discovered elevated concentrations of metals, particularly heavy metals and other harmful substances like fluoride and nitrate, in groundwater, surpassing acceptable levels, making it unsuitable for consumption.[28] Nitrogen is the most harmful inorganic compound in the environment, and high concentrations cause negative impacts on the environment and living organisms. Additional typical inorganic impurities in groundwater comprise anions, oxyanions (F^-, SO_4^{2-}, and Cl^-), and major cations (Ca^{2+} and Mg^{2+}). Groundwater may also exhibit elevated levels of total dissolved solids (TDS), which indicates the combined presence of both inorganic and organic substances within the groundwater.[29] Organic compounds include hydrocarbons, pesticides, and pharmaceuticals and are broadly used in agricultural, urban, and industries. Organic pollutants are appearing either pure or a mixture of products in groundwater. Several organic contaminants have been associated with hazards to human health and environmental deterioration.[30]

CONCLUSION

Groundwater plays a crucial role in sustaining human well-being, social development, and safeguarding natural ecosystems. Groundwater quality degradation is currently a significant global problem. This study focused on several important contaminant sources from both natural and anthropogenic activities. Seawater intrusion is one other natural source of groundwater contamination. Besides, radionuclides and decaying organic matter (OM) dissolved into groundwater sources. Anthropogenic activities such as industrial and agriculture contaminants represent the primary source of groundwater pollution. Nitrate is the predominant contaminant from anthropogenic source, it causes infant methemoglobinemia and livestock poisoning in animals. Biological contaminants have been identified in

domestic wastes. Drinking water is contaminated with microbial contaminants result in result in severe human diseases like, s diarrheal, typhoid and cholera. Inorganic and organic contaminants have been associated with hazards to human health as well as environmental deterioration. Anthropogenic alterations significantly impact various aspects of the hydrological cycle. Better understanding of sources groundwater contamination is essential for implementing policies and regulation to groundwater resource protection.

Declaration by Authors

Acknowledgement: None
Source of Funding: None
Conflict of Interest: The authors declare no conflict of interest.

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How to cite this article: Jibitha J B, Sabu Joseph. Sources of groundwater contamination: a review. *International Journal of Research and Review*. 2023; 10(10): 121-126. DOI: *https://doi.org/10.52403/ijrr.20231016*

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