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## REVIEW OF GROUNDWATER CONTAMINATION DUE TO SEDIMENT TRANSPORT

Tom, Cyprian N<sup>1\*</sup>, Edet, Joseph A<sup>2</sup> Orji, C. U<sup>3</sup>

\*Correspondence: Tom, Cyprian N

*\*\*Detailed author information and related declarations are provided in the final section of this article.*

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### ABSTRACT

Groundwater contamination presents a significant challenge to environmental sustainability, particularly when caused by sediment transport. This paper reviews the processes by which sediment transport contributes to the degradation of groundwater quality, identifying both natural and anthropogenic sources. Mechanisms such as erosion, surface runoff, and infiltration are examined in the context of contaminant mobility, including heavy metals, nutrients, and pathogens. The review also explores current research, mitigation strategies, and policy interventions necessary to address this environmental issue.

**KEYWORDS:** Review, Groundwater, Contamination, Sediment, Transport

### 1.0 INTRODUCTION

Groundwater is a vital resource for drinking water, agriculture, and industrial activities. However, its quality is increasingly threatened by various contaminants, including those introduced through sediment transport. Sediment particles, often originating from soil erosion, construction, and agricultural activities, can carry harmful substances that leach into aquifers, posing risks to human health and ecosystems. Understanding the relationship between sediment transport and groundwater contamination is crucial for effective water resource management (Zhang, 2015).

Sediment-associated contaminants are pollutants that adhere to or are absorbed by sediment particles in soil, rivers, lakes, and coastal environments. Unlike dissolved contaminants, these are typically bound to fine particles such as clay, silt, or organic matter. Once bound, they can be transported over long distances, resuspended, deposited in aquatic environments, or enter the food chain (Ward *et al.*, 2018).

Groundwater is a vital natural resource that supplies drinking water for nearly half of the global population and supports agricultural, industrial, and ecological systems (World Health Organization (WHO), 2022).

Stored in aquifers beneath the Earth's surface, groundwater is often regarded as a clean and dependable water source due to natural filtration through soil and rock layers. However, increasing anthropogenic activities have led to widespread groundwater contamination, posing serious threats to human health and the environment (USGS, 2020).

According to Fetter (2018), water is one of our most precious resources, especially in rural and farming communities where it supports both people and crops. While much attention is often given to rivers, lakes, and rain, groundwater—the water stored beneath the earth's surface—is just as important. It supplies drinking water to millions and provides irrigation for crops around the world. However, this vital resource is under increasing threat from a problem that often goes unseen: groundwater contamination, especially from agricultural activities.

At the heart of this issue is the way farming practices interact with natural processes like sediment transport. When farmers plow fields, apply fertilizers, or graze animals, the soil becomes more vulnerable to erosion. During heavy rains or irrigation, this loosened soil—known as sediment—can be carried away by water (Gleeson *et al.*, 2012). But sediment doesn't travel alone. It often carries with it a range of pollutants, including chemical fertilizers, pesticides, and even bacteria from animal waste. Once these contaminated sediments move into water bodies or soak into the ground, they can slowly make their way into underground aquifers, polluting the water we depend on (Foster and Chilton, 2003).

Agriculture is essential for feeding the world, but it also generates waste and uses chemicals that don't always stay where they're intended. For instance, nitrogen and phosphorus from fertilizers are crucial for crop growth. However, when applied in excess or before a rainstorm, these nutrients can leach through the soil or run off into nearby ditches, streams, and eventually groundwater (Hillel, 2008). This leads to a condition known as nutrient loading, which not only affects water quality but also promotes algae growth in water bodies—another environmental issue.

Pesticides, which are used to protect crops from insects and diseases, are also a common groundwater contaminant. Some pesticides break down quickly, but others can persist in the soil for months or even years. When rain or irrigation water seeps through the ground, it can carry these persistent chemicals into deeper layers of soil, eventually reaching the groundwater (Kumar and Puri, 2012).

Animal farming contributes in its own way. Manure, which is rich in nutrients and organic matter, is often used as a natural fertilizer. But if not properly managed, it can introduce pathogens like salmonella into the soil. These microbes can be transported by sediments and eventually find their way into groundwater supplies, posing a risk to human health (Fetter, 2018).

### 1.1 THE ROLE OF SEDIMENT TRANSPORT

According to Gleeson *et al.*, (2012), sediment transport may sound like something that only happens in rivers, but it's also very important in farming environments. When soil is disturbed—whether by plowing, heavy rainfall, or livestock movement—it becomes loose and easier to move. Rainfall or irrigation water can pick up these particles and carry them across fields and into nearby water bodies or soil layers.

These tiny soil particles act like sponges or carriers. They can bind to fertilizers, pesticides, heavy metals, and bacteria. So, as the sediment moves, it brings the contaminants along for the ride (Rao *et al.*, 2018). This is especially dangerous in areas where the soil is sandy or porous, as these conditions allow water (and the contaminants it carries) to travel more quickly and deeply into the ground.

Once the contaminated sediment reaches the water table, it's very difficult and expensive to clean. Groundwater moves slowly, so once pollutants are present, they can remain in the system for years or even decades. This slow movement also makes it hard to detect problems early, which is why prevention is so important (Sharma and Sanghi, 2012).

### 1.2 LONG-TERM IMPACTS AND WHY IT MATTERS

According to Hillel (2008), the long-term consequences of groundwater contamination from agriculture can be serious. For one, drinking water safety is at risk. High levels of nitrates in drinking water, for example, can cause a condition in infants known as "blue baby syndrome," which reduces the ability of blood to carry oxygen. Pesticides in drinking water have been linked to various health problems, including some cancers and reproductive issues.

There's also an economic impact. Contaminated water requires expensive treatment, and in rural areas, this burden often falls on individual farmers or small communities. In some cases, wells may need to be closed or replaced altogether (WHO, 2022). Crop yields can also suffer if water used for irrigation is polluted or if soil quality declines due to erosion and nutrient loss.

On a larger scale, groundwater pollution contributes to ecosystem degradation. When polluted water eventually emerges into streams, rivers, or wetlands, it can harm plants, fish, and other wildlife. This creates a ripple effect throughout the environment (USGS, 2020).

In many parts of the world, including Nigeria, groundwater contamination poses a severe threat to public health and environmental sustainability. The Niger Delta, for instance, is characterized by extensive sedimentary basins and is heavily impacted by oil exploration activities. These activities often lead to the mobilization of sediments that carry hydrocarbons and heavy metals into groundwater systems, thereby compromising water quality and posing health risks to local communities.

The objectives of this paper includes; firstly, to investigate the mechanisms of sediment transport and its role in groundwater contamination. Secondly, to assess the impact of sediment-associated pollutants on groundwater quality and finally to evaluate the effectiveness of mitigation strategies to prevent sediment-induced contamination.

Understanding the relationship between sediment transport and groundwater contamination is crucial for developing effective water management strategies. This knowledge can inform policies aimed at protecting groundwater resources, particularly in sediment-rich regions like the Niger Delta. Moreover, the study can contribute to the design of sustainable agricultural and industrial practices that minimize sediment mobilization and pollutant transport.

## 2.1 MAJOR SOURCES OF SEDIMENT-ASSOCIATED CONTAMINANTS

- Agricultural Activities

**Pesticides and Herbicides:** Chemicals used to control pests and weeds can bind to soil particles and be washed into water bodies through runoff and erosion.

**Fertilizers (Nutrients):** Excess nitrogen and phosphorus can attach to soil particles and contribute to eutrophication.

**Manure and Biosolids:** Application of animal waste can introduce pathogens, heavy metals, and antibiotics to sediment.

- Urban Runoff

**Heavy Metals:** Urban surfaces (roads, rooftops) accumulate metals like lead, zinc, and copper which bind to dust and sediments.

**Hydrocarbons:** Oil, grease, and polycyclic aromatic hydrocarbons (PAHs) from vehicle emissions and spills.

**Microplastics:** Break down of synthetic materials, tire wear particles, and road dust (Hillel, 2008).

- Industrial Discharges

Toxic Metals: Mining and industrial operations release metals like arsenic, cadmium, mercury, and chromium which adsorb onto particles.

Persistent Organic Pollutants (POPs): Such as PCBs (polychlorinated biphenyls), dioxins, and furans.

Synthetic Chemicals: Flame retardants, plasticizers (e.g., phthalates), and PFAS (per- and polyfluoroalkyl substances).

- Atmospheric Deposition

Airborne Contaminants: Emissions from industries, vehicles, and power plants deposit contaminants onto land and water surfaces.

Acid Rain Fallout: Can mobilize metals and contribute to their sediment association (Fetter, 2018).

- Mining and Mineral Extraction

Tailings and Waste Rock: Often contain metals and chemicals that bind to fine particles.

Acid Mine Drainage: Mobilizes metals that then associate with sediment in nearby water bodies.

- Wastewater Discharges

Sewage Effluents: Contain organic matter, nutrients, pharmaceuticals, and pathogens.

Sludge: Wastewater treatment produces biosolids rich in both nutrients and heavy metals.

- Construction and Land Development

Erosion of Exposed Soil: Disturbed land can release sediment laden with building materials, cement particles, and associated chemicals.

Paints and Coatings: Heavy metals and solvents can enter stormwater and bind to sediment (WHO, 2022).

- Forestry Practices

Clear-Cutting and Logging Roads: Increase erosion and transport of naturally occurring metals or residual herbicides.

Ash and Burn Residue: From prescribed burns or wildfires may contain metal oxides.

- Natural Sources

Volcanic Activity: Can contribute heavy metals and ash-bound contaminants.

Weathering of Rocks: Releases natural minerals, some of which (like arsenic) can be toxic in high concentrations.

Forest Fires: Can volatilize and redeposit contaminants bound to particles (Zhang, 2015).

## 2.2 TRANSPORT AND FATE

According to Rao et al., (2018) once contaminants are associated with sediments, their environmental fate depends on several factors:

- Hydrological flow: Determines how far and how quickly particles are transported.
- Grain size: Finer particles (clay, silt) travel farther and adsorb more contaminants.
- Organic matter content: High organic content enhances sorption of hydrophobic contaminants.
- Redox conditions: Can affect the solubility of metals and influence their mobility.
- Resuspension: Disturbances (storms, dredging, or bioturbation) can reintroduce contaminants into the water column.

## 2.3 ENVIRONMENTAL AND HEALTH IMPACTS

Ecological Impacts:

- ❖ Toxicity to aquatic life: Metals and organic pollutants can be ingested by benthic organisms.
- ❖ Bioaccumulation: Contaminants can magnify up the food chain (e.g., mercury in fish).
- ❖ Habitat degradation: Sediment pollution can smother habitats like coral reefs or spawning grounds.
- ❖ Human Health Impacts:

Drinking water contamination.

Seafood contamination (e.g., mercury and PCBs in fish).

Recreational exposure (swimming, fishing).

Airborne dust from contaminated sediments in dry environments (Gleeson *et al.*, 2012)

## 2.4 MANAGEMENT AND MITIGATION STRATEGIES

Fortunately, there are ways to reduce both sediment transport and groundwater contamination in agriculture. Conservation farming techniques, such as no-till farming, cover cropping, and contour plowing, help keep soil in place and reduce erosion. Managing fertilizer use more carefully—only applying what’s needed and timing it right—can also limit nutrient leaching.

Buffer zones along fields and waterways, such as grassy strips or wetlands, can trap sediment and absorb pollutants before they reach the water. Properly storing and treating animal waste, and using precision agriculture technologies to monitor soil and crop needs, also go a long way toward protecting water resources (Kumar and Puri, 2012).

Most importantly, education and policy support are crucial. Farmers need access to tools, knowledge, and incentives that make sustainable practices possible. Governments and environmental agencies play a key role in providing this support and enforcing regulations that protect groundwater.

### + Erosion Control

Use of vegetation cover, silt fences, terracing, and riparian buffers.

### + Best Management Practices (BMPs) in Agriculture

Precision application of chemicals, cover crops, conservation tillage.

### + Storm water Management

Green infrastructure (rain gardens, permeable pavements), retention ponds.

### + Sediment Remediation

Dredging, capping, or in-situ stabilization of contaminated sediments.

### + Monitoring and Assessment

Use of sediment quality guidelines, bioassays, and risk assessments (WHO, 20220).

## 3.1 CONCLUSION

Sediment transport plays a significant role in the contamination of groundwater, largely through its ability to carry and deposit a variety of pollutants. While natural processes contribute to this issue, human

activities exacerbate the problem, especially in agricultural and urban areas. A comprehensive understanding of these mechanisms is essential for the development of effective mitigation and remediation strategies. The sources of sediment-associated contaminants are diverse, ranging from human activities like agriculture and industry to natural processes such as weathering. These contaminants pose serious risks to ecosystems and human health due to their persistence and mobility in the environment. Addressing them requires integrated management strategies, strong regulatory frameworks, and continuous monitoring to ensure sustainable land and water use.

### 3.2 RECOMMENDATIONS

- Strengthen land use policies to reduce soil erosion and control sediment flow.
- Enhance monitoring systems with advanced modeling and remote sensing.
- Promote community awareness and stakeholder involvement in watershed management.
- Invest in sustainable agricultural practices that minimize sediment generation.

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## **Author details**

### **Tom, Cyprian N<sup>1\*</sup>**

<sup>1</sup>Department of Agricultural and Environmental Engineering, Rivers State University, Port Harcourt, Rivers State, Nigeria.

### **Edet, Joseph A<sup>2</sup>**

<sup>2</sup>Department of Agricultural and Bioresources Engineering, Michael Okpara University of Agriculture, Umudike, Nigeria.

### **Orji, C. U<sup>3</sup>**

<sup>3</sup>Department of Agricultural and Bioresources Engineering, Michael Okpara University of Agriculture, Umudike, Nigeria.

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