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Effect of Leachate Waste on Groundwater Quality in Bayan-geri, Bauchi Metropolis, Bauchi State, Nigeria

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ABSTRACT

Bayan-geri is within the Bauchi metropolis, located in Bauchi State, Nigeria, faces significant challenges related to the disposal of solid waste and its potential impacts on groundwater quality. Leachate waste generated from landfills poses a threat to the groundwater resources in the region. This research examines the effects of leachate waste on groundwater quality in the Bauchi metropolis, focusing various factors influencing leachate migration, groundwater contamination mechanisms, and potential mitigation strategies are discussed. Over the year various wells and broken pipe bore water has been contaminated and the flow of this leachate into drainages and runoff water during rainy season has been of a deep concern. Leachate waste in form of water sample was collected at the dump site in Bayan-geri where household waste and market waste were usually dumped. Some of the key results from the laboratory sample test are as follows Ca^{2+} 37.88, Pb^{2+} 3.62, Na^{2+} 1707.2, Cd^{2+} 0.0343, COD 487 and BOD5 280 all in mg/l. The machine used was the 210 VGP (AAS). The results show a significant high value of parameters and are harmful to the human health therefore understanding the impacts of leachate on groundwater quality is crucial for sustainable environmental management and public health protection in the Bauchi region.

Keywords: groundwater quality, solid waste, leachate waste

INTRODUCTION

The Bauchi metropolis, one of the major urban centers in Bauchi State, Nigeria, is experiencing rapid population growth and urbanization, leading to increased solid waste generation. Improper disposal of solid waste, particularly in uncontrolled dumpsites and landfills, results in the generation of leachate waste, which can contaminate groundwater resources.

Solid waste management in the Bauchi metropolis faces numerous challenges, including inadequate infrastructure, limited resources, and a lack of effective regulatory frameworks. Recent studies by Abubakar et al. (2019) and Mohammed et al. (2022) have highlighted the prevalence of open dumping and uncontrolled landfilling practices in the region, contributing to the generation of leachate waste and groundwater contamination.

Leachate waste generated from landfills in the Bauchi metropolis exhibits complex chemical compositions, including organic and inorganic contaminants. Recent research by Usman et al. (2021) and Ahmed et al. (2023) has identified various pollutants in leachate samples collected from landfill sites in the region, such as heavy metals, organic compounds, and pathogens. Understanding the characteristics of leachate is essential for assessing its potential impacts on groundwater quality.

Dump site of the area of study.

The migration of leachate contaminants from landfill sites to groundwater aquifers involves complex hydrogeological processes influenced by factors such as soil properties, hydrogeological conditions, and landfill design. Recent studies by Ibrahim et al. (2020) and Aliyu et al. (2023) have investigated the transport mechanisms of leachate contaminants in the Bauchi metropolis, highlighting the importance of groundwater monitoring and modeling to assess contamination risks.

Contaminated groundwater poses significant risks to public health, particularly in communities reliant on groundwater sources for drinking water supply. Recent epidemiological studies by Musa et al. (2021) and Adamu et al. (2023) have documented the health impacts of consuming leachate-contaminated groundwater, including gastrointestinal diseases, respiratory illnesses, and skin infections. Protecting groundwater quality is essential for safeguarding public health and well-being in the Bauchi metropolis.

Effective management of leachate contamination requires robust regulatory frameworks and policy interventions at the local, state, and national levels. Recent developments in environmental legislation, such as the National Environmental Standards and Regulations Enforcement Agency (NESREA) Act and the Bauchi State Environmental Protection Agency (BASEPA) regulations, aim to address solid waste management and groundwater protection challenges in the region (NESREA, 2019).

LITERATURE REVIEW

Leachate is a liquid that forms when water passes through waste materials and absorbs the soluble constituents of the waste. It is a significant environmental concern due to its potential to contaminate soil, groundwater, and surface water. Leachate is commonly associated with landfills, composting facilities, and waste disposal sites.

Ages of Leachate can be seen as follows:

Young Leachate:

Characteristics: Typically less than 5 years old, young leachate is characterized by high levels of organic compounds, such as volatile fatty acids and biological oxygen demand (BOD). It also contains elevated concentrations of ammonia, heavy metals, and other contaminants. Immediate treatment is often necessary to prevent environmental contamination Song et al., (2022).

Example: A new landfill site may produce young leachate with high concentrations of organic pollutants such as acetic acid and methane Song et al., (2022).

1. Mature Leachate:

- Characteristics: Generally, between 5 and 10 years old, mature leachate shows a decrease in organic pollutants due to microbial degradation. However, it may still contain significant concentrations of inorganic compounds, such as ammonia, heavy metals, and chloride as discussed by Patel & Johnson, (2021).

- Example: An established landfill may produce mature leachate with lower BOD but persistent concentrations of ammonia, requiring continued treatment to manage environmental impact.

1. Old Leachate:

- Characteristics: Older than 10 years, old leachate tends to have lower concentrations of both organic and inorganic pollutants due to prolonged microbial activity and dilution effects. However, it may still pose long-term environmental risks due to the persistence of certain contaminants Okoye et al., (2020).
- Example: A decommissioned landfill site may produce old leachate with lower overall pollutant levels but potential long-term risks to groundwater quality.

Types of Leachates:

1. Municipal Solid Waste (MSW) Leachate:

- Characteristics: MSW leachate is produced from the decomposition of household and commercial waste in landfills. It often contains a complex mixture of organic and inorganic compounds, including heavy metals, ammonia, and pathogens Davies et al., (2021).
- Example: A municipal landfill that accepts household waste may produce leachate with high levels of ammonia, BOD, and heavy metals such as lead and mercury.

1. Industrial Waste Leachate:

- Characteristics: Industrial waste leachate is generated from the disposal of industrial waste, such as manufacturing byproducts and chemicals. It may contain high levels of hazardous substances, including heavy metals and toxic organic compounds (Liao et al., 2023).
- Example: An industrial waste disposal site may produce leachate with elevated concentrations of heavy metals such as chromium and cadmium (Liao et al., 2023).

1. Hazardous Waste Leachate:

- Characteristics: Hazardous waste leachate is derived from the disposal of hazardous materials, such as chemicals, solvents, and radioactive substances. It often contains highly toxic substances that pose significant health and environmental risks Anderson & Marks, (2019).
- Example: A hazardous waste disposal facility may produce leachate with high levels of toxic chemicals such as polychlorinated biphenyls (PCBs) and radioactive elements.

Leachate management is crucial for protecting the environment and public health. Effective leachate treatment methods, such as biological treatment, chemical treatment, and physical separation, help reduce the impact of leachate on surrounding ecosystems. Ongoing research and development of advanced treatment technologies are essential for addressing the challenges posed by leachate and ensuring environmental safety.

Ecological Consequences:

Bryan et al., (2021) and Chen et al., (2022). In their work explained that water contamination also has profound ecological effects, impacting aquatic ecosystems, biodiversity, and ecosystem services. Pollution from agricultural runoff, industrial discharge, and urban wastewater can lead to eutrophication, habitat degradation, and loss of biodiversity in freshwater bodies, rivers, and coastal areas. Additionally, chemical contaminants in water can bioaccumulate in aquatic organisms, leading to toxicity and disruption of food chains.

Socio-economic Ramifications:

The socio-economic impacts of contaminated water extend beyond health and environmental consequences, as suggested by Adams et al., (2020) and Mekonnen et al., (2021) affecting livelihoods, economic productivity, and social well-being. Communities reliant on contaminated water sources often face economic hardships due to healthcare costs, reduced agricultural productivity, and loss of tourism revenue. Moreover, waterborne diseases and environmental degradation exacerbate poverty, inequality, and social disparities, particularly in marginalized and vulnerable populations.

Mitigation Strategies and Policy Interventions:

Addressing water contamination requires a multi-faceted approach involving pollution prevention, water quality monitoring, and regulatory measures. Mitigation strategies include improving sanitation and hygiene practices, implementing water treatment technologies, and promoting sustainable water

management practices. Furthermore, WHO, (2019) and UN-Water, (2020) policy interventions such as legislation, enforcement of environmental regulations, and public awareness campaigns are essential for preventing water pollution and ensuring access to secure and clean water for all.

Contaminated water poses complex and multifaceted challenges with far-reaching impacts on human health, ecosystems, and socio-economic development. Addressing water contamination requires concerted efforts from governments, stakeholders, and the international community to implement effective mitigation strategies, execute regulatory measures, and promote sustainable water management practices. By safeguarding water quality and ensuring access to clean and safe water, we can protect public health, preserve environmental integrity, and promote sustainable development.

MATERIALS AND METHODS

- Leachate waste Sample

  Equipments and machines used for analysis:
  - DR/890 Colorimeter
  - pH,
  - TDS/EC and OC meter
  - 210VGP (AAS) Atomic Absorption Spectrophotometer.

The leachate waste sample was taken to the laboratory and about 15 parameters test were carried out of which the result is shown on table 1.

Various procedures were explored in the lab. to achieve the result as the sample under goes different stages and reagents were added to the sample to produce the result.

RESULTS AND DISCUSSIONS

Sample name: Waste water sample (*Leachate*)

Equipment: pH/EC/TDS and ^{O}C meter,
210 VGP (AAS) Atomic Absorption Spectrophotometer.

Table 1

S/N	Parameters	Result
1	pH	7.2
2	Calcium,Ca^{2+} (mg/l)	37.8813
3	Magnesium, $Mg^{2+(}$mg/l)	2.2484
4	Iron,Fe^{2+} (mg/l)	0.8320
5	Manganese, Mn^{2+} (mg/l)	0.0540
6	Lead, Pb^{2+} (mg/l)	3.6156
7	Nickel Ni^{2+} (mg/l)	0.1648
8	Chromium, Cr^{2+} (mg/l)	1.4954
9	Sodium, Na^{2+} (mg/l)	1707.2
10	Potassium, K^{2+} (mg/l)	539.60
11	Copper, Cu^{2+} (mg/l)	4.1090
12	Zinc, Zn^{2+} (mg/l)	0.0549
13	Cadmium, Cd^{2+} (mg/l)	0.0343
14	COD (mg/l)	487
15	BOD5 (mg/l)	280
16	COD/BOD5 ration	1.7:1

From the result of the leachate, it shows that the 15 parameters that were test are all not safe within the require safety measures for drinking water and not good when they seep into groundwater that is basically for use and consumption. Some of the key results from the laboratory sample test are as follows Ca^{2+} 37.88, Pb^{2+} 3.62, Na^{2+} 1707.2, Cd^{2+} 0.0343, COD 487 and BOD5 280 all in mg/l. Most of the physiochemical parameter and microbial are not safe within the human body as it will result to various disease and sickness.

Mitigating the impacts of leachate contamination of groundwater quality requires a combination of preventive measures, groundwater monitoring, and remediation technologies. Recent studies by Haruna et al. (2022) and Yakubu et al. (2023) have evaluated the effectiveness of various remediation techniques, including permeable reactive barriers, constructed wetlands, and phytoremediation, in reducing leachate-induced groundwater pollution in the Bauchi metropolis.

Engaging local communities and stakeholders in solid waste management initiatives and groundwater protection efforts is essential for achieving sustainable environmental outcomes. Recent community-based projects, such as awareness campaigns, waste segregation programs, and participatory monitoring initiatives, have demonstrated the importance of community participation in mitigating leachate contamination and promoting groundwater stewardship in the Bauchi metropolis.

CONCLUSION

The management of leachate waste and its impacts on groundwater quality in the Bauchi metropolis are pressing environmental challenges that require urgent attention from policymakers, researchers, and stakeholders. Recent studies have provided valuable insights into the characteristics of leachate, migration pathways of contaminants, health impacts, and potential mitigation strategies. Implementing integrated solid waste management practices, strengthening regulatory frameworks, and fostering community engagement are essential steps towards protecting groundwater resources and promoting sustainable development in the Bauchi region.

Future research in the Bauchi metropolis should focus on addressing knowledge gaps related to the long-term impacts of leachate contamination of groundwater quality, ecosystem dynamics, and socio-economic well-being. Integrating multidisciplinary approaches, such as hydrogeology, environmental chemistry, and social science, can enhance our understanding of the complex interactions between leachate waste and groundwater resources in the region.

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