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Human Health Risk and Economic implications of Solid Waste Disposal Site Leachates on Groundwater Quality in Port Harcourt, Nigeria

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Abstract-* This study assessed the human health risks associated with solid waste disposal site leachate on groundwater quality Groundwater and the economic implications. Samples were collected from three existing wells (boreholes) near the solid waste dumpsites and Water quality analysis was carried out according to APHA standards for physiochemical parameters and some heavy metals. The determination of human health risk of heavy metals daily consumption of the water by adults and children were also carried out. The physicochemical analysis revealed that the groundwater is predominantly "soft," with exceptionally low concentrations of calcium (2.002 to 0.418 mg/L) and magnesium (0.354 to 0.518 mg/L). Major ions such as sodium and chloride remain well within permissible. Significant aesthetic and toxicological concerns were identified. Iron (0.794–1.596 mg/L) and manganese (0.354–0.518 mg/L) concentrations significantly exceed desirable limits (0.3mg/L and 0.2 mg/L, respectively). More critically, the study detected hazardous levels of toxic heavy metals: Lead (0.094mg/L), Cadmium (0.021–0.072 mg/L), and Nickel (0.209mg/L) which drastically exceeded safe thresholds (0.01mg/L, 0.003mg/L, and 0.02mg/L, respectively). The study identify several economic impacts such as Escalating Healthcare Costs as result outbreaks of Waterborne Diseases, Exorbitant Private Water Sourcing, Loss of Economic Productivity and Increased Public Spending. The findings conclude that the groundwater in the study area is unfit for human consumption without specialized treatment to remove heavy metals. To mitigate groundwater pollution from dumpsite leachates, it is essential to implement stringent waste management policies that regulate landfill operations and prevent leachate infiltration into aquifers. The study emphasizes the urgent need for lined landfill systems and regular groundwater monitoring to mitigate anthropogenic contamination of vital water resources.

***Keywords:* Groundwater Quality, Human health, Risk, Heavy Metals, Dumpsite Leachate, Economic implication, NSDWQ, WHO Standards**

I. INTRODUCTION

Groundwater contamination occurs when man-made or natural substances leach through the soil and pollute underground aquifers. Primary causes include agricultural runoff (pesticides/fertilizers), leaking septic systems, improper industrial waste disposal, toxic leaks from underground storage tanks, and natural mineral deposits dissolving into the water table. Groundwater contaminations due to municipal solid waste dumpsites are mainly due to potential leachate from the waste body. Leachates are a highly polluted, dark-colored liquid formed when rainwater or external liquids filter through decomposing waste in landfills. It carries hazardous dissolved organic/inorganic compounds and heavy metals, posing severe risks of ground and surface water contamination. It is often referred to as "garbage juice" or landfill effluent, containing contaminants like ammonium-nitrogen, chlorinated hydrocarbons, and toxic metals. They contain high levels of Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), heavy metals (e.g. Pb, Cd, Ni, Cu), and ammonia (Nta et al. 2020, Igboama et al., 2022).

The proximity of residential areas to solid waste dumpsites creates a critical vulnerability; hazardous materials and leachates containing non-biodegradable heavy metals like Lead (Pb), Cadmium (Cd), and Nickel (Ni), alongside pathogenic microorganisms readily contaminating the aquifer that serve as the main source of drinking water to the exposed population (Orosun et al., 2020). The consumption of groundwater in the vicinity of municipal waste dumpsites presents a complex toxicological challenge, as the water often serves as a conduit for a diverse cocktail of chemical, biological, and radiological contaminants. In the context of dumpsite-adjacent populations, the primary exposure route is the ingestion of contaminated groundwater. Leachate, a highly polluted liquid produced when water percolates through waste, migrates from unlined landfills into aquifers, contaminating local boreholes and well (Agboeze et al. 2025). Other significant exposure routes include but not limited to ingestion through water and food, inhalation by volatile organic compounds (VOCs), dermal contact through the process of absorption (Naskar et al., 2023, Agboeze et al. 2025). Recent studies (2023–2025) indicate that landfill leachate severely contaminates groundwater and soil with heavy metals (As, Cd, Cr, Pb, Ni) and pathogens, creating high non-carcinogenic and carcinogenic risks for nearby residents. Infiltration into water sources causes skin infections, respiratory problems, gastrointestinal illnesses, and potential chronic diseases due to long-term exposure (Alam and Jauhari, 2020, Naskar et al., 2023, Agboeze et al. 2025). Some studies also emphasize that the health risk is not uniform; it varies significantly based on the depth of the borehole, the permeability of the soil, and the specific composition of the waste leachate (Vaverková, 2019, Alam and Jauhari, 2020).

Studies consistently link waste dumpsite leachate to significant human health risks (Dixit et al. 2024). Human health risk assessment (HHRA) is a systematic process and multi-step scientific process used to evaluate the potential health risks associated with exposure to environmental hazards by humans who may be exposed to chemicals, radiation, or other stressors in contaminated environmental media (EPA, 2026) especially water. This process is essential for informing regulatory decisions, public health interventions, and risk management strategies. Planning and scoping of the risk assessment establish objectives and methodologies for key aspects and steps of the risk assessment process. In the modern regulatory landscape, HHRA serves as the foundational framework for establishing safety standards, informing public health interventions, and guiding remediation efforts in contaminated sites (Vaverková, 2019). To quantify these dangers, the Human Health Risk Assessment (HHRA) framework is utilized to translate environmental concentration data into actionable public health metrics (Adewoyin et al., 2021). To address these complexities, Human Health Risk Assessment (HHRA) models are increasingly utilized to establish quantitative relationships between contaminant levels and potential health hazards. These models, often supported by simulation software like the Groundwater Modeling System (GMS), allow researchers to visualize pollutant dispersion and predict spatial-temporal trends (Adewoyin et al., 2021; Njoku et al., 2023). These systems allow for the visualization of pollutant dispersion over time and space, providing a scientific basis for environmental management and pollution control (Orosun et al., 2020). Such modeling is essential for long-term health risk management, particularly in high-risk zones where the population exploits shallow groundwater for daily survival.

Port Harcourt International Airport Road Dumpsite is one of the largest disposal sites in Port Harcourt, it receives approximately 2,000 tons of refuse daily. The current lack of sophisticated containment at this site raises urgent concerns regarding the infiltration of leachate into the local aquifer, which serves as the primary water source for the surrounding residential areas. Given the potential for significant health burdens, periodic and rigorous quality assessments are vital. This study, therefore, evaluates the levels and associated human health risks associated with groundwater quality often use for domestic purposes in this study areas for developing appropriate regulatory safeguards for the vulnerable local population.

II. MATERIALS AND METHODS

2.1 Brief description of study area

Port Harcourt is the capital and largest city of Rivers State, Nigeria. Known as the "Garden City," it is Nigeria's primary oil-refining hub and one of the wealthiest cities in the country. Founded in 1912 by the British, it has grown into a bustling economic metropolis. The city has several dumpsites one of which is located on the airport road. The study dumpsite is located on the Port Harcourt International Airport link Road, Rivers State Nigeria with a population of over 1,000,884 people, broken down into gender as 519,634 females and 481,252 males according to the National Population Commission (2006). Land use in the study area can be classified into educational, residential, security, commercial, transportation, recreational, and industrial land uses. The study area is situated between latitudes 4o45' N and 4o55' N and longitudes 6o55' E and 7o05' E. It is characterized by a low-lying coastal plain topography within the sedimentary basin of the Niger Delta (Njoku et al., 2023). The region experiences a tropical monsoon climate (Am) with a prolonged rainy season (March to November) and a brief dry season with High annual rainfall, often exceeding 2,500 mm, results in a perennial high-water table, which significantly influences the migration patterns of surface contaminants into the subsurface (Orosun et al., 2020) (Figure 1).

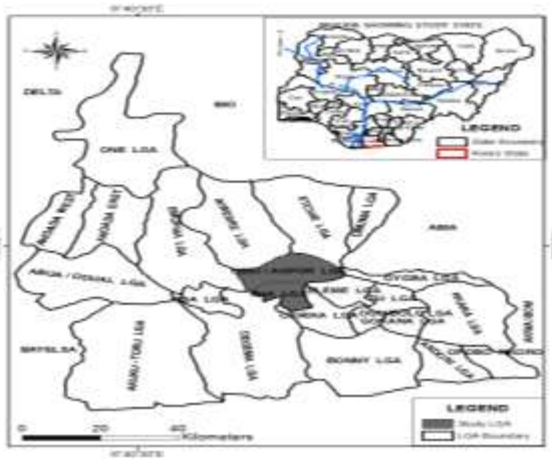

Figure 1: map of Rivers State showing study Area

Also, the study area sits on top the Benin Formation, also known as the Coastal Plain Sands. This formation is a highly productive but vulnerable aquifer system consisting of unconsolidated, coarse-to-medium grained sands with occasional intercalations of silt and clay (Adewoyin et al., 2021). Because the aquifer is largely unconfined and the water table is shallow, ranging from 3m to 15m, it is extremely susceptible to the infiltration of leachate from unlined municipal dumpsites (Orosun et al., 2020). Due to the historical decline of centralized public water infrastructure, over 80% of the population relies on private boreholes and hand-dug wells for domestic water supply (Njoku et al.,2023). Port Harcourt has undergone exponential demographic growth, with an estimated metropolitan population reaching approximately 3.9 million in 2026 (World Population Review, 2026). This growth has far outpaced the city's waste management capabilities.

This study sites, receive an estimated 2,000 tons of refuse daily (Alam and Jauhari, 2020). The sites lack modern liners or leachate collection systems, leading to the seepage of heavy metals, microorganisms, into the surrounding groundwater (Naskar et al., 2023).

2.2 Sample collection

The ground water samples were collected directly from the borehole point with the aid of sterilized sample bottles. The samples for Heavy metal were acidified with 1ml of concentrated hydrochloride Acid while those for pH, conductivity, Bicarbonate (HCO3) and chloride (Cl) were not acidified. The purpose of Acidification is to utter the pH of the medium and to utter the ecosystem suitable for microorganism survival (). The sampling took place during the wet season; when leachate seeping into groundwater would be very pronounce (Naveen et al., 2018). Prior to actual sampling, the bottles were rinsed twice with each borehole water source to prevent dilution and then appropriately labeled. To preserve the integrity of the samples during transportation, they were placed in a cooler with ice blocks, maintaining a low temperature to prevent any changes in the water's chemical composition. The samples were transported promptly to the laboratory for analysis. In the laboratory, various parameters were tested to assess the groundwater quality, including pH, chloride (Cl), iron (Fe), magnesium

(Mg), calcium (Ca), sodium (Na), zinc (Zn), copper (U), manganese (Mn), nickel (Ni), cadmium (Cd), lead (Pb), chromium (Co), and cobalt concentrations. These analyses are crucial for evaluating the suitability of groundwater for various uses and for monitoring potential contamination ().

2.3. Determination of physiochemical properties

Some of the time sensitive parameters were evaluated on-site. The pH levels were determined using the Palintest Micro 800 digital pH meter, Total dissolved solids (TDS) and electrical conductivity (EC) were determined using a portable HM Digital COM-100 TDS Conductivity Meter. Turbidity (NTU) was assessed with the HACH Model DR/2000 Spectrophotometer. Bicarbonate (HCO3), Iron (Fe), Potassium (K), Magnesium (Mg), Calcium (Ca), Sodium (Na), were quantified using the Palintest Photometer 7500. All parameters were measured in accordance with the procedures outlined by APHA standard method for the Examination of Water and Wastewater ().

2.4 Determination of Heavy metals

The heavy metal ion was analyzed using Atomic Absorption Spectrophotometric (model) by varying the wavelength of their absorption as stipulated by standard operational procedure of the equipment. The Atomic Absorption Spectrophotometer was calibrated with the pure metal standard solution, and a standard graph of the metal ion was plotted. Each water sample was thoroughly mixed and then digested by transferring 100 ml of it into a previously cleaned 50-ml beaker, which contained 5 ml of concentrated HNO3. The beaker was heated until the content dried completely and allowed it to cool before an additional 5 ml of concentrated HNO3 was added. It was heated again until a light-colored residue appeared. To dissolve the residue, 1 ml of HNO3 was added, and the heating was done at a low temperature. The aspirating tubing was flushed with distilled de-ionized, and the sample solution was aspirated into the burner, and the spectra of the metal ion was captured and recorded as concentration from the standard graph. Subsequently, the digest was analyzed for the presence of Fe, Cu, Mn, Pb, Cr, Ni, and Zn using the Shimadzu AA-7000, atomic absorption spectrophotometer. The metal ion concentration was displayed in the reader screen on the machine. Continuously, the wavelength of the metal was selected respectively and the concentration read from the machine from further analysis and recorded as mg/L ().

2.5 Determination of Human Health Risk

The human health risk of heavy metals daily consumption of the water by adults and children was determined from the chronic daily intake (CDI) and hazard quotient (HQ) of heavy metals in the water. These were evaluated using Equations (1), (2) and (3)

$$CDI = \frac{Cw \times IR \times EF \times ED}{Bw \times AT} \qquad (1)$$

For the equation above, CDI signifies a consumer’s daily ingestion of heavy metals (mg/L), CW represents the concentration of heavy metals in water (mg/L), IR stands for the ingestion rate, EF represents exposure frequency, ED indicates exposure duration, BW denotes body weight, and AT is the average time. Table 1 shows the standard values for the mentioned parameters.

$$\text{Hazard Quotient (HQ)} = \frac{\text{CDI}}{\text{RfD}} \qquad (2)$$

The hazard quotient is called the non-carcinogenic risk and is the probability that the expose individuals will experience adverse effect.

$$HQ = \frac{(C \times IR \times EF \times ED)}{(BW \times AT \times RfD)} \qquad (3)$$

Where:

- C = Contaminant concentration (mg/kg)
- IR = Ingestion rate (mg/day)
- EF = Exposure frequency (days/year)
- ED = Exposure duration (years)
- BW = Body weight (kg)

- AT = Averaging time (days)
- RfD = Reference Dose (mg/kg/day

Parameters used in estimation of HQ are presented in table 3.1 and classification in table 3.2

RfD (mg/kg/day) ingestion = Ni (0.02), Pb (0.036), Cd (0.001), Cr (0.003) and V (0.009)

RfD (mg/kg/day) inhalation = Ni (0.0206), Pb (0.0035), Cd (0.00000286) and Cr (0.00003)

RfD (mg/kg/day) dermal = Ni (0.000525), Pb (0.000525), Cd (0.000025) and Cr (0.00006)

(Samaila et al, 2021; Kamunda et al. 2016)

Table 1: Parameters for calculation of health hazard risk

Parameters	Unit	Adult
Body weight (BW)	Kg	70
Exposure frequency (EF)	days/year	350
Exposure duration (ED)	Years	30
Ingestion rate (IR)		0.0001
Inhalation rate (IRair)	m³/day	20
Skin surface area (SA)	cm²	5800
Soil adherence factor (AF)	0.2	0.07
Dermal Absorption factor (ABS)	None	0.1
Dermal exposure ratio (FE)	One	0.61
Particulate emission factor (PEF)	m³/kg	1.3 × 10E9
Conversion factor (CF)	kg/mg	1.00E-06
AT		10950

Table 2: Classification Criteria for Health Risk Assessment Parameters (HQ, HI, and CR)

Hazard Quotient	Classification
HQ < 1	No significant health risk
HQ ≥ 1	Potential non-carcinogenic health risk
HI < 1	Acceptable combined risk from multiple contaminants
HI ≥ 1	Combined exposure to multiple contaminants poses potential health risks.
$TCR<10^{-6}$	Negligible risk
$1 \times 10^{-6} \leq TCR \leq 1 \times 10^{-4}$	Acceptable risk range
$TCR > 1 \times 10^{-4}$	Unacceptable risk to humans

2.6 Statistical Analysis

All results obtained were subjected to descriptive statistical analysis by estimating the deviations from the Mean values of three replicate samples.

III. RESULTS AND DISCUSSION

Findings from the water quality parameters assessed (pH, conductivity, Bicarbonate (HCO3), Iron (Fe), Potassium (K), Magnesium (Mg), Calcium (Ca), Sodium (Na), Zinc (Zn), Copper (Cu), Manganese (Mn), Nickel (Ni), Cadmium (Cd), Lead (Pb), and Chromium (Cr) as shown in Table1). The groundwater samples around the dumpsite alone Port Harcourt International airport road, River State, were analyzed to determine the environmental impact of the dumpsite on the groundwater quality. The water samples were analyzed for Heavy metal content to assess the impact of the dumpsite on the groundwater. These Heavy metals analyses help to evaluate the extent of contamination and changes in water quality at different wells around the dumpsite

The pH of the groundwater at the dumpsite ranges from 5.26 mg/L to 5.82 mg/L, as shown in Table 4.1. This indicates that the groundwater is slightly acidic, falling below the acceptable limit for potable water set by the Nigerian standard for drinking water quality (NSDWQ, 2015) and the World Health Organization (WHO, 2022), which is between 6.5 mg/L and 8.5 mg/L. The groundwater around the study area tends to be slightly acidic, which may be due to the dissolution of carbon dioxide from the atmosphere, resulting from excessive burning of waste and the decomposition of organic matter. Natural waters contain gases, colloidal matter, and a variety of electrolyte and non-electrolyte materials; these, together with pH, determine the extent of corrosion in a system. The acidity of the water affects its corrosiveness and influences the speciation of some of its other constituents.

This study evaluates the physicochemical parameters and heavy metal concentrations of groundwater samples relative to the Nigerian Standard for Drinking Water Quality (NSDWQ) and World Health Organization (WHO) guidelines. The analysis highlights significant disparities between essential mineral content and toxic trace metal accumulation. Conductivity serves as a proxy for dissolved solutes; high levels often correlate with objectionable taste and pipe scaling. However, the samples exhibit exceptionally low calcium (0.418–2.002 mg/L) and magnesium (0.354–0.518 mg/L) levels, far below the WHO threshold of 75–200 mg/L. While these levels classify the water as "soft" and prevent scaling, the lack of minerals increases the water’s corrosivity, potentially facilitating the leaching of lead or copper from plumbing systems (NSDWQ, 2017). Sodium and chloride levels remain well within safe limits, indicating a balanced geological influence and a lack of significant salinity-related contamination. Iron and manganese concentrations present primary aesthetic challenges. Iron levels (0.794–1.596 mg/L) significantly exceed the permissible limit of 0.3 mg/L, likely due to the corrosion of discarded metallic waste in nearby dumpsites. Similarly, manganese levels (up to 0.518 mg/L) exceed the 0.2 mg/L NSDWQ limit, contributing to bitter tastes and staining of fixtures (NSDWQ, 2015).

Conversely, zinc, copper, and chromium concentrations remain within safe ranges, posing minimal health risks to the local population. The most critical findings involve toxic heavy metals—specifically lead, cadmium, nickel, and cobalt—which frequently exceed safety thresholds. Lead: Concentrations reached 0.094 mg/L, nearly ten times the WHO limit of 0.01 mg/L. This suggests leachate infiltration from landfills, posing severe neurotoxic risks. Cadmium: Values (0.021–0.072 mg/L) drastically exceed the 0.003 mg/L limit. As a known carcinogen, cadmium accumulation can lead to kidney failure and acute gastrointestinal distress (WHO, 2017). Nickel & Cobalt: Nickel levels in Borehole 1 (0.209 mg/L) and cobalt levels (0.062 mg/L) both surpass international guidelines (0.02 mg/L and 0.01 mg/L, respectively). These elevated levels are typically associated with electronic waste and industrial discharges. The absence of bicarbonates indicates low alkalinity and a heightened potential for leachate-driven acidification. The presence of toxic metals like cadmium and lead is attributed to anthropogenic sources, specifically the migration of leachate from unlined dumpsites into the surrounding aquifer. In contrast, the low sodium and chloride levels suggest that natural mineral leaching (Nwankwoala and Offor,2018). Although groundwater is suitable for agricultural irrigation, its chemical profile renders it unsafe for human consumption without extensive treatment. The prevalence of heavy metals indicates a direct link to local waste management practices, necessitating urgent intervention to protect public health.

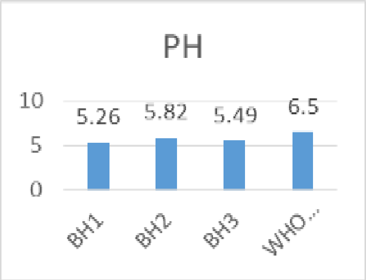

Figure 2: pH values across boreholes.

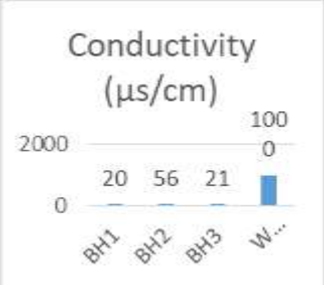

Figure 3: Levels of conductivity across boreholes.

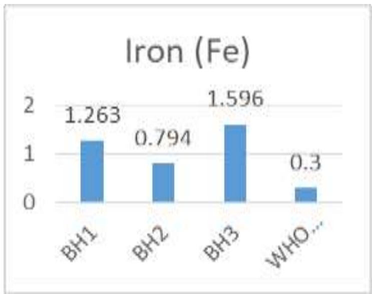

Figure 3: Levels of Iron across boreholes.

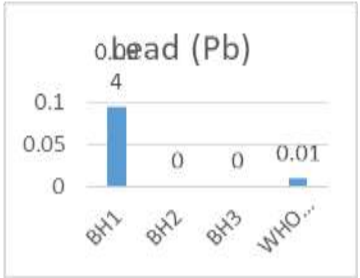

Figure 4: Lead levels across boreholes in the study area.

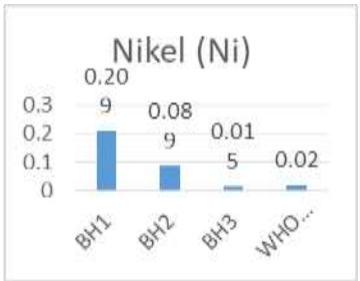

Figure 5: Levels of Nickel across boreholes.

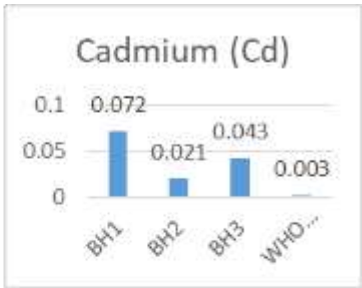

Figure 6: Levels of Cadmium across borehole

3.1 Health Risk Assessment of Heavy Metal Exposure

3.1.1 Non-carcinogenic Risk Assessment

It is very important to evaluate the potential health risks associated with the long-term ingestion of heavy metal in the drinking water of the study area. This study focused solely on the ingestion pathway to evaluate the non-carcinogenic (HQ and HI) and carcinogenic health risks. Table 4 presents the details of the non-carcinogenic health risk to humans in the environment using Target Hazard Quotient (THQ) and Hazard Index (HI). The THQ was calculated for the following exposure pathways: ingestion, inhalation and dermal. The THQ for Fe, Zn, Cu, Mn, Ni, Cd Pb, Cr and Co for Borehole (BH1) were 2.471E-06, 1.913E-03, 4.90E-04, 1.351E-06, 1.432E-05, 9.86E-05, 3.5E-06, 2.511E-05, and 2.781E-06, respectively. Borehole (BH2) indicated THQ of 1.55E-06, 5.47E-04, 2.191E-04, 1.242E-06, 6.096E-06, 2.831E-05, 1.506E-05, ND and 2.83E-06, respectively. For Borehole (BH3) the outcome showed that 3.123E-06, 4.29E-04, 4.932E-05, 9.785E-07, 1.027E-06, 5.890E-05, ND -4.566E-06 and -8.675E-07, respectively as THQ.

The Hazard Index for borehole1 was 2.55E-03, while borehole 2 had an HI of 6.25E-04. For borehole 3 the HI was 5.37E-4. The HI for Fe, Zn, Cu, Mn, Ni, Cd Pb, Cr and Co were 7.15E-06, 2.89E-03, 5.51E-04, 3.57E-06, 2.14E-05, 1.86E-04, 3.58E-06, 3.56E-05, and 4.75E-06.

Table 4: Hazard Quotient (HQ) of heavy metals

HEAVY METALS	BH1	BH2	BH3	HQ(BH1)	HQ(BH2)	HQ(BH3)
Iron (Fe)	1.263	0.794	1.596	2.47162E-06	1.55382E-06	3.12329E-06
Magnesium (Mg)	0.354	0.476	0.518	ND	ND	ND
Calcium (Ca)	0.418	0.283	0.002	ND	ND	ND
Sodium (Na)	2.305	7.862	2.308	ND	ND	ND
Zinc (Zn)	0.419	0.12	0.094	0.001913242	0.000547945	0.000429224
Copper (Cu)	0.179	0.008	0.018	0.000490411	2.19178E-05	4.93151E-05
Manganese (Mn)	0.13	0.12	0.1	1.35029E-	1.24266E-	9.78474E-

	8	7		06	06	07
Nikel (Ni)	0.209	0.089	0.015	1.43151E-05	6.09589E-06	1.0274E-06
Cadmium (Cd)	0.072	0.021	0.043	9.86301E-05	2.87671E-05	5.89041E-05
Lead (Pb)	0.094	ND	ND	3.57686E-06	ND	ND
Chromium (Cr)	0.055	0.033	-0.01	2.51142E-05	1.50685E-05	-4.56621E-06
Cobalt (Co)	0.061	0.062	-0.019	2.78539E-06	2.83105E-06	-8.6758E-07

3.1.2 Carcinogenic Risk Assessment

The Total Carcinogenic Risk (TCR) was also evaluated across the three pathways the results are presented shows, for borehole1 the Total Carcinogenic Risk was 2.71E-04 with Ni, Pb, Cd and Cr having values of 1.7E-04, 5.00E-05, 8.5E-07, 5.01E-05 respectively. This result reveals significant risk of groundwater around the solid waste dumpsite to human health.

IV. ECONOMIC IMPLICATION

The rapid urbanization of Rivers State has triggered a massive increase in municipal solid waste. For Port Harcourt metropolis, leachate seepage from unregulated dumpsites severely contaminates the shallow aquifers. This pollutes nearby boreholes with heavy metals and toxic chemicals, directly driving up healthcare costs, crippling local economic productivity, and lowering property values across the metropolis. The improper sanitary landfills or modern waste treatment facilities, this results in significant economic burdens across areas such as Escalating Healthcare Costs as result outbreaks of Waterborne Diseases, Exorbitant Private Water Sourcing, Loss of Economic Productivity and Increased Public Spending

V. CONCLUSION AND RECOMMENDATIONS

The effect of some physicochemical parameters of ground water, as a result of proximity to dumpsite is with varying levels of impact. The study reveals that there was a reduction in water quality, characterized by the slightly lower pH (slight acidity) and high level of heavy metals such as chromium, copper, Zinc, Sodium, Calcium and Magnesium which are below Nigerian Standard for Drinking Water quality (NSDWQ)/WHO permissible limit. The result of the investigation revealed that the groundwater in the area consists mainly of fresh water. This is seen in the low values of calcium, magnesium and chloride which are all below the NSDWQ/WHO standard for drinking water. However, the study shows poor groundwater quality, demonstrated by high concentrations of iron (Fe), lead (Pb), cadmium (Cd), and cobalt (Co) above the permissible limit and possess significant risk to human health.

Based on the result from this study, there is the need for treatment of the ground water to ensure the water is suitable for its intended uses and regular ground water quality monitoring in the area. Establishing continuous groundwater monitoring programs can help detect contamination trends early and guide timely intervention measures. Additionally, promoting alternative potable water sources in highly contaminated areas is crucial to reducing health risks for affected communities. Understanding the severity of this issue is vital for formulating proactive measures to protect water resources and public health

Therefore the study recommend the adoption of modern landfill technologies, such as leachate treatment and containment systems, should be prioritized to minimize pollution and safeguard water resources for future generations.

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