

# Impact of Waste on Quality of Ground Water Around Some Industrial Locations in JOS, Plateau State

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## Abstract

This research was aimed at determining the quality of groundwater by analyzing the physico-chemical parameters and heavy metal content of samples from selected industrial areas (soap, food, vegetable oil and foam manufacturing industries) in Jos metropolis in comparison to the contaminants in the industrial effluents. Groundwater samples as well as waste-water effluents were collected from within Jos North and Jos south Local Government Areas of Plateau State and analyzed using standard laboratory methods. Higher levels of contamination were present in samples collected from the waste-water effluents. The pH of samples C (location) and its corresponding groundwater (WC) were found to be  $4.98 \pm 0.04$  and  $5.93 \pm 0.01$  respectively. Concentrations of anions in the various Sample, it was found that Sample B (location) and its corresponding Ground water sample GB showed Nitrate ions concentration of 72mg/L and 6.5m/L respectively whereas ground water in some other areas sampled were as low as 1.4mg/L. For the heavy metal concentrations, it was found that for all the samples that showed the contamination of cadmium and nickel, their corresponding groundwater also showed even higher levels of the heavy metal concentration. The cadmium concentrations of A and GA which are 0.003mg/kg and 0.005mg/kg respectively. The project concludes that urgent action is necessary to address this issue, including establishment and enforcement of stringent regulations, advanced treatment technologies, and regular monitoring of industrial effluent discharge to protect groundwater.

**Keywords:** Impact; Industrial Waste; Ground Water Quality; Jos Metropolis.

## 1. Introduction

Industrial wastewater is the aqueous solution that results from the dissolution or suspension of substances in water, typically during an industrial manufacturing process, or cleaning activities that take place during that process (Woodard and Curran, 2006). Industrial waste waters that enter a water body represent a heavy source of environmental pollution in surface water bodies in Nigeria. This affects both the water quality and the microbial and aquatic flora in the environment. With competing demands on limited water resources, awareness of the issues in water pollution has led to considerable public debate on the environmental effects of industrial effluents discharged into aquatic environments. Industrial effluents are characterized by their abnormal turbidity, conductivity, chemical oxygen demand (COD), total suspended solids (TSS), biological oxygen demand (BOD), and total hardness (Kanu et al., 2011).

The total available water on earth, about 97.5%, is salty, therefore not potable. Of the remaining 2.5% of fresh water, only a marginal part, ~ 1%, is available for human consumption (Vivek et al, 2014). In the 1950s, the world population doubled, and water consumption has increased sixfold, which has led to rapid industrial consumption (Florke et al, 2013). Recently, parts of the world like India, China, and some parts of Europe have started feeling the "water crunch." It is believed that by 2025, these countries of Europe and Africa will face water scarcity, and two-thirds of the population of the world could face water stress (UNEP, 2017).

The scarcity of water could be physical scarcity, where water availability is limited, and it could be economic scarcity, where water is available, but there is no infrastructure to provide the quantity and quality needed (Ingrao et al, 2023). As far as the global water scenario is concerned, the distribution of water across the globe is not uniform. The human factor adds to this problem by the wastage of water, pollution of water resources, and inappropriate management of water. Reports by Corcoran et al. (2010) testify that the total wastewater from sewage, industrial, and agricultural discharges globally is in tens of millions of cubic meters per day. It is also believed that a significant portion of all wastewater in developing countries is discharged untreated, resulting in large-scale pollution of rivers and other water bodies. This consequently endangers living organisms, including any surrounding population dependent on these water sources. Reports by UN Water (2008) and the United Nations World Water Assessment Programme (UN/WWAP) 2009 suggest that nearly 80–90% of all the wastewater in developing countries is discharged directly into surface water bodies. Therefore, Nigeria needs to carefully evaluate its water management options (Vivek et al., 2014).

Industrial wastewater has variable quality and volume depending on the type of industry producing it. It may be highly biodegradable or not, and may contain compounds recalcitrant to treatment or not. These include organic synthetic substances and heavy metals whose

content varies. In developing countries, wastewater may be considerably different (in quantity and quality) from that of developed countries. The main concern with industrial wastewater is the increase in quantity and variety of synthetic compounds that are discharged to the environment. The most common pollutants in industrial discharges are heavy metals like arsenic, lead, nickel, cadmium, and chromium; anions like sulphate, phosphate, nitrate, and chloride; microorganisms like bacteria; dissolved and suspended solids (Singh and Mishra, 2023).

Municipal and industrial wastewaters can have high toxicity. Developing countries often discharge wastewater into natural ecosystems without previous treatment, while developed countries treat them using physical, biological, and chemical methods. The efficiency of these treatments are determined using a battery of bioassays after each step and compared with the toxicity of the inputted wastewater (Tongur and Atmaca, 2023). Based on the type of industry, various levels of pollutants are discharged into the environment directly or indirectly through public sewer lines. Wastewater from industries includes employees' sanitary waste, process wastes from manufacturing, wash waters, and relatively uncontaminated water from heating and cooling operations (Hanchang, nd). One of the major sources of groundwater contamination in industrial areas is the discharge of untreated industrial waste into the environment. Other sources of contamination include seepage from landfills, runoff from roads and parking lots, and infiltration from wastewater treatment plants (Thomas and Thomas, 2022).

Pharmaceutical industries generate large quantities of effluent containing organic and inorganic pollutants, heavy metals, and pharmaceutical residues. These pollutants can have significant impacts on aquatic ecosystems and human health, especially in regions where wastewater treatment is inadequate or non-existent (Munzhelele et al, 2023). The soap and detergent industry is one of the largest consumers of water in the manufacturing sector, and as a result, generates significant amounts of effluent. This effluent can contain a wide range of pollutants, including surfactants, phosphates, and heavy metals, which can have adverse impacts on the environment and human health if not properly managed (Gezahegn et al, 2025). A study by Ogwueleka (2016) found that the effluent from a paper mill in Nigeria had high levels of COD, BOD, and TSS, indicating significant organic pollution (NESREA, 2013). The composition and characteristics of brewery effluent depend on the production processes, raw materials, and water sources used in the brewery (Simate et al, 2011). Brewery effluent is typically characterized by high levels of BOD, COD, total suspended solids (TSS), nitrogen, and phosphorus (Terungwa et al, 2016). The effluent also contains a range of organic and inorganic compounds, including ethanol, carbohydrates, proteins, and fats (Zhang et al., 2008). Treatment of tannery effluent is a challenging task due to its complex composition and high levels of pollutants. Various treatment technologies have been proposed for the removal of contaminants from tannery effluent, including physicochemical treatment, biological treatment, and membrane filtration (Yusif et al., 2016).

A study by Gerson et al. (2025) investigated the physicochemical characteristics and heavy metal content of effluent from a soft drink bottling company in Tanzania. The study found that the effluent had high levels of biochemical oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS), and heavy metals such as lead, copper, and zinc. Hence, they recommended the use of biological and chemical treatment methods to effectively treat the effluent.

These pollutants can bioaccumulate in the food chain, leading to long-term health effects such as cancer, organ damage, and reproductive disorders. Additionally, the high levels of toxicity in the effluents can have severe environmental consequences, including the destruction of aquatic ecosystems, loss of biodiversity, and degradation of water quality. Industrialization has led to the discharge of large quantities of untreated or partially treated wastewater into the environment, which has the potential to negatively impact the quality of surrounding groundwater. Therefore, it is essential to understand the extent of this impact by analyzing the physicochemical parameters and heavy metal content of groundwater samples collected from selected industrial areas. Groundwater is a significant source of water for human consumption, agricultural, and industrial activities. As a result, it is crucial to evaluate the impact of industrial effluent on groundwater to ensure that the water is safe for various uses.

## 2. Materials and Methods

### 2.1. Collection of samples

The plastic sample bottles were first washed with clean water and rinsed thoroughly with dilute  $H_2SO_4$ . They were then rinsed with distilled water and allowed to dry. Four (4) samples were collected from discharge points of soap, food, oil, and foam manufacturing industries located within Jos North and Jos South local government areas in Plateau state. Another four (4) samples were then collected from hand dug well water located less than 200 m away from these industries. The samples were transported to the laboratory for analysis after taking measurements of their temperatures, pH, and conductivity.

### 2.2. Determination of the temperature of the sample

The temperature of the water samples was determined on the spot at the point of collection using a 10-300 °C laboratory mercury in glass thermometer. The thermometer was placed vertically into the sample and was allowed to stabilize for 5 minutes before taking the reading.

### 2.3. Determination of the odour of the sample

Each sample of 10 cm<sup>3</sup> was warmed in a fume cupboard and sniffed for any odour by four assessors, and the results were noted.

### 2.4. Determination of pH of water

The pH of the sample was measured using a Labtech no. 513425 digital pH meter, after the electrode was standardized with pH buffer solutions of 4, 7, and 9.2, respectively. Exactly 100 cm<sup>3</sup> of the water samples were measured and transferred into a 150cm<sup>3</sup> beaker. The glass electrode was dipped into the sample, and the pH meter displayed the readings digitally.

### 2.5. Determination of the conductivity of the water sample

A portable Hanna Conductivity meter model HI 86304 with a range of 0.00-19.99 dS/m was used to measure the conductivity of the water samples. The conductivity meter was first standardized using a standard solution. The conductivity cell was rinsed with distilled water, immersed in a beaker containing distilled water to zero the instrument, and then into the sample. It was allowed to attain a constant reading

for two minutes, and the conductivity values were recorded. The electrode was rinsed with distilled water after each measurement to avoid contamination. The process was repeated for all the samples.

## 2.6. Determination of the turbidity of the water sample

Clean sample cells were filled with water to the 25 cm<sup>3</sup> mark. The turbidity meter scale was inserted into the water, and a 450 nm colour filter was selected, and the light shield was closed. The colorimeter switch was pressed, and the zero-adjustment control was adjusted to align the meter needle and was inserted into the meter and adjusted to obtain the zero FTU reading. Then the samples were placed in the cell holder, and the test switch was held down until the reading stabilized and the Formazin Turbidity Unit (FTU) was read.

## 2.7. Determination of total alkalinity of water samples

Using a double titrimetric reaction method, methyl orange and phenolphthalein indicator were used for measuring the total alkalinity. Tetraoxosulphate (VI) acid (H<sub>2</sub>SO<sub>4</sub>) of 0.02N concentration was prepared by dissolving 0.98 g of H<sub>2</sub>SO<sub>4</sub> in 1 L of water. A 50.0cm<sup>3</sup> burette was then filled with the 0.02N sulphuric acid (H<sub>2</sub>SO<sub>4</sub>), which was used as the titrant. Exactly 25.0 cm<sup>3</sup> of the water sample was pipetted into a 50 cm<sup>3</sup> conical flask, and two drops of methyl orange were added. It was slowly and carefully titrated with sulphuric acid, swirled until the solution changed its colour from yellow to pink, indicating its end point and titre value recorded.

$$\text{Total Alkalinity} = \frac{\text{Volume of Acid} \times 1000}{50 \text{ cm}^3 \text{ of sample}}$$

## 2.8. Determination of total dissolved solids in a water sample

The gravimetric method was used. A petri dish was weighed, and the weight (W<sub>1</sub>) was recorded. 50 cm<sup>3</sup> of sample was taken in the dish, weighed, and placed in an oven at a temperature of 105°C until the water completely evaporated. The dish was weighed again after cooling to obtain the weight (W<sub>2</sub>). The weight of the empty dish was subtracted to determine the weight of the dissolved solids. The value was converted to TDS using a conversion factor of 0.67.

## 2.9. Determination of sulphate ion (SO<sub>4</sub><sup>2-</sup>) content of water samples

The Hach DR UV visible spectrophotometric analyzer was used for this analysis. About 10 cm<sup>3</sup> of the water samples were filled in a sample cell, and the content of one SulferVer 4 powder pillow reagent was added to the sample cell. It was swirled to ensure proper mixing, allowed to stand for 5 minutes undisturbed to ensure reaction time. A blank sample was also prepared by filling a second sample cell with the same sample without the addition of the test reagent. The blank sample cell was cleaned and inserted into the cell holder to achieve a zero-background reading of the blank. The prepared sample cell was also cleaned and inserted into the cell holder to obtain the ion concentration in the sample.

## 2.10. Determination of nitrate ion (NO<sub>3</sub><sup>-</sup>) content of water samples

The Hach DR UV visible spectrophotometric analyzer was used for this analysis. A sample cell was filled with 10 cm<sup>3</sup> of the pretreated water sample, and the contents of one NitraVer 5 Nitrate reagent powder pillow were emptied into the sample cell. A stopper was placed on the cell, and a 1-minute reaction time was set on the instrument timer; the cell was vigorously shaken for 1 minute. The cell was left undisturbed for 5 minutes, after which a second sample cell was filled with 10 cm<sup>3</sup> sample to obtain a blank sample. The blank cell was cleaned and inserted into the cell to obtain a zero-background reading. The sample cell was cleaned, and the prepared sample was inserted into the cell holder to obtain the concentration of ions in the sample.

## 2.11. Determination of phosphate ion (PO<sub>4</sub><sup>3-</sup>) content of water samples

The Hach DR UV visible spectrophotometric analyzer was used for this analysis. A pretreated water sample was filled in 10 cm<sup>3</sup> sample cell, and the contents of one PhosVer 3 phosphate reagent powder pillow were added to the cell. It was closed and vigorously shaken for 30 minutes to achieve a proper mixing, and kept for a 2-minute reaction time. A blank sample was prepared by filling a second sample cell. The blank sample cell was cleaned and inserted into the cell holder to achieve a zero-background reading. The prepared sample cell was also cleaned and brought into the cell holder to obtain the reading of the concentration of the ion in the sample.

## 2.12. Determination of chloride ion (Cl<sup>-</sup>) content of water samples

The Hach DR UV visible spectrophotometric analyzer was used for this analysis. About 10 cm<sup>3</sup> of the water samples was filled in a sample cell, and the contents of one powder pillow reagent was added to the sample cell. It was swirled for 20 seconds to ensure proper mixing and allowed for a 3-minute undisturbed reaction time. A blank sample was prepared by filling a second sample cell with the sample without the addition of the test reagent. The blank sample cell was cleaned and inserted into the cell holder to achieve a zero-background reading. The prepared sample cell was also cleaned and inserted into the cell holder to obtain the concentration of Cl<sup>-</sup> ion in the sample.

## 2.13. Determination of biological oxygen demand (BOD) in water samples

The 5-day BOD (Biochemical Oxygen Demand) test was used for determining the amount of organic matter present in the water samples as described by Chesapeake Biological Laboratory Manual, 2011.

$$\text{BOD} = \frac{(\text{DO}_{\text{initial}} - \text{DO}_{\text{final}}) \times \text{Dilution factor}}{\text{Volume of sample taken}}$$

## 2.14. Digestion of water samples for heavy metal content

About 100 cm<sup>3</sup> of water sample was measured into the digestion vessel, a mixture of acids (HNO<sub>3</sub> and HCl) was added and stirred according to the APHA method 3030. The mixture was heated gently until digestion was completed. The mixture was cooled to room temperature, filtered using Whatman filter paper No.41, then transferred to a volumetric flask and diluted to 100 cm<sup>3</sup> with deionized water. This solution was used for Atomic Absorption Spectroscopy (AAS) analysis. The heavy metal content was taken in triplicate using a calibration curve obtained from the absorbance of the standard metals at their various wavelengths.

## 3. Statistical Analysis

All measurements were done in triplicate, and the mean was taken with the standard deviation. Analysis of variance was conducted using one-way ANOVA to determine the relationship between the values at the various locations ( $p > 0.05\%$ ) and two-tailed Pearson Correlation analysis.

## 4. Results

**Table 1:** Physicochemical Properties of the Water Samples

Sample	Temperature (°C)	pH	Conductivity (dS/m)	TDS (mg/L)	Turbidity (FTU)
A	22.50 + 0.70	5.22 + 0.32	6.16 + 2.18	27.00 + 0.01	0.90 + 0.07
B	24.00 + 0.00	5.17 + 0.11	8.68 + 0.04	15.00 + 0.57	72.30 + 0.57
C	31.00 + 0.00	4.98 + 0.04	8.46 + 1.10	30.00 + 1.41	968.00 + 1.41
D	25.00 + 0.00	6.58 + 0.60	0.00 + 0.01	45.00 + 0.57	42.30 + 0.57
GA	24.00 + 0.70	5.42 + 0.01	0.09 + 0.01	2.00 + 0.01	0.10 + 0.01
GB	23.00 + 0.70	6.30 + 0.01	0.05 + 0.01	31.60 + 0.21	3.50 + 0.21
GC	24.00 + 0.00	5.93 + 0.01	0.01 + 0.01	8.00 + 0.07	0.00 + 0.00
GD	24.00 + 0.70	4.66 + 0.01	10.76 + 0.01	10.00 + 0.07	0.70 + 0.07
W*	≤ 25.00	6.50 – 8.50	≤ 0.0025	≤ 500.00	≤ 5.00

Key to Sample

A – Food Manufacturing Industry; B – Soap Manufacturing Industry.

C – Vegetable Oil Manufacturing Industry; D – Foam Manufacturing Industry.

G – Ground Water from the Vicinity of Industries A, B, C, and D

W\* – World Health Organization acceptable standard 2011

**Table 2:** Concentration of Anions in Water Samples (mg/L)

Sample	Sulphate (SO <sub>4</sub> ) <sup>2-</sup>	Nitrate (NO <sub>3</sub> ) <sup>-</sup>	Alkalinity CaCO <sub>3</sub> <sup>-</sup>	Chloride Cl <sup>-</sup>	Phosphate PO <sub>4</sub> <sup>-</sup>
A	35.00 + 0.00	133.50 + 1.50	0.00 + 0.00	0.04 + 0.00	0.10 + 0.00
B	135.33 + 1.15	72.00 + 0.00	0.00 + 0.00	0.09 + 0.01	1.32 + 0.00
C	31.67 + 0.58	22.07 + 9.19	0.00 + 0.00	0.10 + 0.05	6.20 + 0.05
D	2.33 + 0.58	5.60 + 0.53	80.00 + 0.01	0.03 + 0.01	0.04 + 0.01
GA	0.00 + 0.00	4.67 + 0.06	46.00 + 0.02	0.02 + 0.01	0.15 + 0.00
GB	0.33 + 0.58	6.50 + 1.99	56.00 + 0.01	0.02 + 0.00	0.12 + 0.01
GC	8.00 + 0.00	1.40 + 0.10	60.00 + 0.01	0.11 + 0.02	0.14 + 0.01
GD	59.33 + 0.58	140.67 + 0.29	0.00 + 0.00	0.02 + 0.00	0.11 + 0.00
W*	≤ 200.00	≤ 45.00	≤ 200.00	≤ 250.00	0.01 – 0.05

Key to Sample

A – Food Manufacturing Industry; B – Soap Manufacturing Industry.

C – Vegetable Oil Manufacturing Industry; D – Foam Manufacturing Industry.

G – Ground Water from the Vicinity of Industries A, B, C, and D

W\* – World Health Organization acceptable standard 2011

**Table 3:** Heavy Metal Concentration in the Water Samples (mg/L)

Sample	Cadmium	Lead	Nickel	Manganese	Chromium
A	0.003 + 0.001	-0.409 + 0.013	0.101 + 0.005	0.018 + 0.001	-0.013 + 0.022
B	0.003 + 0.002	BDL	0.241 + 0.007	0.054 + 0.001	0.217 + 0.001
C	0.001 + 0.001	BDL	0.104 + 0.003	0.014 + 0.001	BDL
D	0.001 + 0.001	BDL	0.096 + 0.001	BDL	BDL
GA	0.005 + 0.000	BDL	0.114 + 0.005	BDL	BDL
GB	0.004 + 0.001	BDL	0.123 + 0.004	BDL	BDL
GC	0.004 + 0.002	BDL	0.128 + 0.002	BDL	BDL
GD	0.004 + 0.001	BDL	0.129 + 0.008	0.015 + 0.001	BDL
W*	≤ 0.003	≤ 0.010	≤ 0.020	≤ 0.400	≤ 0.050

Key to Sample

A – Food Manufacturing Industry; B – Soap Manufacturing Industry.

C – Vegetable Oil Manufacturing Industry; D – Foam Manufacturing Industry.

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W\* – World Health Organization acceptable standard 2011

BDL - Below Detectable Limit

**Table 4:** Biological Composition of Water Samples

Parameters			
Sample	BOD (mg/l)	Total Plate count (100ml)	Coliform Count (CFU/100ml)
A	0.2	10	13
B	1.2	15	21
C	1.1	43	47
D	0.4	37	49
GA	0.9	15	18
GB	0.1	12	19
GC	0.1	17	19
GD	0.8	19	23
W*	< 3.0	≤ 100	0

Key to Sample

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G – Ground Water from the Vicinity of Industries A, B, C, and D

W\* – World Health Organization Acceptable Standard 2011

**Table 5:** Bacteriological Content of Water Samples

Samples								
Bacteria	A	B	C	D	GA	GB	GC	GD
Staphylococcus aureus	+	+	+	+	+	+	+	+
Escherichia Coli	-	-	+	+	+	-	-	-
Salmonella typhi	-	-	-	+	-	-	-	-
Proteus Spp	-	-	-	-	-	-	-	+

(+): present; (-): absent

Key to Sample

A – Food Manufacturing Industry; B – Soap Manufacturing Industry.

C – Vegetable Oil Manufacturing Industry;

D – Foam Manufacturing Industry.

G – Ground Water from the Vicinity of Industries A, B, C, and D

W\* – World Health Organization acceptable standard 2011

**Table 6:** Correlation Analysis for Heavy Metal Content

Correlations		Cadmium	Lead	Nickel	Manganese	Chromium
Cadmium	Pearson Correlation	1	. <sup>a</sup>	.165	.169	. <sup>a</sup>
	Sig. (2-tailed)	.	.	.697	.831	.
	N	8	1	8	4	2
Lead	Pearson Correlation	. <sup>a</sup>				
	Sig. (2-tailed)	.	.	.	.	.
	N	1	1	1	1	1
Nickel	Pearson Correlation	.165	. <sup>a</sup>	1	.972*	1.000**
	Sig. (2-tailed)	.697	.	.	.028	.
	N	8	1	8	4	2
Manganese	Pearson Correlation	.169	. <sup>a</sup>	.972*	1	1.000**
	Sig. (2-tailed)	.831	.	.028	.	.
	N	4	1	4	4	2
Chromium	Pearson Correlation	. <sup>a</sup>	. <sup>a</sup>	1.000**	1.000**	1
	Sig. (2-tailed)	.	.	.	.	.
	N	2	1	2	2	2

\*. Correlation is significant at the 0.05 level (2-tailed).

\*\* Correlation is significant at the 0.01 level (2-tailed).

## 5. Discussion

From Table 1, the temperature of the effluents ranged from  $22.50 \pm 0.70$  -  $31.00 \pm 0.00$  °C and those of the groundwater were from  $23.00 \pm 0.70$  -  $24.00 \pm 0.70$  °C. The temperature of the effluents at the vegetable oil industry (C) was higher than all other samples, probably because of the heating process involved in distilling the oil. This is in agreement with the works of USEPA (2025), who reported that some industrial activities generate thermal effluents, which can also increase warm water inputs and significantly raise downstream temperatures. Changes in water temperature can be related to several other quality factors. For example, Dissolve Oxygen high concentrations decrease temperature while dissolution of ionic compounds increases temperatures, which can contribute to these water quality stressors. Increases in suspended sediments can increase temperature by increasing heat absorption, and reductions in groundwater discharge, thereby leading to water temperature increase.(USEPA,2025)

The pH levels in this study for industrial effluent samples (ranging from 4.98 to 6.58) are generally acidic, with groundwater samples also showing pH values below the WHO standard (6.5–8.5). Acidic wastewater can be attributed to specific chemicals or byproducts from production processes. Similar trends have been reported in studies focusing on food, soap, and oil industries, where effluents often contain organic acids and byproducts that lower pH levels. A study by Singh et al (2021 in Industrial Water Pollution: Origins, Characteristics, and Treatment reported that food and oil production industries often discharge acidic effluents, which can alter the pH of nearby water sources, making them more corrosive and affecting aquatic life.

Another study by Shimazui et al ( 2021) found that wastewater from vegetable oil industries consistently showed pH values below neutral, primarily due to organic compounds and residual oils in the effluent. The pH value recorded in the groundwater near the oil manufacturing industry was  $4.98 \pm 0.04$ . This finding aligns with the study by Osareme et al (2022), which reported pH values between 4 and 5 in water

samples from industrial areas. The acidity of the effluent may be influenced by free fatty acids released during vegetable oil refining, as well as the use of acidic raw materials, such as vinegar and citric acid, in the manufacturing process. The water sample at point D was nearly neutral, likely because foam manufacturers aim to maintain a balanced pH in their processes, often using neutralizing agents such as sodium bicarbonate or calcium hydroxide. Foam manufacturing (Sample D) typically involves chemicals like polyols and isocyanates, which are slightly acidic. This could result in a near-neutral or slightly basic pH in the effluent, explaining why Sample D has the highest pH (6.58) among the industrial samples. In contrast, the more acidic pH (4.66) observed in Sample GD likely results from cumulative contamination by nearby industries, such as vegetable oil and soap production, which may release acidic byproducts or organic acids, leading to leaching into the untreated groundwater system. Notably, only the pH of the water sample from the foam industry (D,  $6.58 \pm 0.60$ ) met the WHO acceptable standard range of 6.50 to 8.50. The pH of groundwater near the foam industry, GD, was unusually high ( $4.66 \pm 0.01$ ) compared to the corresponding effluent at point D ( $0.00 \pm 0.01$ ). This likely indicates the presence of dissolved acidic minerals in the groundwater, contributing to the observed higher conductivity of 10.76 dS/m. This is in agreement with the results obtained by Akoto et al (2022) from the assessment of groundwater around hostels of Kwame Nkrumah University of Science and Technology in Ghana. Microorganisms thrive in near-neutral pH (7), while extreme pH inhibits their function, making treatment less effective in the biological treatment process. pH controls coagulation and disinfection, and the solubility of metals, other toxins, which can be precipitated out at specific pH levels. Discharged water with high pH values disrupts aquatic ecosystems, harming fish and other organisms, and poses health risks (ACS, nd).

For conductivity, all the samples exceeded the conductivity limit acceptable by WHO, which is 0.0025 dS/m, except at the foam industry (D), which showed no conductivity at all. High conductivity at the soap industry (B, 8.68dS/m) and the vegetable oil industry (C, 8.46 dS/m), respectively, suggests significant dissolved ionic content, likely from salts or manufacturing chemicals. Conductivity in the groundwater sample GD (10.76 dS/cm) is also elevated, indicating potential contamination from industrial sources. High conductivity in industrial effluents has been linked to the release of dissolved salts, particularly in the soap and chemical manufacturing sectors. Gezahegen et al (2025) noted that soap and chemical manufacturing industries often release high levels of sodium, chloride, and sulphate ions, which increase effluent conductivity. Though some of these ions like  $\text{SO}_4^{2-}$  is a common and nontoxic component of various types of water bodies, high concentrations of it in the water can cause a series of serious environmental problems, which can lead to water mineralization, metal corrosion, pipes and equipment scaling, toxic hydrogen sulphide release, and disruption in the balance of the natural sulphur cycle (Fang, 2017). In addition, high concentrations of  $\text{SO}_4^{2-}$  (>600 mg/L) in the water can cause laxative effects in mammals (Hudaib, 2021). Hence, to protect the environment, the  $\text{SO}_4^{2-}$  concentration in the industrial effluents is set ranging from 250 mg/L to 500 mg/L in many countries (Hudaib, 2021).

Obire and Amusan (2003) in their study observed that effluents from Oilfield formation water in Nigeria had significantly elevated conductivity levels in fresh stream waters, consistent with the findings here.

The result also agrees with the findings of Deshi et al (2021) on the quality of Gurah-Loh-Mancha stream water in Jos. This shows that the discharge of industrial effluent into the Environment had some impact on the conductivity of both ground and surface water. Releasing water that has an extremely high conductivity can have detrimental effects on the health of aquatic life. Keeping conductivity within the acceptable ranges is essential in maintaining a healthy and sustainable ecosystem (Hanna Instruments, 2025).

TDS levels vary in industrial samples, with Sample D (foam industry) recording the highest TDS at 45 mg/L, while groundwater TDS is generally low. This agrees with the study done by Adamu et al (2019), who concluded that the TDS levels in both ground and surface water sources were generally within the acceptable range for drinking water in the study area, but cautioned that the levels may still pose health risks if other contaminants are present. Similar findings were reported in studies where proximity to food and manufacturing plants resulted in increased TDS in adjacent water bodies due to leaching of organic and inorganic materials. Singh et al (2018) in their study on water pollution due to discharge of industrial effluents observed elevated TDS levels in groundwater near food and foam industries, attributing this to both organic effluents, which increase dissolved solids.

The World Health Organization (WHO, 2011) guidelines suggest TDS limits in drinking water at 500 mg/L, noting that lower TDS values are essential for taste and health. While the samples in this study fall within these guidelines, variations in TDS indicate differing levels of contamination potential.

For turbidity and suspended solids, this analysis, along with supporting literature, indicates that industrial activities—especially in soap, oil, and food production can significantly impact water quality, resulting in high conductivity, acidic pH, elevated TDS, and increased turbidity in nearby water sources. Sample C (vegetable oil industry) recorded the highest turbidity (968 NTU), likely due to suspended oil particles and organic matter, while Sample B (soap industry) also exhibited elevated turbidity (72.3 NTU). Such high turbidity levels align with findings from Tunde and Aganmwoyi (2021), who reported significantly elevated turbidity in water bodies near soap and oil industries. The effluent turbidity levels in Samples B (72.3 NTU), C (968 NTU), and D (42.3 NTU) all exceeded the WHO's acceptable standard of 5 NTU, underscoring the need for treatment before discharge to prevent environmental and public health risks. Khumalo et al. (2022) in South Africa found similar results, showing turbidity levels in industrial effluents ranging from 38 to 2,775 NTU. This high turbidity, as the study concluded, reflects the presence of suspended solids that could be harmful if not treated adequately. The oil manufacturing industry. The high turbidity level in sample C is likely due to fats, oils, and greases (FOG), consistent with findings by Sheth et al (2017) demonstrates that substances from soap industries contribute significantly to effluent turbidity. According to the WHO (2011) guidelines, turbidity levels in potable water should be less than 5 NTU to ensure clarity and prevent pathogen growth. The elevated turbidity in the industrial samples, particularly in Sample C from the oil industry, highlights the need for treatment before water discharge to prevent environmental contamination, which can pose great health risks.

In Table 2, all the samples showed the presence of sulphate ions except the groundwater at the food industry (GA). This could be a result of pre-treatment of the effluent by the industry before being discarded. Although the effluent at the foam industry (D) had a very low Sulphate content of 2.33mg/L, the groundwater at point that point (GD) had a higher sulphate content of 59.33mg/L. This is possibly due to the presence of dissolved minerals from surrounding rocks containing sulphate ions, as shown by Liu et al. (2025), whose study supports the idea that the presence of dissolved minerals from surrounding rocks containing sulphate ions can contribute to a higher sulphate content in groundwater. It is important to note that although the samples showed the presence of sulphate ion concentration, they were still within the WHO acceptable standard for water quality of  $\leq 200$ mg/L.

The nitrate concentrations in the effluent at the food industry A (133.50mg/L), soap industry B (72.00mg/L), and groundwater at the foam industry GD (140.67mg/L) all surpassed the WHO acceptable limit of  $\leq 45$ mg/L. The water sample at GD had a higher nitrate content of 140.67mg/L compared to the corresponding sample at point D-foam industry (5.60mg/L). This is possibly due to the presence of dissolved minerals from surrounding rocks containing nitrate ions and not necessarily from industrial effluent (Mencio et al, 2015). Hence, groundwater from these area need to be treated before consumption. Meanwhile, the nitrate ion concentrations in the water samples GA and GB

(Food and soap industries, respectively) had values of 4.67mg/L and 6.50mg/L respectively. These are lower than those from the corresponding industries A and B (Food and soap industries respectively, with values of 133.50mg/L and 72.00mg/L respectively). This could be as a result of dilution and the distance of the groundwater from the discharge point (Rivett et al, 2008), which in this case is about 200 metres.

For alkalinity, only samples D, GA, GB, and GC (Foam Industry, G – Ground Water from Vicinity of Industries A, B, C, respectively) showed the presence of alkalinity, with sample D (foam industry) having the highest value of 80mg/L. This is expected as most of the effluents had high acidity, except sample D, which was almost neutral (6.58). Sample GD also showed zero alkalinity. This is expected because this sample had a high pH value under the physicochemical properties. This is in tandem with the study done by Han et al. (2024), where groundwater quality in shallow aquifers of the northern China plain was analyzed. They found that pH and alkalinity were negatively correlated, with acidic groundwater having low alkalinity levels. Specifically, they reported that the median alkalinity in groundwater with a pH less than 7 was only 94.5 mg/L as CaCO<sub>3</sub>, which is considered to be a low alkalinity level. This study supports the idea that acidic groundwater is likely to have low alkalinity levels. However, all the samples had values within the WHO acceptable limit for water quality of  $\leq 200$ mg/L.

All the samples showed traces of Chloride ions, with concentrations ranging from 0.02mg/L to 0.11mg/L. These levels are not harmful to humans as prescribed by the WHO acceptable limit of  $\leq 250$ mg/L. The phosphate ion concentration in all the samples ranged from 0.02mg/L to 0.11mg/L. These are above the WHO acceptable range of 0.01-0.05mg/L, except sample D (foam industry effluent), which has a value of 0.04±0.01 mg/L. This is probably because foam industries do not use compounds that contain phosphate ions in their formulation process, but rather use polyurethane (Barnes and Ring, 2017; Gama et al, 2018).

Of the heavy metals analyzed, Cadmium and Nickel were present in the samples in various quantities, with cadmium ranging from 0.001 to 0.005mg/kg, and Nickel from 0.0960 to 0.2410mg/kg. This calls for the need to properly treat these groundwaters before they are consumed because the presence of these heavy metals in drinking water can be hazardous. The World Health Organization acceptable limit for Cadmium in potable water is  $\leq 0.0030$ mg/kg, while that for Nickel is  $\leq 0.0200$ mg/kg. Consuming cadmium-contaminated water can lead to kidney damage. Cadmium can accumulate in the kidneys and cause damage to the kidney tubules, leading to reduced kidney function and increased risk of renal disease (Lin et al, 2021). Cadmium can also accumulate in the bones, leading to a loss of calcium and weakened bones, which can increase the risk of fractures (Ran et al, 2023). The renal proximal tubule (PT) is the primary target site for accumulation due to the reabsorption of Cd-metlothionein complexes, leading to significant accumulation (up to 60% of body burden) and a biological half-life of 10 to 30 years. (Yan and Allen, 2021). Inhalation of cadmium fumes or dust can increase the risk of lung cancer. However, the risk of cancer from consuming cadmium in water is less clear (Charkiewicz et al, 2023). Cadmium exposure has also been associated with an increased risk of cardiovascular disease, high blood pressure, and other health problems (Yang et al, 2025).

Nickel can cause skin irritation and allergic reactions, such as eczema and contact dermatitis (Baumann and Crist, 2020). Exposure to nickel in the air or water can cause respiratory problems, such as asthma and bronchitis (Gate et al., 2023). Consuming high levels of nickel can cause nausea, vomiting, and other digestive problems (El Brouzi et al., 2025). There is some evidence that long-term exposure to nickel in drinking water may increase the risk of lung and nasal cancer. However, the evidence is still inconclusive, but its presence is a potential risk to consumers (ATSDR, 2024).

From table 4, the Biological Oxygen Demand (BOD) of all the samples (0.1 - 0.8) mg/L for samples GB, GC, and GD (Ground water from vicinity Soap, oil, and foam industries) respectively, are within the WHO acceptable limit of  $< 3$  mg/L. Also, the Total plate count of samples A, B, and C (food, soap, and vegetable oil industry) is 10, 15, and 23, respectively, and falls within the WHO acceptable limits of  $\leq 100/100$ mls, respectively. Notwithstanding, all samples showed the presence of coliform counts, which makes them unfit for consumption and therefore do not pass the water quality test. This is similar to a study done by Adugna et al (2024) in Ethiopia, where a systematic review and meta-analysis of 62 studies on coliform bacteria contamination of groundwater was done. They found that the overall prevalence of coliform bacteria in groundwater was 48.9%, with significant variation across different regions of the country. The researchers also found that the presence of coliform bacteria was significantly associated with a number of factors, including well depth, well type, and season. The study highlights the need for improved monitoring and management of groundwater resources in Ethiopia to prevent the spread of waterborne diseases associated with coliform bacteria contamination. The World Health Organization standard guideline stipulates zero coliform contamination. From Table 5, all the samples showed the presence of *Staphylococcus aureus*, rendering the ground waters unfit for drinking. Consuming water contaminated with *Staphylococcus aureus* can cause gastrointestinal illness, such as diarrhoea, nausea, and vomiting (CDC, 2024). *Staphylococcus aureus* can cause skin infections, such as impetigo and cellulitis, when it enters through cuts or other openings in the skin (CDC, 2021). In rare cases, *Staphylococcus aureus* can cause respiratory infections, such as pneumonia, particularly in individuals with weakened immune systems (Taylor et al, 2025). In extreme cases, *Staphylococcus aureus* can cause systemic infections, such as sepsis, particularly in individuals with weakened immune systems (Taylor et al, 2025).

Samples GA and GD (Groundwater from the food and foam industry) showed *Escherichia coli* and *Proteus* spp contamination, respectively, but their corresponding water effluent samples were not contaminated. This contamination might likely be from other external sources other than the industrial effluent. Drinking water contaminated by *Escherichia coli* and *Proteus* spp. can result in gastrointestinal illnesses such as diarrhoea, nausea, and vomiting (Mayo Clinic, 2022). According to Michael and Stephen (2025), urinary tract infections caused by *Escherichia coli* and *Proteus* spp. can cause painful urination, frequent urination, and other symptoms. The main pollutants detected in the groundwater were heavy metals such as cadmium (Cd) and Nickel (Ni), total dissolved solids, and organic matter. Additionally, the total dissolved solids (TDS) and organic matter concentrations were higher in groundwater samples taken closer to the industrial discharge points. The analysis of the water quality data showed that the concentration of pollutants in the groundwater exceeded the maximum permissible limits set by regulatory bodies such as the World Health Organization and local regulatory agencies in several instances. The study also found that the pH of the groundwater was generally lower in the vicinity of the industrial discharge points, indicating the influence of the effluent on the natural buffering capacity of the groundwater.

The One-Way ANOVA result revealed that there is no statistically significant difference among the mean values of the physicochemical parameters ( $F = 1.075$ ,  $p = 0.384 > 0.05$ ). The correlation analysis of the physicochemical properties of the water samples showed a strong positive relationship between temperature and turbidity ( $r = 0.967$ ,  $p = 0.000$ ), indicating that higher temperatures are associated with increased turbidity. There was also a strong negative correlation between pH and conductivity ( $r = -0.866$ ,  $p = 0.005$ ), suggesting that more acidic water tends to have higher ionic content. Other correlations among temperature, TDS, conductivity, and turbidity were weak and not statistically significant.

The One-Way ANOVA result indicated that there is a statistically significant difference among the mean concentrations of the anions ( $F = 2.683$ ,  $p = 0.047 < 0.05$ ). The correlation analysis of anions in the water samples showed a significant negative correlation between nitrate and alkalinity ( $r = -0.756$ ,  $p = 0.030$ ). This shows that higher nitrate concentrations are associated with lower alkalinity levels. Sulphate showed a moderate positive correlation with nitrate ( $r = 0.540$ ) and a moderate negative correlation with alkalinity ( $r = -0.694$ ),

although these were not statistically significant. Other correlations among sulphate, chloride, phosphate, and the other anions were weak and not significant.

The One-Way ANOVA result showed a highly statistically significant difference among the mean concentrations of the heavy metals ( $F = 34.045$ ,  $p = 0.000 < 0.05$ ). The correlation analysis of heavy metal concentrations in the water samples showed a strong positive correlation between nickel and manganese ( $r = 0.972$ ,  $p = 0.028$ ), indicating that higher nickel levels are associated with higher manganese concentrations. Chromium also showed perfect positive correlations with both nickel and manganese ( $r = 1.000$ ). Cadmium showed weak positive correlations with nickel ( $r = 0.165$ ) and manganese ( $r = 0.169$ ), which were not statistically significant. Significant linear relationships were mainly observed between nickel and manganese.

The One-Way ANOVA result revealed a statistically significant difference among the mean values of BOD, total plate count, and coliform count ( $F = 12.923$ ,  $p = 0.000 < 0.05$ ). The correlation of the biological composition of the water samples was strongly positive and statistically significant with the total plate count and coliform count ( $r = 0.977$ ,  $p = 0.000$ ), indicating that higher total bacterial counts are associated with higher coliform levels. BOD showed weak positive correlations with both total plate count ( $r = 0.334$ ) and coliform count ( $r = 0.276$ ), and were statistically insignificant.

## 6. Conclusions

This analysis, supported by literature, indicates that industrial activities—particularly those involving soap, oil, and food production can lead to high conductivity, acidic pH, elevated TDS, and turbidity in nearby water sources. This trend has been observed in similar studies, suggesting that without adequate wastewater treatment, industries can contribute to groundwater pollution, impacting both environmental and human health.

By comparing these results with previous research, it's clear that effective wastewater management and adherence to regulatory standards are essential to protect water quality in industrial zones. The elevated turbidity, low pH, and high conductivity observed in this study underscore the importance of monitoring and mitigating industrial pollutants to prevent contamination of groundwater resources. Furthermore, the study revealed that the impact of industrial effluent on groundwater quality was influenced by several factors, including the type and volume of effluent discharged, the characteristics of the soil and aquifer materials, and the hydraulic conductivity of the aquifer.

In conclusion, the study highlights the potential risks of industrial effluent on groundwater quality and the need for improved monitoring and management of industrial discharge to minimize the impact on the environment and public health. It is a well-known and established fact that the air, soil, and water around manufacturing companies are contaminated by the waste/bye products discharged or emitted by such industries. It will therefore be wrong to assume that because water is colourless, odourless, and tasteless, it is fit for use, especially for drinking and cooking purposes. Therefore, it is important that water, especially from such environments that are prone to contamination, be assessed and adequately treated before being ratified as fit for consumption. This is even more important and necessary because sometimes, the pollution may not necessarily come directly from the manufacturing industries, as shown by some of the results obtained from this research, but also from human activities and other natural pollutants. Point source pollution comes from identifiable localized sources such as factory ditches, which is easier to control, but nonpoint source pollution comes from rainfall or snow melt moving on land picking up pollutants like agricultural waste, and depositing into waterways, which can be difficult to control.

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