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INVESTIGATING THE IMPACT OF AGRICULTURAL ACTIVITIES ON GROUNDWATER QUALITY IN A FARM SETTLEMENT

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Abstract - Agricultural activities are essential for food security globally, especially in developing countries. However, they can also become a source of pollution for groundwater and other water bodies. This paper evaluates the effects of agricultural activities on groundwater quality, highlighting management strategies in relation to pollutant concentration during the wet and dry seasons using water samples from different wells within Ebenebe town in Anambra State. The findings of this study identified nitrates, phosphates, and heavy metals as major contaminants in groundwater resulting from agricultural activities, especially during rainy seasons. The concentrations of pH, turbidity, and conductivity were within WHO and NSDWQ acceptable limits of 6.5-8.5, < 5 NTU, and 1000 μScm^{-1}, respectively, while alkalinity and Total hardness had a few samples that moderately exceeded the permissible limits. Also, Dissolved Oxygen exceeded both the WHO and NSDWQ standards; nonetheless, all samples were colourless and odourless in line with standards. The Standard Deviation (SD) of data obtained during the investigation indicates moderate variability, consistency, and predictability of not more than 20 % of the mean values for most of the parameters. However, phosphates (PO_4^{3-}) had a high SD of about 36 % of the mean values, which shows high variability, suggesting noticeable fluctuations. Effective management strategies, which include conservative agriculture and policy interventions, can mitigate overuse of fertilizers and pesticides and reduce groundwater contamination.

Keywords: Groundwater Quality, Agricultural Activities, Dissolved Oxygen, Nitrates, Phosphates, Heavy Metals

1. Introduction

Having access to adequate food security is the greatest need aside from only availability of drinking water, which makes agriculture an integral part of the economy globally. Although mechanization of farming in some countries has led to a drastic decrease in the percentage of the population working in the agriculture sector. However, the pressure to produce more food resulted in a global impact on agricultural practices in many countries. Furthermore, this desire to produce more food has resulted in agricultural expansion, such as subsistence farming FAO, (2021). So many countries require irrigation expansion, increased pesticides, and fertilizers for sustainable farming,which leads to food security. Sequel to the above, FAO 2021's Strategy on water as an important factor in agricultural sustainability, is in line with the United Nations 2017 Conference on Development of the Environment. This conference highlighted challenges of food security in the 21st century, such as socio-economic, environmental, and human health effects,which should be included in developmental plans. Therefore, agricultural activities play a vital role in food security, but also pose significant threats to groundwater quality. The overuse of fertilizers, pesticides, and irrigation can lead to contamination, affecting human health and the environment.

Groundwater, on the other hand, is a vital component of the global water supply, providing drinking water for millions of people and supporting agricultural and industrial activities(Craswell 2021). It constitutes a significant portion of the global freshwater supply. However, groundwater is susceptible to contamination from various sources, including agricultural activities. Agricultural waste, comprising both organic and inorganic materials, can have profound impacts on groundwater quality. This includes polluted runoff as a result of fertilizers, pesticides, and animal manure application on agricultural fields that can infiltrate groundwater systems. Maintaining high groundwater quality is crucial for public health and the environment. Contaminated groundwater can lead to a range of health issues, including methemoglobinemia (blue baby syndrome) from nitrate pollution, cancer from pesticide exposure, and neurological damage from heavy metal contamination (Anijiofor-Ike 2023). Furthermore, poor groundwater quality can affect crop yields and livestock health, ultimately impacting food security and economic stability.

Modern agricultural practices often rely heavily on chemical inputs to enhance productivity. Fertilizers are applied to increase crop yields, while pesticides control pests and diseases. However, excessive and improper use of these chemicals can result in significant environmental pollution (Srivastav 2020). For instance, nitrates from fertilizers can leach into groundwater, while pesticide residues can persist in the soil and migrate to water sources. Additionally, animal farming produces large quantities of waste that can contain pathogens, nutrients, and pharmaceuticals. Several non-point source pollutants are transported through soil by stormwater, and these pollutants infiltrate groundwater, move through wetlands, lakes, rivers, and oceans in the form of sediments, termed ``Sediment Transport. These pollutants affect the ecosystem in various ways, which involves birds, fish, animals, and even humans. Canada and the United States have undertaken several programmes of point and non-point source identification and control to assess the level of pollutant transport. These programmes raised public awareness on deterioration in water quality, indication of algal blooms, and an increase in aquatic weeds, although the situation is known as hypertrophic conditions caused by excessive phosphorus in surface and groundwater sources.

According to the World Health Organization (2011), about 4 million children die yearly from diarrhoea caused by water-borne infection. It has been noted that agricultural pollution affects human health both directly and indirectly. The WHO alsoreported the increase in nitrogen concentration in groundwater in several parts of the world due to intensified farming practices (WHO, 2011). These increased Nitrate levels have exposed more than 10% of the population to nitrate in drinking water, with cases of methaemoglobinaemia, which affects mainly infants (EPA, 2020). Despite the fact that these problems are not extensively documented, groundwater pollution as a result of excessive nitrogen is a major problem in developing countries. According to Dlamini (2020), nitrate concentrations of about 40-45 mg N/L were recorded in irrigation wells near intensively cultivated farmlands, while Cosmos et. al (2015) noted that water pollution has consequences on both agriculture and human health, especially in developing countries. Contamination of water supplies primarily by pesticides and fertilizers has known health effects.Kaur and Sinha (2019) also stated that agriculture is a significant non-point source contributor to surface and groundwater pollution due to intense cultivation and livestock operations. In a recent study, (UN, 2017; EEA, 2019) compared domestic, agricultural, and industrial sources of pollution and concluded that agriculture was the leading source of phosphorus compounds and sediment.Dlamini (2020) stated that excessive concentration of nitrate in polluted water could cause stomach disorders in adults.

Metals have a specific gravity greater than 4.0 and exist in water as colloidal, particulate, and dissolved stages with their original form in water bodies. Most heavy metals constitute environmental and health hazards, while others cause corrosion. Although some of these elements in very minute quantities are necessary for humans, others are toxic or carcinogenic. According to Brady et al. (2010), heavy metals do not decompose like organic pollutants therfore, groundwater should be considered an essential aquatic ecosystem in addition to a source of drinking water (Anijiofor-Ike, 2023). Indeed, groundwater provides more than half of the yearly flow in several rivers, so any form of groundwater deterioration could affect several aquatic and land ecosystems. Furthermore, due to high salinity and mineral concentrations, groundwater quality frequently deteriorates and availability gradually declines beyond this level. (Ahmad, 2020). According to Husseinet al. (2022), pollution arising from agricultural, industrial, and household sources directly through effluent discharge or through the spread of pesticides and fertilizers or through leaching action from landfills remains a major environmental and health concern.Toxic and dangerous waste can lead to possible carcinogenic fibres being introduced into the smoke plume when burned with other waste, such as asbestos fibre. In further studies, Ike et al (2018) and Anijiofor et. al (2021)stated that lead, which is a major source of water pollution, has been implicated in various diseases such as anaemia, anorexia, brain damage, vomiting, mental deficiency, and even death in humans. Furthermore, cadmium has been linked to antagonistic and agonistic effects on enzymes and hormones, which lead to liver and kidney diseases, lung cancer, a decrease in bone strength,and bone loss. There are, therefore very extensive possible health effects from groundwater pollution.

This paper investigates the effects of agricultural activities on groundwater quality, identifying the most significant pollutants and recommending sustainable practices to mitigate these impacts using a farm settlement in Ebenebe Town, Awka L.G.A. as a case study.

2. Methodology

The location for the study is Ebenebe town in Awka North LGA of Anambra State, Nigeria, which has an estimated population of 45,897 (2016 Nigerian census). It is located at coordinates $6^{o}20'02''$ N, and $7^{o}07'45''$ E. The town is about 25 km from Awka, the state capital, and has climate and soil conditions favorable for farming. Ebenebe town is a major hub for agricultural activities, and so the town is recognised as one of the highest producers of agricultural products in Anambra State, with people coming from surrounding towns and cities to buy farm produce during its several daily markets. Ebenebe has boundaries with Amansea towards the South, towards the west, it has boundaries with Odoli River and Mgbakwu, Agbaja, Ezeagu in Enugu State to the East, and Ugbenu towards the North. The town experiences a significant amount of rainfall and high humidity, especially during the rainy season from March to October, while the dry season is experienced from December to March.. The city also experiences other weather conditions such as Harmattan, which is a dusty wind that lasts few weeks in December and January.

Three sampling locations 1, 2, and 3, were designated for this study, and sampling was done in both dry and wet seasons, covering September and December 2024. Three water samples were collected for water quality analysis, two times within four (4) months, represented as September (A), October (B), November (C), and December (D). The water samples were collected in well-labelled plastic bottles and labeled properly, and then immediately transported to the Water lab for laboratory analysis. The groundwater samples were collected in triplicate from each sampling point using plastic bottles, which were previously washed with 1 N hydrochloric acid and then distilled water. The bottles were labeled A1, A2, and A3 according to the sampling points. The water samples were collected in well-labelled plastic bottles and labeled properly, and then immediately transported to the Water lab for laboratory analysis. This was used for the determination of physio-chemical properties of water samples in the laboratory.

The water quality parameters investigated were physical and chemical properties using established analytical procedures (APHA 1992). The determinants were pH and temperature, Electrical conductivity (EC), Dissolved Oxygen (DO), Total Alkalinity, Total Hardness (TH), Lead (Pb), Copper (Cu), and Manganese, Nitrate (NO^{3-}), nitrite (NO^{2-}), and phosphate ($PO4^{3-}$) which are significant to this this study. Electrical Conductivity was measured using a conductivity meter, while pH/Temperature were determined using the pH meter. Spectrophotometry was used to determine nutrient concentrations such as nitrates and phosphates, while Gas Chromatography-Mass Spectrometry (GC-MS) was used for the detection of pesticide residues. Heavy metals in water were analysed by Inductively Coupled Plasma Mass Spectrometry (ICP-MS). Before heavy metals determination, 100 ml of each of the samples was digested with 5ml of nitric acid (HNO3) for organic molecules to be liberated from the samples, and then heated at 45 °C to 65°C before being taken to the laboratory for analysis.

3. Results and Discussions

The analysis of the physical parameters from the sampled well water shows that in virtually all the sample locations, colour, turbidity, and odour were within acceptable WHO standards as presented in Table 1.

Table 1: Summary of Results for Physical Parameters

	Colour	ODOUR	TURBIDITY
WHO STANDARD	Colourless	Odourless	5 NTU (mg/l)
A1	Colourless	Odourless	< 5
A2	Colourless	Odourless	< 5
A3	Colourless	Odourless	< 5
B1	Colourless	Odourless	< 5
B2	Colourless	Odourless	< 5
B3	Colourless	Odourless	< 5
C1	Colourless	Odourless	< 5
C2	Colourless	Odourless	< 5
C3	Colourless	Odourless	< 5
D1	Colourless	Odourless	< 5
D2	Colourless	Odourless	< 5
D3	Colourless	Odourless	< 5

NB: Turbidity less than 5 NTU signifies CLEAR water

From Table 1, all physical variables for all the water samples were in total compliance with the WHO standards. This showed that the groundwater is colourless and odourless at the time of sampling, and turbidity was at an acceptable range, with all samples less than 5 NTU.

Table 2: Summary of Results for Chemical Parameters

	Ph	Total Alkalinity(mg/l)	Total Hardness (mg/l)	Dissolved Oxygen (mg/l)	Conductivity (μScm^{-1})
WHO STANDARD	6.5 – 8.5	200	100	2	1000
NSDWQ	6.5 – 8.5	NS	NS	NS	1000
A1	6.99	116	70	5.40	680
A2	6.85	122	60	5.60	618
A3	6.80	109	58	6.00	452
B1	7.77	90	60	6.10	133
B2	7.11	78	60	6.00	481

B3	7.33	82	40	6.60	662
C1	7.60	106	65	7.10	591
C2	7.48	272	155	6.80	1020
C3	6.40	254	173	5.30	960
D1	6.33	190	102	4.90	840
D2	7.82	154	85	7.70	494
D3	7.83	189	95	6.80	474

The chemical parameters tested during the sampling period are presented in Table 2 and subsequently compared with the WHO and NSDWQ standards. The results showed visible variations in all the chemical parameters sampled from wells around the area. The observed pH variations, which ranged from slightly acidic to slightly alkaline, influence the solubility and mobility of contaminants. The pH varied between 6.33 and 7.83, which showed neutral to slightly alkaline nonetheless, the values were within range for both WHO and NSDWQ standards, while the temperature ranged between 25.1 ^{o}C and 26.2 ^{o}C, which is below the standard limit of 35 ^{o}C – 40 ^{o}C. Meanwhile, cases of pH values of 6.33 and 6.40 indicate possible runoff from fertilized fields. Alkalinity, which is the ability of water to neutralize acids, is underscored by its ability to control pH changes. However, in this study, there were slightly elevated levels of alkalinity and total hardness, which suspects possible pollution from agricultural activities, although more water samples showed values within permissible limits for both WHO and NSDWQ standards. In the case of Dissolved Oxygen, the results obtained from the sampled water showed high values for dissolved oxygen, which were more than the WHO and NSDWQ permissible standards. This could be explained because groundwater hassubstantially high levels of Dissolved Oxygen. However, the ideal DO in water is dependent on factors such as PH and temperature. High levels of conductivity showed moderate pollution of well water, which could be a result of agricultural activities such as fertilizers and irrigation return flows. Meanwhile, the values for conductivity fluctuated within the WHO and NSDWQ range for the permissible standard. Moderate Conductivity values indicate possible nitrate and phosphate levels, suggesting a link between agricultural runoff and increased dissolved solids, which is in line with other studies (Pradhan et. al., 2023; Chakraborty, 2021; Victor, 2020; Ugochukwu and Ojike, 2020)

Table 3: Summary of Results for Heavy Metals and Nutrients

Parameters	**Lead mg/L**	**Copper mg/L**	**Manganese mg/L**	**Nitrates mg/L**	**Phosphates mg/L**
WHO STANDARD	0.015	0.5	0.5	50.0	10
NSDWQ	0.01	1.0	0.2	50.0	10
A1	0.00	0.04	0.7	66.3	16.1
A2	0.00	0.03	0.5	59.5	14.8
A3	0.00	0.10	0.6	62.4	14.2
B1	0.00	0.03	0.2	58.6	14.6
B2	0.00	0.05	0.5	59.8	13.4
B3	0.00	0.05	0.6	50.7	9.3
C1	0.00	0.04	0.7	55.3	9.8
C2	0.00	0.04	0.6	50.3	8.7
C3	0.00	0.05	0.6	39.0	8.9
D1	0.00	0.13	0.8	42.4	7.1
D2	0.00	0.04	0.6	32.5	6.2
D3	0.00	0.05	0.6	44.6	4.1

The samples were also assessed for possible heavy metals (Lead, Copper, and Manganese), and Nutrient pollution (Nitrates NO_3^- and Phosphates PO_4^{3-}), and the summary of the results is shown in Table 3. It shows that there was no lead concentration in the samples and so has 100% compliance with the WHO and NSDWQ. According to Payne (2008), lead is a very dangerous heavy metal that has toxic effects on human health, especially children, as most vulnerable population. Various problems associated with neuro-development and increased attention-deficit hyperactivity disorder risk in children have been linked to excessive exposure to lead (Payne, 2008). However, in this study, the concentrations of Lead in the samples were insignificant to pose any serious health threat to individuals. The level of Copper concentration in the sampled water in Table 3, which was in the range of 0.02 to 0.13 mg/L, suggests thatall the samples were within the WHO limit and NSDWQ standard. Although this indicates moderate pollution, it does not pose any serious health risks. High intake of copper can cause vomiting, stomach ache, diarrhoea, and dizziness, and can also result in kidney and liver damage, which eventually may lead to death. The level of Manganese concentration in the sampled water in the range of 0.2 to 0.8 mg/L shows that there were slight variations from the WHO and NSDWQ standards in most of the samples, which indicates moderate pollution. Manganese concentration in river water varies depending on land use, geology, and human activities such as agricultural activities like fertilizer use, soil type, and irrigation practices. Although a small amount of manganese is essential for human health, recent research suggests that too much manganese in drinking water can be risky to health.

Excess nutrients from fertilizers and manure can leach into the soil and contaminate groundwater. Also, irrigation, soil erosion, and livestock grazing are all forms of agricultural activities that cause nutrient pollution of groundwater. Nitrate levels exceeded the safe drinking water limit in about 40% of the samples, particularly in areas with intensive fertilizer use, especially during the rainyseason.Elevated phosphate levels, especially during the rainy season as seen in samples A and B in Table 3, suggest significant runoff from fertilized fields.

3.1 Statistical Analysis

The statistical analysis of the parameters was calculated and presented in Table 4.

Table 4:Statistics of Investigated Parameters

Parameters	Range	Mean	Standard deviation
pH	6.33-7.83	7.19	0.53
Total Alkalinity(mg/l)	104	146.80	35.84
Total Hardness (mg/l)	133	85.25	39.37
Dissolved Oxygen(mg/l)	2.8	6.19	0.83
Conductivity(μScm^{-1})	887	617.08	143.46
Lead (mg/l)	0.00	0.00	0.00
Copper (mg/l)	0.1	0.054	0.03023
Manganese (mg/l)	0.60	0.583	0.1475
Nitrates (mg/L)	33.8	51.78	10.376
Pphosphates (mg/L)	12.0	10.6	3.901

Table 4 shows the statistics of parameters investigated during the period, which include the range, mean, and standard deviation. Standard deviation (SD) is a measure of the amount of variation of a set of data. It plays a crucial role in understanding and interpreting pollutant values in water quality assessments. The SD values in Table 4 indicate a moderate variability in the data set of not more than 20 % for most of the parameters however, phosphates had a high SD of about 36 % of the mean values, which shows high variability, suggesting noticeable fluctuations. The data points are spread out however, most of them are still close to the mean,which suggests that the data has some level of consistency, variability, and predictability but allows for some fluctuations. It also explains compliance of pollutants with regulatory guidelines, which have been established for most of the parameters investigated.

4. Conclusion and Recommendations

This study identified nitrates, phosphates, and heavy metals as major contaminants in groundwater resulting from agricultural activities. Pollutant levels varied significantly at different seasons and locations, with higher concentrations in areas of intensive agriculture and during rainy seasons. The concentrations of pH, turbidity, and conductivity were within WHO and NSDWQ acceptable limits of 6.5-8.5, < 5 NTU, and 1000 **μScm^{-1}**, respectively. Alkalinity and Total hardness had a few samples which moderately exceeded the acceptable limits,which are 200 mg/L and 100 mg/L, respectively, while Dissolved Oxygen exceeded both WHO and NSDWQ standards with very high values greater than 2 mg/L. Also, heavy metals and nutrientshad concentrations slightly higher, although the majority of the parameters were significantly within the range of permissible limits for WHO and NSDWQ standards.These Elevated levels of nitrates and phosphates were noticed during the rainy season.

Nonetheless, all samples were colourless and odourless in line with WHO and NSDWQ standards for drinking water quality. Overuse of fertilizers and pesticides, and lack of buffer zones were identified as key contributors to groundwater contamination. The contamination of groundwater affects drinking water quality and also has broader environmental implications, including the potential for eutrophication in connected surface water bodies. The presence of harmful contaminants in groundwater poses serious public health risks, necessitating urgent attention and action. Current agricultural practices need to be reassessed and improved to ensure they do not continue to degrade groundwater quality.Integrated Pest Management (IPM) practices should be adopted to minimize pesticide use and reduce the risk of contamination. Incentives and support for farmers should be put in place to adopt sustainable agricultural practices, such as subsidies for organic farming and financial assistance for implementing BMPs.

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