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Environmental Impact and Physico-Chemical Analysis of Flood Water Intrusion in Domestic Boreholes and Well Water Quality in Isoko North Local Government Area and Environs in Delta State, Nigeria

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Abstract

Environmental impact and water quality characteristics of flood water intrusion in domestic boreholes and well water quality were investigated with the view to determining the extent of pollution. Parameters such as physic-chemical, heavy metal and micro-biological content were tested for and their impact identified. This research was based on the hydro-geo-pollution cycle as these chemical elements return back to man eventually through the process of bio-accumulation. The water samples from boreholes and wells had high levels of dissolved oxygen (DO), pH, and heavy metals, particularly Pb^{2+} and Fe^{+}, according to a physico-chemical examination. Analysis was made possible by mapping the GPS-measured locations of the fifteen sample sites onto the topography plan of the research region. WHO and NSDWQ, responsible for drinking water standards were contrasted with findings to determine any differences. The water sample has a "VI" grade on the Heavy Metal Index calculation scale, indicating a "Seriously Affected" water distribution mechanism, due to a substantial amount of heavy metals, especially Pb^{2+} and Fe^{2+}.The study shows that in some areas, the flood water intrusion for physico-chemical parameters is predominant as evident in some of the samples as against others. This means therefore, that the flood water influences the physic-chemical, heavy metal and micro-biological concentrations of the groundwater quality of the affected areas, either through direct inflow into the water supply system, or through the process of elluviation.

***Keywords**: Boreholes, quality, environs, flood, groundwater, accumulation.*

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1. Introduction

In most moderately humid climates, stream channels adjust to accommodate average stream flows, where the water level may have been well below the stream bank height for much of the year, though, heavy rains or sudden snow melt can deliver more water than the stream can carry (Plummer et al. 2021). The excess water that overflows the stream banks and covers adjacent land is considered as flood (Cunningham & Cunningham, 2006). Plummer et al., (2021), also described flood as the high water occurrence as a result of slow rate of infiltration due to a higher rate of precipitation and saturation, which results to the accumulation of water over streets, agricultural fields, invading buildings, shorting out electrical lines and backing up sewers. Water supply systems may fail or be contaminated, as is in the case of this research area. During flooding, certain environmentally challenging occurrences takes place, such as scarcity of safe drinking water (Joannou *et al.*, 2019 and Barbetta *et al.*, 2022), disruption of water treatment facilities and as a consequence to these effects, disease out-break (Shimi *et al.*, 2010) amongst others are typically prevalent issues that bedevils the inhabitants of the area affected. Moreover, the degradation pollution transmission and the consequences of flooding on groundwater recharge are potential causes of groundwater quality declines (Zhang *et al*. 2017, Comte *et al*., 2018 and Alam *et al.* 2020). Severe floods can also result in turbidity in stored water, which degrades its quality, and stop abstraction from constructed reservoirs (Chou and Wu, 2010). According to Joannou *et al*., (2019) and Sweya and Wilkinson (2020), flooding can have an impact on fields of wells plus lead to pump failure added to the entry of chemically or microbiologically polluted water from floods into wrecked structures and submerged wells. It may potentially result in harm with relation to the manner of care for the element, which would prevent treatment or water quality management from continuing (Barnes *et al.*, 2012, Koh *et al.*, 2017). Last but not least, flooding can harm the infrastructure of the supply network, impairing supply services and contaminating water supplies (Arrighi *et al*. 2017, Joannou *et al.*, 2019 and Barbetta *et al*., 2022). Flooding may occur as an overflow of water from water bodies, such as rivers, lakes or dams, in which the water overtops or breaks levees, resulting in some of that water escaping its usual boundaries (Si *et al.* 2022) or it could happen because of rainwater collecting on soggy soil and causing an aerial flood. Seasonal variations in rains and snowmelt will affect lakes and other body of water's size, but these changes won't likely be taken seriously unless they cause property to flood or domestic animals to drown (Cunningham & Cunningham, 2006) (see plates 3 – 6 below). About 2 billion people (approximately one-third of the world's population) depending on groundwater for domestic, industrial and other uses (Vasanthavigar *et al.*, 2012; Adeyemi and Ojekunle, 2021). Various pollution indices, namely heavy metal pollution index (HPI), contamination index (Cd), heavy metal evaluation index (HEI) and geopollution index, have been used in the past to evaluate the extent of pollution in groundwater (Prasanna *et al.*, 2012; Venkatramanan *et al.*, 2015; Singh, *et al.*, 2017; Wagh *et al.*, 2018; Herojeet, et al. 2020) with some degree of pollution found. An estimated 700m^3 of water is withdrawn mostly from shallow and easily polluted aquifers (Cunningham & Cunningham, 2006). Various studies prior to now have been carried by different researchers in like vein, to emphasis on the environment health dangers of flood intrusion in consumable water sources, but not restricted to the area under study. They include: Abu and Codjoe, 2018; Joannou et al., 2019; Smiley and Hambati, 2019; Alam et al., 2020; Sweya and Wilkinson 2020; Barbetta, et al., (2022) and Birhan, et al., 2023). This study therefore, is a research that facilitates continuous explorations for creating policies that tackle groundwater contamination in Isoko North Local Government Area, of Delta State, Nigeria. The study aims to examine how flood water intrusion influences the standard of underground water supplies in the research location (see plates 1and 2 below for concrete cast attempt at preventing floodwater inflow. And plates 3 – 7 for other matters).


Plates 1 and 2: Borehole casing pipe with submersible pump encased in a concrete slab to prevent intrusion of flood seen in the study vicinity.


Plates 3 and 4: Intrusion of flood seen in the study vicinity



Plate 5**:** A PVC casing pipe extended above the previous hight in a bid to prevent the intrusion of the floodwater contamination. The mark of the white tape indicates the level the floodwaters above the initial casing in that particular location.

Plate 6: A concrete re-enforced open well, elevated in a beed to prevent the intrusion of the floodwater contamination.

Plate 7: Water sample abstracted from flooding water before transporting to the lab for analysis.

2. Materials and Methods

The study area, Isoko North LGA is located between Latitude 50 151 N to Latitude 50 401 to the north of the equator and Longitude 60 151 E to Longitude 60 251 East relating to the Greenwich Meridian (Olomo and Ejemeyovwi, 2008). The research area lies within a tropical climate zone with a hot and humid temperature, and distinct wet and dry season. The month of April ushers in the season of rainfall, which ends in October, with a brief spell of dry sunny weather of about two weeks in August, referred to as the August break. The yearly temperature starts from 280C to 330C with a mean annual rainfall of between 3000mm south of the area to 2500mm north of the area (Olomo and Ejemeyovwi, 2008). The area's geology is acknowledged to be on the clastic sediments of the Benin Formation and alluvium deposit (Nwajide 2013) See figure 1 below for map of the study area.

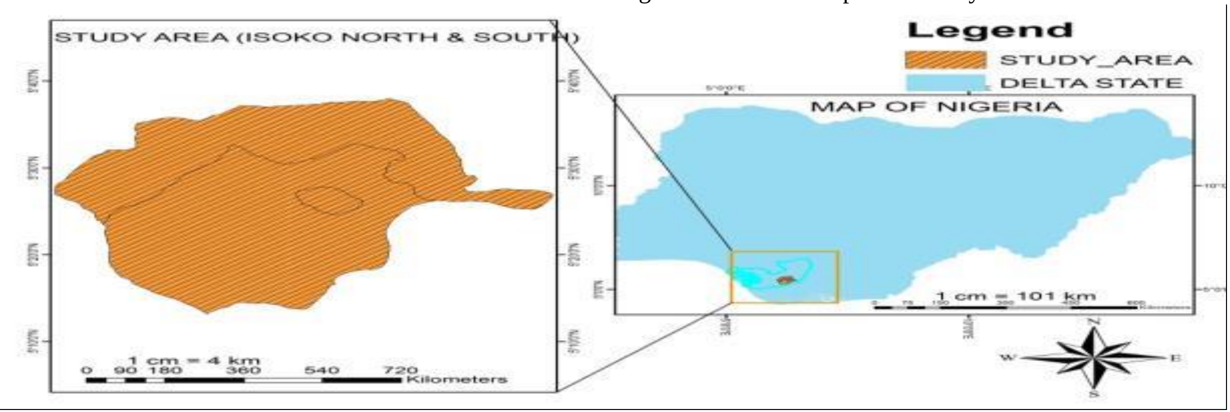


Figure 1: The research area's map.

The Benin Formation is lithologically composed of sandstones, mudrocks, siltstones, and ironstones, especially in the Asaba region. Previous research on the Benin geologic formation suggest that its soils and sediments generally have properties, like the grain size distribution, hydraulic conductivity, transmissivity, and pumping test estimates, these are characteristics of prolific aquifer systems (Nfor, et, al 2007; Nwajide 2013; Egbueri, et, al. 2019). Similar studies of the location's geology have been analysed by Anomohanran (2014). The summary of the geology and associated groundwater resources of Delta State have also been described by Aweto and Akpoborie (2011) among others, as displaying the characteristic features of seaward sloping flat and featureless plain; predominantly sandstone formation.

Isoko North has an estimated landed area of 1536km^2, (Olomo, 2008). The point sampling technique was adopted in this research. And the study adopted the random point sampling method for data collection. Point sampling is particularly relevant in situations where the phenomenon under study is spatially spread over a large area (Awaritefe, 2007). This pattern of distribution is aimed at ensuring equitable sourcing of groundwater sampling. There are in total, fifteen (15) underground water samples taken from the research area for analysis. These specimens were taken from existing and productive boreholes and open wells. Where possible, the history and characteristics of the borehole was noted for record purpose. The samples were collected into fifteen (15) plastic jerry cans of 2 litres each with covers. Once the jerry can was filled with water, it was covered and labeled to minimize oxygen contamination and the escape of dissolved gasses as described by WHO (2004) (see table 1 below for sample location co-ordinates). Samples from each borehole were tested for bacteriological, chemical, and physical characteristics along with presence of heavy metals. The test was conducted in Chemical Engineering Laboratories of Delta State University of Science and Technology, Ozoro, Nigeria. Selection of what is being examined in this study for each parameter is primarily influenced by designs of earlier studies, such as Alam *et al*., (2020). This comprises the following: total Fe, Cu, Zn, K, Mg, Na, Pb, and Ca, Mn, Cr, As, and V for heavy metals; conductivity, turbidity, and total suspended solids (TSS) for the physical parameters and pH, dissolved oxygen (DO), total dissolved solids (TDS), total hardness, Nitrate (NO3), Cl1, HC03, Ak, SO4, P04, TH, BOD, COD, and DO for the chemical parameters. The existence of bacteria and other microbial activities were examined by the bacteriological analyses. The pH levels of the water samples were measured directly using a Mettler Toledo Digital pH meter, the temperature was measured with a mercury thermometer, and the turbidity was measured with a Hach 2100A turbidimeter. Using a spectrophotometer and traditional laboratory analysis, the samples' DO levels, total hardness, and TDS were evaluated. Chloride in sampled water was analyzed in a lab using standard titration techniques (American Public Health Association, 2005). Using an Atomic Absorption Apectrophotometer (AAS), concentration of heavy metals for instance Ca_{2+}, Mg^{2+}, Na^{+}, K^{+}, Fe^{2+}, Cu^{2+}, Zn^{2+}, and Pb^{2+} was determined. By using membrane filter and autoclave procedure for Thermotolerant Coliform Bacteria and E-coli investigation, the bacteriological parameter was ascertained. The values of World Health Organization (WHO) and Nigerian Standard for Drinking Water Quality (NSDWQ) served as control variables. To prevent deterioration by environmental variables, samples were assessed for pollution parameters as soon as possible after collection using the recommended analytical techniques (WHO, 2017 & NSDWQ, 2007). Tables 2, 3 and 4 below, show findings from different water samples and comparison of parameters in cooperation with World Health Organization (WHO) and Nigerian Standard for Drinking Water Quality (NSDWQ) (while table 1 displays the GPS coordinates of sampled areas).

Table 1: The GPS location of the sample area.

Sample Location	Latitude	Longitude
BH1 (NA)	5.536403	6.218654
BH2 (NA)	5.468365	6.208672
BH3 (NA)	5.462736	6.205812
BH1 (A+)	5.456837	6.197635
BH2 (A+)	5.444701	6.196412
BH3 (A+)	5.45326	6.209913
Ww1 (NA)	5.536705	6.218691
Ww2 (NA)	5.468583	6.208747
Ww3 (NA)	5.4627	6.205775
Ww1 (A+)	5.5637	6.244153
Ww2 (A+)	5.456492	6.197913
Ww3 (A+)	5.452932	6.209946
FL1	5.68376	6.243414
FL2	5.446023	6.197212
FL3	5.453686	6.208891

3. Results and Discussion

For purpose of understanding, certain abbreviations where utilized to signify some terms. These abbreviations include: SP Id to represent Sample Identity, BH (NA) as boreholes were water samples were taken from, in areas where flooding did not affect. BH A+ represents areas with flood water affecting the areas and possibly the water in the area. WW1 (NA) represents well water taken from areas where flood did not ravage, WW1 (A+) represents areas well water was taken from in flood ravaged area. While FL1 represented the flood water sample obtained for confirmatory test of certain suspected parameters.

On pH, the value for BH1 (NA), BH2 (NA), BH3 (NA), BH1 (A+), BH2 (A+), WW1 (A+), WW2 (A+) and WW3 (A+) have values lower than 6.5, indication that the water samples are acidic in content. The pH ranged from which is more to the acidic side, confirms that there are heavy metals found within the samples particularly toxic metals. These slightly falls beneath the WHO permissible range of 6.5-8.5 and confirmed the acidic nature of the underground water from the boreholes. This finding conforms with that of Christopher *et al., (*2011) and Aharoni *et al.*, (2020). Metals such as Zn, damaged battery cells (Pb, Hg and alkaline) and improperly disposed used cans of aerosol and other disinfectants disposed off as waste, may have reacted with air and water, and found their way to the boreholes through seepage to give it its current poisonous, corrosive character. Although 7.0 is considered neutral, up to 9.2 may be accepted if certain conditions are met, microbiological monitoring showed no deterioration in bacteriological quality (WHO, 2004).

Total Dissolved Solid (TDS), apart from FL1 with a value of 37, which is above the recommended permissible limit, every other sample has a lower figure. Though lower than WHO and NSDWQ values, its presence still indicates pollution in the specimens (WHO, 2004).

For Turbidity (NTU), BH2 (NA), WW1 (A+) the flood waters has values greater than the recommended permissible limits, this indication of the groundwater in BH2 and WW1 (A+) interaction with the rock type in the research area, which results to its high turbidity value. While flood waters had current while flowing, thereby washing along particle of sediments it come across. This finding is in synchronism with of Aharoni *et al.*, (2020). NH_3(mg/l), BH1 (NA), WW1 (NA), WW2 (NA), WW3 (NA) and FL3 all have values more than the allowable limit. The build up of excess ammonia in packaged water, makes it difficult for organisms to excrete the toxicant sufficiently, thereby resulting in toxic accumulation in internal organs and blood; a long term use of ammonium in packaged water alkalizes the blood plasma, which can result in cell hypoxia, it can in turn, potentially lead to death. (WHO, 2017 and Yushchenko, et al., 2023). AK (mg/L), BH1(NA), BH3(A+), WW1(NA), WW2(NA), WW3(NA), WW2(A+), WW3(A+) plus the flood samples all have indication of alkalinity within the specimens. The possible influx of seawater into natural waterways of the environment during flooding might have spiked up the alkalinity level base in the specimens. Wherefore, excessive drinking water salinity is associated with an increased risk of hypertension, risk of preeclampsia and gestational hypertension. Others include, infant mortality, cholera outbreak and skin diarrheal diseases (Dasgupta and Huq, 2016; Al Nahim, *et al.*, 2018 and Chakraborty, *et al.*, 2019). DO (mg/L), BH1(NA), BH2(NA), BH2(A+), BH3(A+) and WW2(NA) all have values that exceed the allowable limit. This indicates the depletion of oxygen in the borehole samples, implying the presence of pollutants that deplete the oxygen in water. All these agreed with observations made by (Igbinosa & Okoh, 2009; Aharoni et al., 2020). Heavy usage of the DO by the pollutants were noticed and showed that the boreholes waters are unsafe for consumption, indicating the direct effect of the floodwater on them. Similar findings were reported in (Akinbile, 2006), emphasizing pollutants in the water in significant levels. DO is a vital variable in water quality regulation, and identical values were logged by (Jaji *et al., 2007*).

K(ppm), only BH1(NA), BH2(NA), FL1 and FL2 have parameters inside the allowable range. Others are far superior. Though, potassium in drinking water is not a health risk, but an increased exposure of potassium could result in significant health effects in people with kidney disease or other conditions, such as heart disease, coronary artery disease, hypertension, diabetes, adrenal insufficiency and pre-existing hyperkalaemia amongst others. This finding is consistent with Ahmad *et al*. (2008) and WHO (2019). The potassium spike in borehole waters is thought to have been caused by sea water invading the environment attributed to the extreme flooding (see figure 2 below for semivariogram of potassium (K) from the study area).

Table 2: The values for physico-chemical parameters

SP Id	pH	CD (uS/cm)	TDS (mg/l)	TSS (mg/l)	CR (pt-co)	TB (NTU)	NH_3 (mg/l)	$HC0_3$ (mg/L)	AK (mg/L)	$S0_4$ (mg/L)	CL_1 (mg/L)	$P0_4$ (mg/L)	TH (mg/L)	COD (mg/L	BOD_5 (mg/L)	DO (mg/L)
BH1 (NA)	6.19	31.20	15.66	2.0	0.0	0.0	0.970	12.2	10.0	4.0	7.0	0.0	5.0	NIL	3.0	8.0
BH2 (NA)	5.19	25.10	12.55	1.0	5.0	13.0	0.0	0.0	0.0	3.0	5.5	0.0	2.0	NIL	2.8	8.8
BH3 (NA)	5.69	93.30	46.13	2.0	0.0	0.0	0.33	0.0	0.0	11.0	22.0	0.0	16.0	NIL	3.0	6.8
BH1 (A+)	5.12	125.00	63.54	2.0	0.0	0.0	0.06	0.0	0.0	17.0	30.0	0.0	18.0	NIL	3.0	7.0
BH2 (A+)	5.25	85.50	42.98	1.0	0.0	0.0	0.02	0.0	0.0	9.0	15.0	0.0	8.0	NIL	2.5	9.0
BH3 (A+)	7.11	61.90	31.03	8.0	3.0	5.0	0.04	19.52	16.0	7.0	12.0	0.0	3.0	NIL	2.0	8.0
Ww1 (NA)	7.50	137.90	68.11	2.0	2.0	4.0	0.55	26.84	22.0	15.0	25.0	0.0	3.0	NIL	2.0	6.4
Ww2 (NA)	7.18	225.00	112.76	2.0	2.0	4.0	0.66	24.40	20.0	22.0	55.0	0.0	16.0	NIL	2.5	8.8
Ww3 (NA)	7.09	315.00	156.22	2.0	1.0	2.0	0.76	17.08	14.0	31.0	68.8	0.0	26.0	NIL	3.0	6.0
Ww1 (A+)	5.72	23.70	11.99	1.0	4.0	6.0	0.22	0.0	0.0	2.0	5.0	0.0	2.0	NIL	1.8	3.0
Ww2 (A+)	6.42	136.70	68.77	0.0	1.0	0.0	0.03	14.64	12.0	18.88	26.0	0.0	18.0	NIL	2.0	5.0
Ww3 (A+)	6.30	133.00	67.01	0.0	2.0	0.0	0.09	13.42	11.0	15.0	27.0	0.0	17.0	NIL	2.0	4.6
FL1	6.87	36.80	18.40	37.0	60.0	135.0	0.05	17.08	14.0	2.0	6.0	0.9	6.0	4.0	6.0	7.0
FL2	7.40	35.50	17.88	10.0	10.0	24.0	0.056	29.28	24.0	2.0	5.0	0.03	3.0	6.0	5.0	6.0
FL3	8.10	292.00	148.12	20.0	35.0	75.0	0.560	40.26	33.0	20.4	44.0	0.34	22.0	22.0	3.4	4.0
WHO STD	**6.5-8.5**	**3000**	**1000**	**5-25**	**0.05**	**1-5**	**0.5**	**NA**	**7**	**200-400**	**250**	**2.8-7.0**	**100**	**250**	**10**	**7.5**
NSDWQ	**6.5-8.5**	**3000**	**1000**	**5-25**	**0.05**	**1-5**	**0.5**	**NA**	**7**	**200-400**	**250**	**2.8-7.0**	**100**	**250**	**10**	**7.5**

From table 2, the values for physic-chemical parameters intrusion in the study were computed, with their outstanding values derived

Table 3: The values for heavy metals parameters intrusion in the study area

SAMPLE Id	Na (ppm)	K (ppm)	Mg (ppm)	Ca (ppm)	Mn (ppm)	Pb (ppm)	Fe (ppm)	Cu (ppm)	Zn (ppm)	Cr (ppm)	As (ppm)	V (ppm)	Ni (ppm)
BH1 (NA)	5.315	4.106	2.671	3.392	<0.001	<0.001	0.030	0.010	0.060	<0.001	<0.001	<0.001	<0.001
BH2 (NA)	4.276	3.303	2.149	2.729	<0.001	<0.001	0.080	0.030	0.020	<0.001	<0.001	<0.001	<0.001
BH3 (NA)	15.894	12.278	7.987	10.143	<0.001	<0.001	<0.001	0.010	0.040	<0.001	<0.001	<0.001	<0.001
BH1 (A+)	21.295	16.450	10.701	13.589	<0.001	<0.001	<0.001	<0.001	0.010	<0.001	<0.001	<0.001	<0.001
BH2 (A+)	14.566	11.251	7.319	9.295	<0.001	<0.001	<0.001	<0.001	0.070	<0.001	<0.001	<0.001	<0.001
BH3 (A+)	10.545	8.146	5.299	6.730	<0.001	<0.001	0.550	0.040	0.022	<0.001	<0.001	<0.001	<0.001
Ww1 (NA)	23.441	18.108	11.780	14.959	2.330	0.022	0.100	0.050	0.130	<0.001	<0.001	<0.001	<0.001
Ww2 (NA)	38.330	29.609	19.262	24.461	1.220	0.050	0.040	0.400	0.060	<0.001	<0.001	<0.001	<0.001
Ww3 (NA)	53.663	41.453	26.966	34.245	0.900	0.088	0.030	0.010	0.010	<0.001	<0.001	<0.001	<0.001
Ww1 (A+)	4.037	3.119	2.029	2.577	1.430	<0.001	<0.001	0.050	1.440	<0.001	<0.001	<0.001	<0.001
Ww2 (A+)	23.288	17.989	11.702	14.9	0.760	<0.001	<0.001	0.500	<0.001	<0.001	<0.001	<0.001	<0.001
Ww3 (A+)	22.658	17.502	11.386	14.5	0.060	<0.001	<0.001	0.050	<0.001	<0.001	<0.001	<0.001	<0.001
FL1	6.269	4.843	3.150	4.001	8.880	0.980	44.660	16.700	35.660	<0.001	<0.001	0.990	1.230
FL2	6.048	4.672	3.039	3.859	5.340	0.440	28.540	6.770	27.880	<0.001	<0.001	0.330	0.760
FL3	49.744	38.426	24.997	31.745	7.870	0.040	78.600	13.440	45.720	<0.001	<0.001	0.165	0.312
WHO STD	**200**	**5**	**3-100**	**NIL**	**0.2**	**0.01**	**0.3–1.0**	**1.5**	**3**	**NIL**	**0.01**	**0.1**	**0.02**

The values for heavy metal parameters intrusion were computed using table 3.0 above, and their outstanding values were derived.

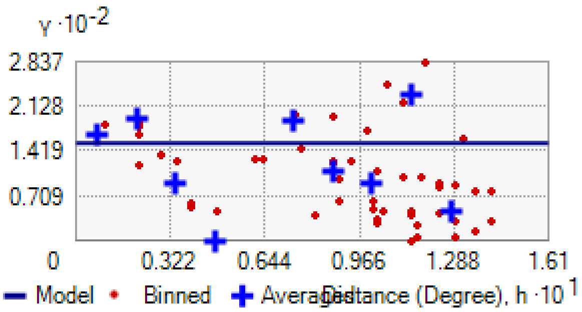
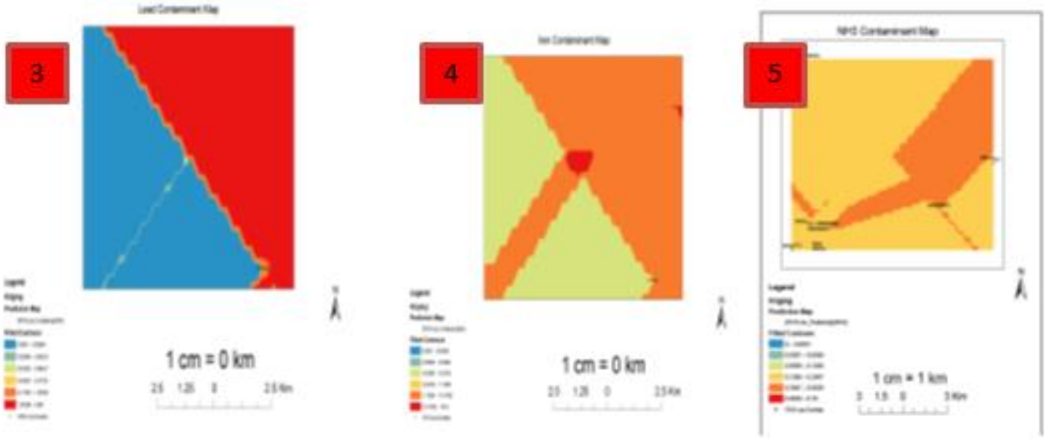


Figure 2: Semivariogram for potassium (K).

Mn (ppm), WW1(NA), WW2(NA), WW3(NA), WW1(A+), WW2(A+), WW3(A+), and all flood water samples exceed the allowable limit of 0.2 (ppm). Kids as well as adults who consume manganese-rich water for an extended period of time may experience recollection, attention, and skill issues. While children may experience learning difficulties if they consume excessive manganese (Iyare, 2019; Friedman, et al., 2023). Though, manganese could be detected in the specimens of the ecological environment like soil and rock. This infiltration can be traced back to different human activities in the ecosystem, such as industrial discharges and landfill leaching from the numerous dumpsites that litter the landscape. This finding is consistent with the presence of manganese in it, with that off Joode, et al., (2016).

Pb (ppm), apart from BH1(NA), BH2(NA), BH3(NA), BH1(A+), BH2(A+) and BH3(A+), all other water samples have permissible limits way above the 0.01 (ppm) WHO and NSDWQ standard. Lead in water can't be detected by sight, smell, or odour, which means lead poisoning can be hard to detect. Its presence is an indication of the presence of toxic wastes, perhaps from disposed of battery cells, used aerosol cans and other materials with a certain toxicity. This can be can be said to have been washed from a nearby mechanic work shop, leachate from landfill sites, car spraying shops and other workshop where carbide is used for generating fire and disposed off on the land without proper care. The effect of excessive lead consumption in water can create major health concerns if too much enters the human anatomy through drinking water. It causes damages to the brain and kidneys and can interfere with the production of red blood cells that carry oxygen to all parts of the body system. Symptoms don't typically appear until a dangerous amount has been accumulated in the body. Infants and younger children absorb this toxin more easily, making them more susceptible and immediately reactive to the health effects of lead in drinking water. These effects include abdominal pain, diarrhea, vomiting weight loss, fatigue, hearing loss amongst others. These findings are consistent with those of Podchashinskiy et al. (2017), Hartono and Pretiwi, (2020) and Madushika et al. (2023). These figures were greater than the desired concentrations for domestic water consumption, hence unfit for use as potable water. This observation was also consistent with (WHO, 2006). This reflects the risk to customers if the water is used indefinitely. Indicating a significant concentration of lead in water samples thought to have been brought by floodwaters.

Fe (ppm), only BH3(A+) with a value OF 0.550 and the flood water have parameters higher than the WHO and NSDWQ recommended values for iron. The maximum permissible value for iron content in drinking water is 1.0 mgL^{-1} above which the water is unsafe for consumption. Ass determined by the organization known as World Health Organization report from 2004, the range of values from 0.3 to 1 mg L-1 is permissible for iron metals in waters above which an objectionable and sour taste in the mouth is given. Also mentioned was goiter in adults, caused by the ingestion of water with an excess of iron (Shyamala, 2008). The iron (Fe) IN BH3+ result is 0.550 mg/l, indicating the iron concentration within the water sample is becoming a source of concern for the residents of the region. This finding is consistent with WHO's, (2019) and Birhan, et al., (2023) findings (see figures 3,4 and 5 for contaminant spread maps of Pb, Fe and NH_3).



Figures 3, 4 and 5. Contaminant spread maps for Pb, Fe and NH_3.

Table 4: The microbiological parameter incursion levels of investigated area

SAMPLE Id	cfu／ ml x 10^2		(MPN／100ml)	cfu／ ml x 10^2
	THB	**THF**	**T.COLI**	**F.COLI**
BH1(NA)	0.39	0.14	7.6	NIL
BH (NA)	NIL	NIL	NIL	Nil
BH3(NA)	0.44	0.05	13.2	0.02
BH1(A+)	0.62	0.07	7.6	NIL
BH2(A+)	0.66	0.03	8.6	NIL
BH3(A+)	0.35	0.02	16.6	NIL
Ww1(NA)	0.1	NIL	15.2	0.01
Ww2(NA)	0.19	0.01	15.2	0.02
Ww3(NA)	0.25	0.14	11.4	0.02
Ww1(A+)	1.4	0.13	9.6	0.06
Ww2(A+)	0.04	0.06	11.4	0.05
Ww3(A+)	0.49	0.05	8.6	NIL
FL1	0.2	0.09	7.6	NIL
FL2	0.55	0.02	13.2	NIL
FL3	NIL	0.2	8.6	NIL
WHO STD	**100-500**	**<500**	**0**	**0**

The values for micro-biological parameter intrusion in the investigated region were imputed from table 4.0 above, and their outstanding values were produced.

Water samples including flood water; contain Total Heterophobic Bacteria (THB) and Total Heterophobic Fungi (THF) values that are within WHO and NSDQW acceptable limits. This demonstrates that the flood is very dynamic and not stagnant; bacteria and fungi could not survive on dead and rotting creatures inside it, this occurrence would be impossible to achieve until the water settled down. Except otherwise noted BH2 (NA), for Total Coli (T.COLI) (see figure 6 for semivariogram of T-Coli below). Other water specimens had readings that are greater than WHO and NSDWQ suggested tolerable range, ranging from 7.9 to 16.6 (MPN 100ml).

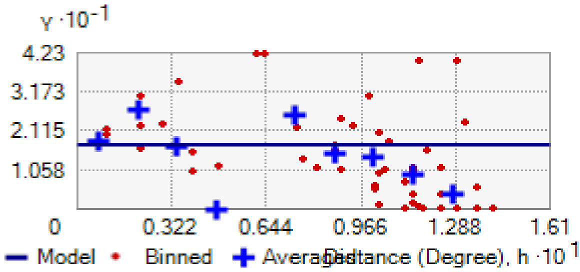
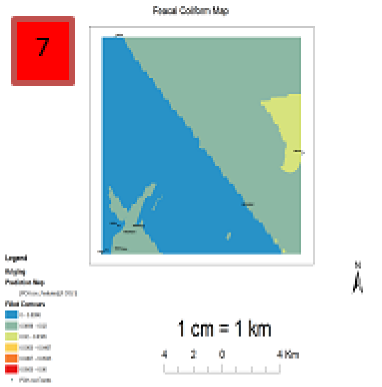


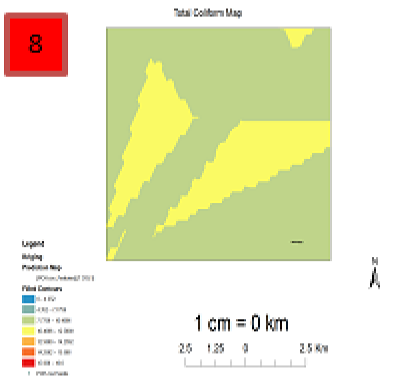
Figure 6. Semivariogram for T.Coli

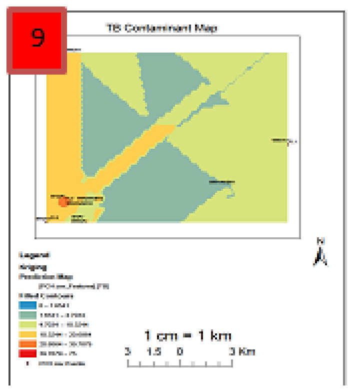
Only samples like BH3, Ww1, Ww2, Ww3, Ww1A+, and Ww2A+ with values ranging from 0.01 to 0.06 (cfu ml x 102), have levels more than WHO and NSDQW permitted drinking water limit. The bacteriological standard of water specimen should be the first consideration of any water quality inspection. Fecal coliform, in particular, serves as a marker for the existence of feces from warm-blooded animals and can be utilized as a bacteriological replacement for assessing water quality, according to Motlagh and Yang (2019). The quantity of fecal coliforms observed in water specimens from the area exceeds WHO and NSDQW recommendations. This could be a consequence of fact that the flood incident has destroyed and infiltrated sanitary facilities and borehole systems; that may result in fecal pollution of underground water sources and poor water quality. This finding in in agreement with that of WHO (2006), Roopavathi and Mamatha, (2016) Motlagh and Yang (2019) and Birhan, *et al*., (2023). Observations revealed, that most of the well heads have been reinforced with concrete enclosed cast (see plates 1 and 2), in a bid to prevent surface flood water from draining into the borehole vent, while some others have resulted in extending the casing pipes of the borehole upward, in a bid to deter the floodwaters pouring into the well (see plate 5 above). But there is the series of natural occurrences like capillarity, where floodwater infiltrates through the pore spaces of the soil type to infiltrate the water system. Either way, the flooding has a negative influence on the quality of water in the region. This assertion is in agreement with that of Meribi & Ayenew (2016) and Gwimbi, et al., (2019) (see figures 7,8 and 9 below, for contaminant spread maps of feacal coliform, total coliform and total bacteriological contaminant**.**

Heavy Metal Index (MI)

Heavy Metal Index (MI) is an indexing tool used to evaluate heavy metal pollution in underground water resources. Its use is to confirm the effect of heavy metal on the groundwater resources. The formula for calculating MI is thus (Ci/MAC).







Figures 7, 8 and 9: Contaminant spread maps for F.Coli, T.Coli and TB

Table 5: Data from heavy metal samples already converted to ppb from mg/l for derivation of Ci values

Stations	Σci/MAC	Class	Properties
Stations 1	20.2267	VI	Seriously Affected
Stations 2	16.3343	VI	Seriously Affected
Stations 3	60.3559	VI	Seriously Affected
Stations 4	80.8465	VI	Seriously Affected
Stations 5	55.3619	VI	Seriously Affected
Stations 6	40.6121	VI	Seriously Affected
Stations 7	324.3458	VI	Seriously Affected
Stations 8	272.7758	VI	Seriously Affected
Stations 9	302.5682	VI	Seriously Affected
Stations 10	158.6437	VI	Seriously Affected
Stations 11	134.7688	VI	Seriously Affected
Stations 12	223.567	VI	Seriously Affected
Stations 13	1119.45055	VI	Seriously Affected
Stations 14	614.9633	VI	Seriously Affected
Stations 15	1082.57306	VI	Seriously Affected

4. Conclusion

Domestic water supply, also known as boreholes and open wells, has significantly contributed to the alleviation of water scarcity in most Sub-Saharan African countries. The study region is no exception, with open wells and privately owned boreholes aplenty. The influx of floodwater into the research area is alarmingly increasing yearly. Where flood water takes over and negatively affects public and private infrastructure. Privately owned boreholes constitute the vast majority of water supply scheme in the region, and thus suffer the most affected during flood invation. Because of the laboratory analyses performed, this is the primary concern of this investigation. Water specimens from flood-affected areas were discovered to have values that exceeded physicochemical, heavy metals, and microbacteriological limits. The residents of the region create concrete casts around and over their open wells and boreholes to be able to prevent floodwater from entering wells and boreholes. However, it makes its way into underground water systems by the natural process of elluviation. They ingest these liquids, believing that they are safeguarding their water systems, oblivious to the intrinsic threats they bring to their health. As a result, this investigation is necessary to disclose the dangers of consuming this contaminated water. If an appropriate management and control mechanism for this misfit is not considered, it will snowball to a serious health epidemic.

Basic datasets were used in this investigation, targeted at characterizing spatio-temporal characteristics alongside borehole specimens to reach relevant results. ArcGIS software was used to create geo-spatial maps of the location, which benefited in the review of its topographic aspects. To aid comprehension, physico-chemical, heavy metal and mocrobiological contamination prediction maps were created. This is required because it aids in understanding of the actual impact of pollution infiltration in the investigation area. However, the study's findings revealed a significant increase in pollutants. The heavy metal index water investigation samples revealed a class **"VI"** grade, indicating the existence of serious levels of contaminants on the samples.

It is therefore critical that the agencies tasked with regulating consumable water resources be made accountable for managing this sector to be able to prevent major health problems. The water from the boreholes must be tested in a lab on a regular basis to ensure its quality before consumsion, so as to maintain a consistent standard for safe drinking water.

Declaration

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