FUDMA Journal of Sciences (FJS)
ISSN online: 2616-1370
ISSN print: 2645 - 2944
Vol. 9 No. 5, May, 2025, pp 144 - 154
DOI: https://doi.org/10.33003/fjs-2025-0905-3479

SPATIAL ASSESSMENT OF WATER QUALITY AND ASSOCIATED HEALTH RISKS FROM AGROCHEMICAL POLLUTION AMONG RURAL DWELLERS IN OGUN STATE, NIGERIA

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ABSTRACT

Groundwater represents a primary source of drinking water for rural dwellers. However, it is highly susceptible to contamination by agrochemical pollutants like herbicides and fertilizers resulting from intensive agricultural activities that sustain their livelihoods. This study assessed the rural dwellers' water quality and health risks from agrochemical pollution in Ogun State. 200 farmers selected through a multistage sampling procedure were interviewed using a questionnaire to elicit information on agrochemical application and disposal methods. Descriptive statistics, atomic absorption spectrophotometer and human health risk analysis were employed for data analysis. Findings showed that 75.5%, 92.5% and 60.5% applied fertilizer, herbicides, and insecticides respectively. Also, most (21.0%) of the respondents flush the remaining agrochemicals into the stream. The water samples had a mean value concentration of copper, lead, cadmium, iron and chromium of 2.5 mg/l, 0.018 mg/l, 0.06 mg/l, 0.5 mg/l and 0.004 mg/l, respectively, with pH values between 5.2 and 6.4, electrical conductivity values between 354.5 and 1591 µS/cm, and a mean total dissolved solids value of 535.667±256.746. These results exceeded the World Health Organization's acceptable threshold for quality water. A significant portion of the water examined had cancer risk values of more than 0.0001 and a water hazard index mean value of 2.07±0.9911, suggesting that drinking the sampled water may have negative impacts on the respondents. Water bodies were highly contaminated with heavy metals, suggesting carcinogenic and non-carcinogenic adverse effects among the dwellers. The study recommends an advocacy campaign on the safe use of agrochemicals to reduce risk to human health.

Keywords: Agrochemical, Health risks, Pollution, Rural dwellers, Spatial analysis, Water quality

INTRODUCTION

The rising global demand for food, driven by rapid population growth, has placed significant pressure on agricultural systems to increase productivity. With the world's population projected to reach nearly 10 billion by 2050, food production must grow by an estimated 70% to meet future needs (Saravi & Shokrzadeh, 2011). To achieve this, many farmers, particularly in developing nations like Nigeria, have increasingly adopted agrochemicals, including fertilizers, pesticides and soil amendments as key components of their farming practices. However, while these inputs enhance crop yields, they also pose serious environmental and public health risks due to their persistence, mobility and toxicity (Gill & Garg, 2014).

Water, a critical resource for life, is especially at risk. Although freshwater makes up only about 2.5% of the earth's total water volume, less than 1% is accessible for human use (Ha & Schleiger, 2022). This limited supply is under threat from agrochemical pollutants, which enter both surface and groundwater through multiple pathways, such as agricultural runoff, leaching, aerial spray drift, improper disposal and equipment washing (Chica-Olmo *et al.*, 2017; Adimalla, 2020). The likelihood of water pollution by agrochemicals is influenced by several factors, including their chemical properties (solubility, volatility and persistence), soil characteristics, weather conditions and application methods (Zhang *et al.*, 2007).

In rural areas, especially where groundwater is the primary source of drinking water, the implications of agrochemical contamination are profound. Contaminants such as nitrates and pesticide residues can persist in aquifers, causing health risks ranging from gastrointestinal illness to long-term conditions such as cancer and neurological disorders (World Health Organization, WHO, 2017). Eutrophication, caused by excessive fertilizer runoff, further degrades water bodies by promoting the overgrowth of algae, resulting in oxygen depletion, death of fishes and other aquatic organisms and foul-smelling or unpalatable water (Kerle *et al.*, 2007; Mateo-Sagasta *et al.*, 2017).

In Nigeria, particularly in Ogun State, the use of agrochemicals continues to increase, often without adequate guidance or environmental safeguards. Government extension services have attempted to promote safe handling practices, yet many rural farmers still report symptoms such as dizziness, skin rashes and headaches following agrochemical exposure (Hayes *et al.*, 2006; Alewu & Nosiri, 2011; Mabe *et al.*, 2017; Hassan *et al.*, 2025). These health complaints, coupled with the proximity of farmlands to surface water sources, raise urgent concerns about the potential contamination of rural water supplies.

The threat is especially pronounced in environmentally sensitive zones, where groundwater lies close to the surface and biodiversity is high (Toth & Buhler, 2009). In such settings, both point-source pollution (spills and storage leaks) and nonpoint-source pollution (runoff and leaching) contribute to long-term environmental degradation and human exposure (Singh & Craswell, 2021). Spatial assessment then becomes essential to understand the extent of contamination and identify high-risk areas. Given these challenges, this study aims to conduct a spatial assessment of water quality and associated health risks from agrochemical pollution among rural dwellers in Ogun State, Nigeria, using Ikenne and Ewekoro Local Government Areas as case studies. The findings will help highlight vulnerable communities, inform policy decisions and guide interventions to protect public health and ensure sustainable water management.

MATERIALS AND METHODS

Study area

This study was conducted in Ewekoro and Ikenne Local Government Areas (LGAs), which are two of the twenty LGAs located in Ogun State, Southwestern Nigeria. These LGAs were selected due to their active engagement in agricultural activities and noticeable usage of agrochemicals by rural dwellers. Ogun State lies within the tropical rainforest zone, characterized by a humid climate and bimodal rainfall pattern, which supports a wide range of economic activities, particularly farming and agro-processing (Olanrewaju et al., 2020).

Ewekoro LGA is situated in the western part of Ogun State and shares boundaries with Abeokuta North and Abeokuta South LGAs to the north, Ifo LGA to the south, Yewa North and Yewa South LGAs to the east, and Obafemi-Owode LGA to the west. The LGA covers a land area of approximately 594 km² and has an estimated population of 93,700 people (National Population Commission, NPC, 2022). The administrative headquarters is located in Itori, and the area is home to several rivers including Agodo, Lala and Yobo, which serve as key water sources for both domestic and agricultural use. Ewekoro is also known for hosting the Lafarge Cement Factory, one of Nigeria's major industrial facilities, contributing to both employment and environmental challenges in the region (Aderoju & Adepoju, 2017).

Ikenne LGA, with its headquarters in Ikenne Remo, lies between latitude 6°52’N and longitude 3°43’E and spans a land area of about 144 km². The LGA has an estimated population of 202,600 people (NPC, 2022). It is bordered by Obafemi-Owode LGA to the west and comprises five main towns: Iperu, Ilisan, Ogere, Ironu, and Ikenne. The area is intersected by rivers such as the Uren River in Ikenne and the Ogun River in Ogere, which serve as major water sources for rural communities and support various forms of agricultural irrigation and domestic needs (Adeyemi & Morenikeji, 2015).

Both LGAs experience tropical rainforest climatic conditions with relatively high humidity and ample rainfall, making them highly suitable for agricultural practices, including the cultivation of crops like cassava, maize, vegetables and the rearing of livestock. The geographical and environmental settings of these LGAs have made them hotspots for agrochemical application, especially among smallholder and subsistence farmers who rely heavily on chemical inputs to boost yield (Ojo et al., 2021). This context provides a compelling backdrop for the spatial analysis of water quality and potential health risks arising from agrochemical pollution.

Sampling Techniques

A multistage sampling procedure was employed for this study. In the first stage, Ewekoro and Ikenne Local Government Areas (LGAs) were purposively selected based on their notable engagement in agricultural practices and high usage of agrochemicals. In the second stage, two communities were randomly selected from each LGA. The third stage involved the random selection of 50 farmers from each community, resulting in a total of 200 farmers. These farmers were identified as active users of agrochemicals. Data collection was facilitated through the use of a questionnaire, which captured information such as frequency of agrochemical use, types of chemicals applied and post-usage disposal practices.

Determination of agrochemical application source in the study area

To spatially capture agrochemical application zones, field visits were conducted to farms known for agrochemical use. Using a Garmin eTrex 30 GPS device, the coordinates of 30 farms in Ewekoro and 27 farms in Ikenne were recorded. Additionally, the coordinates of 14 residential buildings in Ewekoro and 22 in Ikenne, all in close proximity to agrochemical treated fields were collected to assess potential residential exposure.

Determination of water pollution in the study area

Water quality analysis focused on surface and groundwater sources located near agrochemical application sites. In each LGA, 3 surface water samples were collected from rivers or streams adjacent to farmland. Additionally, 3 groundwater samples were collected from hand-dug wells situated within or near farmlands and residential areas. In total, 12 water samples (6 from each LGA) were collected and preserved in clean, acid-washed containers for laboratory analysis of agrochemical contamination, following standard water sampling protocols (American Public Health Association, APHA, 2017).

Analytical techniques

Descriptive statistics including mean, frequency and percentage were employed to describe farmers’ agrochemical application and disposal practices. To assess spatial exposure and vulnerability, Geographic Information System (GIS) tools were applied. GIS has proven effective in analyzing environmental exposure and its health implications (Ricketts, 2003; Nuckols et al., 2004). Vulnerability maps were developed to visualize areas with high potential for agrochemical contamination, as adapted from the work of Dabrowski et al., (2002) and Maxwell et al., (2010). Agrochemical exposure risk was modelled using a 500-meter buffer around each agrochemical-treated farm and nearby residences, following methodologies suggested by Šulc et al., (2023) and Madrigal et al., (2023). Google Earth was used to obtain high-resolution imagery of the study area, while Digital Elevation Models (DEM) helped generate hydrological features such as river flow patterns. ArcGIS version 10.4.1 was used to plot geospatial data and conduct the analysis. The Near Tool Analysis function in ArcGIS was utilized to calculate the distance between farms and nearby rivers, as well as the proximity between farms and residential buildings. River networks were buffered to determine which farms were located within a 500-meter radius, consistent with findings from Boscoe e*t al.*, (2004), Waller and Gotway (2004) and Robert *et al.*, (2011), who emphasized that a minimum buffer of 500 meters is essential to minimize agrochemical exposure to humans and water bodies.

In-situ water quality analysis

In-situ water quality parameters including pH, electrical conductivity (EC) and total dissolved solids (TDS) were measured using a HI 98130 Combo Tester. Prior to measurement, the instrument was calibrated using a standard buffer solution (pH 7.0). These parameters provide preliminary insights into the chemical composition and pollution levels of water sources.

Laboratory analysis of heavy metals

Water samples were also analyzed for the presence of selected heavy metals like iron (Fe), lead (Pb), chromium (Cr), copper (Cu) and cadmium (Cd) using an Atomic Absorption Spectrophotometer (AAS), in line with standardized analytical procedures (American Public Health Association, APHA, 2017). These metals were selected based on their common association with agrochemical residues and their known health risks at elevated concentrations.

Heavy metals evaluation index

To evaluate the overall burden of heavy metal contamination in the water samples, the Heavy Metals Evaluation Index (HMEI) was calculated using the formula adapted from Ojekunle et al., (2016). This index provides a single metric for assessing the combined pollution level from multiple metals, helping to classify water quality as safe or hazardous.

Heavy Metals Evaluation Index (HMEI) according to (Ojekunle, *et al.*, 2016):

$$HMEI=\sum_{i=0}^{n} \frac{concentration\ of\ metal\ in\ the\ water\ (mg/l)}{maximum\ permissible\ limit\ (mg/l)} \quad (1)$$

The result that falls into the range of < 0.01 to > 10 of heavy metal evaluation index were classified along the range from either very lightly polluted to very highly polluted, as the case may be.

Human health risk analysis

The human health risk analysis was carried out to determine the level of exposure to carcinogenic and non-carcinogenic health risks when the contaminated water is consumed or used for bathing by an adult. The methods described by the United States Environmental Protection Agency was used (as stated below) to determine the health risk assessment for oral and dermal ingestion (United States Environmental Protection Agency, USEPA., 1989; 2002; 2009).

Chronic daily intake (CDI)

$$CDI\ oral = \frac{C \times IR \times ED \times EF}{BW \times AT} \quad (2)$$

$$CDI\ dermal = \frac{C \times CF \times K \times ET \times SA \times EF \times ED}{BW \times AT} \quad (3)$$

Where: CDI dermal = Chronic Daily Intake of metals through dermal (skin) (mg kg^{-1} day^{-1})

CDI oral = Chronic Daily Intake of metals through oral ingestion of water (drinking) (mg kg^{-1} day^{-1})

IR = Ingestion rate of water (2 $Lday^{-1}$ for an adult)

ET = Exposure time (hour/event); ET = 0.58

ED = Exposure duration (years); ED = 30 years for an adult

C = Concentration of metals in water (mg L^{-1})

EF = Exposure frequency (day $year^{-1}$); EF = 365 days $year^{-1}$ for Oral ingestion and 350 days $year^{-1}$ for dermal ingestion (USEPA, 2004)

K = Permeability coefficient (cm/hour); the value of K for Cu, Fe, Cr & Cd = 0.001; Pb = 0.0001 (USEPA, 2004)

AT = Average time of exposure (days)

CF = Conversion factor (L cm^{-3}); CF = 0.001 (USEPA, 2004)

AT = ED for non-carcinogenic effects, while AT = 61.5^{*} years for carcinogenic effects in adult (WHO, 2015; Taiwo and Awomeso, 2017; Sasu, 2022).

SA = Skin surface Area (cm^2); SA = 1800cm^2 for adult

BW = Body weight (kg); BW= 67.5^{*} kg for an adult

* = Average value for male and female

Hazard Quotient (HQ) and Hazard Index (HI)

The hazard quotient (HQ) for oral and dermal ingestion was calculated using:

$$HQ\ oral = \frac{CDI\ oral}{RfD\ oral} \quad (4)$$

$$HQ\ dermal = \frac{CDI\ dermal}{RfD\ dermal} \quad (5)$$

The Non-carcinogenic Hazard Index (HI) for oral and dermal ingestion was achieved by summing up the hazard quotients (HQ) as shown below:

$$HIoral = \sum_{i=1}^{n} HQoral\ i = 1 \ldots.\ldots n \quad (6)$$

$$HIdermal = \sum_{i=1}^{n} HQdermal\ i = 1 \ldots.\ldots n \quad (7)$$

Where; CDI = Chronic daily intake of metals in water, (mg kg^{-1} day^{-1})

R*f*D_{oral} = Reference dose for oral ingestion (mg kg^{-1} day^{-1}); R*f*D_{oral} values for Pb = 0.0035, Cd= 0.001, Cu = 0.04, Fe = 0.7, Cr = 0.003 (USEPA, 2010; Integrated Risk Information System, IRIS, 1987)

R*f*D_{dermal} = Reference dose for dermal ingestion (mg kg^{-1} day^{-1}); R*f*D_{dermal} values for Fe = 0.3, Cu = 0.012, Cd = 0.000025, Cr =0.000015, Pb = 0.00042 (Tripathee *et al.*, 2016; Khalili *et al.*, 2019)

n = numbers of elements observed

HI > 1 indicates that there is a high risk of non-carcinogenic adverse effect, while HI < 1 shows that there is a low risk of non-carcinogenic adverse effects.

Cancer Risk (CR)

$$CRdermal = CDIdermal \times SF \quad (8)$$

$$CRoral = CDIoral \times SF \quad (9)$$

Where CDI $_{oral}$ = Chronic daily intake of metals in water through drinking (mg kg^{-1} day^{-1}).

CDI $_{dermal}$ = Chronic daily intake of metals in water through dermal (mg kg^{-1} day^{-1})

SF = Cancer slope factor (mg^{-1} kg^{-1} day^{-1}); SF for Cr = 0.42, Pb = 0.0085, Cd =15 (California Office of Environmental Health Hazard Assessment, COEHHA, 2019).

CR > 0.0001 indicates carcinogenic adverse effects, while CR < 0.0001 indicates no carcinogenic adverse effects.

RESULTS AND DISCUSSION

Agrochemicals use, application method and disposal among the respondents

The distribution of respondents according to the frequency of agrochemical applications is shown in Table 1. The result showed that more than half (60.5%) of the respondents applied fertilizer to their field up to 2 times in a season while about 13% of the respondents applied between 3 - 4 times and a negligible percentage of 4% did application of fertilizer up to 5 - 6 times in a farming season in the study areas. On the average, the respondents in the study areas are exposed to chemical fertilizers approximately 2 times in the farming season. Additionally, a large number (68%) of the respondents were exposed to herbicides 3- 4 times and 20.5% used herbicides 1 – 2 times during the last farming season. Only 4.5% of the respondents used herbicide up to 6 times on their farms in the last farming season. This finding suggests that getting exposed to agrochemicals up to three different times within a farming season may not be a healthy practise for the farmers in this study area as more concentration of chemical residue may be trapped in the soil and more concentration be leached into the nearby water source for potential pollution of the water bodies.

Furthermore, very few (35%) of the respondents were exposed to insecticides between 1 – 2 times per season and about 21% were also exposed between 3 – 4 times in the last farming season while 4.5% of the respondents were exposed to insecticide between 5 – 6 times. High frequency of exposure to insecticides may pose a health risk on the respondents and its environments. Fungicide application seems to be unpopular in the study area as only 23.5% of the respondents made use of the chemical, out of which 12.5% respondents applied between 1 – 2 times, 9% used fungicide between 3 – 4 times and only 2% applied it up to 6 times in the last farming season under consideration. On the average, fungicide is only applied 0.67 times among the respondents in the study area. The result in Table 1 further revealed the distribution of the respondents' agrochemical application pattern in the study area and this result showed that majority (41.5 %) of the respondents employed broadcasting method in applying fertilizer to their fields while other respondents (36 %) made use of placement methods in applying fertilizer. The level of exposure during fertilizer application could be higher should the farmers make use of power-driver fertilizer spreader, the level of dust coming from this device could cause real health challenge for the farmers and their communities as a whole. It was also showed from the result that approximately 80% of the respondents applied pesticides to their farms through the use of knapsack sprayer. The result further showed that about 10% of the respondents made use of tractor driven (boom) sprayer in applying pesticides to their farms while about 7% of the respondents made use of hand-pumps in the application of herbicides, insecticides and fungicides. This means that if instructions about the chemical usage were not strictly followed and the farmers were not properly dressed for this operation, most of the farmers and close by residents will be exposed to agrochemical health risks in the study area.

On the respondents' mode of disposal of the left-over agrochemicals, and the chemical containers as shown in Table 1. The result showed that only a few percentages of respondents disposed the agrochemical containers properly by either disposing inside waste bins (11.0 %) or by burying the containers or left-overs (14.0 %). However, it is advisable that burial site of agrochemical must not be close to waterways to avoid pollutions that could result from chemicals leaching into the water bodies or infiltrating into the underground water (Mateo-Sagasta *et al.,* 2017). All other respondents in the study areas disposed the remains of agrochemical or containers in such a bad way that could make them and some other people around them to be exposed to agrochemical. About 15.0% always leave the un-used agrochemical and its containers right on the field after farm operations while about 21.0 % washed their sprayers and unused chemicals into the nearby streams. This action has a high likelihood of putting the farmers, the community and the living organisms inside the water body into a serious hazard. Also, 12.0% and 3.5% of the respondents confirmed to usually dispose the containers to their backyard and inside gutter, respectively, while 4.0 % prefer keeping the left-over of the agrochemical inside their rooms or kitchen and this could result to contamination of drinking water and food from agrochemical exposure.

Table 1: Distribution of respondents according to frequency of agrochemical use, application and disposal methods

Agrochemical Usage Frequency	Frequency	Percentage
Fertilizer (number of applications per season)		
None	45	22.5
1 – 2	121	60.5
3 – 4	26	13.0
5 – 6	8	4.0
		Mean: 1.62
Herbicide (number of applications per season)		
None	15	7.5
1-2	41	20.5
3-4	135	67.5
5-6	8	4.5
		Mean: 2.08
Insecticide (number of applications per season)		
None	79	39.5
1-2	69	34.5
3-4	41	20.5
5-6	9	4.5
> 6	2	1.0
Fungicide (number of applications per season)		
None	153	76.5
1 – 2	25	12.5
3 – 4	18	9.0
5 – 6	4	2.0
		Mean: 0.67
Application Method		
Fertilizer		
None	45	22.5
Broadcasting	83	41.5
Placement	72	36.0
Pesticides		
None	9	4.5
Knapsack sprayer	159	79.5
Hand pump	13	6.5
Boom sprayer	19	9.5

Method of agrochemical disposal		
Thrown to backyard	24	12.0
Inside gutter	7	3.5
Waste bin	22	11.0
Flush to the stream	42	21.0
Buried	28	14.0
Keep inside the kitchen/room	8	4.0
Left on the farm field	30	15.0

Note: Pesticides refers to the combination of herbicides, insecticides and fungicides

Agrochemical application source in the study area

The result in Table 2 revealed that all the residential buildings around some farms visited in Ewekoro LGA were within 500 meters. The farthest residential building from the farm site was 382 meters (house 14), while the closest to the farms where agrochemical were sprayed was 19 meters (house 9). This is an indication that all the sampled residential buildings were likely vulnerable to agrochemical induced ailments in this community, even though, those in houses 1, 2, 5, 6, 7, 8, 9, 11, 12 and 13 were more exposed to agrochemical air drifts from the farm sites due to their proximity to the farms and thus, appears more likely to be vulnerable to agrochemical effects.

Likewise, ten residential buildings out of all the residential buildings sampled in Ikenne community were prone to agrochemical exposure due to their proximity of being within 500 meters to the farm sites where agrochemical were sprayed. These were houses 11 to 18 as well as houses 20 and 21, with residents of house 20 being most likely vulnerable to agrochemical drifts due to very close distance of about 13 meters to farms using agrochemical. It had been established that major significant routes of exposure that can affect rural dwellers mostly occur via residential proximity to agrochemical applications sites (Boscoe *et al*., 2004; Robert *et al*., 2011). The unaware exposure to agrochemical by these rural dwellers, which are mostly farmers, may place stress on their socio-economic activities through frequent treatment of agrochemical induced ailments in the short term. If not promptly and adequately addressed, it may eventually lead to a serious calamity for the rural dwellers. These findings conformed to a earlier study conducted on 11 residences in two rural Iowa counties in the United States, where dwellings near agricultural land had three times the amount of glyphosate in their dust compared to houses that were not close to farms (Curwin, *et al.,* 2007). Additionally, a French study revealed that the median glyphosate concentrations in the dust of residences within 500 meters of farms were around three times greater than those of residences farther away (Saurat, *et al.,* 2023). The residences within 0.5 km had greater median amounts of pesticide dusts than residences without any nearby agrochemical use.

Table 2: Distance of residential buildings to the farms where agrochemicals were used in the study area

Ewekoro Res. Buildings	Near Dist. (m)	Ikenne Res. Buildings	Near Dist. (m)
House 1	39	House 1	1299.5
House 2	81	House 2	1299.5
House 3	368	House 3	611.4
House 4	343	House 4	735.9
House 5	79	House 5	683.6
House 6	26	House 6	1472
House 7	23	House 7	1695
House 8	61	House 8	2492.9
House 9	19	House 9	675
House 10	236	House 10	869.5
House 11	43	House 11	49.8
House 12	31	House 12	48.4
House 13	25	House 13	84.9
House 14	382	House14	174
		House15	235
		House16	495
		House17	53
		House18	46
		House19	1550
		House 20	13
		House 21	63.4
		House 22	1392

Note: m = Meters

Water pollution analysis due to agrochemical application in the study area

The use of agrochemical in closeness to residential areas and water sources may lead to increased dermal exposure among the farming households as well as contamination of the community source of drinking water (Ward *et al.,* 2006; Marco, *et al.,* 2017). In addition to exposing the farmers, this practice also exposed other community citizens going about their daily lives to harmful agrochemical applications that commonly take place close to their residences, children's schools and places of employment (Rull *et al.,* 2009).

The maps of water bodies most likely to be contaminated by agrochemical applications in the study area are shown in Figures 1 and 2. Out of the 30 farms in Ewekoro and 27 farms in Ikenne whose coordinates were taken for this analysis, the results show that approximately 77 % of the farms visited in Ewekoro were located within 500 meters buffer radius of water bodies and about 56 % of the farms visited in Ikenne were close to water body with distance less than 500 meters. This means that there is likelihood that application of agrochemical on these farms would contaminate the water bodies which in turn might put health risks on the rural population who makes use of the water for domestic chores such as washing, bathing, cooking and drinking purposes.

Exposures typically occur when pesticide spray drifts away from target crops while being applied, or occasionally when agrochemicals vapourised and drift to nearby areas days after being applied. The economic activities of these rural towns may be significantly impacted by this action since the farming population may gradually get sicker, visit the hospital more frequently and spend less time on their farming business.

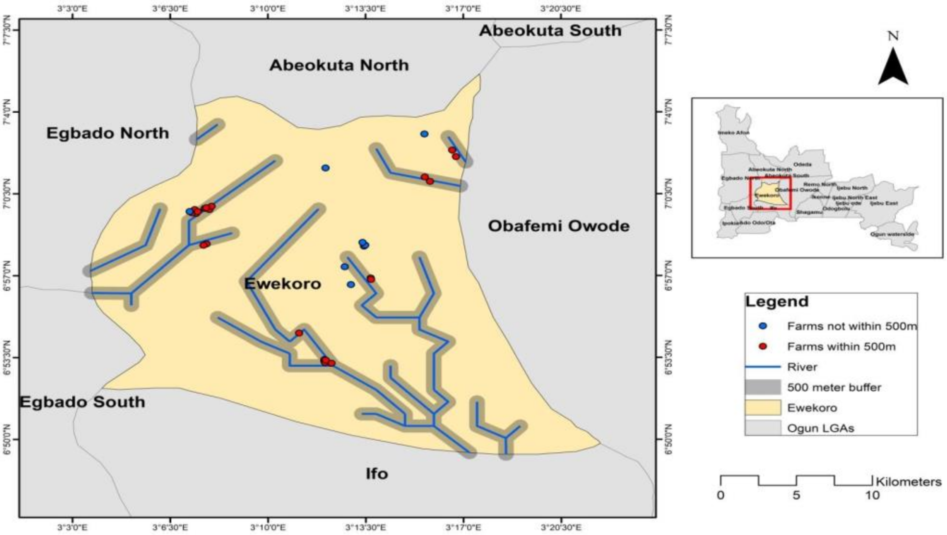

Figure 1: Vulnerability map showing water bodies likely to be contaminated by agrochemical in the Ewekoro LGA

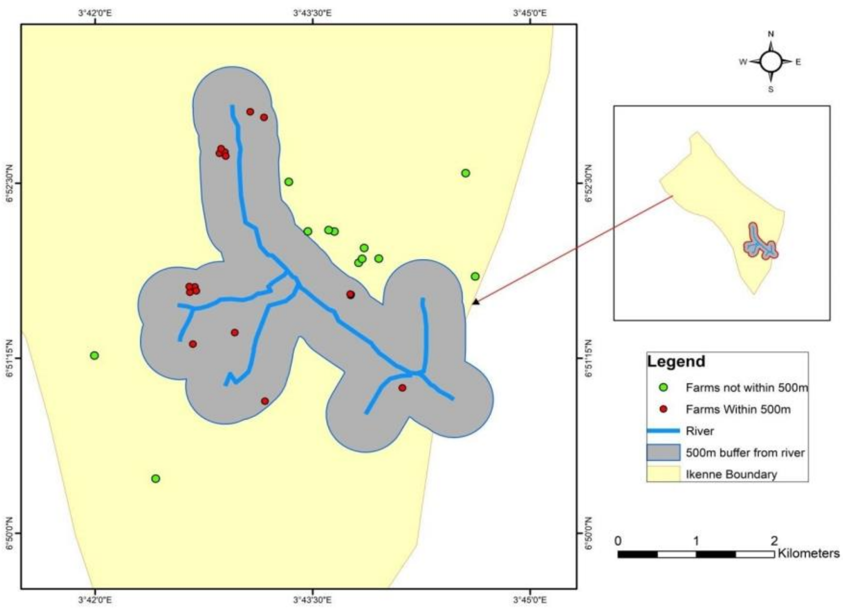

Figure 2: Vulnerability map showing water bodies likely to be contaminated by agrochemical in the Ikenne LGA

The results in Tables 3-5 showed the level of pollution agrochemicals might cause to the water quality in the study area and consequences it might eventually have on the residents' health. Table 3 revealed the range and mean concentration of heavy metals in the water samples collected. The range of values of the results of copper (cu), lead (Pb), cadmium (Cd), iron (Fe) and chromium (Cr) were 0.12 to 2.5 mg/l, 0.005 to 0.018 mg/l, 0.0001 to 0.06 mg/l, 0.05 to 0.5 mg/l, and 0.001 to 0.004 mg/l, respectively. While the corresponding World Health Organization (WHO) permissible limits are 2.0 mg/l, 0.01 mg/l, 0.05 mg/l, 0.3 mg/l and 0.003 mg/l, respectively. The percentage of water samples that contain a higher concentration of copper, lead, cadmium, iron and chromium above WHO permissible limit are 25%, 33.33%, 25%, 58.33% and 33.33% respectively.

The range of the water pH was 5.2 to 6.4, with a mean value of 5.908±0.396. The pH values of all the water samples are outside the recommended range (6.5 to 8.5) by WHO. Also, the total dissolve solid (TDS) values range from 80 to 900 mg/l with a mean value of 535.667±256.746. The percentage of water samples with TDS values above the WHO permissible limit for a drinking water is 58.33%. Similarly, the range of EC was between 354.5 to 1591μS/cm, with a mean value of 968.992 ± 368.783. Furthermore, 83.33% of the water samples have EC values that are above the WHO permissible limit of 400μS/cm for a drinking water. All these values simply indicate that the water samples are contaminated, and this could be as a result of anthropogenic activities in the study area such as intensive use of agrochemicals for agricultural production (Hudak, 2015; Elisante and Muzuka, 2015).

Table 3: Mean distribution of heavy metals concentration and some parameters in the water samples collected in the study area

Parameters/Units	Min	Max	Mean	SD	WHO Limits	PWS
TDS (mg/l)	80	900	535.667	256.746	500	58.33%
EC (μS/cm)	354.5	1591	968.992	368.783	400	83.33%
PH (mg/l)	5.2	6.4	5.908	0.396	6.5 to 8.5	100%
Cu (mg/l)	0.12	2.5	1.565	0.669	2.000	25%
Pb (mg/l)	0.005	0.018	0.010	0.004	0.010	33.33%
Cd (mg/l)	0.0001	0.06	0.026	0.027	0.050	25%
Fe (mg/l)	0.05	0.5	0.326	0.119	0.300	58.33%
Cr (mg/l)	0.001	0.004	0.003	0.001	0.003	33.33%

* PWS = Percentage of water Samples with heavy metals and parameters above the WHO permissible limit

Water quality assessment in the study area

The result of water samples rating using a Heavy Metal Evaluation Index (HMEI) is presented in Table 4. The result indicates that 25 percent (3 samples: S1, S2 and S4) of the water samples were highly polluted while 75 percent of the water samples were moderately polluted. The result also shows that surface water in the study areas is more polluted than the groundwater. This could be as a result of activities of the respondents in the study area, such as frequency use of agrochemicals and indiscriminate disposal of agrochemicals which is transported to the stream through runoff. About 42 of the respondents (representing 21%) agreed to always flush the remains of unused agrochemical in their sprayers into the nearby streams and also used same stream to clean their sprayers, this act has shown to be very detrimental to the quality of the surface water in the study locations. The table also shows that the groundwater samples in the study area were also polluted, even though, at a moderate level. This water contamination could also be as a result of one or combination of the following: leaching of agrochemicals into water bodies after spraying, drifting of agrochemical during applications, infiltration of buried left-over chemicals into the soil or improper disposal of agrochemical containers on the farm or around residential buildings.

Table 4: Water Quality Assessment Using Heavy Metals Evaluation Index Rating

Study location	Water Sample	HMEI	HMEI Rating
Ewekoro	S1	6.32	Highly Polluted
	S2	5.06	Highly Polluted
	S3	4.71	Moderately Polluted
	G1	4.94	Moderately Polluted
	G2	4.37	Moderately Polluted
	G3	4.09	Moderately Polluted
Ikenne	S4	5.03	Highly Polluted
	S5	4.50	Moderately Polluted
	S6	3.58	Moderately Polluted
	G4	4.68	Moderately Polluted
	G5	3.51	Moderately Polluted
	G6	1.26	Moderately Polluted

Note: S = Surface water, G = Groundwater

Human health risks analysis

The values of hazard index (HI) and cancer risks (CR) of the water samples for both the dermal and oral ingestion by the respondents is presented in Table 5. Considering the non-carcinogenic risk of the water samples on the farming communities, the HI dermal values which range from 0.01 to 0.44 with a mean value of 0.21±0.1722 indicates that all the water samples have HI dermal values that are less than 1(figure 3). This implies that bathing with these water sources will not lead to any adverse effect on the farming households. On the other hand, the HI oral values range from 0.16 to 3.77 with a mean value of 2.07±0.9911. This simply means that drinking the water with HI greater than 1 will have adverse effects (though, non-carcinogenic ones) on the members of the farming community. It can be further deduced from the result that all the water samples (both surface and groundwater) in the study area have high tendency of causing adverse effects when consumed, except two groundwater sources (G5 and G6) in Ikenne LGA. In other words, about 83.34 % of the water in the study area will cause adverse health condition for farming households when consumed through oral ingestion. These results confirmed the WHO documentation as reported by Amalraj and Pius, (2013) and Adimalla, (2019) that a significant number of diseases are due to poor quality of drinking water in the world.

Table 5 further revealed the values of the cancer risk (CR) of the sampled water for dermal and oral ingestion. The CR result shows that the dermal values range from 2.98E-07 to 1.39E-04 with mean value of 6.13E-05±6.29E-05. About 58 percent of the water samples have CR dermal values <0.0001 while 41.67 percent of the values are > 0.0001. Furthermore, the range of CR oral is 5.87E-05 to 2.67E-02, with a mean value of 1.18E-027±1.20E-02. A fraction of the water samples (6.9 percent) has CR oral values that are <0.0001 while a huge part (92.31 percent) of the water samples has CR oral values that are >0.0001 (figure 4). The level of cancer risk of consuming the water through which samples were collected is high for both the farming households and the communities at large (Li, *et al.,* 2018). This finding corroborates the earlier reports of Alengebawy *et al*., (2021) and Iredell (2023) that carcinogenic substances are commonly introduced into water sources through a variety of channels, including runoff from agricultural areas, improper waste management and industrial discharges. These different chemicals, which include industrial pollutants, insecticides, and heavy metals like lead, mercury and arsenic, can interact with human DNA. The growth of malignant cells may be triggered by genetic defects that arise from these interactions.

Table 5: Water hazard index and cancer risk values for dermal and oral ingestion by respondents

Study location	Water Sample	Hazard Index		Cancer Risk	
		HI oral	HI dermal	CR oral	CR dermal
Ewekoro	S1	3.77	0.44	2.67E-02	1.39E-04
	S2	3.01	0.38	2.32E-02	1.21E-04
	S3	2.92	0.37	2.23E-02	1.16E-04
	G1	1.83	0.08	9.41E-04	4.90E-06
	G2	1.71	0.06	4.84E-04	2.52E-06
	G3	1.62	0.06	4.84E-04	2.52E-06
Ikenne	S4	2.83	0.41	2.67E-02	1.39E-04
	S5	2.40	0.34	2.18E-02	1.14E-04
	S6	2.10	0.28	1.78E-02	9.29E-05
	G4	1.55	0.06	3.97E-04	2.05E-06
	G5	0.91	0.03	1.94E-04	9.95E-07
	G6	0.16	0.01	5.87E-05	2.98E-07
Min		0.16	0.01	5.87E-05	2.98E-07
Max		3.77	0.44	2.67E-02	1.39E-04
Mean		2.07	0.21	1.18E-02	6.13E-05
SD		0.9911	0.1722	1.20E-02	6.29E-05

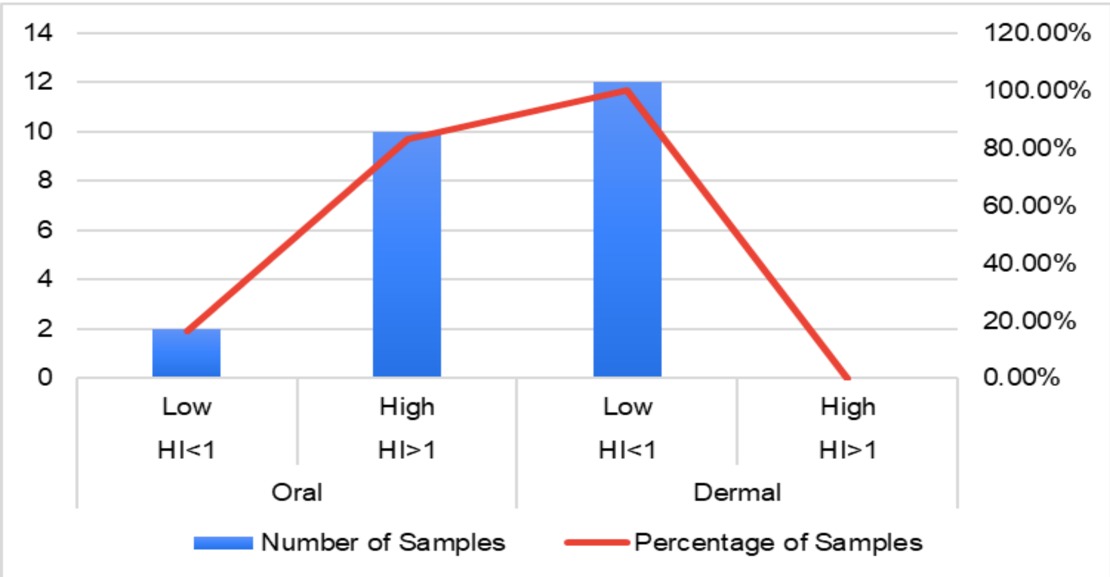

Figure 3: Graph showing non-carcinogenic risk of water samples in the study area

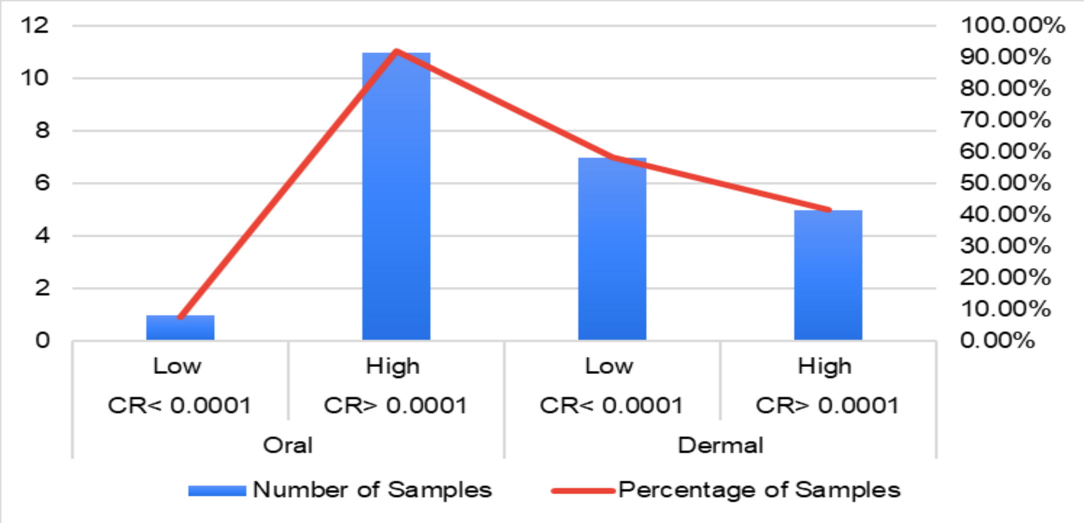

Figure 4: Graph showing the carcinogenic risk of the water samples in the study area

CONCLUSION

The study's findings suggest that most of the visited farms where agrochemicals were used in the study area were in close proximity to water bodies and the residential buildings (within 500 meters). The activities of the farmers, such as frequent application of agrochemicals coupled with the poor disposal of left-over agrochemicals and chemical containers around water bodies has led to the pollution of both surface water and groundwater in the study area. The assessment of water quality in the farmstead as well as nearby residential building shows that both surface and groundwater were contaminated with varying degree of heavy metals resulting from intensive use of agrochemicals. The results of human health risk analysis of the water samples revealed that the level of pollution of the water can eventually cause carcinogenic effects, especially if consumed through oral ingestion.

In order to prevent a future catastrophe in the study area, this study recommends that the residents of the communities must be engaged in a series of health talks on the safe use of agrochemicals and appropriate disposal methods. The relevant stakeholders such as State Ministry of Agriculture, Ogun State Agricultural Development Programme (OGADEP), and the State Ministry of Environment and in conjunction with the Ogun-Osun River Basin Development Authority, should embark on an advocacy campaign that ensures proper water use for human health and biodiversity sustainability. This study also recommends policies that will prevent usage of agrochemical within 500 metres radius of residential buildings and water bodies should be enacted by the stakeholders.

The department of environmental services in the two LGAs is encouraged to create a strong mechanism for accepting complaints about any farmers/individual using agrochemicals in sensitive locations while local government authorities are encouraged to build up water purifying facilities in their communities for safe water consumption.

ACKNOWLEDGEMENTS

The authors wish to appreciate the support gotten from Ogun State Agricultural Development Programme (OGADEP) and the following staff of the organization for their efforts in facilitating meetings with the farmers under their jurisdictions: Mr. Bankole Theophilus (Ewekoro LGA), Mr. Akinlawon (Ewekoro LGA) and Mr. Oriyomi Idowu (Ikenne LGA). Special appreciations to one of the farmers, Mr. Adekunle Idowu-Onabanjo (Ikenne LGA) who volunteered to take the researchers and the OGADEP field officer to all the farms and residential buildings where coordinates were collected and also to water sources where samples were taken, without accepting any payments.

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