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Research Article

Assessment of Agro Allied Chemical Pollution on Surface Water Quality of River Lamurde and Mayo-Gwoi, Jalingo, Taraba State, Nigeria

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Abstract

Water bodies have been severely degraded in recent years due to the indiscriminate use of agro-allied chemicals. The study assesses the agro-allied chemical pollution on the surface water quality in River Lamurde and Mayo Gwoi. Water samples were collected from twenty-one (21) sample locations along the River Lamurde and Mayo-Gwoi to determine the seasonal variation during the wet and dry seasons through field determination of water quality and laboratory-based analysis at Taraba State Rural Water Supply and Sanitation Corporation (TAWASCO) Jalingo laboratory. The water quality parameters that were subjected to test include: Calcium (Ca), Nitrate (NO_3^-), Zinc (Zn), Nitrite (NO_2^-), Chromium (Cr), Phosphate (PO_4^{3-}), Iron (Fe), Sulfate (SO_4) and Copper (Cu), The data acquired from the laboratory test was subjected to the analysis of variance (ANOVA). The result of the laboratory analysis shows that the concentration of copper during the dry season and Sulfate during the wet season in river Lamurde and Mayo Gwoi falls within the permissible limits of WHO/NSDWQ while the concentration of Calcium (Ca), Nitrate (NO_3^-), Zinc (Zn), Nitrite (NO_2^-), Chromium (Cr), Phosphate (PO_4^{3-}) and Iron (Fe) far exceeds the permissible limits of WHO/NSDWQ during the dry and wet season. The findings show that the main causes of the pollution are human activities such as fertilizer application and other agro-allied chemicals around the bank of River Lamurde and Mayo Gwoi. It was recommended that prevention of pollution, treatment of polluted water, safe use of environmentally friendly fertilizers, and other agro-allied chemicals and protection of the ecosystem, among others are desirable actions that will guarantee not only sustainable good quality but also the use of Lamurde and Mayo-Gwoi River water by man.

Keywords
Agro allied chemical; pollution; river; surface water quality

1. Introduction

Water is the source of all life. Man's survival on the planet would be jeopardized without water, and he would be driven to extinction. All biological creatures require water to carry out complicated biochemical reactions that contribute to the survival of life on Earth. Aside from the air we breathe, water makes up more than 70% of the earth's surface and is one of the most crucial components of man.

According to Bwadi, Yusuf, Abdullahi, Giwa, and Audu [1] water is a common natural chemical substance containing two atoms of Hydrogen and an atom of Oxygen. Its common usage refers to liquid form, though it has other forms: solid water - ice and gaseous forms - water vapor and steam. Water is indispensable for the life and socioeconomic development of any society. It is used in domestic activities (cooking, drinking, washing, bathing etc.), agricultural activities (irrigation, gardening), generation of power (hydroelectric power plants), running industries, recreational activities etc. It is essential for human existence and the sustenance of life. Water constitutes 60–70% of the total body weight. A man can live for several days without food but only survive for a few days without water.

Even though water covers around 70% of the earth's surface, only 2.53% is freshwater, with the rest being salt water [2]. The World Water Council also records that of the 3 percent of fresh water, only 0.3 percent is found in rivers and lakes, the rest being frozen [3]. This suggests that man has a relatively low amount of freshwater resources with which he carries out his activities. Unfortunately, man's influence has begun to degrade the freshwater resource available for his development. When effective waste management is not in place, cities are among the most dangerous locations where water bodies are contaminated [2]. Some governments in rapidly urbanizing cities worldwide, particularly in Africa, are contending with rising demand for social utilities such as water, garbage collection, sanitary facilities, appropriate housing, and security. The demand for social amenities has outstripped the ability of city governments to offer them in some African cities. Some residential and industrial institutions are built near dumping garbage into rivers, polluting rivers. According to Danquah, Abass, and Nikoi [4] a river is said to be polluted when the water in it is altered in composition or condition, directly or indirectly as a result of man's activities, so that it is less important for all the purposes for which it would be suitable in its natural state, 'according to Danquah et al. [4], rivers that flow through cities are more likely to be contaminated, which can have major consequences for the health and socioeconomic well-being of individuals who live nearby and those who use the water body downstream [5] River pollution from city-based industries and untreated sewage can lead to serious health problems in downstream settlements, according to the report [5]. Some rivers lose their quality after passing through cities due to various human and agricultural activities contributing to pollution. Settlements downstream that rely heavily on river water for domestic purposes are forced to seek more expensive alternatives where such communities do not have piped water.

The introduction of agro-allied chemical elements into water bodies changes the original composition of water bodies worldwide. When fertilizers are applied at a higher rate than they are fixed by soil particles or exported from the soil, excess nitrogen and phosphates can leak into groundwater or enter streams through surface runoff. Because phosphorus is less soluble than Nitrate and ammonia, it tends to bind to soil particles and enter water bodies through soil erosion. Feedlots are frequently placed on the banks of watercourses in animal rearing. (Nutrient-rich) animal waste (e.g., urine) can be dumped directly into those bodies of water. Manure is typically collected as an organic fertilizer, but the excessive application can result in water pollution. Manure is not stored in confined locations and can be carried into waterways by surface runoff after severe rainstorm events [6].

Nutrient loads provided to water bodies in feed aquaculture are essentially a consequence of feed composition and feed conversion (fecal wastes). In intensive-fed aquaculture, the uneaten feed can contribute significantly to nutrient loads in the water. When combined with other stresses, high nutrients loads can induce eutrophication in lakes, reservoirs, ponds, and coastal waterways, resulting in algal blooms that suffocate aquatic plants and animals. Despite data inadequacies, 415 coastal sites have been recognized as being affected by eutrophication, with 169 hypoxic (WRI, 2008). Due to high quantities of nitrate in drinking water, excessive nutrient accumulation may have negative health consequences, such as blue-baby syndrome [6]. In many nations, agriculture use insecticides, herbicides, and fungicides extensively. They can pollute water resources with carcinogens and other harmful compounds that can harm humans if used and maintained incorrectly. Pesticides may also influence biodiversity by eliminating weeds and insects, resulting in negative consequences farther up the food chain. Acute pesticide poisoning is a leading cause of illness and mortality in humans worldwide, particularly in developing nations, where poor farmers frequently use highly toxic pesticide formulations [7]. The flood plain of the River Lamurde and River Mayo-Gwoi in Jalingo Local government area, Taraba state, Nigeria is intensively cultivated through irrigation and rain-fed agriculture. This is made realistic through farm manures, inorganic fertilizers, and pesticides. Many settlers along the river course rely on it for drinking water. The increasing rate of agro-allied chemicals is a source of pollution affecting the water quality. The people who live along the river course have faced many health challenges due to the river's pollution. Several have been infected with typhoid, diarrhea and cholera. The bioaccumulation of agro-allied chemicals product over time can be carcinogenic (causes problems in the body's tissues) [8].

Generally, the River Lamurde and Mayo-Goi are very important to the people that live along its course. The following are some of the important things derived from the river: boreholes drilled in the area to be used during the dry season irrigation farming, and it serves as sources of drinking water for the inhabitants along the course of the rivers during the dry season. The water is also utilized for domestic purposes such as: washing clothes, utensils, plates, cooking and drinking. The rivers are also used as a recreational center for children and teenagers that live in the area. But the increasing risks to humans health caused by the indiscriminate use of agro-allied chemicals in agriculture on the flood plain of River Lamurde and Mayo Gwoi necessitates this study to be carried out to determine the surface water pollution and the potential consequences of the accumulations of the agro-allied chemicals on the people that live at the course of the river.

Waste from the agrochemical industry, fertilizers, and pesticides (including herbicides and insecticides), are all commonly utilized in crop fields to increase production. Pesticides improperly disposed of from field, farms and agricultural activities add significant contaminants to water bodies and soils. DDT, Aldrin, Dieldrin, Malathion, Hexachloro Benzene, and other pesticides are examples.

Pesticides pollute water bodies by surface runoff from agricultural fields, drifting from spraying, washing down of precipitation, and direct dusting and spraying of pesticides in low-lying regions. Most of them are non-biodegradable and will remain in the environment for a long time. These compounds might enter the human food chain, resulting in biomagnification.

Nutrient sources in surface water may be split into two categories: natural and man-made. Natural sources contribute little to pollution because the natural system maintains a balance between the production and consumption of nutrients over some time.

Agriculture, household, and industrial wastes are all anthropogenic sources of pollutants. Human land use and disturbance gradients have been linked to nutrient concentrations in streams and rivers. Both nitrogen and phosphorus enrichment is linked to the watershed's agricultural and urban land uses of the total nitrogen fluxes in temperate zones. The net anthropogenic nitrogen intake in the basins of rivers that border the North Atlantic Ocean is significantly connected [9]. River total nitrogen and nitrate flows and concentrations are also linked to human population density [9]. The major source of nitrogen in streams and rivers is nitrogen fertilizer [10].

Similarly, anthropogenic nutrient enrichment causes in aquatic systems include point and nonpoints [11]. Nonpoint sources of nutrients, such as livestock, agricultural fertilizers, and urban runoff, have more geographical and temporal variability than point sources of nutrients, which are relatively straightforward to monitor and control. As a result of the Clean Water Act's strict control of point source inputs, nutrients from nonpoint sources are currently the primary source of water contamination in the United States [11].

Many scholars wrote on the quality of surface water in other parts of the world and the study area in particular. Osibanjo, Daso, and Gbadebo [12] in their study on the impact of industries on the surface water quality of the Ona and Alaro rivers in the Aluyole Industrial Estate using laboratory analysis. The study concluded that both rivers were affected by the industrial discharge. Oladipo, Akinwumiju, Aboyeji, and Adelodun [13] in their studies on water quality where the fuzzy logic was compared with the water quality index methods to measure the distribution level of water pollution in the Ikare community of southwestern Nigeria. The study revealed that the fuzzy logic inference was superior to the water quality index. Other studies on the pollution of surface water quality include Yang et al. [14], Ly and Giao [15], Kamboj and Kamboj [16] and Xu et al. [17]. From the study area, Tsunatu, Kurutsi, Dickson, and Bingari [18] evaluate the physicochemical properties of the Nukkai River in Jalingo, while Munta, Unamba, Mejor, and Nwajagu [19] examine the water quality index of Water Supply Agency in Jalingo.

Jalingo is a tropical sub-humid area with a well-defined dry season that lasts for half of the year. The River Lamurde and River Mayo-Gwoi are the only rivers draining the town, which has witnessed a rapid increase in population in recent times. As a result, the Rivers are extremely important in the study area for irrigation, domestic use, and recreation. The continued use of agro-allied chemicals on farm fields along the river floodplains threatens the local people's livelihood. As the human population expands, businesses and agricultural operations spread out, and climate change threatens to produce substantial changes in the hydrological cycle, the loss in water quality and the resulting loss in the supply of clean water has become a global issue of concern. Water scarcity and poor quality, without a doubt; represent major challenges to long-term development. Using agro-allied chemicals like herbicides, insecticides and pesticides has resulted in a steady increase in food production in Jalingo town. The need to continually monitor and assess the water quality becomes necessary as it directly or indirectly affects man.

Water bodies have been severely degraded in recent years due to the indiscriminate use of agro-allied chemicals [20]. The use of agro-allied chemicals is regarded as one of the most important factors contributing significantly to the increase in food production [21]. However, due to the complicated structure of these compounds, their uncontrolled usage has polluted water bodies, resulting in the loss of biodiversity and causing health problems [22]. Even at low concentrations, water pollution caused by agro-allied chemicals is of great concern to the world and its long-term cumulative health effects [23]. Nutrients, pesticides, salts, sediments, organic carbon, pathogens, metals, and drug residues are major agricultural contributors to water pollution and are important priorities for water pollution mitigation. Not much work has been done on the effects of agro-allied chemicals on the water quality in Jalingo. Owning to this fact, there’s a need for a study to be carried out on the agro-allied chemicals pollution of the water quality of River Lamurde and River Mayo-Gwoi. Therefore, this study aims to assess the agro-allied chemicals pollution on the water quality of River Lamurde Jalingo and River Mayo-Gwoi, in Jalingo, Taraba State, Nigeria Hence, the hypothesis for this study: there is no significant relationship between agro-allied chemical pollution and the surface water quality of River Lamude and River Mayo-Gwoi in Jalingo.

2. Materials and Methods

2.1 The Study Area

Jalingo Local Government Area (LGA) is located between latitudes 8°47’ and 9°.01’ N of the equator and longitudes 11°.09’ and 11° E of the green witch meridian (Figure 1). Lau Local Government Area borders it on the north, Yorro Local Government Area on the east, and Ardo Kola Local Government Area on the south and west. Its total land area is around 195 km^2.

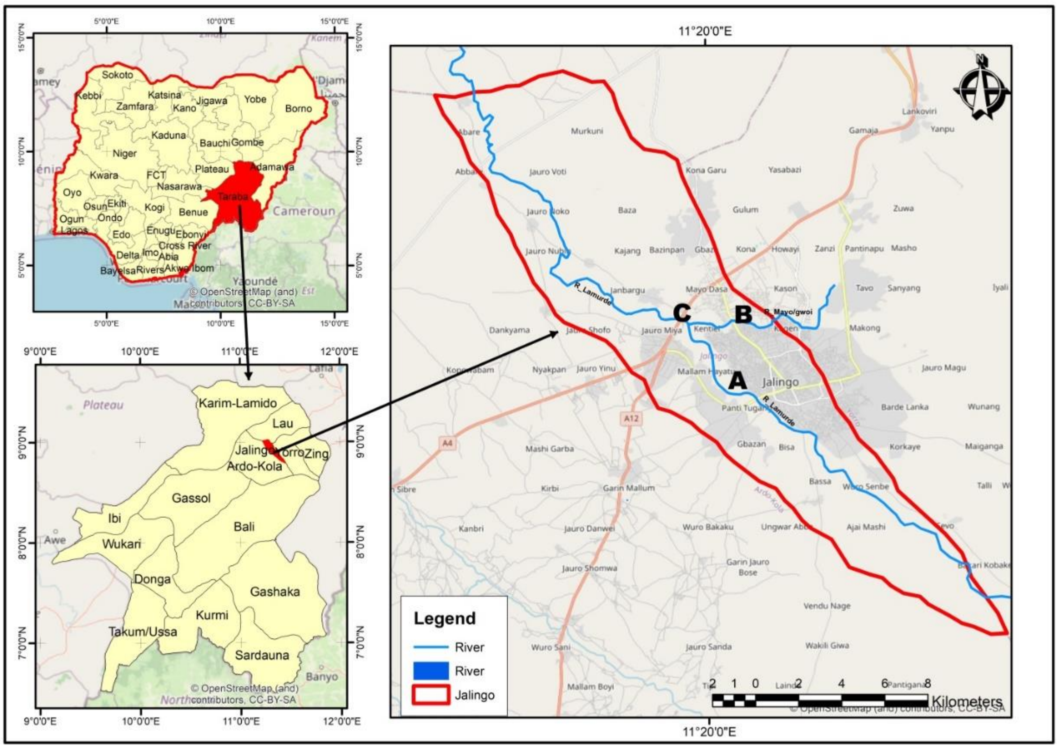

Figure 1 The study area (River Lamurde and River Mayo Gwoi, Jalingo) (Source: Authors Field Survey 2022).

According to the 2006 population census, Jalingo LGA has a population of 139,845, with a projected annual growth rate of 3.6%. In 2020, Jalingo was expected to have a population of 165,774 [24]. The topography of the Jalingo LGA is rolling plains with mountain ranges interspersed. This compact massif of rock outcrops (mountains) runs in a circular form from the Kona area to the border of Jalingo and Lau LGAs down to Yorro and Ardo Kola LGAs to the Gorgon area, given a periscopic semi-circle shape that acts almost as a shield around Jalingo town

Jalingo metropolis is drained by two major rivers, Mayo-gwoi and Lamurde, which originate in the Yorro LGA mountain ranges and empty into the Benue River system at Tau village. The valley of the River Lamurde is dotted with oxbow lakes formed by depositional activities. Jalingo LGA has a tropical continental climate with distinct wet and dry seasons. The wet season typically begins in April and lasts until October while the dry season lasts from November to March [25].

Jalingo lies 183 m above sea level. Jalingo's climate is tropical. In winter, there is more rainfall in Jalingo than in summer. The climate here is classified as AW (The tropical wet-dry climate) by the koppen-Geiger system. The average annual temperature is 27.9°C in Jalingo. In a year, the average rainfall is 958 mm. Precipitation is the lowest in January, with an average of 0mm. With an average of 217 mm, the most precipitation falls in August. At an average temperature of 32.3°C April is the hottest month of the year. December has the lowest average temperature of the year. It is 25.9°C between the driest and the wettest months. The difference in precipitation is 217 mm. During the year, the average temperature varies by 6.3°C.

The climate of Jalingo exhibits a simple pattern of east-west climatic zones distorted by the influence of some highlands, with typically an increase in rainfall on the crest and to the windward and a rain shadow on the leeward side [26]. If not for the effects of the highlands, the area would have had a simple rainfall gradient in a southwest/northeast direction as one would have expected [27].

Jalingo is located within the northern guinea savanna zone characterized by grasses interspersed with tall trees and shrubs. Some trees include locust beans, shea butter, eucalyptus, baobab and silk cotton tree [28].

The major ethnic groups of Jalingo LGA are the Fulani, Kona and Mumuye, while other ethnic groups such as Hausa, Jenjo, Wurkum and Nyandang are also found. The Hausa language is widely spoken as a \medium of communication for social and economic interactions.

Massive farming activities occur along the River Lamurde, where cereals like maize, rice and guinea corn are grown. Vegetables such as okra, onions, pepper (*tartashe*), bitter leaves, and cabbage are also grown along the bank of River Laurde. Tuber crops such as cocoyam, cassava and sweet potatoes are also grown in the area just to mention but a few [29].

The Rivers Lamurde and Mayo Gwoi meet in Jalingo town near Nukkai Bridge. The flood plain of the River Lamurde is extensive on both sides. Despite the increasingly devastating effects of recent floods in the area, the northern bank of the river is heavily populated, while the southern bank is intensively cultivated. The farmers in the area use irrigation to cultivate the land three times a year [30]. The southern part of the town's growth was stifled for a long time. Previously, lands across the River Lamurde With the construction of new roads and bridges along these rivers and an increasing urban population, the land uses along the river's floodplains are rapidly changing (Oruonye, 2015). The River Lamurde is the area's primary source of recharge for underground water, with a typical minimum yield of 648,240 m^3 per year from boreholes within the river's floodplain [31].

The basement rocks beneath the lowland plains appear as isolated rocky hills and ranges with a serrated outline. The rocks are composed of fragments of highly metamorphosed sedimentary rocks and diverse, primarily granitic, plutonic masses known as the older Granites. The oldest rocks are remnants of an ancient sedimentary series nearly completely transformed into migmatites and granite [26]. The basement rocks that underpin the lowland plains appear as isolated rocky hills and low ranges with a serrated outline. The rocks are scattered remnants of highly metamorphosed sedimentary rocks and diverse, primarily granitic, plutonic masses known as the older Granites. The oldest rocks are remnants of an ancient sedimentary series that has been almost entirely transformed into migmatites and granite [32]. Concretionary ironstone is found throughout the area, frequently forming resistant caps; their texture varies greatly, but they are generally vesicular and contain colitic or pisolitic ironstone. Kotzé, Sandhage-Hofmann, Amelung, Oomen, and Du Preez [33] have discussed the wide distribution of these deposits and their mode of origin.

2.2 Flow Chat of the Study Methodology

Figure 2 shows the flow chart illustrating the steps of the methodology in the assessment of Agro-allied chemical pollution on Surface Water Quality of River Lamurde and Mayo-Gwoi, Jalingo, Taraba State, Nigeria. The laboratory tests are recorded in the flow chart and categorized into their parameters. The purpose of this study is to assess the contaminated level of the surface water quality of River Lamude and River Mayo-Gwoi by agro-allied chemicals to ascertain whether it would be suitable for consumption. The study involves analyzing data from previous studies published about the water quality of the study area. The first step is identifying the water quality parameters that must be tested. Then this was followed by data collection from the sampled sites. Next was the laboratory test to determine the agro-allied chemical pollution of the surface water in River Lamurde and Mayo-Gwoi. After that, the water quality was analyzed based on WHO/NSDWQ raw water quality standards to know whether the surface water from the study area was potable or not for consumption. The next step is suggestions for the prevention of agro-allied chemical pollution, treatment of polluted water, and safe use of environmentally friendly fertilizers.

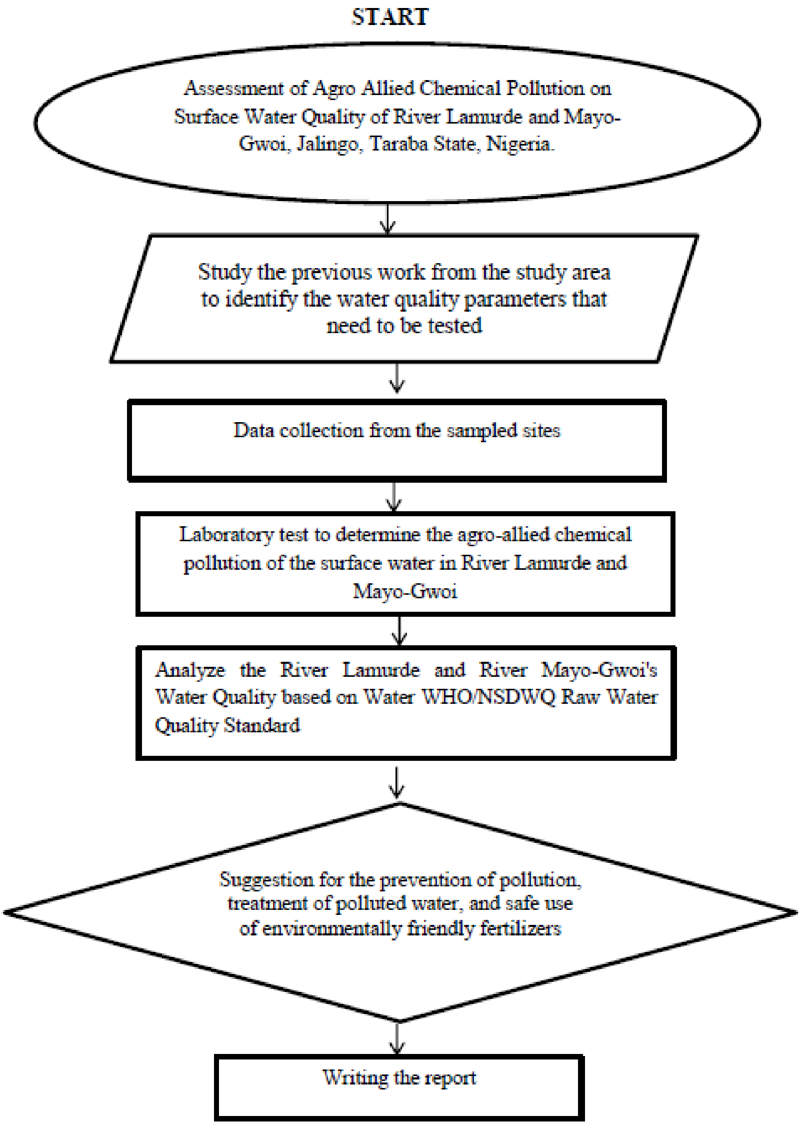

Figure 2 The flow-chart illustrating the steps of the methodology. (Source: Authors Field Survey, 2022).

2.3 Collection of Data

The sampling locations were carefully chosen to include upstream and downstream areas of the rivers (Figure 1). The upstream is comprised of the Lamudi River (A) and Mayo-Gwoi River (B), while the downstream (C) is where the two rivers meet at Nukkai Bridge and flow down. The duration within which the data was collected is six months from March to August 2022. These months cover dry and wet seasons in the area, when farming activities are ongoing and pollution of water resources is likely to be high due to water's solvent activity. Water samples were collected from twenty-one (21) sample sites along the Rivers and replicated three times in both the dry and wet seasons, given sixty-three (63) samples each for dry and wet seasons respectively. In each zone (A, B and C) seven sampling points were purposively selected for collecting water samples one hundred (100) meters apart along the river course, giving rise to the 21 sites. The coordinates of each of these points were taken using the Global Positioning Station (GPS). The water was collected inside sterilized bottles and sent to the laboratory for analysis in Taraba State Rural water supply and sanitation corporation (TAWASCO) Jalingo Taraba State, Nigeria.

Water samples were taken at each sampling site at a point in the river where there was good mixing and stored in a clean plastic bottle. The samples were kept in ice on the field then refrigerated at 4°C in the laboratory. Standard analytical methods were used to conduct agro-allied chemical evaluations on water samples. The parameters that were subjected to laboratory tests comprised: Nitrite, nitrate, zinc, Calcium, Chromium, sulfate, Iron, phosphorous and copper to be measured by using HARCH DR 600 spectrophotometer.

Except for nitrate, all parameters were determined using Standard Method for water quality analysis by American Public Health Association [34]. Nitrate was detected by nitrating 3,4-xylenol in an acidic medium and extracting the nitration product with an appropriate organic solvent (toluene). This was then treated with a strong alkali solution (NaOH) to produce a colored product, the absorbance of which was measured at 432 nm with a CECIL CE202 UV spectrophotometer [35].

2.4 Methods of Data Analysis

The data acquired from the laboratory test was subjected to the analysis of variance (ANOVA) process in a randomized design using the conventional linear approach of the statistical analysis system. The hypothesis was developed to test if there is any significant relationship between agro-allied chemicals pollution and the water quality of River Lamurde and River Mayo_Gwoi in Jalingo town: The most appropriate statistical test for assessing the given hypothesis is the Analysis of Variance ANOVA). This was performed with the Statistical Package for Social Sciences (SPSS).

3. Results and Discussion

3.1 Results

The use of observation and water quality testing of water sampled from the three zones, that is the upstream River Lamude (A), River Mayo-Gwoi (B), and the downstream (C) where the two rivers meet at Nukkai Bridge was used to present the results and discuss the findings in this study.

The results in Table 1 show the content of the agro-allied chemicals in the various sample locations in the study area during the dry seasons. The table clearly states the variation in the content of the agro-allied chemicals from the three sampling locations which are: (A) Lamurde River, (B) Mayo-Gwoi River and (C) the main river downstream. From the table it can be seen that at sample location (A) nitrite content was 520.3 mg/l; at location (B) the content was 578.7 mg/l and at location (C) it was above 600 mg/l. From the same table we discovered that the distribution of copper in the three locations is in this order, at location (A) we have 0.93 mg/l, at location (B) we have 2.09 mg/l and at location (C) which is the main river we have 0 mg/l during the dry season.

Table 1 Average value of agro-allied chemical content of A, B and C water during the Dry Season (for 63 Samples).

PARAMETERS (mg/L)	A	B	C	WHO*/NSDWQ*
Calcium	28.2	40.04	35.06	60
Nitrate	153.02	346	275	50
Zinc	9.77	15.05	0.44	3
Nitrite	520.3	578.7	603.04	50
Chromium	2.54	1.46	1.61	0.05
Phosphate	18.58	22.15	16.86	0.01
Sulfate	318.5	421.4	103.1	100
Iron	3.26	1.87	0.49	0.3
Copper	0.93	2.09	0	2

Source: Field Survey, 2022

WHO*/ [36]

NSDWQ* [37]

This work is similar to a study carried out on river Kaduna considering the Assessment of the heavy metals level of River Kaduna at Kaduna Metropolis, Nigeria by Abui, Ezra, Bonet, and Amos [38], in the study some heavy metals were tested to determine their contents in the River Kaduna. In that study, most heavy metals were above the limit of NSDWQ/WHO as shown in Table 2.

Table 2 Mean value of agro-allied chemical content of A, B and C water during the dry Season compare with the WHO[36]/NSDWQ[37].

PARAMETER	A	B	C	WHO/NSDWQ
Calcium mg/L	5.01 ± 0.77^a	6.09 ± 0.47^a	4.03 ± 0.31^a	60
Nitrate mg/L	39.29 ± 11.70^a	49.43 ± 6.83^a	21.86 ± 0.12^a	50
Zinc mg/L	0.06 ± 0.02^b	2.15 ± 0.27^a	1.41 ± 7.28^b	3
Nitrite mg/L	86.2 ± 5.92^a	82.67 ± 10.55^a	74.33 ± 7.28^a	50
Chromium mg/L	0.23 ± 0.11^b	0.21 ± 0.035^b	0.36 ± 0.08^b	0.05
Phosphate mg/L	2.41 ± 0.31^a	3.16 ± 0.46^a	2.65 ± 0.15^b	0.01
Sulfate mg/L	14.73 ± 0.42^a	60.2 ± 3.61^a	45.5 ± 5.66^a	100
Iron mg/L	0.07 ± 0.09^b	0.27 ± 0.19^b	0.47 ± 0.07^b	0.3
Copper mg/L	0	0.30 ± 0.10^b	0.13 ± 0.05^b	2

Source: Field Survey, 2022

There's no significant difference between means with same superscript across rows ($a = P > 0.05$; $b = P < 0.05$)

The results of the water samples in Table 3 suggest that the agro-allied chemicals utilized have contaminated the River Lamurde and Mayo-Gwoi in Jalingo. These agro-allied chemicals were released into the rivers without being treated.

Table 3 Average value of agro-allied chemical content of A, B and C water during the wet season (for 63 samples).

PARAMETERS (mg/L)	A	B	C	WHO/NSDWQ
Calcium	219	381	357	60
Nitrate	442	294.2	254.41	50
Zinc	4.24	14.72	13.8	3
Nitrite	276	564.11	479	50
Chromium	0.61	3.39	3.69	0.05
Phosphate	10.03	91.2	58.57	0.01
Sulfate	0	0	0	100
Iron	2.42	6.89	4.36	0.3
Copper	0	12.66	19.92	2

Source: Field Survey, 2022

In his study, Tanko [39] found that the concentrations of agro-allied chemicals in surface water and sediments are regulated by input from the source. Most of the agro-allied chemicals examined were above the WHO's permissible limit, especially during the dry season when the river's flow drops. Among the agro-allied chemicals examined nitrite had significant levels over the WHO-permitted limit in the river during both the wet and dry seasons. The presence of high levels of nitrates, copper, zinc, and sulfates in the river throughout both the wet and dry seasons indicates the discharge of significant levels of agro-allied chemicals into the river. An excess of iron in the body might create health problems such as gastrointestinal discomfort. Because of the poisonous impact of iron compounds, excess iron in rivers can impede animal survival, development, and reproduction.

3.2 Discussion

3.2.1 Agro-allied Chemicals Concentration on the Surface Water Quality along A, B and C during the Dry and Wet Seasons

Calcium (Ca). The amount of Calcium in the 100 ml of water samples as obtained from the laboratory analysis for the dry season along the Rivers were 28.2 mg/L, 40.04 mg/L and 35.06 mg/L for samples A, B, and C respectively as shown in Table 1, during the dry season and 219 mg/l, 381 mg/l and 357 mg/l for sample A, B and C as shown in Table 3 during the wet season. The values for the dry season were lower than the WHO/NSDWQ and within the permissible limit of 60 mg/L required for drinking water quality. In contrast, during the wet season, the values were greater than the WHO/NSDWQ and above the permissible limit of 60 mg/L during the wet season as shown in Table 4. The result for calcium in this study is in contrast to that of Oyatayo, Songu, Amos, and Nebula [40], who reported higher values in the hand-dug well water samples. The high amount of calcium in the study area could result from the application of gypsum (a soft sulfate mineral composed of calcium sulfate hydrate) by farmers within the study area since the study area is used for crop production. The high calcium content results in water's hardness [41]. Nitrate (NO_3^-). The nitrate (NO_3^-) levels obtained in the study were 153.02 mg/l, 346 mg/l and 275 mg/l for sample sites A, B and C respectively as shown in Table 1 and during the wet season, sample sites A, B, and C NO_3 levels of 442 mg/l, 294.2 mg/l, and 254.41 mg/l, as shown in Table 3. These values are above the permissible limit of 0.33 and 2.37 mg/l reported by Popoola et al. [42] in the assessment of natural groundwater Physicochemical properties in major industrial and residential locations of the Lagos metropolis. All the nitrate values obtained in the study are above the permissible limit of the World Health Organization [36] recommended guideline value of 50 mg/l. as shown in Table 2 and Table 4 The high values of the Nitrate obtained in the study area could be attributed to the overuse of chemical fertilizer or improper disposal of human and animal waste within the study area. This implies that the nitrate concentrations obtained in the study are above the permissible standards and might pose a health risk to either humans or animals that may drink it [43].

Table 4 Mean value of agro-allied chemical content of A, B and C water during the wet season compare with the WHO/NSDWQ.

Parameter	A	B	C	WHO/NSDWQ
Calcium mg/L	31.29 ± 16.15^a	54.43 ± 20.40^a	51 ± 12.03^a	60
Nitrate mg/L	63.14 ± 15.75^a	42.03 ± 16^a	36.34 ± 7.18^a	50
Zinc mg/L	0.61 ± 0.70^a	2.10 ± 0.72^a	1.97 ± 0.30^a	3
Nitrite mg/L	39.43 ± 8.58^a	96.29 ± 14.58^a	68.43 ± 20.14^a	50
Chromium mg/L	0.09 ± 0.06^b	0.48 ± 0.30^a	0.53 ± 0.71^a	0.05
Phosphate mg/L	1.43 ± 0.43^a	13.03 ± 1.45^a	8.37 ± 5.38^a	0.01
Sulfate mg/L	0	0	0	100
Iron mg/L	0.35 ± 0.12^b	0.98 ± 0.46^a	0.62 ± 0.39^a	0.3
Copper mg/L	0	1.82 ± 0.34^a	2.85 ± 1.13^a	2

There's no significant difference between means with same superscript across rows (a = $P > 0.05$; b = $P < 0.05$)

Zinc (Zn). The amount of zinc obtained from the laboratory analysis was 9.77 mg/l, 15.05 mg/l and 0.44 mg/l for samples A, B and C respectively as shown in Table 1 during the dry season. It was 4.24 mg/l, 14.72 mg/l, and 13.8 mg/l for sample site A, B, and C, as shown in Table 3 during the wet season. The concentrations of zinc within the study area are above the range of 0.00 mg/l, 0.00 mg/l, 0.00 mg/l and 0.00 mg/l as reported by Oyatayo et al. [40] in the Assessment of heavy metal concentration in hand-dug well water from selected land uses in Wukari town, Wukari, Taraba State, Nigeria.

The laboratory values obtained are all above the permissible limits of 3 mg/l as stipulated by WHO/NSDWQ as shown in Table 2 and Table 4. Since there is a high concentration of zinc within the study area as indicated in this study, it is evident that people and animals that drink from these sources could suffer from stomach cramps, nausea, vomiting and anemia [44].

Nitrite (NO_2^-). The nitrite (NO_2^-) levels obtained in this study are 520.3 mg/l, 578.7 mg/l and 603.04 for sampled sites A, B and C respectively as shown in Table 1 during the dry season and 276 mg/l, 564.11 mg/l and 479 mg/l for Nitrite (NO_2^-) in sample sites A, B and C respectively as indicated in Table 3 of this study during the wet season. Bamidele and Fasakin [45] reported a higher value of 0.27 ± 0.005 mg/l in their study of the physicochemical properties of coastal waters in Ondo State, Nigeria. The high values of Nitrite obtained in the study area could be attributed to the overuse of chemical fertilizer or improper disposal of human and animal waste within the study area. All the nitrite values obtained in the study area are higher than the WHO-recommended guideline value of 50 mg/l as shown in Table 4. This implies that the nitrite concentrations obtained in the study area are in excess and might disrupt the oxygen delivering ability of hemoglobin in the bloodstream of humans and animals [46].

Chromium (Cr). The amount of chromium in samples A, B and C obtained from the laboratory analysis are 0.61 mg/l, 3.39 mg/l and 3.69 mg/l for samples A, B and C respectively as shown in Table 1 during the dry season and 0.61 mg/l, 3.39 mg/l and 3.69 mg/l for sample sites A, B and C respectively as recorded in Table 3 of this study during the wet season. The concentrations of chromium within the study area are above the range of 0.01 mg/l, 0.01 and mg/l, 0.01 mg/l as reported by Oyatayo et al. [40] in an assessment of heavy metal concentration in hand-dug well water from selected land uses in Wukari Town, Wukari, Taraba State, Nigeria.

The laboratory values obtained in this stud are all above the permissible limits of 0.05 mg/l as stipulated by WHO/NSDWQ as shown in Table 2 and Table 4. The high value of chromium in the study area could be a result of inadequate industrial waste disposal within the study area. Since it is above the permissible limit for drinking water quality, it shows that it will imply the health of people and animals that may drink from the source. Water containing chromium over the set limit may have an erythropoietin effect such as the increased occurrence of goiter among humans and animals.

Phosphate (PO_4^{3-}). The amount of phosphate as obtained from the laboratory analysis was 18.58 mg/l, 22.15 mg/l and 16.86 mg/l for samples A, B and C respectively as shown in Table 1 during the dry season and 10.03 mg/l, 91.2 mg/l and 58.57 mg/l for sample sites A, B and C respectively as shown in Table 3 of this work during the wet season. The obtained values are in contrast to that of Musa, Shaibu, and Kudamnya [47] who reported 0.85 mg/l, 0.07 mg/l and 0.3 mg/l in Heavy Metal Concentration in Groundwater around Obajana and its Environs, Kogi State, North Central Nigeria. The laboratory values obtained are above the permissible limit of 0.01 mg/l stipulated by WHO/NSDWQ as shown in Table 2 and Table 4. Phosphate is necessary for the formation of bone and teeth [48]. It is equally used as a building block for several important substances, including those used by the cell for energy etc. Too much phosphorus can cause increased growth of algae and large aquatic plants which can result in decreased levels of dissolved oxygen (a process called eutrophication) [49].

Sulfate (SO_4). The sulfate (SO_4) concentration of the samples collected from the sites in the study area are 318.5 mg/l, 421.4 mg/l and 103.1 for sample sites A, B and C respectively as shown in Table 1 of this study during the dry season and 0 mg/l for all sample sites during the wet season. The concentrations during the wet season are above 3.10 mg/l to 66.10 mg/L reported by Moses and Ishaku [50] in evaluating the physicochemical properties of well water qualities in selected villages in Zing Local Government Area of Taraba State, Nigeria. Also, the range found in this study during the dry season is higher than the range of 13-63 mg/L reported by Popoola, Yusuff, and Aderibigbe [42], in the Assessment of natural groundwater physio-chemical properties in major industrial and residential locations of Lagos metropolis. The over-concentration of the sulfate in the study area could be attributed to the high application of fertilizer containing sulfate and calcium by the farmers around the study area. The permissible value by World Health Organization

[36] is 100 mg/L. Therefore, the sulfate concentrations found in the water from the sampled sites are above the permissible limit of WHO standards for good-quality water. Therefore, it can cause a laxative effect on humans and animals when combined with calcium [51].

Iron (Fe). The amount of iron in samples A, B and C during the dry season were: 3.26 mg/l, 1.87 mg/l and 0.47 mg/l respectively as shown in Table 1 and 2.42 mg/l, 6.89 mg/l and 4.36 mg/l for sample sites A, B and C during the wet season as shown in Table 3 of this study. These values of iron concentration are above the permissible limit compared to the 0.3 mg/l permissible limits set by WHO/NSDWQ in Table 2 and Table 4. The beneficial effects include; chlorophyll synthesis, oxidation-reduction in respiration, and constituent of certain enzymes and proteins [52].

Excess concentration of iron has a negative effect as it can cause gastrointestinal irritation and enhance the growth of iron bacteria that affects the water taste [53]. The high concentration values of iron can potentially stain laundry and metal pipes for reticulation and to scale in pipes [54]. It can also result in gene mutation leading to haemochromatosis, whose symptoms include fatigue, weight loss, joint pains, heart disease, liver problems and diabetes [55].

Copper (Cu). The amount of copper in the 100 ml of water samples as obtained from the laboratory analysis during the dry season at River Lamurde were 0.93 mg/l, 2.09 mg/l and 0 mg/l for sample sites A, B and C respectively as shown in Table 1 and 0 mg/l from sample site A, 12.66 mg/l for sample site B and 19.92 mg/l for sample site C during the wet season as recorded in Table 3 of this study. The values from point A and C during the dry season falls below the Permissible limit of 2.0 mg/l set by WHO/NSDWQ which makes it safe for drinking while the values from sample site B and C during the wet season are far above the permissible limit as shown in Table 3. Though still within permissible limits during the dry season, some people who drink water containing copper over the action level in the short term may experience gastrointestinal distress while those with long-term exposure may experience anemia and liver or kidney damage [56]. Also, long term exposure to copper water can cause irritation of the nose, mouth and eyes, leading to headaches, dizziness, vomiting and diarrhea, among other health hazards [44].

The findings from this study show that the concentration of all the parameters except copper during the dry season and sulfate during the wet season at River Lamurde and River Mayo Gwoi are all above the set permissible limit of WHO/NSDWQ as shown in Table 1 and Table 3. This confirms the findings of the Federal Environmental Protection Agency [57] in Guidelines and Standards for Environmental Pollution Control in Nigeria.

3.2.2 The ANOVA Result

The mean scores by sites from the different sampling sites in Table 5 could be approximated into the same magnitude. This accounted for the result in the ANOVA test presented in Table 6. The mean indicated that the agricultural practices and chemical properties differed in the selected sites/locations.

Table 5 Mean and Standard Deviation scores by sources.

Classes	**F**	**Mean**	**Std. Deviation**	**Std. Error**
A	7	2.553	0.26101	0.03175

B	7	2.711	0.25181	0.02316
C	7	2.663	0.27014	0.02251
Total	21	2.642	0.26098	

Table 6 Analysis of variance.

Variations	Mean	Df	Mean Square	F	Sig.
Within group	0.812	2	0.406	2.575	0.077
Between groups	65.716	25	0.158		
Total	66.528	27			

The ANOVA result presented in Table 6 shows a P-Value of 0.077 which is more than 0.05 ($P > 0.05$), implying that there is no significant difference between agro-allied chemical pollution and the surface water quality in the study area. Therefore, this implies that the water quality of each of the selected sites is determined by the type of agrochemicals used.

The findings from this study show that the concentration of all the parameters except copper during the dry season and sulfate during the wet season at Lumurde and Mayo Gwoi Rivers are all above the set permissible limit of WHO/NSDWQ as shown in Table 1 and Table 3. This confirms the findings of FEPA [57] in Nigeria's Guidelines and Standards for Environmental Pollution Control.

4. Conclusion

Water plays a crucial part in the sustenance of life. The River Lamurde and Mayo Gwoi, which flow through the Jalingo metropolis, are being polluted mostly through human activities, which have serious health implications for persons living along the course of the river and beyond. The water in the River Lamurde and Mayo Gwoi was subjected to agro-allied chemical tests. The parameters tested were: Calcium, Nitrate, Zinc, Nitrite, Chromium, Phosphate, Sulfate, Iron, and copper. Copper and Calcium (Ca) concentrations were 28.2 mg/L, 40.04 mg/L and 35.06 mg/L for samples A, B and C, respectively, during the dry season and 219 mg/l, 381 mg/l and 357 mg/l for sample A, B and C. Nitrate concentration was recorded153.02 mg/l, 346 mg/l and 275 mg/l for sample sites A, B and C during the dry season and 442 mg/l, 294.2 mg/l and 254.41 mg/l for sample site A, B and C during the wet season. Zinc concentrations obtained during the study were 9.77 mg/l, 15.05 mg/l and 0.44 mg/l for samples A, B and C, respectively during the dry season and 4.24 mg/l, 14.72 mg/l and 13.8 mg/l for sample site A, B and C during the wet season. The nitrite levels obtained in this study were 520.3 mg/l, 578.7 mg/l and 603.04 for sampled sites A, B and C during the dry season and 276 mg/l, 564.11 mg/l and 479 mg/l for sample sites A, B and during the wet season. 0.61 mg/l, 3.39 mg/l and 3.69 mg/l for samples A, B and C respectively during the dry season and 0.61 mg/l, 3.39 mg/l and 3.69 mg/l for sample sites A, B and C during the wet season were recorded for Chromium during the study. The amount of phosphate recorded during the laboratory analysis was 18.58 mg/l, 22.15 mg/l and 16.86 mg/l for samples A, B and C during the dry season and 10.03 mg/l, 91.2 mg/l and 58.57 mg/l for sample sites A, B and C during the wet season. 318.5 mg/l, 421.4 mg/l and 103.1 for sample sites A, B and C during the dry season and 0 mg/l from all the sample sites during the wet season were recorded for Sulfate during the study. During the findings, 3.26 mg/l, 1.87 mg/l and 0.47 mg/l were recorded for Iron during the dry season and 2.42 mg/l, 6.89 mg/l and 4.36 mg/l for sample sites A, B and C during the wet season. 0.93 mg/l, 2.09 mg/l and 0 mg/l for sample sites A, B and C respectively were recorded during the dry season and 0 mg/l from sample site A, 12.66 mg/l for sample site B and 19.92 mg/l for sample site C were also obtained during the wet season. The findings showed that the water from River Lamurde did not meet WHO/NSDWQ drinking water standards since all the parameters tested were above the permissible limit except for copper during the dry season and sulfate during the wet season was within the permissible limit of WHO/NSDWQ. The main causes of the pollution were induced by rapid population growth and human activities such as fertilizer application on farms and dumping of wastes around River Lamurde's bank. The River Lmaurde and Mayo Gwoi are polluted not only through anthropogenic causes but also through natural causes. When it rains, streets, lawns, roofs, pavements and compounds of homes are washed and urban runoff carries sand, silt, particulate matter and organic matter into the River Lamurde. and Mayo Gwoi.

The result of the laboratory analysis showed that the concentration of copper during the dry season and sulfate during the wet season in River Lamurde and Mayo Gwoi falls within the permissible limits of WHO/NSDWQ while the concentration of Calcium, Nitrate, Zinc, Nitrite, Chromium, Phosphate and Iron were above the permissible limits of WHO/NSDWQ. The results indicated that the water quality is becoming deteriorated because most of the parameters tested for are not found to be at permissible limits, except for Sulfate and Copper which are found to be at the permissible limit because they are found to be at low levels in concentration. For now, it can be concluded that River Lamurde and Mayo Gwoi are not fit for domestic use, particularly drinking, but effo" {centration by having control on the anthropogenic factors (domestic wastewater, heavy metals, fumigation, local industries effluents) that lead to such high concentration levels or else, soon this source of water may go worse than it is now for domestic use.

5. Recommendations

Based on the finding of the study, the following were recommended for the mitigation of the excess concentration of agro-allied chemicals along the River Lamurdeand Mayo Gwoi:

Using agro-allied chemicals such as fertilizers, herbicides and pesticides should be avoided.

If agro-allied chemicals must be used along the floodplain of River Lamurde and Mayo Gwoi the right proportion should be used.

Environmentally friendly fertilizers (composting organic litter) such as dropping from poultry, farm yard manure, residues from homes and cow dung be applied on the farm along the plain to avoid the pollution of the water

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Author Contributions

Ezekiel, B Bwadi – Do the development of the manuscript and all correspondence. Adelalu Temitope G. – Conducted the statistical analysis. Christopher James N, - Collection of data and Proofreading. Alhassan Tijjani, - Collection of data and Proofreading.

Competing Interests

The authors have declared that no competing interests exist.

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