Copper Concentration and Distribution in the Ground Water of Delta State Polytechnic, Ozoro, Nigeria

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Authors' contributions

This work was carried out in collaboration between both authors. Author ORA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author HU managed the analyses of the study and managed the literature searches. Both authors read and approved the final manuscript.

Original Research Article

ABSTRACT

Copper toxicity in the ecosystems have becomes a global concern in recent times; therefore, there is need to curtail the increment of copper concentration within the environment. In this study, a total of 67 ground water samples were collected from the premises of Delta State Polytechnic, Ozoro, at a depth of 90 cm. The water samples were collected during the peak of the rainy season (September 2019); when the water table of the study area was very high, close to the soil surface. Copper concentration of all the water samples collected was measured using the Atomic Absorption Spectrophotometer (AAS). The results showed that copper concentration in the study ranged between 1.01 mg/L and 2.105 mg/L. The spatial distribution of the copper concentration within the study area was determined using Geostatistical tool. Variation map developed from the results showed that the copper concentration does not spread uniformly across the study area. High copper concentration was generally recorded at the North Eastern and central parts of the school; while low copper concentration was recorded at the South Eastern part of the school. Furthermore,

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the results strongly showed that waste dump potentially affects the copper concentration of the ground water within the study area. This study results advocated the need for proper waste disposal with the polytechnic environment, and the adequate treatment of the groundwater before human consumption.

1. INTRODUCTION

Heavy metals pollution is one of the major global environmental problems, which contribute immensely to the contamination of the ecosystems [1]. This is because they are elusive invisibility, persistent and irreversible, as well as highly toxic [2,3]. According to Wang and Chen [4], there are three main categories of heavy metals; these include the valuable metals (Ag, Au, Pd, Pt, etc.), harmful metals (As, Cu, Co, Cd, Cr, Hg, Ni, Pb, etc.) and radionuclides (Am, Th, Ra, etc.). Experimental results have shown that heavy metals cause a wide range of human diseases and various long-term negative environmental consequences; thus endangering overall global sustainable development initiatives [5,6]. Heavy metals are transmitted to the plant's system either through direct assimilation by the plant's roots system; or assimilation by the plant's leaves through foliar application using the contaminated water. In human beings and animals, heavy metals are transmitted into their body system either through consumption of the contaminated plants, or through direct/indirect consumption of the contaminated water [7,8].

Copper (Cu) is a trace element, with an atomic number of 29, present in rocks, soil, volcanic dust, plants and animals [9]. Copper intrusion in soils is dependent on both natural as well as anthropogenic sources; but agricultural soils receive considerable toxic levels of Cu from environmental pollution resulting from anthropogenic activities [10,11]. Copper solubility and availability in soil is highly influenced by the soil pH (below 6) and dissolved organic matter content [12,13]. Copper Phytotoxicity is influenced by its solubility and availability in the soil. High copper concentration in the soil is strongly phytotoxic and can alter vital biochemical processes, and modified the membrane permeability, chromatin structure, protein synthesis of the plants [13,14]. When compared with other potentially toxic essential trace elements, such as Mn, Cd and Zn; high concentration of Cu is more toxic to plants; but less harmful to animals and human beings [15,16]. For instance, in rice roots, excess Cu can specifically altered the genes involved in fatty acid metabolism and cellular component biogenesis [17]. A study on the expression of four metallochaperone genes, ATX1, CCS, HIPP05 and HIPP06, involved in metal homeostasis and Cu detoxification in rapeseed showed that, Cu stress activated the expression of the CCS gene in both leaves and roots [13,18]. In the rapeseed of mustard plants, there was 35% reduction in content of photosynthetic pigments when the plants were treated with high dose (100 µM) of copper for 72 hours [18].

The toxic effects of heavy metals on human beings cannot be over-emphasized. According to the Agency for Toxic Substances and Disease Registry (ATSDR), the effects of heavy metals on the human body depend on the dosage, the duration, how you are exposed, personal traits and habits [9]. Human beings can be exposed to toxic substances through breathing, eating, drinking, or by skin contact. Copper is an essential micronutrient needed by the body for good health, however, a higher dose of it becomes toxic to the body. Excess in copper in the body dust can cause headaches, dizziness, nausea, stomach cramps, stretch marks, diarrhea liver and kidney failure [9]. If copper is taken in high dosage, it often causes connective tissues problem, arthritis osteoporosis, muscle weakness, tendons disorders and renal complications. Acute renal failure developed in 20-40% of patients with acute copper sulphate poisoning. In addition, urinary abnormalities such as albuminuria, hemoglobinuria and hematuria were reported in people with excess copper in their body [19].

To date, a large number of studies have reported on the spatial distribution of heavy metals in the ecosystems. Tyokumbur and Okorie [20] investigated the accumulation of some heavy metals in edible crabs and frogs (*Rana esculentus* and *Xenopuslaevis*) collected from Alaro stream located at Ibadan, Nigeria. They reported that the frogs' liver contains a higher concentration of the heavy metals when compared to the other organs. Likewise; a study conducted on soils samples collected from

Ishiagu community of Nigeria revealed that, lead concentration varied across the depth of the soil profile. These lead concentrations 305.46 mg/kg, 216.24 mg/kg and 105.31 mg/kg were recorded at these 5, 10, 100 m soil depths respectively [21]. Atikpo and Ihimekpen [22] studied the spatial distributions of lead (Pb) in Amaonye forest in Ebonyi State, Nigeria. Their results showed that lead had irregular spatial distribution in the forest, with the highest concentration located around the stream and spread in the direction of water-flow into the forest soil as influenced by the topography of the landscape. The spatial distribution and contamination of some heavy metals (Cd, Cr, Cu, Ni, Pb, and Zn) in inshore sediments of Bohai Bay, Caofeidian were studied; and it was observed that the heavy metal metals concentrations were generally higher in the area of Caofeidian, when compared to results obtained from other Chinese bays and estuaries [23]. Furthermore, the spatial distributions of some heavy metals in River Ngada, Borno State, Nigeria were investigated. It observed from the investigation that the heavy metals concentration and distribution varied across the area; with the concentrations of the heavy metals increasing as the sediment depth increases, indicating age-long accumulation of heavy metals from anthropogenic sources [24].

However, there is inadequate literature on the concentration and distribution of copper metal within the Delta State Polytechnic, Ozoro, ground water during the rainy season (flooding period), when the water table is very high. Therefore, the aim of this study is to investigate the spatial distribution of copper (Cu) in the ground water of Delta State Polytechnic, Ozoro, Nigeria. The main objectives are to; (i) investigate the spatial distribution of copper in the area, (ii) explore the possible controlling factors for the spatial distributions, and (iii) assess the contamination and potential ecological risk of the heavy metal. The appropriate identification of copper metal flashpoint is necessary as prerequisite to appropriate action.

2. MATERIALS AND METHODS

2.1 Description of Experimental Area

This study was conducted within the premises of Delta State Polytechnic, Ozoro, located in Isoko North Local Government Area of Delta State, Nigeria (Fig. 1). Ozoro falls within the southern tropical evergreen forest zone of Nigeria, and characterized by two climatic seasons (rainy and the dry season). During the rainy season (between April and October), Ozoro usually experienced high water Table levels throughout the entire community, and seasonal flooding in most parts of the community.

The total experimental area used for this study, within the school premises was 1 km by 1 km, which was gridded at 100 m intervals. The coordinates of all location was captured and registered using a hand-held global positioning system (GPS) receiver. The study area is prone to very high water level during the rainy season (between April and October). At the northern border of the study area (the school), there was an active landfill, and a lot of vehicle repair workshops. The landfill site is about 4 acres of land. The waste are brought from Ozoro metropolis and dumped by the municipality waste collection contractor's trucks. The waste materials include plastic materials, food items, grass clippings, abandoned furniture, street sweepings, etc. Residential buildings are located at the Eastern and Western borders of the school; while the southern border is subjected to peasant farming. Water samples were obtained at the grid points at depth of 90 cm. The water sampling was carried out during September, 2019.

2.2 Water Samples Collection

Holes (90 cm deep) were bore at each spatial (registered) location with the aid of a calibrated soil auger. Due to obstruction caused by buildings and other structures, not all the grid points were covered. But a total of 61 spatial points were bored. Water sample was collected from each individual bore hole and poured into an individual plastic bottle. The collection and handling of all the water samples from the spatial points were conducted in accordance with standard international recommendations.

2.3 Determination of Copper Content of Water Samples

The copper concentration of the water samples was measured by using the Atomic Absorption Spectrophotometer (AAS) with flame detection, in accordance with standard procedures recommended by ASTM. All the tests were done in triplicate at laboratory temperature (24±4°C).
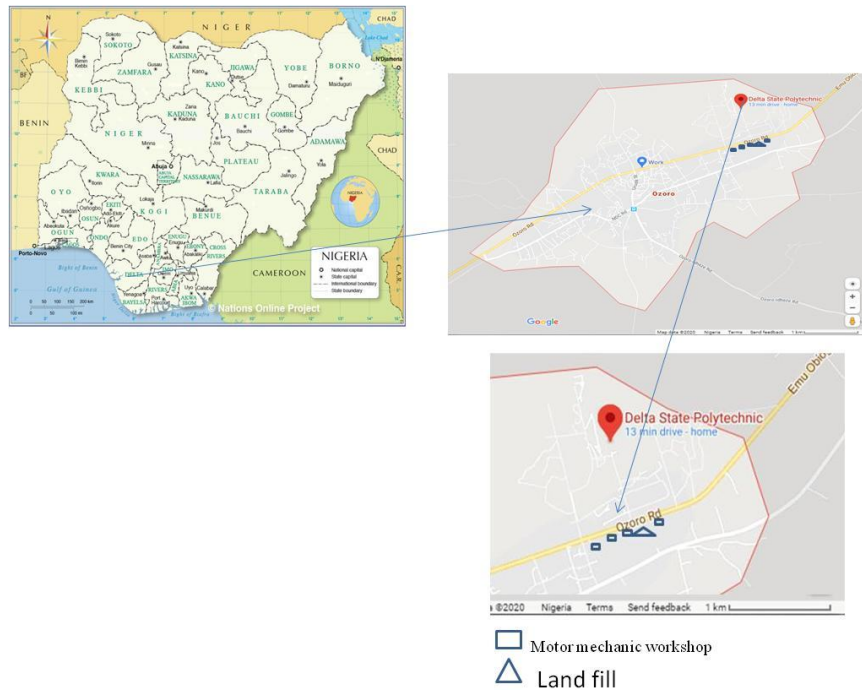
Fig. 1. Map of isoko north local government area of delta state, Nigeria showing ozoro community and the polytechnic where the water was collected. source: [29]

2.4 Data Analysis

The spatial distribution of copper metal concentrations was constructed using geostatistical tool. The data obtained from this study were analyzed statistically by using the Microsoft Excel for Windows.

3. RESULTS AND DISCUSSION

The results obtained in this study showed that copper concentration of the groundwater within the study area ranged between 2.105 mg/L and 1.01 mg/L. Variation map and Semivariogram plotted from the results (Figs. 2 and 3) depicted that the copper concentration was not uniformly distributed across the study area. High copper concentration was recorded at the North Eastern and central parts of the school; while low copper concentration was recorded at the Eastern part of the school. As we move from the North East to the North West, it was observed that copper concentration generally declined. The high copper concentration observed at the North Eastern part of the school may be attributed to the landfill located at about 200 m from the North Eastern region of the school. Research results have shown that landfills have the capability of increasing heavy metals concentrations in the soil and water bodies, to a dangerous level [25].

Naveen et al. [25] observed that the concentrations of the heavy metals declined as the spatial locations moved away from the polluting sources; implying that the surface water was more dependent on proximity to landfill sites. Likewise, the high significant copper concentrations located at the central part of the study area could be attributed to waste dumps, septic tanks and other laboratory wastes indiscriminately discharged into the environment. According to United States Environmental Protection Agency, concentration of copper in water body is complex and is highly depended on the pH, dissolved oxygen and presence of oxidizing agents and chelating compounds or ions [26]. The low copper concentration recorded at the South Eastern parts of the study area could be attributed to the clay-loamy soil and green plants predominant in that region. Citing Barceloux [27], clay soil has a strong adsorption for copper in a pH dependent fashion, which is facilitated by the presence of organic materials. The results showed that the water quality obtained mostly from the southern part of the school falls short of international permissible maximum limit. United States Environmental Protection Agency (US EPA) recommends that copper concentration of drinking water must not exceed 1.3 mg/L [28].
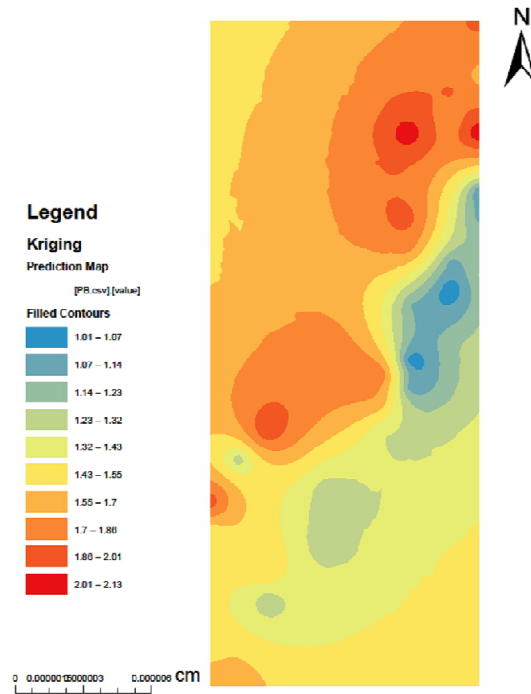
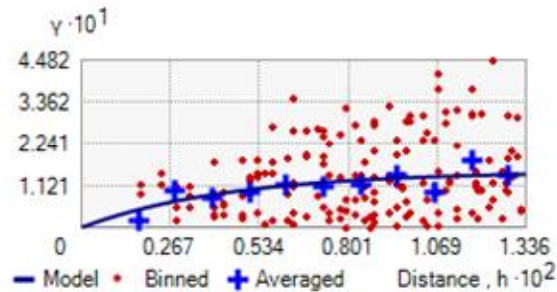**Fig. 2. Variation map showing distribution of copper concentration**

Fig. 3. Semveriogram showing spatial distribution of copper within the study area

Our findings in this study followed similar trends by previous researchers. ATSDR [9] reported that copper concentrations in surface waters in America ranged from 0.0005 to 1 mg/L, with a median value of 0.01 mg/L. Another group of researchers observed a wide variation in the spatial distribution of some heavy metals in the surface waters of Voghji, Norashenik, and Geghi Rivers located at Armenia [30]. Likewise, strong variations were observed in the concentrations of heavy metals in the pore water of the Fuyang River, Haihe Basin, and most of the concentrations recorded were above the Interstitial Water Criteria Toxic limit [31]. Spatial distribution of heavy metals is a powerful tool in

identifying the contamination hotspots and possible sources of heavy metals [30]. Low level of Cu (50 mg/kg of soil) increased the biomass and macro- and micronutrients of green gram grown for 45 days, while excess Cu has an opposite effect on these parameters [32]. This relatively high copper concentration will not only be harmful to the human beings that consume the water without appropriate treatment, but also to the crops that thrive in the area. If cucumber is exposed to higher dosage of copper (20 mg Cu/kg of sand), the distribution of Ca, K and Mg in its root and shoots systems, is highly altered [13,33]. Proper understanding of the hazardous metals in ground water is important for

environmental management and protection. Copper toxicity is a priority in the aquatic ecosystems [23,34]; therefore, there is urgent need to curtail the increase in the concentrations of heavy metals within the ecosystems. The spatial distribution pattern of the copper concentration in the ground water showed that landfill and educational activities are the principal copper pollutant sources within the study area.

4. CONCLUSION

This study was conducted to evaluate the spatial distribution of copper within the premises of Delta State Polytechnic, Ozoro, Nigeria. A total of 67 ground water samples were collected from the premises of Delta State Polytechnic, Ozoro, at the depth of 90 cm. The water samples were sampled during the peak of the rainy season, September 2019; with the area experiencing high water Table. Copper concentration of the water samples was determined by using standard recommended procedures. Results obtained from the laboratory showed that copper concentration ranged between 2.105 mg/L and 1.01 mg/L, within the study area. Furthermore, the spatial distribution pattern of the copper concentration in the ground water showed that waste dumps and laboratory wastes are the principal copper pollutant sources within the study area. Data obtained from this study will be useful in planning central waste disposal unit within the school environment, and the need to curtail the increase in the concentrations of heavy metals within the ecosystems.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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