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Assessment of Some Heavy Metals Concentration and Perfluoroalkyl Substances in Water from Bade and Jakusko LGAs of Yobe State

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Abstract

The contamination of aquatic and terrestrial ecosystems by heavy metals and perfluoroalkyl substances (PFAS) has raised significant global environmental and public health concerns. Heavy metals such as lead (Pb), cadmium (Cd), chromium (Cr), and mercury (Hg) are persistent in the environment and can bioaccumulate in living organisms. Similarly, PFAS are synthetic chemicals widely used in industrial and consumer products. This study evaluates the concentrations of heavy metals and perfluoroalkyl substances (PFAS) in water samples from Bade and Jakusko Local Government Areas (LGAs) of Yobe State, Nigeria. The research highlights the contamination of aquatic systems by heavy metals such as chromium (Cr), cobalt (Co), nickel (Ni), cadmium (Cd), arsenic (As), and lead (Pb), as well as PFAS, which includes compounds like perfluorooctanoic acid (PFOA). Water samples from selected wards in both LGAs were analyzed, and their concentrations were compared with standards set by the World Health Organization (WHO), the National Agency for Food and Drug Administration and Control (NAFDAC), and the Environmental Protection Agency (EPA). Results reveal alarming levels of heavy metals, particularly lead (Pb) and cadmium (Cd), which exceeded permissible limits in all sampled locations. PFAS concentrations, though lower than heavy metals, occasionally surpassed EPA-recommended levels for PFOA. For instance, lead levels reached 53.71 mg/L in Katuzu, Bade, and 61.77 mg/L in Katamma, Jakusko, far exceeding the permissible limit of 0.01 mg/L. Similarly, PFOA concentrations in some wards exceeded EPA guidelines, suggesting potential risks to aquatic ecosystems and human health. The findings highlight significant environmental and public health implications, emphasizing the urgent need for remediation strategies, improved waste management, and enforcement of water quality standards in these regions.

Keywords: AI, Technologies, Impact, Architecture, Optimization, Transformation.

Introduction

The contamination of aquatic and terrestrial ecosystems by heavy metals and perfluoroalkyl substances (PFAS) has raised significant environmental and public health concerns globally. Heavy metals such as lead (Pb), cadmium (Cd), chromium (Cr), and mercury (Hg) are persistent in the environment and can bioaccumulate in living organisms. Similarly, PFAS are synthetic chemicals widely used in industrial and consumer products, recognized for their persistence, bioaccumulation potential, and adverse effects on health (Adamu, A., 2020). Heavy metals are naturally present in the environment but their concentrations are significantly elevated by anthropogenic activities such as agriculture, mining, industrial discharge, and urbanization. Studies have shown that these metals can enter aquatic systems through runoff and effluents, affecting fish and water quality. Soil contamination occurs through irrigation with polluted water, improper waste disposal, and atmospheric deposition, impacting crop growth and accumulation in vegetables consumed by humans (Tchounwou, P., (2012). For example, high concentrations of cadmium and lead have been associated with industrial activities and agricultural practices. Studies in northern Nigeria, including Yobe State, reveal that irrigation with contaminated water leads to the accumulation of metals in vegetables and soils, posing risks to human health due to consumption of these crops (Mohammed, I., 2019)

PFAS are a class of chemicals that include perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS). They are widely used for their non-stick, stain-resistant, and water-repellent properties. However, PFAS are persistent, resist environmental degradation, and bioaccumulate in aquatic organisms, particularly fish, which are often indicators of environmental contamination. Research has shown that PFAS contamination arises from industrial discharge, wastewater treatment plants, and household waste. In aquatic environments, PFAS accumulate in fish tissue, raising concerns about their entry into the food chain. Similarly, studies from arid and semi-arid regions in Africa suggest that improper waste management contributes significantly to PFAS levels in soil and water Heavy metals such as lead and cadmium are known neurotoxins and carcinogens, while PFAS exposure is associated with immunotoxicity, endocrine disruption, and adverse developmental effects. Contaminated soil and water not only affect the growth and safety of vegetables but also pose risks to ecosystems and human health when consumed directly or through bioaccumulation in the food chain (Wang, Z., et al., 2017).

Bade and Jakusko LGAs of Yobe State are characterized by agricultural practices that depend heavily on water sources prone to pollution. Limited studies have assessed the prevalence of heavy metals and PFAS in these areas, highlighting the need for comprehensive analysis to evaluate their concentrations in fish, soil, vegetables, and water. Identifying the primary sources of contamination and assessing risks to human and ecosystem health are essential for informed policy-making and environmental management (Suleiman, A. (2021).

Water is produced via the chemical fusion of hydrogen and oxygen in a 2:1 ratio and is the most prevailing compound, encompassing roughly three-quarters of the Earth's crust. The body of water on our planet, including oceans, seas, rivers, and springs, is composed of hydrogen and oxygen. Pure water has an estimated solid impurity content of 0.001% (Magdalena *et al.*, 2001). The characteristics of water exhibit a degree of heterogeneity, which is contingent upon the origin of water. There exists a variance in the corrosive nature of water, influenced by the geographical location of the water source (Darren and Mallikarjuna, 2010).

Trace elements of natural origin are transported by rivers and transferred to the coastal marine system through estuaries. The trace elements are distributed between the dissolved and particulate phase, while their fate and bioavailability depend on the particle chemistry and competition between surface and dissolved forms in terms of complex processes (Oronsaye *et al.*, 2010). Hence, the estuaries constitute a natural reactor in which heterogeneous processes at the interface between dissolved phase and suspended particulate matter which constitute an important part of the trace elements geochemical cycles (Censi *et al.*, 2006).

Human activities such as mining, manufacturing and fossil fuel burning has resulted in the accumulation of lead and its compounds in the environment, including air, water and soil. Lead is used for the production of batteries, cosmetics, metal products such as ammunitions, solder and pipes. Lead is highly toxic and hence its use in various products, such as paints gasoline, has been considerably reduced nowadays. The main sources of lead exposure are lead based paints, gasoline, cosmetics, toys, household dust, contaminated soil, industrial emissions. Lead poisoning was considered to be a classic disease and the signs that were seen in children and adults were mainly pertaining to the central nervous system and the gastrointestinal tract (Martin-Del *et al.*, 2002).

Toxicity of lead, also called lead poisoning, can be either acute or chronic. Acute exposure can cause loss of appetite, headache, hypertension, abdominal pain, renal dysfunction, fatigue, sleeplessness, arthritis, hallucinations and vertigo. Chronic exposure of lead can result in mental retardation, birth defects, psychosis, autism, allergies, dyslexia, weight loss, hyperactivity, paralysis, muscular weakness, brain damage, kidney damage and may even cause death (Mtanga and Machiwa, 2007).

Cadmium is released into the environment through natural activities such as volcanic eruptions, weathering, river transport and some human activities such as mining, smelting, tobacco smoking, incineration of municipal waste, and manufacture of fertilizers. On very long exposure time at lower concentrations, it can become deposited in the kidney and finally lead to kidney disease, fragile bones and lung damage (Agatha, 2010).

Chromium is present in rocks, soil, animals and plants. It can be solid, liquid, and in the form of gas. Occupational sources of chromium include protective metal coatings, metal alloys, magnetic tapes, paint pigments, rubber, cement, paper, wood preservatives, leather tanning and metal plating (Mwegoha and Kihampa, 2010). Chromate compounds can induce deoxyribonucleic acid (DNA) in many ways and can lead to the formation of DNA adducts, chromosomal aberrations, alterations in replication and transcription of DNA (Obasohan and Oronsaye, 2010) which have resulted in the release of substantial volumes of hazardous chemicals, notably heavy in light of its environmental toxicity, abundance, and durability, metal contamination in the aquatic environment has international attention in recent years. This is attributable to the global surge in population and intensive domestic activities, as well as the escalating levels of industrial and agricultural production, metals, into rivers across the globe (Siraju-Islam et al., 2021).

Perfluoroalkyl Substances

Perfluoroalkyl substances (PFAS) are a collection of synthetic compounds extensively utilized in diverse industrial sectors and consumer goods since the 1950s. These substances are distinguished by their distinctive chemical composition, consisting of a wholly fluorinated carbon chain chemically linked to a range of functional groups (USEPA, 2020).
PFAS are renowned for their exceptional resistance to water and grease, as well as their thermal stability and low surface tension. PFAS have been extensively utilized in a broad spectrum of applications, encompassing the manufacturing of non-stick cookware, oil and water-repellent coatings for textiles and carpets, firefighting foams, electronic components, and various industrial processes (Li *et al.*, 2019). Owing to their extensive utilization and prolonged persistence, PFAS has permeated the environment. The presence of PFAS in the environment raises concerns due to their enduring nature, potential for bioaccumulation, and possible adverse health effects (Field *et al.*, 2020). PFAS within the environment, including water, soil, and sediments, and have been detected in wildlife as well as in globally distributed samples of human blood, urine, and breast milk (USEPA, 2020). Examples of PFAS Found in Soil are Perfluorooctanoic Acid (PFOA), Perfluorooctanesulfonic Acid (PFOS) and Perfluorohexane sulfonic acid (PFHxS). (Gomis et al., 2020).
Perfluorooctanoic acid (PFOA), also referred to as C8, is an artificial chemical compound that falls under the classification of per- and polyfluoroalkyl substances (PFAS). Its extensive utilization and enduring presence in the environment, along with its potential detrimental effects on human health, have attracted substantial attention (USEPA, 2020). PFOA has been widely employed in various industries for the production of fluoropolymers and surfactants. It is associated with a diverse range of adverse health consequences, including developmental and reproductive complications, liver damage, and potential carcinogenicity (Tsai *et al.*, 2017). PFOA has been utilized for numerous decades in the manufacturing of various consumer goods and industrial applications, such as non-stick cookware, stain-resistant fabrics, water-repellent coatings, firefighting foams, and numerous other products. Its distinctive chemical properties, such as high surface tension and resistance to heat, confer significant value to these applications (USEPA, 2020).
Perfluorooctanesulfonic acid (PFOS) is classified as a persistent organic pollutant within the per- and polyfluoroalkyl substances (PFAS) group (Gomis *et al.*, 2020). Its synthetic nature has garnered considerable attention due to its extensive use, resistance to environmental degradation, and potential detrimental impacts on both human health and the ecosystem. PFOS was commonly employed in firefighting foams and as a repellent for stains on fabrics. Additionally, it has been detected in various environmental matrices, including soil (Zhang

et al., 2016). Exposure to PFOS has been associated with a range of health concerns, such as suppression of the immune system and potential effects on development (USEPA, 2020). PFOS has found application in a multitude of industrial and commercial sectors, notably in firefighting foams, stain-resistant coatings for textiles, paper and packaging, metal plating, and electronics manufacturing. Its molecular structure comprises an eight-carbon chain with a sulfonic acid group, wherein all hydrogen atoms are substituted with fluorine atoms, conferring exceptional stability and resistance to degradation (Field *et al.*, 2020). The environmental persistence of PFOS poses a significant apprehension, as studies have demonstrated its resistance to natural degradation processes, leading to its accumulation in the environment over time (Weber, 2018).

Per- and polyfluoroalkyl substances (PFAS) encompass a collection of over 4000 synthetic chemicals. These compounds are endowed with distinct chemical and physical properties, such a soil and water repellency, thermal stability, and friction reduction. As a result of these attributes, PFAS have found extensive employment in consumer goods and industrial processes. Notable examples of PFAS applications include nonstick coatings, fast food packaging, water and stain repellants, polishes, textile coatings, paper products, cosmetics, pesticides, herbicides, and firefighting foams. Furthermore, PFAS are also utilized in the industrial manufacturing of photographic, automotive, semiconductor, aerospace, construction, electronics, and aviation products (Swati, Amar and Muhammad, 2021).

Perfluoroalkyl substances (PFAS) have been evaluated across various environmental mediums. Research has shown that PFAS have the ability to taint irrigation water and soil, thereby instigating apprehension about their existence in food crops (Gomis *et al*., 2020). PFAS examination has been conducted on vegetable specimens, revealing that short-chain Perfluoroalkyl substances (PFAS) possess greater potential for translocation and bioaccumulation in plants (Wang *et al*., 2018). PFAS has also been detected in fish, encompassing sport fish from areas known, suspected to be contaminated, commercial seafood from grocery stores and fish markets (Shoemaker *et al*., 2009). Furthermore, Perfluoroalkyl substances (PFAS) has been identified in food articles and water samples from the Faroe Islands, where long-chain PFAS prevail in the former, signifying exposure from PFOS and PFOA replacement compounds (Weihe *et al*., 2017). The general population's exposure to PFAS is primarily believed to occur via seafood consumption, with specific PFAS levels being linked to fish and shellfish intake. (Domingo *et al*., 2008).

Extensive contamination of the environment has resulted from the use of per- and polyfluoroalkyl substances (PFASs) in industrial and consumer products (e.g., paper and food packaging, nonstick products, chrome plating, aqueous film forming foam [AFFF], textiles) and their unique hydrophobic and lipophobic properties. Long-chain perfluoroa lkyl carboxylates (PFCAs), perfluorooctanoate [PFOA] and longer) and long-chain perfluoroalkyl sulfonates (PFSAs; i.e., perfluorohexane sulfonate [PFHxS] and longer) are characterized as extremely persistent, bioaccumulative, and toxic. The short-chain PFCAs and PFSAs bioaccumulate less in animals, and yet they bioaccumulate and readily translocate in plants. However, their occurrence, behavior, fate, and toxicity are poorly characterized (Brown *et al.*, 2020). Human activities are increasingly and fundamentally impacting the Earth's surface, particularly soils, which function as the interface between the biosphere, hydrosphere, atmosphere, and lithosphere. These soils are currently experiencing physical, chemical, and biological stressors that are linked to anthropogenic activities. Chemical pollution is a significant category of these influences, which is widely recognized as a global change factor. The perfluoroalkyl and polyfluoroalkyl substances (PFAS) are a highly diverse family of chemicals that are of concern. Soil is a primary sink for persistent organic chemicals in the environment. There are numerous pathways for PFAS entering the soil environment, including fluoride factory emissions, sludge application, the degradation of aqueous film-forming foam, landfills as direct sources, and atmospheric deposition and runoff as non-point sources. PFAS has been widely detected in soils at varying concentrations (Xe et al., 2022)

The bioaccumulation factors about perfluoroalkyl acids (PFAAs), a subset of per- and polyfluoroalkyl substances (PFASs) encompassing perfluorocarboxylic acids (PFCAs) and perfluorosulfonic acids (PFSAs), from both water and soil into plants signify the accumulation of PFASs in above-ground plant tissues. This, in turn, emphasizes the criticality of evaluating potential human health hazards associated with the consumption of food crops (Brown *et al.*, 2020). Uptake studies conducted on agricultural plants have revealed that short-chain PFAAs exhibit a greater tendency to accumulate in plants than their long-chain counterparts, and PFCAs tend to accumulate more than PFSAs. The transfer of contaminants into food crops is influenced by various factors such as PFAS concentrations and mixtures, plant species and compartment(s), soil organic carbon, and other soil characteristics, as well as growth conditions (Brown *et al*., 2020).

Heavy Metals in Water

Water is produced via the chemical fusion of hydrogen and oxygen in a 2:1 ratio and is the most prevailing compound, encompassing roughly three-quarters of the Earth's crust. The body of water on our planet, including oceans, seas, rivers, and springs, is composed of hydrogen and oxygen. Pure water has an estimated solid impurity content of 0.001% (Magdalena *et al.,* 2001). The characteristics of water exhibit a degree of heterogeneity, which is depending upon the origin of water. There exists a natural variance in the corrosive nature of water, influenced by the geographical location of the water source. (Darren and Mallikarjuna, 2010).

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particulate matter which constitute an important part of the trace elements geochemical cycles (Censi *et al*., 2006).
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This work was aims to determine the levels of heavy metals and perfluoroalkyl substances (PFAS) in water samples collected from six selected wards in Bade and Jakusko Local Government Area Yobe State Nigeria.

Statement of the Problem
The statement of the problem for this research work can be outlined as follows:

- **Limited knowledge about the presence and concentration of heavy metals and perfluoroalkyl substances in the soil, water fish, and vegetables**: There exists an insufficiency of all-inclusive information concerning the quantities of high-density materials (such as lead, cadmium, mercury, arsenic, etc.) and perfluoroalkyl substances (PFAS) within the soil of various regions in Bade Emirate of Yobe state. This knowledge gap impedes the efficient evaluation and control of plausible environmental and human health hazards linked with these impurities.
- **Potential environmental and human health risk:** Heavy metals and per- and polyfluoroalkyl substances (PFAS) are recognized to have deleterious impacts on the environment and the well-being of humans. They possess the capability to pollute water resources, accumulate in the food chain, and present hazards to ecosystems and human populations. The absence of a comprehensive comprehension of their concentrations and dispersion in the soil presents a formidable obstacle in implementing appropriate mitigation strategies and ensuring the safeguarding of the environment and local communities in Bade Local Government Area.
- **Lack of baseline data for future monitoring and assessment:** Acquiring initial data concerning the concentrations of significant metallic elements and per- and poly-fluoroalkyl substances within the ground is imperative for forthcoming surveillance and appraisal intentions. This data shall function as a benchmark for juxtaposition, thereby facilitating the detection of any alterations or patterns throughout a given period. In the absence of this fundamental data, evaluating the efficiency of any forthcoming rectification or control measures executed to tackle potential pollution matters becomes arduous.
- **Inadequate awareness and information sharing**: There exists a necessity to heighten consciousness and enhance the exchange of information among indigenous groups, agriculturists, and pertinent participants concerning the existence and plausible hazards connected with weighty metals and PFAS in the earth. The objective of this endeavor is to produce empirical erudition that can be dispersed to participants, facilitating them to construct judicious determinations about the utilization of land, agricultural methodologies, and measures to safeguard health.

Theoretical Framework

This study is guided by the Environmental Pollution and Risk Assessment Framework, which integrates ecological and human health perspectives. Key elements include:

- **Source-Pathway-Receptor Model**

Sources: Industrial discharge, agricultural practices, and urban runoff.

Pathways: Soil leaching, water transport, and food chain accumulation.

Receptors: Humans, plants, and aquatic organisms.

- **Toxicokinetics and Bioaccumulation:** Heavy metals and PFAS exhibit distinct bioaccumulation patterns due to their chemical stability and persistence, emphasizing the need for targeted biomonitoring.
- **Ecological Risk Assessment** examines the impact on biodiversity, ecosystem functions, and potential threshold exceedance in contamination levels.
- **Human Health Risk Assessment** focuses on direct and indirect exposure routes (ingestion, dermal contact, and inhalation) to evaluate potential health impacts.
- **Sustainability and Environmental Justice:** Explores contamination impacts on local livelihoods and aligns research with sustainable development goals.

This framework provides a robust lens to assess contamination in Bade and Jakusko LGAs, informing mitigation strategies and policy-making.

Sample Collection

The sample for this research was collected from different locations in the different wards of each Local Government of Bade emirate of Yobe State, Nigeria. However, there are two (2) Local Governments in the study area that is Bade emirate (Bade and Jakusko).

Materials

- The equipment and instruments used in the study were all calibrated to check their status before and in the middle of the experiments.
- Apparatus such as volumetric flasks, measuring cylinders, and digestion flasks were thoroughly washed with detergents and tap water and then rinsed with deionized water.
- All Glassware was cleaned with 10% concentrated Nitric acid (HNO_3) to remove any heavy metal on its surfaces and then rinsed with distilled-deionized water.
- The digestion tubes were soaked with 1% (w/v) potassium dichromate in 98% (v/v) H_2SO_4 and the volumetric flasks in 10% (v/v) HNO_3 for 24 hours. After 24 hours, the tubes and flasks were rinsed with deionized water and then dried in an oven.
- All apparatus and materials were kept in dust dust-free place (drying cabinet) during the analysis.
- Before each use, the apparatus was soaked and rinsed in deionized water.

Equipment and Apparatus

- Analytical balance, 250g capacity, resolution 0.0001g, OHAUS, PA214 pioneer USA
- Microwave digestion system and Teflon double wall digestion vessels (Master 40, Sineo Chemistry Technology China, No:40G106M).
- Borosilicate volumetric flasks (25, 50 ml, 100 ml & 1000 ml)
- Measuring cylinders
- Micropipettes (1-10 ml, 100-1000 ml)

- Atomic absorption spectrophotometer (Buck scientific model 210VGP AAS, USA; equipped with hollow cathode lamps and air-acetylene flame)

Reagents and Chemicals

The reagents and chemicals used for the laboratory works were all of the analytical grade;

- Deionized water (chemically pure with conductivity of 1.5 µs/cm and below prepared in the laboratory) was used for dilution of sample and intermediate metal standard solutions prior to analysis and rinsing glassware and sample bottles.
- The Preparation of deionized water is prepared by connecting the deionization system to a water source using the inlet and outlet ports. The water passes through the ion-exchange resins, and ions are exchanged for hydrogen and hydroxide ions, resulting in deionized water.
- 65% HNO_3 (Loba chemie India)
- 30% v/v H_2O_2 (Sigma)
- HF (Sigma)

Methods

The water from the mapped-out locations was collected from the water source of the emirate (Bade) of Yobe State, which was determined for the probable presence of heavy metal concentration and perfluoroalkyl substances using standard kinds of literature and procedures. The methods in this research work were GC-MS for the presence of perfluoroalkyl substances in water and Atomic Absorption Spectroscopy (AAS), Differential Pulse Anodic Stripping Voltammetry (DPASV), water samples acidified to 1% with nitric acid and then stored in Double capped polyethylene bottles (Skoog, Holler and Crouch, 2007). The heavy metals concentrations determined were Cr, Co, Ni, Cd, As, and Pb. The concentrations of the heavy metals determined were compared with the National and International Organization Standards, like WHO and NAFDAC.

Results

TABLE I: SHOWING THE CONCENTRATION OF Cr, Co, Ni, Cd, As, AND Pb IN WATER FROM SOME SELECTED WARD OF BADE LOCAL GOVERNMENT AND THEIR STANDARD LIMIT.

Ward	Dagona	Katuzu	Usur	NAFDAC	WHO
Chromium mg/l	4.86±0.30	4.79±0.30	50.28±3.00	1.0	1.0
Cobalt mg/l	24.16±2.00	27.26±2.00	26.82±2.00	0.01	0.01
Nikel mg/l	7.55±0.50	8.52±0.50	8.38±0.50	0.02	0.02
Cadnium mg/l	16.09±1.00	18.17±1.00	17.88±1.00	0.003	0.003
Arsenic mg/l	4.25±0.30	4.79±0.30	4.71±0.30	0.01	0.01
Lead mg/l	47.60±3.00	53.71±3.00	52.82±3.00	0.01	0.01

TABLE II: SHOWING THE CONCENTRATION OF Cr, Co, Ni, Cd, As, AND Pb IN WATER FROM SOME SELECTED WARD OF JAKUSKO LOCAL GOVERNMENT AND THEIR STANDARD LIMIT.

Ward	Dachia	Gwayo	Katamma	NAFDAC	WHO
Chromium mg/l	4.79±0.30	4.79±0.30	58.56±4.00	1.0	1.0
Cobalt mg/l	26.82±2.00	24.16±2.00	31.23±2.00	0.01	0.01
Nikel mg/l	8.38±0.50	7.55±0.50	20.59±2.00	0.02	0.02
Cadnium mg/l	16.09±1.00	16.09±1.00	9.76±0.70	0.003	0.003
Arsenic mg/l	4.25±0.30	4.25±0.30	5.49±0.40	0.01	0.01
Lead mg/l	47.60±3.00	47.60±3.00	61.77±4.00	0.01	0.01

TABLE III: SHOWING THE CONCENTRATION OF PERFLUOROALKYL SUBSTANCES (PFAS) IN THE DIFFERENT SAMPLES OF WATER FROM BADE LOCAL GOVERNMENT

Wards	PFOA	PFHxS	PFOS	PFNA	PFDA	PFUnA	PFDoA
Dagona	0.10	-	-	-	-	-	-
Katuzu	0.02	-	-	-	-	-	-
Usur	0.42	-	-	-	-	-	-
EPA	**0.01 to 0.1 µg/kg**						

TABLE IV: SHOWING THE CONCENTRATION OF PERFLUOROALKYL SUBSTANCES (PFAS) IN DIFFERENT SAMPLES OF WATER FROM JAKUSKO LOCAL GOVERNMENT.

Wards	PFOA	PFHxS	PFOS	PFNA	PFDA	PFUnA	PFDoA
Dachia	0.20	-	-	-	-	-	-
Gwayo	0.10	-	-	-	-	-	-
Katamma	0.02	-	-	-	-	-	-
EPA	**0.01 to 0.1 µg/kg**						

Statistical Analysis

All analysis was performed in triplicates. Results were expressed by means of ±SD. Statistical significance was established using one-way analysis of variance (ANOVA). Means were separated according to Duncan's multiple range analysis ($p < 0.05$) based on this ANOVA test, there is no significant evidence to conclude that the means of the groups are different. The differences observed in the sample means could be due to random variation rather than actual differences in the population means.

Discussion

Heavy metals in water samples from both LGAs exceeded the permissible limits set by WHO and NAFDAC as seen in table I and II. The Concentration of Heavy Metals (example): **Lead (Pb)**: Detected up to 53.71 mg/L (Jakusko) and 47.60 mg/L (Bade), far exceeding the permissible limit of 0.01 mg/L. **Cadmium (Cd)**: Ranged from 9.76 mg/L to 18.17 mg/L, permissible limit is 0.003 mg/L. Drinking water contamination poses significant health risks, especially kidney diseases and neurological disorders.

The Concentrations of Perfluoroalkyl Substances (PFAS) in Water: were detected in water samples, with concentrations ranging from 0.02 to 0.42 µg/L as given in table III. However, there is no significant detection of other PFAS compounds like PFOS or PFHxS. Even low levels of PFOA in drinking water are concerning due to its potential links to liver damage, thyroid disease, and developmental issues.

Conclusion

The experiment was conducted to assess the Heavy Metals Concentration and Perfluoroalkyl Substances in Water from Bade and Jakusko LGAs of Yobe State. Heavy metals such as Chromium (Cr), Cobalt (Co), Nickel (Ni), Cadmium (Cd), Arsenic (As), and (Lead Pb) were all found to have higher concentrations above the maximum permissible limit in the water sample from all the two Local Government (Bade and Jakusko), when compared with standard organization limit (WHO and NAFDAC). However, for perfluoroalkyl Substances only perfluorooctanoate (PFOA) was found to have concentration in all the water sample from the study area. Heavy metals in water samples from both LGAs exceeded the permissible limits set by WHO and NAFDAC as seen in table I. The Concentration of Heavy Metals (example): Lead (Pb): Detected up to 53.71 mg/L (Jakusko) and 47.60 mg/L (Bade), far exceeding the permissible limit of 0.01 mg/L.Cadmium (Cd): Ranged from 9.76 mg/L to 18.17 mg/L, permissible limit is 0.003 mg/L. Drinking water contamination poses significant health risks, especially kidney diseases and neurological disorders. Table III, presents the concentrations of various perfluoroalkyl substances (PFAS) detected in water samples from different wards (Dagona, Katuzu, and Usur) in Bade Local Government. PFAS are synthetic chemicals that are persistent in the environment and can have harmful health effects. The PFOA is detected in all three locations, with the highest concentration in Usur (0.42 µg/l) and the lowest in Katuzu (0.02 µg/l). These levels may indicate varying degrees of contamination among the locations.The only perfluoroalkyl substances (PFAS) detected in the water samples is PFOA, with varying concentrations across the wards, Usur shows the highest concentration of PFOA (0.42 µg/l), followed by Dagona (0.10 µg/l), and Katuzu (0.02 µg/l). No other PFAS (PFHxS, PFOS, PFNA, PFDA, PFUnA, or PFDoA) were detected in the water samples from any of the wards. The Concentrations of Perfluoroalkyl Substances (PFAS) in Water: were detected in water samples, with concentrations ranging from 0.02 to 0.42 µg/L as given in table IV.

Recommendations

- There should be immediate Implementation of a comprehensive monitoring program to regularly assess water quality in the affected areas, particularly focusing on heavy metals and PFAS levels. This monitoring should involve collaboration with relevant environmental and health agencies.
- The government should introduce water filtration systems in communities, possibly using advanced treatment technologies such as activated carbon or reverse osmosis, which have been effectively active in reducing heavy metal and PFAS concentrations.
- Government should launch public health educational programs to inform the local population about the risks associated with heavy metal and PFAS contamination. Additionally, provide guidelines on safe water usage and encourage the use of alternative water sources where available.
- Further Research are recommended to explore the long-term health effects of exposure to these contaminants in the region's population and to assess the efficacy of proposed remediation measures.

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