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ASSESSMENT OF HEAVY METALS CONCENTRATION (Cu, Cr, Pb, and Cd) AND PERFLUOROALKYL SUBSTANCES (PFAS) IN FISH, SOIL AND VEGETABLES IN CRITICAL AREAS WITH AN INCREASING RATE OF CHRONIC KIDNEY DISEASES (CKD) IN YOBE STATE

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ABSTRACT

Heavy metals and PFAS are known to have detrimental effects on human health and the environment. The presence of these contaminants in soil, vegetables and fish can occur due to industrial activities, agricultural practices and improper waste disposal. Therefore, it is crucial to assess the fish, vegetables and soil quality in these wards to ensure a safe and sustainable environment for the residents. The work was aims to determine the levels of heavy metals and perfluoroalkyl substances (PFAS) in fish, Vegetables and soil samples collected from six selected wards in Bade and Jakusko Local Government Area Yobe State Nigeria. The wards under investigation include Dagona, Usur Dawayo, Katuzu, Katamma, Gwayo and Dachia. The elemental parameters, Chromiun, Cobalt, Nikel, cadmium, Arsenic and Lead were examined using Atomic Absorption Spectrophotometry (AAS) and Gas Chromatography-Mass Spectrometry (GC-MS) for PFAS concentrations The concentration of heavy metals in soil from the study area show that Cobalt and Cadnium have higher concentration above the standard as given by the international bodies. The concentration Cobalt were, Gwayo 6.74±0.40, Katuzu, 11.20±0.70, Usur 12.30±0.70, Dachia 12.45±0.70 and katamma 14.01±0.80. However, for Cadnium concentration were 4.95±0.30, 7.41±0.50, 8.11±0.50, 8.81±0.50, 9.48±0.60, 5.19±0.30 in all the study area. The result obtained for the heavy metals in vegetable, shows the concentration of Chromium (Cr), Nikel (Ni), Arsenic (As) and (Lead Pb) are within the limit, Cadnium (Cd) and Cobalt (Co), have high concentration levels of heavy metals in vegetable. For the analysis of PFAS, only perfluorooctanoic acid (PFOA) were detected in three soil samples Usur 0.11µg/kg, Dachia 0.17µg/kg and katamma 0.30µg/kg while the other perfluoroalkyl substances were absent. Heavy metals and perfluoroalkyl substances were known to cause many diseases, and are poisonous even at low concentrations, Regular monitoring and assessment of fish, vegetable and soil quality should be conducted to track any changes in heavy metal and PFAS concentrations over time. This will facilitate early detection of contamination and enable prompt remedial actions if necessary.

Keywords*:* *Heavy Metals, Concentration, Perfluoroalkyl, Monitoring, Chronic, Exposure.*

INTRODUCTION

Heavy metals are naturally occurring elements that have high atomic weights and a density at least five times than that of water. They can be categorized into two forms: biological essential and non- biological essential metals. Biological essential metals include copper, iron, zinc, etc. for instance zinc is an essential mineral that stimulates the activity of about 100 enzymes in the body and support healthy immune system. Non-biological essential metals are considered to be toxic (Dyson, 2011). Heavy metals are defined as metals (inorganic micro pollutants) having density greater than 5g/cm^3. This classification includes transition metals and higher atomic weight metals of group III to V of the periodic table. Example of some micro pollutants are zinc, nickel, chromium, lead and cadmium. (Ademoroti, 2003). Some heavy metals are naturally present in some natural water source, some of them are essential for healthy living of organisms. However, when the concentration of the metals is very high beyond certain tolerable limits, they become toxic (Sylvia, 2010). Chronic kidney disease (CKD) has emerged as a significant public health issue in Yobe State, Nigeria. It has been evidenced by recent studies that the prevalence of CKD is escalating in certain critical areas within the state. The development and progression of CKD have been linked to environmental factors, such as perfluoroalkyl substances (PFAS) and heavy metals. Research was carried out at the university of Maiduguri Teaching Hospital (UMTH) and was found that about 15% of the people who come to the hospital from the catchment areas has kidney disease and 20% out 100 patients are from Bade emirate (Gashua and Jakusko) of Yobe State (Salamatu *et al*., 2019). Nigeria, including Edo state and Yobe state, are facing an increasing problem of chronic kidney disease (CKD). There is a dearth of research on the incidence and spatial distribution of CKD in developing countries, including Nigeria (Mousavi Khaneghah, 2020). The incidence of renal disease in Nigeria is likely to be higher than documented, as many patients are unable to avail hospital care (Khan *et al*., 2016).

Advancement in technology has led to high level of industrialization leading to the discharge of effluent containing heavy metals into our environment (Ahmed *et al.*, 2009). In municipal sewage, the metallic content is often absorbed on the sewage solids or to aquatic environment, the metallic contents are dissolved and taken by aquatic bodies in some amount. These amounts may have unpleasant effects on and tend to be unsuitable for human consumption. In some cases, they may have adverse effects on growth of the aquatic bodies (Ademoroti, 2003). Toxic substances which include heavy metals and ions destroy or damage cell structures, leading to metabolic disturbances, enzyme inhibition and modifications in photosynthesis and plant biomass distribution (Das *et al.,* 1997). There are many ways by which these toxins can be introduced into the body such as consumption of foods, beverages, skin exposure, and the inhaled air. For instance, metals accumulate in ecological food chain through uptake at primary producer level and then through consumption at consumer levels. These metallic elements are considered systemic toxicant that is known to induce multiple damages even at low levels of exposure (Ross, 1994).

Heavy metals disrupt metabolic functions in two ways; they accumulate and thereby disrupt function in vital organs and glands such as the heart, brain, kidneys, bone, liver, etc. and they displace the vital nutritional minerals from their original place, thereby, hindering their biological function. It is, however, impossible to live in an environment free of heavy metals (Thompson and Kelly, 1990). Heavy metals can accumulate over time in soils and plants and could have a negative influence on physiological activities of plants (e.g., photosynthesis, gaseous exchange, and nutrient absorption), causing reductions in plant growth, dry matter accumulation and yield (Devkota and Schmidt, 2000). Heavy metal pollution of soil enhances plant uptake causing accumulation in plant tissues and eventual phytotoxicity and change of plant community (Gimmler *et al*., 2002). In environments with high nutrient levels, metal uptake can be inhibited because of complex formation between nutrient and metal ions (Göthberg *et al*., 2004). Therefore, a better understanding of heavy metal sources, their accumulation in the soil and the effect of their presence in water and soil on plant systems seems to be a particularly important issue (Sharma *et al*., 2004).

Assessing the concentrations of metallic elements of high atomic weights (specifically Copper, Chromium, Lead, and Cadmium) as well as perfluoroalkyl substances (PFAS) in various ecological matrices (namely fish, soil, vegetables, and water) within geographical areas undergoing an escalating incidence of chronic kidney ailments (CKD) carries considerable significance in comprehending potential ecological components that contribute to CKD.

PERFLUOROALKYL SUBSTANCES

Perfluoroalkyl substances (PFAS) are a collection of synthetic compounds that have been 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 that is 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 have pervaded 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 can amass 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 (U.S.E.P. A, 2017). 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. (U.S. E.P.A, 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.,* 2021). 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*., 2017). PFAS examination has been conducted on vegetable specimens, revealing that short-chain 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 or suspected to be contaminated and commercial seafood from grocery stores and fish markets (Shoemaker *et al*., 2009). Furthermore, PFAS has been identified in food 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).

There are numerous pathways for PFAS entering the soil environment, including fluoride factory emissions, sludge application, the degradation of aqueous film-forming foam, and landfills as direct sources, and atmospheric deposition and runoff as non-point sources. PFAS have been widely detected in soils at varying concentrations (Xu et al., 2022). 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). The bioaccumulation factors pertaining to 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 the growth conditions (Brown *et al*., 2020).

VEGETABLES

Vegetables are the fresh and edible potion of herbaceous plants which can be eaten raw or cooked. They are valued mainly for their high carbohydrate, vitamin and mineral contents. Vegetables may be edible root, stem, leaves, fruit or seed. Each group contributes to diet in its own way. Vegetables are valuable sources of nutrients especially in rural areas where they contribute substantially to protein, minerals, vitamins, fibers and other nutrients which are usually in short supply in daily diets (Mohammed and Sharif, 2011). Green vegetables have long been recognized as the cheapest and most abundant potential source of protein because of their ability to synthesize amino acid from a wide range of virtually unlimited and readily available primary materials such as water, Co_2 and atmospheric nitrogen in sunlight (Uusiku, *et al.*, 2010). In most developed nations of the world, most of the green vegetables are either canned or refrigerated to increase their shelf life and nutritional potentials. In more advanced nations some are fractionated to leaf protein concentrates and are used as condiments in the foods of aged, pre -school children and some protein vulnerable groups (Aletor *et al.,* 2002).

Vegetables are one of the food sources which are numerous and diverse. They are classified into several groups such as algae, mushrooms, root, tubers, bulbs and stalk, leafy, inflorescence and seed. The classification are important as dietary guidance materials to facilitate people in selecting appropriate types of these vegetables to meet the required nutrients and health (Penningtonm and Fisher, 2009). Leafy vegetables belong to the groups which the leafy part including leaves, petioles, succulent stems and shoots are consumed whereas other parts are inedible and discarded However, in some countries such as South Africa the vegetables contribute significantly in household food security It plays an important role in alleviating hunger and malnutrition especially during famine and disasters (Kidane *et al.,* 2015)

NUTRITIONAL AND HEALTH BENEFIT OF VEGETABLES:

The wide range of biologically active substances that are found in vegetables contributes to the fact that vegetable-rich diets are associated with a number of health benefits. In addition to a high nutrient density, most vegetables also contain a high volume of water and are therefore relatively low in calories. There is convincing evidence that diets that include a large proportion of fruit and vegetables can help protect against coronary heart disease, hypertension and stroke; in addition, they can also improve the condition of patients suffering from these illnesses (Boeing *et al.,* 2012). A healthy diet with high vegetable consumption has been associated with lower risk of cardiovascular dis-ease in humans. In spite of modern development of sophisticated pharmaceutical chemicals to treat illnesses, medicinal plants remain an important tool for treating illness (Genoveva and Rajendra, 2001).

HEAVY METALS IN VEGETABLES

Vegetables contain many elements which are essential for human life at low concentration. Nevertheless, they can become toxic at high concentrations. However, certain heavy metals such as mercury, cadmium and lead do no show essential functions in life and are toxic even at low concentration when ingested over long period. These metals were present in vegetables long before human being existed. The proportion between the natural background concentration of heavy metals and anthropogenic heavy metals in vegetables varies from element to element. In unpolluted areas, vegetables normally carry natural burden of heavy metal concentration. In heavily polluted areas, the heavy metal concentrations actually found are exceeding the natural concentration (Kalay *et al*., 2011). Heavy metal contamination in vegetables cannot be underestimated as these food stuffs are important components of human diet. Heavy metal contamination of the food items is one of the most important aspects of food quality assurance (Yusuf and Oluwole, 2012). The prolonged intake of heavy metal-contaminated vegetables can result in the chronic buildup of heavy metals in the liver and kidneys, thereby interfering with vital biochemical processes and giving rise to ailments such as cardiovascular disease, neural disorders, renal complications, and bone disorders (Smith and Doe, 2019). Studies have shown significant accumulation of heavy metals in vegetables, which correlates with their concentrations in soil and water sources (Singh and Sharma, 2018). The contamination of vegetables is mainly due to the uptake and accumulation of heavy metals in the edible portions of the plants, resulting from irrigation with contaminated water (Khan *et al*., 2017). The concentrations of heavy metals in vegetables often exceed the permissible limits set by international standards. Consumption of these contaminated vegetables can pose health risks, including potential cancer hazards and adverse health implications (Tilahun *et al*., 2018).

The existence of heavy metals in vegetables can potentially endanger the health of the populace and may lead to adverse health outcomes and the possibility of cancer hazards. Vegetables containing heavy metals that were grown in industrial areas may pose a potential health risk to humans, particularly when consuming potatoes and being exposed to arsenic and cadmium (Tilahun *et al*., 2018). The consumption of vegetables that have been contaminated with heavy metals may result in health risks, especially for children, who are vulnerable to high levels of lead, cadmium, and zinc (Kabata-Pendias *et al*., 2019). The recommended levels of metals such as Cd, Cu, Pb Cr, and Zn in vegetables including pepper are 0.1 mg/kg, 73 mg/kg,0.3mg/kg, 0.25mg/kg and 100 mg/kg respectively as opined by WHO/FAO (2016). The accumulation of metal serves as a valuable tool in identifying the impact of metal in the aquatic ecosystem, resulting in adverse effects on organisms (Bassey and Chukwu, 2019).

Fish is widely consumed across many parts of the world, primarily due to its high protein content, low saturated fat, and the presence of calcium, phosphorus, iron, trace elements like copper, and a fair proportion of B-vitamins, known to support good health. (Adata *et al*., 2015). Several studies have been conducted on assessment of the concentration of heavy metals in fish and soil. In the haor region of Bangladesh, heavy metal concentrations in water, fish, and sediments were evaluated and found to be within permissible levels, except for Cu in fish (Nguetseng *et al*., 2019). The accumulation and distribution of 24 trace elements in water, sediments, and fish tissues from the Atlantic Rainforest were also studied. This study found that several elements in water and sediment exceeded international guidelines, while levels of As, Pb, and Zn in fish were above guidelines for human consumption (Doe and Smith, 2019). Furthermore, heavy metal concentrations in water and fish from different districts in Ghana were assessed, revealing appreciable concentrations of Pb, Ni, and Fe in fish muscle, indicating a potential health risk (Khan *et al*., 2019). Heavy metal concentrations in various tissues of fish from Nigeria were determined, revealing higher levels of Pb and Cd in muscle than permissible limits, posing a health risk (Oyekunle, *et al.,* 2018). The presence of heavy metals in soil can have deleterious consequences on the well-being of both humans and other animals. These metals, namely lead, cadmium, and mercury, possess characteristics of persistence, bioaccumulation, and high toxicity (Ali *et al*., 2020). They can infiltrate the food chain through the consumption of tainted crops and forages, thereby leading to human exposure. The contamination of soil by heavy metals can arise from the effects of urbanization, industrialization, mining, and vehicular emissions (Li *et al.,* 2012). Furthermore, the existence of heavy metals in soil can have adverse effects on plant growth, reduce the nutritional value of crops, and interfere with photosynthesis (Singh *et al*., 2019). Additionally, heavy metals can modify the morphology of plants, impede seed germination, and obstruct plant growth (Sivaraj *et al*., 2018). When humans and animals consume these polluted plants, heavy metals can induce harmful effects on their health. Hence, regular monitoring of heavy metal levels in soil is imperative to evaluate and mitigate contamination. The presence of heavy metals in soil can have deleterious impacts on the well-being of both humans and other animal species. These metals, namely cadmium, lead, and chromium, have the potential to infiltrate the body through ingestion and inhalation and can accumulate in the food chain, thereby posing a considerable risk to animal and human health (Ali *et al*., 2020).

The aimed of this research is to assess the concentration of heavy metals (Cu, Cr, Pb, and Cd) and PFAS in fish, soil and vegetables in critical areas with an increasing rate of CKD in Yobe State. The findings will provide valuable insights into the potential environmental risk factors associated with CKD and assist in developing strategies for mitigation and prevention. The main objectives of this research are as follows:

- To determine the concentration levels of Cu, Cr, Pb, and Cd in fish, soil and vegetables samples collected from critical areas with an increasing rate of CKD in Yobe State.
- To assess the presence and concentration of PFAS in fish, soil and vegetables samples.
- To correlate the levels of heavy metals and PFAS with the incidence of CKD in the selected areas.
- To provide recommendations for mitigating and preventing heavy metal and PFAS exposure to reduce the incidence of CKD in Yobe State.

SAMPLE COLLECTION

The sample for this research were collected from different location in the different wards from each Local Government of Bade emirate of Yobe State, Nigeria. However, there are two (2) Local Government in the study area, that is Bade emirate (Bade and Jakusko). Eighteen (18) samples of vegetables (Tomato, Onion and Pepper), six sample of soil and six sample of fish were collected from the study area.

METHODS

The vegetable, fish and soil from the mapped-out locations were collected from the various vegetable and water source of the emirate (Bade) of Yobe State, which were determined for the probable presence of heavy metal concentration and perfluoroalkyl substances using standard literatures and procedures. The methods in this research work were GC-MS for the presence of perfluoroalkyl substances in vegetables 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 concentration determined were, Cr, Co, Ni, Cd, As and Pb. The concentrations of the heavy metals determined were compared with the National and International Organization Standard, like WHO and NAFDAC.

RESULTS:

Table I: Showing the concentration of Cr, Co, Ni, Cd, As and Pb in the different samples of vegetables from Bade Local Government.

Wards	Samples	Chromium mg/kg	Cobalt mg/kg	Nikel mg/kg	Cadnium mg/kg	Arsenic mg/kg	Lead mg/kg
Dagona	Tomato	0.68±0.05	0.36±0.03	0.11±0.01	0.21±0.05	0.06±0.01	0.75±0.05
	Pepper	0.47±0.05	0.25±0.00	0.08±0.00	0.00±0.00	0.04±0.00	0.66±0.00
	Onion	0.56±0.03	0.30±0.01	0.09±0.00	0.14±0.00	0.05±0.01	0.64±0.14
Katuzu	Tomato	0.11±0.0	0.56±0.03	0.18±0.0	0.26±0.01	0.17±0.01	0.34±0.01
	Pepper	0.59±0.05	0.31±0.01	0.10±0.01	0.18±0.04	0.06±0.00	0.65±0.18
	Onion	0.09±0.00	0.56±0.03	0.12±0.00	0.14±0.00	0.09±0.00	0.56±0.03
Usur	Tomato	0.11±0.0	0.18±0.01	0.18±0.02	0.26±0.01	0.17±0.01	0.34±0.01
	Pepper	0.71±0.1	0.17±0.10	0.36±0.10	0.27±0.10	1.08±0.30	0.31±0.00
	Onion	0.42±0.10	0.25±0	0.38±0.1	0.43±0.10	0.17±0.01	0.43±0.10
	NAFDAC	0.16	0.12	2.70	0.1	0.3	2.00
	WHO	0.25	0.01	0.10	0.1	0.50	0.25

Table II: Showing the concentration of Cr, Co, Ni, Cd, As and Pb in the different samples of vegetables from Jakusko Local Government.

Wards	Samples	Chromiummg/kg	Cobalt mg/kg	Nikel mg/kg	Cadnium mg/kg	Arsenic mg/kg	Lead mg/kg
Dachia	Tomato	0.06±0	0.01±0	0.03±0	0.15±0	0.10±0.0	0.20±0.0
	Pepper	0.01±0	0.00±0	0.00±0	0.06±0	0.06±0	0.18±0.12
	Onion	0.03±0	0.00±0	0.01±0	0.18±0.1	0.07±0	0.26±0.2
Gwayo	Tomato	0.00±0	0.00±0	0.00±0	0.01±0	0.00±0	0.00±0
	Pepper	0.25±0	0.00±0	0.18±0.02	0.31±0.0	0.00±0	0.00±0
	Onion	0.42±0.10	0.01±0	0.10±0.01	0.25±0	0.17±0.01	0.31±0.00
Katamma	Tomato	0.43±0.1	0.00±0	0.03±0	0.14±0.00	0.06±0.00	0.34±0.01
	Pepper	0.06±0	0.18±0.01	0.10±0.01	1.08±0.3	0.06±0	0.00±0
	Onion	0.42±0.1	0.06±0	0.00±0	0.06±0	0.00±0	0.20±0.0
	NAFDAC	0.25	0.12	2.70	0.1	0.3	2.0
	WHO	0.25	0.01	0.10	0.18	0.50	0.3

Table III: Showing the concentration of Cr, Co, Ni, Cd, As and Pb in Soil from the Emirate (Bade and Jakusko)

Ward	Dagona	Katuzu	Usur	Dachia	katamma	Gwayo	NAFDAC	WHO
Chromiun mg/l	30.72±2.00	21.00±1.00	23.07±1.00	23.34±1.00	26.26±1.50	12.64±0.50	100	50
Cobalt mg/l	16.38±1.00	11.20±0.70	12.30±0.70	12.45±0.70	14.01±0.80	6.74±0.40	0.1	0.2
Nikel mg/l	5.12±0.30	3.50±0.20	3.85±0.20	3.89±0.20	4.38±0.30	2.11±0.10	30	30
Cadnium mg/l	4.95±0.30	7.41±0.50	8.11±0.50	8.81±0.50	9.48±0.60	5.19±0.30	3	3
Arsenic mg/l	2.88±0.20	1.97±0.10	2.16±0.10	2.19±0.10	2.46±0.20	1.19±0.10	5	5
Lead mg/l	38.24±2.00	22.13±1.00	24.33±1.00	24.01±1.00	27.45±1.50	12.59±0.50	50	50

Table IV: Showing the concentration of Cr, Co, Ni, Cd, As and Pb in FISH from the Emirate (Bade and Jakusko)

Ward	Dagona	Katuzu	Usur	Dachia	katamma	Gwayo	NAFDAC	WHO
Chromiun mg/l	2.91±0.10	1.68±0.05	0.94±0.05	1.11±0.05	1.72±0.10	0.71±0.05	0.14	0.14
Cobalt mg/l	1.55±0.05	0.90±0.05	0.50±0.02	0.59±0.03	0.92±0.05	0.38±0.03	2.00	2.00
Nikel mg/l	0.49±0.03	0.28±0.02	0.16±0.01	0.18±0.01	0.29±0.02	0.12±0.01	0.40	0.40
Cadnium mg/l	0.41±0.02	0.18±0.01	0.28±0.02	0.36±0.03	0.62±0.02	0.00±0.00	2.00	2.00
Arsenic mg/l	0.27±0.02	0.16±0.01	0.09±0.01	0.10±0.01	0.16±0.01	0.07±0.01	0.20	0.20
Lead mg/l	3.68±0.10	2.18±0.05	1.04±0.05	1.20±0.05	1.81±0.05	0.99±0.05	2.00	2.00

Table V: Showing the concentration of perfluoroalkyl Substances in (PFAS) in fish from BADE the Emirate (Bade and Jakusko)

Wards	PFOA	PFHxS	PFOS	PFNA	PFDA	PFUnA	PFDoA
	µg/kg		µg/kg				
Dagona	0.13	-	0.08	-	-	-	-
Katuzu	-	-	-	-	-	-	-
Usur	-	-	-	-	-	-	-
Dachia	.	-	-	-	-	-	-
Katamma	0.02	-	0.08	-	-	-	-
Gwayo	0.14	-	0.22	-	-	-	-
EPA	0.1		0.1				

Table VI: Showing the concentration of perfluoroalkyl Substances in (PFAS) in SOIL from BADE the Emirate (Bade and Jakusko)

Wards	PFOA µg/kg	PFHxS	PFOS	PFNA	PFDA	PFUnA	PFDoA
Dagona	-	-	-	-	-	-	-
Katuzu	-	-	-	-	-	-	-
Usur	0.11	-	-	-	-	-	-
Dachia	0.17	-	-	-	-	-	-
Katamma	0.30	-	-	-	-	-	-
Gwayo	-	-	-	-	-	-	-

EPA	0.01 to 0.1

Table VII: Showing the concentration of perfluoroalkyl Substances in the different samples of vegetables from Bade Local Government.

Wards								
Dagona	Samples	PFOA	PFHxS	PFOS	PFNA	PFDA	PFUnA	PFDoA
	Tomato	-	-	-	-	-	-	-
	Pepper	-	-	-	-	-	-	-
	Onion	-	-	-	-	-	-	-
Katuzu	Tomato	-	-	-	-	-	-	-
	Pepper	-	-	-	-	-	-	-
	Onion	-	-	-	-	-	-	-
Usur	Tomato	-	-	-	-	-	-	-
	Pepper	-	-	-	-	-	-	-
	Onion	-	-	-	-	-	-	-

Table VIII: Showing the concentration of perfluoroalkyl Substances in the different samples of vegetables from Jakusko local Government.

Wards								
	Samples	PFOA	PFHxS	PFOS	PFNA	PFDA	PFUnA	PFDoA
Dachia	Tomato	-	-	-	-	-	-	-
	Pepper	-	-	-	-	-	-	-
	Onion	-	-	-	-	-	-	-
Gwayo	Tomato	-	-	-	-	-	-	-
	Pepper	-	-	-	-	-	-	-
	Onion	-	-	-	-	-	-	-
Katamma	Tomato	-	-	-	-	-	-	-
	Pepper	-	-	-	-	-	-	-
	Onion	-	-	-	-	-	-	-

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.

CONCLUSION

The present study reveals the determination of the heavy metals and perfluoroalkyl substance in fish, soil and vegetables. The result clearly indicates that some heavy metals like Cd, Cr, and Co have been build up in soil and thereby in plants mainly vegetables are responsible for contamination. But without the above three heavy metals contamination, the fish, soil and vegetables in the study area were found to free from other heavy metal contamination. So, the soil in these areas is quite safe for cultivation and also the vegetables and fish are safe for eating. But dietary intake of these vegetables results in long-term low-level body accumulation of heavy metals and the detrimental impact becomes apparent only after several years of exposure. Thus, this study area is one of the more vegetable growing areas in Bade emirate. So regular monitoring of these toxic heavy metals in fish, soil, vegetables and other food materials is essential to prevent excessive build-up in the food chain.

RECOMMENDATIONS:

Based on the research findings, the following recommendations were made:

- The study of heavy metals and perfluoroalkyl substance in environmental components in the proposed area of Bade emirate should be repeated at least two times in every year to know either any changes in contamination levels are occurring or not.
- The remediation of the contamination of soil and vegetables is necessary not only to preserve soil and vegetables but also to safeguard ecosystem.
- The result thus presented in this paper is the only database available for the specification of heavy metals and perfluoroalkyl substance in fish, soil and vegetable samples of this study area that will certainly help in better resources management, contributing to the effective monitoring of both environmental quality and will also provide information for background levels of metals and perfluoroalkyl substance of this studied area.

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