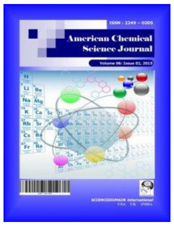

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Determination of Heavy Metals in Public Tap Water in Ibadan Metropolis, Southwestern Nigeria

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Authors' contributions

This work was carried out in collaboration amongst all the three authors. Author FJO designed the study, wrote the protocol and managed the literature searches. Authors FJO and POO wrote the first draft of the manuscript. Authors OAA and POO managed the analyses of the study. All the three authors read and approved the final manuscript.

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ABSTRACT

The quality of public taps water transiting from the point of distribution to the end users was analyzed in this study to assess the level of chemical contamination en route, and the result obtained were compared with WHO and NIS/SON recommended standards for drinking water. Sixteen samples were collected from five different areas and the distribution point following standard procedure. The water samples were digested and analyzed for physicochemical properties and heavy metals concentration. The heavy metals determination was done using Atomic Absorption Spectrophotometer, Perkin Elmer A Analyst 200 model. In all the samples analyzed, the physicochemical properties which include pH, Total Solids (TS), Total Dissolved Solids (TDS), and Total Suspended Solids (TSS) were within the WHO and SON recommended limits. The heavy metals determined were lead (Pb), cadmium (Cd), Iron (Fe), and zinc (Zn). All the heavy metals determined were within the recommended limits at the distribution point except Pb

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0.030 mg/l. Values higher than the recommended limits were observed for Pb (0.060 to 0.290 mg/l) and Cd (0.002 to 0.008 mg/l) at consumers end. The lowest value for lead 0.030 mg/l was observed at the distribution point and highest at Apata area. The highest value of cadmium was observed at Molete area and lowest at Eleyele area. Elevated levels of heavy metals in the public drinking water sampled as compared to the one obtained from the distribution point suggest likely contamination of the water during transit which may be due to the effect of rust pipes and fixtures, contamination from run offs from dumpsites and roadsides which enters the water through burst pipes. Therefore constant monitoring of the supply and distribution system is essential in order to safeguard the health of the consumers of this public potable water.

Keywords: Heavy metals; contamination; distribution point; potable water; recommended limits; WHO.

1. INTRODUCTION

Heavy metals are defined as metallic elements that have a relatively high density compared to water and they show toxicity at low level of exposure in the environment [1,2]. Heavy metals contamination in the environment has both natural and anthropogenic sources. Natural sources of heavy metals include leaching from rocks and soils. Natural phenomena such as weathering and volcanic eruptions have been reported to significantly contribute to heavy metal pollution [3,4]. Although heavy metals are naturally occurring elements that are found throughout the earth's crust, most environmental contamination and human exposure result from anthropogenic activities such as mining and smelting operations, industrial production and use, domestic and agricultural use of metals and metal-containing compounds [4-6]. Environmental contamination can also occur through metal corrosion, atmospheric deposition, soil erosion of metal ions and leaching of heavy metals, sediment re-suspension and metal evaporation from water resources to soil and ground water [7,8]. The aquatic ecosystems seem to be mostly vulnerable to these contaminations. The increase of industrial activities has intensified environmental pollution problem and the deterioration of several aquatic ecosystems with the accumulation of metals in biota and flora [9].

Most chemicals generated from industrial, agricultural and other human activities will eventually end up in our water ways which may there after affect our drinking water thereby posing a great danger to human lives. These dangerous chemicals enter the rivers, lakes and underground water which supply our drinking water [10]. The heavy metals in drinking water that are linked most often to human poisoning are lead, iron, cadmium, copper, zinc, chromium [11]. Some of these metals like Iron, copper, zinc are essential trace elements required by the body but they show toxicity if recommended limit is exceeded. Lead is a highly poisonous metal (if inhaled or swallowed) affecting almost every organ and system in the body. The main target for lead toxicity is the nervous system, both in adults and children. Lead is believed to have adverse effects on the central nervous system, the cardiovascular system, kidneys and the immune system [1]. Cadmium is a severe pulmonary and gastrointestinal irritant, which can be fatal if inhaled or ingested. After acute ingestion, symptoms such as abdominal pain, burning sensation, nausea, vomiting, salivation, muscle cramps, vertigo, shock, loss of consciousness and convulsions usually appear within 15 to 30 minutes [12]. Acute cadmium ingestion can also cause gastrointestinal tract erosion, pulmonary, hepatic or renal injury and coma, depending on the route of poisoning [12]. Chronic exposure to cadmium has a depressive effect on levels of norepinephrine, serotonin, and acetylcholine [13]. Rodent studies have shown that chronic inhalation of cadmium causes pulmonary adenocarcinomas [14,15]. It can also cause prostatic proliferative lesions including adenocarcinomas, after systemic or direct exposure [16]. Zinc is an essential trace element because very small amount of zinc are necessary for human health. It is also used for boosting the inner system, treating the common cold and recurrent ear infections, and preventing lower respiratory infections. It is also used for malaria and other diseases caused by parasites, however excess intake of zinc may be teratogenic [17]. Excess intake of zinc above the recommended dietary intake can cause abdominal pain, nausea, vomiting, and diarrhea [18]. Other reported effects include gastric irritation, irritability, lethargy, anemia, and dizziness. Iron also is an essential component of hemoglobin that transfers oxygen from the lungs to the tissues. Iron supports metabolism and it is necessary for growth and development, normal cellular functioning and synthesis of some hormones and connective tissues. Acute intake of more than the recommended intake of iron can lead to gastric upset, constipation, nausea abdominal pain [19] and it reduces zinc absorption.

Drinking or potable water should be safe enough for general human consumption and should not represent any significant risk to health over a lifetime of consumption, including different sensitivities that may occur between life stages [20].

Every human should have access to this quality drinking water because of its essentiality and health benefits. But most populace still lack access to quality drinking water, most especially in rural areas. According to [21], one in nine people worldwide still lacks access to improved sources of drinking water and one in three lacks improved sanitation. 82% of those who lack access to improved water live in rural areas, while just 18% live in urban areas [20]. The water problem is a global issue, most especially in developing countries.

In Oyo state, Nigeria for an example, only 25% of the population of about 3.5 million people have access to public potable water [22], which leaves the remaining 75% to resort to drinking from other sources like boreholes, hand dug wells, streams and rivers.

Regardless of where drinking water are sourced; either from ground or surface water, different form of contamination may still not be inevitable. In the case of Oyo state, the public tap water is sourced from two major dams: Asejire and Eleyele dams [23]. The Eleyele schemes collects water from two major rivers: the Ona and Ogunpa, which pass through Ibadan and are often polluted with effluent from unregulated industrial, commercial and residential quarters [22]. These dams are not unaffected by pollution from industrial effluents and run offs from agricultural and mining sites.

Studies have also shown that contamination is not limited to the sources of this water alone, after the water must have been treated and distributed, the public tap water can still suffer from contamination during transit between the point of distribution and the point of use. This can be largely attributed to contamination through burst pipes, which will permit run offs from dumpsites and roadsides. Contribution of leaded pipes, old and rusting pipes to contamination are also worth considering.

Metal contamination also occurred in the distribution system and, in particular, post-treatment contamination was substantial for cadmium and lead. However, most of the disease burden associated with these two contaminants appeared to be due to contaminated dam water and ineffective treatment. Consequently, reducing the disease burden could best be achieved by protecting water catchment and upgrading water treatment systems.

Guideline values for many chemical constituents of drinking water have been established by WHO and other national environmental agencies which represents the concentration of a constituent that does not result in any significant risk to health over a lifetime of consumption.

This study will aim at assessing some physicochemical properties and level of heavy metals contamination in tap water transiting from the point of distribution to the point of consumption in some selected areas in the city of Ibadan Oyo state, Nigeria, and compare the values obtained with the permissible limits as established by WHO and Standard Organization of Nigeria (SON).

2. MATERIALS AND METHODS

2.1 Description of Sampling Area

Ibadan is located in Southwestern Nigeria. It is the capital of Oyo State, and is reported to be the largest indigenous city in Africa, South of the Sahara. Ibadan had been center of administration of the old western region, Nigeria since the day of the British colonial rule. It is situated 78 miles in land from Lagos, and is a prominent transit point between the coastal region and the areas to the north. Parts of the city's ancient protective walls still stand till today and its population is estimated to be about 3,800,000 according to 2006 estimates. The principal inhabitants of the city are the Yorubas. It has five urban Local Government areas.

2.2 Sample Collection

Sixteen taps water samples were randomly collected from five areas within Ibadan Metropolis and at the distribution point of Oyo State water corporation, Eleyele, Ibadan.

The sampling areas fall within three local government areas in Ibadan which are Ibadan North-West (NW), Ibadan South-West (SW) and Ibadan South-East (SE) Local Government Areas (LGA). The bottles were thoroughly washed with detergent and rinsed thoroughly with distilled water to remove detergent residue. All sampling containers were soaked in 10% nitric acid overnight. They were then rinsed thoroughly with distilled water. The plastic bottles were then taken to sampling sites where water samples were collected. Two 1.5 liters sampling bottles were used to collect the water samples. At each sampling point, the bottles were rinsed with the tap water and were allowed to run for 3 minutes before the samples were collected. 5 ml nitric acid was added to the water samples for heavy metals analysis for preservation. The samples were taken in an ice cooler to the laboratory and stored at 4°C prior to analysis.

2.3 Sample Analysis

Temperature and pH were measured immediately on site after collection with mercury-in-glass thermometer and a digital portable pH meter, respectively. Total solids (TS), Total suspended solids (TSS) and Total dissolved solids (TDS) were determined by gravimetric method. The acidified water samples were digested with concentrated nitric acid to determine heavy metals.

The digested samples were analyzed in duplicate for heavy metals using Atomic Absorption Spectrophotometer (AAS) Perkin Elmer A Analyst 200 model. Blank was also carried out to check possible errors. The instruments used in all the analysis were calibrated with appropriate standards before any measurement and analysis.

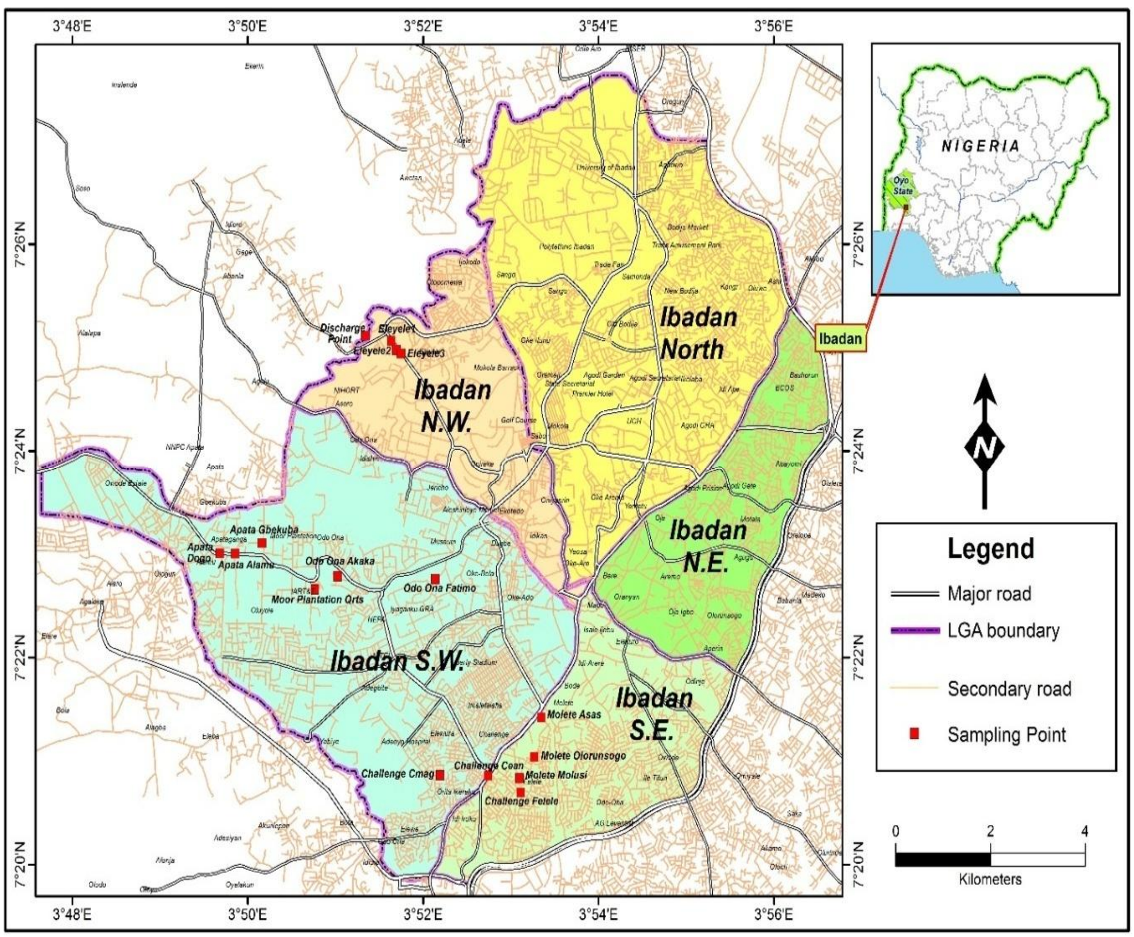

Fig. 1. The map of Ibadan metropolis showing the sampling area and sampling points

3. RESULTS AND DISCUSSION

The results of the physicochemical properties were presented in Table 1 and Fig. 2 while that of heavy metals analysis were presented in Table 2 and Figs. 3-6. At the distribution point and in all the areas sampled, all the physicochemical properties determined were within the WHO and SON recommended limits. The heavy metals concentrations determined were within the WHO and SON recommended limits except lead and cadmium (Table 2 and Figs. 3-6). In all the areas sampled, the pH ranged from 6.59-7.60 (Table 1). The lowest was recorded at Eleyele and highest at Apata area, these values are within the WHO and SON recommended limits (Fig. 2). Water with a pH less than 6.5 is considered acidic and is typically corrosive and soft. It may contain metal ions, such as copper, iron, lead, manganese and zinc. The metal ions may be toxic, for example lead. They may produce a metallic taste, and can stain fixtures and fabrics. The low pH can damage metal pipes and fixtures. Water with a pH higher than 8.5 is considered basic or alkaline. This water is often hard, containing ions that can form scale deposits in pipes and contribute to an alkali taste.

The Total Solid (TS) which is a measure of the suspended and dissolved solids in water ranged from 10.89- 51.20 mg/l, the lowest at distribution point and the highest at Eleyele area, are all within the recommended limits. Elevated level of TS in drinking water is responsible for turbidity which makes the water unclear and unpleasant for drinking.

The Total Suspended Solids (TSS) ranged from 6.80 - 7.50 mg/l, the highest at Eleyele area and the lowest at Challenge and Odo- ona area. TSS represents those solids that can be retained on a glass fibre filter. High levels of TSS will increase water temperatures and decrease dissolved oxygen levels. Their values are within the recommended limits in all the water sampled. In the Total dissolved solids (TDS) determined in all the samples, highest value was observed at Eleyele area and the lowest at the distribution point. They were all within the recommended limits of WHO and SON.

The heavy metals determined were iron, zinc, cadmium and lead (Table 2). All these metals were observed to be within the recommended limits at the distribution point but values higher than the permissible limits were observed as the water transit to the point of use in some areas. The value of lead was observed to be lowest at the distribution point (0.03 mg/l), this can be attributed to the level of treatment before the distribution of the water to the public. In transit the level of lead has risen to 0.29 mg/l at Apata area, this might be connected to the contribution of old and rusting metal pipes or burst pipes which might permit run offs from dumpsites into the drinking water. This could have adverse effect on the consumer of this water. The values obtained for iron ranged from 0.27 to 1.88 mg/l, the lowest at Eleyele and Odo-Ona areas and highest at Molete.

Zinc was determined and ranged from 0.02 to 0.12 mg/l the lowest at Odo-Ona (0.02 mg/l), the highest at the distribution point (0.12 mg/l) and are within the recommended limits of SON and WHO. Cadmium is also one of the very toxic heavy metals, permissible limit for cadmium in drinking water according to WHO and SON is 0.003 mg/l. At the distribution point the value for cadmium 0.002 mg/l was observed to be within the permissible limit. In transit, the values ranged from 0.01 mg/l at Apata to 0.008 mg/l at Eleyele and Molete area (0.008 mg/l) which were above recommended limits. The presence of cadmium in drinking water can be as a result of leaching

Table 1. Mean values of physiochemical properties of with recommended limits

Location	pH	Temp (°C)	TS (mg/l)	TSS (mg/l)	TDS (mg/l)
Eleyele	6.59	30.3	51.2	7.5	43.7
Odo-Ona	7.53	32.1	46.1	6.8	39.3
Apata	7.60	30.6	42.1	7.3	34.8
Challenge	7.47	31.0	50.1	6.8	43.3
Molete	7.21	29.5	33.7	7.1	26.6
Distribution point	6.79	30.0	10.8	7.20	3.60
WHO	6.5-8.5	30	1500	NA	1000
SON	6.5-8.5	30	NA	NA	500

WHO: World Health Organization; SON: Standard Organization of Nigeria; Temp: Temperature; NA: Not Available

Table 2. Mean concentration (mg/l) of heavy metals in water samples compared with recommended limits

Location	Fe	Zn	Pb	Cd
Eleyele	0.270	0.030	0.100	0.008
Odo-Ona	0.270	0.020	0.220	0.005
Apata	0.530	0.090	0.290	0.001
Challenge	0.680	0.040	0.060	0.004
Molete	1.880	0.060	0.190	0.008
Distribution point	0.980	0.120	0.030	0.002
WHO	0.300	3.000	0.010	0.003
SON	0.300	3.000	0.010	0.003

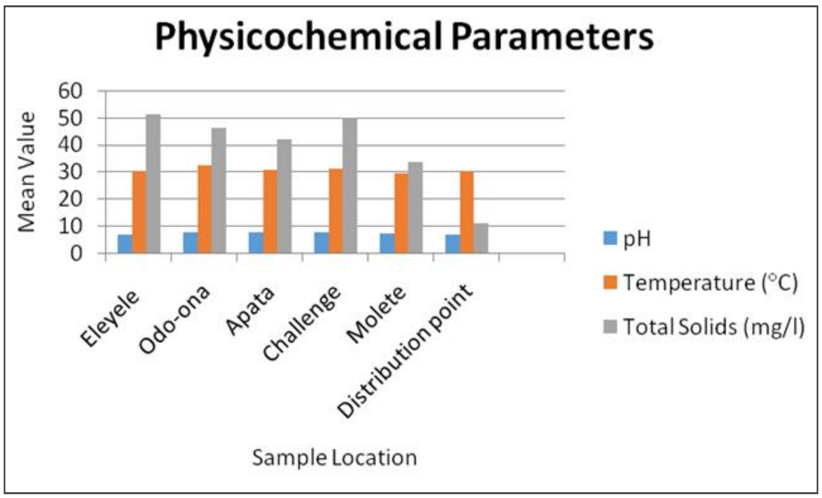

Fig. 2. Mean values of physicochemical parameters of the water samples

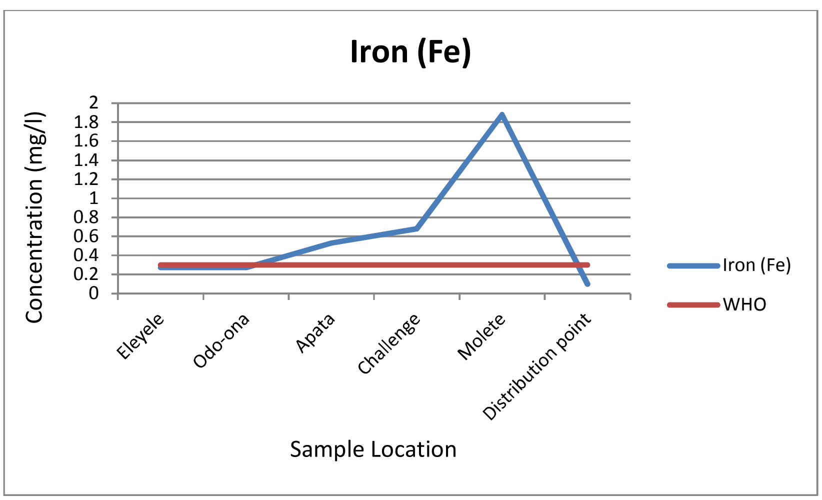

Fig. 3. Mean concentration of iron in samples compared with WHO limit

from galvanized pipes and fittings or through the environmental release of fertilizers or metallurgical industries and mining [24]. This result is comparable to the one obtained by [23] which showed that metal contamination occurred in the distribution system and in particular, post-treatment contamination was substantial for cadmium and lead.

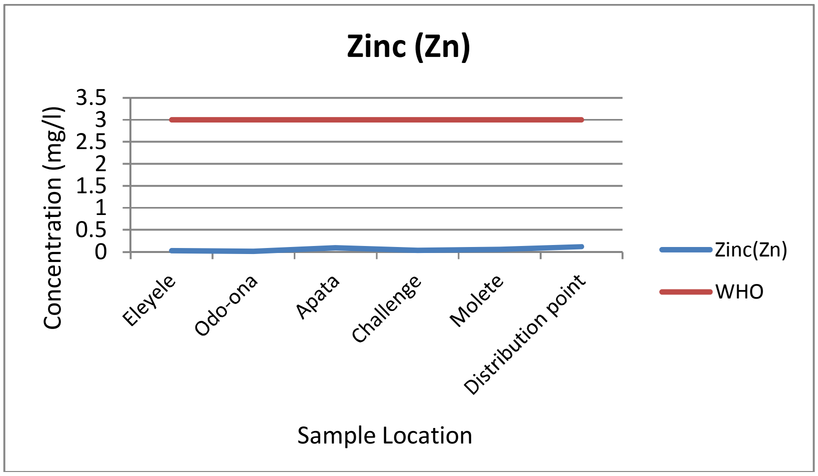

Fig. 4. Mean concentration of zinc in samples compared with WHO limit

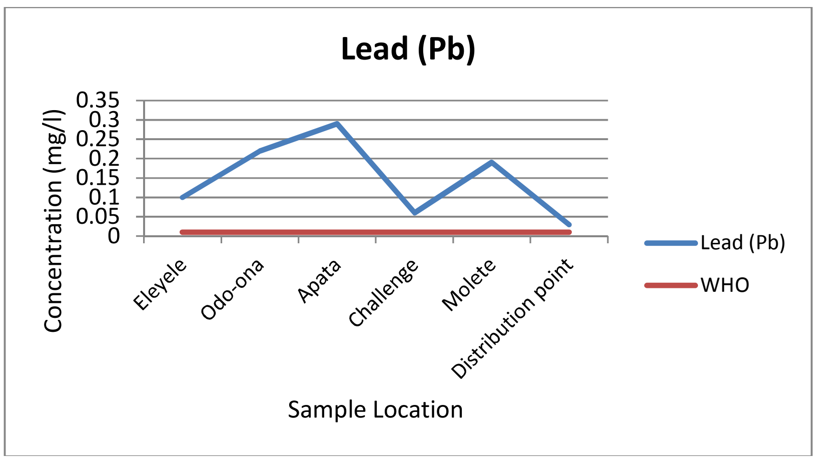

Fig. 5. Mean concentration of lead in samples compared with WHO limit

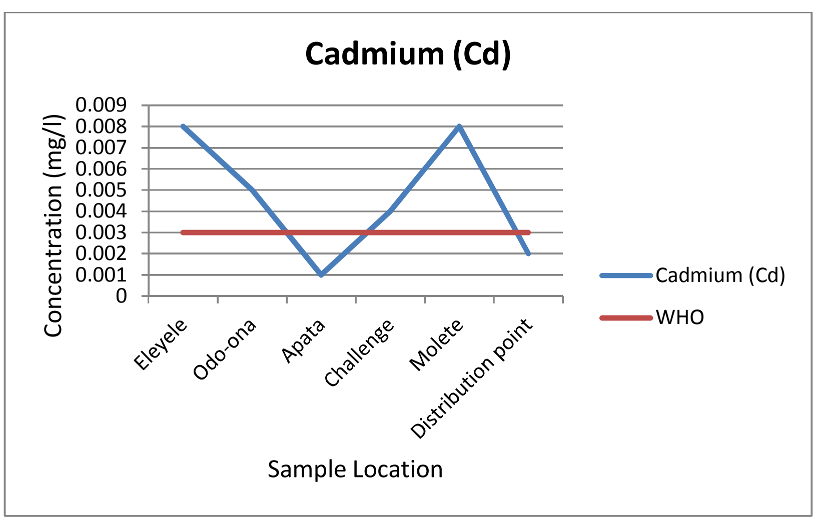

Fig. 6. Mean concentration of cadmium in samples compared with WHO limit

4. CONCLUSION

Diseases related to consuming contaminated water is a major burden on human health. According to WHO, a holistic approach to drinking-water supply risk assessment and risk management increases confidence in the safety of drinking-water. This approach entails systematic assessment of risks throughout a drinking-water supply – from the catchment and its source water through to the consumer. There is the need therefore to intensify effort to minimize or completely eliminate post treatment contamination of public tap water by effective monitoring of the distribution system.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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