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Comparative Analysis of Physicochemical Parameters and Heavy Metals of Public Water Supply in Kaduna Metropolis.

S.Z, Kazaure[2], H.A, Isa[1], Y. Mohammed[3], M.M, Namadi[4]
Chemistry Department (Environmental chemistry) Nigerian Defense academy Kaduna. Nigeria[1,2,3,4]

Abstract: *The study examined the physicochemical and heavy metal analysis of municipal water supply along the distribution channels from source (raw water) to end user points of Kaduna metropolis. Water samples were collected from the raw water sources of the treatment plants in the metropolis (Malali and Barnawa water works), treated water from the treatment plant reservoirs, the three booster stations (Kawo, Lugard Hall and Tudun Wada) and randomly from residential areas which includes; Malali, Barnawa, Tudun Wada, Marafa, Kabala costain, Badiko, Kurmin Mashi and UnguwanSunusi area of the metropolis. The samples were analyzed for pH, turbidity, electrical conductivity, total dissolved solids, total hardness, calcium hardness, magnesium hardness, alkalinity, sulphate, nitrate, DO, BOD, COD, iron and free CO_2 using standard procedure described by American public Health Association(APHA),heavy metals such as chromium, lead, nickel, copper and cadmium were analyzed using atomic absorption spectroscopy, The result obtained was compared with the WHO and the Nigerian Standard for Drinking Water set by the Standard Organization of Nigeria(SON). pH and turbidity of all samples from raw water to treated water delivered to end users with mean values of pH of 5.67 for raw water and a range of 4.48-4.60 for treated water all falls above the permissible limit of 6.5-8.5, turbidity values of 1883NTU for raw water and a range of 11.60-41.36NTU for treated water all falls above the permissible limit of 5NTU for portable water other parameters were all within the standard limit, copper and iron were detected in all samples but within the permissible limit ,lead ,chromium, nickel and cadmium were above maximum permissible in all samples analyzed.*

Keywords: *Physicochemical parameters, heavy metals, Municipal water, W.H.O, water quality.*

I. Introduction

Changes in water quality are reflected in its physical, biological, and chemical conditions; and these in turn are influenced by natural and anthropogenic activities [1]. Water quality has direct influence on public health. When water gets contaminated with various pathogenic as well as opportunistic micro flora and toxic chemical compounds, it serves as the commonest vehicle of transmission of a number of infectious diseases. Unfortunately, over a billion people in the developing world do not have access to satisfactory water supply. The WHO has estimated that up to 80% of all sickness and disease in the world is caused by inadequate sanitation, polluted or unavailability of water. The pollution of drinking water is responsible for a large number of mortalities and morbidities due to water-borne diseases like typhoid, cholera, dysentery, hepatitis as well as many protozoan and helminthic infestations [2].

However, access to safe drinking water and sanitation is critical in terms of health, especially for children. For instance, unsafe drinking water contributed to numerous health problems in developing countries such as the one billion or more incidents of diarrhea that occur annually [3].

An adequate supply of portable water assist in preventing the spread of gastrointestinal diseases, support domestic and personal hygiene and improve the standard of living [4]

Today human activities around sources, treatment facilities and distribution channels of public water are constantly adding industrial, domestic and agricultural waste to portable water sources at alarming rate [5]. In the same vein both the quantity and quality of water are affected by an increase in anthropogenic activities and any pollution either physical or chemical causes changes to the water quality of the receiving water body[5].Chemical contaminant occur in drinking water throughout the world which could possibly threaten human health[6].

Delivery of safe portable drinking water to communities in Nigeria is the responsibility of the government which in most cases has been inefficient and adequate, Kaduna metropolis as a city is one of such communities where adequate and safe drinking water is not guaranteed.

The effect of physicochemical parameters on the quality of water has become one of the major environmental challenges in our society[7].These physicochemical parameters determine the survival and growth of microorganisms in them and the growth also varies according to the requirement of these organisms, hence physicochemical parameters are the physical factors such as temperature, turbidity, colour, pH, taste, total dissolved solids, conductivity, suspended solids and chemical factors such as carbon phosphorus, dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, salinity, total hardness, phosphate, nitrates, ammonia, residual chlorine ,heavy metals such as iron, cadmium, copper, lead, nickel etc.[7].

II. Materials And Methods

2.1 Study site and samples collection

The study areas are Kaduna state water works which are: old works Malali, new works Malali and barnawa water works. The booster stations are the Lugard hall, Tudun Wada, and state house (Kawo) booster stations.
Samples of treated and untreated water were collected at four categorical points (raw water from the plant, treated water from the plant reservoir and treated water from the booster stations and consumer points) Using 2liter sterile sampling bottles, raw water samples were collected from the raw water storage; samples for the treated were collected from the reservoir while the treated samples at booster stations were collected at the three booster stations, samples at consumer point were collected at random from different locations within the metropolis. The water samples were analyzed once weekly for a period of five weeks, meanwhile each batch of the samples was transported to the laboratory for microbiological and physicochemical analyses within 4hrs of collection. The allotted samples for mineral analysis were chemically preserved by the addition of 5ml concentrated HNO_3 per litre of the water samples.

2.2 Determination of Physicochemical Parameters

The pH was measured instrumentally using pHep pocket size pH meter Hanna instrument, the electrical conductivity using conductivity meter of model DDS 307, oxygen demand and biochemical oxygen demand using DO meter with model JBD-607 portable dissolved oxygen analyzer, turbidity meter of model HACH 200Q was used to determine the turbidity of the samples.
PAQUALAB photometer was used for the determination of nitrate at 570nm, sulphate and iron at 520nm.Total hardness, calcium hardness, magnesium hardness, alkalinity, chloride, chemical oxygen demand, free carbon dioxide where determined using standard procedures describe by American Public Health Association (APHA)[8]

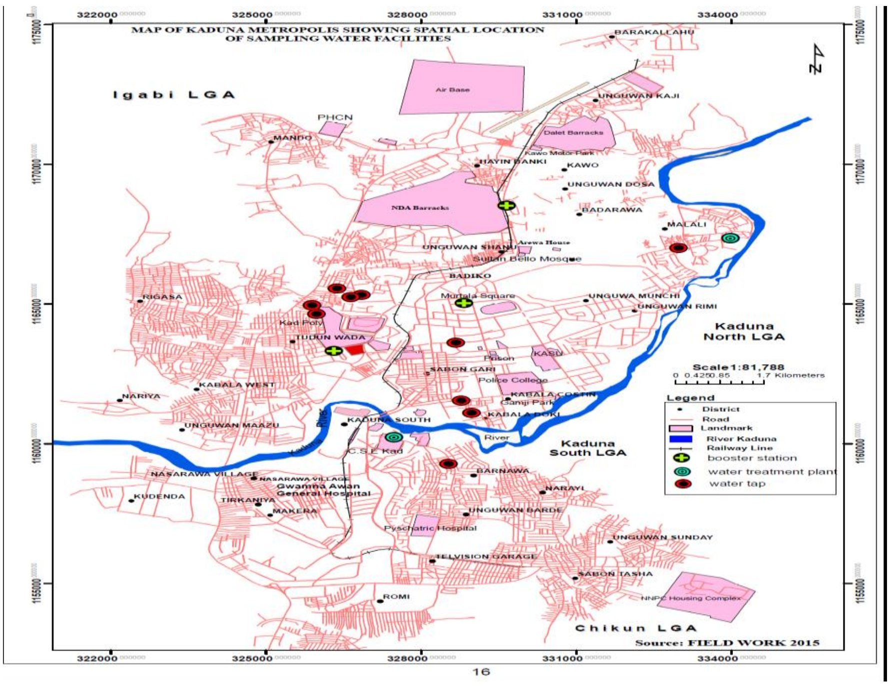

Figure 1: Map showing the sampling points within Kaduna metropolis

2.3 Digestion of sample for heavy metal determination

100ml of well-mixed sample was taken in to a beaker followed by 2ml of concentrated HNO_3 and 5 ml of concentrated HCl. The sample was covered with a watch glass and heated on a hot plate at 90 to 95^{o}C until the volume has been reduced to 15-20 ml.

The beakers were then removed and allow cooling. The content of the beaker was filtered with the watch glass washed in to the beaker with distilled water and filtered to remove silicates and other insoluble material that could clog the nebulizer. The final volume was adjusted to 100 ml with distilled water [9].

The sample was then taken for analysis of cations such as lead, cadmium, nickel, chromium and copper using atomic absorption spectroscopy of model of model AAS buck scientific Model 210VGB.

III. Result And Discussion

The mean results of the physicochemical parameters of the water samples analyzed are presented on table 1 and the results the heavy metals are presented on figure 1. Tables 3 and 4 show the maximum permissible limit allowed by both Nigerian standard for drinking water and the W.H.O

Table1: Mean physicochemical parameters of Kaduna municipal water supply along its chain of distribution

Parameters	Raw water	Reservoir Malali	Reservoir Barnawa	Booster station Kawo	Booster station Tudun wada	Booster station Lugard Hall	End user point
pH	5.67	5.02	4.56	4.56	4.60	4.48	4.60
Turbidity	1883.10	41.36	18.58	14.64	11.60	14.68	13.52
Conductivity	92.95	84.38	82.04	83.22	82.90	83.54	83.10
TDS	62.22	56.53	54.96	55.75	55.54	55.966	55.67
Hardness	36.48	27.62	30.20	57.676	40.29	24.37	35.98
Calcium	22.87	20.66	24.49	49.86	18.89	20.08	23.74
Magnesium	13.51	6.80	11.51	7.81	8.40	7.484	12.30
Alkalinity	21.52	19.60	21.26	12.65	32.79	8.59	13.80
DO	4.15	2.07	2.24	2.18	2.63	2.32	2.03
BOD	0.93	0.56	0.54	0.46	1.06	0.84	0.80
COD	124.83	77.12	84.40	120,00	95.60	141.56	147.46
Nitrate	18.46	2.75	2.03	1.29	1.58	1.15	1.30
Sulphate	44.68	44.00	30.00	25.34	28.30	31.96	23.26
Iron	0.52	0.17	0.12	0.11	0.15	0.13	0.09
Free CO_2	12.51	27.86	24.84	25.75	19.50	23.52	25.54
Chloride	24.25	18.96	30.39	25.27	34.28	25.42	24.85

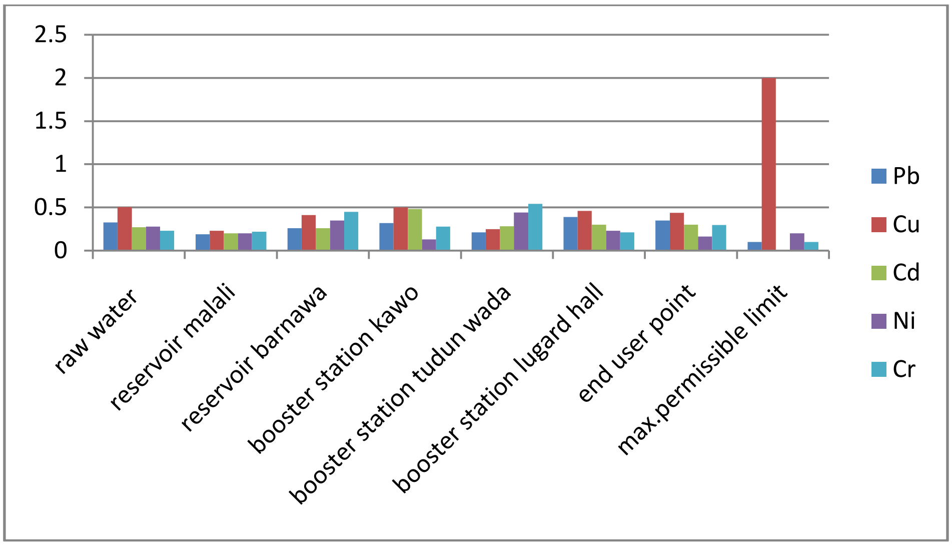

Figure 2: Comparison of the mean of the mean of all the water samples with the WHO maximum permissible limit

IV. Discussion

The mean of the physicochemical parameters showed that the pH of all the samples collected within the sampling period where below WHO and Nigerian standard for drinking water maximum permissible limit of 6.5-8.5 [10]. The mean pH values for raw water was 5.67` and the treated water ranged from 4.8-5.02. The lowest values where recorded was at the booster station. The increased acidity of raw water could be attributed to the presence of acidic metabolite or an indication of contamination of the water by household waste and sewage [11] while the acidic pH levels recorded for the treated could be attributed to poor treatment of the water for pH adjustment. Acidity in water makes it possible for easy dissolution of metals especially heavy metals [12]. Thus the pH of this water has to be adjusted in order to prevent it from being a health hazard.

Turbidity consists of suspended particles in the water and may be caused by a number of materials organic or inorganic. The mean turbidity of the samples collected within the sampling period was all above the WHO and Nigerian standard for drinking water maximum permissible limit of 5NTU. The occurrence of turbidity in surface water may be permanent or seasonal (John et al., 2008) this was justified from the observed variation of the turbidity of the raw water (River Kaduna) which was 1883.10NTU during the sampling period while the treated water at the treatment plant was 11.60-41.36NTU) (table 1). Turbidity has long been known to hinder disinfection by shielding microbes, some of them perhaps pathogens. This is the most important significance of turbidity monitoring and therefore it has been an indication of the effectiveness of filtration and coagulation of water supplies [13]

The mean conductivity measurement data obtained for this study was 92.95µS/cm for raw water (Table1) and 82.04- 83.34µS/cm for the treated water samples. The maximum permissible standard for conductivity of drinking water are 250µS/cm (WHO) and 1000µS/cm by Nigerian standard for drinking water, thus, the conductivity of all the water samples were within the permissible limit of both W.H.O and the standard organization of Nigeria.

Total dissolved solid (TDS) comprises inorganic salts (principally calcium, magnesium, potassium, sodium, bicarbonate, chlorides and sulphate) and small amounts of organic matter that are dissolved in water [14].The maximum permissible standard for drinking water is 1000mg/l. The mean values obtain for this work are 62.22mg/l for raw water and a range of 54.96-55.96mg/l. These indicate that all values obtain are below the maximum permissible limit.

Total hardness is a function of the geology of the area with which the water is associated, it may affect the taste of the water as well as influence its lathering ability when used [15]. The mean values obtain for this study as shown on table 1 for total hardness of the water samples which are all within the permissible limit of WHO (500mg/l)and the standard organization of Nigeria (150mg/l) . Calcium which is essential for nervous system and for the formation of bones is commonly present in all water bodies where it usually comes from the leaching of rocks; on the other hand magnesium is found in the earth crust in much lower amounts as compared to calcium [16]. High concentration of magnesium in drinking water gives it unpleasant taste and also has a laxative effect [17]

Alkalinity indicates the levels of carbonate and hydroxyl groups in water although hydroxyl is uncommon in natural water. Alkalinity leads to corrosion and influences chemical and biochemical reactions in the water and also imparts bitter taste [18].

The mean alkalinity of the samples were all within the permissible limit of WHO (500mg/l) and the Nigerian standard organization (100mg/l) for drinking water as presented on table 1.

WHO standard specifies minimum value under the Dissolved Oxygen (DO) test as 5.0mg/l. The mean results of water analysis showed wide range of DO, with the raw water sample having 4.15mg/l and a mean range of 2.03-20.63mg/l. This values falls within the maximum permissible limit of 5.0mg/l by W.H.O and the Nigerian standards organization.

The biochemical oxygen demand (BOD) which gives the relative oxygen requirement for the degradation of organic materials showed a mean value of 0.93mg/l for the raw water samples. The treated water sample has a mean of 0.46-1.06mg/l for treated water (Table1). These values are all within the permissible limit for BOD reported by Vinod (2008) while the chemical oxygen demand (COD) of the samples which gives the empirical values of the oxygen requirement for the oxidation of organic matter with strong chemical oxidant showed a mean of 124.83mg/l for raw water samples, the mean value of the treated water range from 77.12-147.46mg/l.

Nitrates are readily converted to nitrites and vice versa and are present naturally in soils, water and food. They get into water through chemical fertilizers, soils, foods and explosives [19] these compounds are very soluble in water and can enter surface water when it rains or groundwater through leaching. Nitrate is a normal component of the human diet and it is relatively non-toxic but when swallowed, it is converted to nitrite which reacts with hemoglobin in the blood causing methemoglobin that could result in coma and deaths especially in infants. It also causes diuresis and hemorrhage of the spleen. Excess of it in water is used as an indicator of poor water quality [12]. The highest mean value recorded for nitrate in the water sample was 18.46 mg/l for raw water and a minimum of 1.14mg/l for treated water sample (table 1). These values were all within the maximum permissible limit of WHO and Nigerian standard for drinking water of 50 mg/l.

Sulphate occur naturally in drinking water and health concerns regarding its level has been linked with diarrhea due to its laxative effects especially when there is change from drinking water with low sulphate to drinking water with high sulphate concentration [10]. In drinking water, this ion has a secondary maximum contaminants level (SMCL) of 250mg/l which is a value provided as a guideline for public water works [20] the mean concentration of all the water samples was far below the maximum permissible limit with the highest mean value at 44.68mg/l for raw water samples and the lowest of 23.36mg/l for samples from end user points.

The highest mean concentration of chlorides recorded within the sampling period was 30.39mg/l for raw water sample and the minimum mean concentration of 18.96mg/l for treated water at end user point. The values are far much below the maximum permissible limit of 250mg/l set by WHO and the Nigerian standard for drinking water. Excessive chloride concentration in water increases rate of corrosion of metals in the distribution system depending on the alkalinity of the water. This can lead to increased concentration of metals in the water supply [21]. Chloride ion is one of the major ions in water it is generally associated with sodium and calcium, high concentration of chloride in water may lead to objectionable salty taste [22].

The mean iron concentration of all the treated water samples ranged from 0.09mg/l to 0.15mg/l, these values are all within the WHO permissible limit of 0.3mg/l for drinking water but the mean concentration of iron in the raw water before treatment of 0.5mg/l exceeded the permissible limit. Iron is a natural constituent of the earth crust. It is present in drinking water as a result of the use of iron coagulant or the corrosion of steel and cast iron pipes during water distribution [22]. The level found in this study is of no health concern.

For the protection of human health, guidelines for the presence of heavy metals in drinking water have been set by different International national Organizations such as USEPA, WHO, EPA, and the European Union Commission and also the Standard organization of Nigeria. Thus, heavy metals have maximum acceptable concentration in drinking water as specified by these organizations. Maximum acceptable concentration (MAC) is an enforceable standard set at a numerical value with an adequate margin of safety to ensure no adverse effect on human health. It is the highest level of a contaminant that is allowed in a water system [23].The copper content of all the water samples were below the maximum acceptable limit of 2.0mg/l for drinking water. The maximum mean concentration of copper detected was 0.50mg/l (figure 2) for raw water samples and treated water sample from Kawo booster station. However, copper was detected in all the water samples and since toxicity is associated with continuous low level exposure, this can eventually lead to serious health effects. Contamination of drinking water with high level of copper may lead to chronic **[**22]. Studies have shown that ingesting copper may also be implicated in coronary heart diseases and high blood pressure, although coronary heart diseases have also been linked to copper deficiency. High levels of copper in drinking water can cause vomiting, abdominal pain, nausea and diarrhea. The occurrence of copper in water may be from brass taps or chemical leaching from coatings taken up from contact with surface during treatment or disinfections.

Result obtained for the analysis of lead in the sample showed concentration of lead at Marafa was beyond detectable limit but all other sample showed concentration above maximum acceptable limit of 0.1mg/kg (figure 2). This unusual high level of lead in tap water might be due to fittings made from brass, also the extend of lead pick up depends on various factors such as temperature, pH and hardness [23].

All samples also showed detectable levels of cadmium above the permissible maximum concentration of 0.003mg/kg for drinking water (figure 2). This is of concern because some studies suggest it may be a reproductive toxin and can cause premature birth, low birth weight, still birth and spontaneous abortion [22]

The concentration of chromium was beyond detectable limit at some point within the sampling period but most samples showed concentration above the maximum permissible limit of 0.1mg/kg by the WHO. Concentration of Nickel also exceeded the permissible limit of 0.2mg/kg for drinking water in all samples within the sampling period.

V. Conclusions

On the basis of the physicochemical parameters examined in this study, the municipal water supply is suitable for domestic use as at the time of this study. However, the low pH, high turbidity and most of the heavy metal recorded for all the water samples falls outside W.H.O and the Nigerian Standard for Drinking water maximum permissible limit and this raises a serious health concern.

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