QUALITY OF SOME COMMONLY CONSUMED "PURE" AND BOTTLED WATERS IN AGO IWOYE, OGUN STATE, NIGERIA - A COMPARATIVE STUDY*

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Abstract

Quality of fifteen different commercial sachet water samples commonly called "pure water" and five different commercial bottled waters from Ago Iwoye, Ogun State were investigated to establish the quality of the products and their suitability for human consumption. Generally, results of some physical parameters such as Electrical Conductivity (EC), Total dissolved Solids (TDS) and pH for the "pure" and bottled water samples were within WHO safe limits for drinking water. There was no bacterial contamination detected in all the bottled water samples while 73.3% of the "pure water" samples had values for total bacterial count well above the recommended value of 100 cfu/ml by the National Agency for Food and Drug Administration and Control (NAFDAC). E. coli was also detected in 40% of the "pure water" samples.

Levels of trace metals viz: Cr^{2+}, Zn^{2+}, Mn^{2+}, Cd^{2+}, Pb^{2+} and Ni^{2+} were determined in the water samples by Atomic Absorption Spectrophotometry (AAS) after acid digestion and ranged from (ND - 1.30) mg/L, (ND - 0.455) mg/L, (ND - 0.510) mg/L, (ND - 0.559) mg/L, (ND - 13.534) mg/L, (ND - 0.350) mg/L respectively for the "pure water" samples and (0.025 - 0.135) mg/L, (ND - 0.965) mg/L, (0.230 - 0.370) mg/L, (ND - 0.280) mg/L, (ND - 10.707) mg/L and (ND - 0.20) mg/L respectively for the bottled water samples.

There were only few violations of the WHO limits for these metals in the bottled water samples compared with the 'pure waters'. This study showed that 'pure water' samples contain higher levels of toxic elements – Cd, Pb and Ni than in the bottled water samples while the essential elements- Zn and Mn needful to the body are more abundant in bottled waters than the pure water samples.

Generally, results of the trace metals and microbial analyses showed that bottle water is of better quality compared to 'pure waters'. Pure water is not properly treated and hence not fit for human consumption because of the very high risk factors involved.

Key Words: 'Pure water', bottled water, trace metals, Ogun State, bacteria count.

1. Introduction

Water is the most important resource on earth; without water life is not possible. Water played a crucial role in the origin of life and has an essential role in maintaining plant and animal life. Plants depend on water for the transfer of nutrients and for photosynthesis. Owing to the presence of water in cells and body fluids such as blood, human beings are approximately 70% water. Given the importance of water, it is not surprising to note that man can survive very much longer without food than they can without water (Mathews, 1996).

Apart from the ions in water, there are elements which also occur in water in small concentrations. Even though some trace elements are essential to man, essential as well as non-essential elements at elevated levels can cause morphological abnormalities, reduced growth, increased mortality and mutagenic effects in humans. Drinking water however, plays a major role in the intake of a number of these nutritional and sometimes toxic trace elements in humans. Concern that trace elements and faecal contaminations in drinking water present a potential health hazard if they exceed certain concentrations is well known (Theroux *et al.*, 1943; Ogunfowokan *et al.*, 2000 and Prescott *et al.*, 2005). The presence of pathogenic bacteria in water samples is evaluated indirectly in the water samples by determining the most probable number of coliform bacteria. About 100 to 400 of these organisms are excreted from the intestines of a single human everyday. Their presence in water due to improper disposal of wastes and ineffective water treatments can cause typhoid fever and cholera (Moore and Moore, 1976).

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Earlier efforts on the study of trace elements in Nigerian drinking water were carried out by Asubiojo *et al.* (1997) and Nkono and Asubiojo, (1997; 1998). These workers focused on the analysis of trace elements in well, tap waters and soft drinks and reported varying levels of trace element contamination in drinking waters and soft drinks. In our preliminary work on sachet water, commonly called 'pure water' some physicochemical parameters in the water samples from Ile Ife and its environs were analysed for the first time in Nigeria (Ogunfowokan *et al.*, 2000). Our preliminary results showed that the risk factors in the potability of the 'pure water' samples are more than what can be overlooked. Results from our study prompted two Nigerian National dailies – Nigerian Tribune (Thursday 17 February, 2000, pp 15) and The Guardian (Sunday 5 February, 2000, pp 38) to alert Nigerians on the impending danger of drinking 'pure water' in their publications entitled 'pure water contains cancerous substance' and 'pure water or poor water' respectively'. These publications by the two dailies were credited to our early study of the year 2000 on 'pure water'. Results of our study showed that Nigeria was unable to meet up with the target of clean, pure potable water and 'Health for all by the year 2000' campaign by the World Health Organization. In Nigeria today, the crave of the populace for pure and hygienic drinkable water is still on the increase. Consequently, the 'pure water' industries are still springing up indiscriminately without paying adequate attention to the proper treatment and hence quality of the product inspite of the stringent measure being put in place by the National Agency for Food and Drug Administration Control (NAFDAC).

As a result of the impending danger associated with the consumption of the common 'pure waters' people have now resulted to the consumption of bottled waters which are believed to be pure compared to the so-called 'pure waters'. Good as this may be, the bottled waters are expensive and are not affordable to common Nigerians especially the teeming student populace of the Olabisi Onabanjo University, Ago Iwoye, Nigeria. Hence the need to investigate further whether there has been an improvement in the quality of the commonly consumed and affordable 'pure waters' of Nigeria as a follow-up to our earlier study. This study therefore, aims to determine and compare the quality of some commonly consumed so-called 'pure waters' and bottled waters from Ago Iwoye a University town in Ogun state, Nigeria and to assess the conformity or otherwise of their qualities with those of standards set by World Health Organization (WHO) for drinking water.

2. Experimental

Sample Collection

A market survey of the commonly consumed "pure water" and bottled water brands was carried out in Ago Iwoye and its environs, Ogun State and cafeterias of the Olabisi Onabanjo University, in September 2006. Over twenty different "pure water" brands, packaged into sachets and ten bottled water brands packaged in transparent polyethene bottles were discovered. Six samples each of fifteen randomly selected pure water brands and two samples each of five selected bottled water brands were purchased and stored at 4 °C in a refrigerator prior to analysis.

Pretreatment

In other to avoid contamination of the samples, all the glassware and sample bottles to be used during analysis were first washed with detergent, rinsed with distilled water and then soaked in 10% concentration HNO_3 for 48 hours after which they were rinsed with distilled water prior to usage.

Quality Control Study

The extractive concentration method was evaluated for the quality assurance of water samples. This was done by recovery work using standard addition experiment since standard water reference materials for metals were not available to us. Double-distilled water was spiked at fortification levels of 10 mg/L each of mixture of Cd, Pb, Cr, Zn and Ni. 25 ml of doubly distilled water was placed in each of the three 100 ml beakers. The digestion was carried out using the same procedure described for the samples below. The worked-up samples were analysed using the Atomic Absorption Spectrophotometer (AAS) available at the Central Science Laboratory of the Obafemi Awolowo University, Ile-Ife, Nigeria and the percentage recoveries of the metals calculated after triplicate analyses of the fortified samples. The recovery work was necessary to ascertain the efficiency of the analytical procedure described in this study.

Sample Preparation for Trace Metal Analysis

About 25 ml of each sample was measured into a 100 ml beaker. 10 ml of concentrated HNO_3 was added to the content of the beaker. The sample was heated on a hot plate to boiling point and evaporated to about 10 ml. The digested sample was transferred into a 50 ml standard flask and made up to the mark with distilled water (APHA 1992). The elemental analysis was carried out using the Atomic Absorption Spectrophotometer (AAS) available at the Central Science Laboratory of the Obafemi Awolowo University, Ile-Ife, Nigeria. The instrument was operated as per the manufacturer's manual.

Determination of the Total Bacterial and E.Coli Count.

The total bacteria colony forming unit (cfu) was estimated using the standard pour plate technique (Seeley and Vandemark, 1981; Theroux *et al.*, 1943). The samples were appropriately diluted using sterile distilled water. One milliliter (1 ml) of the diluted water sample was dispensed into a sterile Petri dish. Molten nutrient agar (40 °C) was gently poured into the dish and mixed by gentle swirling. The agar was then allowed to cool forming a uniform layer and the Petri dishes were then left on a horizontal surface for one hour before being incubated in an inverted position at 37 °C for 48 hours. After incubation, red colonies indicating total coliform and blue colonies indicating *E. Coli* were observed. Viable count were carried out on plate where the number of colony was between 30 and 300 and the number of bacteria per milliliter of the water sample was determined by multiplying the number of colonies on the plate by the dilution factor.

3. Results and Discussion

Table 1 shows results of the quality control study obtained for the doubly-distilled water samples as percentage recoveries of Cr, Pb, Cd, Zn and Ni from the spiked water sample. The percentage recoveries of these elements were 92.53% Cr, 89.23% Pd, 91.10% Cd, 79.86Zn and 76.57% Ni. The percentage recoveries obtained which ranged from 76.57% Ni to 92.53% Cr for the water samples are generally high and indicate that the sample preparation method and the analytical procedure described in this study are satisfactory. Tables 2 and 3 show the results of the chemical, physical and microbial analyses of fifteen commonly sold "pure water" samples in Ago Iwoye, Ogun State and those of the bottled waters respectively.

The mean concentrations of the metals studied ranged from Ni^{2+} 0.110 mg/L to Pb^{2+} 4.631 mg/L for the "pure water" samples and Ni^{2+} 0.007 mg/L to Pb^{2+} 4.194 mg/L in the bottled water samples (Tables 2 and 3). The overall mean values for Electrical conductivity, TDS and pH for the "pure water" samples were 46.71 μScm^{-1}, 23.65 mg/L and 6.23 respectively while those for the bottled waters were 112.8 μScm^{-1}, 40.72 mg/L and 7.32 respectively (Fig. 2).

The average Total Bacterial Count (TBC) in the "pure waters" was 2.4 x 10^3 cfu/mL while *E. coli* count average was 0.5 x 10^3 cfu/mL. There was no bacterial contamination detected in all the bottled water samples (Table 3 and Fig. 2).

The Electrical conductivity of the "pure water" samples ranged from 19.70 to 66.70 µS/cm while the range in the bottled water samples was from 20.50 to 300.00 µS/cm. The Total Dissolved Solids (TDS) in the "pure water" samples ranged between 9.80 and 33.30 mg/L and 10.50 and 148.90 mg/L in the bottled water samples. The pH range for the "pure water" samples was from 5.80 to 6.79 while it was 6.84 to 7.40 in the bottled waters.

The TDS and pH of all the "pure waters" and bottled waters were below WHO safe limit for drinking water of 1000 mg/L and 8 respectively. The EC and TDS of samples P and T were unexpectedly high compared to the values obtained for the other bottled water samples. This may be as a result of inadequate filtration of the water before packaging. There was no bacterial contamination detected in all the bottled water samples while 73.3% of the "pure water" samples had values for total bacterial count well above the recommended value of 100cfu/ml by the National Agency for Food and Drug Administration and Control (NAFDAC). *E. coli* was also detected in 40% of the "pure water" samples. The unusually high values for Total Bacterial Count suggests that most of the "pure water" manufacturers do not properly treat the water during production so that various organisms which are supposed to be filtered off by microfilter amongst other treatments such as shining ultraviolet light to the packaged water prior to their distribution for sale and consumption find their way into the finished product. This situation calls for serious concern due to the adverse health effects of these micro organisms to humans. Some of the diseases caused by micro-organisms through water include typhoid fever, cholera, diarrhoea, hepatitis just to mention a few (Moore and Moore, 1976; Ogunfowokan *et al.*, 2000). Based on the results obtained for the physical and microbial analysis bottled water is preferred for human consumption compared to the 'pure water'.

All the samples ("pure water" and bottled water) had concentration of Zn below the WHO recommended level for drinking water. However, there were violations of the recommended limits for most of the other metals studied in the 'pure' and bottled water samples.

Table 1: Percentage recovery of heavy metals in doubly distilled water

Element	Amount added (mg/L)	Amount recovered (mg/L)	% Recovery
Cr	10	9.253	92.53
Pb	10	8.923	89.23
Cd	10	9.110	91.10
Zn	10	7.986	79.86
Ni	10	7.657	76.57

Table 2: Mean concentration of heavy metals, EC, TDS, pH, Total Bacteria Count (TBC) and *E. coli* Count in freshly packaged "pure water" samples

SAMPLE	Cr^{2+} Mg/L	Zn^{2+} mg/L	Mn^{2+} mg/L	Cd^{2+} mg/L	Pb^{2+} Mg/L	Ni^{2+} Mg/L	EC µScm^{-1}	TDS Mg/L	pH	TBC Cfu/ml x 10^3	E. coli Cfu/ml x 10^3
A	0.030 (0.01)	0.230 (0.09)	0.085 (0.08)	0.794 (0.26)	6.090 (3.40)	0.250 (0.05)	21.70	10.80	6.53	3.00	NIL
B	0.005 (0.02)	0.020 (0.01)	ND	0.009 (0.02)	2.145 (0.31)	ND	47.60	24.30	6.00	4.00	NIL
C	ND	0.455 (0.16)	0.420 (0.20)	ND	4.760 (0.83)	0.050 (0.01)	33.70	16.80	6.47	3.00	1 00
D	0.015 (0.01)	ND	0.510 (0.20)	0.394 (0.13)	6.235 (2.62)	0.200 (0.10)	58.80	29 40	5.80	1.00	NIL
E	0.045 (0.03)	ND	0.150 (0.13)	0.390 (0.11)	5.858 (0.60)	0.200 (0.03)	56.20	28.00	6.04	NIL	NIL
F	0.035 (0.04)	0.115 (0.07)	ND	0.227 (0.06)	ND	ND	53.60	30 40	6.62	NIL	NIL
G	0.075 (0.03)	0.145 (0.12)	0.285 (0.05)	0.193 (0.04)	4.135 (2.10)	0.150 (0.01)	38.30	19.10	6.22	5.00	1.00
H	ND	0.265 (0.05)	0 360 (0.03)	ND	13.534 (2.70)	0.250 (0.15)	58.10	29.40	5.87	2.00	1.00
I	0.675 (0.08)	ND	0.160 (0.07)	0.401 (0.17)	10.177 (4.37)	0.050 (0.01)	53.90	27.00	6.48	4.00	1.00
J	ND	0.365 (0.03)	ND	0.018 (0.02)	0 955 (0.41)	0.100 (0.03)	42.80	21.40	6.16	2.00	1.00
K	0.005 (0.07)	0.250 (0.12)	0.330 (0.21)	0.189 (0.09)	ND	ND	49.90	25 00	5.99	7 00	NIL
L	1.300 (0.05)	ND	0.100 (0.07)	0.391 (0.06)	7.077 (2.59)	0.050 (0.03)	19.70	09 80	5 79	NIL	NIL
M	0.075 (0.05)	0.265 (0.20)	0.010 (0.01)	ND	2.145 (0.42)	ND	49.70	25.00	5.83	3.00	2.00
N	0.040 (0.10)	0.115 (0.10)	0.225 (0.20)	0.559 (0.15)	6.353 (3.24)	ND	66.70	33.30	6.54	2.00	NIL
O	ND	0 270 (0.09)	0.240 (0.19)	1.151 (0.29)	ND	0.350 (0.25)	50.00	25.00	6.13	NIL	NIL
WHO Standards	0.05	5 00	0.05	0.005	0.05	0.05	-	<1000§	<8	<100 cfu/mL	-

Values in parenthesis are standard deviations; §NAFDAC standard permissible value for TDS

Table 3: Mean concentration of heavy metals, EC, TDS, pH, Total Bacterial Count (TBC) and *E. coli* count in bottled water samples.

SAMPLE	Cr^{2+} Mg/L	Zn^{2+} mg/L	Mn^{2+} mg/L	Cd^{2+} mg/L	Pb^{2+} Mg/L	Ni^{2+} Mg/L	EC µScm^{-1}	TDS mg/L	pH	TBC Cfu/ml x 10^3	E. coli Cfu/ml x 10^3
P	0.135 (0.03)	0.330 (0.12)	0.230 (0.04)	0.072 (0.01)	0.910 (0.30)	ND	155.30	77.60	7.40	NIL	NIL
Q	0.025 (0.01)	0.150 (0.03)	0.250 (0.14)	ND	5.370 (1.35)	ND	20.50	10.50	6.96	NIL	NIL
R	0.100 (0.02)	ND	0.270 (0.13)	0.146 (0.04)	3.960 (1.34)	0.200 (0.31)	65.50	32.80	6.84	NIL	NIL
S	0.065 (0.04)	0.390 (0.23)	0.370 (0.22)	ND	ND	ND	22.70	11 40	7.24	NIL	NIL
T	0.050 (0.13)	0.965 (0.34)	0.325 (0.23)	0.280 (0.14)	10.701 (3.20)	0.150 (0.02)	300.00	148.90	7.17	NIL	NIL
WHO Standards	0.05	5.00	0.05	0.005	0.05	0.05	-	<1000§	<8	<100cfu/mL	

Values in parenthesis are standard deviations; §NAFDAC standard permissible value for TDS

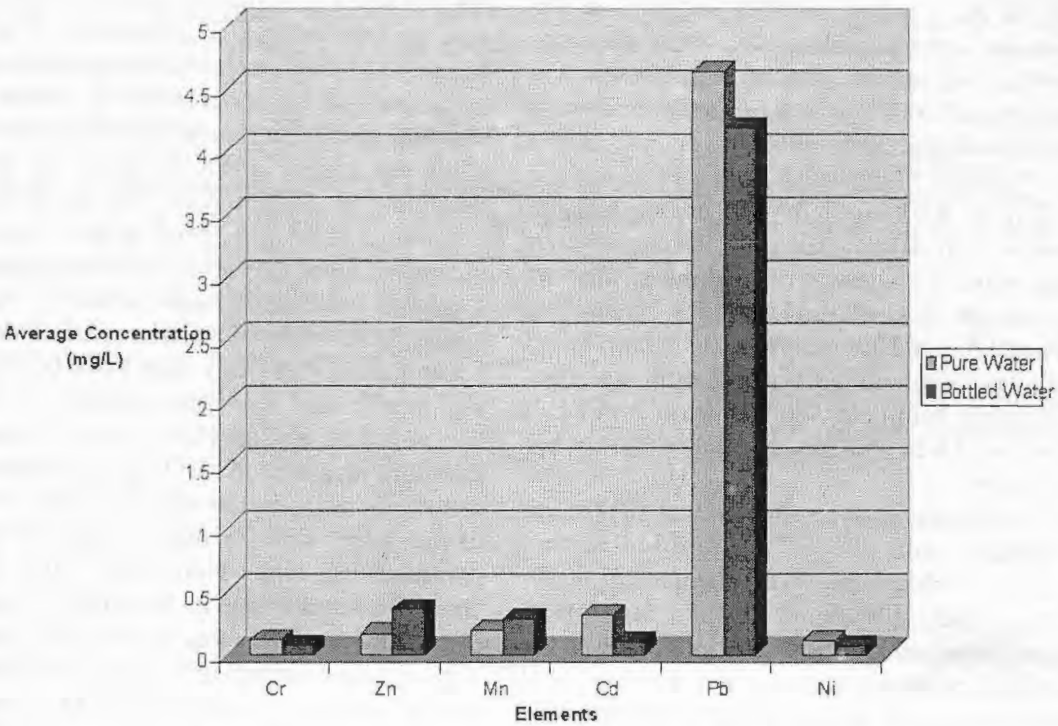

Fig. 1: Abundance of trace elements in bottled and 'pure' waters

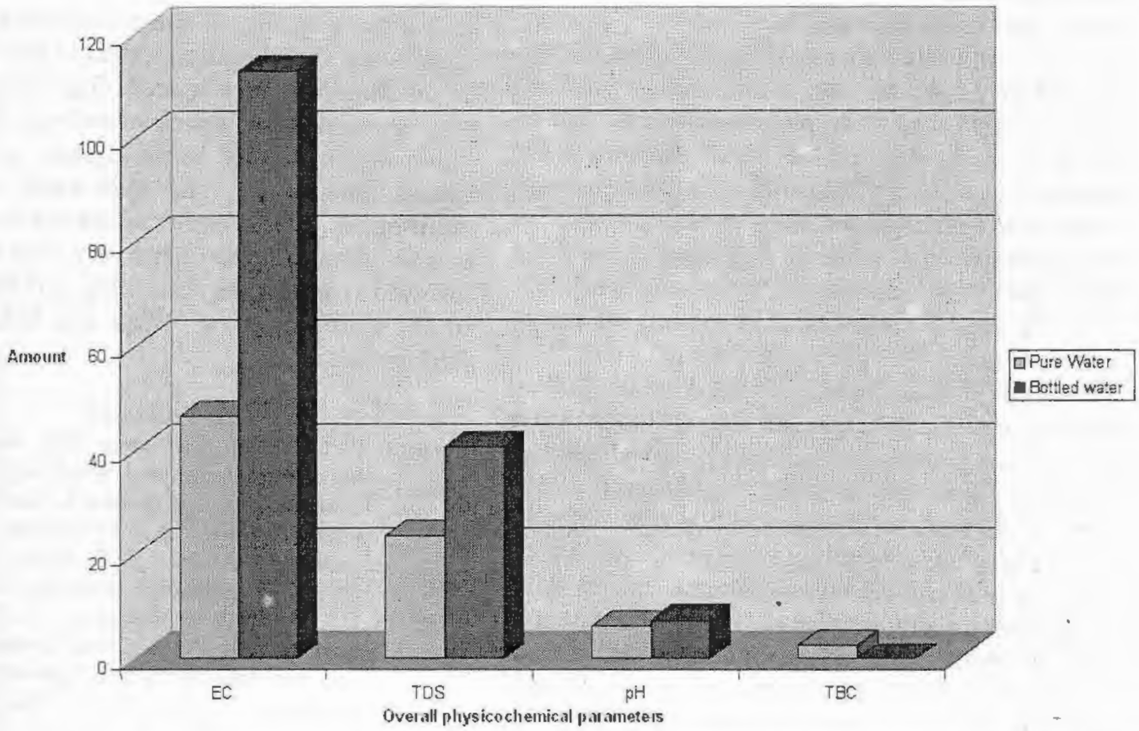

Fig. 2: Variation of physicochemical parameters: electrical conductivity [EC] (μScm^{-1}); total dissolved solids [TDS] (mgL^{-1}); pH and total bacterial count [TBC] (cfu) in 'pure' and bottled waters

The range of concentration of Cr^{2+} in the "pure water" was (ND - 1.300) mg/L while in the bottled waters, it was (0.025-0.100) mg/L. This shows that 26% of the "pure water" samples and 60% of the bottled water samples violated the WHO standard. Cr is widely used in metal plating and although it is essential to man as Cr^{3+}, it is toxic as Cr^{4+} and it is a suspect carcinogen Stanley (1999).

About 73% of the "pure water" samples violated the WHO limit of 0.05 mg/L for Mn having a range concentration of (ND-0.510) mg/L. Mn can occur in drinking water as a result of prolonged time of storage. Large dosage of Mn causes headaches, apathy, irritability and insomnia while long-term heavy dosage may result in nervous system disorder (www.lenntech.com/heavy-metals/health.htm-21k). There was a violation of this limit also in few of the bottled waters.

Result of cadmium analysis showed that 80% of the 'pure waters" and 60% of the bottled waters respectively, violated the WHO standard of 0.005 mg Cd /L. The high values of concentration of Cadmium in the samples pose a serious threat to the health of the consumers as it adversely affects several important enzymes in the human body. The dramatic toxic affect of Cd is the development of the Itai-Itai disease where the outcome is osteomalacia, which is the softening of bones is an intensely painful disease leading to deformity of bones and is usually produced by the deficiency of vitamin D (www.lenntech.com/heavy-metals/health.htm-21k).

Violations of drinking water limits of 0.05mg/L was also observed for Ni with a range of (ND-0.350) mg/L for "pure water" samples while a range of (ND-0.20) mg/L in the bottled water samples were observed resulting in 47% and 40% violations in "pure water" and bottled water samples respectively.

The highest level of violation was observed for Pb in both "pure water" and bottled water samples at 80% in both set of samples. The observed range concentration in the "pure water" samples was (ND-13.534) mg/L and (ND-10.77) mg/L in the bottled water samples. Lead can get into drinking water through alloy pipes containing Pb and plumbings (Stanley, 1999). In this study, we observed during some of our visits to some production sites that most "pure water" manufacturers simply package tap and deep well-water, bore holes and some are still using alloy pipes directly without any further treatment of the water primarily for economic benefits and without any regard for the health of humans. This negligence calls for urgent concern due to the toxic effects of Pb among which are anaemia, renal disease, peripheral neuropathy with demyelination of long neurons, ataxia and memory loss (Poitrowski and Coleman, 1980; Greaf, 1992 and 1994).

Results of the abundance of trace elements in the 'pure' and bottled water samples presented in Fig. 1 shows that pure water samples contain higher levels of toxic elements - Cd, Pb and Ni than the bottled water samples while the essential elements- Zn and Mn are more abundant in bottled waters than the pure water samples. Furthermore, Fig.2 shows variations of the physicochemical parameters studied in the two set of water samples. There were no bacterial contaminations in the bottled water samples, while the higher levels of the other parameters reported- pH, TDS and EC for the bottled waters compared with the 'pure water' samples are acceptable since they are within the stipulated WHO standards for drinking water. Although some of the bottled waters showed violations in the levels of some heavy metals, this study shows that bottled water is still preferable for consumption by Nigerians compared to the so-called 'pure water' and is therefore recommended. On-going research by our team is focusing on the determination of the quality of the 'pure water' samples after two months of manufacture, since NAFDAC warns that 'pure water' becomes unsafe for drinking after two months of production. This study showed that there has not been any improvement in the quality of Nigerian "pure waters" seven years after our earlier investigation in spite of the public enlightenment and stringent measure put in place by NAFDAC to stop quack from the business.

4. Conclusion

In this study, quality of some commonly consumed "pure waters" and bottled waters in Ago Iwoye and its environs was investigated. Generally, results of the trace metals and microbial analyses showed that the quality of bottled water samples is better than that of 'pure waters'. The 'pure water' samples are not properly treated and thus, are not fit for human consumption because of the very high risk factors involved as most of the water samples did not conform to the criteria set by WHO and NAFDAC for drinking water.

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