Radiometric and Photometric Investigations on some Table Water produced in Yola Metropolis, Northeastern Nigeria

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ABSTRACT

Some samples of packaged table water were investigated using both radiometric and the photometric processes to study their levels of purity. The samples used include MAUTECH, MICOH, FAAL, ZUMA, NAFAN and FARO, all manufactured and consumed in Yola and its environs. The radiometric method involved passing gamma rays through the sample to find their extent of transmission and absorption while photometric approach involved passing light at various wavelengths through the samples. The result showed that FARO has the highest transmitted intensity of gamma radiation (0.9 µSv/hr), FAAL has 0.8 µSv/hr, and MICOH has 0.6 µSv/hr, ZUMA, NAFAN and FARO have the same transmitted intensity of 0.4 µSv/hr. Photometric investigation showed FARO has the highest % transmittance of 83.1% at light wavelength of 350 nm and 98.6% at 600 nm. FAAL has the next highest transmission of light with 79.4% transmission at 350 nm and 95.6% at 600 nm. MAUTECH and ZUMA generally have the lowest % transmittance of light at all wavelengths with values of 60.5 and 62.7 at 350 nm respectively while at 600 nm they have 75.1% and 70.7% respectively. MICOH and NAFAN were transmitted at intermediate value of FARO and FAAL, with MAUTECH and ZUMA at lower values. Our result shows that both the radiometric and photometric techniques agree with each other. Using a blank transmission of 98% recorded it was possible to calculate the percentage deviation of light transmission of the samples as 4%, 7%, 15%, 22%, 33% and 33% for FARO, FAAL, ZUMA, MICOH, MAUTECH and NAFAN respectively. Although it could not immediately be concluded that those with high percentage deviations are not fit for consumption, it is recommended that at least all samples above 20% be improved upon for higher quality.

KEYWORDS: Safe drinking water, Sachet table water, Radiation intensity, Photometric method, Absorption coefficient Transmittance

Introduction

Pure water is a colourless, tasteless and odourless liquid at standard ambient temperature and pressure, but it often co-exists on earth with its solid state, ice and gaseous state, steam (vapour). It also exists as snow, fog, dew and cloud. Only 2.5% of the earth's water is fresh water and 98.8% of that water is in ice (except in ice and clouds) and groundwater. Less than 0.3% of freshwater is in rivers, lakes and the atmosphere, and an even smaller amount of the earth's freshwater (0.003%) is contained within biological bodies and manufactured products. The ground water comes from natural underground layers, often of sand and/or gravel that contain water, a formation called aquifers (Skipton *et al.,* 2011). Water as the most important and highly consuming nutrition material, must be safe and healthy. It may be the source of different infectious diseases; therefore periodic evaluation of drinking water is of utmost importance (Mardani *et al.,* 2007).

Water becomes contaminated by the substances with which it comes into contact with in its pathway to reach people (Fasunwon *et al.*, 2008) and therefore not available for use in its pure state. To some degree, water can dissolve every naturally occurring substance on the earth and has therefore, been termed a "Universal Solvent". Although beneficial to mankind, the solvency power of water can pose a major threat to industrial equipment (Nikoladze *et al.,* 1994). Corrosion reactions cause the slow dissolution of metals by water. Deposition reactions, which produce scale on heat transfer surfaces, represent a change in the solvency power of water as its temperature is varied. The control of corrosion and scale is a major focus of water treatment technology.

Water impurities include dissolved and suspended solids. Calcium bicarbonate is a soluble salt. A solution of Calcium Bicarbonate is clear because the Calcium and Bicarbonate are present as atomic sized ions which are not large enough to reflect light. Some soluble minerals impart colour to the solution. Soluble iron salts produce pale yellow or green solutions; some copper salts form intensely blue solutions. Although coloured, these solutions are clear. Suspended solids are substances that are not completely soluble in water and are present as particles. These particles usually impart a visible turbidity to these water; dissolved and suspended solids are present in most surface waters. Sea water is very high in soluble Sodium Chloride; suspended sand and silt makes it slightly cloudy. It has also been reported that radionuclides from both natural and artificial sources can come into contact with water through several ways; they may be deposited from air, they may also be released to the water from the ground through human activities such as mining and drilling (Ajayi and Achuka, 2009). Intake of water from such source and other sources mentioned above could pose serious health implications (WAN, 2006) if not purified and made safe for consumption.

Safe drinking water is essential to humans and other life forms (Inegbenebor *et al.,* 2012) even though it provides no calories or organic nutrients. Access to safe drinking water has improved over the last decades in almost every part of the world. However, the search for good and safe drinking water is still the greatest task of man especially with continuous population growth and urbanization (Shi *et al.,* 2012). Such safe and clean water free of impurities for human consumption is difficult to come by in many Nigeria settlements. In about the same decade ago, only about 48% of the total population of Nigeria was estimated to be served by improved water sources (WHO, 2006; Nnamdi *et al*., 2010) leaving about 52% of the population without safe domestic water. This need has necessitated, over the years, the production of portable drinking water in sachets of polythene (which is generally called "pure water") by many businessmen and companies using different methods of purification. Many of these purification techniques do not guarantee the safeness of the end products as some treatments for nitrate and bacteria should be complemented with tests for other substances (Skipton *et al.,* 2011). Sachet table water is found not only in urban areas but also in many rural communities.

The high demand for table water, especially during hot seasons and non-availability of other good sources of water in many communities have led to unconventional, unhygienic and unacceptable method of production this essential commodity. The result is that many users of the product have contracted sickness like diarrhea and other water borne diseases (Wells 1977) which have led to loss of lives beside family incomes. Quality assurance test is therefore, needed to assess the level of purity as it affects the impurity contents, turbidity and other physical and chemical properties. Over production is also another problem that leads to a chunk of the products not sold before the expiry period even though this is not easily noticed by a careless or the uninformed user.

In this work, we have carried out radiometric and photometric investigations, using gamma rays and some visible light wavelengths, on some selected table water produced in Yola metropolis to assess their level purity for their daily consumption by the masses. The result obtained from this type of investigation could serve to advise the manufacturer on need for more considerations for quality. The public too could benefit in that it would save them of many health risks and ultimately from unnecessary wastage of finances that might arise from huge medical bill occasioned by water borne diseases. Although, there are some techniques that have been used for testing the purity of water like the turbid meter, refractometer or pH meter, a physical method as presently adopted in our investigation could serve for preliminary or complementary analysis to prevent the general public from the problem of dissolved impurities in domestic water.

Theory

Transmission of Gamma-Rays and other Electromagnetic Radiation through Matter

All electromagnetic radiations pass through matter in a similar way different from ionizing radiation that has defined masses. Their transmission through spaces obeys an inverse square law. Generally, the reduction in the intensity of the radiation as it transverses matter follows an exponential law. This additionally proves they deposit energy along their tracks as they move causing the reduction of their intensities through the medium which they pass.

When gamma radiation of intensity I_o is incident on an absorber of thickness *l*, the intensity *I* transmitted by the absorber is given by the exponential expression

$$I = I_0 e^{-\mu l} \qquad (1)$$

where μ is the attenuation coefficient, expressed in unit of m^{-1}. The mass attenuation coefficient is defined as $\mu_m = \mu / \rho$ where ρ is the density of the material. Equation (1) can be written as

$$I = I_0 e^{-\frac{\mu}{\rho}\rho l}$$

so that

$$I = I_0 e^{-\mu_m \rho l} \qquad (2)$$

where the thickness of the absorber ρl is measured in terms of mass per unit area (kgm^{-2}). μ_m has unit of m^2/kg. The ratio I/I_0 is called the gamma ray transmission. The mass attenuation coefficient is independent of density for the example mentioned above; water, ice, and steam all have the value of μ . The above scheme also determines the transmission of photon in a given medium.

Materials and Methods

Sampling

The materials used for the investigation include six samples of some sachet table water manufactured and consumed in Yola. Yola is the state headquarters of Adamawa State located in the northeastern flank of Nigeria. The city enjoys raining season beginning scantly from April to September and the dry season from October and stretching even to around April. The long dry season period makes the weather in this period very harsh. The outside temperature during the hottest season could be as high as 40 ºC even to 42 ºC in extreme weather conditions. The lack of conventional public water for domestic consumption causes table water business to thrive more favourably during this period. The sampling of the water was done considering their prominence around the Modibbo Adama University of Technology, Yola and the entire Yola metropolis. Using their trade names the samples include MAUTECH manufactured by Consultancy Services, Bukar-Mele Complex, Modibbo Adama University of Technology, Yola, labeled as Sample I; MICOH manufactured by Micoh B. P. Nig Ltd Sangere Rocks Opp. MAUTECH Yola labeled as Sample II; FAAL manufactured by FAAL Integrated Ventures, Sangere Rocks Opp. MAUTECH Yola labeled as Sample III; ZUMA manufactured by A.S.M. Enterprises, No. 1 Sangere Ward Opp MAUTECH Yola labeled as Sample IV; NAFAN manufactured by NAFAN Nig Ltd, No. 40 Jambutu Ward, Jimeta Yola labeled as Sample IV and FARO manufactured by Adamawa Beverages, Kofare Industrial Layout, Jimeta Yola. FARO water is used far beyond the borders of Yola. All samples were collected from the manufacturers the same day they were produced and also used for the investigation the same day to avoid any problem of bacterial or fungal action that might result from temporal actions.

Measurements

The measuring instruments include a gamma ray source, Cesium 137m/Barium 137m, 9 mCuries, made in China, capable of producing up to 1000 small aliquots of the short lived Ba-137m isotope with a half –life of 2.6 minutes; Radiation Alert Monitor 4, manufactured by S. E International, Inc. USA, which is a Geiger Muller counter and Microprocessor Spectrophotometer with wavelength ranging from 340 to 960 nm. The principle of operation of the spectrophotometer and measurement of transmittance and concentration of solute in solution has been explained by Holwill and Silvester (1976). A wooden box opened at opposite ends was constructed so that each sample could fit in to give the same thickness and length to the water samples.

First of all, without any sample in the wooden box the intensity of the Gamma-ray at a particular source – counter distance within the box was measured. Now with a sample placed in the box, the cap on the mini-generator (Celsium 137m) was removed and radiation alert switched on. The intensities converted to dose equivalent before and after passing through a sample were taken on the radiation alert monitor 4 in $\mu Sv/hr$. This same process was repeated for all the other samples. The measured results are presented in Table 1. To quantify the samples absorbence and transmittance of light, seven cuvettes were washed properly to avoid dirt and dried. One of the seven cuvettes was used as a blank sample while the remaining six were filled with samples. A cuvette with a sample was put in the sample holder of the spectrophotometer and the lid closed. Using prescribed procedure, the values of the % transmittance was obtained at a wavelength of 350 nm. Since the energy, E of light is a function of the wavelength, λ according to $E = h\upsilon$ or $E = hc/\lambda$ where h = Planck's constant and υ is the frequency, the process was repeated for all other samples at various wavelengths of 400, 450, 500, 550 and 600 nm. The results of these measurements are given in Table 3. Using Excel word program, bar graphs of the radiation intensity transmitted with the sample, the absorption coefficients of the samples for gamma rays, the variation of percentage transmittance of light with samples at the various wavelengths and their linear graphs were obtained.

Result and Discussion

The Transmission of Gamma-rays through Table Water

Table 1 shows the results of transmission of the gamma rays radiation through the samples. It indicates that FARO has the highest transmitted radiation intensity (0.9 µSv/hr) while FAAL showed the next lower intensity transmission with a value of 0.8 µSv/hr followed by MICOH with value of 0.6 µSv/hr. MAUTECH, ZUMA and NAFAN have the lowest transmitted intensity with the same value of 0.4 µSv/hr. The transmitted intensities through all the water samples are shown in figure 1. This result implied then that FARO with highest transmission of radiation has less impurity content than all the samples followed by FAAL and MICOH respectively. MAUTECH, ZUMA and NAFAN showing less intensity transmission give indication of more impurities in them than the other samples as corroborated in the following calculation.

Using the intensity law equation (equation 1), we have the absorption coefficient of gamma rays for all samples considered. As given by the equation,

$$I = I_0 e^{-\mu l}$$

Taking the natural logarithm on both sides in $\ln I = \ln I_0 - \mu x$ so that

$$\mu = \frac{\ln I_0 - \ln I}{x} \qquad (3)$$

where x is the distance (thickness of the medium). A thickness value of x = 13 cm for all samples was used in this investigation.

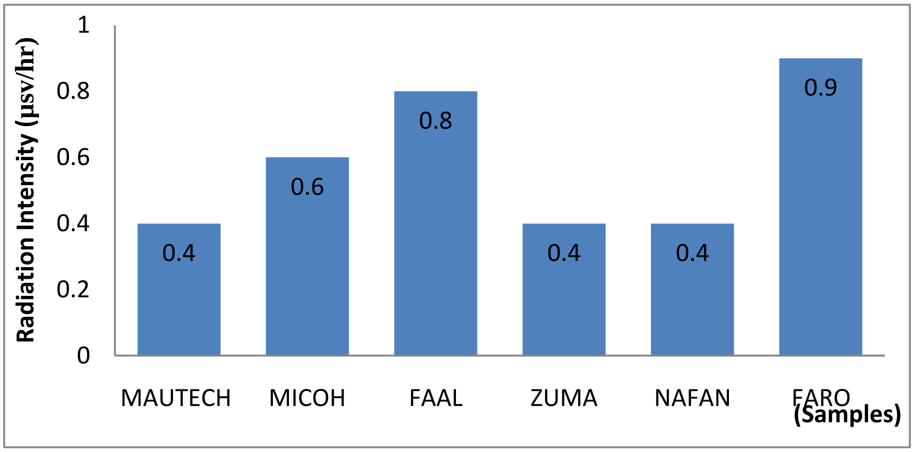

Figure 1: Variation of transmitted gamma-ray intensity with samples

Using initial intensity, I_0 = 1.6 µSv/hr as measured and x = 0.13 m, we have for example, the absorption of MAUTECH as

$$\mu = \frac{\ln(1.6) - \ln(0.4)}{0.13} = 10.66 \text{ m}^{-1}$$

For FARO with the highest transmitted intensity,

$$\mu = \frac{\ln(1.6) - \ln(0.9)}{0.13} = 4.43 \text{ m}^{-1}.$$

Looking at the values of the absorption coefficients (Table 1), FARO has the lowest calculated value than of all the samples with a value of 4.43 m^{-1}. FAAL has calculated value of absorption coefficient of 5.33 m^{-1} and MICOH with a value of 7.54 m^{-1}. The plot of the absorption coefficient of the water sample is given in figure 2. Lower absorption coefficient obviously signifies more transmission of gamma ray and consequently lower impurity content. The highest absorption coefficient was calculated for MAUTECH, NAFAN and ZUMA all having a value of 10.66 m^{-1}. The absorbing power of solution is a measure of the ability of it to scatter (absorb) light intensity reaching it (Howill and Silvester, 1976). MAUTECH, NAFAN and ZUMA table water therefore, have higher impurity contents than FARO, FAAL and MICOH table water.

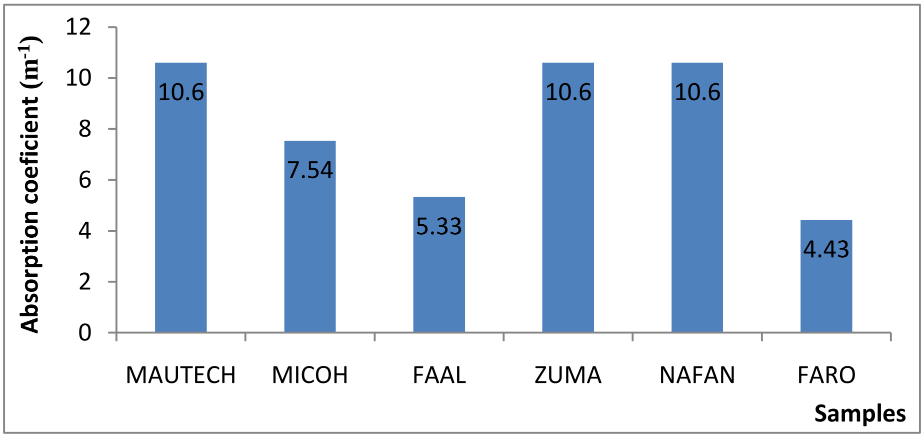

Figure 2: Variation of gamma ray absorption coefficient (μ) with samples

Table 2 gives the result of passing electromagnetic energy from upper ultraviolet (UV) wavelength of 350 nm to the upper range of the visible spectrum through the samples of table water products. Figure 3 shows clearly the variations of the transmittance of light through all the samples at the wavelengths of 350 nm. Since the transmission of light indicates less availability of absorption or scattering agents, it becomes obvious that FARO water contained the lowest impurity which is synonymous with the result obtained using the gamma rays. Figures 4 to 8 show the variations of the transmittance of light through all the samples at the different wavelengths from 450 to 600 nm. The variations of their absorption or transmission powers were consistent at all wavelengths. At all the wavelengths, FARO showed the highest transmittance to light. FAAL showed the next highest transmittance followed by MICOH.

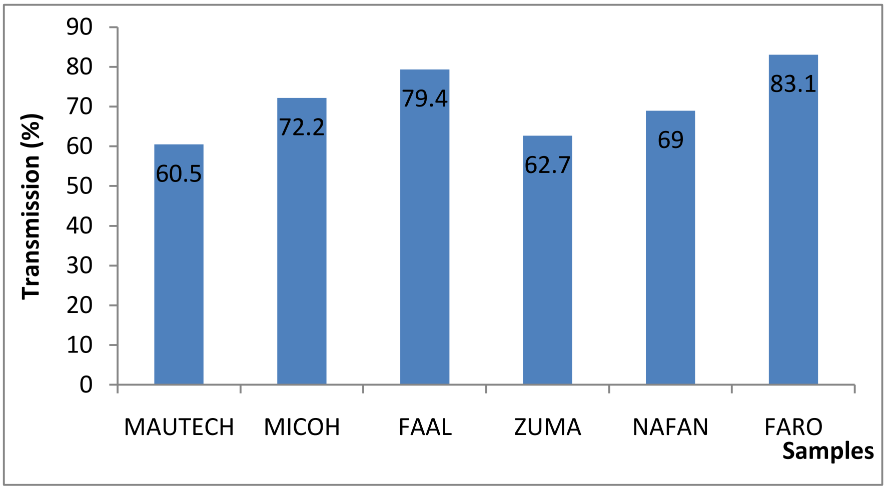

Figure 3: Variation of the % Transmission of light with samples at λ = 350 nm.

Figure 9 gives at a glance, the plot of the transmittance of light with the wavelengths for all the samples. Furthermore, it was found that at higher wavelengths, transmission of light was generally higher in all samples of the water (Figure 9). This shows that at higher wavelength light scattering in water becomes lower. In other words photo absorption of the light is higher at lower energy, *E* according to the earlier equation, $E = \frac{hc}{\lambda}$. Additionally, using the photometric technique, the percentage transmittance has been calculated for MAUTECH, NAFAN and ZUMA for example as 60.5%, 62.5%, and 75.1% at 350 nm, 450 nm and 600 nm; correspondingly, FARO has transmittance of 83.1%, 89.9% and 98.6% respectively at the same 350 nm, 450nnm and 600 nm respectively. The investigation showed that by comparison, the result of transmission of the gamma-rays through water was also consistent with that of the photometric process, that is to say, one validates the other.

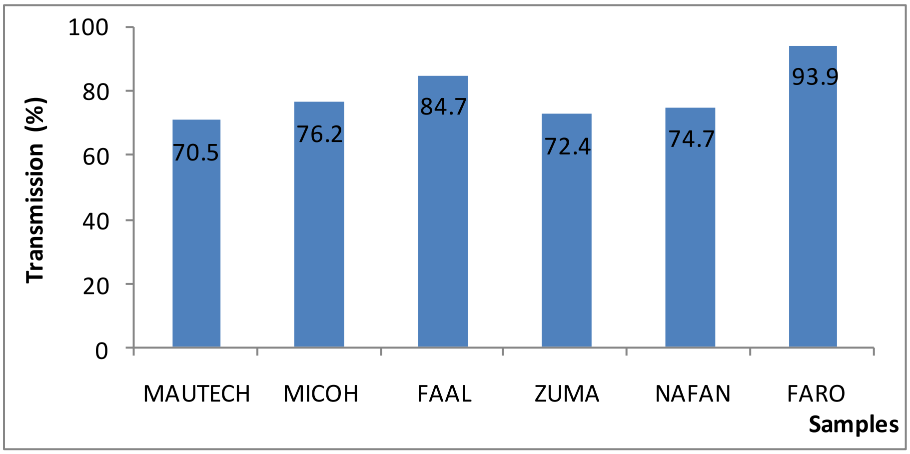

Figure 4: Variation of the % Transmission of light with samples at λ= 400nm

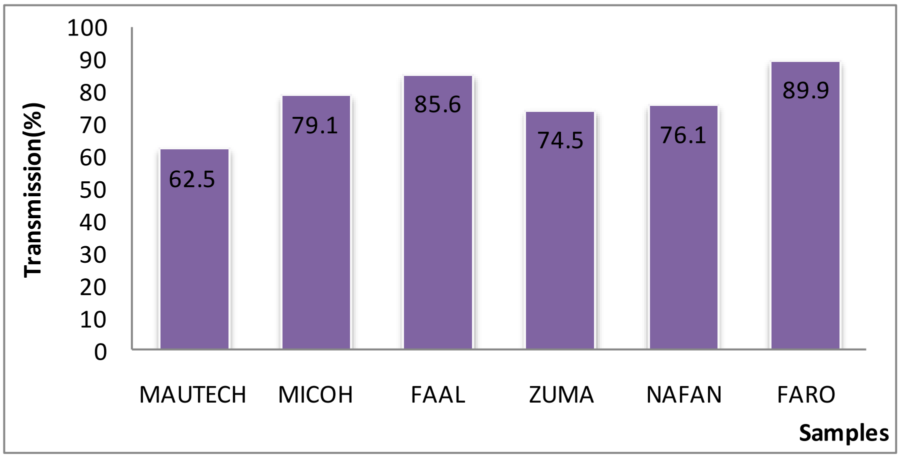

Figure 5: Variation of the % Transmission of light with samples at λ = 450 nm

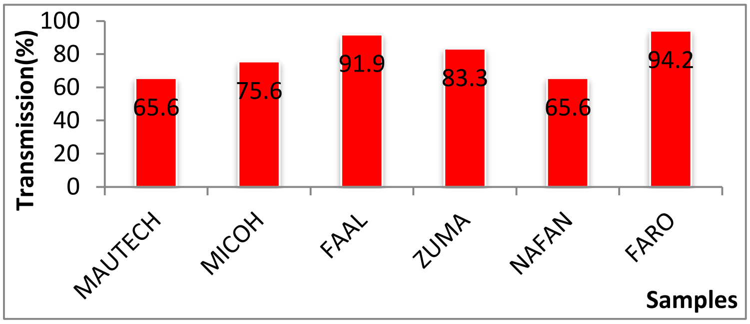

Figure 6: Variation of the % Transmission of light with samples at λ = 500 nm

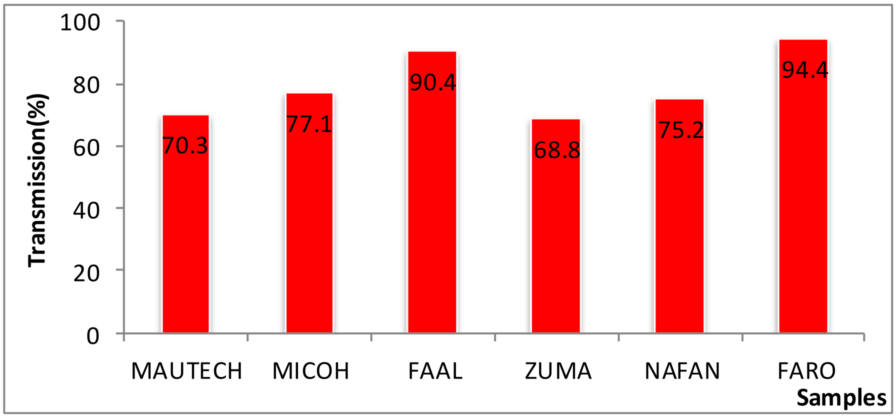

Figure 7: Variation of the % Transmission of light with samples at λ = 550 nm

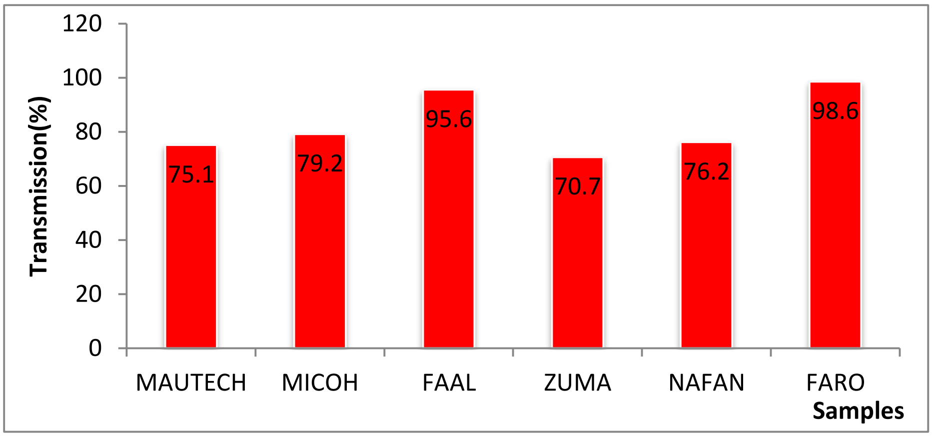

Figure 8: Variation of the % Transmission of light with samples at λ = 600 nm

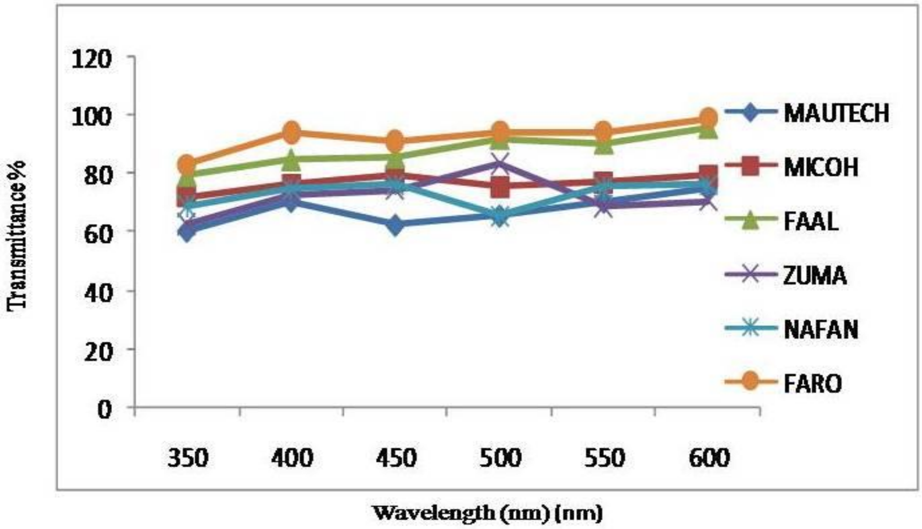

Figure 9: Graph of % Transmission of light in samples at various wavelengths

Conclusion

The samples of some table water (MAUTECH, MICOH, FAAL, ZUMA, NAFAN and FARO) have been subjected to both radiometric and photometric analysis. While FARO, FAAL and MICOH have shown to possess the lowest impurities and MAUTECH, ZUMA and NAFAN seemed to be less qualitative. This result has shown consistency in the two of analytical techniques. Using a blank transmission of 98% for the photometric method, we have found that their percentage deviations are 4%, 7%, 15%, 22%, 33% and 33% respectively for FARO, FAAL, MICOH, ZUMA, NAFAN and MAUTECH respectively. While a percentage deviation of 33% may not render the water altogether unsafe for drinking, it is expected that those with percentage deviation greater than 20% need to be improved upon for quality enhancement and human consumption.

Table 1: The transmitted intensity in dose equivalent and absorption coefficient of gamma-rays through water samples

I_o=1.60 µSv/hr

S/N	Samples	Transmitted radiation intensity (µSv/hr)	Calculated absorption coefficient (m^{-1})
1	MAUTECH	0.4	10.66
2	MICOH	0.6	7.54
3	FAAL	0.8	5.33
4	ZUMA	0.4	10.66
5	NAFAN	0.4	10.66
6	FARO	0.9	4.43

Table 2: Showing the Absorbance and % Transmission of samples at various wavelengths

S/N	Samples	Wavelength (λ=350nm)		Wavelength (λ=400nm)		wavelength (λ= 450nm)		wavelength (λ= 500nm)		wavelength (λ= 550 nm)		wavelength (λ= 600nm)	
		Abs	(%) T	Abs	(%) T	Abs	(%) T	Abs	(%) T	Abs	(%) T	Abs	(%) T
1	MAUTECH	0.04	60.5	0.001	70.5	0.03	62.5	0.040	65.6	0.22	70.3	0.04	75.1
2	MICOH	0.14	72.2	0.015	76.2	0.019	79.1	0.054	75.6	0.01	77.1	0.02	79.2
3	FAAL	0.17	79.4	0.100	84.7	0.039	85.6	0.081	91.9	0.12	90.4	0.06	95.6
4	ZUMA	0.06	62.7	0.001	72.4	0.16	74.5	0.041	83.3	0.15	68.8	0.04	70.7
5	NAFAN	0.12	69.0	0.011	74.7	0.17	76.1	0.053	65.6	0.05	75.2	0.02	76.2
6	FARO	0.07	83.1	0.083	93.9	0.20	90.9	0.050	94.2	0.18	94.3	0.02	98.6

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