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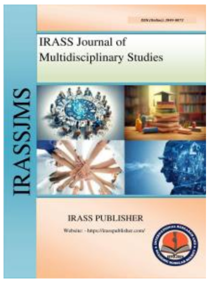

Comparative Evaluation of Physico-Chemical Parameters of Raw Water and Treated Water in Malali Water Works, Kaduna State, Nigeria.

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Abstract: Portable water is essential element for living organism's welfare and healthy living. On estimation, a large number of over 1 billion individuals do not have access to safe water and 2.4 billion need essential sanitation. This study seeks to evaluate the physico-chemical of raw and treated water in Malali water works. Using standard techniques, physico-chemical parameters were determined and related to permissible limits. The mean temperature of raw water significantly varied from month to month, with the least temperature recorded in September (20.7±0.12°C) and highest temperature in March (27.9±0.05°C). The highest temperature of treated water samples was observed in March (29.1±0.15°C) while the least was recorded in September (20.7±0.10°C). Total dissolved solids content was between 270.0 and 582.5±9.75 mg/l; lower values were observed in dry season months while higher values occurred in the wet season. All TDS values for raw water were below the WHO and NSDWQ set limits except in September where it was higher (582.5mg/L). Fluorides and magnesium were detected but in minute concentrations below permissible limits. It can be concluded therefore that treated water at the Malali water works is of better quality than raw untreated water. Generally, treated water at Malali water works area is less turbid and safe for use.

Keywords: Water, physic-chemical parameters, contamination, water pollution.

1.0 Introduction

All living organisms, environmental systems, anthropological well-being, Agricultural activities and commercial growth depend largely on water, it obviously remains a significant natural resources on earth (1). Decrease in water supply happens to be a substantial predicament of our environment affecting different nations on earth (2).

Raw water exists as a natural water which originates from the environment that has not been purified as well as having any of its minerals, particles, and microorganisms removed. This comprises of ground water, rainwater, water from infiltrated wells, as well as surface water (3). Raw water is made unsafe for drinking by humans due to the presence of contaminants. Quality water can be described with respect to physical, chemical and biological parameters, determining the quality is essential to enable usage that include drinking, farming, recreation and for industrial uses. (4). It is evaluated in the laboratory using certain techniques to identify contamination level. Different levels of pollutant can be identified in water samples depending on the parameters investigated (5).

Surface water is the major freshwater resource for humans, although, it is contaminated with heterogeneous discharge of sewage, industrial waste and excess anthropogenic activities influences its physico-chemical characteristics (6).

The transmittance of disease through drinking water is an elementary concern for drinking water to be safe. Pollution of drinking water by fecal matter introduces a variety of pathogens which can result into diseases from moderate gastroenteritis to advance and fatal dysentery, cholera, diarrhea, typhoid, hepatitis, giardiasis and a host of other related diseases (7, 8). This study provides update of physico-chemical parameters of water in river Kaduna along Malali water works of Kaduna State, Nigeria.

2.0 Materials and Method

2.1 Study area

The research was carried out at Malali water works, Kaduna with coordinates (10^{o} 33' 35” N, 7^{o} 28' 50” E). Malali water works was founded in 1960 and commissioned in 1972. The water works have a total capacity of 270ML/D.

The water works is serving Kaduna town, Malali, Kawo, Anguwan Rimi, Anguwan Dosa, Tudun Wada, Unguwan Sarki, part of Sabo and part of Barnawa.

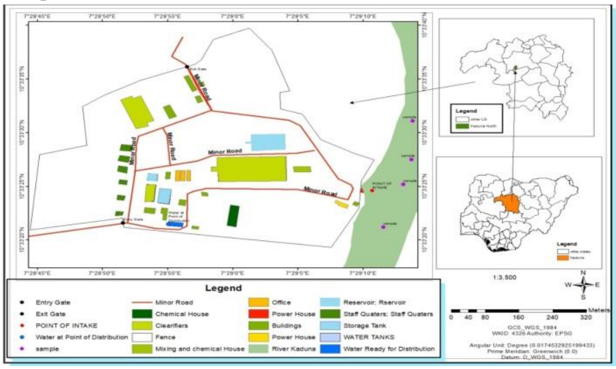

Figure 1. Cadastral map of Malali water works along sampling points

2.2 Water samples collection

Samples of water were collected twice within a month for six months using plastic bottles (1000ml). The samples were collected from River Kaduna at the point of raw water intake into the water works, and treated water at the point of distribution from the water works.

Samples collected at the River (point of intake) were collected by submerging the sample container into the river between 10 cm –15 cm below the surface with an open end against the direction of current flow (9).

The sample bottles were rinsed with deionized water before collecting the samples and kept in a cool and dry container so as to maintain the temperature and other conditions necessary to keep the physical and chemical properties intact. (10).

2.3 Physico-chemical analysis

The analysis of samples were carried out in Kaduna Environmental Protection Authority (KEPA) laboratory in Kaduna State.

pH, Temperature and Electric Conductivity of the samples were determined using a universal pH meter (PH/MV/TEMP. meter SUNTEX TS-2) after the methods of (11,12).

Total dissolved solids test was carried out using TDS meter (AQUALYTIC TDS meter), by immersing the electrode into the sample and the reading was taken in. mg/L.

Portable meter-H198703 was used to determine turbidity. The sample was shaken so as to disperse the solid contents evenly and allowing the air bubbles that may occur to disappear. The sample was poured into the meter tube and reading was taken directly from the instrument scale.

Dissolved oxygen test was carried out using DO meter (Sper Scientific 850081 DOK). The meter was calibrated to read zero. The probe of the meter was immersed into the sample and allowed to stabilize after which reading was taken in mg/L.

Flouride and nitrates tests were carried out using portable data logging spectrophotometer (HACH DR/2010) after (13).

2.5 Data analysis

Data is presented as mean ± standard error of mean (SEM) for each parameter. One way Analysis of Variance (ANOVA) was used to compare mean values; $p \leq 0.05$ was considered to be significant. Duncan multiple range test was used for multiple comparison of significantly differing mean values.

3.0 Results and Discussion

Mean monthly pH of raw water showed statistically significant differences ($p < 0.05$) with values ranging from 6.83±0.05 in September to 7.68±0.05 in January (Table 4.1a). pH of the raw water samples was slightly alkaline except in September where the pH was slightly acidic.

There were significant differences ($p \leq 0.05$) in monthly pH values of the treated water samples observed with the least pH recorded in the month of September (6.48±0.05) and the highest pH in March (7.86±0.32) (Table 4.1b). Between January and March (dry season months) the pH of treated water samples was slightly alkaline (7.68-7.86) with no significant differences ($p > 0.05$) between them; in the rainy season months of August and September, however, the pH values recorded for treated water samples were slightly acidic(6.55±0.06 and 6.48±0.05, respectively) (Table 3.1).

Despite the seasonal variations in pH values of the water samples, the values for both treated and untreated water were within the pH range stipulated by WHO and NSDWQ (6.5-8.5) (Tables 4.1a and 4.1b). There was no significant difference ($p < 0.05$) in the overall pH of treated and untreated (raw) water samples. The overall mean pH of raw water was 7.44±0.29 (95% CI: 7.31-7.56), while the overall pH of treated water was 7.23±0.58 (95% CI: 6.98-7.47).

The mean temperature of raw water varied significantly from month to month, with the least temperature recorded in September (20.7±0.12°C) and peak temperature in March (27.9±0.05°C) (Table 3.1). In raw water samples, higher temperatures were generally associated with the late dry season months of February and March.

Table 3.1 Physical parameters of treated water samples at the Malali water works Kaduna

Treated	pH	Temperature (°C)	Conductivity (µS/cm)	Turbidity (mg/L)	TDS (mg/L)
July 2018	7.12±0.05[b]	23.23±0.08[c]	90.75±2.21[d]	12.5±1.0[a]	211.1±1.15[d]
Aug 2018	6.55±0.06[c]	22.25±0.13[d]	63±0.816[e]	8.25±1.258[b]	171.3±2.50[e]
Sept 2018	6.48±0.05[c]	20.65±0.10[e]	57.75±0.5[f]	9.50±1.0[b]	240±0.0[c]
Jan. 2019	7.68±0.05[a]	22.3±0.4[d]	113.4±0.5[b]	3.25±0.5[c]	260±0.0[b]
Feb. 2019	7.85±0.05[a]	26.8±0.0[b]	111.5±0.58[c]	2.5±0.58[c]	260±0.0[b]
Mar. 2019	7.86±0.32[a]	28.1±0.15[a]	127.0±0.0[a]	2.5±0.58[c]	270±0.0[a]
Mean	7.23±0.57	23.9±2.69	93.9±26.6	6.42±4.04	235.4±35.3
WHO	6.5-8.5	Ambient	1000	1.5	500
p value	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001

Mean values with different superscripts are significantly different ($p \leq 0.05$); NSDWQ: Nigerian Standard for Drinking Water Quality; WHO: World Health Organization

Water samples with conductivity values ranging between 57.8±0.5µS/cm (March) and 127.0±0.0µS/cm (September).

Higher conductivities were associated with the rainy season months while lower conductivities were observed in the dry season months (Table 4.1b). There was no significant difference ($p \leq 0.05$) in the overall mean electrical conductivity between treated and untreated (raw) water samples (Table 4.1a and 4.1b). The overall mean electrical conductivity of raw and treated water were 104.1±13.0 µS/cm (95% CI: 98.59-109.6 µS/cm) and 93.9±26.6 µS/cm (95% CI: 82.7-105.1 µS/cm). The electrical conductivities recorded for both treated and untreated water samples were well below the upper limit set by the WHO and NSDWQ (1000 µS/cm) (Tables 3.2).

Statistically significant differences ($p < 0.05$) were observed in the mean monthly turbidity of raw water samples with the least turbidity recorded in February (16.5±1.0 NTU) and peak turbidity in July (875.5±13.4 NTU) (Table 4.1a). Lower turbidity values were observed in raw water samples during the dry season months while higher values were associated with the rainy season months (Table 4.1a). For raw water, turbidity values were above the permissible limit set by the NSDWQ and WHO. In treated water, the monthly turbidity values ranged between 2.5±0.58 mg/L and 12.5±1.0 NTU (Table 4.1a). Furthermore, the turbidity values of treated water samples varied significantly ($p < 0.05$) from month to month, with the values recorded during the rainy seasons above the permissible limits of the WHO (1.5 NTU) and NSDWQ (5 NTU) (Table 3.2). Statistically significant differences ($p < 0.05$) was recorded in the overall mean turbidity of treated and raw water samples, with untreated (raw) water being more turbid than treated water. Raw water samples had an overall mean turbidity of 332.7±364.0 NTU (95% CI: 179.0 - 486.4 NTU), while the mean turbidity of treated water sample was 6.42±4.04 NTU (95% CI: 4.71 – 8.12 NTU).

In the raw water samples, TDS content was between 270.0 and 582.5±9.75 mg/l; lower values were observed during the dry season months while higher values in the wet season. The total dissolved solid content in treated water showed statistically significant difference from month to month with values ranging between 171.3±2.5 mg/L and 270.0±0.10 mg/L; all values were within the WHO and NSDWQ permissible limits of 500 mg/L. Marginally lower values of TDS were associated with the rainy season months while higher values were observed during the dry season with peak value of TDS recorded in March and least value in August (Table 4.1b). All TDS values for raw water were below the WHO and NSDWQ set limits except in September where it was higher (582.5mg/L) (Table 3.2).

The dissolved oxygen content in raw water varied significantly ($p < 0.05$) from month to month with values ranging from 2.14±0.68 mg/L (July) and 9.83±0.53 mg/L (January) (Table 4.2a). DO content in treated water also show significant monthly variation with values ranging from 5.92±0.17 mg/L (January and 25.4±7.98 mg/L (August) (Table 3.2).

In raw water the nitrate concentration varied significantly from month to month with values ranging between 11.9±0.05 mg/L (March) and 70.5±9.35 mg/L (August). When compared with WHO and NSDWQ recommended values, the concentrations of nitrate in untreated water samples were below the upper permissible limit of 50 mg/L (Table 3.2).

Table 3.2 Chemical parameters of raw water samples at the Malali water works Kaduna

Raw	DO (mg/L)	Nitrates (mg/L)	Fluorides (mg/L)	Magnesium (mg/L)
July 2018	2.14±0.68[c]	35.3±2.62[b]	ND	1.47±0.31[b]
Aug 2018	8.825±1.367[a]	70.45±9.35[a]	ND	1.899±0.201[a]
Sept 2018	7.3±0.216[b]	30.65±1.112[b]	ND	1.009±0.03[c]
Jan. 2019	9.83±0.53[a]	12.3±0.11[c]	ND	0.226±0.017[d]

Feb. 2019	9.38±0.15[a]	12.2±0.13[c]	ND	0.224±0.0087[d]
Mar. 2019	6.47±0.28[b]	11.9±0.05[c]	0.28	0.265±0.004[d]
Mean	7.32±2.17	28.3±21.6	0.046±0.11	0.85±0.69
WHO	-	50	1.5	-
p value	< 0.0001	< 0.0001	< 0.0001	< 0.0001

Mean values with different superscripts have statistically significant difference ($p < 0.05$); NSDWQ: Nigerian Standard for Drinking Water Quality; WHO: World Health Organization; ND: Not Detected

The nitrate concentration in treated water was between 10.6±0.13 mg/L (February) and 16.0±0.93 mg/L (August); all the values were within the WHO and NSDWQ permissible limits and showed significant ($p < 0.05$) monthly variations (Table 3.3).

Fluoride was detected only in raw water samples the month of March at a concentration of 0.28 mg/L which was below the permissible limits (1.5 mg/L) of both the WHO and NSDWQ (Table 4.2a). Similarly, fluoride was detected in treated water samples only in the month of March at a concentration of 0.31 mg/L which was also below the WHO and NSDWQ permissible limit for fluoride in water (Table 3.3).

Magnesium content in raw water samples were all within the NSDWQ set limit of 20 mg/l with the values ranging from 0.224 mg/L (February) and 1.899 mg/L (August). ANOVA showed that the mean values differed significantly from month to month. Lower values of magnesium were observed during the dry season months while higher values were recorded in the rainy season months (Table 3.3).

Values for magnesium in treated water were between 0.012 mg/L (in January) and 0.993 mg/L (in August); all the values were below the NSDWQ set limit of 20 mg/L. one way analysis of variance indicated that there were significant monthly variations in the monthly magnesium content in treated water (Table 3.3).

Table 3.3 Chemical parameters of treated water samples at the Malali water works Kaduna

Treated	DO (mg/L)	Nitrates (mg/L)	Fluorides (mg/L)	Magnesium (mg/L)
July 2018	9.98±2.51[cd]	11.9±0.479[bc]	ND	0.415±0.01[b]
Aug 2018	25.37±7.98[a]	16.0±0.93[a]	ND	0.993±0.01[a]
Sept 2018	17.5±0.998[b]	12.7±1.92[b]	ND	0.208±0.011[c]
Jan. 2019	5.92±0.17[d]	10.9±0.54[c]	ND	0.072±00024[e]
Feb. 2019	6.15±0.19[d]	10.6±0.13[c]	ND	0.0925±0.005[d]
Mar. 2019	13.0±0.58[bc]	11.5±0.05[bc]	0.31	0.097±0.0013[d]
Mean	13.0±7.62	12.3±2.01	0.05±0.11	0.32±0.33
WHO	-	50	1.5	-
p value	< 0.0001	< 0.0001	-	< 0.0001

Mean values with different superscripts have statistically significant difference ($p \leq 0.05$); NSDWQ: Nigerian Standard for Drinking Water Quality; WHO: World Health Organization

The quality of water, which is a measure of the condition of water relative to the requirements of one or more biotic species and or to any human need or purpose, is defined by the aggregates of its chemical, physical, biological, and radiological characteristics (14, 15, 16).Though abundant potable water is scare. Natural water sources have suffered significant amount of pollution such that they have become unfit for human use or consumption without undergoing some form of treatment. Water pollution has largely been the result of increased human activity. The present study was designed to compare the quality of both raw and treated water at the Malali water works, Kaduna, in order to ascertain water treatment efficiency by the water treatment plant. Parameters assayed included physicochemical properties (pH, electrical conductivity, turbidity, dissolved oxygen, total dissolved solids, fluoride, nitrates, and magnesium) the values obtained were compared against national (Nigerian Standard of Drinking Water Quality, NSDWQ) and World Health Organization (WHO) permissible limits.

The pH of water quantifies on a logarithm scale the concentration of the hydrogen ion in the water (17). Many biological and chemical processes in nature are influence by the pH of the medium, thus making pH an essential variable in determining the acid-base dynamics of water (18, 19, 20). The mean pH of raw water in the present study was alkalinic. This is in agreement with (21) who reported that for most natural water sources, pH usually ranges from 6.5-8.5, adding that changes in optimum water pH may lead to elevations or decrease in the harmful effects of toxins in water bodies. The recorded pH of raw water from this study promotes the survival of aquatic organisms (22). The recorded mean pH of treated water was also within the WHO and NSDWQ. Thus, the treated water is safe and may not cause any deleterious effects on users (17). Besides health effects, pH affects the taste of water. Treated water with pH values below the WHO permissible limits may be corrosive to plumbing and pipes, especially at pH less than 6, while water with pH values above the permissible limits have a bitter or soda-like taste (17, 20). Furthermore, pH directly influences the recreational uses of water. This becomes very important in bathing water and swimming pools in which water at very high or low pH water may cause skin and eye irritation (20).

Mean temperatures of treated and untreated water were within the WHO and NSDWQ permissible limits. These observations agree with those of (21, 22). The estimation of water temperature is important in the determination of water quality as many chemical reactions which take place in water are temperature dependent. Solubility of gases which are essential from life in aquatic environments is strongly correlated with water temperature (19), with increased gas solubility being associated with low temperatures of water. The temperature of raw water as determined in the study is low enough to support the survival of many aquatic species due to higher gas solubility (23). (22) enumerated factors which may influence water temperature. They include thermal discharges, depth and size of water body, source of water, location, sampling time, and cloud cover. The temperature of treated water, however, is largely dependent on atmospheric conditions. The increased solubility of gases in cool treated water, especially of CO_2, impacts a pleasant taste. Thus, the palatability of the water from this study could be taken as satisfactory. The observed seasonal variation in water temperature for both raw and treated water is in consonance with the findings of (24) who also recorded lower water temperatures during the wet season as contrasted with the higher values recorded during the drier seasons of the year.

Electrical conductivity gives an estimate of the amount of inorganic ions present in a sample of water, and because the migration of the ions constitutes electric current, EC measurements quantify the ability of water to conduct electric current. Basically, EC values are positively correlated with the total dissolved solids (22). Inorganic ions implicated in elevations in EC values include hydrogen ion, sodium ion, potassium ion, magnesium ion, calcium ions, chloride, sulfate and bicarbonate (24, 25). The results from the present studies indicated the EC values of raw and treated water samples were both within WHO/NSDWQ permissible limits, an observation which further corroborates the finding of (17, 25, 17) remarked that on the basis on EC alone, water with low ionic conductance is portable water. The pattern of seasonal variations in EC observed in this study corroborated the findings of (22, 26) who also reported elevations in EC values during the dry seasons. They attributed this raise in EC values during the dry season to be due to the effect of increased rates of evaporation which in turn concentrates inorganic ions within water bodies. (27) has argued that EC impacts only on the aesthetic (taste) value of water, with no direct implications on health. However, some other authors have posited the role of elevation in systemic diseases such as kidney stones and failure, hypertension, and strokes (20). Furthermore, water with high conductivity may cause corrosion of metal surface of equipment such as boiler. Food-plant and habitat-forming plant species are also eliminated by excessive conductivity (27).

In raw water, mean turbidity observed agrees with those of (22) and (28) who also recorded significantly high turbidity in untreated water samples. Turbidity is associated with the presence of suspended and colloidal matter as well as microorganisms in water (18, 20). Increased turbidity of raw water samples may be attributed to influx organic materials from runoff water or the presence of decaying organic matter (29). Upon water treatment, significant reduction in turbidity was observed (Table 4.1b). Water treatment processes which reduce turbidity include coagulation, sedimentation and filtration. Turbidity is an important operational parameter in process control and can indicate problems with treatment processes, particularly coagulation/sedimentation and filtration. High turbidity in treated water is usually due to inadequate filtration. Particulates can protect microorganisms from the effects of disinfection and can stimulate bacterial growth. Thus, for effective disinfection of treated water, turbidity must be below 0.1 NTU (30). In both treated and raw water samples, significantly higher turbidity was associated with the rainy season months than with the dry season months. These observations agree with those of (26) who attributed such elevations in water turbidity to increased precipitation associated with the rainy season. Surface run offs during rainy season impact raw water with colloidal and suspended particles, and this could overwhelm the subsisting operational water treatment protocols if adjustment are not made to accommodate such seasonal increases.

The mean TDS in raw water was lower than the maximum permissible limit for total dissolved solids recommended by the WHO and NSDWQ. This indicates that the untreated water may be suitable for irrigation purposes as proposed by (17, 31). Factors which affect the level of TDS in raw water include water source, underlying rocks, sandy particles and anthropogenic activities (16). The increase in TDS observed during the rainy season may be due to an increased influx of dissolved salt as a result of increased rainfall (24). River Kaduna, the main source of raw water at the Malali Water works, receives water from streams and gullies carrying water from diverse sources including quarries, abattoirs, households, industries and junk yards. The mean total dissolved solid in treated water indicated a decrease which is indicative of an efficient treatment process which ensured the removal of dissolved solids from treated water before distribution. TDS is an important indication of general water quality as it has a direct influence on the aesthetic value of water. At high TDS of greater than 500mg/L, water may be unacceptable to consumers because of its taste (17, 31).

Dissolved oxygen is an essential requirement for the survival of aquatic organism as they need oxygen to carry out metabolic reactions required for energy production, growth, and reproduction (32, 23). The mean DO content in raw water recorded in this study agrees favorably with the result of (22) who reported DO values ranging from 8.65 to 9.72 mg/L. Factors that determine DO content in raw water include salinity, wind turbulence, water current, temperature, and organic matter content (22). Significantly higher mean values of DO were recorded in treated water than in raw water. This may be attributed to the processes of aeration which were applied during water treatment (23). Significantly higher concentrations of dissolved oxygen were observed in raw water samples during the dry season months than in the rainy season months. This observation agrees with those of (22, 24) who also observed similar seasonal fluctuations in dissolved oxygen content of natural water bodies.

The nitrate concentration in raw water was higher than that recorded by (25). According to (23), the concentrations of nitrate in natural water sources are often low. Nitrates, which are the principal form of nitrogen in natural water bodies, are important limiting nutrients for growth of plants and aquatic organisms such as algae (22). The principal sources of nitrates in untreated water bodies include the use of nitrogen based fertilizers, domestic sewage, animal dung, ammonia, and urban wastes (33). From the present study, the higher nitrate concentration in treated water indicates that water treatment processes remove nitrate from water as observed by (23). While it is recognized as an important nutrient source for humans and livestock, reduction in nitrate level in portable water is essential as nitrate concentrations in large quantity can cause methamoglobinemia in infants, resulting in coma and probably death. Elevations in water nitrate concentrations have been implicated in diuresis and hemorrhage of the spleen (25). Thus, it can be inferred that the treated water during the period of the study was not safe for consumption, especially for infants less than six months old (34). Seasonal fluctuations in nitrate concentrations were observed in both treated and raw water, with higher values recorded during the raining season. This is in agreement with the result of (22) contradicts the results of (24). The observed increase in nitrate content during the raining season may be associated with accumulation of nitrogen-based matter in natural water source due to increased surface run off water (22).

In most natural water sources, fluoride is usually found in trace amounts. Higher amounts are usually associated with the type of rock underlying the ground over which the water flows (34). The mean fluoride concentration of raw and treated water was lower than WHO acceptable limits in portable water (17). Thus, water from the Malali Water Works may predispose consumers to risk of developing tooth decay due to insufficient fluoride content (31). Despite its utility, acute consumption of large amounts of fluoride may result in fluorosis (fluoride toxicity). This inherent toxicity associated with the consumption of fluoride may have informed the decision to supplement the treated water with reduced quantity of fluoride as it is known to exhibit cumulative toxicity. Some signs of fluoride intoxication include mottling of the tooth, calcification (hardening) of soft tissues, skeletal deformity, and hyperthyroidism (34).

Magnesium is natural water constituent, it is essential for proper functioning of living organisms and occurs in minerals like magnetite and dolomite. Together with calcium, magnesium contributes to the hardness of water (35). Magnesium concentration for raw and treated water were below the permissible limit in drinking water set by the WHO. The observed for magnesium is in agreement with that of (36, 27). It has been observed also that higher concentration of magnesium in drinking water gives it unpleasant taste and also has a laxative effect (37).

Conclusions

On the basis of the physiochemical parameters evaluated, treated water at the Malali water works is of better quality than raw untreated water. Generally, treated water is less turbid and safe for use following the comparative standard presented by WHO. More so, the quality of treated water and raw water showed seasonal variations. pH, temperature, dissolved oxygen content, and electrical conductivity in raw water were generally lower in the rainy season months than in the dry season months, while turbidity, TDS, nitrates, magnesium and bacterial contamination were higher during the rainy season months. In treated water samples, pH, temperature, conductivity and TDS were lower in the rainy season months.

Recommendations

Efforts should be made at increasing public awareness on the level of water pollution in raw water especially in the rural areas where water is largely untreated before use. Stringent water quality control measures should be implemented at the Malali Water Works to check the seasonal fluctuations seen in some of the physicochemical parameters. Furthermore, efforts should be made to improve water quality at the Malali Water Works so that the physicochemical and bacterial parameters of treated water should be consistently within WHO and NSDWQ permissible limits.

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Conflict of interest

All authors declare that there is no area of conflict.

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