Clean Water Initiative for Health and Nutrition. A Case Study of Bungoma County

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Abstract

Water, especially in rural areas is normally found contaminated cause of inadequate protection of water points both surface and underground due to poor hygiene practices. Water contaminants contributes to various chronic communicable diseases that affects humanity. Convention methods applied for water treatment remain expensive, unreliable and inaccessible for majority in developing countries. A study was done to determine the potential of hydrogen (pH) and microbial assay of water samples from different sources in Bungoma county. The water samples were collected from various part and obtained from different sources. The parameter used to test water quality were pH instrumentally and total bacterial count for microbial assay done using pour plate isolation technique. The efficiency of ultra violet radiation from natural sunlight as bactericide was determined using WADI equipment. The total bacterial counts in the samples were compared after sterilization with the results showing notable difference between treated and untreated samples. Majority of the treated water samples with exception of one were within allowable limit for non-pathogenic colonies for drinking water of 100 colonies per ml. pH of most the water samples was found to be acidic and values not within the recommended WHO acceptable limits of between 6.5 to 8.6. The values of parameters used to assess water quality from the various samples were analysed using R analytics and found to be significantly different ($p < 0.05$). The results obtained showed that the quality of most water sources did not conform to the required standard for domestic water hence need for remediation process and public sensitization of the community.

Key words: Aquatic, Toxicants, Sanitation, Effluents, Bioaccumulation

INTRODUCTION

Water contributes to various physiological processes in micro-organism, plants and advance animals that sustain life (Hara *et al*., 2022). Water total bacterial count and pH are prime factors that's affects the quality of life in an aquatic ecosystem (WHO,2021). Africa continent greatest challenge in public health is accessing clean hygiene domestic water this due to increasing population, pollution and ineffective treatment methods (Wen *et al*., 2020). The main water sources contaminants are microbial pathogens and inorganic ion (Potgieter, 2019). Pollution agents can alter water pH, making it toxic for consumption and sustaining life in aquatic ecosystem (Ungureanu *et al*., 2022).

The backbone of a country economic is dependent on proper maintenance of appropriate water sanitation standards (Kong *et al*., 2020). The core contributors of water pollutants in developing countries are urbanization and industrial waste effluents (Nkiaka *et al.*, 2021). There is a need for more research and public sensitization on dangers of environmental pollutants to prevent the increase in risk factors associated with toxins accumulated in the water sources (Quinete *et al*., 2021). Plants can accrue heavy metals deposits carcinogens by bioaccumulation which are transferred to human tissues through food web (Alengebawy *et*

al., 2022). The levels of total suspended solid, turbidity and cation precipitants are important aspects that governs domestic water standards (Hamid *et al.,* 2020).

pH is principal physicochemical parameter that influence the overall quality of water (Ma *et al*., 2020a). The pH of body fluids controls the cell physiology and other biochemical processes in human tissues (Perez & Riveros, 2018). At extreme high pH, metals precipitate compounds like ammonia converting them to toxicants while some anions like cyanide show similar properties at low pH (Saalidong *et al*., 2022). The effects low pH in drinking water leads to acidity which is a risk factor for some medical conditions like heart burn and gastroenteritis (Hansen *et al*., 2018). The recommended allowable limit pH for drinking water as per WHO standard is between 6.5 to 8.6 (Sila, 2019).

Bacterial adulteration of domestic water is a dominant public health challenge in the countryside regions of sub-Saharan Africa (Gizaw, 2019). The common microbe found in drinking water in the developing countries are *Escherichia coli* and *total coliform* which are indicators of presence fecal effluence sources (Luvhimbi *et al*., 2022). Microbial analysis is the key in assaying pathogens responsible for waterborne diseases, like coliform bacteria (Kumar *et al.,* 2019). The quantity of effluents entering water sources is a substantial factor that affect bacteria sedimentation in water sources (Lu *et al.,* 2022).

Micro-organism can interact with water distribution channels through treatments and mixing with contaminated substrates (Novak, *et al.,* 2020). Micro-organism colonies in transparent liquid medium like water can be disinfected using natural UV light (Mariita, *et al.,* 2021) a form of green energy. This due to UV irradiation exposure to DNA cause mutation by disrupting their bioactive components leading to death of the microbes (Kim *et al*., 2023). Some non-pathogenic microbes are important has they have been found to play important role in biodegradation of some wastes in water surfaces (Pathak *et al.,* 2022).

Figure 1: Drinking water from remediated Kibisi dam funded by Core health and Wealth international

Microbes' pathogens need to be eradicated in water sources to control water borne diseases as they are the principal causative agents (Lin *et al*., 2022). Thus, a case study, on the levels of total bacterial counts and PH were assay to determine the quality of water from different sources in Bungoma county Kenya. The results obtain not only provided vital information on the contaminants present water sources but also provided an insight on how they can be eradicated using basic remediation techniques.

MATERIALS AND METHODS

Experimental site and samples

The research was conducted at University of Eldoret laboratories located in Uasin Gishu county Kenya a region having an altitude of 2090 mm of above sea level, latitude of 0°C 55` North and longitude of 34°C 50`East. The mean maximum and minimum temperatures of the laboratory were 25±4°C and 16±2°C, respectively during the period the experiment. The samples were collected from water sources in different parts of Bungoma County that borders the west of Republic of Uganda, Trans Nzoia, Kakamega, Teso, Mumias and Busia districts that has major physical features which includes Mt. Elgon and River Nzoia. The water samples were collected from the sources by holding the sterilized bottle in one hand with protective gloves near the base, removing the screw cap with the other and dipping the container approximately 300 mm below the water surface.

Methodology

Determination of pH

This was done using Hanna pH 211 model. The pH meter was calibrated using freshly prepared buffer of pH 4 and 7 at 25^0C.The pH were determined by inserting the electrodes on the water samples after homogenizing by mixing.

Microbial analysis

This was done as explained by Terrones *et al.,* 2023 where twenty water samples for microbial assay from different sources were randomly and aseptically collected from the whole consignment.

Sterilization

The glass wares were cleaned with warm water containing disinfectant. They were further sterilized by dry heat in hot-air oven set at 170°C for 2 hrs. The lamina hood was used for inoculation and its surrounding was sterilized using 70% absolute ethanol aerosol (Moretto & Weiss, 2019).

Media preparation

The culture media used for the study was nutrient agar prepared by weighing 28 grams of the dehydrated powder in a weighing balance and dissolving in 1liter of distilled water. The suspension was then heated to boiling to dissolve the medium completely. The dissolved medium was then sterilized using an autoclaved at 15 lbs. pressure (121°C) for 15 minutes (Orekan *et al.,* 2021).

Innoculation and cultivation of microbes

The water samples were serially diluted using distilled water with a dilution factor of 0.1, 0.01 and 0.001 of the original water sample to make the innoculum followed by sterilization. The pour plate method was applied as microbial technique for culturing and isolating bacteria in the water samples.

Water sample 1ml as an inoculum was placed in the center of sterile petri dish using a sterile pipette. Molten cooled agar 15mL was poured into the petri dish containing the inoculum and mixed. The plates were then inverted and incubated at 37°C for 24-48 hours after the agar had solidified. The samples were run in triplicates (Adesoji *et al.,* 2019).

Sterilization of water samples using natural UV light

Water samples twenty in numbers were randomly selected from the whole batch factoring in the sources and well labelled. Water samples 50ml were measured, placed clean sterilized bottle and attached on the WADI equipment used to monitor bacterial disinfection by

sunlight. They were exposed to natural light at temperature of between 20 to 29°C for between 3 to 4 hours until disinfection process was completed and were referred to treated samples while replicate of the same which were not subjected to UV light using WADI equipment were referred to us untreated. The samples both treated and untreated were subjected to pour plated method microbial assay using serially diluted inoculum for microbial assay total number of colonies on each plate was counted with the help of a colony counter equipment (Bai *et al.,* 2019).

Statistical Analysis

One-way analysis of variance (ANOVA) using R statistical analytic were used to determine the relationship between water samples from different sources, pH and total bacteria count. The means and marginal means of the values were used to determine significant difference between water samples from different sources. The value $p \leq 0.05$ was considered to be statistically significant during data analysis with results represented in form of tables and figures.

RESULTS

Results for pH for water samples from different sources

The values of pH of water samples from different sources are shown in Table 1 and figure 2 below.

The pH results from the water samples were mainly acidic ranging between 4.48 to 6.79 this may be due to environmental factors in the surrounding ecosystem which majority are small scale subsistence farmers which thrives well in acidic soil (Odhiambo *et al.,* 2020) which can wash to waters during rainy seasons the landscape been relief region.

Table 1: pH of Water samples from different Sources

Sample	pH	Sample	pH	Sample	pH	Sample	pH	Sample	pH	Sample	pH	Sample	pH
1	5.92	**12**	5.21	**23**	5.59	**34**	6.27	**45**	5.73	56	6.63	**67**	5.23
2	5.88	**13**	5.32	**24**	5.50	**35**	5.15	**46**	5.50	57	5.74	**68**	5.44
3	5.87	**14**	5.64	**25**	5.27	**36**	5.06	**47**	6.64	58	5.86	**69**	5.66
4	5.43	**15**	5.44	**26**	5.11	**37**	4.99	**48**	6.66	59	5.23	**70**	6.12
5	5.64	**16**	5.54	**27**	5.43	**38**	5.77	**49**	6.61	60	5.05	**71**	5.27
6	5.74	**17**	5.48	**28**	5.05	**39**	4.48	**50**	6.72	61	5.83	**72**	5.40
7	5.37	**18**	6.57	**29**	4.87	**40**	5.01	**51**	4.80	62	6.03	**73**	6.16
8	5.23	**19**	5.01	**30**	5.00	**41**	5.69	**52**	5.33	63	4.84	**74**	5.45
9	6.21	**20**	5.14	**31**	5.65	**42**	6.79	**53**	5.52	64	5.33	**75**	4.89
10	5.00	**21**	5.59	**32**	5.43	**43**	7.14	**54**	5.32	65	5.31	**76**	5.74
11	4.96	**22**	5.50	**33**	5.21	**44**	5.06	**55**	6.47	66	6.53	**77**	5.29

The marginal means for water pH samples from different sources

The water samples from stream and river recorded the highest marginal mean pH of 6.6 while rain water had highest acidity of with lowest pH marginal mean of 5.1. The effect can be associated with dissolution of carbon dioxide and other green gases to form acids like carbonic acid in rain (Payus *et al.*,2020). The low acidity in river samples may be as a result of minimal disposal toxic waste due to lack of industrial activities in the region a dominant source of toxic effluent (Comber et al.,2022).

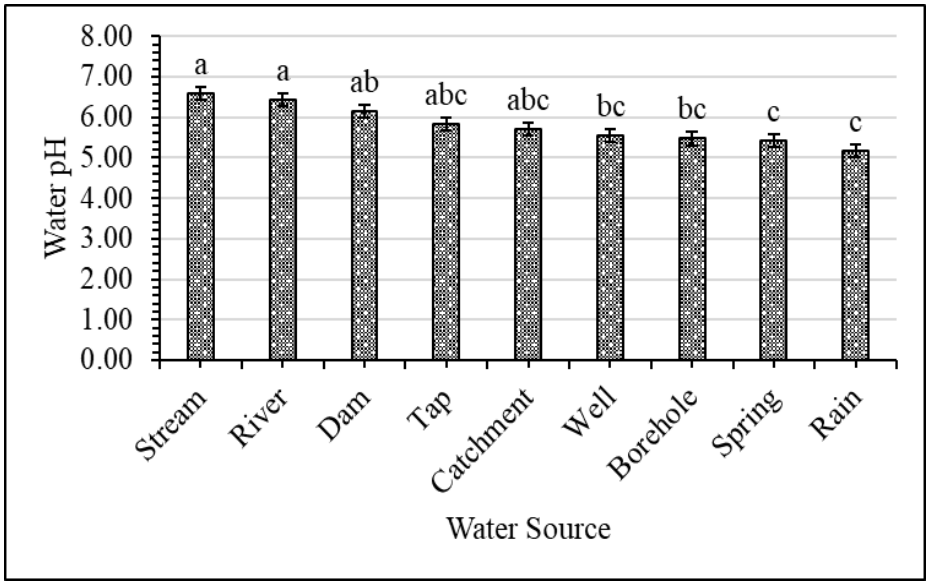

Figure 2: Mean for pH of water samples from different sources

Microbial analysis

Total viable count

The results for total viable count are represented in Table 2 for data and figure 3 respectively which showed significant variation.

Table 2: Total bacterial count of untreated water from different sources

Sample code	Number of colonies per plate		
Dilution factor	**0.1**	**0.01**	**0.001**
1	988	38	32
2	650	27	23
5	36	32	30
9	96	25	18
32	101	42	25
37	50	8	6
45	602	58	38
46	656	33	28
49	1800	388	40
53	1920	603	106
56	866	156	26
59	901	163	28
60	450	203	40
62	1602	265	61
69	58	26	22
70	364	28	40
71	899	301	52
72	88	68	40
73	86	25	36
74	45	22	16

The table 2 shows total bacterial counts of colonies from various serially diluted innoculum. The water samples collected had high microbial load agreeing with Odonkor& Mahami (2020) that drinking water sources in rural are vulnerable to microbial contamination.

Marginal mean for total bacterial counts for untreated water samples for different sources

The number of total bacteria for untreated samples from different sources had microbial

pollution that varied significantly ($p \leq 0.05$) with the dam having highest levels of microbial contaminants with a marginal mean of 4.81 while shallow water sources recorded the least total bacterial count of 2.01. This can be attributed to dam obtain water from multiple channels and as they flow down chances of collecting surface wastes with high fecal matter major source of microbes increases (García-Aljaro *et al.*, 2019).

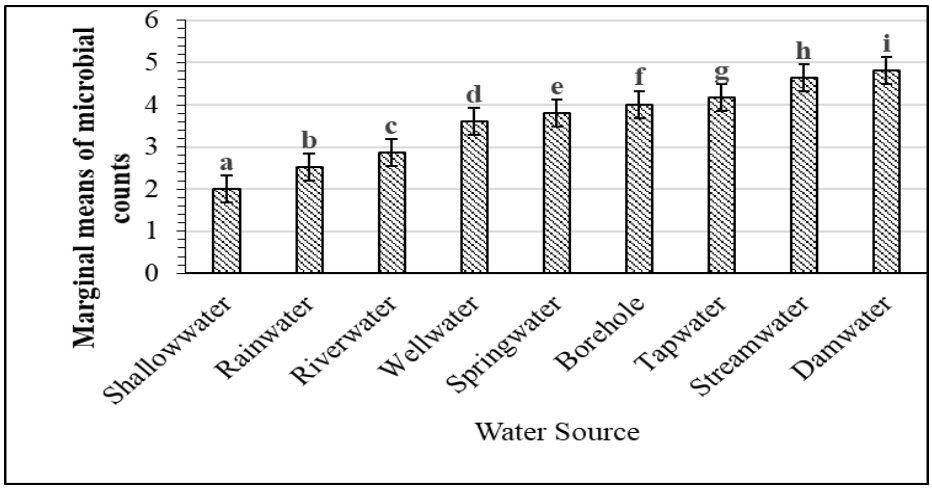

Figure 3: Variation in the marginal mean for total bacterial counts in water samples

Bactericidal effects of sunlight UV on colonies

The effects of natural UV light on the number of colonies per plates are illustrated in Table 3 representing raw data and figure 4 for statistically analyzed data.

Table 3: Variation on total bacterial count of treated water from different sources

Sample code	*Number of colonies per plate*		
Dilution factor	**0.1**	**0.01**	**0.001**
1	5	4	2
2	12	6	4
5	15	8	4
9	22	10	8
32	20	10	6
37	8	6	5
45	21	11	10
46	6	1	0
49	1 6	14	8
53	12	8	10
56	650	108	80
59	50	28	22
60	24	18	10
62	45	30	15
69	30	25	14
70	40	22	15
71	50	26	21
72	46	18	16
73	54	26	17
74	6	7	9

The Marginal mean for total bacterial counts for untreated and treated water samples

Generally microbial loads in treated and untreated water samples display significant difference ($p \leq 0.05$) in the marginals mean this can interrelated to effects of continuous exposure of UV light that inhibits bacteria multiplication by denaturing microbes' DNA biochemical component essential for cellular life (Rezaie *et al.,* 2020) leading to drastic decrease the population of colonies in the water samples

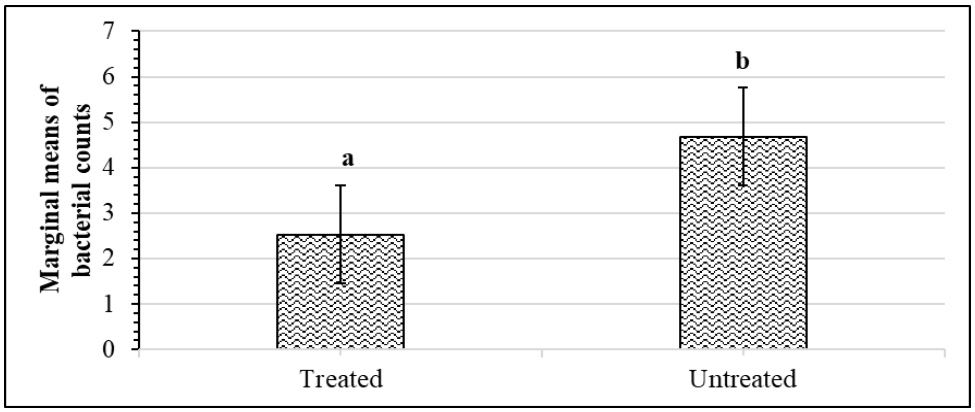

Figure 4: Marginal means for total bacterial counts for treated and untreated water

Culture plates

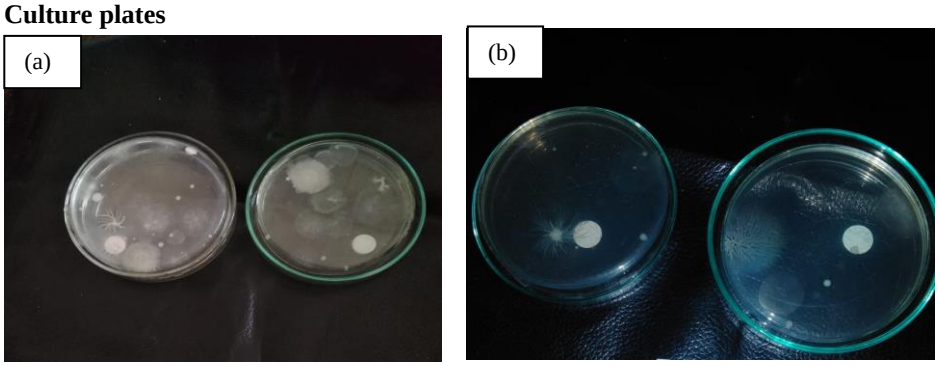

Figure 5: Total bacterial for same sample code 74 untreated (a) and treated water (b).

This due to the bactericidal effects of UV light which are absorbed by proteins in microbes at specific wavelengths, this interfere with cellular biochemical components by forming dimers in genetic components (Narita *et al*., 2020) leading to death.

The variation in number of colonies with dilution of innoculum

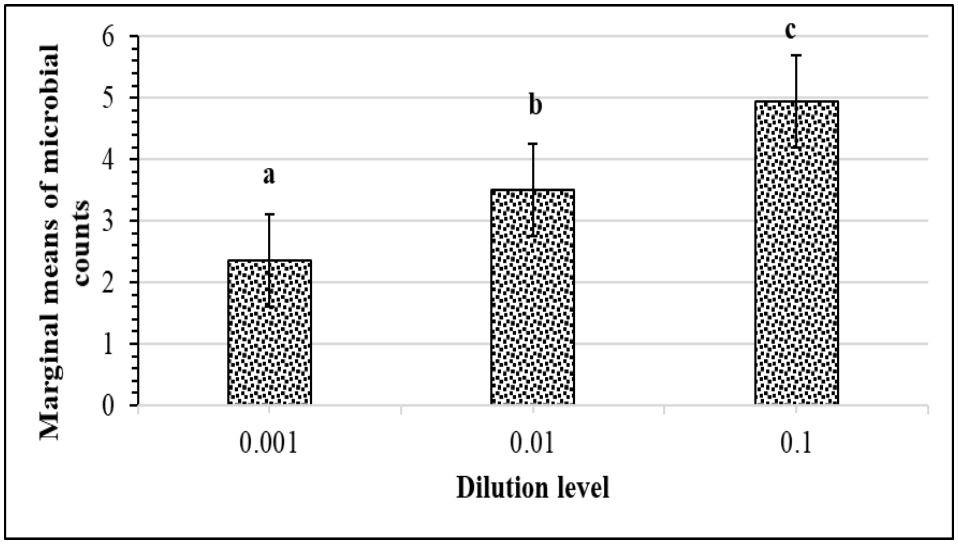

Figure 6: Marginal means for total bacterial counts with varying inoculum dilutions

They were significant decrease in marginal means on the number of colonies with dilution resulting to isolation of colonies as indicated below in figure 6. The was done to enable easy isolation and identification of colonies on water samples from different sources as a standard confirmatory test for variation on colony per ml as done by Garre *et al.,* (2019) a study that revealed serial dilution is a factor in specific quantification viable bacteria in a colony per ml in an inoculum.

DISCUSSION

The mean pH value for most of the water samples was found to be acidic with a pH range of between 6.66 for stream to 5.16 for rain with some of the values falling below the recommended WHO acceptable limits thus risk factor for health (Table 1 and Fig. 2). This makes it a matter of urgency for plans to start remediation strategies and also to protect the sources from further contamination. Low water pH can be due to toxicity of heavy metal pollutants as their salts are acidic in solution (Ma *et al*., 2020b). Water pH is a critical factor that determines bioavailability of aquatic ecosystem and nutrient in a biocoenosis (Gavrilescu, 2021). The presence of toxic levels of mercury, arsenic and low pH has been linked to type 1 diabetes as they reduce insulin optimum biochemical activity in regulating blood sugar levels (Chafe *et al*., 2018).

The water samples had high microbial load which is contrary to WHO recommendations the water for domestic used should be free from microbial contaminants (Favere *et al.,* 2021). The shallow water samples had the lowest marginal mean of 2.01 bacterial counts while the dam recorded the highest value of 4.81 (Fig. 3). They were significant decrease in numbers of colonies after the samples were subjected to natural UV light with untreated having marginal mean of 4.68 untreated compared with 2.53 for treated (Fig. 4 and Fig. 5). The WADI equipment was found to be effective in monitoring the effectiveness of natural UV light as microbial sterilizing agent for contaminated water samples.

The most serially diluted inoculum recorded the lowest bacteria count with marginal of 2.36 this correlates with the study done by (Beal *et al*., 2020b) on effects on concentration of culture in isolation of bacteria (Fig. 6). Contaminated ground can be a potential source Hepatitis A contagious viral infectious disease that affects the liver which is also classified carcinogenic (Ryu *et al*., 2019). Thus, training the community on basic techniques of purifying water using available resources like affordable transparent plastic containers and natural sunlight can significantly abate microbial contaminants in drinking water in rural settlements (Ngasala *et al*., 2019).

The effects of infections arising due to drinking contaminated water can also be considerably reduced by training the community on simple effective water treatment method like using controlled amount chemicals like chlorine as a disinfectant. The acidity in water sources can be significantly and safely neutralized by *addition of control amount of* Soda ash (sodium carbonate) and sodium hydroxide (caustic soda) as regulating agent (Yehia & Said, 2021). The reduction of water levels and pollutants can also be controlled by avoiding farming near riparian land (Mateo-Sagasta *et al.,* 2017).

CONCLUSION

This study shows most water samples had PH values that were not within the allowable limits for drinking water. The results for total count from microbial analysis revealed all sample assay contained micro-organisms which was against WHO standards for drinking water. Natural sunlight UV light was found to be effective water sterilizing agent against microbes.

RECOMMENDATIONS

Thus, the community need to be sensitized on the risks associated with contaminated water, prevention and be empowered with elementary affordable technique that can be applied locally in remediation of the water sources.

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