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Effects of Magnetic Flux Density on the Population of *Escherichia coli* in River Njoro Water

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Abstract In this study, the experimental results of the concentration of *Escherichia coli* in water exposed to magnetic flux density are presented. Water samples were collected from River Njoro, Nakuru County, Kenya. The initial *Escherichia coli (E.coli)* counts for the samples were obtained using Membrane Filtration techniques. The samples were then exposed to different magnetic flux densities (2mT, 6mT and 10mT) at time intervals of 6 hours and 18 hours for each magnetic flux. Membrane filtration was also done after magnetic treatment of the samples. The data obtained was photographed and presented in tables and bar graphs. The maximum disinfection efficiency was 82.2% for bacteria exposed to a magnetic flux of 10 mT for 6 hours. This study proved that magnetic field can be used as inhibitory factor against the *E.coli*.

Keywords: *Magnetic Flux Density (MFD), Colony Forming Units (CFU), Escherichia Coli (E. coli)*

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1. Introduction

Many rivers are reportedly prone to high bacterial contamination due to heightened ecological activities and may be unsuitable for human consumption when untreated [1]. Previous studies have indicated that the microbial quality of the River Njoro water sources is poor and unacceptable for human consumption due to consistent increase in total and fecal coliforms, and also due to pathogenic loading downstream [2]. This water is contaminated with pathogens which lead to widespread of acute and chronic illnesses, which are major causes of death and misery among the residents of Njoro. A recent report indicates that about 3.41 million people die each year from water, sanitation and hygiene-related causes [3]. Water and sanitation crisis claim more lives through related diseases than wars claim [4,5]. Pathogenic microorganism, especially *Escherichia coli*, was chosen to be an experimental model in this study: it is widely distributed in the environment such as soil, water and air; it causes several diseases such as urinary tract infection, wound infection, traveler's diarrhea, sepsis and meningitis; the presence of *E.coli* in water also indicates recent fecal contamination and the possible presence of disease-causing pathogens, such as bacteria, viruses, and parasites.

One of the key cornerstones of public health is access to safe water, however, water purification is an expensive process and this has hindered the government effort of providing majority of the population with treated water despite this being one of the requirements of the millennium development goals. Moreover, most common water purification methods have been shown to have serious negative impact to health and the environment. Chlorination for instance, which is one of the most widely used disinfectants [6] produce chemical compounds known as disinfection by-products (DBPs). Of these, Trihalomethanes (THMs) and Halo acetic acids (HAAs) found in the highest concentrations in chlorine treated drinking water are linked to high risks of cancer [7]. There has been growing concern over the health effects of boiling water as a purification method. This is because boiling tends to concentrate harmful inorganic contaminants, hence reducing water portability [8]. Again in developing countries, the major source of energy for cooking and boiling water is firewood which is expensive and environmentally unfriendly. Helping people gain access to safe drinking water is one of the most important health-related infrastructure programs in the world hence in the new millennium, there is a growing concern for the need to balance the risks of the need to disinfect the water to reduce the threat of disease from microorganisms against the potential health risks from disinfection byproducts that are formed as a result of adding a disinfectant. This study therefore intended to address this dilemma by establishing a water purification strategy that circumvents the health risks associated with the classical purification procedures.

It has been realized that the advantages of using water exposed to magnetic field as compared to normal water are enormous. Magnetic waste water treatment is a process that has been introduced to chemical industries to remove heavy metals and organic pollutants from waste water [17]. Stimulation of both animal and plant growth with magnetic field as a way to increase the quality and quantity of yield has caught the interest of many scientists worldwide [16]. For instance, it has been established that magnetic treatment of irrigation water can improve primary productivity of water resulting to an increased crop production, a decrease in plant disease rate and an improved taste of agricultural products [16]. It is not clearly known how this is achieved but it could be attributed to the ability of such water to retain and highly dissolve the essential minerals [15].

In latest years, several studies have been performed to verify direct effects exerted by extremely low-frequency (ELF) electromagnetic fields (EMFs) on cell functions. In particular, it has been demonstrated that ELF-EMF can negatively [14] or positively [18] affect functional parameters (cell growth and viability) of a cell. The effects of magnetic fields on cells are thus not fully understood since some of the results have been inconsistent and have in other cases contradicted each other. The aim of this study was thus to evaluate the effect of magnetic flux density on the population of *E.coli* in River Njoro water.

2. Materials and Methods

2.1. Study Area

Njoro River is located within the Kenyan Rift Valley in Nakuru County and is approximately 60 kilometers (km) in length [9]. It has its source on the eastern slopes of the Mau Escarpment and its mouth in Lake Nakuru [9]. It is the main source of water to people and animals living in Njoro area.

2.2. Experimental Design

The voltage amount required was controlled by a variable transformer with low voltage power unit 022.317: 0–25 V, 8.5A rms max. This device is manufactured by Dexing magnet tech. Co.,Ltd, Fujian, China and distributed by UNILAB, Kenya. Magnetic field strength for the Helmholtz coils was set at 2 mT with the aid of a magnetic flux density unit (PHWE 612.002) and by varying the current in the coil. Petri dish 2mT was placed in between the two pairs of Helmholtz coils. The specifications of Helmholtz coil used are model PHWE 06990.10; 320 turns, diameter 14 cm. This coil is manufactured by San Electrical industries, Mumbai, India. For the next 6 hours, water in Petri dish 2mT was exposed to the Helmholtz field set at 2 mT. The Petri dish C served as a control under the same conditions except for the fact that it was not exposed to a magnetic field. The Bacterial count was done before and after exposure of the water samples to the magnetic flux. The magnetic field strength was increased from 2mT to 6 mT and finally 10 mT and the above procedure was repeated for each case. Exposure time was varied from 6 and 18 hours for each set magnetic field. The experiments were repeated three times. The Magnetic flux density was measured using a magnetic flux density unit (manufactured by Seatrend tech and development Company Ltd, Chongqing, China) connected to a multimeter model ALDAAVD830B, manufactured by Salicon Nano Technology Private Limited in Delhi, India.

2.3. Bacteriological Analysis

Membrane filtration was done according to American Public Health Association [10]. Appropriate dilutions of the water samples were done using distilled water. 100ml of the sample or its dilution was aseptically filtered through a membrane filter (47mm diameter, 0.45µm pore size) on a filtration unit. The filter was then taken off using a pair of sterilized forceps and placed on the surface of the corresponding culture media. Colony forming units (CFU) per 100 ml of the sample or its dilution were calculated as described in the United States Department of Agriculture, Food Safety and Inspection Services manual [11]. Filters were placed on Chromocult agar (merck) plates (manufactured by Henan Boom Gelatin Co., Ltd, Henan, China) and incubated at 37^0C for 18-24 hours. Typical colonies appearing blue were counted as *E.coli* and expressed as CFU's /100ml.

2.4. Statistical Analysis

All experiments were repeated three times and data was presented in tables and graphs. Statistical significance of each difference observed among the mean values was determined by standard error analysis. All mean data were statistically analyzed with a general linear model procedure of statistical analysis system. The Statistical analysis was done using the Statistical Package for Social Sciences (SPSS) software (Version 17.5). Pearson correlation analysis was carried out to determine the relationship between magnetic field intensity and bacterial count. One-way ANOVA with 95% confidence level was done to compare the effect of the magnetic field intensities with the bacterial count.

3. Results and Discussion

Different trends on the densities of *E. coli* at different levels of treatment were noted and results obtained indicated in Table 1 and Figure 3, Figure 4, Figure 5 and Figure 6. Presence of *E.coli* was characterized by development of blue colonies on the surface of the Chromocult culture medium. Figure 1 and Figure 2 (a, b, c, d) show *E.coli* density without B-field exposure (control), under a B-field exposure of 2mT, of 6 mT and of 10 mT for 6 and 18 hours respectively.

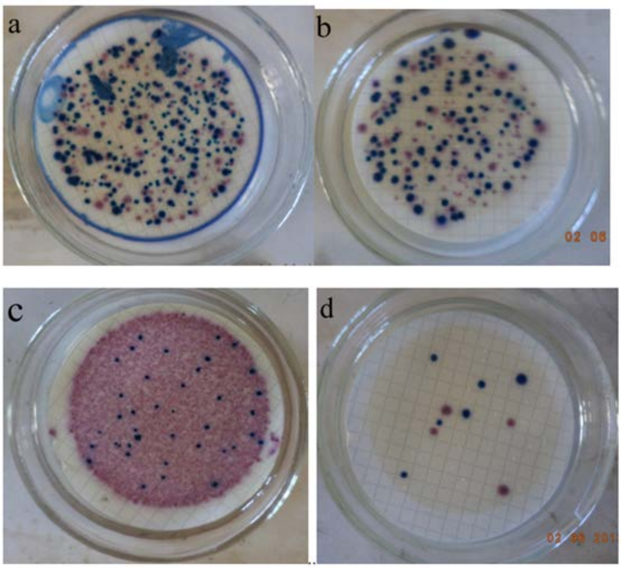

Figure 1. Shows plates a, b, c, d with *E.coli* Densities (blue colonies) after 6 Hours of Exposure: a) Without Magnetic Field; b) Magnetic Field of 2mT; c) Magnetic Field of 6 mT; d) Magnetic Field of 10 mT.

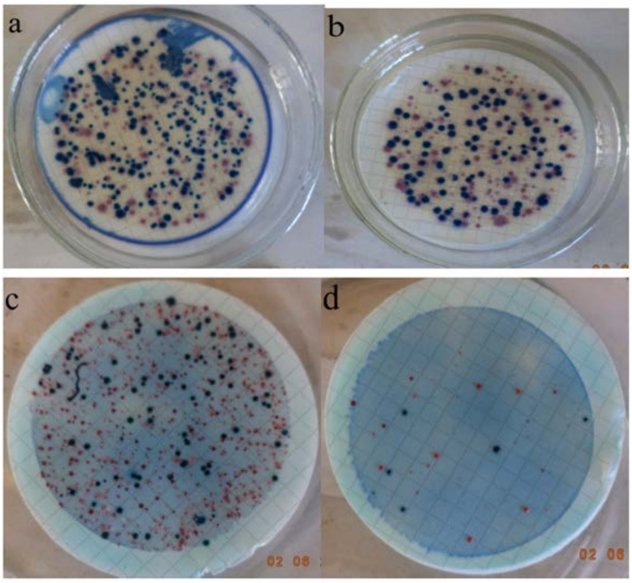

Figure 2. Shows plates a, b, c, d with *E.coli* Densities (blue colonies) after 18 Hours of Exposure: a) Without Magnetic Field; b) Magnetic Field of 2mT; c) Magnetic Field of 6 mT; d) Magnetic Field of 10 mT

It was observed that the control recorded the highest number of CFUs for both 6 and 18hours. Increasing the magnitude of magnetic field led to a significant decrease in the numbers of *E. coli* with the least number of CFUs given by the highest magnetic flux density. MFD was able to decrease *E. coli* concentration in River Njoro water significantly and hence proved to be a possible small scale cost-effective method of disinfecting water for domestic consumption and reducing incidences of waterborne diseases. More time of exposure to radiation for disinfection was required for low magnetic fields. This is similar to [12] who studied the effect of pulsed magnetic field intensity on bactericidal property in sterilization fresh watermelon juice and showed that the overall bactericidal effect was strengthened as the magnetic field intensity increased.

Table 1. Effect of Different Magnetic Flux Densities on *E. coli* Numbers (CFU/100ml) after 6Hrs and 18Hrs of Exposure (average ± standard deviation)

Time of exposure	MFD	Mean± Std. Dev
6hrs	control	687.5± 172.31
	2 mT	337.5± 95.35
	6mT	237.5± 102.1
	10 mT	122.5± 42.72
18hrs	control	680±176.3
	2 mT	542.5± 153.3
	6mT	225±68.56
	10 mT	125±51.96

Results in Table 1 showed that, the highest means of *E. coli* were recorded with the control. The *E. coli* numbers decreased proportionally with the increase in the magnetic intensity. The least magnetic intensity of 2mT at 6hrs gave a mean number of 337.5 CFU/100ml but after 18hrs the number increased to 542.5 CFU/100ml. The magnetic intensity of 6mT had more inhibitory effects on *E. coli* at both 6hrs and 18hrs of magnetic treatment, where bacteria counts were 225 CFU/100ml and 237.5 CFU/100ml respectively. This study showed that the highest magnetic intensity of 10mT gave the least mean numbers of *E. coli* as122.5 CFU/100ml and 125CFU/100ml after 6hrs and 18hrs of exposure respectively.

The acceptable level of *E.coli* in any drinking water is 0 – 100 CFU /100 ml (WHO, 2006). In this study, the highest MFD gave a disinfection level of 122.5 CFU/ 100ml of water which is very close to the WHO maximum acceptable contamination level of *E. coli* in drinking water. Looking at the trend of the results obtained in this study, this level could be reached by increasing the strength of MFD slightly since as the MFD is increased the number of CFUs are decreased significantly.

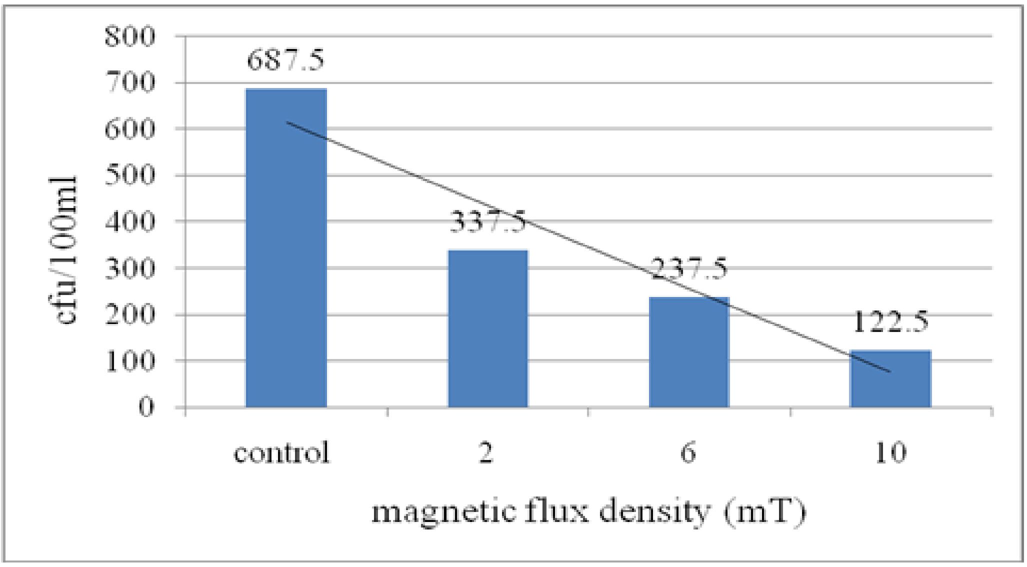

Figure 3. Mean Densities of *E. coli* (cfu/100ml) Due to Different Strengths of MFD after 6 Hours of Exposure

Figure 3 and Figure 4 show a strong inverse relationship between magnetic flux density and mean numbers of *E.coli*. It is clear that with increasing strength of magnetic field, the mean numbers of *E.coli* decreased significantly. The application of electromagnetic pulses evidently causes a lethal effect on *E. coli* cells [13].

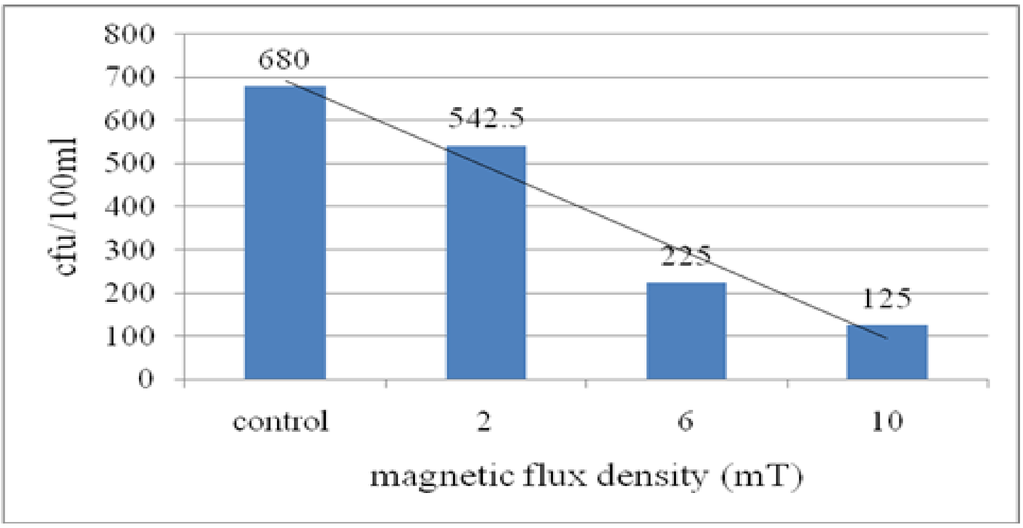

Figure 4. Mean Densities of *E.coli* (cfu/100ml) Due to Different Strengths of MFD after 18 Hours of Exposure

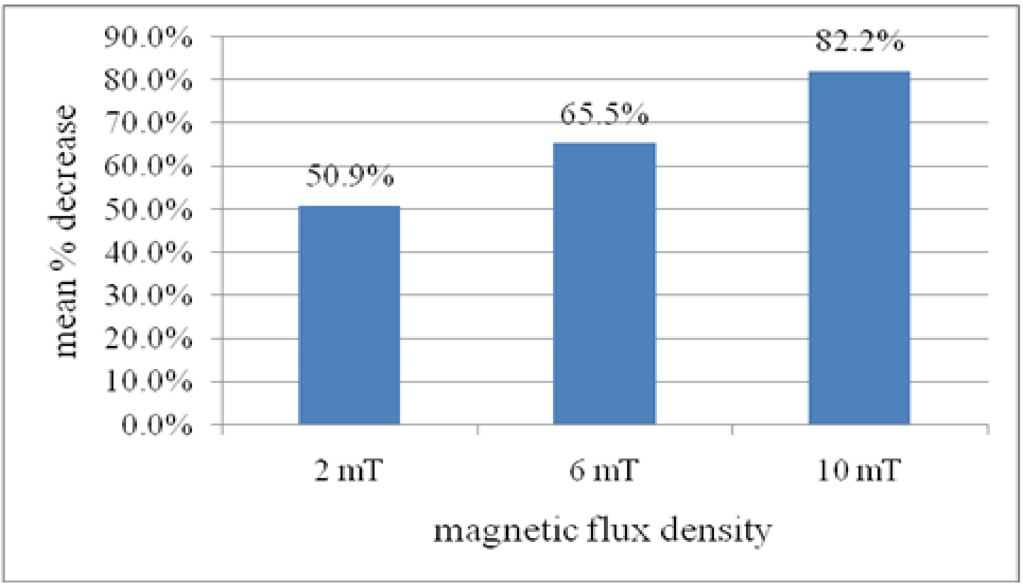

Figure 5. Percentage Decrease in the Mean Number of *E.coli* in Water after 6 Hours of Exposure to Different Intensities of MFD (2mT, 6mT and 10mT)

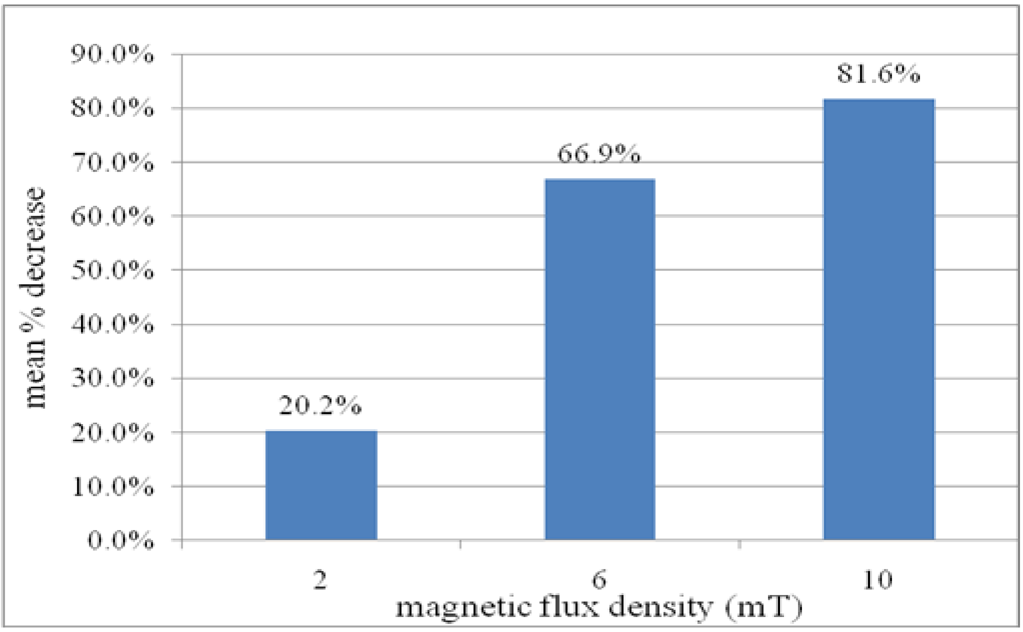

Figure 6. Percentage Decrease in the Mean Number of *E.coli* in Water after 18 Hours of Exposure to Different Intensities of MFD (2mT, 6mT and 10mT)

This study indicates that treatment of water with constant magnetic fields always gives rise to a disinfection effect. The magnitude of this effect depends on the strength of magnetic flux density used as well as the time of exposure. Fields of 2mT, 6mT and 10mT caused percentage decrease of 50.9, 65.5 and 82.2 respectively in the number of *E.coli* as compared to the control after 6 hours of exposure (Figure 5) and a percentage decrease of 20.2, 66.9 and 81.6 respectively after 18 hours of exposure (Figure 6).

The maximum disinfection level for *E.coli* attained in this study was 82.2% with increasing strength of the magnetic flux and period of exposure. This could possibly imply that with a slight increase in both the MFD and time of exposure, the disinfection level could get to at least 99%. The main damaging role of the magnetic fields might be on the cellular membrane that strongly affects, not only the cellular physiological functions, but also the cell-to-cell communications of the bacteria [14].

Table 2. Correlation between MFD (mT) and Mean Number of *E.coli* (cfu/100ml) after 6 Hours of Exposure

		MFD	MEAN
MFD	Pearson Correlation	1	-.999(*)
	Sig. (2-tailed)	.	.026
	N	3	3
MEAN	Pearson Correlation	-.999(*)	1
	Sig. (2-tailed)	.026	.
	N	3	3

* Correlation is significant at the 0.05 level (2-tailed).

Table 3. Correlation between MFD (mT) and Mean Number of *E.coli* (cfu/100ml) after 18 Hours of Exposure

		MFD	MEAN
MFD	Pearson Correlation	1	-.976(*)
	Sig. (2-tailed)	.	.024
	N	4	4
MEAN	Pearson Correlation	-.976(*)	1
	Sig. (2-tailed)	.024	.
	N	4	4

* Correlation is significant at the 0.05 level (2-tailed).

An inhibitory effect of EMF on the growth of *E.coli* may be due to the interaction between electric charges induced by EMF and that of the cytoplasm membrane resulting in partial abolishment of electric potential of the cytoplasm membrane with a subsequent decrease in the macromolecular biosynthesis. Also EMF may cause damage of bacterial DNA and inhibition of its replication. The cellular membrane of the microorganism could also have been affected by the external magnetic field, resulting to a disturbance in their metabolic activity and, consequently, a change in their cell division. Correlation analysis demonstrated that MFD was negatively significantly correlated with mean number of CFU ($r = -.999$, $p<0.05$) and ($r = -976$, $p<0.05$) for 6hours and 18hours of exposure respectively as shown in Table 2 and Table 3.

4. Conclusion

The findings of this study have met the initial aim of this research which was to investigate the effect of magnetic field on the concentration of *E.coli* in River Njoro water. The ANOVA significance test ($p < 0.05$) showed that magnetic field has a significant effect on the microbiological aspect of river Njoro water. The maximum disinfection efficiency was recorded as 82.2% for *E.coli* exposed to 10mT magnetic flux density for a period of 6 hours. This proves to be a promising method of disinfecting water.

Arising from the findings of this study, we propose that further research on the following areas concerns need to be done:

- A study to show how long the inhibitory effects of magnetic field lasts in the treated water after withdrawing the field;
- A study to show effect of magnetic field treatment on other strains of bacteria.

References

[1] World Water Assessment Program, "Kenya National Water Development Report. Case study", UNESCO VOL.12, pp 1-244, 2006.

[2] Kiruki, S, Mageto, OK, Ncene, WB and Gikuru, SK. "Prevalence of multidrug resistant enteropathogenic bacteria causing diarrhea in Kibera community in Nairobi, Kenya", Journal of Tropical Microbiology and Biotechnology, VOL 2: 24-30, 2006.

[3] World Health Organization. *The World Health Report*. World health Organization, 2012.

[4] World Health Organization. *The World Health Statistics*. World health Organization, 2011.

[5] Abel, PD. *Water Pollution Biology*. Taylor and Francis, pp.179-184, 2002.

[6] Vesilind PA, Peirce, JJ and Weiner, RF. *Environmental Pollution and Control*. 3rd ed. Butter WorthHeinmann, Bosten, pp. 77-83, 1990.

[7] United States Environmental Protection Agency, Current Drinking Water Standards. United States Environmental Protection Agency: Washington, DC, May, 2016.

[8] Rubenowitz-Lundin, E and Hiscock, K. *Water hardness and health effects*. Essential of Medical Geology, Elsevier Academic Press, pp. 331-345, 2005.

[9] Jenkins, MW and Lelo, FK and Chiuri, W and Shivoga, WA and Miller, SN, "World Water and Environmental Resources Congress: Community Perceptions and Priorities for Managing Water and Environmental Resources in the River Njoro Watershed in Kenya", Environmental Resources Congress, Salt Lake City, Utah, June 27-July 1, 2004.

[10] America Public Health Association. *Standard Methods for the Examination of water and Wastewater*. American Public Health Association/American Water Works Association/Food safety and Inspection Services: Washington, DC, 2008.

[11] United States Department of Agriculture Food Safety and Inspection Service. Most probable number procedures and tables: Laboratory Guide Book. pp. 5-8, United States Department of Agriculture Food Safety and Inspection Service, Washington, June 2014.

[12] Ma, H, Zhongli, P, Mengxiang, G and Lin, L. "Efficacy in Microbial Sterilization of Pulsed Magnetic Field Treatment" International Journal of Food Engineering, Berkeley Electronic Press, Vol. 4 2008.

[13] Li, M, Qu, J and Peng, Y. "Sterilization of Escherichia coli cells by the application of pulsed magnetic field". Journal of Environmental Science, VOL 16, pp. 348-352, 2004.

[14] Molouk, MKA and Amna, ANS. "The effect of magnetic field on the physical, chemical and microbiological properties of the lake water in Saudi Arabia". .Journal of Evolutionary Biology Research, VOL **2**, pp. 7-14, 2010.

[15] Johan, S, Fadil, O and Zularisham, A. Effect of Magnetic Fields on Suspended Particles in Sewage. Malaysian Journal of Science, 23: 141-148, 2004.

[16] Maheshwari, BL and Grewal, HS. Magnetic treatment of irrigation water: its effects on vegetable crop yield and water productivity. Agriculture and Water Management, 96: 1229-1236, 2009.

[17] Tomska, A, Wolny, L. Enhancement of biological wastewater treatment by magnetic field exposure. Desalination 222, 368-373, 2007.

[18] Smothers KW, Curtiss CD, Gard BT, Strauss RH and Hock VF. Magnetic Water Treatment Public Works Technical Bulletin, 420:34-449, 2001.