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Physico-chemical and bacteriological quality assessment of shallow wells in Kitui town, Kenya

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Kitui town, a small but fast growing town in arid south-eastern Kenya faces unreliable water supply and residents are highly dependent on shallow wells as the main source of water for domestic use. A study was carried out to assess the physical-chemical and bacteriological quality of water from shallow wells within the town's main residential areas. 96 water samples were collected from 8 main residential estates within the town between May and July 2011 and analysed for physical-chemical characteristics and bacterial quantity and species. Water analysis revealed presence of 9 pathogenic genera including *Salmonella, Escherichia coli, Vibrio, Listeria, Staphylococcus, Streptococcus, Enterobacter, Klebsiella* and *Pseudomonas*. Multiple-tube fermentation technique was used to enumerate coliform bacteria in water. Total aerobic bacterial load ranged from 3.70 $x10^2$ to 2.352 $x10^3$ CFU/ml. *E. Coli* was isolated from Majengo and Mjini estates only and the bacterial load estimated as 1.10 $x10^2$ CFU/ml and 0.20 $x10^2$ CFU/ml respectively while *Salmonella* sp. was isolated from water samples from Kunda Kindu, JICA and Mjini estates. Conductivity and pH levels were above World Health Organization acceptable levels for drinking water in all samples. All samples tested did not meet the WHO bacteriological standards for drinking water. The presence of *Salmonella, Vibrio, Listeria* and *E. Coli* should particularly raise serious public health concerns over the quality of the town's shallow wells water. Intervention measures including creating awareness and educating residents on shallow well construction, citing and care, boiling of water and improving sanitation should be urgently instituted. There is also need to construct sewerage works for the rapidly expanding Kitui town to reduce incidences of contamination from septic tanks.

Key words: Kenya, Kitui town, shallow wells, water quality, bacteriology, physico-chemical characteristics.

INTRODUCTION

The majority of the populations in developing countries are not adequately supplied with potable water and are thus compelled to use water from sources like shallow wells and boreholes that render the water unsafe for domestic and drinking purposes due to high possibilities of contamination (WHO 2006, 2011). In Kenya, only a minority of residents draw their water from piped municipal supplies. Even in Nairobi and Mombasa, the two major cities, less than half the population rely on piped water, with the remainder drawing from boreholes, rivers and water vendors (Kimani-Murage and Ngindu, 2007). Risks of water borne diseases are therefore a major public health concern in Kenya's urban areas. Provision of safe drinking water and sanitation are thus some of the major challenges rapidly expanding urban centres face and have been recognized as some of the

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major developmental challenges facing the country in meeting the Millennium Development Goal of reducing by half the proportion of people without sustainable access to safe drinking water by 2015 (www.vision2030.go.ke,). The increasing human population is likely to exert even a higher pressure on provision of safe drinking water to urban centres in developing countries (Jamieson *et. al*., 2004). Groundwater is a reliable source of water supply, because it is often unpolluted due to restricted movement of pollutants in the soil profile.

However, shallow and permeable water table aquifers are most susceptible to contamination (Adejuwon and Mbuk, 2011). Water pollution results in transmission of infectious diseases such as cholera, diarrhoea and typhoid (Nassinyama *et. al*., 2000). Thus, contamination of drinking water from any source is of primary importance due to the danger and risk of water diseases. In 1997, the World Health Organization (WHO) reported that 40% of deaths in developing nations occur due to infections from water related diseases and an estimated 500 million cases of diarrhoea, occurs every year in children below 5 years in parts of Asia, Africa and Latin America (WHO, 2011).

Domestic pollution of drinking water sources may involve seepage from broken septic tanks and pit latrines. Agricultural pollution emanates mainly from irrigation water and run off water after rains, carrying fertilizers, pesticides, herbicide and faecal matter (Kumasi *et. al*., 2011). The main bacterial microorganisms of concern in contaminated water include *Salmonella* sp., *Shigella sp., Escherichia coli* and *Vibrio cholera* (Rajendran *et. al.,* 2006). The presence of faecal coliforms or *E. Coli* has been widely used as an indicator for the presence of any of these waterborne pathogens (Ibe and Okplenye, 2005; Kelly *et. al*., 1997; Rajendran *et. al.,* 2006). The World Health Organization (WHO) recommends that no faecal coliform be present in 100ml of drinking water (USEPA, 2001). Since identifying pathogenic organisms in the water is extremely difficult, unreliable and not routinely undertaken as a laboratory procedure, the presence of the indicator organisms, which may be associated with pathogenic organisms is usually determined. Presence of *E. coli,* a common intestinal bacterium, indicates presence of faecal contamination and the possibility of contamination by pathogenic microorganisms (Rajendran *et. al*., 2006).

Kitui lies, for most part, at elevations of 2000 to 4000 feet between the coastal plain and the highlands to the west. The central part of the district is characterised by hilly ridges, separated by low lying areas between 600 and 900 metres above sea level (Lasage *et. al*., 2007). There are no permanent streams and during wet periods the district is drained by 'sand rivers' the largest of which, Tiva and Kyua, barely reach the Tana river. Approximately 555,000 people inhabit the district and the growth rate is estimated to be 2.2 percent a year (Loon and Droogers, 2007). The town and the surrounding villages are supplied by the Masinga reservoir and several privately constructed shallow wells within residential 'plots'. The sewage from the town is disposed of as surface water flow. About 80% drains into river Kalundu close to Kitui town and 20% infiltrates to the groundwater. Although the World Health Organization (WHO) recommends that boreholes and shallow wells should be located at least 30m away from latrines and 17m from septic tanks (Chukwurah, 2001) in Kitui town, shallow wells are usually located within 'plots' where the residential houses are at distances certainly much less than 17m from the house's drainage system and are therefore susceptible to cross contamination from the sewerage systems. The unreliable water supply within Kitui town has forced residents to increasingly depend on shallow wells as the main source of water for domestic use. Approximately 85% of the town's residents regularly or occasionally depend on such shallow wells as the main source of water. These underground water supplies are usually considered safe provided they are properly located, constructed and operated according to the World Health Organization Guidelines for Drinking Water (Okonko *et. al*., 2008; Macharia, 2010). While recent studies have involved water evaluation and planning systems and water quality within the wider Kitui County, (Loon and Droogers, 2006) no published work has evaluated the quality of the town's shallow wells water. To safeguard the health of residents, it is imperative that the quality of the water be ascertained. The overall goal of this study was therefore to determine the potability of water from shallow wells located in Kitui town, Kenya, by pursuing the following specific objectives:

i. determining the incidence, density and bacterial species composition of shallow wells in Kitui town,
ii. assessing the physical and chemical quality of water in shallow wells in Kitui town and,
iii. comparing the levels of bacterial contamination between shallow wells located in different parts of the town.

MATERIALS AND METHODS

Sampling site

Kitui town is located at located at 1.37° South latitude, 38.02° East longitude and about 1152 meters altitude above the sea level. Samples were collected from the following main residential estates of Kitui town: Kunda Kindu, Kalundu, Majengo, Bondeni, California, Mjini, JICA and Valley view.

Sample collection and treatment

Water samples were collected weekly from May to July

2011. Samples were collected from the 8 residential estates on the same day during the study period using sterilized 500ml Duran Scott bottles. Distance between the shallow well and closest septic tank/toilet was measured. Samples were immediately transported to the laboratory and were analysed within three hours of collection. The following physical-chemical parameters were determined *in situ* at the time of sample collection, pH, Temp, ^{0}C and Conductivity, µS/cm. Ca_2CO_3 (mg/l) and Cl^{2-} (mg/l) were determined by titration while NH_4^{2+} (mg/l), PO_4^{2-} (mg/l), NO_3^- (mg/l) and SO_4^{2-} (mg/l) were determined by spectrophotometry.

Total bacterial count

The spread plate method was used. Water samples were diluted serially using 1ml pipettes and 9ml sterile physiological saline. Aliquots of 0.1ml of water sample and water at 10 and 100 times dilutions were plated on nutrient agar. The plates were incubated at 37^{0}C for 24 hours before enumeration. Total bacteria were enumerated as Colony Forming Units (CFU/ml) using the formula:

N x D x V = CFU/ml (Bednarski, 2006).
Where;
N= Number of colonies
D= Dilution factor
V= Volume factor

Enumeration of *E.coli*

Presumptive coliform test was performed using Oxoid broth. Three sets of tubes were inoculated with 10ml, 1ml and 0.1ml of water samples. The tubes were incubated at 37^{0}C to 44^{0}C for 24 to 48 hours and examined for acid and gas production. Acid production was determined by colour change of the broth from reddish purple to yellow and gas production confirmed by gas entrapment in the tube. Confirmed test was performed by transferring a loop of culture from a positive tube into a tube of Brilliant Green Lactose Bile (BGLB) with Durham tubes. The tubes were incubated at 37^{0}C for 24 to 48 hours for total coliform and 44^{0}C for faecal coliform and observed for gas production. The completed test was performed to confirm if the colony was *E.coli*. A loop of the broth from a positive tube was streaked onto Eosin Methylene Blue (EMB) agar plates. The plates were incubated at 37^{0}C for 24 to 48 hours. Based on cultural and morphological characteristics and biochemical tests, the colonies were identified as coliform or faecal coliforms (*E.coli*). For faecal coliforms, colonies with green metallic sheen were Gram stained and the IMViC Test was carried out on Nutrient agar stock cultures and used to confirm presence of *E.coli*.

Identification of bacterial isolates

Stock cultures of the isolates with different cultural characteristics were made on nutrient agar. Gram staining was used to identify bacteria based on morphological characteristics. Oxidase, motility, catalase, urease, coagulase, indole, methyl red and citrate utilization tests (Bednarski *et. al*., 2006) were performed to confirm presence of bacteria based on chemical reactions.

RESULTS AND DATA ANALYSIS

Physical-chemical quality of shallow wells water

The results of the physiochemical analysis of the water samples of the selected wells are shown in Table 1. All the water samples were colourless. The pH values of the samples ranged from 5.7 to 6.6. Chloride, nitrate, and sulphates ranged from 9.92 to 127.74 mg/L, 0.03 to 0.67 mg/L, and 2.56 to 53.27 mg/L, respectively. pH and conductivity as well as concentration of Ca_2CO_3 were all above the acceptable WHO values for drinking water in all samples. The concentration of chloride although not considered a water quality parameter was also consistently high in all samples making the water taste salty. Concentration of phosphates, sulphates, nitrates and ammonia showed varying concentrations between estates but were generally within acceptable levels.

Location of shallow wells

The distance of septic tanks/pit latrine from shallow wells varied from less than 10m in Bondeni, Majengo and Mjini estates and 11 to 23m in the other five estates (Table 2). The depth of the wells ranged between 5 and 25M.

Identification of bacterial isolates

Water analysis revealed presence of 9 pathogenic genera including *Salmonella, Escherichia coli, Vibrio, Listeria, Staphylococcus, Streptococcus, Enterobacter, Klebsiella* and *Pseudomonas* and 3 non pathogenic bacteria (Tables 3 and 4). Except for *E. Coli, Vibrio* sp. and *Klebsiella* sp, nearly all bacteria were identified from all the samples at frequencies ranging between 3% to 54% .

Total bacterial count

Total aerobic bacterial load was high ranging from 2.10 x10^2 to 5.300 x10^3CFU/ml. (Table 5)**.** The bacterial load however varied highly between the 8 sites. No correlation was established between distance from the wells and the bacterial load.

Table 1. Physico-chemical characteristics of water from shallow wells in Kitui town, Kenya

Parameter	Kunda-Kindu	Kalundu	Majengo	Bondeni	JICA	Mjini	California	Valley View	WHO Standard.(2006)
pH	6.2	6.1	6.0	5.8	6.5	6.1	5.7	6.6	7.0
Temp, ^{0}C	24.9	25.0	25.1	25.2	25.2	24.8	24.9	23.6	25
Conductivity, µS/cm	949	988	1055	1107	293	1186	828	245	<125
Ca_2CO_3 (mg/l)	11.48	17.81	11.93	19.74	12.75	26.42	13.13	4.52	
Cl^{2-} (mg/l)	100.86	84.53	127.74	121.96	9.92	105.54	99.50	22.07	
NH_4^{2+} (mg/l)	0.88	0.52	0.09*	0.24	0.24	1.76	0.17*	0.16*	0.2
PO_4^{2-} (mg/l)	3.10	0.34*	0.32*	0.32*	0.17*	0.13*	0.62*	0.19*	2.2
NO_3^- (mg/l)	0.67*	0.07*	0.34*	0.27*	0.03*	0.42*	0.07*	0.21*	50.0
SO_4^{2-} (mg/l)	-	49.55*	30.48*	53.27*	36.11*	41.18*	30.45*	2.56*	150

Values marked * are within the WHO (2006) accepted levels for concentration in drinking water.

Table 2: Mean distance of shallow wells from septic tanks/toilets

Residential estate	Mean distance (M)
Kunda- Kindu	12.2±3.06
Kalundu	16.0±3.97
Majengo	7.3±1.23
Bondeni	6.0±1.08
JICA	22.5±9.62
Mjini	5.0±1.60
California	17.0±4.71
Valley View	11.7±2.38

Table 3. Occurrence of bacterial genera in shallow wells within 8 residential estates in Kitui town, Kenya

Genus	Kunda-Kindu	Kalundu	Majengo	Bondeni	JICA	Mjini	California	Valley View
Pseudomonas Sp.	0.19	0.40	0.14	0.32	0.30	0.41	0.19	0.54
Proteus Sp.	0.19	0.03	0.05	0.05	0.09	-	0.05	-
Salmonella Sp.	0.10	-	-	0.17	0.05	-	0.03	
Lactobacillus Sp.	0.06	0.11	0.05	0.18	-	0.10	0.32	0.05
Bacillus Sp.	0.10	0.14	0.23	0.09	0.04	0.08	0.24	0.14
Listeria Sp.	0.03	0.06	0.03	-	-	0.08	0.05	0.08
Staphylococcus Sp.	0.13	0.09	0.03	0.14	0.13	0.05	0.02	0.05
Streptococcus Sp.	0.06	0.03	0.22	0.14	0.04	0.05	0.05	0.08
Enterobacter Sp.	-	0.06	0.05	0.05	0.08	-	-	-
E. coli	-	-	0.03	-	-	0.03	-	-
Vibrio Sp.	0.10	-	-	-	-	-	-	-
Klebsiella Sp.	-	0.06	-	-	-	-	-	-

E. coli count

E. Coli was isolated from Majengo and Mjini estates only and the bacterial load estimated as 1.10×10^2 CFU/ml and 0.20×10^2 CFU/ml respectively.

DISCUSSION

Increase in human population has exerted an enormous pressure on the provision of safe drinking water especially in developing countries. Provision of adequate and high quality water as well as protecting and conserving scarce water resources is therefore one of the greatest challenges currently facing national and regional governments (Jamieson *et. al*., 2004). Water and sanitation is one of the major pillars of development identified by the Kenya government (www.vision2030.go.ke). The quality of drinking water is determined by both its physical and biological characteristics. In this study, physical-chemical analysis

Table 4: Biochemical characterization and possible identification of bacteril isolates from shallow wells in Kitui town, Kenya

Isolate	Gram stain	Morphology	Motility	Oxidase	Catalase	Urease	Coagulase	Indole	Methyl red	Citrate	Probable identification
1	-	Rods	+	+	+	-	-	-	-	-	*Pseudomonas Sp.*
2	-	Rods	+	-	+	+	-	+	+	-	*Proteus Sp.*
3	-	Rods	/	-	/	-	/	/	/	/	*Salmonella Sp.*
4	+	Rods	/	/	-	/	/	/	/	/	*Lactobacillus Sp.*
5	+	Rod	/	/	/	/	/	/	/	/	*Bacillus Sp.*
6	+	Rods	/	/	+	/	/	/	/	/	*Listeria Sp.*
7	+	Cocci	-	-	+	-	+	-	+	-	*Staphyloccus Sp.*
8	+	Cocci	/	/	-	/	/	/	/	/	*Streptococcus Sp.*
9	-	Rods	+	-	+	-	-	-	-	+	*Enterobacter Sp.*
10	-	Rods	+	-	+	-	-	+	+	-	*E. coli*
11	-	Rod	/	+	/	/	/	/	/	/	*Vibrio Sp.*
12	-	Rods	-	-	+	+	-	-	-	+	*Klebsiella Sp.*

Table 5: Total aerobic bacteria load in 8 main residential estates in Kitui town, Kenya

Residential estate	Mean total bacteria (CFU/ml)	Range
Kunda-Kindu	$1.71x10^3$	$6.80 x10^2$ – $3.000 x10^3$
Kalundu	$2.034x10^3$	$1.200 x10^3$ – $5.300 x10^3$
Majengo	$2.352x10^3$	$3.50 x10^2$ – $4.500 x10^3$
Bondeni	$4.740x10^2$	$3.00 x10^2$ – $7.40 x10^2$
JICA	$3.70 x10^2$	$3.70 x10^2$ – $4.00 x10^2$
Mjini	$4.870 x10^2$	$2.10 x10^2$ – $8.40 x10^2$
California	$1.710 x10^3$	$5.70 x10^2$ – $3.000 x10^2$
Valley View	$7.80 x10^2$	$3.20 x10^2$ – $9.10 x10^2$

revealed presence of high concentrations of chloride in water from the shallow wells which is manifested through the saltiness of water from wells. Various nutrients also occurred in concentrations above acceptable WHO levels in various estates. The water quality of shallow wells in Kitui town is therefore poor in terms of one or several physical and chemical parameters investigated. Water intended for drinking should contain no detectable *E. Coli* or any thermotolerant coliform bacteria. In this study *E. coli* was isolated from samples from Mjini and Majengo estates ('Mjini' and 'Majengo' are Swahili words for town and informal settlements, respectively). These two estates also harbour the highest concentrations of septic tanks that serve the various business premises and residences. These facilities are also the oldest in town. Chances of bacterial transfer to shallow wells due to seepage are therefore highest here. The conditions found in Mjini and Majengo estates are particularly conducive to facilitating fecal contamination of ground water. While (WHO, 2006) recommends that there should be an adequate lateral separation between the pit latrine and the well to reduce chances of fecal contamination of the ground water, the mean distance between the pit latrines/septic tanks in Mjini and Majengo were only 5.0±1.6M and 7.3±1.2M respectively . This could account for the presence of E. coli in shallow wells from the two estates. Owing to the fecal contamination, there is a high possibility of the presence of disease pathogens in the water. Salmonella sp. was also isolated from water from Mjini residential estate. The presence of E.coli, Vibrio, Listeria and Salmonella sp. not only makes the water unsuitable for human consumption, but also poses serious health concerns. The presence of these pathogenic micro organisms predispose the residents to diseases such as typhoid, cholera and dysentery. Water from Mjini estate can thus be considered as the most unsuitable for human consumption within Kitui town. The lack of storm drainage system within Kitui town could aid in contamination of the wells from surface run off resulting from flash storm events.

Overall the findings of this study suggest that shallow wells, the most reliable source of water for domestic use in Kitui town are both chemically and bacteriologically contaminated and are not suitable for human use without further processing. Numerous studies also attest to the generally poor quality of water from similar water sources in the tropics (Kimani-Murage and Ngindu, 2007; Adejuwon and Mbuk, 2011; Okonko et al., 2008; Kumasi et. al., 2011; Ahamefula, 2011; Macharia, 2010) attributed to pollution from widespread and indiscriminate human and animal defecation and general poor sanitation. None of the shallow wells studied met the (WHO 2006, 2011) chemical and /or bacteriological standards for drinking water.

Several factors could possibly contribute to this state of affairs. The location of septic tanks and/or toilets close to the shallow wells could be one of the factors contributing to contamination of the shallow wells. This raises the risk of contamination of the water sources as coliforms migrate from the pit latrines to the wells. The WHO recommends that the distance between such shallow wells and pit latrines or septic tanks be at least 30m. Although all wells sampled in this study were located less than 30m from the septic tanks, no correlation was established between the distance between shallow wells and septic tanks and the bacterial load. Other factors including well-toilet orientation, age of the well, topography and overall sanitation could therefore also play a role in determining bacterial contamination of the wells. In this study it was observed that most wells were not properly secured thus exposing them to contamination from animal wastes as well as surface runoff. Public health interventions to improve the water quality including boiling, chlorination and use of ceramic filter technology as well as improving the overall sanitation within the residential areas should be instituted. Improving sanitation has been shown to have greater impacts as it leads to improvement of the quality of the water at the source (Esrey, 1996). Further interventions should also include providing technical advice on proper well construction including installation of pumps, well citing, monitoring and decommissioning unsanitary wells.

Conclusion

The results of this study strongly suggest that the bacteriological and chemical quality of shallow wells in Kitui are poor and do not meet the WHO guidelines for drinking water quality for various parameters. This poses serious public health concerns to unsuspecting water users. To safeguard the health of the town's residents, intervention measures including creating awareness and educating residents on shallow well construction, citing and care, boiling of water and improving general sanitation should be urgently instituted. There is also need to construct sewerage works for the rapidly expanding Kitui town to reduce incidences of contamination from septic tanks. Further studies should aim at identifying specific sources of pollution, monitoring seasonal changes in bacterial incidences and correlating this to outbreaks of waterborne diseases in the town.

RECOMMENDATIONS

To obtain data that can form the basis of a comprehensive public health intervention programme, there is need to incorporate not only biological and chemical data as presented in this study but also socio-economic information including sources and methods of treatment of domestic water, the type of toilet facility used, methods of human waste disposal, the perceptions of possible sources of water contamination in the area as well as data on age, methods of shallow well construction and maintenance.

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REFERENCES

Adejuwon JO, Mbuk CJ (2011). Biological and physiochemical properties of shallow wells in Ikorodu town, Lagos Nigeria. J. Geol. Min. Res., 3(6), 161-168.

Ahamefula AC, Onyekuru SO (2011). A Comparative Assessment of the Physico-Chemical and Microbial Trends in Njaba River, Niger Delta Basin, Southeastern Nigeria. J. Wat. Res. Prot., 3, 686-693.

Bednarski A, Kranz R, Weston-Hafer K, Richards E (2006). Identifying

Unknown Bacteria Using Biochemical and Molecular Methods. Washington University in Saint Louis, 2006.
Chukwurah EI (2001). Aquatic Microbiology. Otoba Press Limited, Onitsha. Nigeria. 2001.
Esrey SA (1996). Water, waste, and well-being: a multi-country study. American Jnl. Epidemiol., 143: 608-623.
Ibe SN, Okplenye JI (2005). Bacterial analysis of borehole water in Uli, Nigeria. Afr. Jnl. Appl. Zool. Env. Biol., (7): 116-119.
Jamieson R, Gordon R, Joy D, Lee H (2004). Assessing microbial pollution of rural surface waters: A review of current watershed scale modelling approaches. Agr. Water Manage., 70: 1-17.
Kelly PB, Ndubani KS, Nchito P, Luo NA, Feldman RA, Farthing MJ (1997). Cryptosporidiosis in adults in Lusaka, Zambia and its relationship to oocyst contamination of drinking water. Jnl. Infect. Dis., 176: 1120-1125.
Kimani-Murage EW, Ngindu AM (2007). Quality of Water the Slum Dwellers Use: The Case of a Kenyan Slum. J. Urban Health 84(6): 829-838.
Kumasi CT, Kwasi O, Ephraim JH (2011). Microbial quality of water in Barekese reservoir and feeder streams in Ghana. Lakes and Reservoirs: Res. Manage., 16: 49-60.
Lasage R, Aerts J, Mutiso GCM, De Vries A (2007). Potential for community based adaptation to droughts: Sand Dams in Kitui, Kenya. ScienceDirect, Elsevier).
Loon VA, Droogers P (2006). Water Evaluation and Planning systems in Kitui, Kenya. http://www.futurewater.nl/watmansup,
Macharia PW (2010). Microbial quality of drinking water and its effect on health in sub-saharan Africa: A survey of Njoro town, Kenya. MSc. Thesis. Institute of Limnology, Austria, 2010.
Nassinyama GW, McEwen SA, Wilson JB, Waltmer-Tower D, Gyles CL, Opuda J (2000). Risk Factors for Acute Diarrhoea among inhabitants of Kampala District Uganda. S. Afr. Med. J., 90(90): 891-898.
Okonko IO, Adejoye OD, Ogunnusi TA, Fajobi EA, Shittu OB (2008). Microbiological and physicochemical analysis of different water samples used for domestic purposes in Abeokuta and Ojota, Lagos State, Nigeria. Afr. J. Biotechnol., 7(3): 617-621.
Rajendran P, Murugan S, Raju S, Sundararaj T, Kanthesh BM, EV Reddy (2006). Bacterial analysis of water samples from Tsunami hit coastal areas of Kanyakumari district, India. Ind. Jnl. Med. Microbiol., 24(2): 114-6.
USEPA (2001). Current Drinking Water Standards . United States Environmental Protection Agency. Washington,DC.
World Health Organization (2006). Guidelines for Drinking Water Quality. First Addedum to 3rd Edition, vol. 1. Geneva. WHO press, 2006. 515pp.
World Health Organization (2011). Guidelines for Drinking Water Quality. 4TH Edition. WHO press, 2011. 564pp. ISBN 978 92 4 154815.