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Full Length Research Paper

Quality of groundwater in Valikamam area, Jaffna Peninsula, Sri Lanka

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The Jaffna Peninsula depends largely on groundwater resources for domestic as well as agricultural purposes. On several instances, it was pointed out that the groundwater is deteriorating due to overuse and is polluted by excessive usage of agrochemical, fertilizers, waste oil and improper sewage disposal. Hence, an experimental study was undertaken to assess the analysis of groundwater quality. To achieve this, water samples were collected from the area around the Power Station, Chunnakam. All selected 16 wells were contaminated with coliforms. Tested chemicals concentrations are not in risk level even though Average Nitrate nitrogen concentration of tested 16 well ranges from 8.2 to 29.8 mg/l with the mean value of 19.25625. However the SLS gives that the maximum permissible level of drinking water is 10 mg/l. Groundwater condition of Valikamam area, Jaffna peninsula is not much suitable for drinking purpose.

Key words: Chemical parameters, drinking water, groundwater pollution, groundwater quality, microbial contaminations.

INTRODUCTION

Groundwater is the major natural water resource in the Jaffna Peninsula and is used for home, agricultural and manufacturing purposes. The Jaffna Peninsula lies in the northern part of Sri Lanka and is dependent on groundwater for all its water requirements.

Today's vast chemical industries and their production of synthetic organic chemicals, have introduced new problems to all living organisms to get good quality drinking water. Based on this, scientists engaged in providing and protecting the Nation's supply of pure water (Middleton and Rosen, 1956). Groundwater is an extremely valuable resource and pollution of groundwater resources is a matter of serious concern. Among the major threats to groundwater from which drinking water supplies are obtained, are leachates from human and animal waste matter, along with other chemical pollutants. Agricultural leachates often contribute significantly to groundwater pollution. These originate mainly from human and animal wastes, oil contamination as well as from nitrogenous fertilizers that are often used in large quantities in agriculture.

Rapid urbanization, especially in developing countries, has affected the availability and quality of groundwater due to its overexploitation and improper waste disposal, especially in urban areas. According to World Health Organization (WHO), about 80% of all the diseases in

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Figure 1. The clear picture of the groundwater sample collection points.

human beings are caused by water. Once the ground-water is contaminated, its quality cannot be restored by stopping the pollutants from the source (Ramakrishnaiah et al., 2009).

The quality of drinking water is normally analyzed by physical, chemical, and microbiological parameters. To ensure the safety of drinking water, quality standards for physical, chemical, and microbiological parameters have been analyzed via this study. Chemical parameters of water involve pH, electrical conductivity, chloride, nitrate content, total iron, and total phosphorous. Water is thus examined for total coli forms and *Escherichia coli*.

METHODOLOGY

Microbial analysis

Location and selection of wells

Groundwater samples were collected from wells located around Chunnakam, Sri Lanka Power Station for this research study. Altogether 16 wells were selected to collect the groundwater samples. Figure 1 shows the clear picture of the groundwater sample collection points.

Determining the aerobic and anerobic bacterial count

The aerobic bacterial count in the water samples were determined by spreading plate method (Sinclair and Ghiorse, 1989). After the inoculation, it was incubated in the inverted position at 37°C for 24 h. After 24 h, the colonies were counted in each dish. Same procedure was followed for all well water samples, thereafter the total anaerobic bacterial count in the water samples were determined by Pour plate method (Aranki et al., 1969).

Testing for coliform bacteria

Multiple fermentation tube technique was used (Eckner, 1998) in testing for coliform bacteria. It is customary to report results of the multiple fermentation tube tests for coliforms as a most probable number (MPN) index. This is an index of the number of coliform

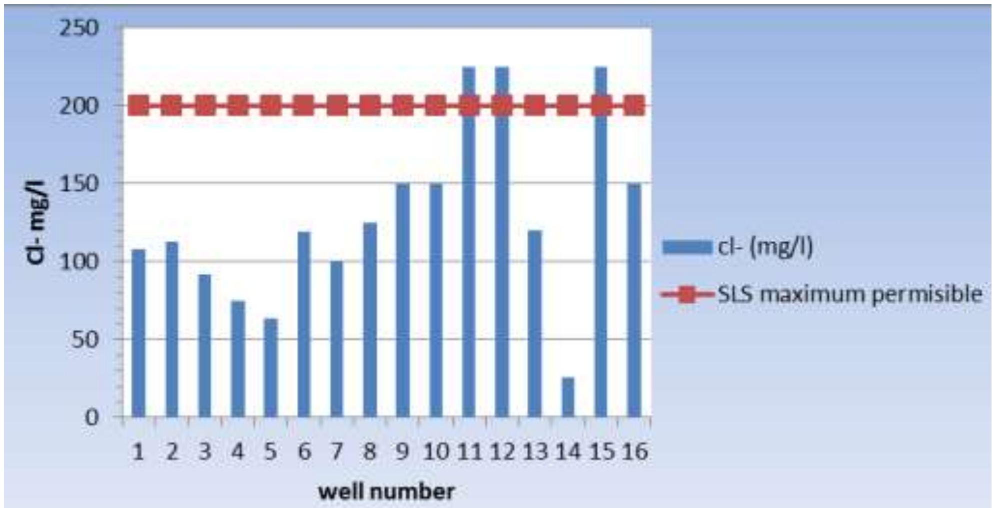

Figure 2. Chloride content of selected 16 wells.

bacteria that would more probably than any other number, give the results showing that MPN method is based on taking the original sample, dividing it by orders of magnitude and assessing presence/ absence of organisms.

Measuring chemical characters of the water samples

The chloride content was estimated by silver nitrate titration (Cotlove, 1964). The amount of chloride present in water can be easily determined by titrating the given water sample with silver nitrate solution. Cadmium reduction method was used for nitrate-nitrogen analysis (Green et al., 1982). Cadmium metals reduce nitrates in the sample to nitrite. The nitrite ion reacts in an acidic medium with sulfanilic acid to form an intermediate diazonium salt. The salt couples with gentisic acid to form an amber colour solution.

Whereas ascorbic acid method was used to measure the phosphorous (John, 1970), phenanthroline method was used to measure the iron, pH was analyzed using Thermo Orion pH meter and electrical conductivity (EC) was measured using CE470 conductivity meter.

The determination of total dissolved solids can be measured using multi meter. Total conductance is easily measured and gives results that are convenient as a general indication of dissolved solids.

RESULTS AND DISCUSSION

Chemical characteristics of water

Chloride concentration ranged from 25.927 to 225.24 mg/L. Figure 2 shows the concentration of chloride of all measured wells with Sri Lankan standards of drinking water. All tested wells results showed that 100% of well water contains chloride concentration of less than 600 mg/L. Chloride concentration in excess 250 mg/L can give rise to detectable taste in water (De Silva and Ayomi, 2004). The WHO recommended and maximum limits are 200 and 600 ppm, respectively (Dissanayake and Weerasooriy, 1985) and the action level is 250 ppm.

EC levels vary in all wells and range from 418 to 823 µs/cm. Figure 3 shows the average EC value of all sampled wells. Since the measured values of most of the wells were less than Sri Lankan permissible level of 750 µS/cm, few domestic wells had relatively high value of 824 µS/cm, which is an indication of abundant dissolved ionic species. Based on EC, 18.75% of wells are not suitable for drinking.

The total dissolved solids variation and comparison with WHO level was shown for 16 domestic wells in Figure 4. The total dissolved solids (TDS) values of selected wells water were determined as ranging from 210 to 412 mg/L. TDS values of all selected wells were below WHO level as 500 mg/L. So according to the results of TDS values, all selected wells were considered as under fresh water well (<1000 mg/L).

The physical and chemical properties of water mainly depend on the total TDS contents. Water containing more than 1000 mg/L of TDS (WHO, 2004) is generally not recommended for drinking purpose.

The average pH value variation in the 16 selected wells is as shown in Figure 5. These values were compared with Sri Lankan Standard, a result that indicates pH values of the selected domestic wells ranges from 6.69 to 7.63 which was slightly alkali. All sampled wells water were within acceptable pH values for drinking.

Drinking water with a pH between 6.5 and 8.5 is generally considered satisfactory (Sri Lankan Standards [SLS], 2013). Waters with a pH above 8.5 may have a bitter or soda-like taste. Alkalinity pH can cause several health hazardous effects to human.

According to the Sri Lankan Standards (SLS) (2013), total phosphate content must be below 2 mg/L in drinking water. The total phosphate variation and comparison with Sri Lankan Standard levels for the selected domestic

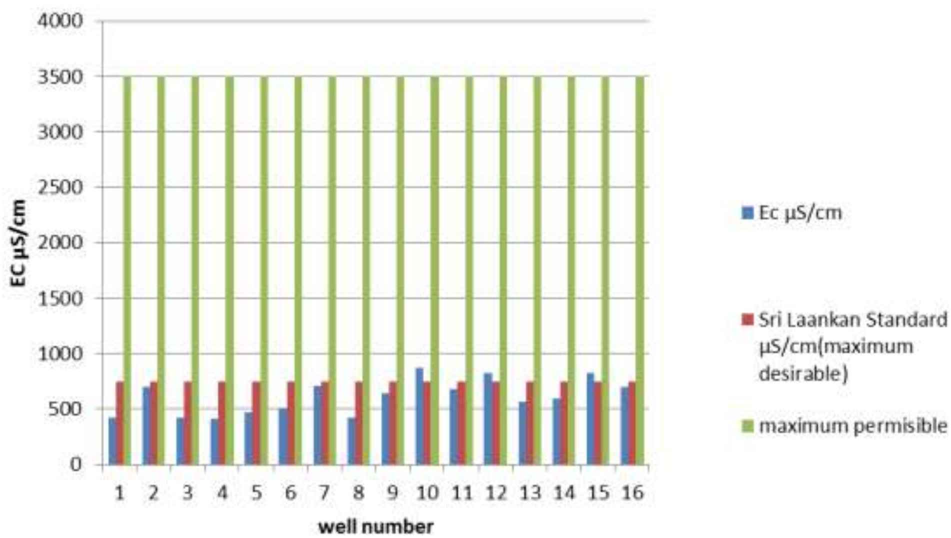

Figure 3. EC value of selected 16 wells.

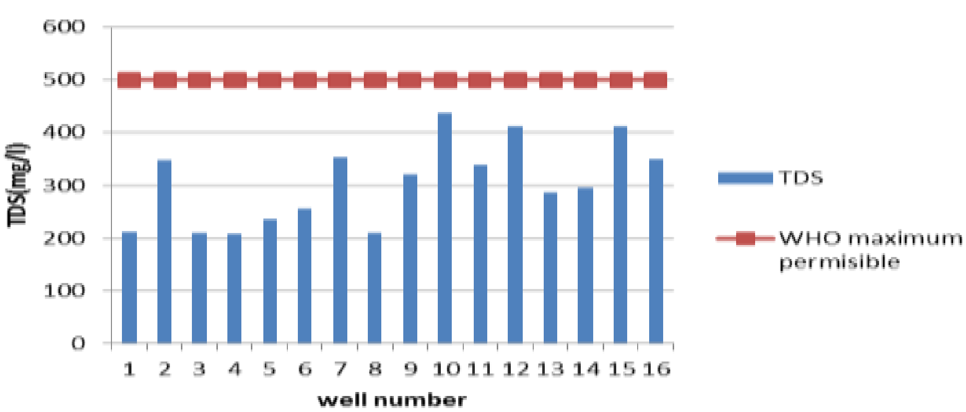

Figure 4. TDS of selected 16 wells.

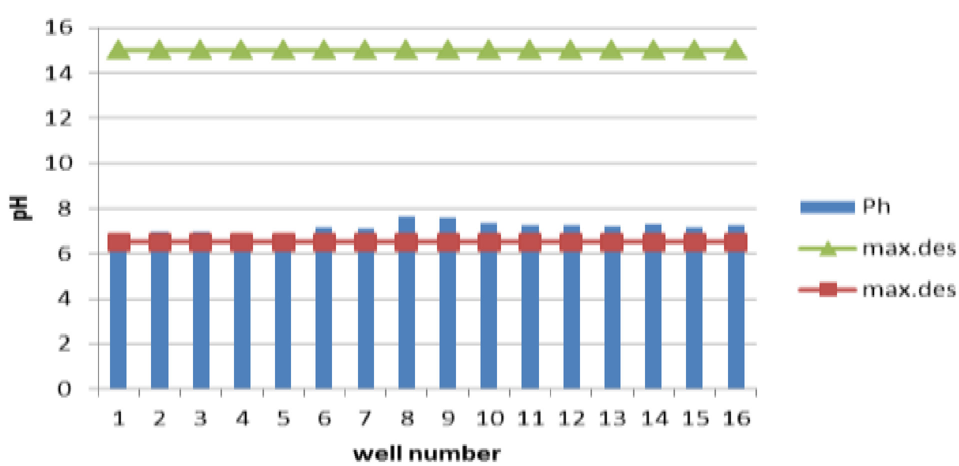

Figure 5. pH values of selected 16 wells.

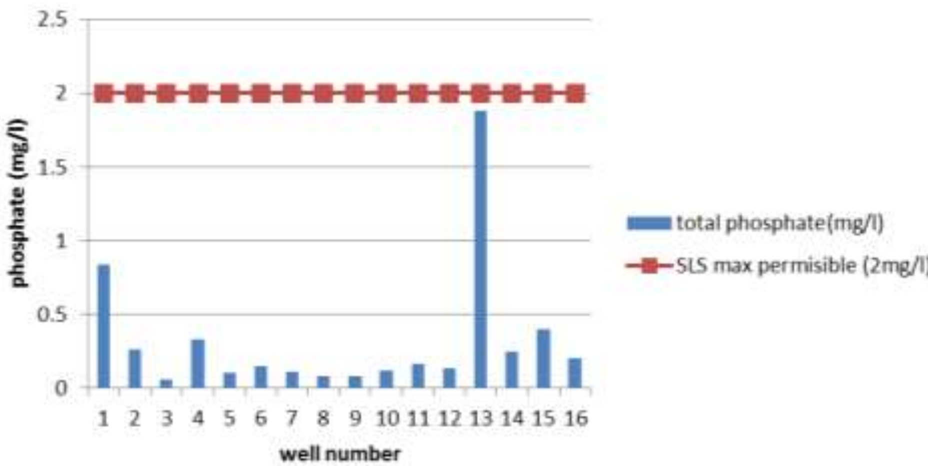

Figure 6. Phosphate content of selected 16 wells.

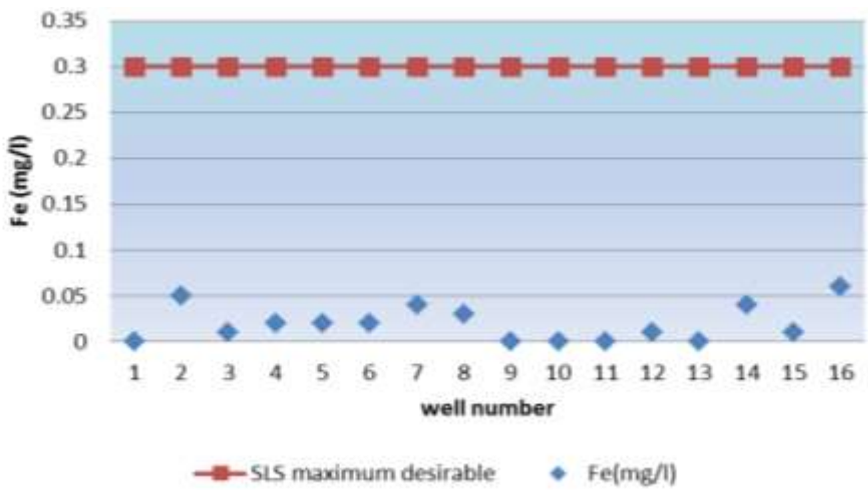

Figure 7. Total iron content of selected wells.

wells are as shown in Figure 6.

Algae may become a problem in water with more than 0.05 to 0.09 mg/L phosphate depending on other conditions. Algae blooms form in fresh water when cyanobacteria (blue-green algae) grow quickly and form scums or mats in the water. Some blooms can produce toxins harmful to people and animals (Neal et al., 2002).

Figure 7 shows the total iron content of selected wells with the comparison of Sri Lankan Standard. Drinking water iron levels should not exceed 0.2 to 0.3 mg/L, because iron can give water an unpleasant taste, odor and color. Iron causes reddish-brown stains on laundry, porcelain, dishes, utensils, glassware, sinks, fixtures and concrete. Detergents do not remove these stains; and chlorine bleach and alkaline builders (such as sodium and carbonate) may even intensify the stains (Mark and Monty, 1996). Some guidelines suggest that 0.2 mg/L is the upper limit. According to the SLS standard, all selected wells were suitable for drinking purpose.

High concentrations of nitrates may be a health problem for infants. Nitrates, in combination with phosphates are largely responsible for eutrophication, an excessive production in waterways sometimes involving blue-green algae.

For drinking water, 10 mg/L is considered the upper limit (Kross et al., 1990). In unpolluted water, nitrate is rarely above 1 mg/L, hence higher levels may indicate contamination. Nitrates are very soluble in water and adhere weakly to soils, so they are often quickly leached. Nitrate concentrations of over 20 mg/L have been recorded in most of the wells.

Average nitrate nitrogen concentration of the tested 16 well ranges from 8.2 to 29.8 mg/L with the mean value of 19.25625. However, the SLS gives that the maximum

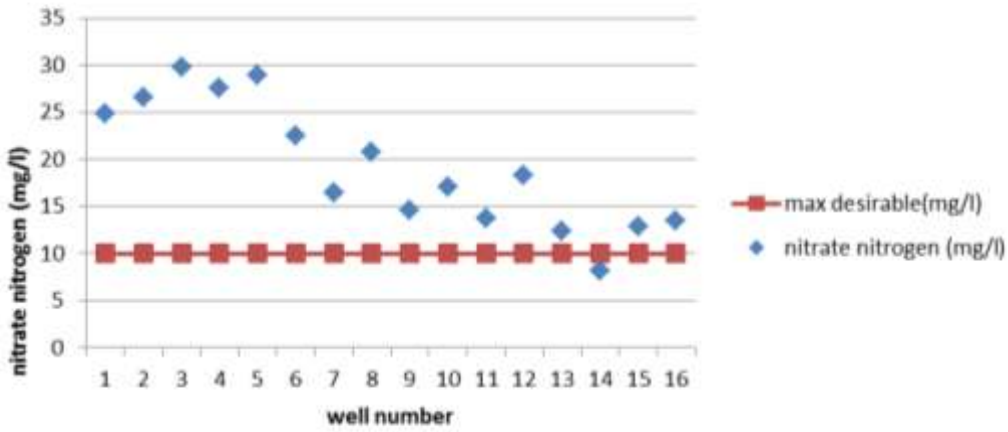

Figure 8. Concentration of nitrate nitrogen.

Table 1. Number of bacterial count in cfu/ml of 16 well.

Well number	Aerobic bacteria (cfu/ml)	Anaerobic bacteria (cfu/ml)
1	1.9×10^{6}	0
2	5×10^{5}	3×10^{5}
3	2.1×10^{6}	2×10^{5}
4	7×10^{5}	0
5	3×10^{6}	1×10^{5}
6	2.7×10^{6}	2×10^{5}
7	3×10^{5}	6×10^{5}
8	2×10^{5}	1×10^{5}
9	8×10^{5}	2×10^{5}
10	3×10^{6}	1.9×10^{5}
11	2.6×10^{6}	0
12	1.7×10^{6}	0
13	1.5×10^{6}	1×10^{5}
14	9×10^{5}	2×10^{5}
15	2.8×10^{6}	1×10^{5}
16	2.3×10^{6}	2×10^{5}

permissible level of drinking water is 10 mg/L. Most of the tested wells show that the concentration is higher than the SLS (Figure 8).

Aerobic and anaerobic bacterial counts

Table 1 shows the aerobic bacterial count present in different well water samples. Total aerobic count varied from 2×10^{5} to 3×10^{6} cfu/ml with a mean value of 1.6875×10^{6} cfu/ml. Total anaerobic bacterial count varied from 0 to 6×10^{5} cfu/ml, whereas some of the wells did not show anaerobic bacterial contamination.

The maximum acceptable concentration for bacteria is zero organisms detectable per 100 ml of water. According to the Sri Lankan Standard 894 (2003), acceptable aerobic count is from 1×10^{2} to 1×10^{4} cfu/ml. Based on the SLS requirement, all wells water were not suitable for drinking. The selected 16 wells were contaminated.

Total coliforms and fecal coliform

Total coliforms are a group of bacteria commonly found in the environment, for example, in soil or vegetation, as well as the intestines of mammals. The presence of *E. coli* in water indicates recent fecal contamination.

According to the results, all the selected wells were affected by bacterial contamination severely. No well was

Table 2. Results obtained for normal coliform and feacal coliform contaminated well water.

Well No.	10 ml	1 ml	0.1 ml	MPN/100 ml	10 ml	1 ml	0.1 ml	Remarks
1	5Ts	2Ts	2ts	94	3Ts	Ncr	Ncr	+
2	5Ts	4Ts	1ts	170	Ncr	Ncr	1Ts	+
3	5Ts	4Ts	2ts	220	5Ts	4Ts	1Ts	+
4	3Ts	4Ts	2ts	28	2Ts	1Ts	1Ts	+
5	3Ts	2Ts	1ts	17	2Ts	2Ts	1Ts	+
6	4Ts	4Ts	1ts	40	2Ts	2Ts	Ncr	+
7	3Ts	1Ts	Np	11	3Ts	1Ts	Ncr	+
8	4Ts	1Ts	Np	17	4Ts	1Ts	Ncr	+
9	3Ts	1Ts	Np	11	2Ts	1Ts	1Ts	+
10	3Ts	1Ts	Np	11	2Ts	1Ts	Ncr	+
11	3Ts	Np	Np	8	2Ts	Ncr	Ncr	+
12	3Ts	Np	Np	8	2Ts	Ncr	Ncr	+
13	1Ts	Np	Np	2	Ncr	Ncr	Ncr	-
14	3Ts	Np	Np	8	Ncr	Ncr	Ncr	-
15	3Ts	Np	Np	8	Ncr	Ncr	Ncr	-
16	3Ts	Np	Np	8	Ncr	Ncr	Ncr	-

Ts: Number of tubes give gas production and colour change; Np: no tubes give gas production and colour change; Ncr: No tubes give gas production and red ring formation with Kovac's indole reagent. +: positive; -: negative.

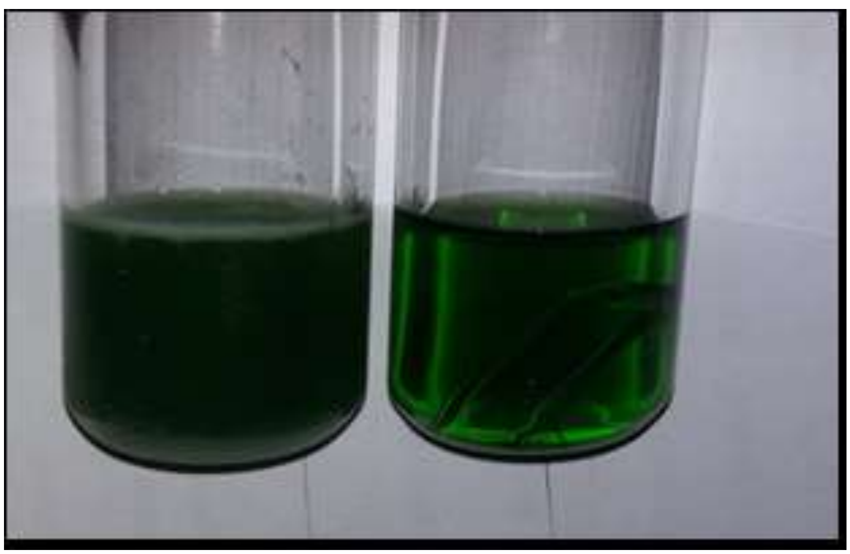

Figure 9. Colour change (green to light green) and gas production of brilliant green bile.

suitable for drinking. Well numbers 1, 2, 3 and 6 showed higher MPN/100 ml, because these wells were located very close to the toilet pits. Well numbers 13, 14, 15 and 16 were given positive results for coliform test with low number of MPN/100 ml (Table 2), however, these wells water were not given red colour ring on top of the tryptone water with Kovac's Indole reagent. This means that these wells were free from fecal coliforms contamination (Figures 9 and 10).

Conclusion

Selected 16 wells did not have the water quality problem in case of physical and chemical properties except nitrate nitrogen content. wells numbers 11, 12 and 15 have higher chloride content than maximum desirable level and other remaining wells have chloride content below this level. In the case of pH, all 16 wells have pH content between maximum desirable levels. Since measured

Figure 10. Red ring formation of tryptone broth with Kovac's Indole reagent.

values of most of the wells were less than Sri Lankan permissible level of 750 µS/cm, well numbers 10, 12 and 15 had relatively high value of 824 µS/cm. Based on EC, 18.75% of wells are not suitable for drinking. Water containing more than 1000 mg/L of TDS (WHO, 2004) is generally not recommended for drinking purpose. From this statement, all the selected wells are suitable for drinking purpose because all wells contain TDS below WHO recommended level. Total phosphate and nitrate nitrogen contents of the all selected wells are higher than recommended level except Well number 14 which contains nitrate nitrogen below maximum permissible level. All the selected 16 wells have total iron content below WHO recommended level. When considering the bacteriological contamination of wells, all wells were severely contaminated by normal coliform as well as faecal coliforms except well numbers 13, 14, 15 and 16 having only normal coliform contamination. However, the selected 16 wells at Valikamam area were not suitable for drinking water. Within those 16 wells, well numbers 2 and 3 have shown higher MPN/100 ml for normal coliform examination. This is because these wells are located close to their toilet pits.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

Evaluation of bacteriological and physicochemical quality of water supply systems in Welkite Town, Southwest-Ethiopia

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Water supply systems provide consumers with drinking water that is adequately free of microbial pathogens to prevent waterborne diseases. The key to produce water of such desired quality is to implement multiple barriers, which control microbiological pathogens and chemical contaminants that may enter the water supply system. The objective of this study was to evaluate bacteriological and physicochemical quality of water supply system in Welkite Town, southwest Ethiopia. The water samples were examined on site for total coliform and thermo tolerant coliform using membrane filtration method. Raw water samples were positive for total coliform and thermo tolerant coliform, and there was high bacteriological load in Bojebar spring source which is total coliform: 16 cfu/100 ml, thermo tolerant coliform: 8 cfu/100 ml and in balancing reservoir, there was no detection for both total coliform and thermo tolerant coliform, whereas total coliform and thermo tolerant coliform were detected in the pipeline (counted as 6 and 1 cfu/100 ml, respectively). Similarly, in the service reservoir, the result indicated 9 and 1 cfu/100 ml for both total coliforms and thermo tolerant coliforms, respectively. On the other hand, temperature at all sampling sites was above the permissible limit set by World Health Organization but pH, electrical conductivity, turbidity, total hardness and total dissolved solids were all within the permissible limit set by World Health Organization. The free chlorine residual was 0.02, 0.84, 0.67, 0.48, 0.45 and 0.1 mg/l at six different sampling points, respectively, while the sanitary survey showed that cumulative risk score of all water supply systems was 27.2, 54.5, 90.09, 45.5 and 64% from the source to distribution, respectively.

Key words: Bacteriological parameters, sanitary survey, total coliform, thermo tolerant coliform.

INTRODUCTION

Water is the most abundant chemical in the human body and plays a central role in the regulation of nutrient transport, toxic waste removal, thermal regulation and digestion, organ functioning and metabolic activities. However, if water is fecally polluted it spreads diseases in consumers to a great number of people (Alhassan and

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Kwakwa, 2014). The quality of drinking water is very essential for public health and primary concern of people living in developing countries is obtaining clean drinking water. Pollutants in drinking water threaten survival of the human species. Expanding urbanization, industrial operations and agricultural production have resulted in complex inter-relationships between socioeconomic factors and natural hydrological and ecological conditions. The availability of safe drinking water is thus becoming an ongoing challenge (Alhassan and Kwakwa, 2014; Diduch et al., 2013). The quality of drinking water may be controlled through a combination of protection of water sources, control of treatment processes and management of the distribution and handling of the water (Diduch et al., 2013). Standard drinking water treatment includes coagulation/flocculation, sedimentation, filtration and disinfection.

Groundwater is the major source of drinking water in Ethiopia. More than 80% of the country's drinking water supply source is from ground water (Nakade, 2013). The water supply system of Welkite town was established in 1989 when a borehole was drilled in the town and connected to a 30 m^3 elevated steel tanks. However, the present daily water yield of Welkite town from the spring source (Bojebar) is estimated to be 150 L/s in dry season and it reaches 200 L/s in wet season .The Welkite water supply treatment plant, which is the major tap water supplier in Welkite town and the neighboring Woreda, provides the current production 3801.6 m^3/day in 18 h pumping. The drinking water supply system serves about 54,946 for Welkite town and the rural areas. The current water supply system in Welkite town comprises the following major components: Bojebar spring source, rising and gravity mains, pump sand electro-mechanical equipment, treatment facilities, service reservoirs, distribution network to newly developed and future expansion areas, operation buildings at intake, pump station, guard house and fences (Solomon, 2011). This study provides baseline information on the quality and quantity of drinking water of Welkite town and provides a framework to sanitary situation for the water supply system, major operational or treatment problems that may enhance the possible contamination (Verma et al., 2012). Besides, it provides relationships between physicochemical parameters like temperature, pH, free residual chlorine and turbidity and with bacteriological parameters such as total coliform and thermo tolerant coliform/fecal coliform on the treatment plants (Rao et al., 2012). In addition, the study findings have provided information on the differences between treated and non-treated water in Welkite.

MATERIALS AND METHODS

Description of the study area

The Welkite Town is located at 8° 16' 50''N and 37° 46' 40''E and it is 157 km from Addis Ababa, capital city of Ethiopia (Figure 1). The water supply coverage of the town is 40% and it has surface area of 72 km^2, elevation of 1820 to 1900 m.a.s.l which receives mean annual rainfall of 1310 mm/year (Southern Nations Nationality Peoples Region, 2008).

Sampling point location and selection

Cross-sectional laboratory based study was conducted to determine the bacteriological, physical, and chemical quality of drinking water at spring sources, disinfection in the balancing reservoir, pipeline and main distribution systems, examining deficiency of treatment units, using a standard sanitary survey work sheet; interview and observational (Rao et al., 2012; Muazu et al., 2012) checklists (Figures 2 to 4). In addition, these six representative sampling sites were selected based on the rate of human interference, pipeline leakage, improper installation and agricultural activities that have been taking place along the water supply system.

Sampling methods

A triplicate of grab sampling method was conducted in which a single volume of water sample was taken once from a single point. As a result, using aseptic techniques, water samples were collected directly from the spring and five different sampling points along the flow path of the spring using 100 ml sterile polyethylene plastic bottles. The number of water samples taken were as follows: three samples from weir fenced springs water source; three samples from balancing reservoir after travelling 1.5 km; three samples from main pipeline after travelling 13 km; three samples from service reservoir and three water samples from each main distribution (Table 2). An *in situ* water quality testing kit was used to determine the microbiological quality of water. This test kit enabled water quality to be tested in line with the World Health Organization standards and Ethiopian drinking water standards. The water sample bottles were rinsed three times with source water before collecting the sample and rinsed with 70% methanol to minimize the risk of external contamination (Muazu et al., 2012), then, the microbiological analysis was carried out *in situ* so that the microbiological parameters would not change with time. An *in situ* water quality testing kit 'Hanna HI 93710 meter (Romania), HI 93703 Portable Microprocessor and turbidity meter were used to determine the physicochemical parameters of the water samples such as pH, turbidity, temperature, and electrical conductivity from the six selected sampling sites (Table 3). On the other hand, free residual chlorine, total dissolved solids and total hardness were analyzed and chemically preserved by adding 5 ml concentrated HNO_3 per liter of the sample and distilled water to avoid contamination and transported to the Federal Environmental Protection Authority laboratory using ice box (Rao et al., 2012; Muazu et al., 2012; Timilshina et al., 2012).

Bacteriological analyses

The number of total coliform and thermo tolerant coliforms was determined using membrane filtration technique. As a result, the measured volume of water sample (100 ml) was filtered under vacuum, through a cellulose acetate membrane of uniform pore and diameter of 0.45 µm and 47 mm diameters, on an absorbent cloth with diameter of 47 mm, thickness of 0.8 mm, and was capable of absorbing 2.0 ± 0.2 ml Endo broths. Indicator bacteria were retained on the surface of the membrane which was placed on a suitable selective medium in a sterile container and incubated at an appropriate temperature immediately, for total and Thermo tolerant

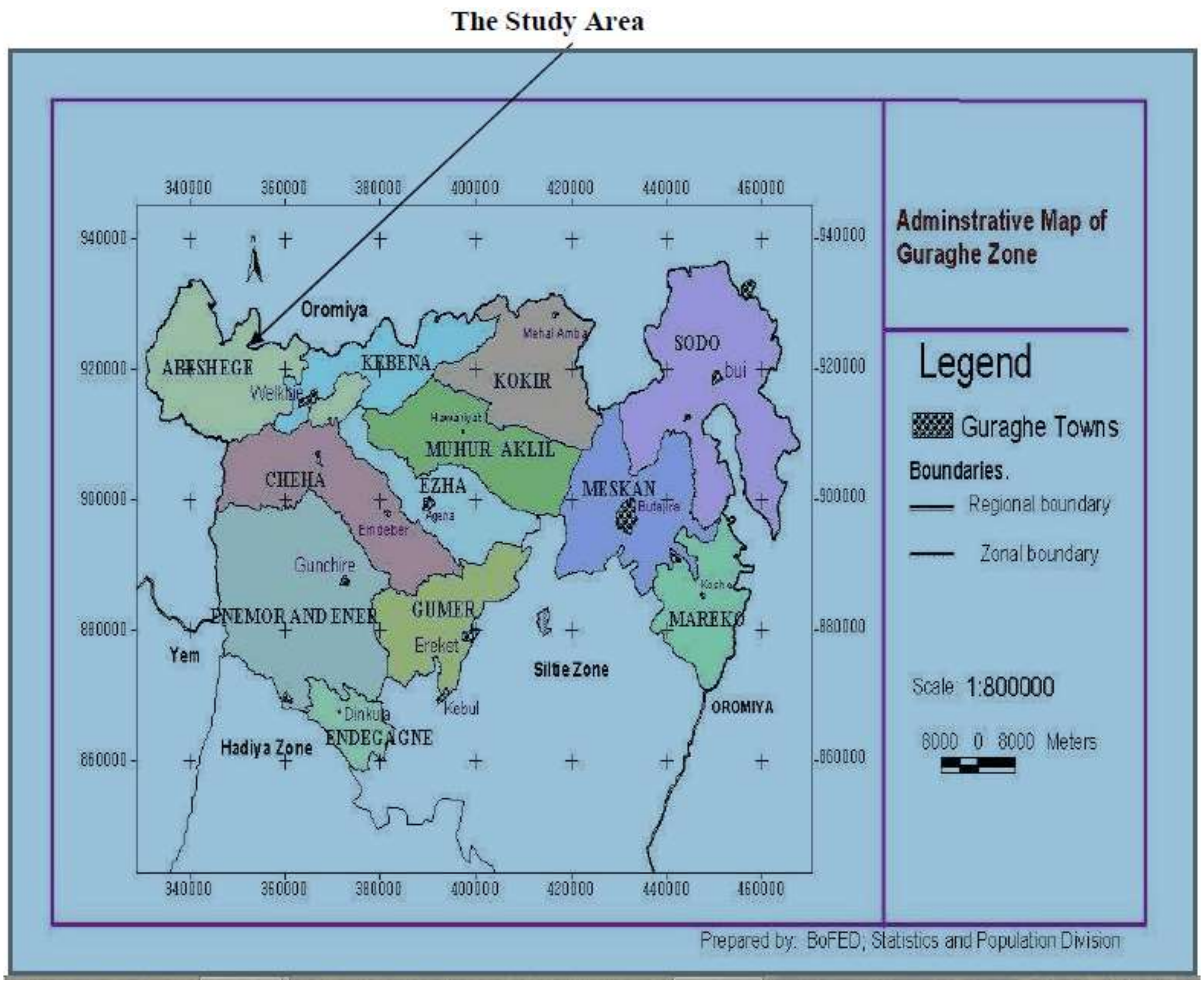


Figure 1. Map of the study area.

coliforms; it was placed at 37 and 44.5°C, respectively for 24 h while growing indicator bacteria into visible colonies and counted manually using triplicate test for consistency (Figure 3).

Physico-chemical analyses

The water sample temperature was taken on site using a thermometer calibrated in °C while turbidity was determined on site using portable microprocessor turbidity meter, HI 93703 (Hanna, Romania) pH was determined using HI 93710 meter (Hanna, Romania), and electrical conductivity was measured with a portable waterproof conductivity meter HI 9033 (Hanna, Romania) on site. On the other hand, determination of total hardness was carried out using titration methods by which EDTA was used as a , whereas total dissolved solids was carried out using gravimetric methods while free residual chlorine test has was conducted for all sites, which contain chlorinated samples. This test was done using a stable reagent in a powder form for analysis of free chlorine (Timilshina et al., 2012) (Table 3).

Sanitary survey

The on-site sanitary survey was conducted to evaluate facilities of pump stations and the treatment plant of balancing reservoir, pipeline, service reservoir and the main distribution systems. Seven checklists, each with eleven questions “yes” and “no” options for designated risks were developed to determine the sanitary risk (Timilshina et al., 2012; Tagoe et al., 2011) giving a score of one point for each “yes” answer (risk observed) and zero point for each “no” answer (no risk observed). As a result, summing all “yes” scores, a final risk score was obtained, which provided the overall assessment of the risk profile of each site. The cumulative risk score was graded as very high (81 to 100%), high (51 to 80%), medium (31 to 50%) and low (1 to 30%). In order to insure the data quality and consistency, the sanitary survey checklist was pre tested (Figure 2 and Table 4).

RESULTS

Preliminary treatment units

The purpose of preliminary treatment is to ensure a satisfactory quality of final effluent and final sludge production and to protect the treatment process. As a result of the investigation, the floating materials were

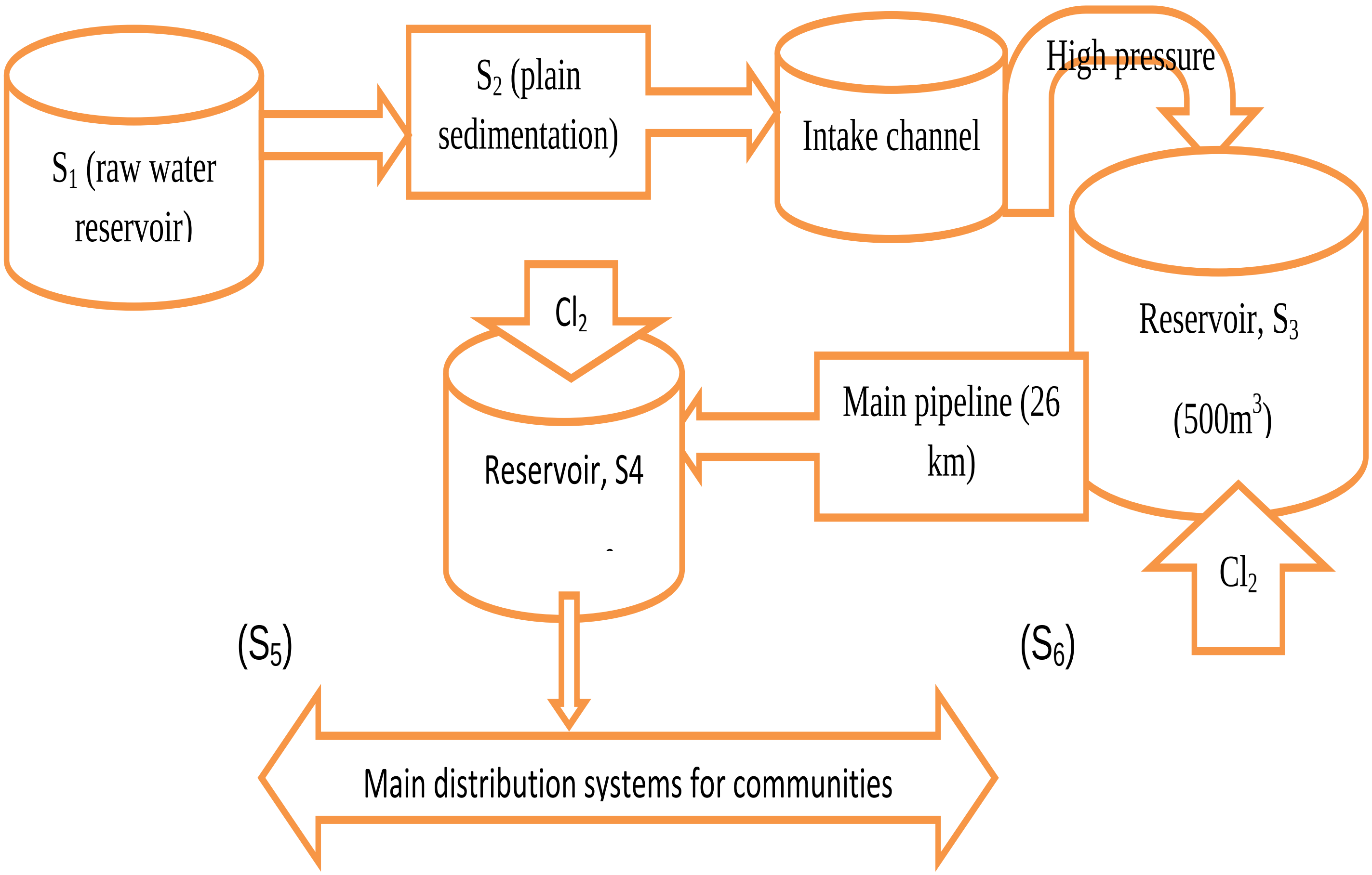
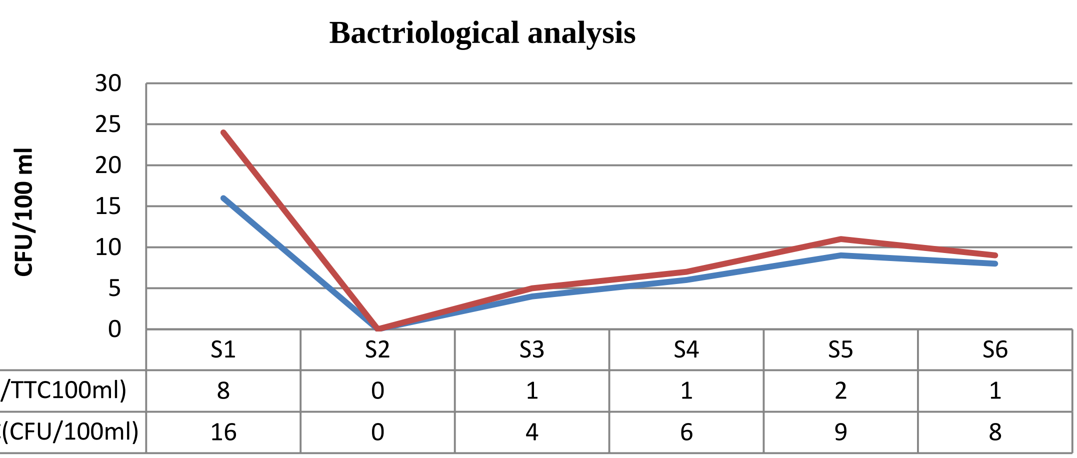


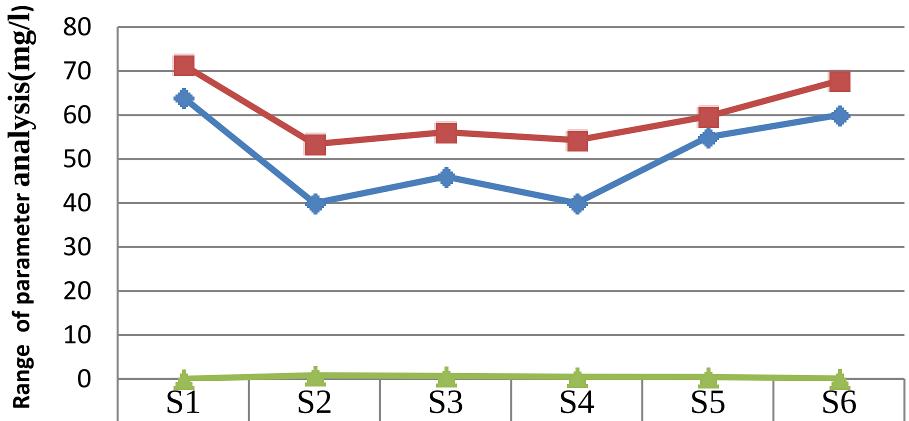
Figure 2. Typical treatment process of Welkite water treatment plant.



	S1	S2	S3	S4	S5	S6
FC/TTC100ml)	8	0	1	1	2	1
TC(CFU/100ml)	16	0	4	6	9	8

Figure 3. The mean bacteriological analysis of water samples from Bojebar spring in Welkite town.

observed and created problem for the downstream treatment process. The plain sedimentation spring pond has area of 300 m^2 and depth of 7.8 m which made it very difficult to avoid the long-standing sludge accumulation because of lack of temporary diversion ditch in the area for clearance (Tagoe et al., 2011).



	S1	S2	S3	S4	S5	S6
Total hardness	64	40	46	40	55	60
Total dissolved solid	71.4	53.4	56.1	54.3	59.7	67.8
Chorine residual	0.02	0.84	0.67	0.48	0.45	0.1

Figure 4. The mean chemical analysis of water samples from Bojebar spring in Welkite town.

Table 1. Design aspects of plain sedimentation pond, current situation.

S/N	Parameter	Plain sedimentation pond	Improved channel	Wet well	Metal screening	Functional
1	quantity	1	1	1	1	✓
2	Total area	300 m^2	90 m^2	32.5 m^3	1mx1m=1m^2	✓
3	Length	20 m	30 m	6.5 m	1m	
4	Width	15 m	3 m	5 m		
5	Depth	7.8 m	4.5 m	3 m		
6	Volume	2340 m^3	405 m^3	98 m^3		
7	Slope	5%	5%			

Table 2. The design aspects of balancing reservoir, service reservoir, valve chamber and operability.

S/N	Parameters	Balancing reservoir	Service reservoir	Valve chamber
1	Area ($A = \pi r^2$)	200.6 m^2	254 m^2	27.75 m^2
2	Type	Circular concrete structure	Circular concrete structure	Rectangular structure
3	Height(depth)	3.0 m	5.9 m	3 m^2
4	Diameter	16 m	18 m	-
5	volume ($V = \pi r^2$h)	602.88 m^3	1498.6m^3	74.25 m^3
7	Inspection time	Once in 3 month / year	Once in 3 month /year	Conditional
8	Finished water storage	-	1498.6 and 100 m^3	-

Consequently, the high accumulation of sludge in the pond led to deterioration in water supplies in terms of quality as well as quantity for consumers. Improved channel was constructed 30 m downstream from the pond, which allows the spring water flow to the proposed temporary well structure of 98 m^3. The total capacity of the channel is 405 m^3, but it allows (150 to 160 L/s) raw water flow through the channel (Table 1).

Table 3. The mean physico-chemical analysis of water samples from Bojebar spring to Welkite Town.

Parameter	Collection sites							Standard	
	Unit	S_1	S_2	S_3	S_4	S5	S_6	WHO	ES
Temperature	°C	22.6	22.9	24	23.5	25.1	26.2	15	*
pH	pH units	6.9	7.2	7.4	7.1	8.1	7.8	6.5-8.5	6.5-8.5
Conductivity	µS/cm, µmµ, S/cm	107.3	112	106.1	104	102.4	108.3		
Turbidity	NTU	1.4	0.9	1	0.1	1.3	0.7	5	5

*Not specified.

Table 4. Cumulative risk score of sanitary survey from source to distribution.

S/N	Elements	Cumulative risk score (%)
1	Raw water source protection (spring water)	27.2
2	Wet well with mechanized pumping	18.2
3	Pumps/pump facilities and control	54.5
4	Treatment process (balancing reservoir) (S_2)	54.5
5	Pipeline from source to finished storage (S_3)	90.09
6	Finished water storage (service reservoir) (S_4)	45.5
7	Distribution system (S_5 and S_6)	64

DISCUSSION

Chlorination of balancing reservoirs

The balancing reservoir is made of concrete circular structure with a capacity of 500 m^3; area of 113 m^2, height of 3 m and a diameter of 12 m. It has been provided with inlet and out let pipes, overflow pipe and vent pipes in which inlet, outlet and drainpipes have been provided with valves and has been fenced. As a result, it is not suitable for disinfection purpose as it does not allow sufficient time for the water to combine with the added chlorine and has short residence time since the incoming water leave immediately to the pipe line and to the distribution line. To this effect, a granular calciumhypochlorite $(CaOCl)_2$ containing 65 to 70% active chlorine was used to disinfect raw water at the balancing reservoir. Two calcium hypochlorite preparation tanks of 500 L, mixing motor, and gravity dozer was installed on the top of the 500 m^3 of balancing reservoir and 1 kg/500 L/d calcium hypochlorite was used. However, dosing of the dry granules or powder is not recommended since calcium hypochlorite is hygroscopic and decomposes in air to form chlorine gas. As a result, the current amount of chlorine dosed for disinfection in the balancing reservoirs is 1 kg/500 L/day or 1.33 mg/L which is within the range of USEPA standard of 0.5 to 5 mg/l (Sohani and Iqbal, 2012).

Design capacity of Welkite treatment plant

The capacity of the plant surveyed during the investigation was 3801.6 m^3/day and 136,876 m^3/year. According to the design capacity of Welkite treatment plant, nowadays, it treats only 29.3% of its design capacity; however, the current yield of raw water ranges from 12,960m^3/d to 13,824 m^3/day and 4,665,600 to 4,976,640 m^3/year which is not sufficient for the existing population of 54,946 in the town of Welkite.

Spring water reservoir

The microbiological water quality results have shown that the total coliforms and thermo tolerant coliforms were found to be 16 and 8 cfu/100 ml from the spring water reservoir. This was because the water source is unprotected from small animals like amphibian, fish and larger animal like monkey and birds, which interfere with spring water reservoir. This result compared favorably with the report of Sohani and Iqbal (2012) which indicates that the presence of bushes and shrubs make smaller mammals to come around these water bodies to drink water; thereby, passing out faeces into the water. Therefore, the average count of total coliforms and thermo tolerant coliforms in the source water were above the recommended value. On the other hand, highest values of turbidity (1.4 NTU), total dissolved solids (52.7 to 75.3 mg/l) and free-residual chlorine were observed in this reservoir which is within the recommended limits.

Balancing reservoir

The mean total coliform and thermo tolerant values were zero which are within the acceptable limit (Farkas et al., 2012) and the cumulative risk score of disinfection point was 54.5% which is in the range of 51 to 80% of high cumulative risk score. The turbidity measured at this reservoir was 0.9 NTU which is less than 5 NTU; however, the higher concentration of free residual chlorine in balancing reservoirs was attributed to the application of chlorine in the form of dissolved calcium hypochlorite.

Pipeline

In terms of total coliform and thermo tolerant coliform, the mean results in pipeline were found to be 4 and 1 cfu/100 ml, respectively, due to the leakage of old pipeline, installation of pipeline along the road sides and passing the high trafficking bridge. With the overall risk-to-health matrix at the pipeline, the cumulative risk score was found to be 90.9% which showed very high cumulative risk score and the free residual chlorine which was 0.67 mg/l and was above acceptable limits.

Service reservoir

In service reservoir, the mean values of total coliforms and thermo tolerant coliforms were found to be 6 and 1 cfu/100 ml due to recontamination in its way while travelling 26 km from the disinfection point, leakage from pipeline, and the reduction of residual chlorine due to reaction with other substances along the path and counts in the range of 1.01 to 9.99 cfu/100 ml which brought low risk of infection; however, the average count were beyond the recommended values. Therefore, combined analysis of the sanitary survey and water-quality data showed that there were 45.5% of cumulative risk score recorded due to the presence of hazardous substances and sanitation condition of storage tanks.

Main distribution systems

The distribution system is the final barrier in preventing waterborne disease outbreaks on one hand and may contribute to water quality deterioration on the other. In terms of total coliform and thermo tolerant coliforms, the mean result were found to be 9 and 2 cfu/100 ml; however, the cumulative risk score of the distribution systems scored 64% which falls in the range of high cumulative risks score but indicated a large reduction in the concentration of free chlorine residual as the water is far from disinfection points.

Conclusion

It can be recommended that the proper sanitary survey, design and implementation of water and sanitation projects; regular disinfections, maintenances and supervisions of water sources and regular bacteriological assessment of all water sources for drinking should be planned and conducted. The capacity of the plant surveyed during the investigation was 3801.6 m^3/day and 1368576 m^3/year. However, the maximum daily flow of treated water is 1600 m^3/day. There is a need to regulate the pipeline and distribution systems from vulnerability of mechanical damage since it is installed by roadside and on the side of the high trafficking bridge. So, there is need for immediate change of installation of pipeline possibly away from the bridge and the nearby road for sustainable protection of the distribution system.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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