INT. J. BIOL. BIOTECH., 16 (1): 189-198, 2019.

COMMUNAL HEALTH PERCEPTION OF TAP WATER QUALITY SUPPLIED TO SHAH FAISAL TOWN, KARACHI

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ABSTRACT

The study comprises physico-chemical and bacteriological analysis of tap water quality supplied to Shah Faisal town, a densely populated town of Karachi. Twenty six samples were collected from different sites. The assessed physico-chemical parameters (pH, Turbidity, TSS, TDS, chlorides, hardness, calcium, magnesium, sodium and potassium) were found within acceptable limits set by WHO and NSDWQ guidelines for drinking water whereas, sulphate concentration slightly exceeded from the limits. Chlorine was found in 5 stations only. The problem is provoked by poor sanitation and water supply conditions. Twenty-two water samples failed to meet the water quality criteria set by NSDWQ and WHO and were found to be extremely faecally contaminated and posed serious health problems. Effective measures are urgently required for water quality management in the city.

Keywords: Tap water, Public Health, Chlorine, Shah Faisal Town

INTRODUCTION

With the expansion in human population, rapid urbanization and industrial development in economically developing countries, the provision of essential and basic services for life such as water and sanitation has been on decline in the megacities of South Asia mainly due to poor sanitation, contamination of wastewater in surface and ground water (Rahman *et al*., 1997). Climate change and increase in water demand for agricultural activities are the other aspects of endangering the availability of water in future as these factors disrupt the natural hydrological cycle (Abrahão *et al*., 2015). Despite greater importance of water in life, the human beings are the major cause of depletion of resources of this vital element because of pollution of water bodies due to anthropogenic reasons (Khoso *et al*., 2015). Contamination and shortage of surface water have caused greater consumption of ground water. Over drawing of ground water lowered the water table and consequently the lowering of aquifers and increase in salinity occurred (Schäfer *et al*., 2009). Water scarcity has forced the people of developing countries to use contaminated and polluted water which is a source of increasing water-borne diseases Worldwide, especially in children (Aziz, 2005).

According to Asian Development Bank, the population of Karachi will rise up to 50% in next 15 years. The major sources through which water is being supplied to Karachi city are River Indus and Hub dam which provide around 695 MGD water, out of which the major contribution is from River Indus as Hub dam is fed by rain water and it may supply about 30-75 MGD only. The supply from the River Indus and Hub dam comes via old and poorly managed canals and water pipelines.

Several studies have been conducted in Karachi to assess the quality of tap and underground water. The studies indicate heavy chemical and microbial contamination of water in different towns in Karachi (Arain *et al*., 2009; Hasnie and Qureshi, 2004; Alamgir *et al*., 2015a and b). Lack of proper water distribution system, non-point sources of untreated domestic and industrial effluents, technical difficulties, leakage and seepages of old pipe lines causes failure of water supply and high level of contamination in Karachi city

This study focuses on the assessment of physico-chemical and microbiological quality of tap water supplied to Shah Faisal Town Karachi and used by the local community for drinking and other purposes.

MATERIALS AND METHODS

Study Area

Shah Faisal Town is a commercial and residential area located in District Korangi, Karachi. It is relatively small and densely populated area. According to Census 1998, its population is 335,823. The town is surrounded by Malir Town to the northeast, Bin Qasim Town to the east, Korangi and Landhi Towns to the South, and Faisal Cantonment and Malir Cantonment to the West and Northwest, respectively. The Malir River forms the southern periphery of the town and the Shahrah-e-Faisal highway forms much of the northern periphery with the Jinnah International Airport at the Northern end of the town.

Sampling

A total of 26 tap water samples were collected from the study area. The sites for sample collection are mentioned in Table 1 and Fig.1. The samples for physico-chemical and bacteriological analysis were collected separately. The samples for chemical analysis were collected in clean plastic containers while the samples for bacteriological examination were taken in pre-sterilized glass bottles. Samples were kept at a low temperature in an ice box and were conveyed to the Institute of Environmental Studies, University of Karachi.

Table 1. Location of sites for sample collection

Sample Code	GIS Coordinates	Site
A-1	24°52'55.28"N, 67° 9'10.43"E	Shah Faisal Colony #3, Noor Mosque
A-2	24°52'39.68"N, 67° 9'9.32"E	Shah Faisal Colony #3, Reta Plot, Jamia Masjid Sehra
A-3	24°52'39.29"N, 67° 8'49.28"E	Shah Faisal Colony #2, Reta Plot
A-4	24°53'3.28"N, 67° 8'42.07"E	Shama Shopping Centre
A-5	24°52'48.07"N, 67° 8'31.66"E	Shah Faisal Colony #1, Madina Masjid
A-6	24°52'40.67"N, 67° 8'16.11"E	Shah Faisal Colony #4, Khokhar Club area
A-7	24°52'31.85"N, 67° 8'28.00"E	Reta Plot Shah Faisal Colony #1
A-8	24°52'16.97"N, 67° 7'55.08"E	Roshanabad, Shah Faisal Colony #5
A-9	24°52'20.07"N, 67° 7'35.57"E	Qadria Mosque, Shah Faisal Colony #5
A-10	24°52'45.63"N, 67° 8'6.50"E	Pak Colony
A-11	24°52'43.89"N, 67° 7'54.65"E	Sadat Colony
A-12	24°53'0.81"N,67° 8'12.81"E	Natha Khan Goth
A-13	24°53'7.29"N, 67° 7'37.99"E	Hanfia Masjid, Drigh Road
A-14	24°52'53.62"N, 67° 7'45.53"E	Azeemabad, Drigh Road
A-15	24°53'5.49"N, 67° 9'17.85"E	Al-Falah Society
A-16	24°52'52.46"N, 67° 9'30.07"E	Green Town, Pathar Road
A-17	24°52'22.63"N, 67° 9'47.35"E	Azeempura
A-18	24°52'22.78"N, 67° 9'59.16"E	Gulfishan Housing Society
A-19	24°52'18.43"N, 67°10'12.89"E	Millat Town
A-20	24°52'32.77"N, 67°10'16.83"E	Bilal Town
A-21	24°52'48.55"N, 67°10'28.82"E	Rafay-e-Aam Society
A-22	24°52'43.11"N, 67°10'12.14"E	Shamsi Society
A-23	24°52'54.91"N, 67°10'3.55"E	Punjab Town
A-24	24°52'57.38"N, 67° 9'51.81"E	Golden Town
A-25	24°53'2.66"N, 67° 9'37.12"E	Little Master School, Asifabad Green Town
A-26	24°52'49.65"N, 67° 9'42.09"E	Street #5, Asifabad Green Town, Farabi Coaching Centre

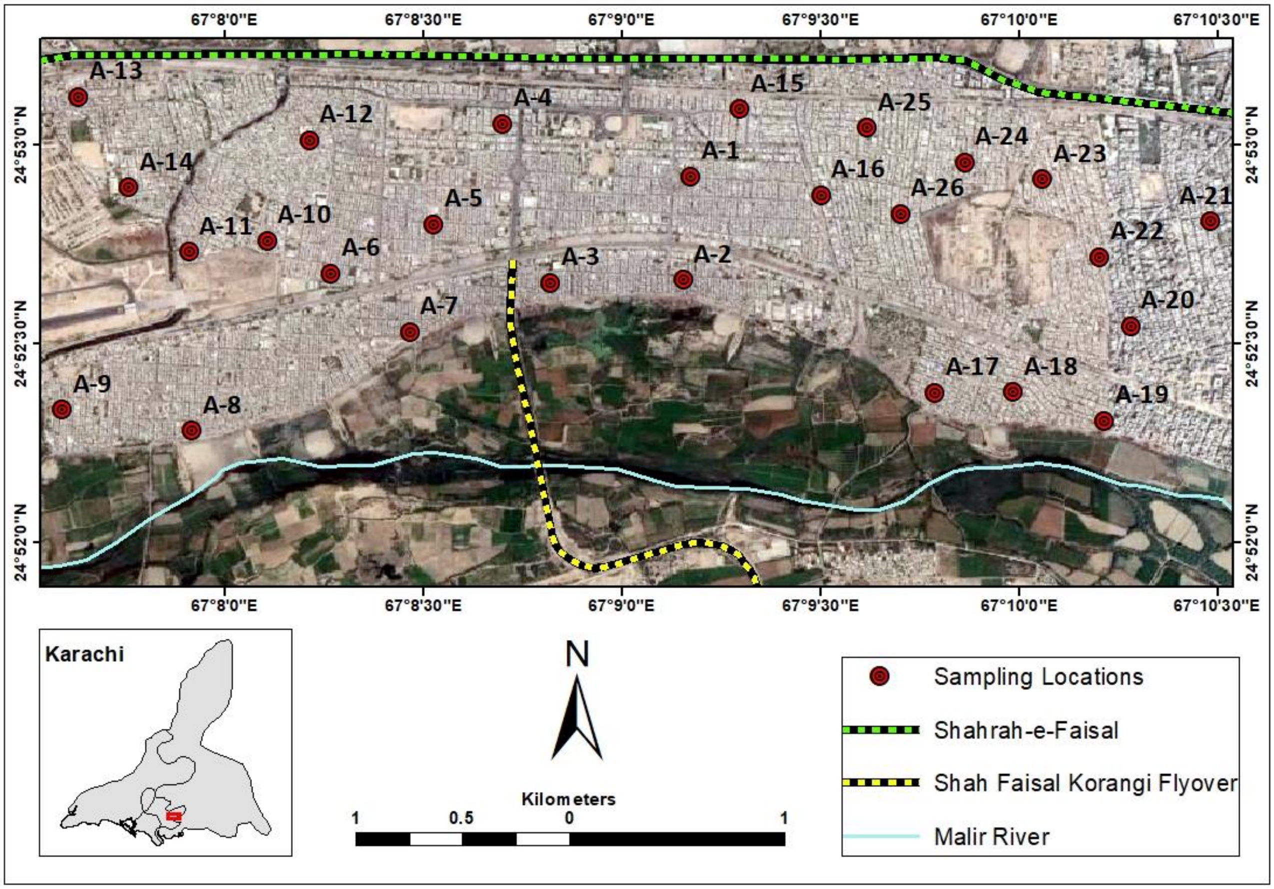

Fig.1 Sampling sites of Shah Faisal Town.

Physico-chemical analysis

The water samples were analyzed for pH, Turbidity, Solids (Total dissolved and suspended solids; TDS and TSS), Chloride, Hardness (as $CaCO_3$), Sulphate and Residual Chlorine. The pH and Turbidity were noted on site by Hanna pH meter (HI98107) and EUTECH turbidity meter (TN-100). TSS, TDS and sulphate of water samples were analyzed by gravimetric method. Argentometric method was employed for chloride estimation while EDTA titration method was applied for estimation of Hardness (as $CaCO_3$). Calcium, Magnesium, Sodium and Potassium were estimated using flame photometry. The above mentioned parameters were analyzed in accordance with the methods described in APHA (2005). Residual chlorine was determined through Merck kits (Germany).

Bacteriological analysis

Bacteriological analysis was performed by MPN technique (APHA 2005). The water samples were investigated for the detection of Total Coliforms Count (TCC), Total faecal Coliforms Count (TFC) and TFS Total Faecal Streptococci Count (TFS). Sterility was maintained throughout the analysis by using laminar flow hood. TCC was estimated by lactose broth (Merck, Germany) of single and double strength. TFC were examined through EC broth (Merck, Germany) by using positive single and double strength lactose broth tubes.

Statistical analysis

The data were subjected to statistical analysis through software (STATISTICA, 99 Edition, Tulsa, Oklahoma) for descriptive statistics. Cluster analysis and principal component analysis (PCA) were also executed using the software mentioned above. Un-weighted pair group method was used for Cluster analysis using Euclidean distance as the resemblance function.

RESULTS AND DISCUSSION

Physicochemical and bacteriological analysis of all the tap water samples are shown in Table 2 in the form of descriptive statistics of 15 parameters. pH values of all the samples are within a range of 7.1 to 7.6 having mean value of 7.29. 13 samples out of 26 having pH 7.1-7.3. This indicates the water samples are neutral while the remaining shows slightly alkaline but within the permissible limits set by NSDWQ (2008) and WHO (2011). These results corroborate with the findings of Orangi Town (Alamgir *et al.*, 2015a) and Malir Town (Alamgir *et al.*, 2015b), Karachi. On the other hand, Hasnie and Qureshi (2004) reported the alkaline mean pH (7.8 and 7.9) for drinking water of the coastal village (Rehri Goth) Karachi.

Colloidal and fine suspended solids are responsible for turbidity in water bodies which provide favorable conditions for multiplication of microorganisms and causes health problems. The tap water samples analyzed in this research are not considered to be turbid as the minimum value in terms of turbidity is represented by sample A-5 with a value of 0.11 NTU while maximum is 0.88 NTU (A-26) having a mean level of 0.4311 NTU. It is found to be within the limit set by WHO (2011) and NSDWQ (2008). These results are in agreement with the findings for Malir Town, Karachi (Alamgir *et al.* 2015b). However, an increased level of turbidity can be observed in a recent study conducted to assess water quality of Keenjhar Lake which is a source of drinking water supply in Karachi, where the mean turbidity value is 9.368 NTU in pre-monsoon and 8.99 NTU in post monsoon season (Yahya *et al*., 2016).

Physical, chemical and biological properties of water bodies are altered, if SS (Suspended Solids) concentration is exaggerated. The physical disparities induced by SS may comprise of temperature changes, filling of water basins through the accumulation of solids and low sunlight penetration. Total suspended solids (TSS) are in a range of 72 to 177 mg/l with a mean value of 115.0385 mg/l whereas total dissolved solids (TDS) are within the acceptable limits i.e. <1000 mg/l. The mean value of TDS for all the samples is 611 mg/l while minimum value is found to be 507 mg/l (A-8, Roshanabad, Shah Faisal Colony #5) and a maximum TDS value of 709 mg/l was observed at A-16 (Green Town, Pathar Road). Water having high TDS values is considered to be a cause of change in taste but it may not be observed in the studied samples. Comparatively, TSS and TDS results corroborates with the findings of Malir Town Karachi (Alamgir *et al.* 2015b). A very low concentration of TSS is present in drinking water of Southern Sindh as reported by Memon *et al.*, (2011) having a range of 0–1.4 mg/l, whereas Alamgir *et al.*, (2016) reported a relatively higher concentration of TSS i.e. 80 to 680 mg/l in ground water of coastal areas of Sindh.

High calcium and magnesium levels are a source of increased hardness in a water body. Calcium, magnesium and hardness levels found in all the samples are considered to be safe as they do not cross the maximum limit as mentioned in Table 2. Average concentration of Hardness, Magnesium and calcium are 167.34 mg/l, 28.33 mg/l and 51.68 mg/l in all the samples respectively. Site A-26 (Asifabad Green Town Street #5) receives low hardness (121 mg/l) and Mg (19.44 mg/l) contents while site A-15 (Al-Falah Society) having maximum hardness (232 mg/l) and Mg (45.93 mg/l) contents. On the other hand, the minimum value of calcium found in tap water samples was observed at Pak Colony (A-10, 35 mg/l) while the maximum calcium value of 76.5 mg/l was found at Reta plot Shah Faisal colony #3 (A-2) which is close to Malir river. The present findings of hardness and calcium can also be correlated with Malir Town having hardness and calcium level of 167.31 mg/l and 53.85 mg/l respectively but on the contrary high Mg contents in tap water were reported from Malir Town (Alamgir *et al.*, 2015b). High calcium level is not desirable in bathing, laundering and washing. Magnesium level remained relatively at a lower level than calcium in the study sites.

Sodium and potassium are important minerals that are needed by a human body for proper functioning and increase or decrease in their levels for longer time period can cause health problems. For aesthetic purpose 200 mg/l sodium and 12 mg/l potassium is set by WHO (2011). In this study, both are within safe limit. Sodium concentration fluctuates between 22 mg/l (A-19) to 41.5 mg/l (A-04) whereas potassium concentration varies from 4 mg/l (A-15) to 6.5 mg/l (A-1). Comparatively these results match with those reported earlier for Malir town (Alamgir *et al.*, 2015b) and Orangi Town (Alamgir *et al.*, 2015a) whereas Korangi and Landhi towns of Karachi have high sodium levels of 250 mg/l for 29% of samples but an elevated level of sodium *i.e.* 1050 to 3499 mg/l for 18% of the samples mainly from nearby industrial areas (Mahmood *et al.*, 1997).

The present study disclosed that sulphate is found to be slightly higher than the acceptable limits of 250 mg/L as set by WHO (2011). Sulphate concentrations of all sites are depicted based on GIS in Fig 2. The minimum value of sulphate is 243 mg/L found at A-17 (Azeem Pura) while maximum value is 361 mg/l in A-13 (Drigh road) with a mean concentration of 303 mg/L Kazi (2014) found sulphate concentration in tap water of 9 different sites of Karachi within a range of 65.47 to 396.4 mg/L that pointed toward the similar situation of slightly higher in the current study area.

The chloride contents ranged between 100.7-167 mg/L with a mean value of 128.30 mg/L. All the samples are less than the potable water desirable limit of 250 mg/L and the allowable limit of 1000 mg/L of chloride set by WHO (2011). Khattak and Khattak (2013) reported the chloride levels in a range of 198 to 2054 mg/L from four districts of Karachi that give the idea that comparatively all samples are of better quality in terms of chlorides. Out of 26, only 5 stations have residual chlorine that varied from 0.11-0.18 mg/L (Fig 3 and Table 2. These are Shama Shopping Centre area (A-4), Azeem Abad (A-14), Green Town Pathar Road (A-16), Golden Town (A-24) and Asifabad Green town (A-25). Around 81% samples have zero chlorine level which is very alarming from the standpoint public health.

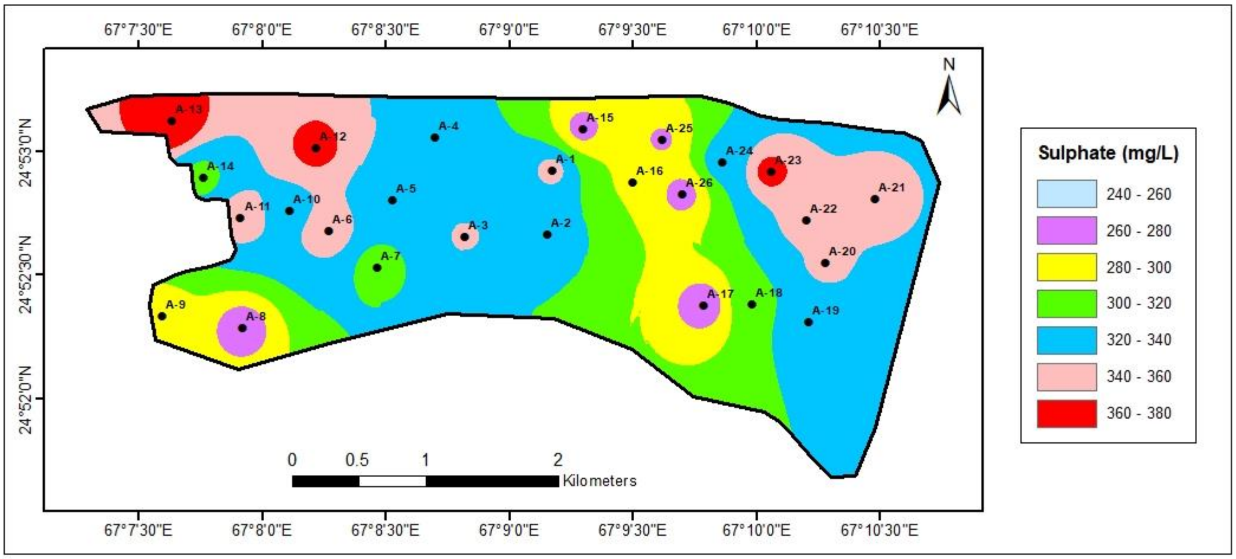

Fig.2. Sulphate concentrations in Shah Faisal Town based on GIS.

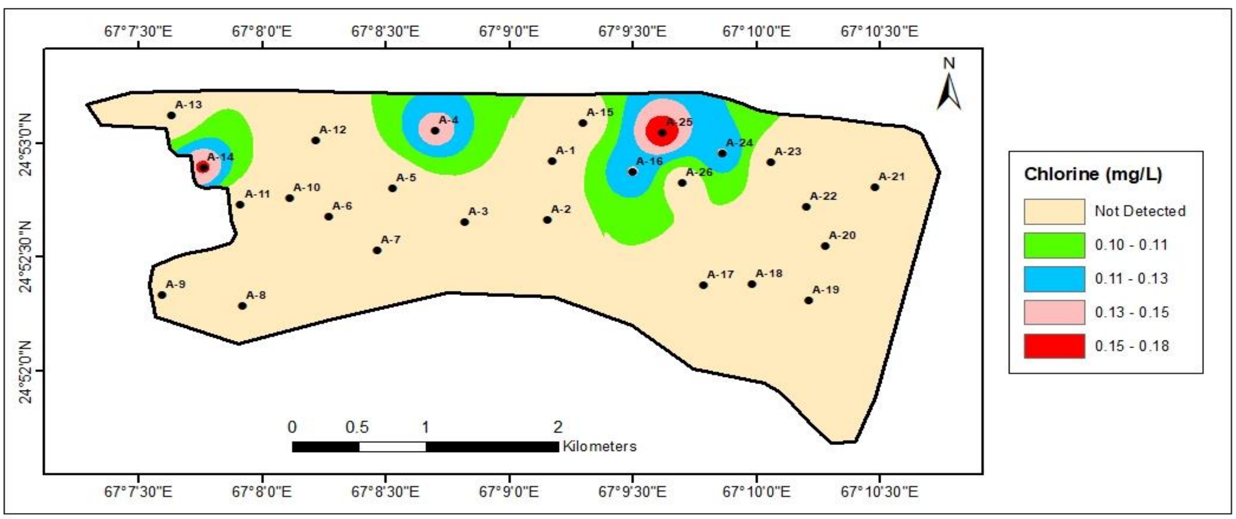

Fig.3. Residual Chlorine concentrations in Shah Faisal Town based on GIS.

In the inspection, 22 tap water samples (84.6 %) failed to meet the WHO guidelines (2011). The bacterial load was exceptionally higher which reveals the organic contamination. About 50 % samples have >2400 TCC (MPN/100mL). In Pakistan, the faecal coliforms up to 10^6 per 100 mLare very common (Meyberk, 1985) in drinking water resources which is persistent cause of water borne diseases among the local population. Gumbo (1985) stated that specific water borne diseases is a matter of serious concern in developing countries. Fig. 4 shows the distribution of TCC in tap water collected from Shah Faisal town. In the current examination, 76% samples have > 210 TFC (MPN/100) while 15.38 % samples have >2400 TFC (MPN/100ml) which are presented in Fig 5. The number of faecal streptococci was quite low in all the samples (Fig 6). It may be due to the fact that such organisms cannot thrive in harsh environmental conditions and may die off when the distance between the source and receiver increases. It may be argued that anthropogenic activities near the source could be the prime source of faecal contamination. This is usually true as the sanitation facilities are in highly deplorable condition in the study area.

During sample collection it was noted the study area has poor water and sewerage system like other towns in Karachi. Most of the sites in the study area have rusty and broken water and sewerage pipelines which are crisscrossed.

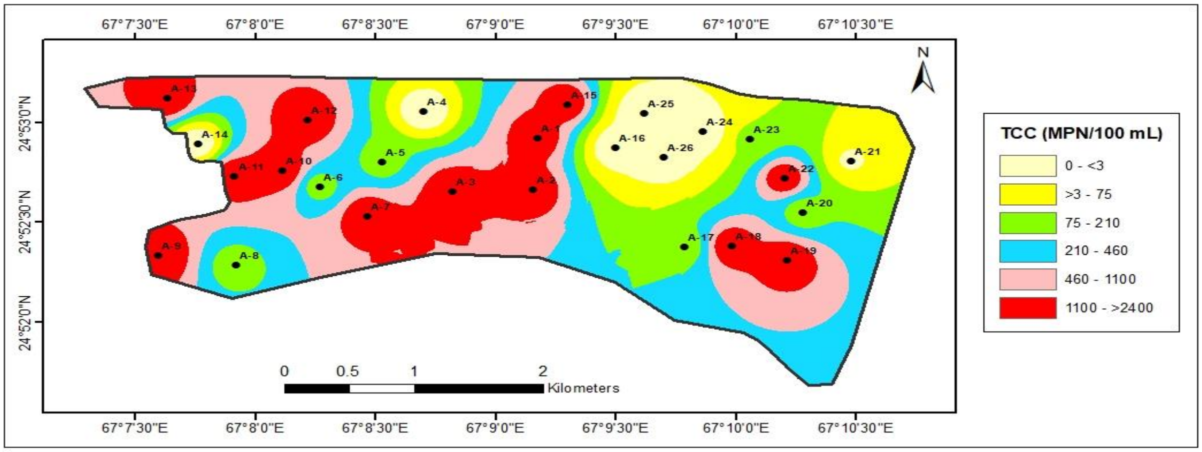

Fig.4. Distribution of Total Coliforms Count (TCC) in Shah Faisal Town tap water based on GIS.

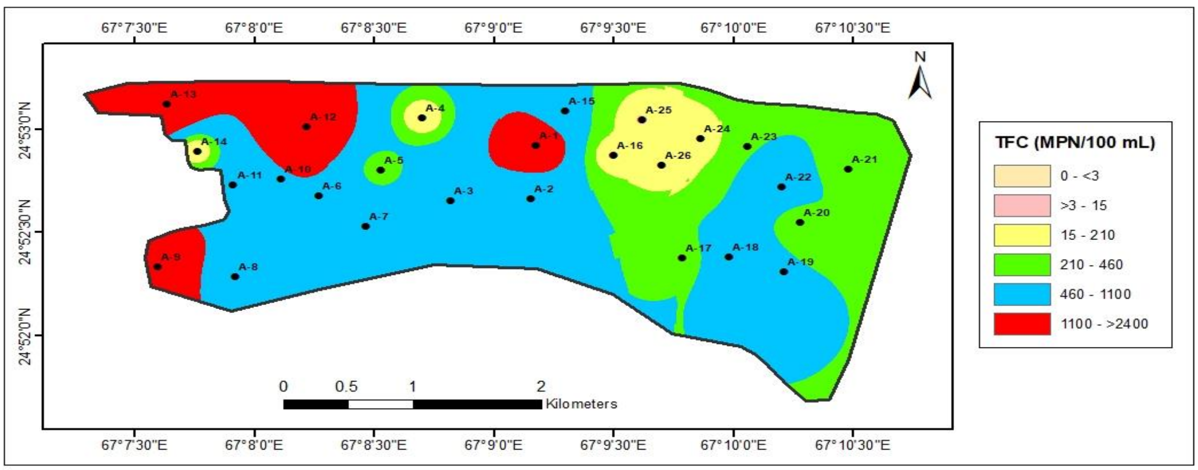

Fig.5. Distribution of total faecal Coliform (TFC) in Shah Faisal Town tap water based on GIS.

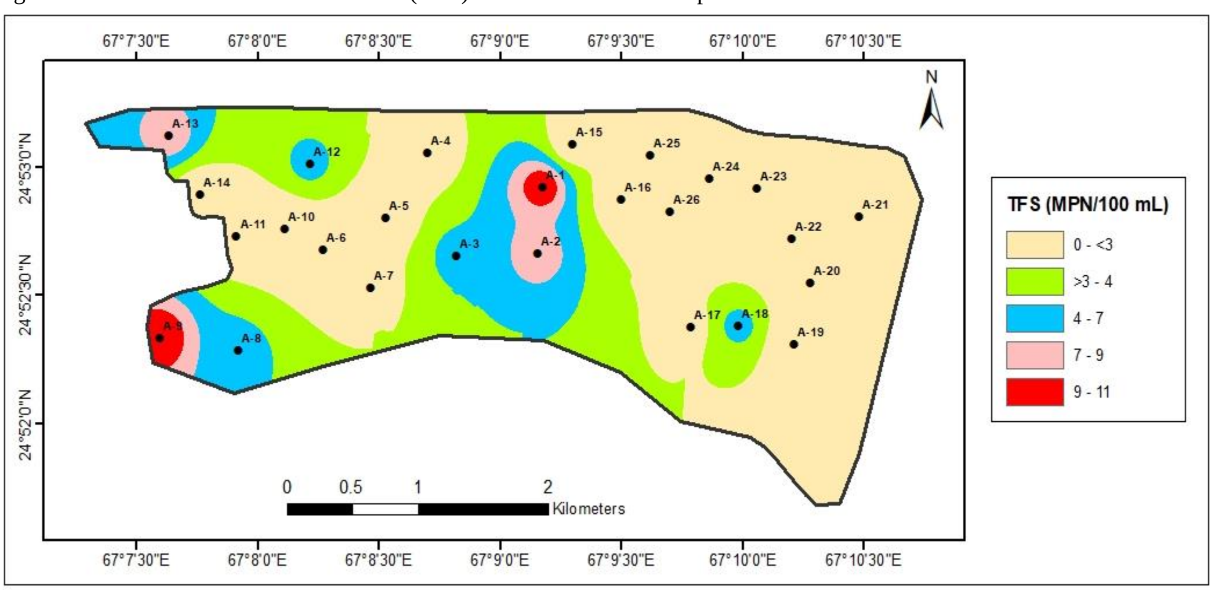

Fig.6. Distribution of total faecal Streptococci (TFS) in Shah Faisal Town tap water based on GIS.

Table 2. Physical, chemical and microbial characteristics of tap water samples of Shah Faisal Town, Karachi.

Parameters mg/L	Mean	Median	Min.	Max.	Std. dev.	Std. error	NSDWQ	WHO Guidelines 2011
pH	7.29	7.3	7.1	7.6	0.1565	0.031	6.5-8.5	6.5-8.5
Turbidity (NTU)	0.431	0.375	0.11	0.88	0.235	0.046	<5	5
TSS	115.03	105	72	177	31.35	6.148	N/A	N/A
TDS	611	609	507	709	58.92	11.55	<1000	<1000
Chloride	128.30	127	100.7	167	18.47	3.6236	<250	250
Hardness as $CaCO_3$	167.346	164	121	232	24.84	4.871	<500	500
Sulphate	303.38	312.5	243	361	34.297	6.726	N/A	250
Calcium	51.68	44	35	76.5	13.05	2.56	N/A	100
Magnesium	28.10	28.33	19.44	45.93	5.75	1.128	N/A	150
Sodium	32.12	33	22	41.5	5.122	1.004	N/A	200
Potassium	5.01	5	4	6.5	0.590	0.115	N/A	12
Free Chlorine	0.026154	0	0	0.18	0.056	0.01	0.2-0.5	N/A
TCC MPN/100mL	1476.3	1750	3	2400	1013.6	198.7	0	0
TFC MPN/100mL	762.92	460	3	2400	815.18	159.8	0	0
TFS MPN/100mL	4.807	3	3	11	2.698	0.529	0	0

NSDWQ= National Standards for Drinking Water Quality, 2008, Ministry of Environment, Government of Pakistan; N/A= Not available: MPN= Most probable number; TCC; Total coliform count; TFC; Total faecal coliform; TFS; Total faecal streptococci

Table 3. Results of principal component analysis (PCA) of physical, chemical and microbiological parameters

Component	Eigenvalue	Percentage variance	Cumulative percentage variance	First four eigenvector coefficients	Associated variables
1	4.567063	30.44709	30.44709	-0.26236	TDS
				0.260913	Sulphate
				-0.25017	Mg
				0.144377	pH
2	2.522363	16.81575	47.26284	0.268703	Na
				-0.16765	Hardness
				-0.11825	TDS
				-0.10002	pH
3	2.040105	13.6007	60.86354	0.029540	TSS
				0.020750	TFS
				0.016034	TDS
				0.003105	TCC

The study also confirms the findings of Aziz (2005) who advocated that almost all of the drinking water supplies in the Pakistan are faecally contaminated which consequently results in high incidences of water borne ailments. Mujahid *et al.* (2015) also reported the similar results of faecal contamination in tap water of Karachi city. However, in Southern Sindh, faecal pollution has also been observed in the drinking water from different sources as reported by Memon *et al.* (2011) and Alamgir *et al*. (2016). The contamination of water in the study area is also due to the use of contaminated utensils used for the collection and storage of water. The utensils used for drinking water are also often not cleaned properly, which may increase the bacterial load in drinking water. Furthermore, contamination of water resources could also add extensive cost in terms of health impacts.

Results of Principal Component Analysis (PCA) are presented in Table 3 and Fig 2. The first principal component that explained 30.44% of the total explained variance was primarily a function of TDS, SO4, Mg and pH which represents the chemical gradient. The second component explaining 16.81% of the total variance was basically regulated by Na, hardness, TDS and pH, and essentially represents physic-chemical at mixture. The third principal component that explained 13.68% of the total variance was chiefly controlled by TSS, TFS, TDS and TCC, and tends to represent bacteriological influence.

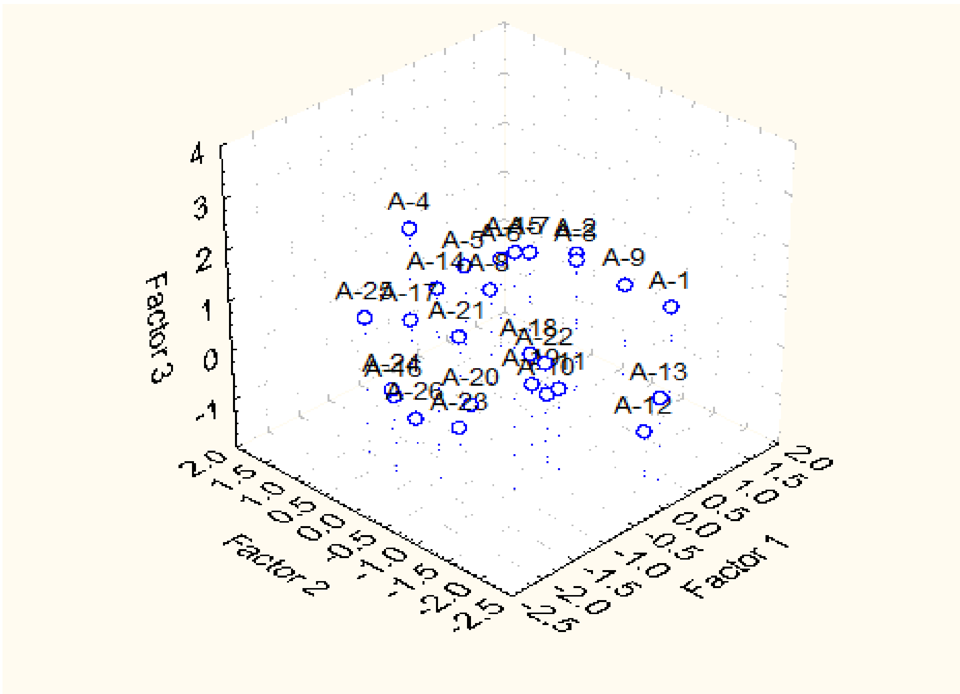

Fig 7. Principal Component Analysis ordination (3D) of physico-chemical and microbiological parameters of tap water samples of Shah Faisal Town, Karachi.

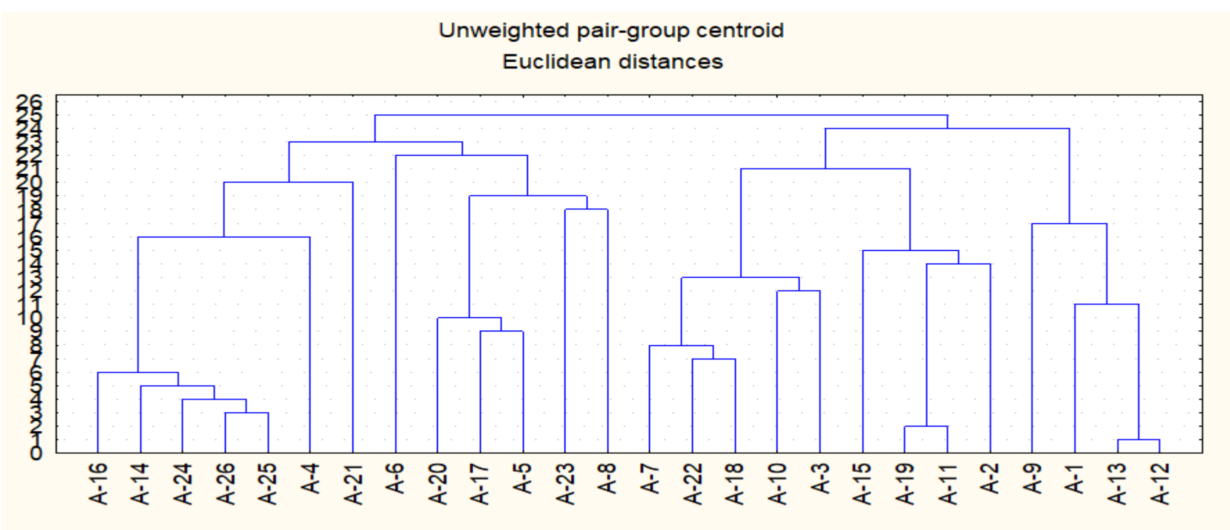

Fig.8. Dendrogram derived from unweighted pair group average method for 26 sites based on physico-chemical and microbiological parameters of tap water samples of Shah Faisal Town, Karachi

Dendrogram resulting from agglomerative cluster analysis is presented in Fig. 8. Two main groups were readily apparent. Each of the two groups (A and B) consist of 13 sites (locations). Group A (left) comprises of mostly sites with moderate TDS and low in Ca, Mg, Na, Hardness and chlorine. Sulphate has higher level. Group B has low TSS and turbidity while Ca, Mg, Na and K are high.

CONCLUSION

From the above discussion it can be easily concluded that the study area has poor, faulty and obsolete water supply and sewerage system. Majority of the people rely on tap water and cannot afford to buy bottled water for drinking purpose. At the same time unhygienic and insanitary conditions prevailing in the area need immediate attention. The system of sewerage is faulty to the extent that the domestic wastewater crisscrosses into the pipe water supplies and thereby causes contamination. Results have disclosed that although water is fit with respect to its physico-chemical characteristics except for sulphate but unfit for human consumption because of high bacterial load. Majority of the samples were grossly faecal-contaminated.

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(*Accepted for publication December 2018*)