Pakistan Journal of Pharmaceutical Research
Faculty of Pharmacy, Bahauddin Zakariya University Multan, Pakistan
ISSN: 2410-6275 **Jan 2020** **DOI:** 10.22200/pjpr.202018-17

Research Article

Effects of Monsoon on the Quality of Drinking Water Supplied to Karachi, Pakistan

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Received: Dec, 22, 2020
Revised: Jan, 26, 2021
Accepted: Apr, 04, 2021
Online: Apr 30, 2021

Abstract

To study the effects of monsoon on the quality of drinking water, supplied by Karachi Water and Sewerage Board (KWSB) to the city of Karachi, quality parameters of drinking water were analyzed before monsoon and after monsoon. A total of 13domestic water connections were selected as sampling points in Gulshan, North Karachi, Nazimabad, Gulberg, Liaquatabad, Landhi, Korangi, Shah Faisal, Jamshed, Saddar, Orangi, Baldia, Lyari and Keamari towns of Karachi. Samples were collected before monsoon (three times during June2020) and after monsoon (three times during Aug-Sept 2020) from each of the sampling point. Various quality parameters of the drinking water samples collected from selected locations such as pH, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Electrical Conductivity (EC), hardness, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, SO_4^{2-} and NO_3^{-} were determined using standard methods. Detection of total possible microbial count was carried out for Total Coliform Count (TCC) and Total Fecal Coliform (TFC). The analysis shows that the physicochemical parameters for all the samples were found within the limits prescribed by WHO, except the values of EC, were found to be higher than the acceptable limit in the samples before monsoon. Whereas the entire drinking water samples tested after monsoon were found to contain TCC and TFC, making them not suitable for drinking. The major reasons of bacteriological contamination may be entering of waste water and the rain water through leakage of pipes during no flow situations. It is suggested to carry out strict monitoring of chlorination process of drinking water supply. To avoid microbial contamination, the underground pipelines of drinking water and sewer water should be distant. Overhead tanks in each town will help to maintain pressure in the drinking water pipelines.

Keywords: monsoon, drinking water, water quality, contamination, physicochemical characteristics; bacteriological characteristics

Introduction

Water is an essential need of human being. Every person on this planet requires at least 20 to 50 liters of safe water in a day for drinking, cooking and other purposes. The quality of drinking water is a basic and important requirement of human life as it is very essential for the biochemical processes of human bodies. The major source of drinking water supplies of the major cities of Pakistan is ground and river water (Kausar and Ahmad, 2009). Pakistani citizens are facing very less availability of safe and clean drinking water due to several external factors; mainly leakages in rusty pipes carrying drinking water, which may cause sewage water contamination in drinking water. Further, possible unhygienic handling and uncovered storage of drinking water by the potable water supply authority's members, are the other factors of contamination of drinking water. On the other hand, unavailability of proper arrangements of monitoring and water treatment also affects the supply of safe and clean water to the citizens (Kahlown *et al.*, 2005).

Karachi is the largest city of Pakistan. It is the center of professional and commercial activities with a developed port. The population of Karachi was estimated as 16 million in 2019 (Bongaarts, 2014). River Indus and Hub dam are two major sources for the supply of water to Karachi. The overall demand of Karachi is 1.2 billion gallons per day. Water supply to the city of Karachi is carried out through conduits from River Indus (by gravity) and 66inches main

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pipelines are used to supply water from both of the resources (by pumping) by Karachi Water and Sewerage Board (KWSB) (Pervaiz *et al.*, 2008).

During current rainy season this year, Sindh especially Karachi faced heavy rain. Due to the water overflowed from water streams carrying sewage/rain water and the sewerage lines, the old, rusty and cracked drinking water supply lines might have been contaminated (Liu and Jiang, 2020). Due to apparent ineffective pretreatment facilities i.e. filtration or chlorination, this contamination might have increased the microbial contamination to the drinking water (Shuja and Jaffar, 1998).

Unsafe water is major cause of disease across the entire globe. It is reported to be a major reason of morbidity to human beings (Ghazanfar *et al.*, 2017, Kosek *et al.*, 2003). About 58% of deaths are reported due to fecal contamination in drinking water supply (Liu *et al.*, 2015, Zeitoun and Mehana, 2014). Results of several reported studies indicate that microbes and salinity are the major contaminants of drinking water (Daud *et al.*, 2017). Several studies (Kim *et al.*, 2000, Park *et al.*, 2010)have been carried out for the safe supply of drinking water, but a few have focused on the effects of rainfall and climate change.

Keeping in view the reported facts from various areas of the World i.e. effects of rainy season on drinking water quality and water borne diseases, this study was conducted to assess the effects of monsoon on the quality of drinking water supply to the less privileged city of Karachi. To avoid morbidity and mortality associated with consumption of contaminated drinking water, physico-chemical and microbial analysis of water was carried out before the monsoon and after it passes and to compare quality of drinking water with World health standards (WHO, 2011) and National Standards for Drinking Water Quality, Ministry of Environment, Government of Pakistan (Dil *et al.*, 2008).

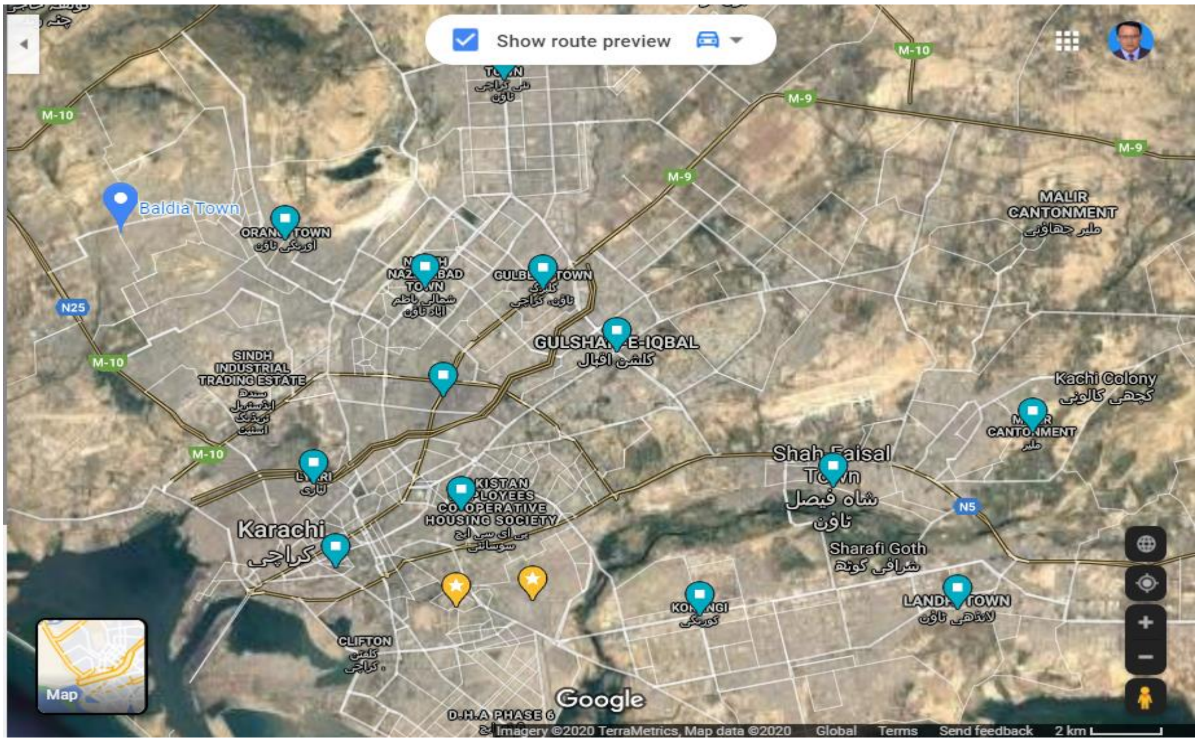

Figure 1: Location of Sampling Points in Karachi

Table 1: Geographic Locations of Sampling Points

S. No.	Towns	Geographic Locations
1.	**Gulshan Town**	24.9204° N, 67.1344° E
2.	**North Karachi**	24.9372° N, 67.0423° E
3.	**Gulberg Town**	24.9368° N, 67.0760° E
4.	**Liaquatabad Town**	24.9107° N, 67.0311° E
5.	**Landhi Town**	24.8406° N, 67.1948° E
6.	**Korangi Town**	24.8387° N, 67.1209° E
7.	**Shah Faisal Town**	24.8773° N, 67.1591° E
8.	**Jamshed Town**	24.8702° N, 67.0524° E
9.	**Saddar Town**	24.8532° N, 67.0167° E
10.	**Orangi Town**	24.9517° N, 67.0023° E
11.	**Baldia Town**	24.9525° N, 66.9550° E
12.	**Malir Town**	25.0329° N, 67.3325° E
13.	**Lyari Town**	24.8784° N, 67.0103° E

Materials and Methods

Sampling Site

The sampling points were selected in the residential area where drinking water is supplied from both of the resources i.e. River Indus and Hub River by KWSB. A total of 13 domestic water connections were selected as sampling points in Gulshan, North Karachi, Nazimabad, Gulberg, Liaquatabad, Landhi, Korangi, Shah Faisal, Jamshed, Saddar, Orangi, Baldia, Lyari and Keamari towns. Figure-1 shows the labeled locations of sampling points in the city. The coordinates of geographical location are mentioned in Table-1.

Sample Collection

Samples were collected before monsoon (three times during June2020) and after monsoon (three times during Aug-Sept 2020) on specific dates from each of the sampling point. Water samples were collected in sterilized, screw caped high-density Polyethylene Terephthalate (PET) bottles. The bottles were cleaned and rinsed with 1M HNO_3 followed by washing with de-ionized water before taking the sample. The bottles were thoroughly rinsed with the sample water, before taking the sample and filled according to the prescribed method. To obtain a true sample of the main resources of Karachi, samples were collected directly from the supply tap either it is supplied directly from the main line or sucked through pumps from main water supply line of KWSB. The samples were labeled and kept at 4°C till analyzed (Association *et al.*, 1912).

Analytical procedures

After samples collection, samples were evaluated for colour, odour and taste acceptability by a trained panelist consisting of 15 members, with an age ranges from 22-50 years. The panelist scored the samples in a suitable line intensity scale (Standard). The colour of drinking water was detected in true colour units (TCU) according to method described earlier (Bean, 1962).

pH was determined through pH meter. pH meter was calibrated with pH 7 and 4 buffer before estimating the pH of the samples. TDS was analyzed by TDS meter. The turbidity of water sample was determined by the turbidimeter (Jenway). Conductivity test was carried out by conductivity meter (Jenway 470). Total hardness was determined by EDTA titration method. The standard procedure was used for ash analysis according AOAC method (Amarchand *et al.*, 1998). Na^+ and K^+ were investigated by Flame photometer (Jenway).

Standard solutions were prepared with chemicals of analytical grade and distilled water was used for dilution of solutions.

Chloride in samples was determined using silver nitrate method. All analysis was carried out in triplicate. The determination of nitrate was performed as reported before (Jackson, 2001).

Microbial analysis

Detection of total possible microbial count was carried out for Total Coliform Count

(TCC) and Total Fecal Coliform (TFC). The standard method for the microbial examination of water by Most Probable Number (MON) was used to estimate microbial counts (Association *et al.*, 1912).

Table 2: Physico-chemical Analysis of drinking water samples before monsoon

Parameters	GT	NK	GgT	LT	LdT	KT	SFT	JT	ST	OT	BT	MT	LyT	WHO	NSDWQ
Colour (TCU)	≤ 15	≤ 15	≤ 15	≤ 15	≤ 15	≤ 15	≤ 15	≤ 15	≤ 15	≤ 15	≤ 15	≤ 15	≤ 15	≤ 15	≤ 15
Odour	A	A	A	A	A	A	A	A	A	A	A	A	A	**A**	**A**
Taste	A	A	A	A	A	A	A	A	A	A	A	A	A	**A**	**A**
pH	7.1	7.7	7.8	7.2	7.2	6.8	7.2	7.5	6.8	7.7	6.9	7.5	7.6	**6.5-8.5**	**6.5-8.5**
TDS (mg/L)	377	498	525	475	519	474	495	494	571	959	376	574	590	**1000**	**1000**
TSS (ppm)	102	100	103	88	87	87	106	110	96	91	94	104	93	**500**	**500**
EC (μs/cm)	1186	1457	1699	1439	1538	1384	1457	1440	1405	1242	1188	1402	1788	**1400**	----
Na^+ (mg/L)	60	70	50	85	80	90	85	95	90	75	70	80	85	**200**	-----
K^+ (mg/L)	3.5	5.5	5.6	6.1	7.1	5.5	5.5	6.4	6.1	5.0	7.0	5.5	6.0	----	-----
Hardness (mg/L)	259	288	282	288	72	288	295	288	288	249	236	228	295	**500**	**<500**
Ca^{2+} (mg/L)	50	55	55	49	60	55	51	58	63	52	45	62	58	**100**	----
Mg^{2+} (mg/L)	19	17	15	16	19	23	30	23	18	18	19	20	17	**150**	----
Cl^- (mg/L)	115	135	140	135	160	155	175	135	139	105	95	175	135	**250**	**250**
SO_4^{2-} (mg/L)	45	80	50	95	85	54	43	41	74	105	91	43	80	**250**	-----
NO_3^-(mg/L	1.5	0.8	1.1	0.8	1.5	1.2	1.4	1.0	0.6	1.2	1.1	1.2	0.8	**5.0**	**≤ 50**

TCU = True Colour Units **A =** Acceptable, **U =** Unacceptable,

Towns:

GT = Gulshan Town, **NK =** North Karachi, **GgT =** Gulberg Town, **LT =** Liaquatabad Town, **LdT =** Landhi Town, **KT =** KorangiTown, **SFS =** Shah Faisal Town, **JT =** Jamshed Town, **ST** = Saddar Town, **OT =** Orangi Town, **BT** = Baldia Town, **LyT =** Lyari and **MT =** Malir Town

Table 3: Physico-chemical Analysis of drinking water samples after monsoon

Parameters	GT	NK	GlbgT	LT	LdT	KT	SFT	JT	ST	OT	BT	MT	LyT	WHO	NSDWQ
Colour (TCU)	>15	>15	>15	>15	>15	>15	>15	>15	>15	>15	>15	>15	>15	≤ 15	≤ 15
Odour	A	U	A	U	U	A	A	A	U	U	A	A	U	**A**	**A**
Taste	A	U	A	A	A	A	A	A	U	U	A	A	U	**A**	**A**
pH	8.1	8.5	8.2	8.5	8.5	8.0	8.5	8.8	8.0	8.9	8.1	8.8	8.9	**6.5-8.5**	**6.5-8.5**
TDS (mg/L)	330	436	459	416	454	415	433	432	500	839	329	502	516	**1000**	**1000**
TSS (ppm)	118	116	119	102	101	100	123	127	111	105	109	120	107	**500**	**500**
EC(μs/cm)	659	865	1055	855	910	880	865	869	825	690	660	890	1160	**1400**	----
Na (mg/L)	90	80	95	80	98	99	89	91	93	85	80	80	85	**200**	-----
K (mg/L)	2.6	4.0	4.1	4.5	5.2	4.0	4.0	4.7	4.5	3.7	5.1	4.0	4.4	----	-----
Hardness (mg/L)	198	220	215	220	55	220	225	220	220	190	180	174	225	**500**	**<500**
Ca (mg/L)	54	59	65	59	58	58	59	63	68	62	54	69	68	**100**	----
Mg(mg/L)	21	27	25	26	21	23	23	33	27	26	26	28	29	**150**	----
Clorides (mg/L)	98	115	119	115	136	132	149	115	118	89	81	149	115	**250**	**250**
SO_4(mg/L)	59	105	66	124	111	71	56	54	119	138	97	56	105	**250**	-----
NO_3(mg/L)	1.8	1.2	1.4	1.8	2.1	1.0	1.9	1.6	1.6	1.4	1.7	1.2	1.0	**5.0**	**≤ 50**

TCU = True Colour Units **A =** Acceptable, **U =** Unacceptable,

Towns:

GT = Gulshan Town, **NK =** North Karachi, **GlbgT =** Gulberg Town, **LT =** Liaquatabad Town, **LdT =** Landhi Town, **KT =** KorangiTown, **SFS =** Shah Faisal Town, **JT =** Jamshed Town, **ST** = Saddar Town, **OT =** Orangi Town, **BT** = Baldia Town, **LyT =** Lyari and **MT =** Malir Town

Results and Discussion

The physico-chemical analysis of drinking water sample collected from the 13 sampling points in Karachi city (three times during June-2020), i.e. before monsoon is summarized in, Table-2 and results of, samples collected after monsoon (three times during Aug-Sept 2020) from each of the sampling point are recorded in Table-3. The results are the mean values of samples collected three times from each sampling point in triplicate. Table-2 indicates that the values of all of the parameters investigated in the drinking water before monsoon met the WHO guidelines as well as are in accordance with the standard set for Pakistan (Dil *et al.*, 2008). The results of physico-chemical parameters after monsoon (Table-3) show a definite change in pH, TDS, TSS, conductivity and hardness.

The pH values of samples before and after monsoon are shown in Fig-2. The pH of the water samples analyzed before monsoon was recorded within the range of 6.8-7.8, whereas pH of drinking sample after monsoon was found to be in the range of 8.0 to 8.9 which falls in the acceptable range of pH for drinking according to WHO guidelines (WHO, 2011). Most of the samples were alkaline, whereas pH of the sample of Saddar, Keamari and Baldia Towns collected before monsoon was found to be less than 7.0. A distinct increase in pH for all samples after monsoon has been observed with a pH range 8.0 to 8.9. This increase in pH shows that the samples collected after monsoon may contain more bicarbonate. It is pertinent to mention that no health-based guidelines are available in case of pH of drinking water is found below 6.5 or above 8.5; however, it is one of the most important operational quality parameters. Water with pH less than 4.0 or more than 11.0 is not suitable to be used as drinking water. Such

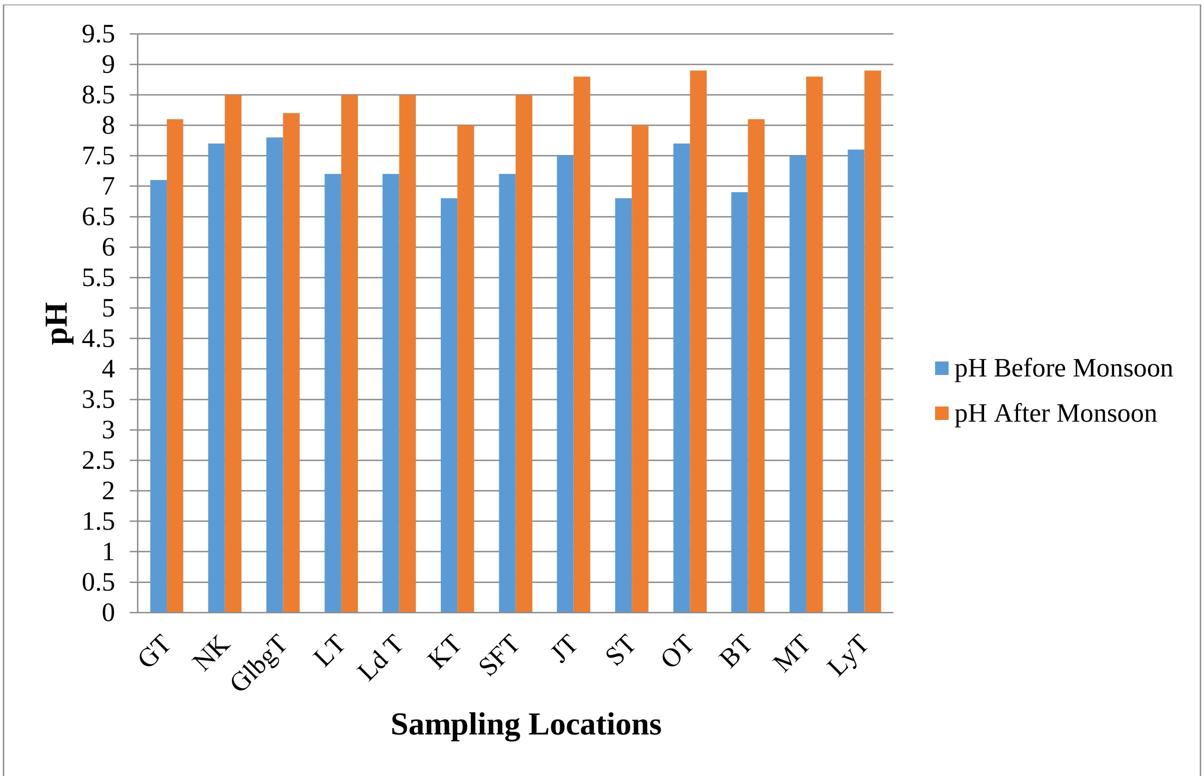

Figure 2: Comparison of pH before and after the monsoon at various sampling locations

water may cause corrosive effects (pH.11.0) and is harmful for skin and eyes (pH 4.0) when utilized for drinking (WHO, 2011).

The TDS values of drinking water samples before and after monsoon are shown in Fig-3. The TDS values of drinking water samples were found in a range of 377 – 959mg/dL before monsoon and the values are lowered after monsoon as 330 to 839mg/L. The values of TDS fall within the acceptable range of TDS in drinking according to NSDWQ and WHO guidelines, which recommends that water with TDS >600 mg/L should not be used for drinking, although the maximum permissible level for TDS in drinking water is 1000 ppm.

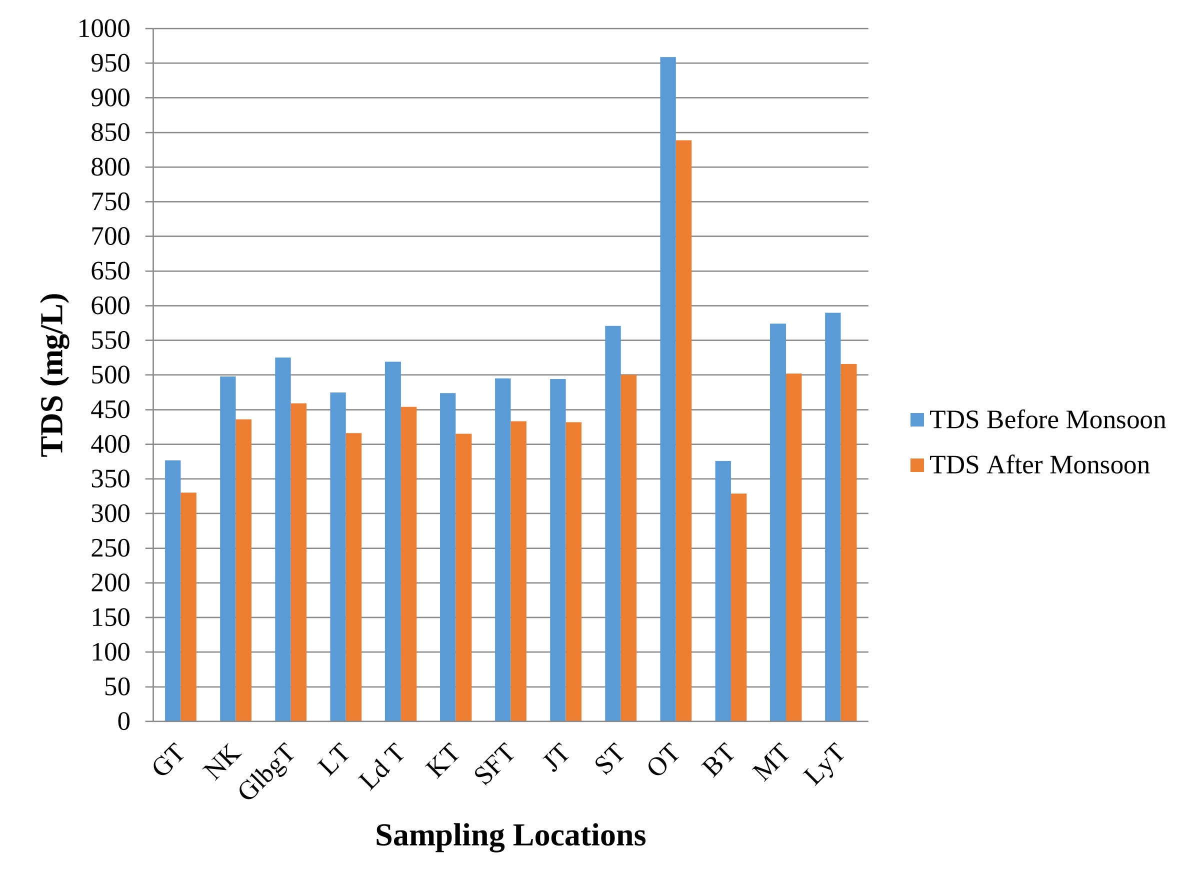

Figure 3: Comparison of TDS before and after the monsoon at various sampling locations

TDS value higher than 1000ppm gives undesirable taste to the water and may also cause scaling in pipes. The values of TDS were found >600mg/L in Landhi, Gulburg, Saddar, Malir, Lyari and Oringi Town. Orangi town contains the highest amount of dissolved organic Solids with a TDS value of 959mg/L making it unusable as drinking water. The reason of lower values of TDS after monsoon are may be due to dilution of drinking water supply by rain water from surface water of any area or buildings.

The TSS values of samples before and after monsoon are shown in Fig-4. An increasing pattern was observed in the values of TSS estimated before to after monsoon. TSS ranged from 87 to 110mg/L before monsoon and 100 to 123mg/L after monsoon. Higher values of TSS after monsoon are may be due to the enhanced amount of organic and inorganic substances such as sewage and fine sand, clay, or other material carried by running water and deposited as a sediment.

However, all these parameters are not uniform may depend upon various factors mainly geological strata, geo hydrological and geomorphologic conditions of the area. Pre and post monsoon values of TSS are found within the acceptable range for drinking according to WHO guidelines.

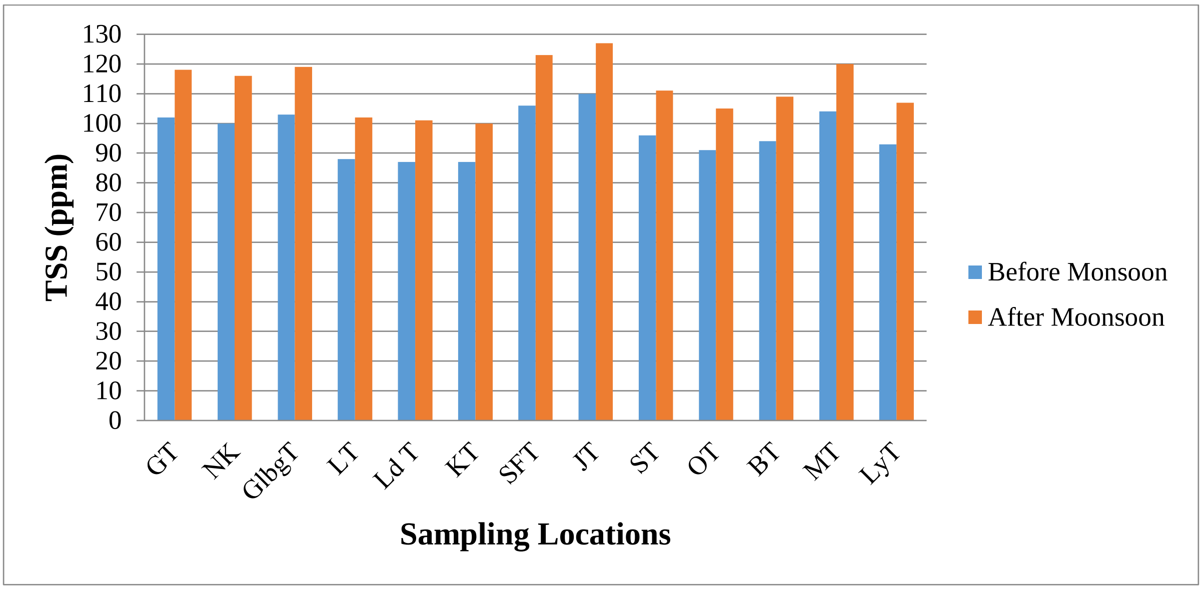

Figure 4: Comparison of TSS before and after the monsoon at various sampling locations

The pre and post monsoon values of Electrical Conductivity (EC) are shown in Fig-5. The values of EC are found to be in a range of 1186-1788µs/cm before monsoon and after monsoon, the values are found to be from 659-1160µs/cm. EC of water represents the total soluble ionic substances in water. The lower EC values in post monsoon season are possibly due to dilution caused as a result of soften rain water.

The pre and post monsoon values of hardness are shown in Fig-6. Hardness values of the drinking water samples are found decreasing from (72-288mg/L) in before monsoon to (55-225mg/L mg/L) after monsoon.

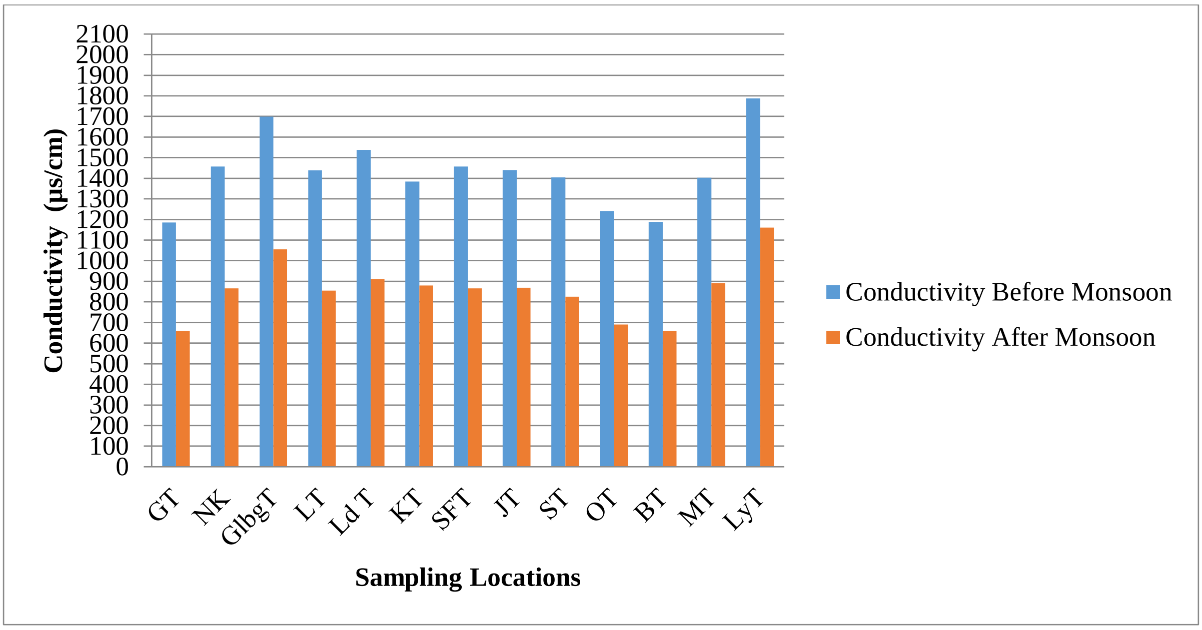

Figure 5: Comparison of Conductivity before and after the monsoon at various sampling locations

The hardness values of the drinking water sample analyzed before and after monsoon are found to be within the permissible range 500mg/L of WHO. Water with hardness >500mg/L is not suitable for drinking as it effects the kidney and neurological functions. Chronic effects include kidney dysfunction cerebrovascular disease and diabetes mellitus (Sengupta, 2013).

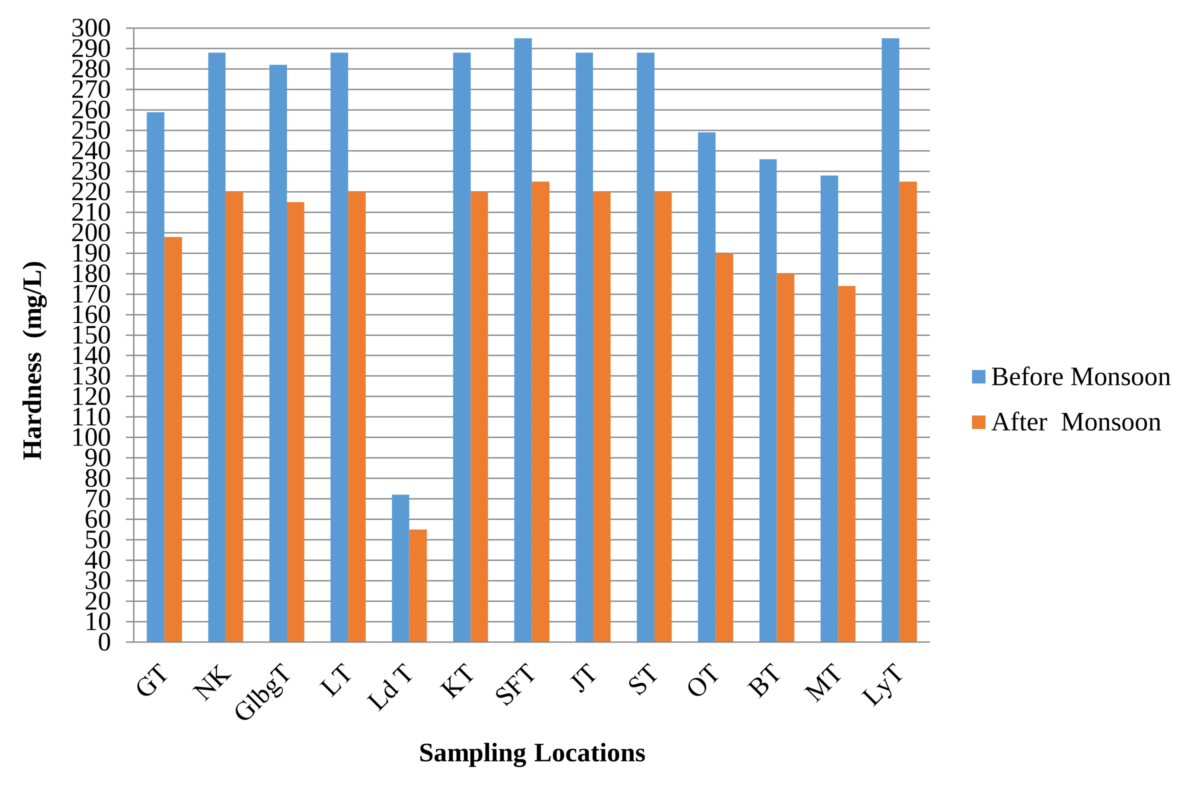

Figure 6: Comparison of Hardness before and after the monsoon at various sampling locations

Very distinct increase in the concentration of cat-ions has been observed in the samples of drinking water analyzed before and after monsoon (Table-2 & 3). However, the values of magnesium are found in a range of 15-30mg/L before monsoon and 21-29mg/L after monsoon, calcium 49-63mg/L before monsoon and 54-69mg/L after monsoon are fall within the acceptable range of WHO. Presence of calcium and magnesium are the major reason for the hardness of water, which is evident from the data, indicating higher values of hardness (Table-3). Magnesium helps in phytoplankton growth. Magnesium ions are also major cause of enhancing several enzymes in the human body (Jadhav *et al.*, 2013). Increased concentration of calcium ion in water may cause stomach disorder. During monsoon calcium may enters in the water supply system through concrete pipeline leakage which hinders the flow of domestic water by establishing deposits in the pipelines (Pradhan and Pirasteh, 2011).

Sodium can cause high blood pressure of may cause heart disease if it is present in drinking water. The values of sodium ion in our analysis were in the range of 75-95mg/L before monsoon and 80-99mg/L after monsoon and are within the acceptable limits of WHO.

Microbiological Analysis

The mean values of TCC and TFC before and after monsoon are recorded as Table-4

Table 4: Microbiological Analysis of drinking water samples before monsoon

Parameters	GT	NK	GlbgT	LT	Ld T	KT	SFT	JT	ST	OT	BT	MT	LyT	WHO	NSDWQ
TCC (MPN /100mL)	0	0	0	2.1	2.1	1.3	1.6	0	1.3	2.3	2.1	1.1	2.0	0	0
TFC (MPN /100mL)	0	1.2	0	1.3	2.3	2.1	1.3	0	2.1	2.1	2.3	1.6	2.0	0	0

Table 5: Microbiological Analysis of drinking water samples after monsoon

Parameters	GT	NK	GlbgT	LT	Ld T	KT	SFT	JT	ST	OT	BT	MT	LyT	WHO	NSDWQ
TCC (MPN /100mL)	8	7.2	6	8.8	6.3	7.8	9.6	6	6.8	7.5	6.2	5.8	8	0	0
TFC (MPN /100mL)	5.6	1.2	6.3	1.3	2.3	2.1	1.3	4.5	2.1	2.1	2.3	1.6	2.0	0	0

and Table-5 respectively. The presence of TCC and TFC shows the presence of soil, plants and human faeces in the drinking water analyzed. Drinking water sample of Gulshan, North Karachi, Gulberg and Jamshed towns were found free of TCC and TFC before monsoon, showing good water supply in those area. Samples taken from all other towns before or after monsoon found to contain TCC and TFC. The major reasons of bacteriological contamination may be entering of waste water and the rain water through leakage of pipes during no flow situations. In few of the towns the drinking water supply and sewage pipelines were laid in close proximity. Overloading of sewage to the surface was also observed during the rainy period making a pond of mixture of sewer and rain water for a long period of time.

Conclusion

The physico-chemical parameters for all the samples were found within the limits prescribed by WHO, except the values of EC, were found to be higher than the acceptable limit of WHO in the pre monsoon samples. Whereas the entire drinking water samples tested after monsoon were found to contain TCC and TFC, making them not suitable for drinking. In this regards it is suggested that underground pipelines installed for drinking water supply and sewage water should be installed at a proper distance. Drinking water supply by KWSB to the city of Karachi is usually carried out from underground tanks using high pressure pumps, due to which during no flow situations, it is become possible that sewage and rain water spills may enter into drinking water through the leakage of pipeline causing bacteriological contamination. To handle such situation overhead drinking water tanks may be provided to each of the town of Karachi city that maintain constant pressure to restrain the entrance of sewer and rain water into the drinking water. Chlorination of drinking water supply may also be strictly monitored to stop such incidences. Drainage of rain water should be improved to stop pounding of mixture of rain and sewer water on the streets of Karachi.

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