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Environmental impact of pollutants on water quality of Keenjhar Lake, Thatta

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ABSTRACT

Keenjhar Lake is the main source of drinking water for the metropolitan city of Karachi. The release of untreated wastewater from Kotri industrial area and other sources have made the lake water polluted. This study was subjected to determine the impact of such pollutant sources on the water quality of Keenjhar Lake. The study involves analysis of water quality parameters of Keenjhar Lake and its feeding source (KB Feeder). The sampling sites were selected based on the sources of contamination. The water samples are tested for physical, chemical and micro biological parameters. The result of water analysis indicates the contamination level of lake is quite alarming for the sites of Kotri effluent and WAPDA colony where total dissolved solids, chlorides and other ionic metals were quite higher in concentration than other sites. These sites are also contaminated with fluoride and arsenic which are carcinogenic elements. The study reveals that the contamination level of feeding source is causing a big non-reversible damage to the lake if continued to be uncontrolled. This contamination is mainly due to the release of toxic metals and ions in the KB feeder caused by human carelessness.

Keywords: Water quality; Lake water; Toxic metals; Health

1. Introduction

Environmental degradation of addable water source is of great concern in the 21st century. Water plays a vital role in everyday activities of living organisms [1]. Availability of safe and clean water is very essential. The rapid growth in population is affecting dramatically the quality of fresh water, ultimately declining availability of fresh water per capita per year.

Lakes, rivers, ponds and underground water are some most common sources of fresh water. Water in lakes and ponds is more vulnerable to environmental degradation as compared with flowing and underground water because of its steady nature [2]. Water pollution is categorized as natural and anthropogenic act, which is further classified based on its origin as point and non-point sources. Point sources pollution has some fixed sources (e.g., effluent discharge, etc.), which can be identified and treated directly [3–9]. Whenever toxic metals and unnecessary materials enter into water it becomes polluted [10,11]. While non-point sources pollution is unidentifiable, for example, leaching of nutrients from agricultural land, etc., which are hard to identify and evaluate directly. The large amount of pesticides as well as their poor handling may damage agriculture ecosystem [12,13]. Water pollution may also be caused by domestic/industrial sewage water and this polluted water can harm fish, weeds

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and other organisms living in water. About 70%–80% water is polluted by domestic/industrial sewage [14,15].

Lakes are open reservoirs and integrated components of the watershed. They are considered to be the chief source of fresh water. Watershed influences lake's environment and ecology which is governed by the quality of water and sediments entering, leaving or settling in the lake. Water storage period of lakes varies from months to several years. Flow of water currents within the lake is multidirectional and many lakes have alternating periods of stratification and vertical mixing [1].

Keenjhar Lake plays a vital role in providing fresh water to the city of Karachi and Thatta for domestic and commercial purposes. This water is used for recreational activities, industrial usage, drinking purpose and for gardening and agriculture. The Lake is fed by KB feeder via Kotri barrage originating from River Indus. The anthropogenic pollution sources contaminating the Lake water are KB feeder and Lake itself. KB canal faces various effluent discharge points before releasing its water into Keenjhar Lake [16]. The effluent waste of industries operating in Kotri industrial area is discharged into the canal without proper treatment, the chemicals present in it may become deadly to living beings. Fruits and vegetables may also be polluted by them [17]. The other potential pollution sources for the canal water are the municipal waste of WAPDA Colony and domestic waste of villages located along with the canal. Flood and extreme weather conditions are also responsible for different diseases in underdeveloping and developed countries [18,19]. The Keenjhar Lake has also various sources of pollution located at various points within the Lake. The sources of contamination may also include wastewater of houses and population living around it. The waste originates from agricultural fields and cattle farms located within the range of Keenjhar Lake. The waste of Sindh Irrigation Department Rest House near lake is also contaminating lake water to some extent.

2. Experimental materials and methods

Grab water samples were collected from top, center and bottom of the sampling sites for physicochemical analysis of the samples. The composite of samples was made by adding them to each other. Pre-sterilized sampling bottles of borosilicate glass (200–500 mL capacity) were used for microbial sampling [20].

The parameters to be used in the analysis are temperature, pH, total dissolved solids (TDS), electrical conductivity, turbidity, calcium, bicarbonate, alkalinity, hardness, magnesium, potassium, sodium, sulfate, fluorides, chlorides, arsenic, dissolved oxygen (DO), *E. coli* and total coliform. These parameters are analyzed according to the method defined by the American Public Health Association (APHA) manual for drinking water and wastewater. Water samples were analyzed at Drainage and Reclamation Institute of Pakistan Under Soil and Water Analysis Laboratory, Tando Jam.

All the glassware were thoroughly washed and soaked overnight in 1 M HNO_3, and rinsed with de-ionized water before use. All the chemicals used were of analytical or equivalent grade and purchased from Sigma-Aldrich (St. Loius, MO, USA). Temperature was measured with a mercury thermometer at concern sites; alkalinity was measured by titration with sulfuric acid and chloride with silver nitrate. DO content of water samples was determined with DO meter on site. Electrical conductivity (TDS) was determined with a WTW LF 320 conductivity meter. Standard titration methods [4,5] were used to determine TDS and pH with an Orion model 420 pH meter (Pennsylvania, USA). Turbidity was determined by Secchi disk method, calcium and magnesium were determined by EDTA titration method, potassium and sodium through flame photometer, sulfate and fluoride were determined by colorimeter DR/890, hardness was determined by EDTA titration method, arsenic was determined by Kit method, *E. coli* and total coliform were determined by membrane filtration (MF) method [6].

2.1. Site selection

The badly contaminated sites were selected as sampling points. The non-point sources sampling stations were selected based on the location of the station that serves in feeding and extracting lake. While for point sources, the stations were selected according to the discharge of the effluent from industrial areas which directly drain into the KB Feeder. The points of sampling were taken from point sources, that is, KB canal, which is the feeding source of fresh water for Keenjhar Lake. The industrial effluent of Kotri industrial area is discharged into the canal; this is one of the major source of anthropogenic contamination of lake water. Other potential point source of pollution is municipal waste of WAPDA Colony and domestic waste of villages settled beside the canal. The sampling points are indicated in Table 1.

3. Results and discussion

The analysis of water quality parameters is based on World Health Organization (WHO) standards and standards set by Pakistan Council for Research in Water Resources (PCRWR) for the physio-chemical parameters of the drinking water. The APHA standard was used for the determination of drinking water quality parameters [20]. The WHO standards were used for the assessment of biological parameters of water (Table 2).

Table 2 indicates the results of various water quality parameters compared with National Environmental Quality Standards (NEQS) limits. Here, the NEQS limits are given in the top of the table. The parameters which are given in this table include temperature (Temp.), pH and TDS (Table 3).

Table 3 indicates the results of various water quality parameters compared with NEQS limits. Here the NEQS limits are given at the top of the table. The parameters which are given in this table include electrical conductivity (EC), turbidity and calcium.

Table 4 indicates results of various water quality parameters with comparison to NEQS limits. Here the NEQS limits are given at the top of the table. The parameters which are given in this table include: bicarbonate, alkalinity and hardness.

Table 5 indicates results of various water quality parameters with comparison to NEQS limits. Here the NEQS limits

Table 1
Location of sampling stations

Station No	Description
RD-16-1	Kalri Baghar Feeder Upper Right side
RD-16-2	Kalri Baghar Feeder Upper Mid-point
RD-36-1	Kalri Baghar Feeder Upper-WAPDA Colony municipal effluent
RD-36-2	Kalri Baghar Feeder Upper-Industrial waste discharge point
RD-36-3	Kalri Baghar Feeder Upper
RD-50	Kalri Baghar Feeder Upper
KL-1	Near KG Canal Karachi Feeder
KL-2	Near Lake Bank at RD-50
KL-3	Sindh Irrigation Department Rest House
KL-4	Near Nori Jam Tamachi Mazar
KL-5	Mid of Lake Between Noori Jam Tamachi Mazar and Picnic Point
KL-6	Near Picnic Point

Table 2
Results of various water quality parameters

Sample ID	Temperature (°C)	pH	TDS (mg/L)
WHO/NEQS Limits	30.5	6.5–8.5	1,000
Kalri Baghar Feeder Upper Right side	30.2	8.5	541
Kalri Baghar Feeder Upper Mid-point	30.4	7.89	554
Kalri Baghar Feeder Upper-WAPDA Colony municipal effluent	31	8.51	813
Kalri Baghar Feeder Upper-Industrial waste discharge point	31.5	7.36	721
Kalri Baghar Feeder Upper	30	7.88	586
Kalri Baghar Feeder Upper	30	8.12	557
Near KG Canal Karachi Feeder	30	8.4	325
Near Lake Bank at RD-50	30.3	8.5	309
Sindh Irrigation Department Rest House	30.5	8.7	304
Near Nori Jam Tamachi Mazar	29.9	8.42	333
Mid of Lake Between Noori Jam Tamachi Mazar and Picnic Point	30	8.35	364
Near Picnic Point	30	8.47	359

Table 3
Results of various water quality parameters

Sample ID	Electrical conductivity (uS/cm)	Turbidity (NTU)	Calcium (mg/L)
WHO/NEQS limits	1,000	5	NGVS
Kalri Baghar Feeder Upper Right side	846	22.1	36
Kalri Baghar Feeder Upper Mid-point	865	31	40
Kalri Baghar Feeder Upper-WAPDA Colony municipal effluent	1,270	46.5	40
Kalri Baghar Feeder Upper-Industrial waste discharge point	1,127	40	56
Kalri Baghar Feeder Upper	915	32.9	48
Kalri Baghar Feeder Upper	871	37.7	40
Near KG Canal Karachi Feeder	508	8.75	36
Near Lake Bank at RD-50	483	1.77	36
Sindh Irrigation Department Rest House	475	1.33	40
Near Nori Jam Tamachi Mazar	520	1.73	44
Mid of Lake Between Noori Jam Tamachi Mazar and Picnic Point	569	1.72	44
Near Picnic Point	561	2.68	46

Table 4
Results of various water quality parameters

Sample ID	Bicarbonate (mg/L)	Alkalinity (mmol/L)	Hardness (mg/L)
WHO/NEQS limits	NGVS	NGVS	500
Kalri Baghar Feeder Upper Right side	150	3	260
Kalri Baghar Feeder Upper Mid-point	160	3.2	250
Kalri Baghar Feeder Upper-WAPDA Colony municipal effluent	170	3	300
Kalri Baghar Feeder Upper-Industrial waste discharge point	160	3.2	300
Kalri Baghar Feeder Upper	140	2.8	280
Kalri Baghar Feeder Upper	150	3	220
Near KG Canal Karachi Feeder	110	2.2	180
Near Lake Bank at RD-50	100	2	170
Sindh Irrigation Department Rest House	250	5	230
Near Nori Jam Tamachi Mazar	130	2.6	180
Mid of Lake Between Noori Jam Tamachi Mazar and Picnic Point	140	2.8	190
Near Picnic Point	130	2.6	190

Table 5
Results of various water quality parameters

Sample ID	Magnesium (mg/L)	Potassium (mg/L)	Sodium (mg/L)
WHO/NEQS Limits	150	12	200
Kalri Baghar Feeder Upper Right side	41.31	5.6	69
Kalri Baghar Feeder Upper Mid-point	36.4	3.5	99
Kalri Baghar Feeder Upper-WAPDA Colony municipal effluent	48.6	4.2	147
Kalri Baghar Feeder Upper-Industrial waste discharge point	38.88	4	114
Kalri Baghar Feeder Upper	38.88	4.2	78
Kalri Baghar Feeder Upper	29.16	3.7	90
Near KG Canal Karachi Feeder	21.87	3.8	30
Near Lake Bank at RD-50	19.47	3.5	29
Sindh Irrigation Department Rest House	17.01	4.4	28
Near Nori Jam Tamachi Mazar	17.01	2.4	35
Mid of Lake Between Noori Jam Tamachi Mazar and Picnic Point	19.44	4	40
Near Picnic Point	18.22	3	40

are given at the top of the table. The parameters which are given in this table include magnesium, potassium and sodium.

Table 6 indicates results of various water quality parameters with comparison to NEQS limits. Here the NEQS limits are given at the top of the table. The parameters which are given in this table include sulfate, fluoride, chloride and arsenic.

Table 7 indicates results of various water quality parameters with comparison to NEQS limits. Here the NEQS limits are given at the top of the table. The parameters which are given in this table include

3.1. Temperature (°C)

The values of temperature are recorded at selected sampling stations for KB Feeder and Keenjhar Lake and are plotted in Fig. 1.

The higher values of temperature are found for the site RD-36-1 and RD-36-2 where WAPDA colony municipal waste and Kotri industrial area effluent inflows to KB Feeder. For the above-mentioned sites, the values of temperature are higher than the NEQS limits while for all the other sites the values of temperature are within safe limits. The higher values might be due to disposal of hot industrial water from various thermal plants and cooling chambers of industries. The lower values for lake water could be due to thermal stratification and restricted mixing of layers.

3.2. pH

The values of pH are recorded at selected sampling stations for KB feeder and Keenjhar Lake and are plotted in Fig. 2.

The higher value of pH is found for the site KL-3, where Sindh Irrigation Department Rest House is located. The value

Table 6
Results of various water quality parameters

Sample ID	Sulfate (mg/L)	Floride (mg/L)	Chloride (mg/L)	Arsenic (ppb)
WHO/NEQS limits	250	1.5	250	10
Kalri Baghar Feeder Upper Right side	158	1	127	0
Kalri Baghar Feeder Upper Mid-point	145	1	129	0
Kalri Baghar Feeder Upper-WAPDA Colony municipal effluent	239	0	235	5
Kalri Baghar Feeder Upper-Industrial waste discharge point	270	1.7	265	10
Kalri Baghar Feeder Upper	150	0.5	196	0
Kalri Baghar Feeder Upper	85	0	139	0
Near KG Canal Karachi Feeder	33	0	69	0
Near Lake Bank at RD-50	32	0	67	0
Sindh Irrigation Department Rest House	30	0	65	0
Near Nori Jam Tamachi Mazar	32	0	60	0
Mid of Lake Between Noori Jam Tamachi Mazar and Picnic Point	37	0	71	0
Near Picnic Point	35	0	73	0

Table 7
Results of various water quality parameters

Sample ID	DO (mg/L)	*E. coli* (CFU/1mL)	Total coliform (CFU/1mL)
WHO/NEQS Limits	NGVS	0	0
Kalri Baghar Feeder Upper Right side	13.6	130	250
Kalri Baghar Feeder Upper Mid-point	15.3	128	270
Kalri Baghar Feeder Upper-WAPDA Colony municipal effluent	13.4	300	500
Kalri Baghar Feeder Upper-Industrial waste discharge point	16.2	250	500
Kalri Baghar Feeder Upper	11.9	270	450
Kalri Baghar Feeder Upper	14.7	118	240
Near KG Canal Karachi Feeder	14.3	120	230
Near Lake Bank at RD-50	13	125	300
Sindh Irrigation Department Rest House	9.3	128	250
Near Nori Jam Tamachi Mazar	10	120	300
Mid of Lake between Noori Jam Tamachi Mazar and Picnic Point	10.2	128	300
Near Picnic Point	10	128	300

Dissolved oxygen (DO), *E. coli* and total coliform.

found for above-mentioned site is 8.7 higher than the NEQS limit. However, average value of pH for Keenjhar Lake is higher than the average value of pH for KB Feeder. The reason behind this could be occurrence of various layers of calcium bicarbonate in the Lake. High bicarbonate values are ultimately responsible for increase in pH.

3.3. Total dissolved solids

The values of TDS are recorded at selected sampling stations for KB Feeder and Keenjhar Lake and are plotted in Fig. 3.

The higher values of TDS are found for station RD-36 particularly at substation RD-36-1, where WAPDA colony municipal waste inflows into the KB Feeder. All the sites have TDS values within safe limits. The values of TDS are quite stable for Keenjhar Lake as it has stationary water. The settling of suspended and dissolved solids has made no fluctuations in TDS values for the lake, while KB Feeder has some flowing speed so its values fluctuate.

3.4. Electrical conductivity

The values of electrical conductivity are recorded at selected sampling stations for KB Feeder and Keenjhar Lake and are plotted in Fig. 4.

The higher values of EC are found for station RD-36 particularly at substation RD-36-1 where WAPDA colony municipal waste inflows into the KB Feeder. All the sites have values of EC within safe limits. EC shows significant correlation with TDS. There is no reliable data available on the health effects of EC in drinking water but 1,500 μS/cm is considered to be standard value. The values of EC are quite stable for Keenjhar Lake as it has stationary water. The

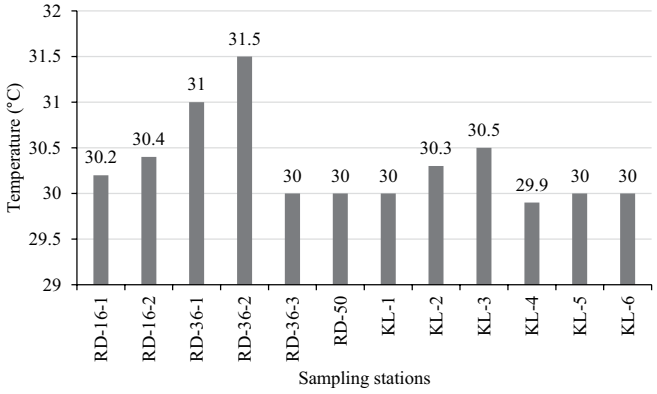

Fig. 1. Temperature recorded at selected sampling stations for KB Feeder and Keenjhar Lake.

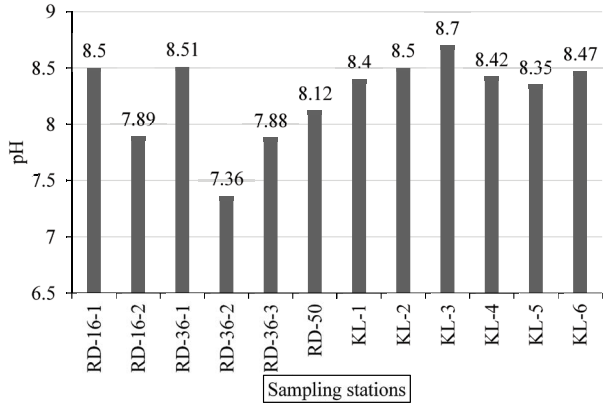

Fig. 2. pH values recorded at selected sampling stations for KB Feeder and Keenjhar Lake.

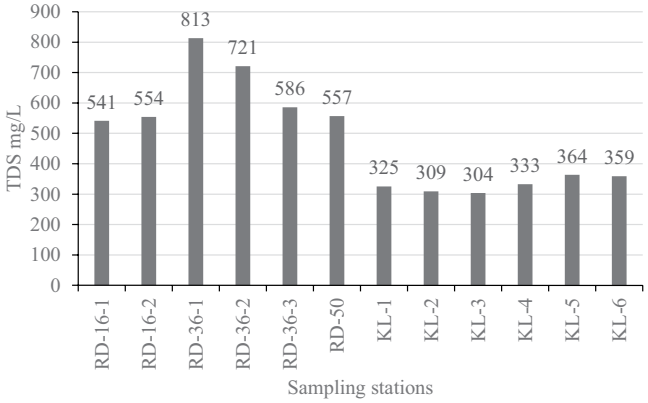

Fig. 3. TDS values recorded at selected sampling stations for KB Feeder and Keenjhar Lake.

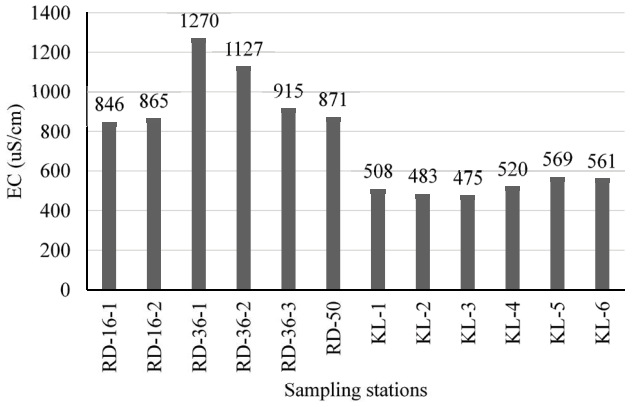

Fig. 4. Electrical conductivity recorded at selected sampling stations for KB Feeder and Keenjhar Lake.

settling of salts (calcium, magnesium, sodium and potassium) and carbonate has made no fluctuations in electrical conductivity values for the lake while KB Feeder has certain flowing speed so its values fluctuate.

3.5. Turbidity

The values of turbidity are recorded at selected sampling stations for KB Feeder and Keenjhar Lake and are plotted in Fig. 5.

3.6. Bicarbonate

The values of bicarbonate are recorded at selected sampling stations for KB feeder and Keenjhar Lake and are plotted in Fig. 6.

Higher values of turbidity are found for KB Feeder particularly for site RD-36-1. The values of turbidity for KB Feeder are higher than the safe limits. The values found in Keenjhar Lake are within safe limits and are also quite stable. The higher values for KB Feeder could be due to the reason that KB Feeder has high concentration of suspended clay and silt particles. Their movement with flowing water make water cloudy ultimately causing for severe turbidity. The Keenjhar Lake is a calm reservoir having velocity of 0.001 to 0.1 m/s causes turbid water of KB Feeder to be settled down in different layers.

3.7. Calcium

The values of calcium are recorded at selected sampling stations for KB Feeder and Keenjhar Lake and are plotted in Fig. 7.

Higher value of bicarbonate is found to be at KL-3 point in Keenjhar Lake which is near Sindh Irrigation Department Rest House. While for all the other sites, they are quite stable. All the values are within safe limits.

3.8. Alkalinity

The values of alkalinity are recorded at selected sampling stations for KB Feeder and Keenjhar Lake and are plotted in Fig. 8.

Higher value of calcium is found at RD-36-2 where effluent inflow of Kotri industrial area occurs to KB feeder. While for all the other sites, the value of calcium is appropriate from drinking point of view. Guideline value for calcium is not defined but drinking water must have within the range of 40–50 mg/L.

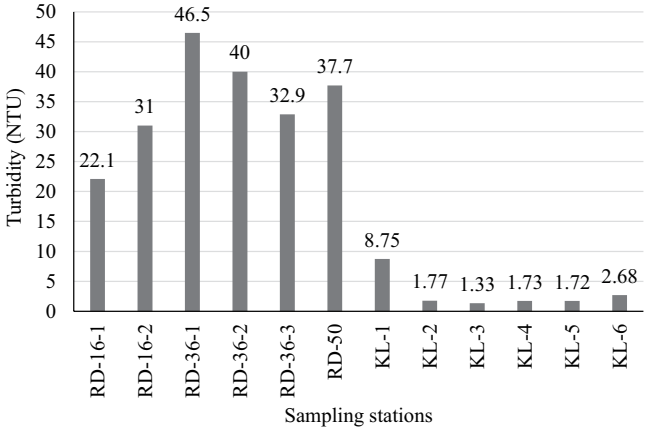

Fig. 5. Turbidity values recorded at selected sampling stations for KB Feeder and Keenjhar Lake.

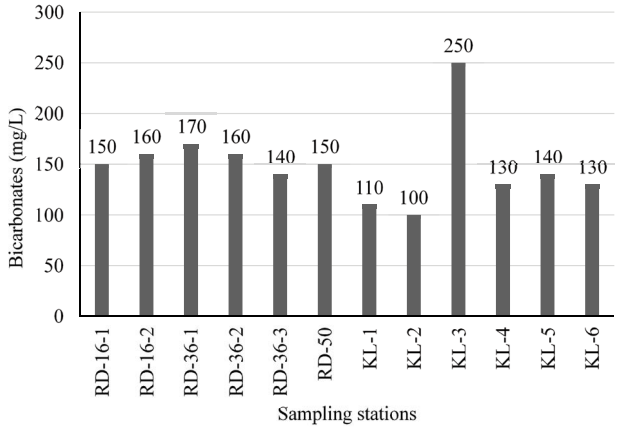

Fig. 6. Bicarbonate values recorded at selected sampling stations for KB Feeder and Keenjhar Lake.

Higher value of alkalinity is found to be at KL-3 point in Keenjhar Lake which is near Sindh Irrigation Department Rest House. While for all the other sites, they are quite stable. All the values are within safe limits. Alkalinity is composed of carbonate and bicarbonate that's why it has analogues results to bicarbonate. Alkalinity acts as stabilizer for pH. The high value of pH is found also for KL-3 point located in Keenjhar Lake. The result indicates that this location has higher concentration of calcium ores.

3.9. Total hardness

The values of hardness are recorded at selected sampling stations for KB Feeder and Keenjhar Lake and are plotted in Fig. 9.

Higher values are found for KB feeder while lower and quite stable values are found for Keenjhar Lake. But at RD-36 station where WAPDA colony municipal waste and Kotri industrial effluent inflows are located have higher concentration than other sites. Hardness in drinking water is mainly caused by presence of various salts. The settling of those salts across the lake water may have decreased the overall concentration in the lake.

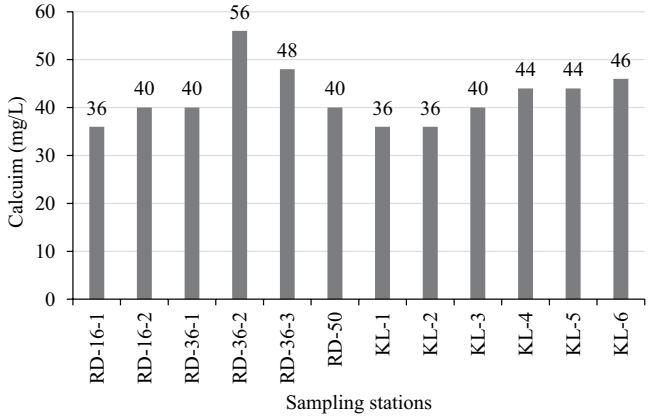

Fig. 7. Calcium values recorded at selected sampling stations for KB Feeder and Keenjhar Lake.

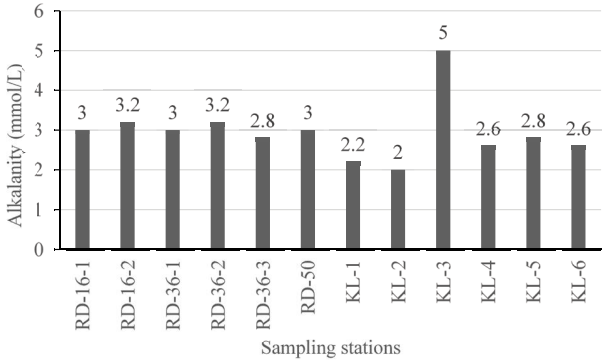

Fig. 8. Alkalinity values recorded at selected sampling stations for KB Feeder and Keenjhar Lake.

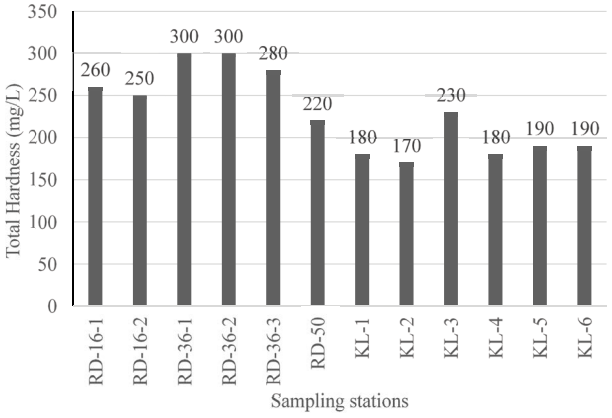

Fig. 9. Hardness values recorded at selected sampling stations for KB Feeder and Keenjhar Lake.

3.10. Magnesium

The values of magnesium are recorded at selected sampling stations for KB Feeder and Keenjhar Lake and are plotted in Fig. 10.

Higher values are found for KB feeder particularly for site RD-36-1, where municipal waste of WAPDA colony

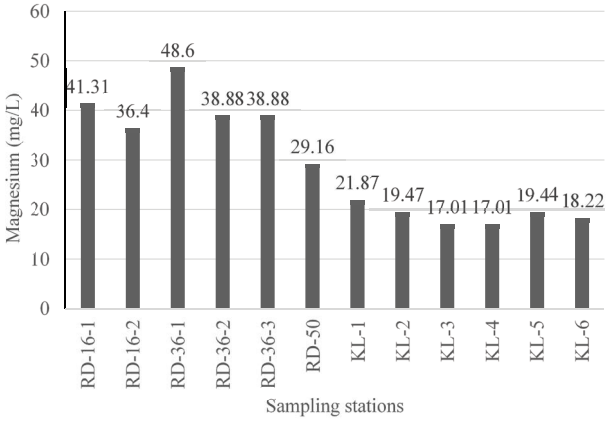

Fig. 10. Magnesium values recorded at selected sampling stations for KB Feeder and Keenjhar Lake.

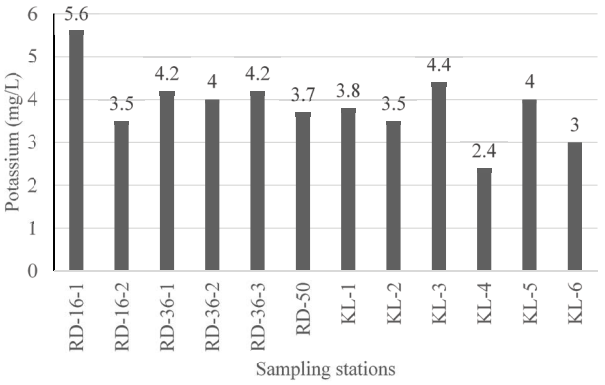

Fig. 11. Potassium values recorded at selected sampling stations for KB Feeder and Keenjhar Lake.

inflows into the canal. This anthropogenic contamination has lower effects on Keenjhar Lake water where settling of magnesium salts reduces its overall strength. All the values are within safe limits and no significant impact could be considered for magnesium on lake water. Since, the magnesium has strong role in preventing cardiovascular diseases [21].

3.11. Potassium

The values of potassium are recorded at selected sampling stations for KB Feeder and Keenjhar Lake and are plotted in Fig. 11.

Higher value is found for RD-16-1 which is the origin point of KB Feeder. This location lies near the shore of KB Feeder having higher concentration of potassium caused by soil runoff and sewage inflows. The value is found quite stable for all the other sites except KL-4 which lies near Noori Jam Tamachi at Keenjhar Lake. The lower value for this point may be due to high depth of Lake at this point. Potassium is an essential element in human nutrition so no limit is set while WHO recommends 12 mg/L.

3.12. Sodium

The values of sodium are recorded at selected sampling stations for KB Feeder and Keenjhar Lake and are plotted in Fig. 12.

Higher values of sodium are found for KB Feeder especially for RD-36-1, where WAPDA municipal colony is located. Main source of sodium for drinking water is municipal, industrial and erosion inflows. The lower values are found for Keenjhar and they are quite stable for all the sites. The content of sodium is not regulated however, WHO has recommended its value as 200 mg/L.

3.13. Sulfate

The values of sulfate are recorded at selected sampling stations for KB Feeder and Keenjhar Lake and are plotted in Fig. 13.

Higher values of sulfate are found for KB Feeder especially at RD-36-2 where industrial effluent of Kotri industrial

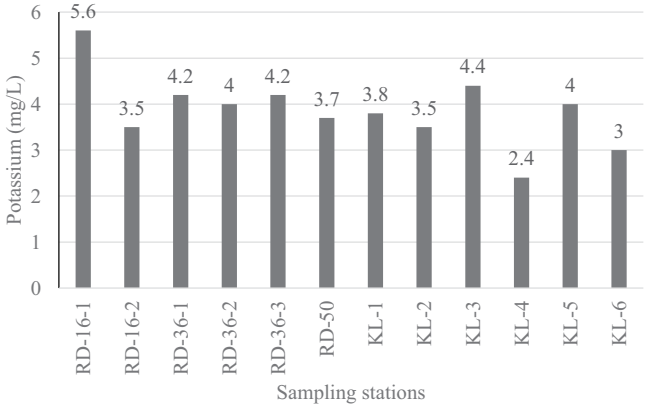

Fig. 12. Sodium values recorded at selected sampling stations for KB Feeder and Keenjhar Lake.

area is discharged into KB Feeder. The sulfate occurs in natural water due to erosion of rocks and soil, atmospheric precipitation and from industrial sewage. The lower values are found for Keenjhar Lake stable for all the sites.

3.14. Fluoride

The values of fluoride are recorded at selected sampling stations for KB Feeder and Keenjhar Lake and are plotted in Fig. 14.

Higher values of fluoride are found at RD-36-2 where Kotri industrial area inflows into KB Feeder. The value found for above site is higher than safe limits. Higher concentration of fluoride is very harmful for humans. No fluoride is found in Keenjhar Lake due to settling of fluoride ion in Keenjhar water.

3.15. Chloride

The values of chloride are recorded at selected sampling stations for KB Feeder and Keenjhar Lake and are plotted in Fig. 15.

Higher values of chloride are found at station RD-36, where effluent water inflows to canal. Main source of chloride is sewage and industrial wastewater. The value found

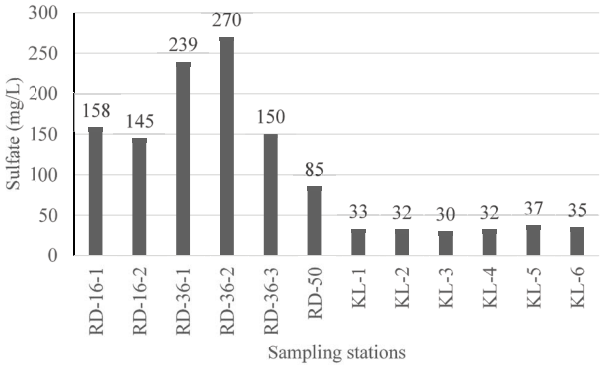

Fig. 13. Sulfate values recorded at selected sampling stations for KB Feeder and Keenjhar Lake.

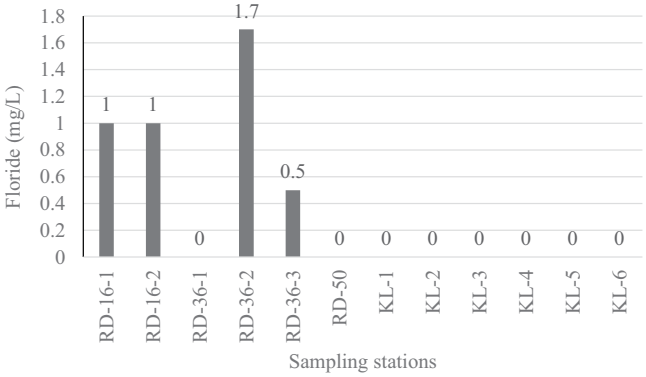

Fig. 14. Fluoride values recorded at selected sampling stations for KB Feeder and Keenjhar Lake.

at RD-36-2 where Kotri industrial water inflows into canal is higher than the safe limits while all the other sites of KB Feeder have values within safe limits. Lower and quite stable values are found for Keenjhar Lake which are within safe limits. These stable values for lake might be due to settling of chloride ions in Lake bottom. Here equal distribution can be due to very low velocities in deep water.

3.16. Arsenic

The values of arsenic are recorded at selected sampling stations for KB Feeder and Keenjhar Lake and are plotted in Fig. 16.

Arsenic is found only for two sites of KB Feeder while its concentration for Keenjhar Lake water was zero. The arsenic was found in the sites RD-36-1 and RD-36-2, where WAPDA colony waste and Kotri industrial area effluent inflows into lake, respectively. The higher values of arsenic can cause severe skin problems.

3.17. Dissolved oxygen

The values of dissolved oxygen are recorded at selected sampling stations for KB feeder and Keenjhar Lake and are plotted in Fig. 17.

Higher values of dissolved oxygen were found for KB Feeder while lower were found for Keenjhar Lake. All the

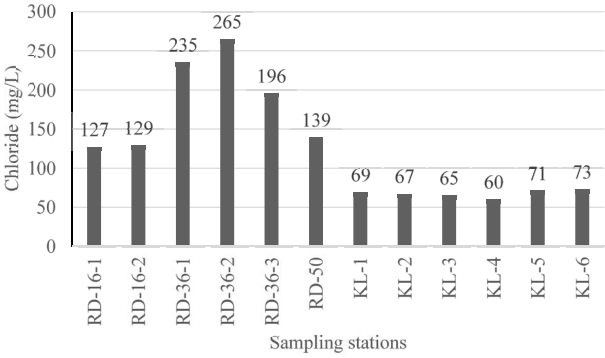

Fig. 15. Chloride values recorded at selected sampling stations for KB Feeder and Keenjhar Lake.

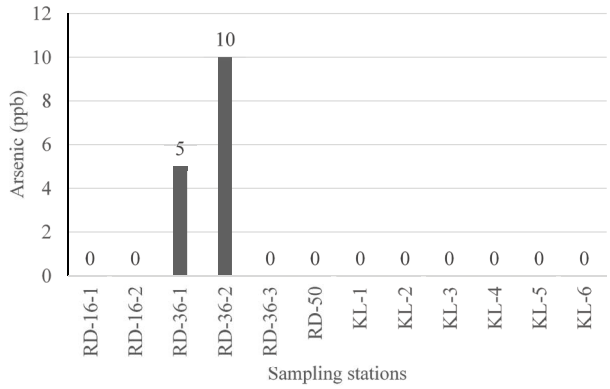

Fig. 16. Arsenic values recorded at selected sampling stations for KB Feeder and Keenjhar Lake.

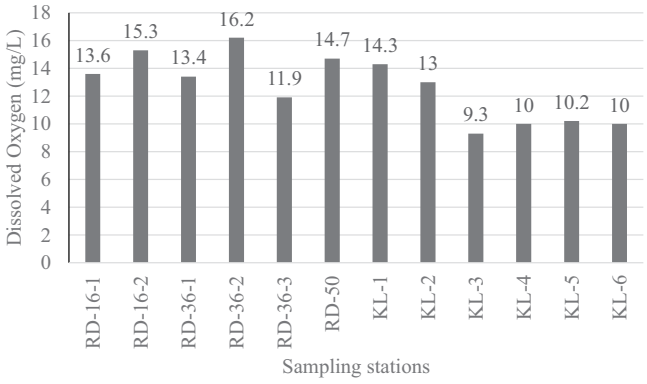

Fig. 17. Dissolved oxygen values recorded at selected sampling stations for KB Feeder and Keenjhar Lake.

values were within safe limits. The higher values in KB Feeder might be due to the reason of flowing water with high dissolved oxygen level as compared with stagnant water because water movement increases the surface area of water so that water having more surface area has higher chances to come in contact with air. No guideline values are set for dissolved oxygen but 5 mg/L is considered to be standard value.

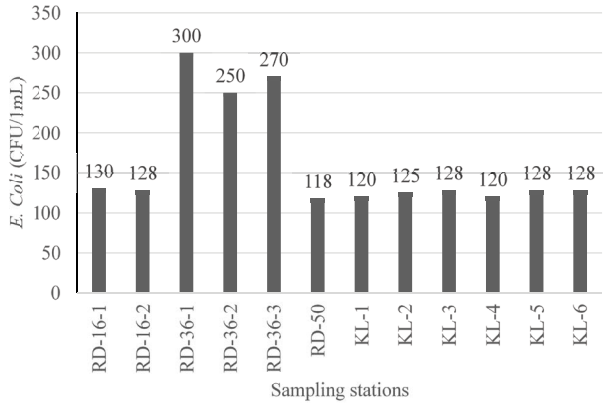

Fig. 18. Values of *E. coli* recorded at selected sampling stations for KB Feeder and Keenjhar Lake.

3.18. E. coli

The values of *E. coli* are recorded at selected sampling stations for KB Feeder and Keenjhar Lake and are plotted in Fig. 18.

Higher values of *E. coli* are found in KB Feeder particularly for station RD-36 where human and animal waste inflow occurs while lower and quite stable values are found for Keenjhar Lake. The KL-6 and KL-3 points have high *E. coli* values than other sites in Keenjhar Lake because the area is located near picnic point and Sindh Irrigation Department, respectively. We found some cattle farms and villages along the bank of canal near RD-36 so it might be possible that this increase in value for above-mentioned sites could be due to disposal of their waste to canal. Lake water is not safe to drink without any treatment because according to WHO Standards drinking water must have zero *E. coli*.

3.19. Total coliform

The values of total coliform are recorded at selected sampling stations for KB Feeder and Keenjhar Lake.

Higher values of total coliform are found in KB Feeder particularly for station RD-36 where human and animal waste inflow occurs while lower and quite stable values are found for Keenjhar Lake. The KL-6 and KL-3 points have high total coliform value than other sites in Keenjhar Lake because the area is located near picnic point and Sindh Irrigation Department, respectively. We found some cattle farms and villages along the bank of canal near RD-36 so it might be possible that this increase in value for above-mentioned sites could be due to disposal of their waste to canal. Lake water is not safe to drink without any treatment because according to WHO Standards drinking water must have zero total coliform.

4. Conclusions

The result indicates that the KB Feeder is the main point where pollution accumulates due to wastewater discharge of anthropogenic pollution sources. This untreated wastewater feeding to KB Feeder ultimately contaminated the fresh water of Keenjhar Lake on which aquatic and human life relies. Higher alkalinity and pH values of Keenjhar Reservoir near Sindh Irrigation Department Rest House (KL3) provides most favorable environment for biological activities so it is concluded that municipal waste of rest house is big menace for lake water. The lower DO value indicates the accumulation of nutrients at the bottom of lake causing abrupt growth of harmful algae. The analysis of water quality parameters indicates that higher values of temperature were found for the site RD-36-1 and RD-36-2 where WAPDA colony municipal waste and Kotri industrial effluent water inflows occur. The values were higher than NEQS limits. The values found for pH were higher for Keenjhar Lake whereas quite fluctuating for KB Feeder. The parameters such as TDS, electrical conductivity (EC), turbidity, hardness, magnesium, sodium, sulfate, fluoride, chloride, arsenic, dissolved oxygen, *E. coli* and total coliform were found higher for KB Feeder water while lower for Keenjhar Lake water. The higher values for KB Feeder could be due to flowing water and nearness to pollution sources whereas stationary water at Keenjhar Lake causes these parameters to be settled down. The levels of electrical conductivity, TDS, hardness, chloride (Cl^-), sulfate $(SO_4)^{2-}$, nitrate $(NO_3)^{1-}$ and total coliform were found higher in sample of RD-36 where Kotri industrial effluent and WAPDA Colony wastewater flows. The water quality parameters of the lake are within safe limits as given by Pak NEQS. Dissolved oxygen (DO) value was measured near KG Canal where lake water has exit which could be because of occurrence of organic species in the lake. Moreover, *E. coli* and fecal coliform bacteria were also detected in each of water sample which make lake water unfit for dinking purposes without treating. Finally, we can conclude that Keenjhar Lake water is deteriorating.

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