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Evaluation of physico-chemical parameters of Manchar Lake water and their comparison with other global published values

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Abstract
The aim of current study was to evaluate the status of the Manchar lake water with respect to different physico-chemical parameters (electric conductivity, pH, chloride, phosphate, sulfate, total alkalinity, potassium, calcium, magnesium, manganese, iron, cadmium, copper, arsenic, nickel, zinc, chromium lead and selenium) in 2005-2007. Among the elemental investigation of Manchar Lake water except Co, Cr, Cu and Mn, other elements (Al, As, Ca, Cd, Fe, Mg, Na, K, Ni, Pb and Se) have higher values as compared to the permissible level of these elements in drinking water. The results were compared with WHO water quality guidelines as well as with literature values reported for global lake water.

***Keywords**:* Lake water, physico-chemical parameters, provisional guideline values, trace and toxic elements

Introduction

Water is an essential component for survival of life on earth, which contains minerals, important for man [1]. Lakes and surface water reservoirs are the planet's most important freshwater resources and provide innumerable benefits. Which are used as domestic and irrigation purposes, and provide ecosystems for aquatic live especially fish, thereby functioning as a source of essential protein, and for significant elements of the world's biological diversity. They have important social and economic benefits as a result of tourism and recreation, and are culturally and aesthetically important for people throughout the world. They also play an equally important role in flood control [2]. However, the remarkable increase in population resulted in a considerable consumption of the water reserves world wide [3]. The quality of surface water is largely affected by natural processes (weathering and soil erosion) as well as anthropogenic inputs (municipal and industrial wastewater discharge). The anthropogenic discharges represent a constant polluting source, whereas surface runoff is a seasonal phenomenon, largely affected by climatic conditions [4-6].

Among environmental pollutants, metals are of particular concern, due to their potential toxic effect and ability to bioaccumulation in aquatic ecosystems [7, 8]. Therefore, it has public interest [9, 10]. The serious environmental problems have been faced in developing as well as developed countries [11]. Dissolved constituents of water bodies are often determined as a major component for baseline limnological studies. The major ions Ca^{++}, Mg^{++}, Na^{+}, K^{+}, Cl^{-}, SO_4^{--}, HCO_3^{-}, and CO_3^{--} are essential constitute of water and responsible for ionic salinity as compared with other ions [12]. Contamination of aquatic ecosystems with heavy metals is a serious problem, all over the world [13, 14].

Water quality monitoring has a high priority for the determination of current conditions and long-term trends for effective management. The supply of safe water has a significant impact on the anticipation of water transmissible diseases [15]. The abundance of

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organic compounds, radionuclides, toxic chemicals, nitrites and nitrates in water may cause unfavorable effects on the human health especially cancer, other human body malfunctions and chronic illnesses [16]. Therefore, it is necessary to frequently monitor water quality, used for drinking purposes.

In Pakistan, drinking water comes from groundwater and surface water including rivers, lakes and reservoirs. The free style way of disposal of agricultural, industrial and domestic effluents into natural water bodies may cause serious contamination. Run-off from agricultural land and saline seeps subject the most vulnerable water pollution to increased salinity, so the freshwater lakes are highly affected. The Manchar Lake, Pakistan's largest freshwater lake is an example. It is a main source of domestic drinking water because groundwater in the surrounding area is saline and is not suitable for drinking [17]. The lake's water in downstream areas is also important for farmers and fishermen, who depend on the lake for irrigation and fishery.

Extensive evaporation of water from the lake due to high temperature and low rain, enhances the amount of salts, heavy metals and other pollutants, which are conscientious factors for the poor quality of the lake ecosystem. Up to now, there was no systematic environmental study carried out for the quality control assessment of Manchar Lake. The present study is a part of a comprehensive program conducted, to evaluate the toxicological effects of contaminated water of Manchar Lake, which had caused up to 60 deaths, mostly of children in Hyderabad during 2004 [18]. The objective of the present study was to check the quality status of the Manchar lake water during 2005–07, with respect to different physico-chemical parameters. In addition, the under studied areas there has no any serious attention been paid previously due to the unawareness of high content of metals and metalloids present in lake and underground water. These factors reinforced us to make awareness at local and international levels for environmental protection agencies, about the terrible condition of understudy communities as compared to other effected areas.

Experimental

Reagents and glassware

Ultrapure water obtained from ELGA Labwater System (Bucks, UK) was used throughout the work. The extractant solution of EDTA, nitric acid and hydrogen peroxide were of analytical grade Merck (Darmstadt, Germany) and were checked for possible trace element contamination. Standard solutions of all 16 elements were prepared by dilution of certified standard solutions 1000 ppm, Fluka Kamica (Buchs SG and Switzerland) of corresponding metal ions. Argon gas with 99.99% purity was used as sheath gas for the atomizer and for internal purge. Glassware were kept overnight in 5 M HNO_3, rinsed with deionized water before use.

Apparatus

WTW 740 Germany, pH-meter was used for pH measurements of the reagents, water samples. Electrical conductivity was measured in water using an EC meter (WTW inoLab Cond: 720 Germany). Global positioning system (GPS) iFinder (Lowrance^{TM}, Mexico) was used for searching same sampling site during study. Atomic absorption spectrometer of Hitachi Ltd., Model 180-50 (Japan) and Perkin-Elmer atomic absorption spectrometer model AA700 (Norwalk, CT, USA) were used for recording analytical data of the elements under investigation.

Sampling site

Manchar is the biggest shallow-water natural lake of Pakistan (Fig. 1) situated at a distance of about 18 km from Sehwan Sharif, Jamshoro district, Sindh (26°3' N: 67°6'E). It is a huge natural depression flanked by the Khirthar hills in the west, the Laki hills in the south and the river Indus in the east. The mean depth of Manchar Lake is approximately 2.5–3.75m and it covers an area of 233 km^2. Flood barriers were constructed in 1932 from its northern and northeastern boundaries. The human activities have been changing significantly the original regime of the lake over the last 50 years. The most important activities are construction and enlargement of the artificial channels linking the river to the lake and the construction of flood embankments to the north. The Main Nara Valley Drain (MNVD) brings agricultural, municipal, industrial and saline water constitutes constant polluting sources for the lake, whereas surface runoff is a season's phenomenon, and it has not been significant due to dry seasons in 2000–05.

Sample collection

The sampling network was designed to cover a wide range of determinates of key sites, which reasonably represent the water quality of the lake system, accounting for the tributary and inputs from wastewater drains that have impact on the water quality (Fig. 1). The sit 1 (MNVD), represents the main entrance of agricultural and industrial waste to the lake and is responsible for deterioration of the lake ecosystem. Sites 2 and 3 which are located at the downstream side of lake, where mostly the boating

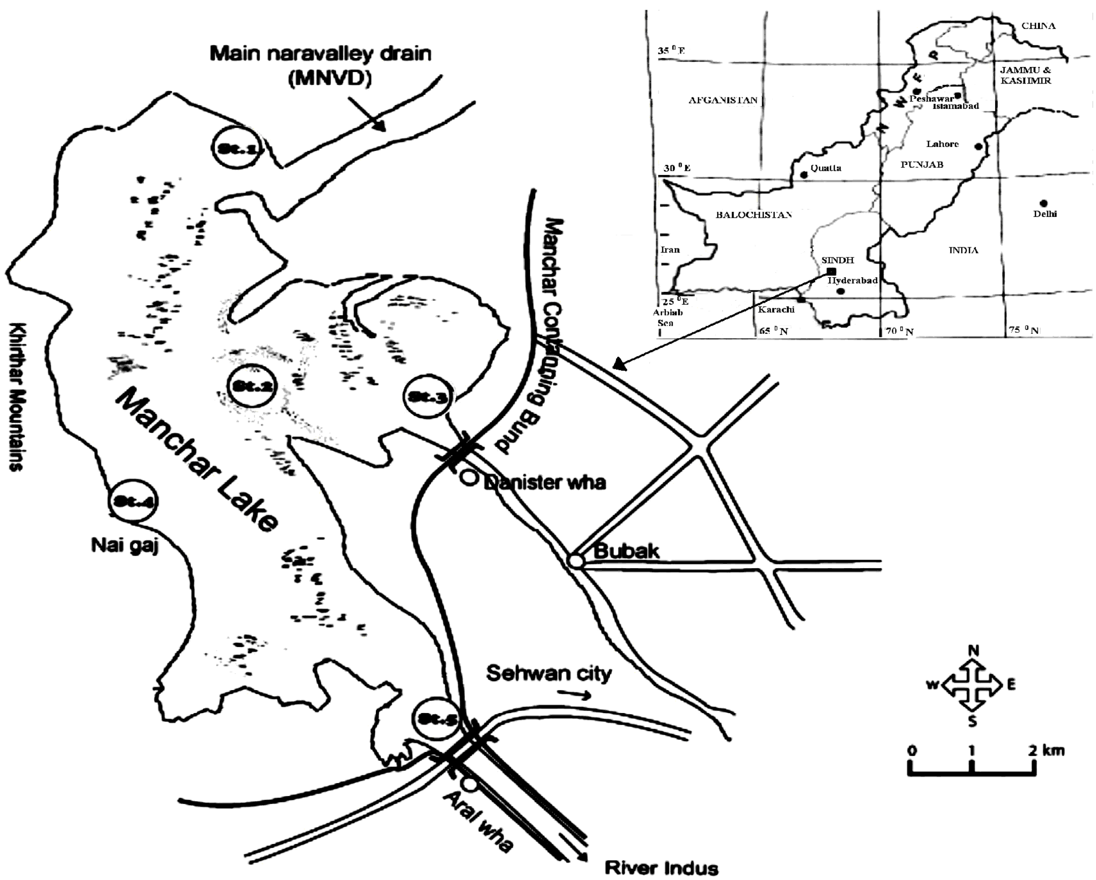

Figure 1. **Map of Manchar Lake and Pakistan**

occurs for fishing and local domestic waste also drains to lake at this site. Site 3 has an outlet of lake water via canal, providing water to agricultural lands. Site 4 is near the hilly area from where mostly fresh water enters into the lake during rainy season. Site 5 is connected to Indus River and has dual aspects, for supply of fresh water when water is available in the Indus River and also as an output of lake water when the level of the Indus River is low. The samples were collected from 8:00 AM to 4:00 PM during 2005-2007. Water samples were collected using open water grab sampler (1.5 L capacity) from 5 to 7 sites of same station randomly. All water samples were stored in insulated cooler containing ice and delivered on the same day to laboratory and all samples were kept at 4°C until processing and analysis [19].

Analytical procedure

The physico-chemical parameters were determined in laboratory following the standard protocols [19]. The temperature, pH, electrical conductivity (EC), of each water sample were measured at the sampling points by a mercury thermometer, digital pH meter and EC meter, respectively. In laboratory the duplicate aqueous samples of about 1000 mL of each batch collected from five sampling sites, were filtered through whatman filter paper No. 42 and the samples were divided into two parts. One part was used for analysis of anions and physico-chemical parameters, while second part treated with 1mL of concentrated HNO_3 for metal analysis. Total alkalinity determined by acid titration using methyl-orange as endpoint and chloride by silver nitrate ($AgNO_3$) titration, using potassium chromate (K_2CrO_4) solution as an indicator. Phosphate was measured by molybdate-ascorbic acid method [19] and SO_4 was determined spectrophotometry by barium sulfate turbidity method [19].

The acid-treated water samples were further diluted 20-time with ultrapure water for analyzing Ca, K and Na , using flame photometry, while Mg was determined by the flame atomic absorption spectrometer

(FAAS). For trace and toxic elements, the volume of water samples was reduced four-fold at 60°C on an electric hot plate. The Cu, Fe and Zn were determined by FAAS using an acetylene-air flame, while Al was determined by acetylene-nitrous oxide flame. Cd, Co, Cr, Mn, Ni and Pb were analyzed using electrothermal atomic absorption spectrometer (ETAAS), while As and Se were determined using hydride generation method (HGAAS).

The quality of the analytical data was ensured through careful standardization, blank measurements and triplicate samples. For the validity of the determination procedure, the standard addition method was used. The ionic balance of each sample was within ±5%.

Analytical figure of merit

Calibration was performed with a series of all sixteen standards. Sensitivity was the slope value obtained by least-square regression analysis of calibration curves based on absorbance and peak area measurements. The linear range of the calibration curve reached from the detection limit up to 2.0, 15.0, 25.0, 200, 200, 125, 200 and 100 ng/mL for Al, As, Cd, Co, Cr, Mg, Ni and Pb, 2.0, 1.0, 2.0, 1.0, 1.0, 0.5, 15.0 and 1.0 µg/mL for Ca, Cu, Fe, K, Mn, Na, Se and Zn, respectively.

The detection and quantification limits, given by

$$LOD = 3 \times \frac{s}{m}$$

and

$$LOQ = 10 \times \frac{s}{m}$$

respectively, where s is the standard deviation of ten measurements of a reagent blank and m is the slope of the calibration graph, were also obtained for each case, LODs of 54.9, 0.036, 164.3, 0.327, 4.7, 6.9, 17.3, 69.2, 14.0, 2.46, 17.7, 5.52, 6.67, 3.38, 0.04 and 10.0 ng/ mL and LOQs of 183, 0.124, 547.4, 1.09, 15.8, 23.0, 57.7, 230.6, 46.8, 8.20, 59.1, 18.4, 22.2, 11.3, 0.133 and 33.5 ng/mL calculated for Al, As, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, Pb, Se and Zn, respectively.

Result and discussion

The Manchar lake water is used for multipurpose such as agriculture, fishing and used for local people for drinking and other domestic purposes. Boating activities for fishing and to stay day and night in boats, while boat repair activities may also cause the contamination, this phenomena is also reported in literature for evaluation of pollution in other lakes [20-21]. The mean with standard deviation values of all physico-chemical parameters and elemental concentrations of water samples collected from five sampling sites are presented in Table 1 and 2, the results are compared with the values of World Health recommended maximum permissible limits [22] and with other global published values on Lakes in different continents.

Air and water temperatures showed a very characteristic annual cycle, with higher values during the summer (30–49°C), and lower values in the winter season (10–28°C). The pH of Manchar lake water samples during study period (pH range: 7.4-8.9) were nearly neutral to mildly alkaline slightly above the upper limit defined by WHO guidelines of 6.5–8.5 [22]. The ions (Ca^{++}, Mg^{++}, Na^{+}, K^{+}, Cl^{-}, $SO4^{--}$, HCO_3^{-}, and CO_3^{--}) were determined, which constitute the total ionic salinity in most fresh waters as reported in literature [23]. The EC values of Marcher Lake water samples exceeded the WHO (2004) guidelines (Table-2) for drinking water, the 12–15- folds higher EC is attributed to the high salinity and mineral contents. The annual rainfall in this basin is very low, so very little variation was obtained in values of conductivity during study period. The mean conductivity values of lake water were higher than those reported in literature for other lakes except in the case of Lake Nakuru, Kenya, which is about five times higher than our results (Table 1). The previous study on Manchar lake in 1995 shows the conductivity is two time lower than the current value as shown in table 1 [32]. The conductivity of Manchar lake water samples was 4.1-227 times higher than the reported mean conductivity value in different lakes [35, 37, 47, 49].

The concentrations of SO_4 and PO_4 in Manchar Lake water did not exceed the WHO recommended values, while the values of SO_4 were higher than literature reported values of other lakes [37, 43, 48, 49]. The chloride concentration was found to be high in lake water samples exceeding the WHO proposed drinking water quality criteria (WHO, 2004). According to Versari et al. (2002) [1], chloride concentrations higher than 200 mg/L are considered to be a risk for human health and may cause unpleasant taste of water.

The mean values of major, trace and toxic elements due to anthropogenic contamination (domestic, industrial and agricultural wastes) in water do not vary among sampling sites. The trend obtained was also supported by the analysis of the results on the raw data of water samples. Among the elemental investigation of Manchar Lake water except Co, Cu, Cr and Mn, other elements (Al, As, Ca, Cd, Fe, Mg, Na, K, Ni, Pb and Se) have higher values as compared to the permissible level of these elements in drinking water [22].

Table 1. **Physico-Chemical Concentration of understudy Lake water and Comparison with other global published values**

	pH	Total Alkalinity (mg $CaCO_3$/L)	Conductivity (µS/cm)	Phosphate (mg/L)	Sulfate (mg/L)	Chloride (mg/L)
WHO 2004 [22]	6.5-8.5	200	-	-	250	250
Manchar Lake	8.02 ± 0.21	157.0 ± 40.3	5243.6 ± 1786	0.44 ± 0.14	163.8 ± 13.4	1260 ± 251
Manchar Lake 1995 (Mastoi, et al., 2008)[32]	8.4±0.2	125.8±46.1	2310 ± 581.3	0.02±0.01	-	431.6±225
Lake Nakuru, Kenya (Ochieng et al., 2007)[33]	10.25 ± 0.21	-	27,500 ± 276	-	-	-
Mc Farlane, Canada (Othman, 2006)[34]	8.22 ± 0.01	-	370 ± 0.6	-	-	-
Lake Balaton, Hungary (Nguyen et al., 2005)[35]	-	-	-	-	-	-
Hazar Lake, Turkey (Ozmen et al., 2004) 24][36]	-	-	-	-	-	-
Tuskegee Lake, USA (Ikem, 2003)[37]	7.44 ± 0.14	29.67 ± 1.29	82.48 ± 0.71	0.07 ± 0.04	8.76 ± 2.04	9.31 ± 0.64
Lake Texoma USA (An, 2003)[38]	-	-	-	-	-	-
Scottish mountain Lake, Scotland (Yang et al., 2002)[39]	-	-	-	-	-	-
Lake Doirani, Greece (Anthemidis et al., 2002) 10][40]		-	-	-	-	-
210 Lakes in Norway (Rognerud and Fjeld, 2001)[41]	6.26 ± 0.63	-	-	-	-	-
Lake Kasumigaura (autumn 95), Japan (Alam et al., 2001)[42]	8	-	-	8	-	-
Siberian Ponde (Gladyshev et al., 2001)[43]	7.7–9.5	-	-	-	1.24	
Ataturk Dam Lake, Bozyazi. (Karadede and Unlu 2000)[44]	-	-	-	-	-	-
Nacharam Lake,Indiad (Govil et al., 1999)[45]	-	-	-	-	-	-
16 Latvian Lakesc (Klavins et al., 1998)[46]	6.5–8.10	-	-	-	-	-
36 Lakes in Lapland, Finland (Mannio et al., 1995)[47]	5.7		1300			
Reference valuesfor freshwater (Markert,1994)[48]	-	-	-	-	8.8–22.6	8
Blue mountain Lake,NE, U.S.A.(Sprenger et al., 1987)[49]	5.3–6.2	-	23.5–30	-	7.9–16	0.497

Table 2 **. Elemental concentrations of understudy Lake water and Comparison with other global published values.**

Parameter	**Al (µg/L)**	**As (µg/L)**	**Ca (µg/L)**	**Cd (µg/L)**	**Co (µg/L)**	**Cr (µg/L)**	**Cu (µg/L)**	**Fe (mg/L)**
WHO 2004[22]	200	10	100	3	40	50	2000	0.3
Manchar Lake	1366.9 ± 312.9	78.9 ± 16.1	219.9 ± 45.9	4.98 ± 1.35	38.5 ± 8.1	7.43 ± 1.62	19.06 ± 4.3	2.78 ± 0.77
Manchar Lake 1995[32]	-	-	707 ± 12.9	1.1 ± 1.0	4.0 ±3.4	-	8.9 ±7.7	0.012 ±0.0035
Lake Nakuru, Kenya[33]	-	-	-	43.0 ± 1.4	316 ± 19.2	-	100 ± 9.66	-
Mc Farlane Canada[34]	-	-	-	0.03 ± 0.001	0.16 ± 0.02	-	11.0 ± 23	-
Lake Balaton, Hungary[35]	-	-	-	$1.5x10^{-3}$	-	-	-	-
Hazar Lake,Turkey[36]	-	-	-	-	-	-	18	0.12-0.43
Tuskegee Lake, USA[37]	155 ± 153.3	0.60 ± 2.2	6.82 ± 1.89	0.001 ± 0.005	0.03 ± 0.09	0.03 ± 0.10	0.5 ± 0.9	0.28 ± 0.15
Lake Texoma, USA[38]	92.0 ± 96.0	<33	102 ± 23	20 ± 0.61	<20.0	4.0 ± 2.0	24.0 ± 0.20	0.199 ± 0.093
Scottish mountain Lake, Scotland[39]	-	-	-	0.09–0.23	-	-	0.18–2.02	-
Lake Doirani, Greece[40]	-	-	-	0.1-0.4	-	1.0-17.0	1.0-13.0	0.029-0.69
210 Lakes in Norway[41]	-	-	-	-	-	-	-	-
Lake Kasumigaura[42]	1140	0.72	14.77	0.02	0.28	0.47	2.88	0.49
Siberian Ponde[43]	0.3 ± 0.04a	-	38.6 ± 2.35	< 1	-	2.03 ± 0.2	2.29 ± 0.43	0.070 ± 0.009
Ataturk Dam Lake, Turkey[44]	-	-	-	-	-	-	25.0	0.062
Nacharam Lake,Indiad[45]	-	9.5 ± 1.5	-	8.9 ± 3.5	-	-	-	-
16 Latvian Lakesc[46]	-	-	1.5–74.1	0.01–0.08	0.03–0.09	-	0.32–0.96	0.29 ± 0.06
36 Lakes in Lapland, Finland[47]	63	0.17	-	0.02	-	0.24	0.28	-
Reference valuesfor freshwater[48]	-	0.5	2	0.2	0.5	1	3	-
Blue mountain Lake, U.S.A.[49]	13–71	-	-	-	-	-	-	0.5

Table 2 **. Elemental concentrations of understudy Lake water and Comparison with other global published values.**

Parameter	K (mg/L)	Mg (mg/L)	Mn (µg/L)	Na (mg /L)	Ni (µg /L)	Pb (µg/L)	Se (µg /L)	Zn (µg /L)
WHO 2004[22]	12	50	100	200	20	10	10	-
Manchar Lake	20.66 ± 4.1	167.1 ± 53.1	0.069 ± 0.01	433.06 ± 93	30.85 ± 8.9	82.2 ± 18.6	42.5 ± 10.7	720.2 ± 146
Manchar Lake 1995[32]	17.6±6.5	56.2±28.9	-	521.5±49.1	4.3±3.4	9.0±2.7	-	15.7± 1
Lake Nakuru, Kenya[33]	-	-	138 ± 10.6	281.0 ± 22	563.0 ± 57	-	235.0 ± 24.4	138 ± 10.6
Mc Farlane Canada[34]	-	-	-	-	37.3 ± 1.7	0.14 ± 0.03	-	2.4 ± 0.4
Lake Balaton, Hungary[35]	-	-	-	-	0.33-0.71	0.04-0.33	-	0.22-1.9
Hazar Lake,Turkey[36]	-	-	4.0-25.0	-	12	-	-	38-71
Tuskegee Lake, USA[37]	2.58 ± 0.72	2.35 ± 0.90	107.7 ± 52.8	3.31 ± 0.24	6.6 ± 2.4	0.1 ± 0.3	-	5.5 ± 4.4
Lake Texoma, USA[38]	5.342 ± 0.799	38.0 ± 10.0	7.0 ± 1.8	204 ± 65	5.0 ± 0.03	<15.0	24.0 ± 5.0	59.0 ± 36.0
Scottish mountain Lake, Scotland[39]	-	-	-	-	-	-	-	-
Lake Doirani, Greece[40]	-	-	14-160	-	1.0-6.0	1.0-1.60	-	6.0-66.0
210 Lakes in Norway[41]	-	-	1.50–7.90	-	0.15–0.85	0.03–0.18	-	2.87–6.80
Lake Kasumigaura[42]	5.07	4.94	0.41	11.52	1.42	0.42	0.28	3.83
Siberian Ponde[43]	-	-	23.0 ± 35.9	-	-	8.8 ± 3.6	7.2 ± 0.8	-
Ataturk Dam Lake, Turkey[44]	-	-	4.1	-	15.4	-	-	64
Nacharam Lake,Indiad[45]	-	-	103–144	-	-	0.9–5.0	-	21–142
16 Latvian Lakesc[46]	-	15.54 ± 0.39	0.06 ± 0.01a	39.03 ± 2.15	1.86 ± 0.2	2.26 ± 0.15	-	0.02 ± 0.02
36 Lakes in Lapland, Finland[47]	-	-	-	-	0.14–0.30	0.51–1.19	-	1.9–3.55
Reference valuesfor freshwater[48]	-	-	-	5.0	-	-	-	5.0
Blue mountain Lake, U.S.A.[49]	2.0	4.0	5.0	-	0.3	3.0	-	-

Na is the most abundant cation in the lake water samples, followed by Ca, Mg and K (Table 2). The high level of Na was due to drainage from lands cultivated with rice and many salt seeps present in the upper basin tributaries that result in salt loading through MNVD (site 1) in the lake. The water of lake is frequently used for drinking by humans as well as animals, because the people have no other resources of drinking water. It has been reported that high consumption of salts, particularly NaCl, may be crucial for the development of hypertension and increases the risk for stroke, left ventricular hypertrophy, osteoporosis, renal stones and asthma [24]. According to the literature, people consumed water with high salinity have frequent renal stones and asthmatic problems, it is consistent with our study [24].

The concentrations of Al were found to be very high in water samples of understudy lake as well as reported values, in the order of: Manchar Lake (1366.9±312.9) > Lake Kasumigaura (1140) > Tuskegee Lake (155±153.3) > Lake Texoma (92.0±96.0) > Lakes in Lapland(63) > Blue mountain Lake(13–71) > Siberian Ponde (0.3 ± 0.04) µg/L. Number of epidemiological studies showed association between aluminum in drinking water and Alzheimer's disease, [25, 26]. The poisoning of Al in patients with chronic renal failure is also the most important clinical problems involving trace metal toxicity [27].

The concentrations of Fe was found to be very high in water samples collected from different sampling sites, mainly due to the inflow of surface run off from hill torrents and agricultural wastes (agricultural and rocks). The results of iron are also consistent with other studies on river water; Fe concentration was in the range of 1.8–5.06 mg/L [28]. Exchangeable Fe usually relates to the adsorbed metals on the sediment surface can be easily remobilized into the Lake water [37]. The level of Fe is also very high than those values obtained for other lakes as shown in table 2.

The concentration of toxic elements As, Cd and Pb detected in all water samples were found to 4–17 folds higher than the permissible limit of these elements in drinking water (Table 2). The main adverse health effects of As are tracheae bronchitis, rhinitis, pharyngitis, shortness of breath and nasal congestions [29]. Similarly, contamination of drinking water from As may also result in blackfoot disease [30, 31]. The adverse health effects of lead consist of various cancers, adverse reproductive outcomes, cardiovascular and neurological diseases [34]. Elevated concentrations of Cd can cause nausea, vomiting, salivation and renal failure as well as kidney, liver and blood damages suggested that high concentrations of Cd may even cause mutations [18]. The level of Cd in Manchar lake water samples were consistently lower than Lake Nakuru (Kenya), Lake Texoma (USA) and Nacharam Lake (Indiad) [33, 38, 45] while significant higher than the other lakes (Table 2). The concentration of Pb in understudy lake water was significantly higher than other 17 lakes water samples [32-49]. The Lake water quality characteristics were mostly above the recommended drinking water standards by WHO. Thus, Manchar Lake water will require chemical and biological treatment at the municipal water works in order to serve as good drinking water.

Conclusion

This study has shown that water samples of Manchar Lake are polluted, especially due to waste water of agricultural land and domestic wastes of urban areas, coming through MNVD (site 1). The high conductivity of water samples shows that high level of salts are present through out the lake sampling sites, which creates health hazards on continuous consumption. The highest concentration in Manchar Lake water were Ca, K, Mg and Na while the permissible limit of all micronutrients and heavy metals except Cu Cr, Co, Mn and Zn were found above the WHO values recommended for drinking water. Fishing and boating activities were also among the major sources responsible for lake water quality deterioration. Interventions should be made to reduce anthropogenic discharges in the Lake basin; otherwise, high levels of pollution will greatly influence the population and will invite socio–economic disasters. These results should be considered for future planning in using the lake's water for drinking purpose.

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