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Appraisal of Hanna lake water quality assessment, Balochistan, Pakistan

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ABSTRACT

Water quality of rivers, natural lakes, and reservoirs in Pakistan is being degraded rapidly because of indiscriminate disposal of liquid and solid waste. Water quality of Hanna Lake; Balochistan province in Pakistan has been investigated during 2014. A total of 22 samples were collected during summer and winter months. The physicochemical parameters, metals and bacteriological analysis were performed and compared with WHO, guidelines 2011 and NSDWQ (National Standard of Drinking Water Quality, Pakistan). pH, chloride, hardness, nitrate, total dissolved solids (TDS), Na, K, and Zn are well within the permissible limit as per World Health Organization (WHO) guidelines and NSDWQ. The concentration of sulphate, Ni and Pb were relatively higher with respect to WHO guidelines and NSDWQ. As concentration was within the limit as per NSDWQ while it is relatively higher (0.04 mg/l) as per WHO guidelines of (0.01 mg/l). All bacteriological parameters (total coliform, total fecal coliforms and total faecal streptococci) were extremely high from public health stand point that renders the water unfit for human consumption. The continued deteriorating environmental conditions of Hanna lake reflect ignorance from government side that can be mended by consistent supervision, long term management and strict enforcement of environmental laws pertaining to the protection of environmental resources. The present study recommends that priority should be given to monitor the water quality of Hanna lake on long term basis which would be helpful in future planning and management of this important water resource in already water scarce area.

Keywords: Hanna Lake; Pollution; Public health; Water scarcity; Water quality

1. Introduction

The water quality and quantity of lakes governed by numerous factors including climatological conditions, geographical setting, catchment area, anthropogenic and natural inputs and outputs [1]. Lake water quality often compromised by chemical and microbiological contaminants. Metals in minor quantities provide nutritional benefits to the life forms in the lakes while they become toxic when they crossed certain threshold limits [2–4]. Pollution in the lakes is generally associated with agriculture run-off, and indiscriminate discharge of domestic and industrial wastewater [5]. The pollutants in the lake water may be activated and induced their hazardous affects due to changes in climatological regime [6]. Pakistan has no exception; as the quality of water resources is generally unfit for human consumption [7].

Balochistan province is an extensive plateau [8] positioned on the southwest of Pakistan and the biggest province in terms of its land area with limited water resources and generally considered as water starved area [9].

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Baluchistan spread over an area of 34.7 million hectare with semiarid to hyper arid climate [10] out of which it has a 770 km long coastline. The province is experiencing severe drought since last decade which aggravated the ever existing problem of water scarcity. In Balochistan there are 22 wetlands out of which only 4 are protected. The major lakes of the province are Akara Dam, Hanna Lake, Marav Lake, Siranda Lake and Wasta Dam [11]. Water quality in Balochistan in general is aesthetically poor and majority of the population has no choice except to consume contaminated water responsible for a number of water borne diseases [9]. Quetta is the capital of Baluchistan province where the quality of water is deteriorating day by day [12]. Very little attention is given to the water supply in Quetta.

Hanna Lake is located near the Urak Valley about 14 km from Quetta; the capital of Balochistan province. The lake is located at 30°15′0″N, 67°6′0″E and covers an area of 11 hectares. The depth is variable depending upon the availability of water. When the lake is filled with water the depth may range from 4.0 to 5.0 m. Hanna Lake was constructed during the British regime in 1894. At the same time, a water conduit was also built to transfer the rainwater and snowmelt into the lake. This conduit was destroyed in 1976 due to heavy flash flood and still not rebuilt. The water level in the lake is falling at an alarming rate due to scarcity of rainfall. The lake receives water from the catchment area starts from Murdar mountain. Due to intense drought from 1999 to 2010 the lake was almost dried. After adequate rainfall in 2011 the lake refilled and has restored the native biodiversity. In the center of lake there is a small Island; which gives unique identity to this lake. It is a famous tourist attraction [13]. On the left of the lake at about 2 km is the Urak Valley having a small waterfall. Ahmad and Yasmin (2011) reported 74 plant species belonging to 16 families in the area [14]. However; vegetation is usually sparse due to local climatological conditions. The site is also an important nesting and breeding ground for winter fowls.

Presently this ecologically important wetland is used as a picnic spot and has also seriously suffered from anthropogenic pollution. Siltation rate is also alarming. According to an unofficial estimate; the lake is silted up to 10–20 ft. The present study attempts to determine the quality of lake water during winter (January–March) and summer (May–September) periods in 2014.

2. Materials and methods

The water quality assessment of the lake was followed through an intensive sampling program of two consecutive periods in 2014. The water samples were collected during summer and winter periods. The sampling program also includes rigorous field surveys. Interviews were also conducted with the stakeholders to determine the predisposing factors of water quality deterioration.

2.1. Sampling

During the study; 22 samples (in duplicate) were collected during summer and winter periods. (11 in each phase). The samples were collected once in April (Summer) and December (Winter). Niskin bottle was used for the random collection of samples for which a boat was hired. The locations of sampling sites are given in Table 1 and Fig. 1. The samples were collected mostly from the surface at a depth of approximately 10 cm from each sampling site. Pre-sterilized glass bottles were used for the collection of samples. Surface contamination through plastic bags, paper, leaves and debris was avoided during sample collection. The samples were appropriately labeled and transported at 4.0°C to the Institute of Environmental Studies, University of Karachi. The samples remained preserved at low temperature until used for analysis.

2.1.1. Physico-chemical analysis

pH and DO were assessed at the time of sample collection. pH and DO (dissolved oxygen) was monitored by Hanna portable pH meter (HI98107) and DO meter (Jenway 970) respectively.

Azide modification method was employed for the estimation of Biological oxygen demand (BOD_5). Argentometric method and EDTA titrimetric method were employed for chloride and Hardness (as $CaCO_3$) estimation respectively. Gravimetric method was applied for the determination of solids (Total dissolved solids and total suspended solids) and Sulphate.

Estimation of nitrate and phosphate was ascertained by brucine method and ascorbic acid method respectively. The above mentioned parameters were in accordance to the Standard Methods for the Examination of Water and Wastewater [15].

2.1.2. Metal analysis

Water samples were also investigated for As, Ca, K, Mg, Na, Ni, Pb and Zn by using selective kits of Merck (NOVA 60), Germany.

2.1.3. Bacteriological analysis

Most probable number (MPN) technique as described in the Standard Methods for the Examination of Water and

Table 1
Site for samples collection during summer and winter

Sample code	GIS coordinate
H-1	30°15′18.14″N,67° 6′3.65″E
H-2	30°15′21.56″N,67° 6′6.90″E
H-3	30°15′27.00″N, 67° 6′9.42″E
H-4	30°15′29.45″N, 67° 6′3.35″E
H-5	30°15′26.32″N,67° 6′1.83″E
H-6	30°15′25.23″N,67° 5′56.35″E
H-7	30°15′20.84″N, 67° 5′59.19″E
H-8	30°15′13.71″N, 67° 5′56.93″E
H-9	30°15′17.71″N,67° 5′49.48″E
H-10	30°15′23.58″N, 67° 5′50.49″E
H-11	30°15′12.75″N,67° 6′2.95″E

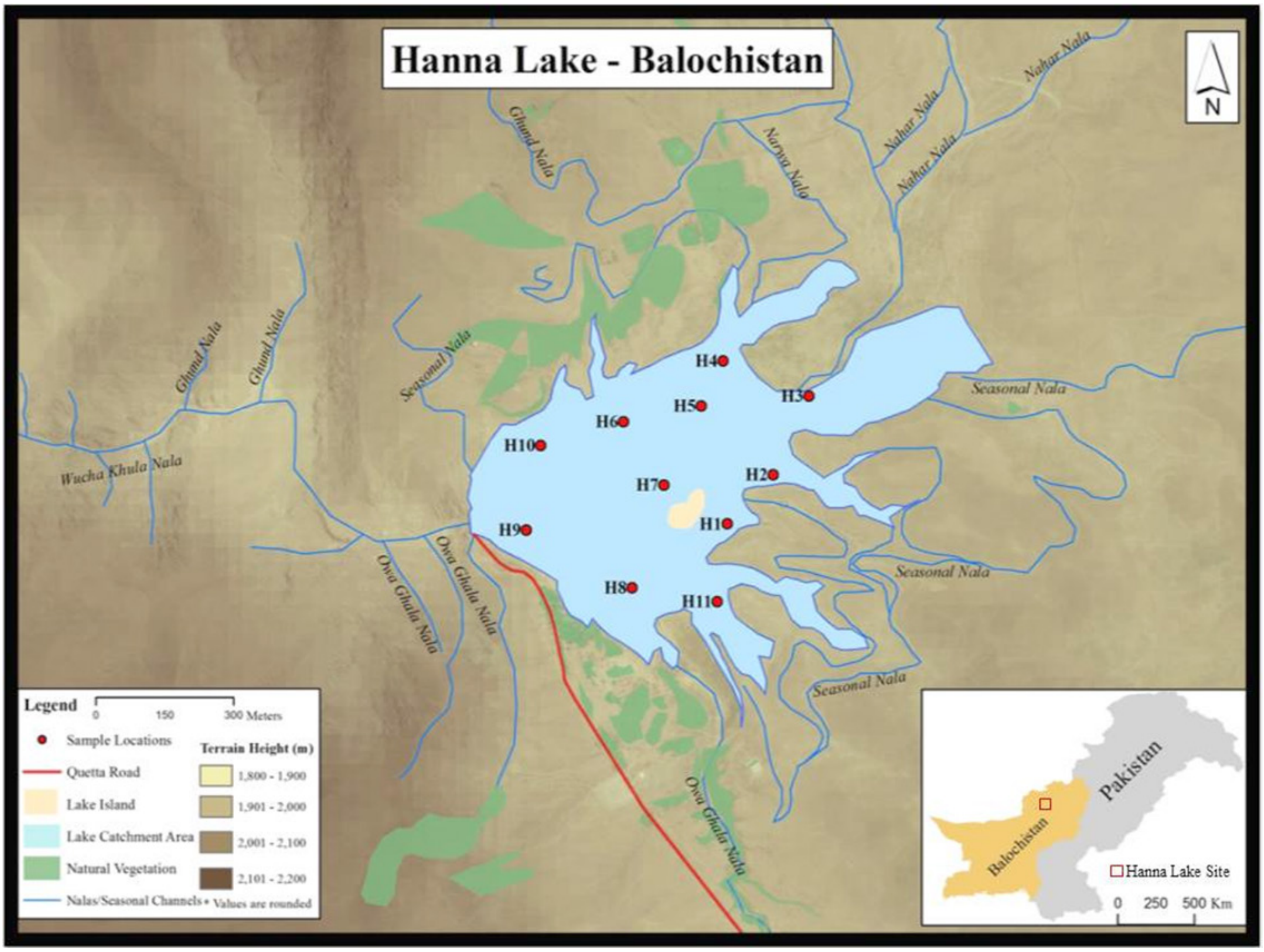

Fig. 1. Sites of sample collection.

Wastewater [15] was employed for the estimation of indicator organisms to asses the public health quality of Hanna lake water.

The samples were administered in laminar flow hood using pre-sterilized bacterial culture media. Appropriate amount of sample was transferred aseptically to the lactose broth (Merck, Germany) of single and double strength for the estimation of Total coliform count (TCC). The lactose broth tubes showing the presence of TCC were used for examining Total fecal coliforms (TFC) by using EC broth (Merck, Germany). Sodium azide broth (Single and double strength medium) was employed for the presence of Total fecal streptococci (TFS) [16].

2.1.4. Statistical analysis

The data on water quality was analyzed using STATISTICA (99 Edition) software. Descriptive statistics were calculated for each parameter mentioned above. The data set of physical, chemical, and microbiological characteristics of lake water was subjected to PCA (Principal component analysis). Cluster analysis was also performed using Ward's agglomerative method.

3. Results and discussion

The results of physicochemical and microbiological analysis during summer and winter seasons are presented in Tables 2 and 3 respectively. In all 11, sites were from which 22 samples were obtained during the study period (11 in each season). The mean pH value of all the samples during summer months was 7.45 while that of winter was 7.28. pH of the samples during the two phases was slightly alkaline. No significant difference in pH was observed during the two periods. Kazi et al (2009) reported similar values of pH of Manchar lake (Sindh province) water samples [17]. pH of the samples are within the permissible limits as per WHO guidelines (2011) [18].

The organic pollution of water bodies is generally determined through biochemical oxygen demand (BOD), chemical oxygen demand (COD), and total organic carbon (TOC). BOD characterizes the amount of organic load susceptible to the biodegradation [19]. High average BOD concentration during the two phases (113. 64 and 110.45 mg/l respectively) can be attributed to high concentration of suspended solids that represents organic pollution. Over 80% of rivers in northern Europe have a BOD of 2.0 mg/l, which shows a comparatively clean river [20]. Given this figure,

Table 2
Descriptive statistics of physical, chemical, metal and microbial characteristics of drinking water in the study area during summer

Parameters mg/l	Mean	Median	Min.	Max.	Quartile range	Std. dev.	Std. error	NSDWQ	WHO Guidelines 2011
pH	7.45	7.40	7.20	7.80	0.20	0.18	0.05	6.5–8.5	6.5–8.5
DO	4.13	4.11	3.85	4.62	0.25	0.23	0.07	N/A	N/A
BOD_5	113.64	110	90.00	140.00	30.00	18.04	5.44	N/A	N/A
Chloride	127.55	128	119.00	138.00	10.00	5.84	1.76	<250	250
Hardness as $CaCO_3$	241.91	236.00	215.00	271.00	31.00	19.19	5.78	<500	500
Sulphate	285.09	275.00	238.00	340.00	65.00	35.50	10.70	N/A	250
Nitrate	7.54	7.50	6.50	8.80	0.80	0.64	0.19	<50	50
Phosphate	3.38	3.40	3.00	3.80	0.40	0.25	0.08	N/A	N/A
TDS	595.55	600.00	532.00	656.00	57.00	38.33	11.56	<1000	<1000
TSS	129.00	126.00	100.00	148.00	22.00	15.15	4.57	N/A	N/A
As	0.04	0.04	0.02	0.05	0.02	0.01	0.00	< 0.05	0.01
Ca	33.53	32.80	29.60	39.10	3.70	2.98	0.90	N/A	N/A
Mg	208.38	206.40	182.90	238.70	29.50	19.38	5.84	N/A	N/A
Ni	0.16	0.15	0.10	0.26	0.07	0.05	0.01	<0.02	0.07
Pb	0.36	0.33	0.29	0.44	0.12	0.06	0.02	<0.05	0.01
Zn	0.64	0.65	0.48	0.75	0.17	0.09	0.03	5.0	N/A
Na	37.86	39.80	30.80	44.60	10.00	5.22	1.57	N/A	200
K	8.74	8.80	7.80	9.50	1.10	0.57	0.17	N/A	N/A
TCC MPN/100ml	1361.82	1100.00	150.00	2400.00	2190.00	1047.61	315.86	0	0
TFC MPN/100ml	1170.91	210.00	64.00	2400.00	2307.00	1177.81	355.12	0	0
TFS MPN/100ml	8.00	9.00	4.00	11.00	7.00	2.97	0.89	0	0

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

all water samples are heavily polluted with organic load. This situation clearly demonstrated that the lake is unprotected. The possible sources of high BOD values could be unchecked haphazard disposal of biological solid waste that undergoes the process of biodegradation and depreciates dissolved oxygen concentration responsible for anoxic condition. Moreover, use of the site for defecation is quiet common. High BOD values during the two phases was observed at H-11 (140 and 130 mg/l respectively). This is the sites where the people get on board to the boats for recreation. The people usually concentrated at this site because of availability of small tuck shops.

The mean dissolved oxygen concentration during the two seasons was 4.13 and 4.39 mg/l respectively. Comparatively low DO values were observed at H-6 and H-8 during the two phases. The availability of global oxygen is directly linked to the plant photosynthesis [21]. At water and sediment interface, aerobic and anaerobic mineralization reduces oxygen and stimulates nutrients production [22] that stimulate phytoplankton blooms responsible for oxygen production [23]. Leader prawns (*Penaeus monodon*) are susceptible to low DO concentration that induced acute toxicity of ammonia [24]. Low DO concentration in water bodies during summer is expected due to high temperature [25]. On an average, the warmest month is July. This was also noticed in the present study. It can be argued that Hanna lake still is not facing hypoxic condition, which is likely to occurs when DO concentration is <2.0 mg/l [26].

The concentration of chloride and hardness of both the phases are well within the limits as per WHO guidelines [18] and NSDWQ. The means of former was 127.5 and 125.2 mg/l while that of later was 241.9 and 240.4 mg/l.

The mean concentration of sulphate was 285.09 mg/l during summer period while that of winter was 260.55 mg/l. The concentration of sulphate is little higher as compared to WHO guidelines [18]. High concentration of sulphate showed that the water has influence of gypsum dissolution [27]. Malkani (2012) reported that the celestite of Sulaiman Range are related to gypsum deposits [28]. However, many workers have reported that in Pakistan, concentration of sulphate in water bodies does not poses any significant threat with respect to public health [29,30]. Ghumman (2011) reported sulphate concentration of 63.92 mg/l from Rawal lake, Islamabad, Pakistan [31]. Globally, the concentration of sulphate is low in lakes [32].

The mean concentration of phosphorus in lake water samples during summer was 3.38 mg/l while that of winter was 3.05 mg/l. As such, there is no substantial difference noticed in the phosphate concentrations during the

Table 3
Descriptive statistics of physical, chemical, metal and microbial characteristics of drinking water in the study area during winter

Parameters mg/l	Mean	Median	Min.	Max.	Quartile range	Std. dev.	Std. error	NSDWQ	WHO Guidelines 2011
pH	7.28	7.30	7.10	7.50	0.20	0.12	0.04	6.5–8.5	6.5–8.5
DO	4.39	4.28	4.09	4.88	0.31	0.24	0.07	N/A	N/A
BOD_5	110.45	110.00	85.00	130.00	20.00	15.24	4.60	N/A	N/A
Chloride	125.27	128.00	110.00	132.00	8.00	6.94	2.09	<250	250
Hardness as $CaCO_3$	240.45	246.00	210.00	259.00	26.00	16.52	4.98	<500	500
Sulphate	260.55	266.00	229.00	284.00	23.00	16.53	4.98	N/A	250
Nitrate	6.81	6.80	6.30	7.50	0.50	0.34	0.10	<50	50
Phosphate	3.05	3.10	2.40	3.70	0.70	0.43	0.13	N/A	N/A
TDS	594.00	596.00	538.00	635.00	50.00	29.10	8.77	<1000	<1000
TSS	130.55	131.00	110.00	146.00	22.00	12.80	3.86	N/A	N/A
As	0.02	0.02	0.01	0.03	0.01	0.01	0.00	< 0.05	0.01
Ca	30.74	30.60	28.60	33.30	0.91	1.20	0.36	N/A	N/A
Mg	209.71	215.10	179.40	228.71	23.30	16.22	4.89	N/A	N/A
Ni	0.20	0.18	0.12	0.28	0.09	0.05	0.02	<0.02	0.07
Pb	0.25	0.24	0.15	0.34	0.12	0.06	0.02	<0.05	0.01
Zn	0.62	0.61	0.54	0.71	0.10	0.06	0.02	5.0	N/A
Na	32.25	31.20	28.60	37.40	5.10	2.93	0.88	N/A	N/A
K	7.06	7.10	6.50	7.60	0.60	0.34	0.10	N/A	N/A
TCC MPN/100ml	2400.00	2400.00	2400.00	2400.00	0.00	0.00	0.00	0	0
TFC MPN/100ml	1435.45	1100.00	210.00	2400.00	1940.00	960.89	289.72	0	0
TFS MPN/100ml	36.09	11.00	4.00	93.00	55.00	35.34	10.65	0	0

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

two seasons. The input of phosphate in Hanna Lake is from nearby anthropogenic sources and also through the use of inorganic fertilizers from the nearby agriculture fields. The highest concentration of phosphates was observed at H-11 the site which explained earlier. This is the area, which represents extensive agriculture on both the sides. The farmers are using mostly inorganic fertilizers that represent the significant source of nitrate and phosphate in the lake water. Both nitrate and phosphate in lake water are responsible for eutrophication and the concentration more than 0.5 and 0.02 µg/l respectively specifies pollution of the Lake water [33]. Mastoi et al. (2008) reported 0.02 mg/l mean phosphate concentration in Manchar lake, Sindh [34]. At the time of this study, the authors did not find any signs of eutrophication in the Lake. Also in the present case no significant findings with respect to eutrophication was observed.

Higher levels of nitrate in water resources in the country is mainly attributed to agriculture runoff [35]. Tahir and Rasheed (2008) pointed that both Sindh and Punjab generally have higher nitrate concentration in water as compared to other parts of the country [36]. Nitrate pollution of water bodies arises by the use of inorganic fertilizer. Water contaminated with the nitrate is responsible for methemoglobinemia commonly known as blue baby syndrome. The mean value of nitrate during the two seasons were 7.54 and 6.81 mg/l respectively, which is well within the maximum permissible limit set by WHO (2011) [18] and NSDWQ indicating no risk to human health. However, continuous accumulation of nitrate and phosphate may be responsible for eutrophication problem.

The mean concentration of TDS during summer and winter periods were 595.5 and 594 mg/l which is well within the permissible limit as set by NSDWQ and WHO [18]. As such no significant difference in TDS values was observed during the two seasons. Water generally considered as brackish if the value exceeds to 1500 mg/l. Ghumann reported 201.8 mg/l of TDS in Rawal lake [31]. Ullah et al. [30] reported that in many areas of Pakistan owing to limited availability of fresh water people have no choice but to drink brackish water. High concentration of TDS may change the colour of lake to muddy brown.

Suspended solids (SS) symbolizes concentration of inorganic and organic matter, which contained in lake, river, stream, or reservoir [37]. These SS are having a size of less than 62 mm [38]. Suspended solids are present naturally in all water bodies [39]. Physical, chemical and biological properties of the water body altered, if SS 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. Since, SS are mostly of organic nature may reduce DO levels thereby creating anoxic conditions detrimental to the desirable life forms. These physical changes produce depreciates aesthetic quality [40] while chemical alterations results in the release of chemical contaminants mostly in the form of heavy metals and pesticides [41,42] and nutrients such as phosphorus [43,44] into the water body. As the Hanna Lake commonly used as picnic and tourist spot therefore, organic pollution is inevitable. This is critical as the interviews and observations confirmed the present findings. The mean TSS values of both the seasons were 129 and 130.55 mg/l. Ideally the water if used for human consumption should have 0.0 mg/l TSS values.

The presence of Ca and Mg ions in fact originated from the limestone and dolomite that represent hardness in water samples. The mean values of Ca and Mg of the samples during summer were 33.53 and 208.38 mg/l while that of winter were 30.74 and 209.71 mg/l respectively. Farah et al. [45] also reported similar results of water samples of Faisalabad district in Punjab province. Mastoi et al. (2008) reported 70.7 mg/l of Ca and 56.20 mg/l of Mg from Manchar lake, Sindh [34]. In the present study the value of Mg is relatively higher which may be attributed to the natural sources such as dolomite rocks in the vicinity of the study area. Mg may comes through the water from nearby catchment area that carries the particles of magnesite that occurs as a rock. The land form profile of Suleman range from where the water comes from in the lake is composed of diverse geological features. The area mostly comprises of sedimentary rocks that are composed of Dolomite, Gypsum, Jurassic Limestone, Eocene Limestone, Black Shale and sediments of sandstone called Siwaliks [46,47]. In a study conducted by Singh et al. [48], whereby they have reported that the origin of minerals like Ca and Mg in the Gomti river India is from dissolution of limestone and gypsum soils in the river catchment area. Vega et al. [49] also reported the similar results in the water samples collected from Pisuerga River, Spain.

The mean concentration of Na in water samples was 37.86 and 32.25 mg/l respectively during the two periods. WHO guidelines [18] for Na in drinking water is 200 mg/l. Therefore, the concentration of Na is well within the limit. As such the source of Na in Hanna lake is natural that comes as dissolved Na in rain water from the Suleman range. The Sulaiman Basin is the biggest basin of Indus Basin that is about 170 thousand Km^2 that is mainly composed of sedimentary rocks ranging in age from Jurassic to Recent [28]. The mean concentration of K in summer was 8.74 and winter was 7.06 mg/l whereas, the WHO guideline for K is 12 mg/l. Hence both Na and K found to be well within the permissible limit.

Pakistan, like other south Asian countries is confronting severe public health threats due to arsenic contaminated water. The situation is quite alarming in Sindh where approximately 36% of the population is consuming water having As concentration of 10 to 50 µg/L [50]. The mean concentration of As in the samples were 0.04 (summer) and 0.02 mg/l (winter). The possible source of As could be natural where the metal may leached out from soil. The concentration seems to be higher as compared to WHO guidelines (2011) [18]. Still if the water used for human consumption it may be responsible for serious health implications.

Naturally occurring Ni in water is present as divalent cation in low concentration. The maximum allowable concentration of Ni as per WHO guidelines [18] is 0.02 mg/l while that of NSDWQ reported a limit of <0.02 mg/l in drinking water. The highest concentration of Ni in water samples in Pakistan has been reported from Khyber Pakhtoonkhwa province [51]. The mean Ni values of the samples during summer and winter periods were 0.16 and 0.20 mg/l which is exceptionally higher than WHO guidelines [18] and NSDWQ. Ni in the Hanna lake water is mainly coming from the naturally occurring sedimentary rocks. Consumption of water with high nickel concentration may be responsible for cardio pulmonary diseases, respiratory cancer and kidney problems [52,53].

Hanna Lake is used for recreational activities. People normally enjoy boating during summer. The boats generally operated in the lake are petrol driven. Paddle boats are also common. Most of these boats are defective through which the fuel leakages are common. The fuel generally contains Pb which is a possible source of Pb contamination in Hanna Lake. The mean Pb concentration during summer was 0.36 while that of winter was 0.25 mg/l. These values are alarming from the public health perspective as compared to NSDWQ (<0.05 mg/l) and WHO guidelines (0.01 mg/l) [18]. Ullah et al. (2009) [30] reported that the water samples from district Sialkot (Punjab province) have higher Pb values than the threshold level of 0.01 mg/l. Human exposure to high levels of Pb may cause serious health implications with respect to nervous, cardiovascular, digestive, reproductive and immunological systems [54,55]. Zn concentration during the two phases were 0.64 and 0.62 mg/l which is well within the limits as per NSDWQ (<5.0 mg/l).

In Pakistan bacteriological contamination of drinking water is a common problem which is responsible for severe health implications [56]. The contamination is mainly due to the fact that the water reservoirs are generally unprotected. Moreover, the water distribution networks are usually faulty and obsolete [57–61] and none of the city or town received absolutely clean and safe drinking water. The people even living in the capital of the country, Islamabad are at risk of consuming contaminated water [62]. In rural areas the problem of bacterial contamination of drinking water is frightening where the people have no choice except to consume polluted water that is responsible for variety of water borne diseases [7]. As expected all the water samples were grossly polluted with the organisms of public health importance. Generally, TCC is often considered as indicator organism which if present in the water indicates the presence of pathogenic organism [63]. According to WHO (2011) [18] the TCC and TFC should be zero per 100 ml of water but in the present study the water quality depicted an distressing level (Table 2). In one of the studies conducted by Mohammad et al., (2014) [64] who reported that out of 125 samples collected from Quetta city, 88% of the samples showed the presence of pathogenic bacteria (88%) that is frightening for governmental authorities. The reason for the fecal contamination is merely human activities around the Hanna lake. Aziz [63] reported high frequency of water borne diseases in Pakistan mainly due to the fact that drinking water supplies are often polluted by fecal coliforms. This also represent unhygienic and insanitation conditions prevailing in most of the cities in Pakistan. With respect to the public health quality the surface water is inferior as compared to ground water [65,66]. During intense rain fall and subsequent floods the microbial load is higher in the flowing water that has rendered the water unsafe for human consumption.

Principal component analysis was applied on the normalized data sets of summer periods of different sites of Hanna Lake (Table 4 and Fig. 2). Together the first three components explained 74.02 percent of the total variance. The first component that accounted for 33.44% of variance was primarily controlled by TFS, Zn, Na, BOD and DO. The second component explaining 23.09 percent variance was regulated by TCC, Pb, Nitrate, TFS and TFC whereas, the third component contributing 17.48% variance was basically governed by Pb, DO, TCC, Zn and TFC. Table 5 and Fig. 3 explains the results of PCA of winter period applied on normalized data sets. The cumulative variance for first three components explained 72.49%. The first component explained 38.35% and was largelly controlled by DO, Ni, phosphate, TCC and TFS. The second component which explained 18.01 % variance was governed by sulphate, Mg, chloride, TFC and TSS; while third component having percent variance 16.02% of the total variance was basically a function of sulphate, As, Pb, Na and hardness.

Dendogram derived from Ward's cluster analysis of summer months showed two main groups as shown in Fig 4. Comparison of group 1 and group 2 derived from cluster analysis showed that BOD, As, Chlorides, Zn and TDS had lower values for group 1 compared to group 2. However, no differences were recorded for pH, hardness, DO, Ca, Mg, Na, K, TCC, TFC and TFS. Similarly, Dendogram derived from cluster analysis of winter data set also showed two main groups (Fig. 5). DO, BOD, TSS, TDS, Ca, Mg, Na, Pb, Chloride, hardness and sulphate concentration of group 1 was relatively higher while rest of the parameters of group 1 had lower level compared to group 2. The trend in all metal concentrations was higher in group1. It is interesting to note that the microbial load in terms of TCC, TFC and TFS were almost similar for the two groups.

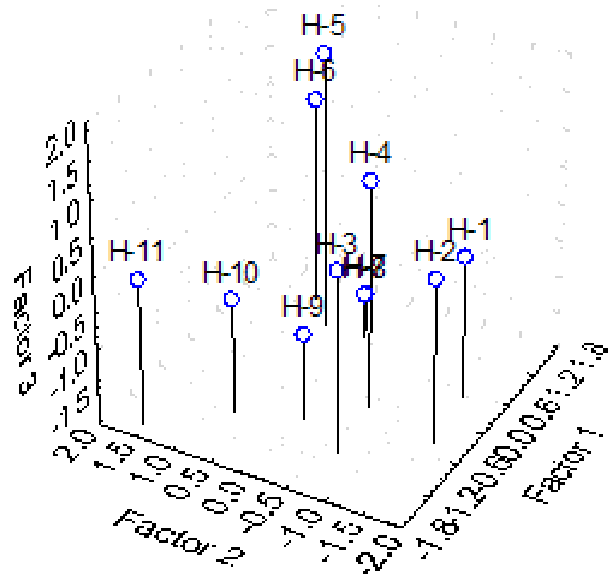

Fig. 2. Principal component analysis ordination (3D) of physical, chemical, metal and bacteriological parameters of water samples of Hanna lake during summer.

Table 4
Results of PCA of physical, chemical and microbiological parameters of water samples of Hanna lake during summer

Component	Eigen value	Percentage variance	Cumulative percentage variance	First 5 Eigen vector coefficients	Associated variables
1	7.023980	33.44752	33.44752	0.177990	TFS
				0.143406	Zn
				−0.130574	Na
				−0.083763	BOD
				−0.082331	DO
2	4.849788	23.09423	56.54175	−0.170561	TCC
				0.088298	Pb
				0.064489	Nitrate
				0.060396	TFS
				0.020424	TFC
3	3.671371	17.48272	74.02447	−0.180723	Pb
				0.094776	DO
				0.040709	TCC
				0.038123	Zn
				−0.000652	TFC

Table 5
Results of PCA of physical, chemical and microbiological parameters of water samples of Hanna lake during winter

Component	Eigen value	Percentage variance	Cumulative percentage variance	First 5 Eigen vector coefficients	Associated variables
1	8.076190	38.45805	38.45805	0.289524	DO
				0.179889	Ni
				−0.173856	PO_4
				−0.169297	TCC
				0.045178	TFS
2	3.783105	18.01479	56.47283	−0.115029	Sulphate
				0.092956	Mg
				−0.021962	Chlorides
				−0.019345	TFC
				−0.015062	TSS
3	3.364506	16.02146	72.49429	0.058807	Sulphate
				−0.053569	As
				0.051521	Pb
				0.033580	Na
				0.033135	Hardness

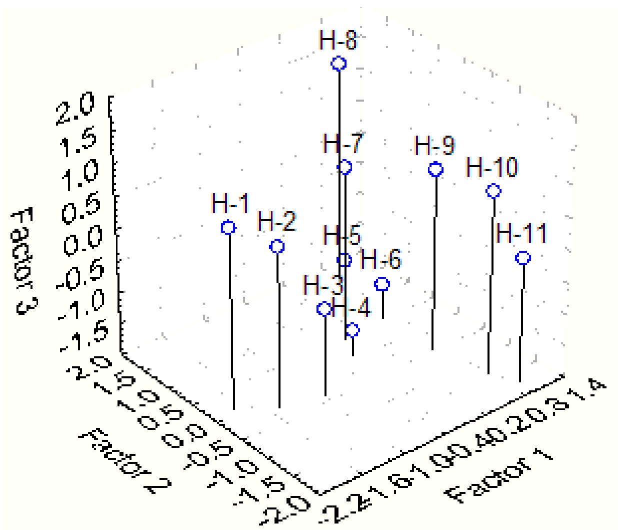

Fig. 3. Principal component analysis ordination (3D) of physical, chemical, metal and bacteriological parameters of water samples of Hanna lake during winter.

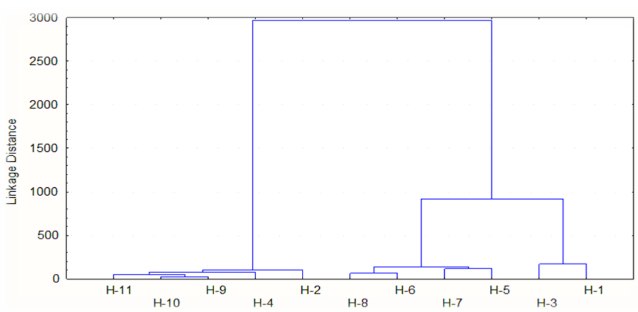

Fig. 4. Dendogram derived from Ward's method of 11 sites based on physical, chemical, metal and bacteriological parameters of water samples of Hanna lake during summer.

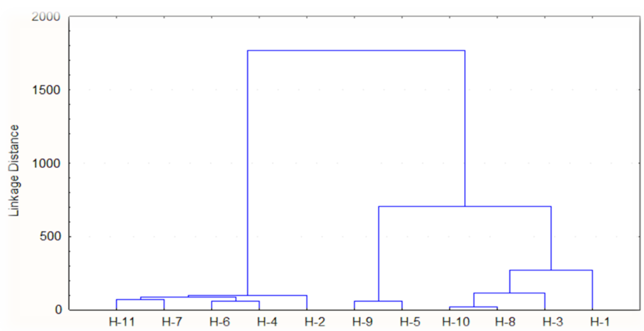

Fig. 5. Dendogram derived from Ward's method of 11 sites based on physical, chemical, metal and bacteriological parameters of water samples of Hanna lake during winter.

4. Conclusions

This study monitored and assessed water quality of Hanna Lake. It is concluded from the present investigation that indiscriminate disposal of biological solid waste, limited disposal of domestic wastewater, and the use of site as recreational area are seriously damaging the lake water quality. Since the site is unprotected it is aggravating unhygienic conditions of Hanna lake which is seriously increasing the negative impacts on adjoining environment including the biodiversity of the reservoir. A look at spatial water quality analysis over the lake suggest a decreasing trend of pollution load towards the center of the lake.

The water scarce country like Pakistan have to rely more on the use of non-conventional water resources to moderately improve water scarcity. Non-conventional water resources may include desalination, suitable pre-use treatment and crop management strategies. However countries like Pakistan cannot afford the heavy cost of sophisticated water treatment systems. To meet these challenges will require sustainable policies that encourage water use efficiency. In Baluchistan the problems of water scarcity is mainly related to over harvesting of ground water, low or nonexistent river flows, deteriorating pollution levels and the overriding problem of climate change that seems to be the most evident indicators of water stress. These problems can be coped by the use of harvesting of rainwater, the use of marginal-quality water for agriculture, realistic water pricing and charging polluters for their effluents.

Whilst, the focus of the provincial government should be on the adaptive capacity of society, recognizing their limitations to adaptive capacities. This paper therefore suggested that there is an increasing demand for an integrated approach covering social, economic and environmental policies together.

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