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Research paper

Water quality assessment of lower Jhelum canal in Pakistan by using geographic information system (GIS)

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ABSTRACT

The aim of this study is to assess the water quality of Lower Jhelum Canal (LJC) and its suitability for irrigation purposes. An effort has been made to develop a method by integrating water quality index with geographic information system (GIS) for an effective interpretation of LJC water quality. The pollution status of LJC was estimated by different physicochemical and biological parameters. Based on results of analysis, a spatial distribution map of selected water quality parameters was prepared using GIS. An inverse distance weighting (IDW), which is an interpolation technique, was applied to prepare a thematic layer of parameters at each station of Lower Jhelum canal. The results of individual parameters showed that the concentrations of contamination were within permissible limits of WHO and NEQS guidelines except for *E. coli*. Overall, most of the water falls in excellent quality category indicating the suitability of water for irrigation purpose. The results suggest that most of the water can be used for irrigation and various intended purposes except direct use of water for potable or drinking purposes without treatment.

1. Introduction

Water is the most significant ingredient for supporting and evolution of life (Kuutondokwa, 2008). Humans get different sorts of benefits from freshwater, which includes water for drinking, industrialization, domestic uses, irrigation, for the production of waterfowl and fisheries, use for leisure, shipping, and waste discarding (Jackson et al., 2001). Water is a source of economic gain. Almost 70% of water is used in agricultural production, which is indirectly the cause of economic growth (Brown and Matlock, 2011). Water resources (Freshwater) are becoming limited for individuals due to overpopulation, so the accessibility of freshwater for human beings decreases (Iqbal et al., 2018). Quality of freshwater deteriorates by developmental activities that contaminate the water bodies, their effects on human health, ecosystem disturbance and issues related to its management and monitoring (Iqbal et al., 2019).

Water quality deterioration is the primary threat to public health at the global level (Rahman et al., 2020). Anthropogenic actions, like improper disposal of municipal, industrialized effluents, and unsystematic use of chemicals in agriculture, are vital aspects causative in the worsening of water quality (Azizullah et al., 2011; Iqbal et al., 2020; Subedi et al., 2019; Shirani et al., 2018; Li et al., 2020). The result of these activities is eutrophication, loss of water quality, loss of biodiversity, effects on human health and social security, deposition of nutrients and other inorganic pollutants, acidification and significant economic losses (Kraemer et al., 2001). Contamination of water leads to water scarcity or it may be polluted at that level where it is expensive to treat (Gupta et al., 2012; Maged et al., 2020; Imran et al., 2020). Consequences of both water treatment and water scarcity with high cost would be the reason for the increase in water prices (Kuutondokwa, 2008). According to (Rogers et al., 2002), water is an efficient good. However, the nations which have water resources could grow their economies, while on the other hand, it will be difficult for poor or developing countries, even to avail of their essential needs. An increase in water prices leads to the marginalization of poor households, as they

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need to increase money spend on basic necessities. They can just fulfill their basic needs, not hygienic conditions (Rogers et al., 1998, 2002; Kuutondokwa, 2008).

There is an increasing need to face the challenge at the global level and ensure access to sufficient water resources for increasing population and economy. The growing community is the leading cause of water stress for the effective use of accessible water supplies to improve the crop and water production (Chatha et al., 2014; Mongat et al., 2015). A most crucial source of surface water for irrigation in Pakistan is the Indus Basin Irrigation System (Arshad and Oad, 2017). The reduction in canal water supply for irrigation systems forced farmers to pump groundwater, significant upturn in their irrigation prices, and stress on the economy (Latif, 2007). So, considering water resources of Pakistan for irrigation in terms of its river and canal schemes, operational management, accessibility and delivery of water to support the farming production is significant for the authorities and planners for handling water and food security concerns in the nation (Arshad and Oad, 2017). Water quality assessment by GIS (geographic information system) technology, Water Quality Index (WQI) is an inventive mean to help envision and assess the issues affecting the water quality. So, nowadays, the advanced approach of GIS has made water quality identification very convenient (Venkateswaran and Deepa, 2015; Nazzal et al., 2019). Development in Geographical Information System (GIS) and spatial analysis assist in assimilating the laboratory assessment data with the geographic data and represents the spatial distributions of water quality parameters, most vigorously and precisely. Currently, GIS is being integrated with groundwater and surface water quality assessment models (Balathandayutham et al., 2015). Assessments of groundwater resources do exist, but they rely on remotely sensed data combined with modelling at national or regional scale (Gowing et al., 2020).

Water quality index (WQI) is developed for the overall quality of the water through a single number like a grade at same time and location based on different parameters of quality of water. Its main objective is to convert complex data of the water quality into useable and accessible information. WQI decreases a large amount of physical, chemical, and biological parameters data to a single number in a reproducible manner. In fact, water quality index has been used for the assessment of many water bodies and the quality of water around the world.

Water management could improve the quality of life and reduces poverty in many ways. It may possibly contribute either pessimistically or optimistically to nutritional status, wellbeing, societal equity and ecosystem (Namara et al., 2010). By using safe water, the diseases will be limited, and hygienic conditions will be improved (Hunter et al., 2010; Li et al., 2018). In the present study, water quality of lower Jhelum canal is assessed for irrigation purposes in terms of water quality index (WQI) using an integrated approach of geographic information system (GIS). The main objectives of this study are 1) evaluation of water quality of LJC 2) assessment of water suitability for irrigation purposes 3) integration of WQI with GIS to provide detailed, quick and reliable information for decision makes to adopt or implement strategies related to water quality of LJC.

2. Material and methods

2.1. Study area

Lower Jhelum canal is an irrigation canal in the Punjab province of Pakistan (Ghumman et al., 2011, 2014). Lower Jhelum canal come out from river Jhelum at Rasul head Barrage and irrigates the area of Chajj Doab in districts Sargodha, Mandi Baha-ud-din, and Jhang area in Punjab, Pakistan (Rashid et al., 2015). At present, the discharge rate of LJC is $156m^3/s$ and $120m^3/s$ for Kharif and for Rabi crops, respectively. The total gross command area (GCA) of Lower Jhelum canal is 660406 ha (Ghumman et al., 2011). The geographical location of Lower Jhelum canal is 32°42′0″ N and 73°33′0″ E in DMS (Degrees Minutes Seconds). The study area of lower Jhelum canal is in between head faqiriyan (73° 6′38.54″E & 32°22′56.25″N) to head Rasul barrage (32°40′38.52″N and73°31′23.59″E) which is 60 km in distance. It covers the major area of Gujrat and Mandi Baha-ud-din district (Fig. 1) Pakistan has excellent and longest canal irrigation system (Aslam et al., 2015). Canal irrigation practices are more common in Punjab, Pakistan. River Jhelum and its tributaries are considered as the primary sources for irrigation (Arshad and Oad, 2017). Water availability for cropping by the Lower Jhelum canal is 252 mm (Tahir and Habib, 2001). The map of the study area is shown in Fig. 1.

2.2. Study design

Forty samples were collected from the lower Jhelum canal using a GPS device to measure the coordinates of specific points. Samples were collected from twenty different locations of the study area. Samples were collected both from the surface and deep-water points. Twenty samples from surface and twenty samples from approximately 3 ft deep of canal water were collected.

2.3. Data collection and analysis

The selected sampling locations are shown in Fig. 2. The samples were collected by stratified simple random sampling from selected points. Grab samples were collected for both in-depth and surface water analysis from all sampling stations in March 2017. The sampling depth for deep water sampling was selected almost 3 ft and the central point of the canal was preferred for data collection. Water samples were collected in propylene water bottles of 500 ml. Before water sampling, containers were washed with distilled water and then two to three times by canal water, which was going to be sampled before being filled with that water. Soon after sampling, the bottles were labeled according to station number and sampling date. Other essential components of interest, including nearby places, villages and populations were noted in the diary. The samples were placed immediately in a cooler box along with packets of ice cubes to maintain 4 °C temperature during fieldwork.

Samples for microbiological tests were collected in sterile glass bottles. To avoid cross-contamination, special care was exercised while removing and applying caps cover. Space was left to allow the mixing of samples. The containers were not overfilled; space was left to enable the mixture of the samples. Samples were then placed in a nice box and were instantly transported to the laboratory in a cooler box stacked with ice. Standard analytical procedures and precautions were employed during the preservation, sampling, handling, transportation, and analysis of the water samples (Keith, 2017).

In the laboratory, samples were stored in a refrigerator at 4 °C. The most abundant cations in surface water: sodium and potassium; magnesium and calcium were analyzed by using a flame photometer (Jenway – PFP) and titration method (Kumar et al., 2014), respectively. Major anions bicarbonate and chloride were analyzed by titration method (Kumar et al., 2014) and sulphate by spectrophotometer (Kojło et al., 1990). Turbidity was conducted by spectra quant (NOVA 60 instrument); EC, TDS, and TSS by conductivity meter (PC Jenway 4510) and CO_3^{2-} was analyzed by titration method (Kumar et al., 2014). Phosphate was determined by UV–Visible Spectrophotometer (Kharat and Pagar, 2009) and pH by using a pH meter. COD was measured according to IS: 3025 (Part 58) reaffirmed 2006 USEPA and APHA. BOD and other trace elements like As, Pb, Cu, and Zn and Fe were determined according to (APHA, 2005). Coliform and *E. coli* was determined by using membrane filtration process (Buckalew et al., 2006).

All statistical analysis was performed by SPSS (statistical package for social sciences). The calculated values of water quality parameters were compared with WHO and NEQS guidelines or other acceptable standards to determine canal water suitability for irrigation purposes.

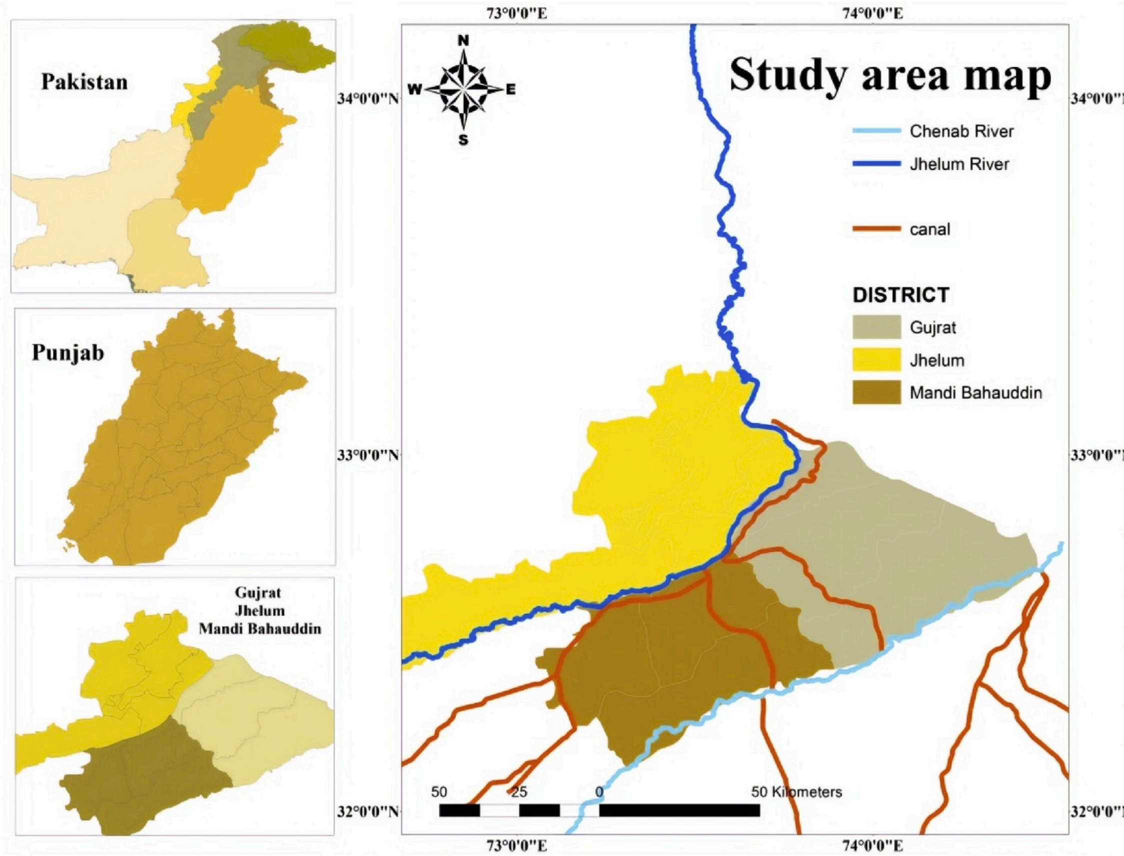

Fig. 1. Study area map.

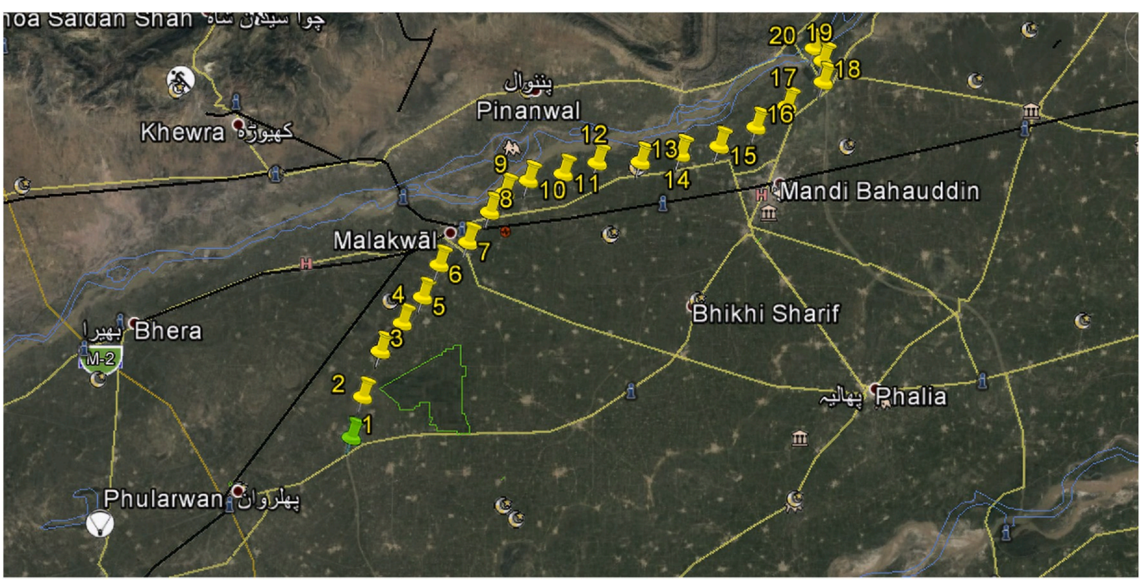

Fig. 2. A map of Lower Jhelum Canal showing the selected sampling sites.

2.4. GIS analysis

A portable GPS device was used to measure the longitude and latitude of the sampling sites. The results of these samples, along with their coordinates were attributed in ArcGIS (version 10.0) software as a point layer. Further, an interpolation technique of inverse distance weighting (IDW) was applied to prepare the thematic layer map of the water quality index (WQI) (Tomczak, 1998). IDW is a reliable method of spatial interpolation to predict the surface water quality in a more accurate format. Basically, it is based on assumptions that the accredited value of an unsampled spot is the weighted average of known values in the nearby places. Weights are inversely proportional to distances between sampled points and predicted points (Lu and Wong, 2008).

2.5. Estimation of water quality index

The water quality index (WQI) was calculated for the determination of water quality. The water quality index provides a more comprehensive image of surface water quality (Sahu and Sikdar, 2008). For the calculation and mapping of WQI, three steps were followed, as reviewed in several papers (Ravikumar et al., 2013; Rokbani et al., 2011; Asadi et al., 2007).

a) All of the chemical parameters were marked with a weight (*wi*) according to their relative importance in water quality or impacts on public health.
b) Relative weight (*wi*) of each parameter are presented in Table 3 by using Eq. (a). Table 3 represents the weight (*wi*), relative weight (*Wi*), and standard values of each parameter according to WHO and NEQS.

$$Wi = \frac{wi}{\sum_{n=1}^{n} wi} \quad \text{(a)}$$

where;
Wi = Relative weight of each parameter.
Wi = Weight of each parameter.
n = Number of parameters.

c) A quality rating scale (*qi*) was computed by dividing the concentration of each parameter in the water samples by own standards, according to the guidelines provided by WHO and NEQS. After that result was multiplied by 100 using Eq. (b).

$$qi = \frac{Ci}{Si} \times 100 \quad \text{(b)}$$

where;
qi = quality rating.
Ci = concentration of each parameter in each water sample in mg/l.
Si = WHO standard of each chemical parameter in mg/l except EC and PH.

d) For the calculation of WQI, it is first necessary to evaluate the Si for every single chemical parameter by using equation Eq. (c). Which is further used to assess the WQI as per given Eq. (d).

$$S_i = W_i \times q_i \quad \text{(c)}$$

$$\text{WQI} = \sum_{i=1}^{n} \text{SIi} \quad \text{(d)}$$

where;
SIi = sub index of ith parameter.
n = number of parameters.
qi = rating based on concentration.

Usually, the calculated water quality index values are categorized in 5 classes: excellent, good, weak, inferior and unfit to use (Ravikumar et al., 2013; Sahu and Sikdar, 2008).

2.6. Water quality determination for irrigation purpose

The suitability of water quality for irrigation purposes was analyzed by selecting the critical parameters of water quality. These parameters (SAR, RSC & Na%) are the general criteria for assessing the water quality for irrigation purposes. The concentrations were calculated with irrigation indexes by using the following formulas.

Sodium absorption ratio

According to (Gangadharan and Vinoth, 2016) SAR was calculated by employing the equation as:

$\text{SAR} = \frac{Na\%}{\sqrt{\frac{Ca+Mg}{2}}} \times 100$ (Concentrations are in mEq/l).

Residual sodium content

It was calculated according to (Reddy, 2013) equation which is as:

$\text{RSC} = [(CO_3^{2-} + HCO_3^{-}) - (Ca^{2+} + Mg^{2+})]$ (Concentrations are in mEq/l).

Sodium percentage (Na %)

According to (Prasanth et al., 2012), the sodium percentage is calculated by the given equation as:

$\text{Na \%} = [(Na^{+} + K^{+})/(Ca^{2+} + Mg^{2+} + Na^{+} + K^{+})] \times 100$.

(Concentrations are in mEq/l).

3. Results and discussion

Estimation of water quality is essential as it determines the appropriateness for irrigation purposes. Statistical summary of physico-chemical and biological parameters from selected sites are listed in Table 1 and Table 2. Usually, the most important parameter for water quality determination is BOD, which was ranged in between 38.5mg/l to 9mg/l, which is within NEQs (80mg/l) permissible limit. This shows that water quality is good for irrigation purpose. High value of BOD determines that water quality is deteriorating and polluted. Another investigation by (Aftab et al., 2011) at the Lahore branch canal, Pakistan, ranges from 10.3 to 18.8mg/l, which is also lower than the current study canal but within NEQS (80) permissible limit. According to (Simeonov et al., 2003), the value of BOD of surface water of Northern Greece ranged between 2.0 and 8.0mg/l, which is within permissible limit and also lower than the current study canal. COD is used to measure water quality. It is widely diverse in the study site and ranged in between 14mg/l to 105mg/l, which is also within NEQs (150mg/l) limit (Goher et al., 2014). pointed out that more COD is due to increased industrial pollution (Aftab et al., 2011). at the Lahore branch canal, Pakistan shows the values of COD ranged in 16.5–42.5mg/l, which is also within the permissible limit but lower than the current study canal. Another study conducted on surface water quality by (Simeonov et al., 2003) in Northern Greece shows the COD value ranged between 4.0 and 94.0mg/l, which is also lower than the current investigation and within the standard limit.

The presence of various sediments from rocks, soil, volcanic eruption, forest fires, agriculture, and industrial pollution are responsible for the arsenic contamination (Smith et al., 2000). In the current study, the values of arsenic ranged between 0.005mg/l to 0.01mg/l, which is within the standard limit of WHO (0.05). In the current study, the estimated values of lead were<0.01mg/l at all sampling points (deep & surface), which is within the standard limit of NEQS (0.5mg/l). An increase in the concentration of Pb metal in surface water has negative impacts on the aquatic ecosystem and disturbs the whole food web by biomagnification and bioaccumulation (Levallois et al., 2014). Phosphate is a vital nutrient and fertilizer component for the growth of a plant that enters waterways from domestic wastewater and agricultural fertilizers. In the current study, the values of phosphate ranged between 3.5 and 3.8mg/l, which is within the WHO (150mg/l) permissible limit. Similarly, all other parameters (Turbidity, carbonate, bicarbonate, calcium, magnesium, pH, EC, TDS, TSS, Ca^{+}, Mg^{+} K^{+}, Na^{+}, Fe, Zn, Cu, sulphate) were within permissible limits of WHO and NEQs whose averaged values are given in Tables 1 and 2. According to United States environmental protection Agency, current standard for *E. coli* is 126 cfu/100 ml in one month and maximum range is 1260 cfu/100 ml while in current study its value ranged in between 489 cfu/100 ml to 1220 cfu/100 ml.

3.1. Water quality index (WQI)

The Water quality index of LJC at 20 investigated sites ranged between 326.703 and 0.00303455. The areas which are shown with red color in Fig. 3 of (WQI) have minimum values (0.00303455) of overall pollution index and reflecting the excellent quality of water. On the other hand, the areas highlighted with purple color have maximum values of WQI (326.703) and unfit for human consumption (Fig. 3). The

Table 1
Statistical Summary of Physicochemical and Biological Parameters of Samples of Lower Jhelum Canal to Determine Water Quality (Surface water samples).

Sr. No	Parameters	Abbreviation	Units	Max	Min	Average	SD	Mode
1	Biological oxygen Demand	BOD	mg/l	38	9	23.63	10	9
2	Chemical Oxygen Demand	COD	mg/l	92	14	46.9	10	58
3	Lead	Pb	mg/l	0	0	–	–	–
4	Arsenic	As	mg/l	0.01	0.005	0.0065	7	0.005
5	Phosphate	PO_4^{3-}	mg/l	3.8	3.5	7.34	9	3.8
6	Turbidity	Turb	FAU	237	97	209.25	10	201
7	Carbonate	CO_3^{2-}	meq/l	0.04	0.02	0.03	1	–
8	Bicarbonate	HCO_3^-	meq/l	1.86	1.86	1.86	6	1.86
9	Potential hydrogen	pH	N/A	7.33	7.03	7.195	8	7.21
10	Electric conductivity	EC	dsm-1	0.9835	0.1211	0.365015	9	0.43
11	Calcium and magnesium	Ca + Mg	meq/l	2.3	1.7	2.07	9	2.2
12	Magnesium	Mg	meq/l	0.9	0.1	0.53	9	0.9
13	Calcium	Ca	meq/l	1.9	1	1.605	9	1.9
14	Chloride	Cl	meq/l	7.9	0.4	2.805	10	0.6
15	Potassium	K	ppm	3.52	1.98	2.7825	9	3.52
16	Zinc	Zn	ppm	0.9421	0.0048	0.0737	9	0.0048
17	Copper	Cu	ppm	0	0	–	–	–
18	Sodium	Na^+	meq/l	7.24	0.27	1.616	10	2.05
19	Total dissolved solids	TDS	meq/l	9.835	2.26	4.18925	10	4.4
20	Total suspended solids	TSS	meq/l	9.83	2.11	3.69485	10	4.3
21	Sulphate	SO_4^{2-}	meq/l	1.23	0.05	0.472	9	0.05
22	Iron	Fe	ppm	0.01	0.01	0.01	1	0.01
23	Biological analysis							
	Escherichia coli	*E. coli*	cfu/100 ml	1220	500	799.1	7	760
	Coliform	TC	cfu/100 ml	Present				

*Lead = less than <0.01 in all samples.
*Coliform = present in all samples.

Table 2
Statistical Summary of Physicochemical and Biological Parameters of Samples of Lower Jhelum Canal to Determine Water Quality (Deep water samples).

Sr.No	Parameters	Abbreviation	Units	Max	Min	Average	SD	Mode
1	Biological oxygen Demand	BOD	mg/l	38.5	9	23.575	6	18
2	Chemical Oxygen Demand	COD	mg/l	105	20	66.45	7	105
3	Lead	Pb	mg/l	0	0	–	–	–
4	Arsenic	As	mg/l	0.005	0.005	0.005	3	0.005
5	Phosphate	PO_4^{3-}	mg/l	3.8	3.5	3.655	6	3.6
6	Turbidity	Turb	FAU	205	136	165.8	7	138
7	Carbonate	CO_3^{2-}	meq/l	0.13	0.11	0.12	1	–
8	Bicarbonate	HCO_3^-	meq/l	2.3	1.7	1.8455	5	1.84
9	Potential hydrogen	pH	N/A	7.42	7.16	7.2515	5	7.23
10	Electric conductivity	EC	dsm^{-1}	0.275	0.2	0.225435	5	0.23
11	Calcium and magnesium	Ca + Mg	meq/l	2.3	1.6	1.875	4	1.8
12	magnesium	Mg	meq/l	1	0.1	0.48	6	0.3
13	Calcium	Ca	meq/l	1.5	0.6	1.084211	6	1.5
14	Chloride	Cl	meq/l	0.9	0.4	0.655	5	0.6
15	Potassium	K	ppm	3.19	1.76	2.4245	6	1.98
16	Zinc	Zn	ppm	0	0	–	–	–
17	Copper	Cu	ppm	0.005	0.003	0.004533	3	–
18	Sodium	Na^+	meq/l	0.95	0.21	0.4155	6	0.39
19	Total dissolved solids	TDS	meq/l	2.75	0.2	2.1615	6	2.2
20	Total suspended solids	TSS	meq/l	2.75	2	2.27135	6	2.3
21	Sulphate	SO_4^{2-}	meq/l	0.19	0.03	0.11111	5	0.03
22	Iron	Fe	ppm	0	0	–	–	–
23	Biological analysis							
	Escherichia coli	E.coli	cfu/100 ml	980	489	763.5	7	980
	Coliform	TC	cfu/100 ml	Present				

*Pb is < 0.01 in all samples.
* Coliform is present in all samples.
*Fe is NIL in all samples.

yellow color in (Fig. 3) of WQI shows the good water quality. The WQI values which are falling in ‘green’ color have a poor quality of water, and ‘blue’ color is showing the inferior water quality in the study area of Lower Jhelum Canal.

3.1.1. *Water quality index map*

The water quality index is a convenient and straightforward technique to express a large number of water quality parameters in a single aggregated value and equivalent scale. WQI elaborates the water quality in a very comprehensive way just as excellent, excellent, good, weak and unfit for use (Pesce and Wunderlin, 2000; Akkoyunlu and Akiner, 2012). WQI was assumed to determine the quality of water of selected water samples of the lower Jhelum canal. The WQI is estimated by keeping in view the appropriateness of surface water for human consumption (Rokbani et al., 2011). For the determination of the water quality index, each of the parameters was assigned by a weight relating to their impacts on ecosystem/human health. The maximum weight (5) was assigned to the parameters which have the primary effect on quality of

Table 3
Calculated Weight and Relative Weight of Selected Parameters and their Standard Values given by WHO and NEQS.

Serial no.	Parameters	Units	Standards limits	Standards	Weight (*wi*)	Relative weight (*Wi*)
1	Pb	mg/l	0.5	NEQS	5	0.084
2	As	mg/l	1.0	NEQS	5	0.084
3	PO_4^{3-}	mg/l	150	WHO	2	0.033
4	Turbidity	FAU	–	–	3	0.05
5	CO_3^-	meq/l	75	WHO	2	0.033
6	HCO_3^-	meq/l	120	WHO	2	0.033
7	pH	N/A	6.5–8.5	NEQS	3	0.05
8	EC	dsm^{-1}	–	WHO	3	0.05
9	Ca + Mg	meq/l	75 + 50	WHO	2	0.033
10	Mg	meq/l	50	WHO	2	0.033
11	Ca	meq/l	75	WHO	2	0.033
12	Cl	meq/l	250	WHO	3	0.05
13	K	ppm	12	WHO	1	0.01
14	Zn	ppm	3.0	WHO	3	0.05
15	Cu	ppm	1.0	NEQS	4	0.06
16	Na^+	meq/l	200	WHO	3	0.05
17	TDS	meq/l	1000	WHO	5	0.084
18	TSS	meq/l	150	NEQS	2	0.033
19	SO_4^{2-}	meq/l	250	WHO	3	0.05
20	Fe	ppm	0.3	WHO	4	0.06
					$\sum wi = 59$	**$\sum Wi = 0.913$**

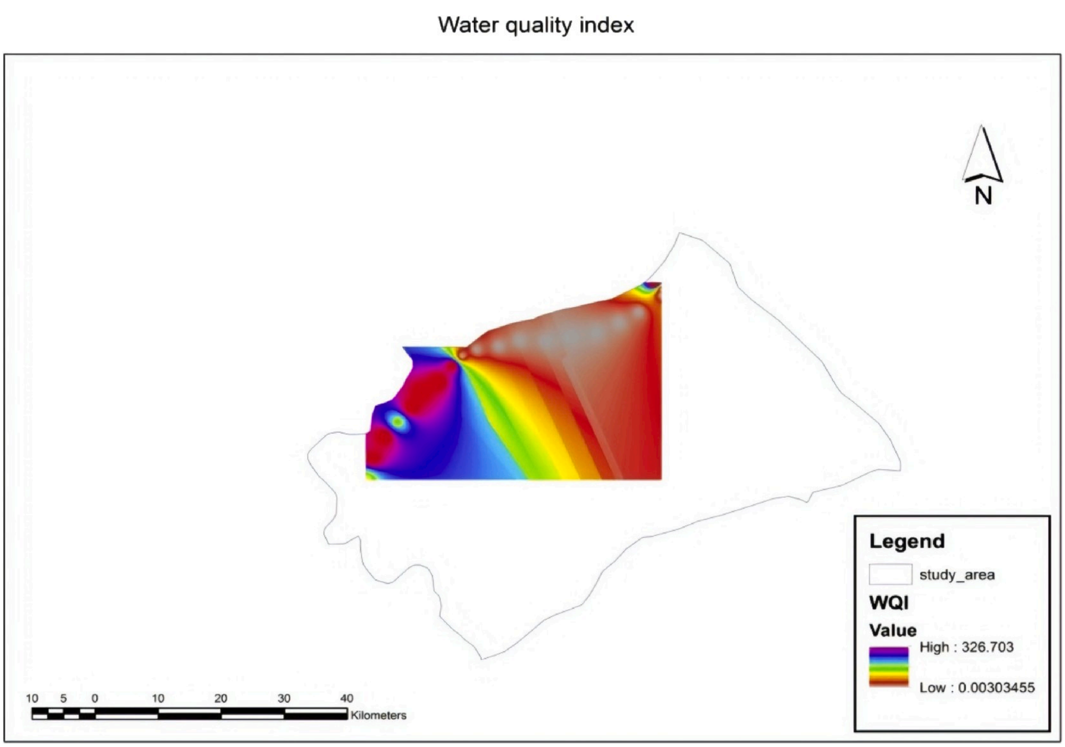

Fig. 3. Water quality index of lower Jhelum canal.

water (i.e., TDS, F^- and NO_3^-) and the minimum weight (2) was assigned to the parameter which has less impact on water quality (Ca^{2+}, Mg^{2+}, K^+) (Rokbani et al., 2011; Ravikumar et al., 2013). Table 3 demonstrates the given weight and relative weight of each parameter and their standard values by NEQS (National environmental quality standards) and WHO (World health organization).

3.2. Water quality index of lower Jhelum canal

According to Table 4, the WQI of samples S & D9 to S & D19 (both surface and Deep) has excellent quality of water in the villages of ChakDaddan, Haweli, Kirtowal, Chak No. 9, Noor PurPiran, Kamal Mustafa and Mongas as elaborated in Table 4. Sample S1 & D1 from the station (no.1) have excellent water quality as shown in Table 4. Sample S4 and D4, which were selected from the station (no.4), have a poor quality of water and sample S & D2 to S&D8, excluding S & D4 has inferior quality in the villages of Miana, Kotehra, Choat, and Koat Matta etc., as shown in Table 4. The samples S & D20 at the station (no. 20) in the village of Rasul and near Rasul Barrage had inferior water quality, which is unfit for use (Table 4). Graphical representation of WQI at all sampling sites is shown in Fig. 4.

3.3. Suitability of Lower Jhelum Canal for irrigation purpose

It was observed from the results that the maximum and minimum value of (WQI) of Lower Jhelum Canal has been found between 326.703

Table 4
Calculation of WQI of water samples at a specific station.

Station no.	Samples description	Locations	WQI	Classification
1	S1 & DI	Mona Depo	76.0115	Good
2	S2 & D2	MianaSyeda	235.6	Very poor water
3	S3 & D3	PindMakko	244.437	Very poor water
4	S4 & D4	BambanWala	103.461	Poor water
5	S5 & D5	KoatDheeran	241.05	Very poor water
6	S6 & D6	Choat, ChakRaib	238.42	Very poor water
7	S7 & D7	Chaht And Chiryana	244.14	Very poor water
8	S8 & D8	Kotehra	247.87	Very poor water
9	S9 & D9	ChakDaddan	0.014883	Excellent
10	S10 & D10	Kot Hasta	0.022729	Excellent
11	S11 & D11	Kamal Mustafa	0.024093	Excellent
12	S12 & D13	Noor PurPiran	0.024228	Excellent
13	S13 & DI3	Majhi	0.00267	Excellent
14	S14 & D14	JhuranaKot	0.0027	Excellent
15	S15 & DI5	Khewa	0.0025	Excellent
16	S16 & D16	Nawan	0.00267	Excellent
17	S17 & D17	Mirkani	0.00281	Excellent
18	S18 & DI8	Mong	0.004268	Excellent
19	S19 & D19	Kotli Afghan	3.12158	Excellent
20	S20 & D20	Rasul	326.9667	Unfit for use

*S =Surface water.
*D = Deep water.

and 0.00303456, respectively. Table 5 elaborates the water quality of each station of study area according to the standards of WQI. In this study, it was observed that majority of the water (55%) is excellent to use for irrigation purpose, (30%) is of inferior quality, (5%) is of good quality, (5%) of poor quality and (5%) is unfit to use for irrigation purpose which needs "special treatment". It may also be reflected that all physical and chemical parameters are within permissible limits of WHO and NEQs, so individually they have no impacts on water quality for irrigation. While *E. coli*, the biological parameter is elevated in approximately all of the sampling points due to fecal contamination.

Water quality index (WQI) evaluates the water quality as a whole, the total density of all selected parameters at each station chosen. It is evident from the results that the water quality is excellent in the middle of LJC from Chak Dadan to Kotli Afghan, while the water quality needs treatment at Rasul barrage, Rasul village and nearby vicinities for agricultural use.

3.4. Water quality for irrigation purpose

Salinity indices such as (Na%), sodium absorption ratio (SAR), and residual sodium content (RSC) are significant parameters to determining the suitability of canal water for irrigation purposes (Ramesh and Elango, 2006). The indices of canal water quality could be used as guidelines by farmers and considered as an essential management practice to control the potential salinity hazard if available water quality would cause any problem to irrigation for maintaining existing productivity of soil with the benefit of high crop yield under irrigation. Table 6 shows the calculated values parameters for each sample.

3.4.1. Sodium absorption ratio (SAR)

SAR is an important parameter for the determination of the suitability of water quality for agricultural use. According to the laboratory of salinity of the US Department of Agriculture (Wilcox, 1955; Richards, 1954), the SAR is calculated using the formula:

3.4.1.1. $SAR = (Na\%)/\sqrt{((Ca+Mg)/2)} \times 100$ *(mEq/l).* High values of SAR in irrigation water suggest sodium hazard by replacing Ca and Mg with Na cationic exchange, which is an undesirable situation. The concentration of SAR in irrigation water is good in between 0 and 3meq/l and undesirable if it is greater than 9mEq/l. In the current study, the values of SAR ranged from 0.3 to 7.09 mEq/l as shown in Table 7. The values of SAR in the Lower Jhelum Canal, which are less than 6mEq/l is 95%, which are excellent for irrigation, and 5% greater than 6mEq/l are doubtful for use.

3.4.2. Sodium percent (Na%)

Sodium percent (SP) is another imperative factor to study sodium hazard. Sodium percentage (Na%) is a popular parameter to access its suitability for irrigation purposes (Wilcox, 1955; Richards, 1954). The amount of Na% is determined by using this equation:

3.4.2.1. $Na\% = Na^{+} \times 100/[Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}]$ *(mEq/l).* The values of Na% in the current study ranged between 4.4 and 59.3mEq/l, which are within permissible limits. Problems of reduced permeability occur if the values of Na% are greater than 15mEq/l. In the current

Table 5
Water quality and water grading standards.

WQI Range	Type of Water
<50	Excellent
50–100	Good water
100–200	Poor water
200–300	Very Poor Water
>300	Unfit for Use

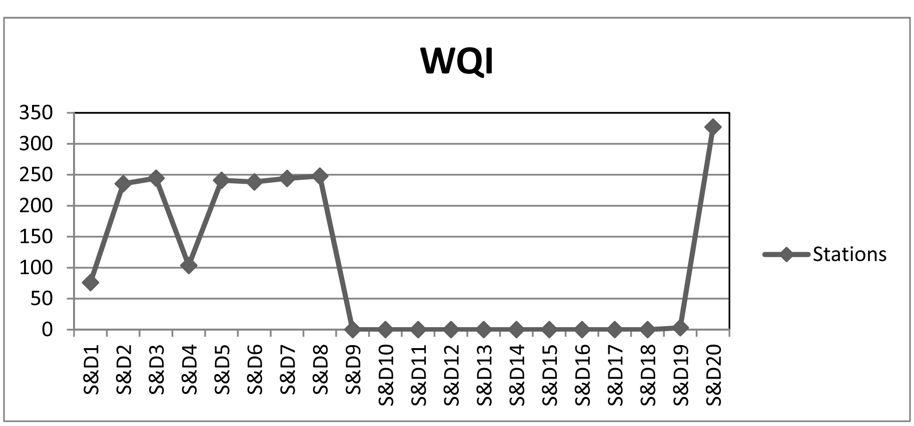

Fig. 4. Graphical representation of WQI at all sampling sites.

Table 6
Summary of important hydro geophysical parameters for irrigation purpose in deep and surface water quality.

Sample no.	SAR		SP (Na %)		RSC	
	Surface	Deep	Surface	Deep	Surface	Deep
1	1.91	0.43	29	8.4	−0.44	0.04
2	1.91	0.42	29.4	8.6	−0.44	0.13
3	1.91	0.43	29.4	8.45	−0.44	0.02
4	0.74	0.98	14	17.3	−0.04	0.1
5	0.74	1	14.6	17.5	−0.04	0.11
6	0.74	1.01	14.7	17.6	−0.04	0.13
7	2.01	0.24	27.7	5.7	−0.34	−0.2
8	2.03	0.24	28.5	5.7	−0.34	−0.19
9	2.01	0.35	28	6.5	−0.34	0.43
10	7.05	0.25	59	5.6	−0.24	1.2
11	7.09	1.04	59.3	10.2	−0.24	1.3
12	0.26	0.29	4.6	5.24	−0.34	0.14
13	0.26	0.39	4.42	8.9	−0.34	0.17
14	0.25	0.35	4.67	8.22	−0.34	0.29
15	0.32	0.40	8.7	11.3	−0.14	0.03
16	0.33	0.41	9.39	9.8	−0.14	−0.09
17	0.33	0.40	9.1	9.6	−0.14	−0.05
18	0.41	0.61	10.4	7.5	0.3	0.96
19	0.41	0.34	5.7	7.3	0.29	0.97
20	0.41	0.3	5.5	7	0.28	0.98

Table 7
Sodium hazard classes based on SAR.

SAR (meq/l)	Water quality	Percentage of samples
0–6	Good	95%
6–9	Doubtful	5%
>9	Unsuitable	–

investigation, 80% of SP lies in excellent, 15% in good quality, and 5% in permissible water quality as shown in Table 8.

3.4.3. Residual sodium content (RSC)

Residual sodium content is a vital factor for assessment of the suitability of water quality for irrigation (Vasanthavigar et al., 2010) calculated using the formula:

3.4.3.1. $RSC = [(CO_3^{2-} + HCO_3^{-}) - (Ca^{2+} + Mg^{2+})]$ (mEq/l). Usually, the values of RSC > 2.5 mEq/l are not good for irrigation. In the current study, the values of RSC ranged in between −0.04 and 1.3meq/l, which all are within permissible limit and excellent to use as shown in Table 9.

4. Conclusion

In this study, the effort was made to estimate and map the water characteristics by using GIS. It was revealed by results drawn from analysis that GIS is an appropriate tool to determine the several digital thematic sheets and maps elaborating the concentration of different factors. Furthermore, the GIS constructs the water quality map in a more logical structure. By WQI, it was estimated that about 55% of water falls in the top category for irrigation use, 30% in inferior water quality, 5% in poor water quality, 5% good water quality and 5% water quality falls in the category of unfit to use for agricultural purpose. Suggesting that most of the water quality of the lower Jhelum canal is suitable for irrigation purposes. The rain during March also makes the pollutants diluted and reduces critical contamination in canal water. *E. coli* and Coliform was present in all samples, so water could not be used for drinking reasons directly without treatment. The elevated level of *E. coli* makes the water unfit for irrigation at some points of the canal about 5%. Otherwise, the water of the lower Jhelum canal is desirable for aquatic life and irrigation purposes. The concerned authorities and the water testing laboratories are also encouraged to survey the pollution levels in nearby villages and other remote regions in district Jhelum.

Table 8
Classification of water-based on Na% (SP).

Na%	Class	Percentage of samples
<20	Excellent	80%
20–40	Good	15%
40–60	Permissible	5%
60–80	Doubtful	-
>80	Unsuitable	-

Table 9
Classification of water-based on Residual sodium carbonate (RSC).

RSC (meq/l)	Class	Percentage of samples
<1.25	Good	100%
1.25–2.5	Marginal	–
>2.5	Unsuitable	–

Because of the poor standards of sanitation and water resource systems, there is strong possibility of higher concentration levels of these pollutants in drinking waters.

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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