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Assessing the water quality of upper Indus Basin (UIB) by framing water quality index (WQI)

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Key words: Analytical hierarchy process; Indus river, NSFWQI, Upper Indus Basin, Water quality index

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Abstract

The water quality of Indus River is badly affected due to higher concentrations of arsenic (As) and lead (Pb). In this study, multi criteria decision making technique is used to assess the water quality of upper Indus basin (UIB). Eight physico-chemical quality parameters from five regions of UIB were utilized to frame water quality index (WQI). Analysis on the basis of this adjusted WQI classify the quality of water into three bands identified as good (0-7), fair (8-20) and bad quality water (>20), respectively. Afterward this adjusted WQI was applied for assessing the water quality of UIB. Water Quality data which include the pH, DO, TDS, EC, salinity, ORP, As & Pb concentration of sixty four samples belonging to UIB was utilized for the purpose. The results in this study show that the new WQI is sensitive to As and Pb. A slight variation of As from WHO recommended values i.e. 10μg/l immediately reflected by index value. According to results obtained water quality of Indus River is seriously affected from As from its start. We hope that adjusted WQI reported in this study might serve as essential part of monitoring protocol to save this valuable water resource of Pakistan.

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Introduction

In majority of cities throughout the world, industrial zones and agriculture related activities are established very close to natural water resources like streams, rivers, and other surface water resources (Dubois, 2011; Priscoli, 2000). Therefore surface water resources and their quality are very important for any society. However, increase in population, change in world climate and deficiency along with increasing demand for water is responsible for putting immense pressure on water-resources. Moreover, water discharge from industry and agriculture activities with dissolved toxic and harmful ingredients in surface water resources is another limitation. It is therefore; essential to have a constant monitoring and protocol for full confidence on the available water resources and their quality.

Generally, for the assessment of any water resource quality various physical and chemical parameters are required. The number of parameters needs to be monitored along with associated time and sample collection cost is the major issue for studying the water quality of any resource. In addition to this, analyses and interpretation of experimental data is some time creates confusion about the resource prevailing over longer region (Hernández-Romero *et al.*, 2004). In order to cope with this problem, efficient water quality classification at end user position and/or application is made on the basis of a set of quality parameters. These parameters should be acceptable by the end users that they are enough informative to give us water resource quality. Although, there are number of water quality indices available to access the quality of water by converting water quality parameters into a number system characteristically having range from 0-100 with the help of mathematical tools but most of them are there for accessing the drinking water quality and also some recently well-established quality index for testing the quality of surface water like rivers from which water is utilized for irrigation purposes (Mirzaei *et al.*, 2005; Sharma *et al.*, 2006). In the subsequent section, an effort is made for summing up the recent progress on framing the some new approaches for assessing the water quality.

Since the introduction of first water quality index (WQI) by Horton in 1965 (Horton, 1965) for assessing the quality of drinking water, efforts are going on and number of other indexes are introduced by various researchers (Cude, 2001; Horton, 1965). The various acceptable quality indices worldwide are summarized in Table-1. Among worldwide recognized practices for assessing the water quality whether it is irrigation or drinking water, the National Sanitation Foundation Water Quality Index (NSFWQI) is comprehensive in its nature. Numbers of researchers have used NSFWQI formula because it is more generic in its nature than others, and comparisons of results from various regions are reliable (Brown *et al.*, 1970; Mirzaei *et al.*, 2016; Misaghi *et al.*, 2017). Mainly nine base parameters are used to obtain the index value are summarized in Table 1.

Some researchers (Jena *et al.*, 2013; Mirzaei *et al.*, 2016; Misaghi *et al.*, 2017) categorized the indices into four groups:

(1) Which don't have much care about the end user and utilized for general measurements of water quality e.g. NSFWQI.

(2) The second one is focused for a particular application of water, e.g. drinking water system and biological community conservation. Oregon Water Quality Index (OWQI) is the example of this category (Misaghi *et al.*, 2017).

(3) This class has the focus especially in administrative activities to deal water asset i.e. outlining, arranging, designing and planning quality indices. British Columbia Water Quality Index (BCWQI) is the example of this category.

(4) Fourth category is based on statistical and factual methods. The basic part of the factual methodology is to assign the acceptable scores and make predictable suppositions for covering the all expected observations of normal water quality.

First three categories are altogether based on resultant conclusion approach or Delphi approach i.e. the expert's panel feedback reflects the importance of water quality parameters (Terrado *et al.*, 2010).

Table 1. The Summary of WQIs in practice to date.

Index**	Aims and Details	Type and Outcomes
NSFWQI	• Used for the comparison of water quality on relative sale • The survey of 35 water quality parameters were carried out by a 140 water quality experts Main Nine parameters are considered ➢ Dissolved oxygen (DO) ➢ Faecal coliform ➢ pH ➢ Biochemical oxygen demand (BOD) ➢ Temperature change ➢ Total phosphate ➢ Nitrate ➢ Turbidity ➢ Total solids	Quality Index (Increasing value represent the water quality) The values for this index were determined as follows: 0 to 25 Very-Bad 26 to 50 Bad 51 to 70 Aver. 71 to 90 good 91 to 100 Very-good
FWQI	• The arithmetic-average average of following parameters ➢ TSS & turbidity ➢ DO & oxygen demanding substance ➢ BOD ➢ COD ➢ TOC ➢ Nitrogen & phosphorus ➢ Faecal coliform ➢ Bio-diversity	Pollutant Index (Increasing value represent the pollutant in water) Outcomes is expressed as follow: 0-45 Good 45-60 Fair 60 to 90 Poor
BCWQI	• It depends on the application and sensitive because of its limitation for comparison among water samples	Pollutant Index (Increasing value represent the water quality)
CWQI	• It has three essential elements: ➢ Variables not up to standard for water-quality objectives i.e. Scope ➢ No. of time when objectives are not to up to required sandard i.e. frequency ➢ The quantitative extent to which objectives are not met in i.e. Amplitude	Quality Index (Increasing value represent the water quality) Outcomes are expressed as follow: • 0 belongs to worst • 100 belongs to best • 5 descriptive categories from 0-100 for more understandable presentation
OWQI	➢ The raw data of each parameter is transformed into unit less sub-index values. ➢ These values range from 10 (worst case) to 100 (ideal). ➢ These sub-indices are then combined to give a single WQI value ranging from 10 to 100. ➢ It also utilized the same parameters as NSFWQI	Quality Index (Increasing value represent the water quality)

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NSFWQI: National Sanitation Foundation Water Quality Index

FWQI: Florida Water Quality Index

BCWQI: British Columbia Water Quality Index

CWQI: Canadian Water Quality Index

OWQI: Oregan Water Quality Index

Zandbergen *et al.,* (Zandbergen, 1998) has used geographic information system (GIS) tool for calculating the urban water quality. Sample points were chosen including impenetrable territories, natural surroundings, water quality, residue quality, contamination points, and the health of general public. They had utilized BCWQI for the examination of water quality of stream. In another study Shokuki *et al.*, (Shokuhi *et al.*, 2012) measure the quality indices of a lake in the north west of Iran.

The water in this lake is supplied to adjacent towns and water system for farming land downstream. Here quality of water was surveyed because of the concern that contamination releases into the supply. Standard quality parameters including temp., broke-up oxygen, bio-chemical & synthetic oxygen-demand, a good number of coliforms, fecal coliforms, add up to broke down solids, turbidity, add up to solids, pH, electrical conductivity and others were estimated at eight unique stations.

The NSFWQI was figured dependent on the collection of samples and investigation plan. The range of the NSFWQI was from 67.96 (May) to 84.89 (July). Dissolved concentration has been found in the dam water in a smaller part. Majority of the sample were in good category according to NSFWQI formula. The results demonstrated a satisfactory water quality for drinking water and irrigation. Recently Misaghi *et al.*, (Misaghi *et al.*, 2017) have utilized the expert choice software in order to have new quality index or direct index for assessing the water quality of Ghezel Ozan river Iran while keeping in view the FAO-29 guidelines, recommendation, and expert's iterative survey of irrigation for irrigation water quality.

Although mentioned indices in table 1 are in practice and some approaches are recently introduced by using geographical information system (GIS) (Zandbergen, 1998) and multiple decision making technique in NSFWQI. These are advanced approaches used for assessing the water quality and mainly rely on nine base parameters having particular importance for irrigation purpose. However, there are some water pollutants (e.g. heavy toxic metals like arsenic, lead etc.) which become the matter of sever concern when exceeded the prescribed limits of World Health Organization (WHO). Therefore, it is necessary to monitor the concentrations of such toxic life threatening elements to define a protocol/index/standard.

Currently, an integrating quality index consisting the set of quality parameters for assessing the surface water quality for irrigation and drinking purpose while considering the life threatening heavy metals like arsenic (As) and lead (Pb). It is therefore, this aims at developing an index extremely sensitive to the concentration of As and lead in the surface water by adjusting the NSFWQI index with a specific focus of agriculture and domestic needs. This study was done in Upper Indus Basis in Pakistan which has growing concerns regarding the higher (well above the WHO recommended) concentration of life threatening heavy metals i.e. As and Pb [FUUAST]. As the Indus river is the backbone for the economy of Pakistan, therefore a new index for assessing the quality of water specifically for irrigation and domestic needs to be developed having base on NSFWQI which is a broadly accepted index.

This particular study is aimed to address the issue while performing the quality assessment of upper Indus basin located in Pakistan. A new quality index is introduced, keeping in view the FAO-29 and WHO guidelines (see table-2). A threshold index value is calculated by using quality parameters for good quality of irrigation water as defined in FAO-29 guidelines and considering the WHO recommended concentration of toxic heavy metals. The final water quality is then framed relative to threshold value. The study then applied to Indus River for the assessment the current status of quality of water and trend in water quality in an existing resource.

Table 2. Irrigation water quality framework guide lines along with WHO recommended concentration of As in µg/l.

Potential Water Quality problem	Units	Degree of restriction on use		
		None	Slight to moderate	Severe
Salinity (affects ??op water availability)				
Ec_w	dS/m	<0.7	0.7-3.0	>3.0
Or				
TDS	mg/l	<450	450-2000	>2000
Infiltration (affects infiltration rate o water into the soil. Evaluate using Ec_w and SAR together)				
SAR =0-3 and Ec_w=		>0.7	0.7-0.2	<0.2
=3-6		>1.2	1.2-0.3	<0.3
=6-12		>1.9	1.9-0.5	<0.5
=12-20		>2.9	2.9-1.3	<1.3
=20-40		>5.0	5.0-2.9	<2.9
Specific ion toxicity (affects sensitive crops)				
Sodium (Na^+)				
Surface irrigation	SA	<3	3-9	>9
Sprinkler irrigation	me/l	<3	>3	
Chloride (alpha)				
Surface irrigation	Me/l	<4	4-10	>10
Sprinkler irrigation	Me/l	<3	>3	
Boron (B)	Mg/l	<0.7	0.7-3.0	>3.0
Trace Elements				
Miscellaneous effects (affects susceptible crops)				
Nitrogen (NO_3^{2-} -N	mg/l	<5	5.0-30	>30
(overhead sprinkling only)	me/l	<1.5	1.5-8.5	>8.5
pH				
		Normal Range 6.5 – 8.4		
As concentration	µg/l	<10		>50

Material and methods

Study Area

The total area 1.12 millionkm^2 of trans-frontier Indus river basin is divided among some Asian countries. The percentage distributed area is: Pakistan (47percent), India (39percent), China (8percent) and

Afghanistan (6 percent). In Pakistan the Indus river basin is expended from the north Himalayan Mountains to the parched sedimentary area of Sindh in south. At last, it washes out into Arabian Sea. The Indus river basin is stretched over the area of approximately 520,2000km^2or 65 percent of dominion of Pakistan. The whole province of Punjab and Khyber Pakhtunkhwa and most of the area of Sindh province and eastern area of Baluchistan is covered by Indus river basin. Indus River is also considered as backbone in the economy of Pakistan.

Through northwest region like Ladakh and Skardu Indus river flows towards Gilgit Baltistan which is located in the south of the karakoram mountain ranges. In this place numerous numbers of water streams, spring cascade from the peaks of snow covered glaciers and rain water submerge into a main water flow near the place of Giglot.

The main reservoir of Indus river is Tarbella dam near Attock in Punjab. There is a densely populated area throughout the passage of Indus River.

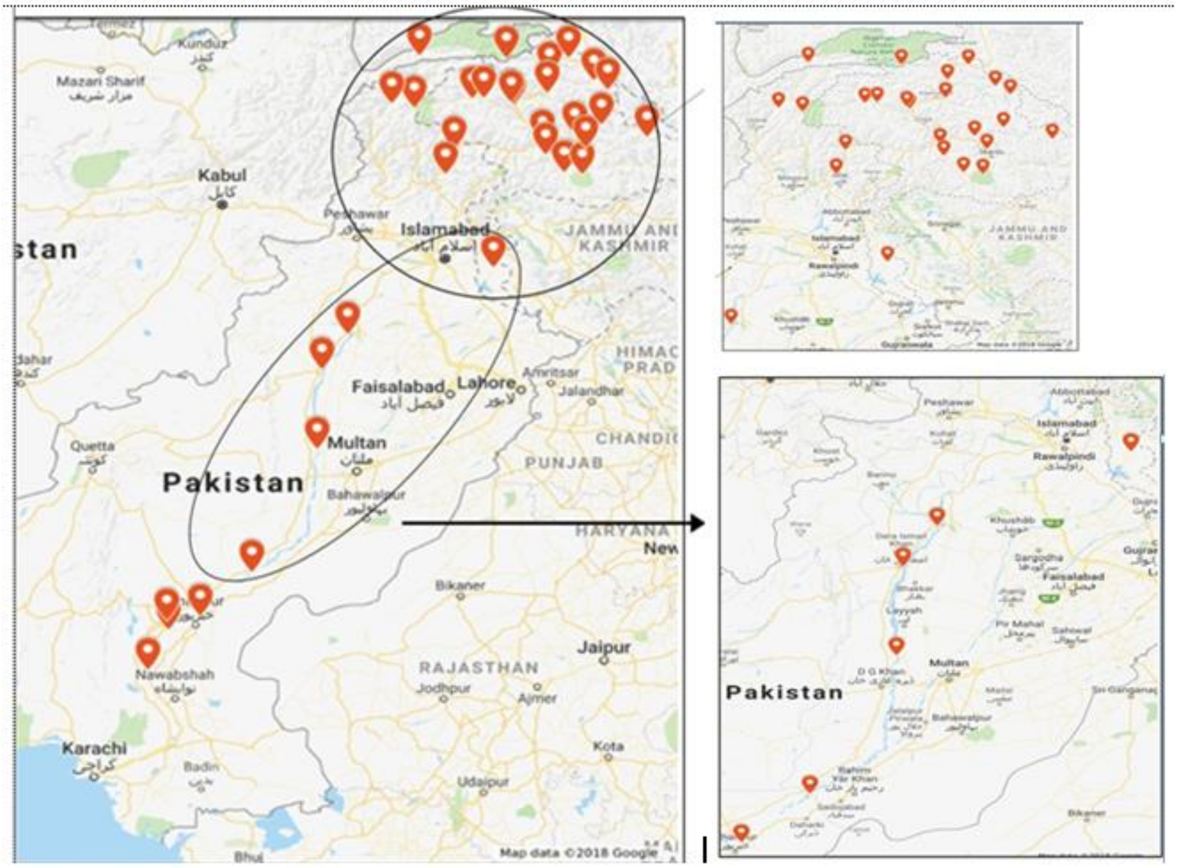

Fig. 1. Main Indus River with marked sample locations obtain while using Google Maps.

The weather conditions in Indus lands wary from barren to semi-barren. In lower lands temperature observed is between to 14 to 20˚C on December to February. Weather is cold during these months. In month of March to June temperature varies from 24 to 44˚C. In these region of upper plain temperature varies from 23 to 49˚C in summer and between 2 to 23˚C in winters. The mean value of yearly precipitation is about 230mm in Indus plains. On average, Larkana and Jacobabad region receives about 90 mm precipitation; Multan receives 150 mm and Lahore receives about 510 mm of precipitation (Karim and Veizer, 2000).

Methodology

In the present study already developed NSFWQI index have been used as a base index. Brown *et al.*, (Brown *et al.*, 1970) first proposed the said NSFWQI index under the support of United States National Sanitation Foundation. The background for the development of this

NSFWQI index was a detail review of literatures from various experts in a study known as Delphi Study. Initially 35 quality parameters are proposed by the experts for quality index. After different rounds of review water quality parameters specialists derived 9 parameters out of 35 from the index. In the present study, a new WQI is proposed by adjusting the NSFWQI formula while keeping in view the FAO-29 guidelines and WHO recommendations given in table 2. FAO-29 describes seven quality parameters for irrigation and drinking purpose which were not included in NFSWQI index. These are Na+, Cl-, pH, HCO3-, Ec, SAR and TDS. In this study the concentrations of arsenic and lead were also considered.

Experts Survey

In order to determine the most influential parameter of the index not only for water system but also for drinking purpose a set of feedback form were prepared and handed over to five groups of twenty specialized experts. In the light of experts opinions all the eight parameters were organized and thus build up a highly weighing factor. In a comparable way to deal with the advancement of the NSFWQI index. Subsequent to accepting and preparing the first round of study reactions, a second study was directed to enable individuals to modify their reaction dependent on the results of the primary review.

The subsequent information delivered a complex multi-criteria analysis issue with a few reactions in regards to fig. out suitable parameters and their weights.

Calculation of Weighting Factors

Focus of this practice was to find priority parameters among the listed parameters and find the most weighing factor. For this purpose analytical hierarchy process (AHP) was used which has the main function to identify proposed WQI most weighing parameters that is suggested in Table 2. Normally multi criteria decision relating problems are extremely convoluted and in the vast majority of the cases expanded exactness of one of the elements may impacts on the precision of alternate parameters. Multi criteria decision-making method technique gives variety of distinctive phases of basic decision-making. For comprehensive understanding of multi criteria decision making and AHP readers are referred to literature (Goepel, 2013).

Calculation of Index Value

The weighting factors for the listed parameters are shown in Fig. 2 as pie chart which suggests that the higher weighing factor belongs to As (0.30) and the minimum to pH (0.05). The values of parameters reported by Ahmed *et al.,* (Ahmed *et al.*, 2017) in upper Indus river basin are utilized as case study. The general NSFWQI formula is adjusted following the FAO-29 and WHO guidelines to obtain more generic WQI.

$$NSFWQI = \frac{\sum_{i=1}^{n} W_i I_i}{\sum W_i}$$

Here

- N is the no. of parameters
- W is the weight factor
- I is the value of parameter

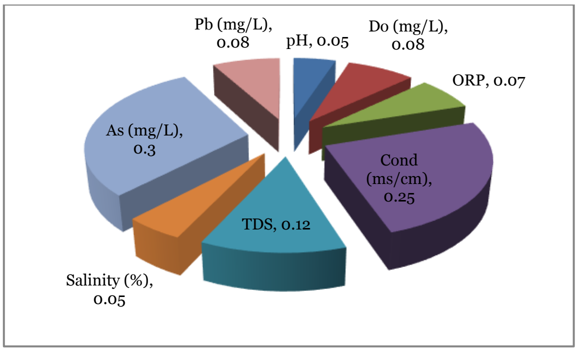

Fig. 2. Weighting factors obtained from AHP protocol and used for calculating WQI.

Results

While keeping in view the survey which contains the opinion of sixty experts on the set of eight water quality parameters data reported by (Ahmed *et al.*, 2017)and used in this study, an analytical hierarchy process (AHP) (Goepel, 2013) was implemented to obtained a 8×8 Eigen matrix and normalized Eigen values. The result of first survey is shown in table 3 below. The Eigen values of three survey set of 20 experts is further averaged to obtain the mean values and used as weighting factors for the calculation of proposed WQI. The obtained weighting fractions are shown in Fig. 1 as pi chart.

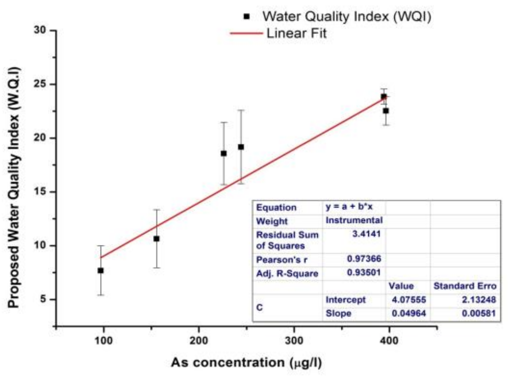

Fig. 3. Correlation among Proposed WQI and As Concentration.

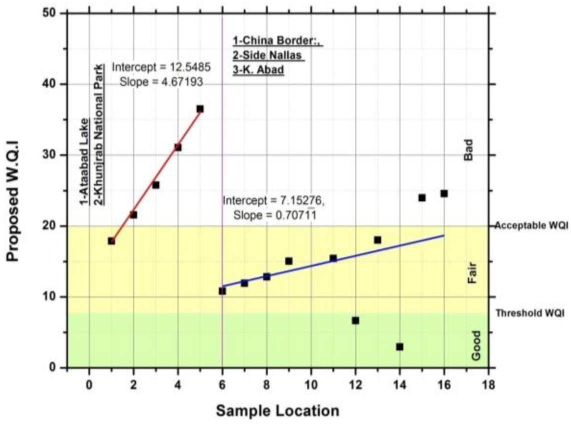

Fig. 4. Proposed WQI of samples from Giligit to Khunjrab Pass.

Table 3. AHP Eigen matrix of physico-chemical parameters and normalized Eigen values obtained from the first survey of experts.

Variables	pH	Do	ORP	Cond	TDS	Salinity	As	Pb	Eigen Vector
pH	1	3	3	3	3	1	1/6	1	12.62%
DO	1/3	1	1	1	1	1/3	1/6	1/3	4.80%
ORP	1/3	1	1	1	1	1/3	1/6	1/3	4.80%
Cond	1/3	1	1	1	1	1/3	1/5	2/7	4.84%
TDS	1/3	1	1	1	1	1/3	1/6	1/3	4.80%
Salinity	1	3	3	3	3	1	1/6	1/3	11.34%
As	5 1/2	5 1/2	5 1/2	4 7/8	5 1/2	5 1/2	1	4	40.86%
Pb	1	3	3	3 2/5	3	3	1/4	1	15.95%

The focus of this study was introducing modified WQI in the light of FAO-29 guidelines for irrigation water quality parameters and WHO recommendations for maximum allowed limit of arsenic (As) and lead (Pb). In proposed WQI the weightage of As was included as an essential quality parameter/ In order to have confidence that this adjusted WQI is reflecting the aforementioned aim or not, proposed WQI obtained for upper Indus regions are plotted as a function of As concentration in µg/l (see Fig. 3). As it is clear from Fig. 3 that proposed WQI has linear correlation with As concentration with a goodness fit value of approximately 93% which means that proposed WQI can be utilized with a reason able confidence for evaluation of water quality. The results of water quality on basis of proposed WQI for six regions of upper Indus basin are hereby explained. Shown in Fig. 4 is the WQI for the sixteen samples collected from Gilgit to Khunjrab Pass region. More specifically these samples were collected from Attabad Lake, Kunjrab National Park, China Border, Side Nallas and Karim Abad, respectively.

The exact locations from where the samples were collected are represented at google map shown in Fig 1. As it is clear from Fig. that proposed WQI for the sample collected from Attabad Lake and Khunjrab National Park is > 20 (i.e. water quality is bad) and have increasing linear trend with respect to their exact location while having the positive slopes. The WQI correspond to each data point in aforementioned region has the value higher than the threshold WQI and acceptable WQI (see Fig. 4). It is worth to mention the details about threshold WQI and acceptable WQI here. Threshold WQI is the water quality index calculated while keeping the recommended maximum allowed concentrations of As, Pb and other water quality parameters mentioned in FAO-29 and WHO guidelines for good quality water (see Table 2). The acceptable WQI is the index calculated while taking the concentration of arsenic as 50µg/l (i.e. maximum allowed limit of As in Pakistan). In this region i.e. from Gilgit to Khunjrab Pass the WQI of samples collected from couple of side Nallas fall below threshold WQI (see Fig. 4) means that the water quality is good. On the other hand, WQI value for samples collected from Khunjrab National Park and China Border is below the acceptable WQI i.e. quality in this region falls in the acceptable WQI i.e. water quality is fair.

The proposed WQI obtained from quality parameter and concentrations of As and Pb for the samples collected from Gilgit to Dossai plan is shown in Fig. 5. The samples locations are side Nallas, Asst. Nalla and

Rama, Dossai plan and showtoe, respectively. The exact locations of sample collection points are shown on Google map shown in Fig. 1. The values of WQI for the samples collected from side Nallas and Showtoe are well below the threshold values i.e. the water samples belonging to side Nallas are coming from snow covered peaks is of good quality. The samples from Dossai plan have acceptable WQI value i.e. water is of fair quality. The proposed WQI shows that the quality of water from Gilgit to Sarkadu and Giligt to Naltar is above the acceptable level i.e. the water quality in this region are bad (see Fig. 6). The data belongs to samples collected from 2427m to 1462m a.s.l from side Nallas and main River. The water quality from majority of collected points in Gilgit to Chitral region falls in the category of good water with respect to proposed WQI, except for couple of samples of side Nallas (see Fig. 7). Lower value of TDS, arsenic, and lead concentration is mainly the reason for good quality water in this region.

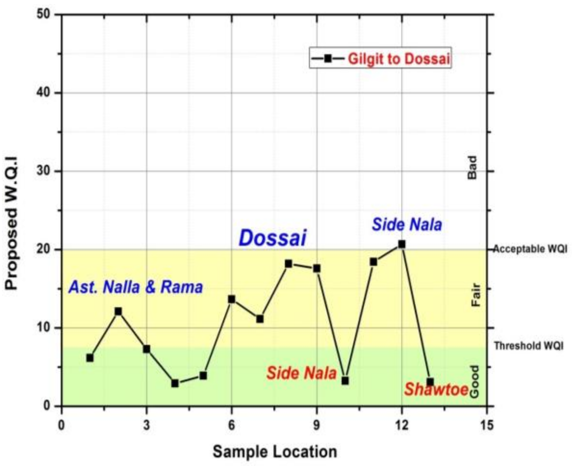

Fig. 5. Proposed WQI of samples from Gilgit to Dossai.

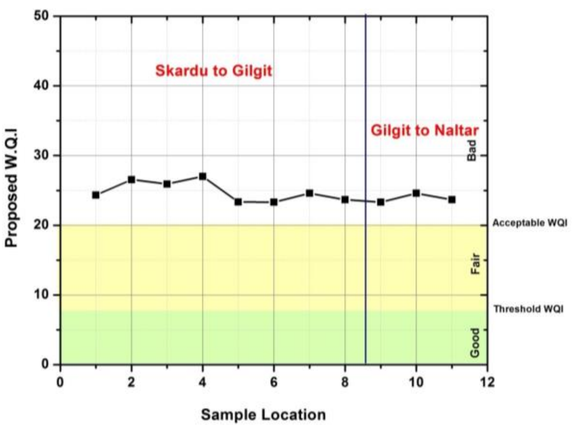

Fig. 6. Proposed WQI of samples from Gilgit to Skardu and Naltar.

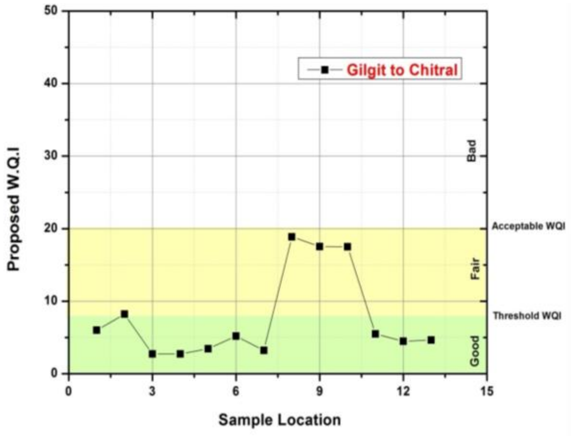

Fig. 7. Proposed WQI of samples from Gilgit to Chitral.

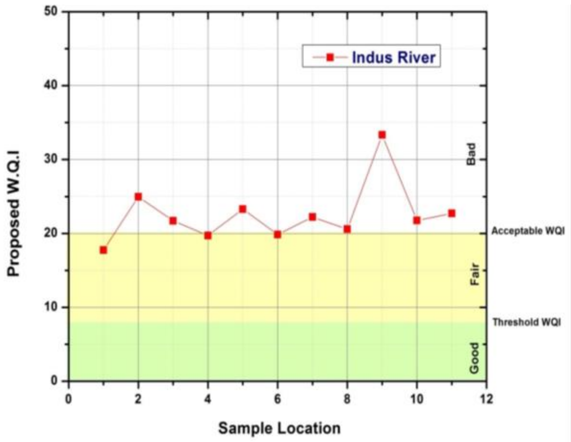

Fig. 8. Proposed WQI of samples from main Indus River.

The aforementioned sub rivers situated in upper Indus basin ultimately falls in main river known as Indus river and this river is the back bone of Pakistan economy. In addition, several other sub rivers, Nallas like Khania, Dubair, Kabul Chilas also have Indus river as their final destination. The values of proposed WQI obtained from the data of water quality parameters, arsenic and lead concentrations corresponding to each water sample and its exact location is shown on Google map (see Fig. 1). The index value for each sample obtained in this region by using the proposed WQI is above acceptable level i.e. the water quality is poor throughout the main Indus River. The data and calculated WQI for Hyderabad show that situation is worst at that position because index value is above 30. Except this, the situation at other areas is not series to this extent but still it is alarming because water quality is just oscillating at the edge of acceptable level as evident from Fig. 8.

Discussion

As our main concern here and reason for framing the new WQI is the higher concentration of arsenic in upper Indus basin. Arsenic basically exists in the earth rust and its average concentration is approximately 5mg/kg (Hughes *et al.*, 2011), and its introduction into water is from its presence in local bed rocks. The contribution of arsenic rich bed rocks decreases with each passing day.

The Attabad Lake was formed back in 2010 due to massive landslide in surrounding of Hanza Valley in Gilgit-Baltistan. Arsenic rich local bedrocks might fall during the aforementioned incident and may be contributing as a source of higher concentration of As and other solvents thus making the water quality bad as evident from Fig. 4. The Dossai plan water have acceptable WQI value i.e. water is of fair quality. The inclusion of domestic and commercial waste in the water of Dossai plan is mainly responsible for affecting the water quality parameters thus creating the difference in water quality in the sample. The higher value of pH (around 8) and lower values of TDS in the samples with lower water quality is responsible for this behavior. From Gilgit to Sarkdu and Gilgit to Naltar TDS, arsenic and lead are not the major contributor to the WQI. The erosion pressure in the upper Indus basin water shed due to the flow of water is mainly responsible for higher values of TDS, electrical conductivity and arsenic thus making the quality of water bad in this region. The water from Gilgit to Chitral region comes from the snow covered peaks and glaciers which and falls into main sub river through side Nallas and most of side Nallas is clear and transparent. There are couple of side Nallas in this region which contain the traces of arsenic and lead might be due to dumping of domestic and commercial waste which belongs to the population in that region. For main Indus river the factors which are responsible for poor water quality are:

- Water turbidity
- Picking of herbs and shrubs for medical use and illegal cutting forest and tress of environmental importance in an un controlled manner
- Amount of dissolved Oxygen which is higher
- The value of Oxidation Reducing Potential (ORP) which is higher
- Water salinity
- And most importantly the concentration of arsenic

This increase in soil erosion in upper Indus basin region may be the one cause for higher concentration of arsenic and lead. In addition to this, increase in ORP is also another reason because heavy toxic metals usually exits in nitrate form i.e. $Pb(NO_3)_2$ and thus oxidizes to lead which degrade the quality of water.

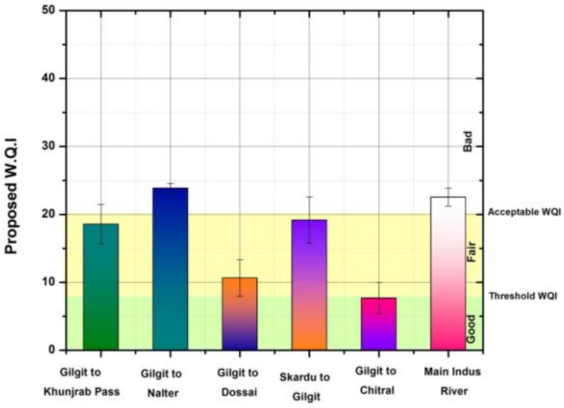

Fig. 9. Means values of WQI from various regions of upper Indus basin.

For conclusive statement, mean values of proposed WQI belong to each sub section are shown as bar graph in Fig. 9. The deviation from mean values corresponding to each study area is shown as error bar. It can be seen that water quality from Gilgit to Nalter is bad and falls in fair quality band for other regions/sub rivers of upper Indus basin. More importantly the value of WQI from Gilgit to Hyderabad which is usually know as main Indus river and all sub rivers falls in this rivers is bad according to proposed WQI. This shows that proposed WQI is extremely sensitive to slight increase in the concentration of arsenic and it immediately reflects the status of water quality according to the guidelines of FAO and WHO.

Conclusions

Adjusted WQI formula obtained by amending the NSFWQI relation according to FAO-29 and WHO guidelines shows that the water quality can be divided three bands representing good, fair and bad quality water.

The water quality from sixty four samples representing six sampling regions of upper Indus basin (UIB) is assessed by using this new proposed WQI. It is found that this new index is extremely sensitive to toxic heavy metals i.e. arsenic and lead. The proposed new WQI in this study confirms that higher concentration of arsenic i.e. approximately 400µg/l is responsible for bad water quality of Indus River from the start.

The aforementioned concentration of arsenic is 40 times higher than minimum WHO recommended level of arsenic concentration which is 10µg/l. The soil erosion due to illegal uprooting of herbs and sherbs of medical importance, land sliding and domestic/industrial waste are the main reasons for bad quality water (as obtained from suggested WQI) in upper Indus basin (UIB).

It is expected that the proposed WQI is of importance for policy makers and managers for constant monitoring of major water resources like Indus River.

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