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Trend Analysis and Spatial Assessment of Various Water Quality Parameters of River Jehlum, J&K, Indiafor an Inclusive Water Quality Monitoring Program

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ABSTRACT: *The water quality issue in Kashmir has not yet got its due importance. A comprehensive water quality monitoring program is indispensable to assess the water quality status of the national rivers. This paper assesses the monitoring data on water quality of the longest river of Kashmir Valley i.e., River Jehlum from 2003 to 2012 and strives to convert it into an understandable format that can be easily interpreted using various analytical techniques pertaining to Water Quality indexing(WQI) such as Canadian Water Quality Index(CWQI) and Arithmetic Water Quality Index(AWQI) where the former is computed using CWQI 1.0 model while the latter is calculated using Weighted Arithmetic Index method. It also formulates certain surface water quality standards according to different water usages and detects long-range trends in selected water quality parameters which account for various potential problems causing alterations to the quality of River Jehlum. This study also identifies most polluted reaches and proposes management scenarios for the reduction of the build-up pollution in River Jehlum.*

Keywords: *River Jehlum, Water Quality Parameters, Water Usages, Analytical Techniques, Water Quality Index*

I. INTRODUCTION

The Monitoring and analysis of the water quality status of River Jhelum is essential in order to detect long-range trends in selected water quality parameters so as to detect actual or potential water quality problems, if such problems exist to determine specific causes. It is intended to identify the most serious parameters which caused alterations to ascertain the quality of River Jhelum by the calculation of water quality indices along the River Jhelum for different water uses like overall water quality, drinking water, irrigation, recreation & Aquatic life[7]. The data used in this study is collected through work plan of the CWC (Central water commission) for the years 2003 to 2012. A monthly variation in the water quality parameters of River Jhelum at three stations namely Sangam, Ram Munshibagh and Saffapora is observed during the years from 2003 to 2012. The water quality assessment shows the variation of water quality parameters. For the spatial variation of water quality in River Jehlum, a readily understood indicator, water quality indices, is calculated using Canadian water quality index (CWQI) 1.0 model [3] showing the spatial variations of the river water for various intended uses (overall, irrigation, drinking, recreation, livestock and aquatic life) & Arithmetic water quality index for determining the overall quality of Jhelum.CWQI results revealthat the overall quality of River Jehlum falls under poor category. Aquatic life and recreation falls under poor quality throughout for the years 2003 to 2012.However, irrigation and livestock are ranked as fair and good respectively throughout for the years 2003 to 2012.In general, the results of Arithmetic water quality index at sampling sites of Sangam, Ram Munshibagh and Saffapora indicate that the values of most parameters such as ElectricalConductivity, Bicarbonate, pH & Chlorine- are beyond the permissible limits and exceed the permissible limits as prescribed by World Health Organization (WHO) standards for overall water quality.

Trend Analysis

Testing water quality data for trend over a period of timehas received considerable attention recently. The interest inmethods of water quality trend arises for two reasons[8].Thefirst is the intrinsic interest in the question of changing waterquality arising out of the environmental concern and activity.The second reason is

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that only recently has there been asubstantial amount of data that is amenable to such ananalysis.Trend analysis determines whether the measured valuesof a water quality variable increase or decrease during atime period[6].

Water Quality Indices

Water quality indices are tools to determine conditions of water quality and, like any other tool require knowledge about principles and basic concepts of water and related issues [9]. It is a well-known method of expressing water quality [8]that offers a stable and reproducible unit of measure which responds to changes in the principal characteristics of water [3]

Canadian Water Quality Index

The CWQI 1.0 model consists of three measures of variance[1] from selected water quality objectives: Scope (F1), the number of variables not meeting water quality objectives; Frequency (F2), the number of times these objectives are not met; and Amplitude (F3), the amount by which the objectives are not met [2]. The index produces a number between zero (worst water quality) and 100 (best water quality)[8].

Water Quality Index (Weighted Arithmetic)

In this model, different water quality components are multiplied by a weighting factor and are then aggregated using simple arithmetic mean.

II. AREA OF STUDY

The Jhelum is a large eastern tributary of the Indus. It drains areas west of Pir Panjal separating Jammu and Kashmir. The Jhelum rises from the spring of Verinag, on the northwestern side of Pir Panjal and flows in a direction parallel to the Indus at an average elevation of 5,500 feet [10]. It drains about 2,300 square miles of alluvial lands in the Kashmir Valley and gets water from various important sources including glaciers located in the north of the valley. The present study describes the application of the Canadian Council ME Water Quality Index and Arithmetic water quality index [8] to monitor the changes in water quality at three sites within River Jehlum.

Sampling Sites and Water Quality Monitoring Station

The present study describes the application of the Canadian Councilof Ministries of the Environment(CCME) Water Quality Index and Arithmetic water quality index to monitor the changes in water quality at the following three sites within River Jehlum, India as shown in (Fig.1& Table 1).

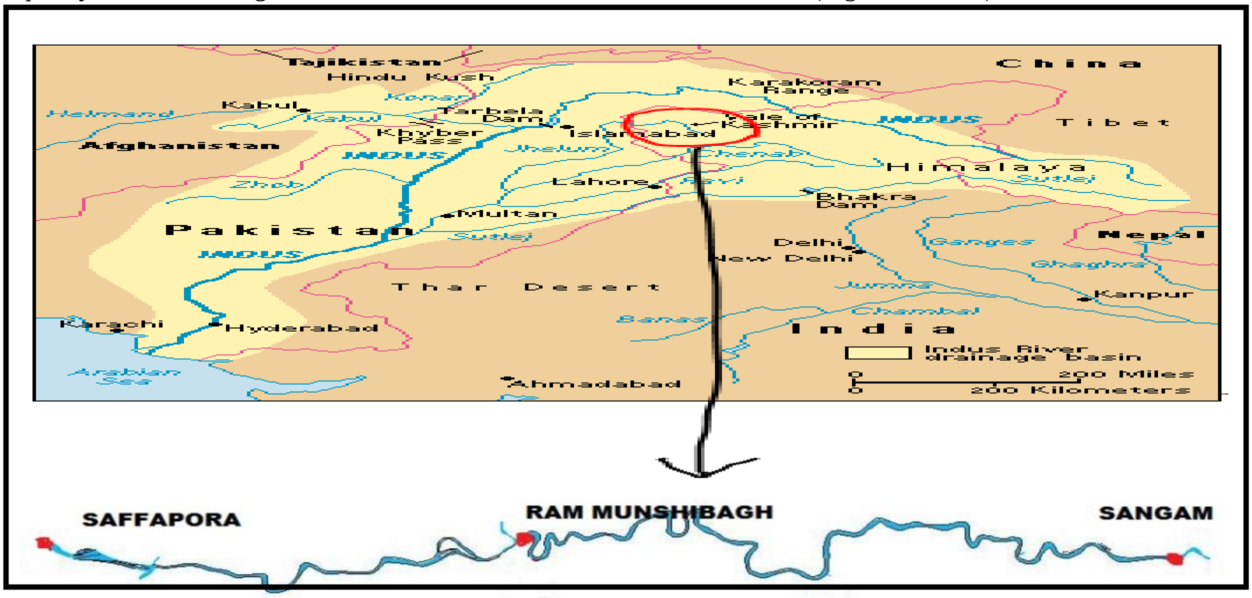


Fig.1

SITE	GEOGRAPHICAL LOCATION
SANGAM	**33º49’21”N , 75º4’32”E**
RAM MUNSHIBAGH	**34º4’20”N , 74º49’59”E**
SAFFAPORA	**34º15’32”N , 74º39’42”E**

Table 1

Data Availability

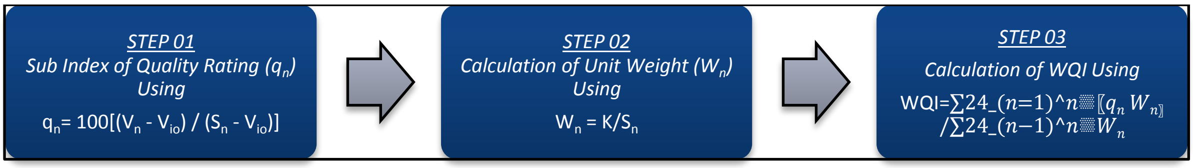
The water quality data for different locations has been obtained from Central Water Commission (Chenab division, Jammu). The requisite data of various water quality parameters (based on monthly analysis) obtained from CWC authorities is from Jan 2003 to Dec 2012.

III. DATA ANALYSIS

Assessment of surface water quality can be a complex process undertaking multiple parameters capable of causing various stresses on overall water quality. To evaluate water quality from a large number of samples, each containing concentrations for many parameters is difficult. Depending on the availability of data, analysis has been carried out using Arithmetic WQI & CWQI for spatial variation[2].The data analysis carried out to calculate Water Quality Indices such as Arithmetic Mean WQI & CWQI is explained below.

Arithmetic Mean Water Quality Index

Various steps involved in the computation of Arithmetic Mean Water Quality Index[4] are shown in Flowchart 01



Flowchart 1

where q_n= quality rating for the nth water quality parameter; V_n= estimated value of the nth parameter at a given sampling station; S_n = standard permissible value of nth parameter; V_{io} = ideal value of nth parameter in pure water; W_n= unit weight for nth parameters; K= constant of proportionality. The process of developing a WQI involves the following steps: Identify water quality parameters of interest and their ranges of acceptability for the intended uses of the water body. Compare the measured value with the subjective rating curve. Define the weighing factor and/or heuristics for each parameter to be considered while building an overall WQI. Select an algorithm and computing the WQI with the available data and assumptions.

Canadian Water Quality Index

The CCME WQI was originally developed as the Canadian Water Quality Index(CWQI). It comprises of three factors [1]which are computed as shown in Flowchart 2(a) & Flowchart 2(b).

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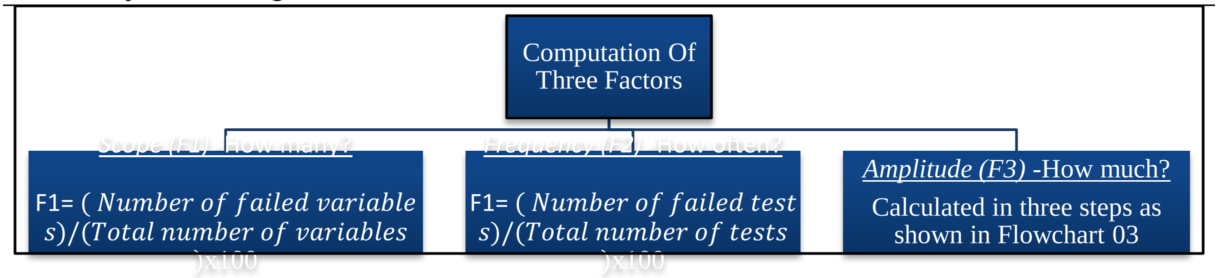
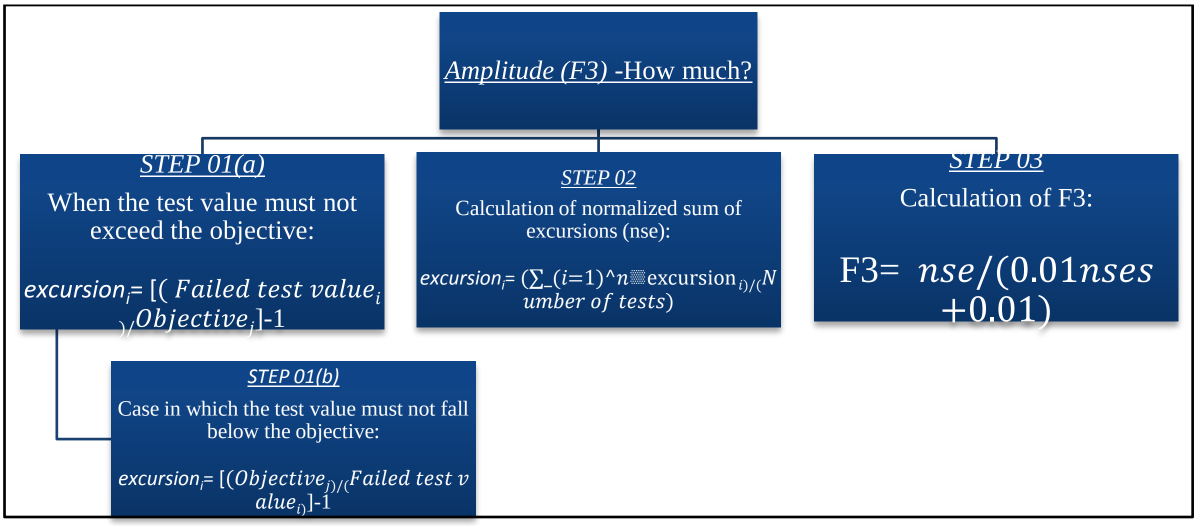


Flowchart 2(a)



Flowchart 2(b)

Similar to other WQIs, this model also produces a number between zero (worst water quality) and 100 (best water quality). In this case, the index is flexible in terms of the benchmarks that are used for calculations, and depends on the information required from the index. This model expresses well when a history of monitored data for different water quality parameters is available. It is recommend that at a minimum four variables sampled at least four times be used in calculation of the index for this approach. This index is considered trustful. However, the possibility of some parameters having disproportionate influence on the final results producing a biased index always exists. Thus, a thorough review and considerations to the weighing factor for each parameter should be discussed and well documented with experts and stakeholders of the water resource. The CCME WQI aids in assessing water quality for general purpose. To determine the suitability of the water body for a specific usage, it should be combined with other appropriate information.

IV. RESULTS & DISCUSSIONS

The values of twenty physicochemical parameters of River Jhelum for calculation of Water Quality Indices by Canadian water quality index (CWQI) and Arithmetic mean water quality index methods are used in the present study. The physical and chemical parameters including :pH (Hydrogen ion concentration), electrical conductivity, boron, calcium ,magnesium, chloride, carbonate, bicarbonate, sodium, potassium, fluoride, iron, silicate, total phosphorus, sulphate ,turbidity, Biochemical oxygen demand, Chemical oxygen demand and Dissolved oxygen have been sampled at the specific sites between the years of 2003 and 2012.

Arithmetic Mean Water Quality Index

Water quality variation for three different sites using arithmetic water quality indices are shown in Fig.2(a) to Fig.2(c):

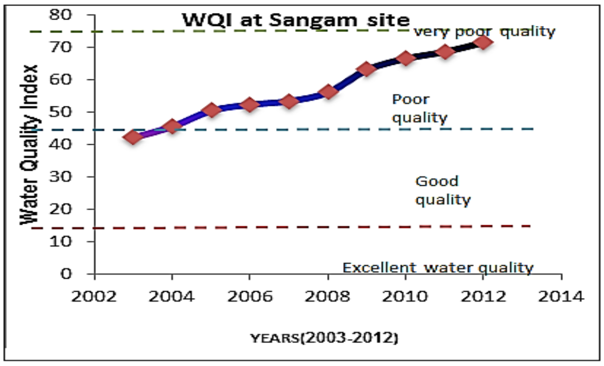


Fig. 2(a)

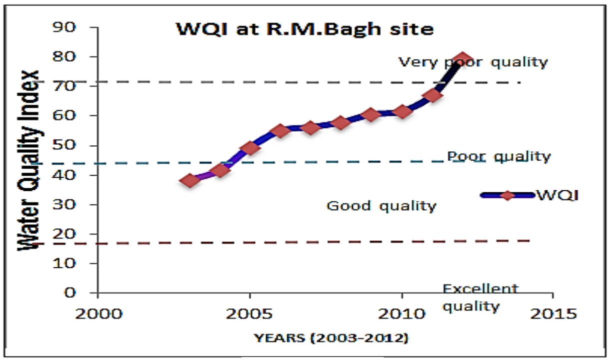


Fig. 2(b)

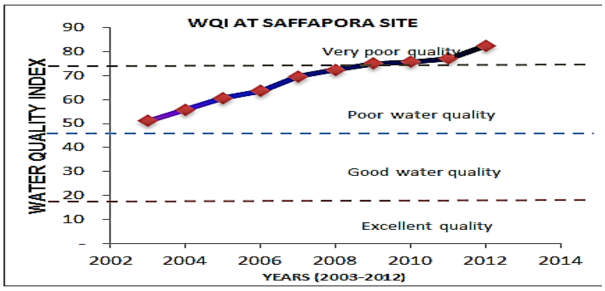


Fig. 2 (c)

Fig. 2(a) indicates the arithmetic water quality indices at site Sangam during years 2003 to 2012. According to water quality index, water quality at site Sangam is rated as good for 2003 and 2004 with water quality ratings as 42.2 and 45.72 respectively. These index values reveal that the status of the River Jhelum is suitable for human uses at sampling site namely Sangam, according to WHO guideline standards, since they are all in the range good class (26-50) throughout.

On the contrary, there is almost general progressive increase in WQI values for the same sampling site from year 2005 onwards. Thus, a general progressive increase in WQI values with time along Sangam site indicates an increase in pollution. According to the Water quality index as shown in Fig.2 (b) water quality at Ram Munshibagh is rated as good from years 2003 to 2005. But beyond 2006 onwards the quality of water is rated as poor to very poor and hence cannot be used for various human activities. Fig.2(c) shows water quality indices at site Saffapora for years 2003 to 2012. Water quality at Saffapora is rated as good for year 2003. But beyond 2004 onwards the quality of water is rated as poor to very poor and hence cannot be used for various human activities.In general, the results of Arithmetic water quality index at the above three sampling sites indicate that the values of most parameters are beyond the permissible. Conductivity in water is due to the presence of inorganic dissolved solids such as chloride, nitrate, sulphate (ions that carry negative charge), or sodium, magnesium, calcium (ions that carry a positive charge) etc. which is present in river Jhelum due to the sewages disposed from the houses constructed along its banks , houseboats and more than 85 dewatering stations (in Srinagar area) which collects sewage from the surrounding areas and disposes untreated sewage into the river Jhelum directly. Water is slightly alkaline having pH ranging from 6.1 to 8.7.Significant changes in pH is due to disposal of industrial wastes, drainages etc. In natural waters pH also changes diurnally and seasonally due to the variation in photosynthesis activity which increases pH due to consumption of CO_2 in the process. Increase in concentration of chloride in water is an index of pollution of animal origin. The most important source of chlorides in water is the discharge of domestic wastes, industries etc. Presence of bicarbonate ions causes alkalizing effect and increases pH.

Canadian Water Quality Index

The analysis of site Sangam has been conducted using CWQI software. According to results obtained by the software, it is observed that the overall quality of CCME WQI for River Jhelum at site Sangam falls under poor category throughout the years (from 2003 to 2012). The drinking water quality initially remained marginal from 2003 to 2010. The reason may be that the river is less affected by anthropogenic activities. The water quality is ranked poor for aquatic life with WQI scores ranging from 21 to 24 throughout the years from 2003 to 2012. Whereas, water quality is ranked as fair for irrigation purposes for years 2003 to 2012.Livestock is ranked as good throughout the years (2003-2012).Recreation is ranked as poor for Sangam site throughout, however this result should be questionable because of the lack of parameters as only one parameter (i.e. chloride) has been used to determine its water quality by CWQI 1.0 software. Overall quality of the site is poor. According to results obtained by the software, it is observed that the overall quality of CCME WQI for River Jhelum at site Ram Munshibagh falls under poor category throughout the years (from 2003 to 2012).Drinking quality is categorized as marginal for years 2003 to 2008 and poor for years 2009 to 2012 .Aquatic life and recreation are poor for years 2003 to 2012. Irrigation and livestock are ranked as fair and good throughout the years 2003 to 2012. In case of site Saffapora the overall quality falls under poor category throughout the years (from 2003 to 2012).Drinking remained marginal for year 2003 but beyond 2004 it is categorized as of poor quality. Aquatic life and recreation remained poor throughout for the years 2003 to 2012.Whereas, Irrigation and livestock has been ranked as fair and good for the years 2003 to 2012.

Year	Data Summary	WQI	Rating
2003	Overall	35	POOR
	Drinking	46	MARGINAL
	Aquatic	21	POOR
	Recreation	39	POOR
	Irrigation	65	FAIR
	Livestock	83	GOOD
2004	Overall	35	POOR
	Drinking	45	MARGINAL
	Aquatic	20	POOR
	Recreation	35	POOR
	Irrigation	67	FAIR
	Livestock	84	GOOD
2005	Overall	36	POOR
	Drinking	46	MARGINAL
	Aquatic	21	POOR
	Recreation	33	POOR
	Irrigation	68	FAIR
	Livestock	84	GOOD
2006	Overall	35	POOR
	Drinking	45	MARGINAL
	[illegible]	[illegible]	[illegible]
2007	Overall	36	POOR
	Drinking	45	MARGINAL
	Aquatic	21	POOR
	Recreation	33	POOR
	Irrigation	67	FAIR
	Livestock	83	GOOD
2008	Overall	38	POOR
	Drinking	45	MARGINAL
	Aquatic	30	POOR
	Recreation	17	POOR
	Irrigation	66	FAIR
	Livestoc	83	GOOD
2009	Overall	35	POOR
	Drinking	42	POOR
	Aquatic	21	POOR
	Recreation	29	POOR
	Irrigation	67	FAIR
	Livestock	82	GOOD
2010	Overall	36	POOR
	Drinking	44	POOR
	Aquatic	21	POOR
	Recreation	24	POOR
	Irrigation	68	FAIR
	Livestock	84	GOOD

Year	Data Summary	WQI	Rating
2003	Overall	36	POOR
	Drinking	45	MARGINAL
	Aquatic	22	POOR
	Recreation	35	POOR
	Irrigation	71	FAIR
	Livestock	87	GOOD
2004	Overall	36	POOR
	Drinking	44	POOR
	Aquatic	21	POOR
	Recreation	35	POOR
	Irrigation	66	FAIR
	Livestock	84	GOOD
2005	Overall	35	POOR
	Drinking	44	POOR
	Aquatic	21	POOR
	Recreation	35	POOR
	Irrigation	66	FAIR
2006	Overall	35	POOR
	Drinking	44	POOR
	Aquatic	21	POOR
	Recreation	35	POOR
	Irrigation	66	FAIR
	Livestock	84	GOOD
2007	Overall	35	POOR
	Drinking	44	POOR
	Aquatic	21	POOR
	Recreation	32	POOR
	Irrigation	65	FAIR
	Livestock	83	GOOD
2008	Overall	37	POOR
	Drinking	43	POOR
	Aquatic	29	POOR
	Recreation	15	POOR
	Irrigation	65	FAIR
	Livestock	81	GOOD
2009	Overall	35	POOR
	Drinking	41	POOR
	Aquatic	19	POOR
	Recreation	20	POOR
	Irrigation	67	FAIR
	Livestock	82	GOOD
2010	Overall	35	POOR
	Drinking	42	POOR
	Aquatic	18	POOR
	Recreation	17	POOR
	Irrigation	67	FAIR
	Livestock	83	GOOD
2011	Overall	35	POOR
	Drinking	42	POOR
	Aquatic	18	POOR
	Recreation	17	POOR
	Irrigation	67	FAIR
	Livestock	83	GOOD

Tables showing CWQI for three sites are shown in Table

Water Quality Monitoring Program
The following Recommendations will effectively enable us to have an efficient Water Quality MonitoringProgram:

Increasing concentration of households on the banks of the river should be checked on priority basis, as it will be very helpful in reducing the load of urban waste entering the river. Moreover, curbs should be provided to the solid waste from the various sources wherefrom it enters the river.
Low cost sanitation of households on both the banks should be provided on priority basis.
It is imperative to undertake remedial measures for prevention of pollution of river Jhelum by formulating schemes for environmental infrastructure works to intercept, divert and treat the domestic and industrial wastewater.
In Srinagar area there are around 85 dewatering stations which dispose off untreated sewage directly into the river Jehlum. These dewatering stations should be provided with some filter mechanism.
Sewage treatment plants should be constructed near the most polluted reaches of the river.

V. CONCLUSION

The Canadian Council of Ministries of the Environment (CCME) Water Quality Index (WQI) and Arithmetic Water Quality Index used for rating of water quality in River Jehlum indicate that the overall quality of water is poor [1]. It is almost always endangered or deteriorated. The condition in it usually deviate from normal levels and the water is not capable to protect or support ample aquatic life. . Aquatic life and recreation falls under poor quality throughout for the years 2003 to 2012.However, irrigation and livestock are ranked as fair and good respectively throughout for the years 2003 to 2012.
This study demonstrated that using CCME WQI is found to be more useful and informative as it helps in assessing the suitability of water for diverse uses, such as aquatic habitat, drinking, irrigation, recreation and

livestock. This information can be of great value for water users (public), water suppliers (municipalities and city councils), planners, policy makers, and scientists reporting on the state of the environment.

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