Development of Water Quality Index of River, Its Trend and Deterioration of WQI: A Review Paper

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Abstract- *An attempt has been made to develop water quality index (WQI), using various water quality parameters such as pH, Dissolved Oxygen, Biochemical Oxygen Demand, Chemical Oxygen Demand (COD), Electrical Conductivity, Total Coliform, Fecal Coliforms and other parameters measured at different stations along the river basin Rating scale is developed based on the tolerance limits of inland waters and health point of view. Weighted arithmetic water quality index method was used to find WQI along the stretch of the river basin. It was observed from this study that the impact of human activity and sewage disposal in the river was severe on most of the parameters. The station located in highly urban area showed the worst water quality followed by the station located in moderately urban area and lastly station located in a moderately rural area. It was observed that the main cause of deterioration in water quality was due to the high anthropogenic activities, illegal discharge of sewage and industrial effluent, lack of proper sanitation, unprotected river sites and urban runoff.*

***Key Words*: Water Quality Index (WQI), Arithmetic Mean, Rating Scale.**

1. INTRODUCTION

Water is the prime requirement for the existence of life and thus it has been man's endeavor for the time immemorial to utilize the available resources. The unbridled exploitation of water for irrigation, drinking and industrial purposes has caused a drastic decline of the quality and availability of water. The over-exploitation of limited resources has not only caused a perceptible decline in the water table, but also resulted in the enormous increase of pollutants concentration. The ever growing population exerts a great pressure on this resource. The never ending growth of population and ill-planned exploitation of the water resource created a situation, where the very survival of man has become endangered. The concern for protecting the quality and overuse of earth's natural resources has been increasing in recent years all over the world. The global awareness and concern for the environment have paved way for the installation of various policies to control and prevent environmental pollution. Implementation of these policies has resulted in development of various technologies, which will allow for the sustainable utilization of earth's resources. Thus preventing and controlling the overall degradation of the quantity and quality of these resources. Hence proper management of available water resources is essential for the survival of mankind. Interpretation of complex water quality data is difficult to understand and to communicate during decision making process. Assembling the various parameters of the water quality data into one single number leads an easy interpretation of data, thus providing an important tool for management and decision making purposes. The purpose of an index is to transform the large quantity of data into information that is easily understandable by the general public. Water quality index exhibits the overall water quality at a specific location and specific time based on several water quality parameters. WQI is a set of standards used to measure changes in water quality in a particular river reach over time and make comparisons from different reaches of a river. A WQI also allows for comparisons to be made between different rivers. This index allows for a general analysis of water quality on many levels that affect a stream's ability to host life and whether the overall quality of water bodies poses a potential threat to various uses of water.

2 CALCULATION OF WATER QUALITY INDEX

The most important factor in determining the WQI is the selection of water quality parameters. Influence of water quality parameters on pollution depends on the permissible levels as suggested by Indian Council of Medical Research (ICMR, 1975). Parameters having low permissible limits will be given high weightage as they are harmful to the quality of water to a great extent, on slight increase in value (ICMR, 1975). Thus we give high weightage to these factors. Parameters having higher permissible limits are less harmful and hence we give less weightage (Pande et al. 1986).

Here,

$$WQI = Wi \times Vr\ Wi$$
$$= K/Vi$$

where,
Wi = Unit weight of chemical factor ;
K = Constant of proportionality)
Vi = Permissible level (ICMR standards)
Wi proportional to 1/Vi K = 1/Σ1/Vi Σ1/Vi = 1/V (pH) + 1/V (TDS) + — — — — — — —n (parameters)
WQI =Wi x Vr Wi x Vr = Wi(pH) x Vr(pH) + Wi(TDS) x Vr(TDS) + — — — — — — — n (parameters)

3. Rating Scale-

The rating scale ranges from 0 to 100.
For better interpretation we can divide these ranges into different classes where,
Vr = 0, water is highly polluted.
Vr = 100, water is absolutely clean.
Medium values indicates intermediate pollution of water

4. WATER QUALITY INDEX

In order to calculate water quality index, following physico-chemical parameters of water have been selected. These factors are pH, TDS, Hardness, Chloride, Sulphate and Turbidity (Mc Nelly et.al., 1979; Fawell and Miller 1992).
The values of Vi, Wi and Vr are given in table 1 .WQI is basically a mathematical way of calculating a single value from multiple test results (Ashwani Kumar and Anisha Dua, 2009). Basic statistical analysis was carried out for each water quality parameter. The WQI results represent the level of water quality in a given water basin (Mariappan et al. 1998)

Table No 1: Water quality factors and assigned unit weights (Kosha A. Shah, Geeta S. Joshi 2015)

Sr. No	Parameters	Vi	Unit Weight
1	pH	< 7.5 – 8.5 >	0.530
2	TDS	< 500 mg/lit	0.008
3	Hardness	< 300 mg/lit	0.014
4	Chlorides	< 250 mg/lit	0.016
5	Sulphate	< 200 mg/lit	0.021
6	Turbidity	< 10 NTU	0.411

Table No 2: Rating for different factors to calculate Water Quality Index (Kosha A. Shah, Geeta S. Joshi 2015)

Parameter	Ranges				
pH	7 – 8.5	8.51 – 8.79 6.80 – 6.99	8.8 – 8.99 6.60 – 6. 79	9 – 9.19 6.39 – 6.59	> 9.2 < 6.4
TDS (mg/lit)	0 – 50	50.1 - 100	100.1 - 150	150. 1 – 500	> 500
Hardness (mg/lit)	0 – 50	50.1 - 100	100.1 - 150	150.1 – 300	> 300
Chlorides (mg/lit)	0 – 62. 5	62.6 – 125	125. 1 - 187.5	187.6 – 250	> 250
Sulphate (mg/lit)	0 – 50	50.1 - 100	100.1 - 150	150.1 – 200	> 200
Turbidity NTU	0 – 2. 5	2.6 - 5	5.1 – 7.5	7.6 - 10	> 10
Rating Vr	100	80	60	40	0

The concentrations ranges of these parameters in the given classes are defined with due consideration of Central Pollution Control Board (CPCB) of India standards/criteria and Indian Standards (IS) 10500. For parameters and classes not included in the CPCB standards, reference was made to the standards defined by other agencies.

pH Central Pollution Control Board (CPCB, ADSORBS/ 3/78–79), has given pH range 6.5–8.5 for classes A, B, D, and E. and 6–9 for class C. Considering the similar classification for pH for this study, pH ranges for classes 1–5 are allotted in increasing or decreasing geometric progression

Dissolved oxygen (DO) The maximum concentration of oxygen that can dissolve in water is the function of water temperature, and therefore may vary from place to place and time to time. In India average tropical temperature is 27 _C. The corresponding average DO saturation concentration reported is 8 mg/l (Metcalf and Eddy 1972).

Biochemical oxygen demand (BOD) Reference is taken from primary water quality criteria for various uses of fresh waters laid down by the Central Pollution Control Board (CPCB). The maximum value of BOD is given by CPCB as 3 mg/l for class B and C. European Community freshwater fish water quality standards indicate Guide Level and Maximum admissible Level of BOD as 3 and 6 mg/l, respectively, which indicate recreational use. The classes 1 and 2 are taken as per this standard in this study. The concentration ranges above this standard are assigned the classes 3, 4, 5 in this study as moderately Polluted, excess Polluted and severely Polluted for higher concentrations.

Total coliform WHO guideline specifies coliform action level in drinking water as absent/100 ml. Hence class 1 has been given a range of total coliform as 0–5 MPN/100 ml in this study. CPCB has classified the total coliform organism count 50, 500 MPN/100 mL, (maximum) in classes A, B, respectively, and the same has been retained in this study as classes 2 and 3, respectively. A count of 10,000 (MPN/ 100 mL) has been indicated as Maximum Admissible Level in European Community (EC) bathing water standards. This value is assigned to class 4 (500–10,000) in this study indicating excess Polluted water quality, making the criteria more stringent. Coliform count more than 10,000 obviously indicates severe pollution, and therefore it is considered in class 5 for this study.

Nitrate nitrogen In CPCB Standard concentration 20 and 50 mg/l are given for class A and C water. Hence a range is assigned to class 1 (0–20) indicating clean and class 2 (20–50) indicating slight pollution in this study. Nitrate nitrogen at or below 90 mg/l have no adverse effect on warm water fish (Train 1979). Therefore, concentration range of 100–200 and[200 mg/l are considered for class 4 and class 5 of water, respectively, for this study.

Electrical conductivity Since CPCB guidelines do not mention the concentration limits for class A, B, and C for the parameter EC, the reference is taken from IS Standards for drinking water and European community Standards. According to IS standards, the limits of EC are 300 micromhos/cm for drinking water; EC Specifies guide level of 400 micromhos/cm. Hence, value[300 micromhos/cm indicates severe pollution, and therefore, it is considered in class 5. Other classes are given in geometrical progression, as class 1, 2, 3, and 4.

5. WEIGHTAGE

The word 'weightage' implies the significance of each of the above mentioned physico-chemical parameters in overall quality of water which is dependent on the permissible levels of drinking water as suggested by Indian Council of Medical Research (ICMR, 1975). The following aspects are important in the determination of WQI. Factors having low permissible limits are harmful to the quality of water to a large extent even if there is only a slight increase (Iwata et.al., 1988). Thus we give high weightage to these factors. On the other hand factors which have higher permissible limits are less harmful and we give less weightage.

6. REVIEW OF Studies on WATER QUALITY INDEX PARAMETER

6.1 Subindex Method

Relevant studies on water quality index (WQI) and its modeling were reviewed. WQI is valuable and unique rating to depict the overall water quality status in a single term that is helpful for the selection of appropriate treatment technique to meet the concerned issues (Tyagi et al. 2013).Water quality indices are tools to determine conditions of water quality. Creating the WQI involves three main steps (US EPA 2009): (1) obtain measurements on individual water quality indicators (2) transform measurements into ''subindex'' values to represent them on a common scale (3) aggregate the individual subindex values into an overall WQI value. Various researchers have attempted to develop water quality index based on five types of WQI aggregation functions: (a) arithmetic aggregation function, (b) multiplicative aggregation function, (b) geometric mean, (c) harmonic mean, and (d) minimum operator.

6.2 Airthmatic Agression Function Method

Horton 1965 used the arithmetic aggregation function for the WQI. He selected 10 most commonly measured water quality variables for his index including dissolved oxygen (DO), pH, coliforms, specific conductance, alkalinity, and chloride. The arithmetic weighing of the water quality variables was multiplied with the temperature and ''obvious pollution'' to obtain the sum aggregation function from which the overall water quality index was found out. The index weight ranged from 1 to 4. Similar to Horton (1965), Brown et al. (1970) also employed basic arithmetic weighting, although without the multiplicative variables. This effort was supported by the National Sanitation Foundation (NSF) in which the water quality variables were chosen using the Delphi method (Dalkey 1968), which generates results from the convergence of expert's opinions. The NSF WQI used ogarithmic transforms to convert water quality variable results into subindex values.

6.3 Multiplicative Aggregation Function Method

Dinius (1987), developed a index based on multiplicative aggregation having decreasing scale, with values expressed as a percentage of perfect water quality corresponding to 100 %. Similar work was carried out by Helmer and Rescher 1959, Dalkey and Helmer 1963 by introducing changes to Delphi method (Dalkey 1968). Brown et al. (1972), Bhargava et al. (1998), Dwivedi et al. (1997), Landwehr and Deininger (1976) gave multiplicative form of the index where weights to individual parameters were assigned based on a subjective opinion based on the judgment and critical analysis of the author.Dee et al. (1973) proposed a system for evaluating the environmental impact of large scale water resources projects.

6.4 Geometric Mean Method

McClelland (1974) introduced the geometric mean form of weighting to the WQI. McClelland was concerned that the arithmetic mean lacked sensitivity to low value parameters, a characteristic later deemed ''eclipsing.'' McClelland instead proposed the weighted geometric mean. Later researchers (Landwehr and Deininger 1976; Walski and Parker 1974; Bhargava 1983; Dinius 1987) have also employed a weighted geometric mean for aggregation.

6.5 Harmonic Mean Method

Dojlido et al. 1994 used the harmonic mean to find the WQI. This mean does not use weights for the individual indicators. Dojlido et al. (1994) found that it was more sensitive to the most impaired indicator than the arithmetic or harmonic means, reducing eclipsing, while still accounting for the influence of other indicators (Walsh and Wheeler 2012). Other indices based on harmonic means are Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI) and British Columbia water quality index. The CCMEWQI compares observations to a benchmark instead of normalizing observed values to subjective rating curves, where the benchmark may be a water quality standard or site specific background concentration

(CCME 2001; Khan et al. 2003; Lumb et al. 2006).British Columbia water quality index was developed by the Canadian Ministry of Environment in 1995 as increasing index to evaluate water quality. This index is similar to CCMEWQI where water quality parameters are measured and their violation is determined by comparison with a predefined limit. It provides possibility to make a classification on the basis of all existing measurement parameters (Bharti and Katyal 2011).

6.6 Index Based Method

Smith et al. (1987a, b) developed an index based on minimum operator for four water uses i.e., contact as well as non-contact. It is a hybrid of the two common index types and is based on expert opinion as well as water quality standards. The selection of parameters for each water class, developing subindices, and assigning weightages were all done using Delphi. The minimum operator technique was used to obtain the final index score (Bharti and Katyal 2011)

7. WATER QUALITY INDEX MODEL

The Water Quality Index model developed in the present study consists of 5 steps:

1. Selection of parameters for measurement of water quality.
2. Development of a rating scale to obtain the rating (Vr).
3. Estimating the unit weight of each indicator parameter (Wi) by considering the weightage of each parameter.
4. Determining the subindex value (Wi * Vr).
5. Aggregating the subindices to obtain the overall WQI.

8. SELECTION OF PARAMETERS FOR MEASUREMENT OF WATER QUALITY

The evidence of high organic pollution is considered as a basis of selecting the water quality parameters viz. pH, DO, BOD, electrical conductivity (EC), nitrate nitrogen, total coliform as significant indicator parameters of surface water quality in the present study.

9. REVIEW STUDIES OF INFLUENCING PARAMETER ON WATER QUALITY INDEX

Effect of pH: The pH is a measure of the acidic or alkaline conditions of the water. When the water is used for drinking purpose, the pH level of the water has an important effect on all body chemistry, health and disease because human body consists of 50–60 % water. The pH level of our body fluid should be in the range 7–7.2. If pH is less than 5.3, assimilation of vitamins or minerals is not possible; hence, it should be above 6.4. If pH is greater than 8.5, causes the water taste bitter or soda-like taste. If the pH is greater than 11, causes eye irritation and exacerbation of skin disorder. pH in the range of 10–12.5 cause hair fibers to swell. pH in the range 3.5–4.5 affects the fish reproduction. (Avvanavar and Shrihari 2008; Leo and Dekkar 2000).

Effect of dissolved oxygen: The amount of DO present in surface waters depends on water temperature, turbulence, salinity, and altitude Natural waters in equilibrium with the atmosphere will contain DO concentrations ranging from about 5 to 14.5 mg O2 per liter. The DO concentration present in water reflects atmospheric dissolution, as well as autotrophic and heterotrophic processes that, respectively, produce and consume oxygen. DO is the factor that determines whether biological changes are brought by aerobic or anaerobic organisms. Thus, dissolved–oxygen measurement is vital for maintaining aerobic treatment. Processes intended to purify domestic and industrial wastewaters. A rapid fall in the DO indicates a high organic pollution in the river. The optimum value for good water quality is 4 to 6 mg/l of DO, which ensures healthy aquatic life in a water body (Sawyer et al. 1994; Leo and Dekkar 2000; Burden et al. 2002; De 2003). Effect of biological oxygen demand Biochemical oxygen demand (BOD) determines the strength in terms of oxygen required to stabilize domestic and industrial wastes. For the degradation of oxidizable organic matter to take place minimum of 2–7 mg/l of DO level is to be maintained at laboratory experimentation or should be available in the natural waters (De 2003).

Effect of total dissolved solids/electrical conductivity Total dissolved solids (TDS): is the amount of dissolved solids (i.e., salts) in the water. TDS can be measured indirectly by measuring the EC. The more dissolved salts in the water, the more electricity the water will conduct. EC is the ability of the water to conduct an electrical current. Conductivity is important because it directly affects the quality of the water used for drinking and irrigation. Waters with higher solids content have laxative and sometimes the reverse effect upon people whose bodies are not adjusted to them and cause the water to have an unpleasant mineral taste. TDS consists of oxygen-demanding wastes, disease-causing agents, which can cause immense harm to public health. The presence of synthetic organic chemicals (fuels, detergents, paints, solvents, etc) imparts objectionable and offensive tastes, odors and colors to fish and aquatic plants even when they are present in low concentrations (Sawyer et al. 1994; Leo and Dekkar 2000). Dissolved ions affect the pH of water, which in turn may influence the health of aquatic species.

Effect of nitrate nitrogen: Excess nitrate nitrogen can cause eutrophication of surface waters due to overstimulation of growth of aquatic plants and algae. It causes anaerobic conditions in the water bodies leading to fish kills, and can even ''kill'' a lake by depriving it of oxygen.High levels of Nitrate nitrogen can cause the respiration efficiency of fish and aquatic invertebrates to lower down, leading to a decrease in animal and plant diversity, and affects use of the water for fishing, swimming, and boating. High levels of Nitrate nitrogen in water can cause serious health hazards. The acute health hazard associated with drinking water with elevated levels of nitrate occurs when bacteria in the digestive system transform nitrate to nitrite. The nitrite reacts with iron in the hemoglobin of red blood cells to form methemoglobin, which lacks the oxygen carrying ability of hemoglobin. This creates the condition known as methemoglobinemia (sometimes referred to as ''blue baby syndrome''), in which blood lacks the ability to carry sufficient oxygen to the individual body cells. Infants under 1 year of age have the highest risk of developing methemoglobinemia from consuming water with elevated levels of nitrate.

10. SUMMARY/CONCLUSION

The WQI is defined as a rating, reflecting the composite influence of different water quality parameters on the overall quality of water. The main objective of computing of water quality index (WQI) is to turn the complex water quality data into information which is easily understandable and usable. The present paper is aimed to assess the environmental impacts on the river water quality and to check the level of pollution at the various stations. From the study of various investigations it is concluded that due to non-availability of the adequate land and full-fledged treatment facilities, large quantity of agricultural, municipal and industrial wastewater enters into river through various drains and nallahs which deteriorate the quality of river water. The 'coefficient of variation (CV %)'on water quality parameters revealed that the variation in most of the parameters is high and which do not fall within the desirable limit range. As per the water quality index study revealed that the water quality index (WQI) by using sub index method which gives current pollution status of the pollution and whether the water is used for portable purpose or not. Also based upon the pollution load the treatment method is employed for the wastewater enters in to a stream

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