Importance of Biological Parameters of Water Quality to Reform Water Quality Index in Practice

RAMANI BAI VARADHARAJAN
Department of Civil Engineering
University of Nottingham (M) Campus
Jalan Broga, 43500 Semenyih, Selangor
MALAYSIA.
Email:vramanibai@gmail.com www.globalclimate-engine.org

Abstract: - Good quality of water to drink or for meeting any demand is expensive these days. An economical and sustainable method of water treatment has not yet been achieved in our water history. Water specialists and water/water related companies are trying hard on technologies from macro to nano methods but end up with some limitations and some compromises. Studies have shown that microbiological pollutants are the significant contaminants for water-related diseases and researches have been carried out to assess the efficiency of water treatment plant to remove microbiological pollutants from the raw water. Globally the use of chlorine-based process for disinfection is the most successful and common in water treatment. Studies have shown that in Malaysia as well chlorination process is the best method to produce "microbiologically safe" water until water problem surfaced in year 2009. Total Coliform violations in the complied chlorine treated water posed problem within the water treatment plant located in Selangor. There is an urgent need to investigate on this problem as the systems continue to deteriorate in recent years. In view of this, properly planned and interdisciplinary studies are being conducted on the causes and sources of Total Coliform-positive occurrences in the water treatment systems. The current WQI to ascribe water quality are mostly physio-chemical based, without consideration for biological specifically microbial based indicators. The objective of the paper is to present the approach of redesigning WQI using neural network and fuzzy logic systems. The model could be packaged into software and further to construct hardware (Water analyser), a hand held unit to test the status of quality of water on- site, for every hour and any time scale. These methods have been successfully used in many fields of studies including water and water related research. Thus, the risk of choosing macro to nanotechnologies to treat the water could be made appropriate by this invention of new software and hardware.

Key-Words: - Water Quality, Water Quality Index, Microbiological Parameter, Neural Network, Fuzzy Logic Systems, Water Analyzer.

1 Introduction

Globally, awareness on water issues has been increased as it will be one of the most critical natural resources in the future. This is due to water scarcity and good quality of water to drink is expensive these days. Therefore, regular monitoring on the existing water resources and to devise ways to protect it becomes imperative. This is followed by the evaluation of water quality in respective countries has become a blooming critical research topic in the recent years. Water quality is a term used to describe the chemical, physical and biological characteristics of water. Observations of these characteristics are crucial to give an overall picture of the state of the water body. Water quality is an extensive and challenging research area due to the complexity in understanding the cause and source for the water issue problem. Reporting of water quality has been made easier in recent years by the development and availability of the Water Quality Index (WQI). Water Quality Index is one of the most effective arithmetic tool for a country to describe the health of water resources and create a baseline for measuring and assessing water quality [1]. The concept of WQI was developed and proposed first by Horton at the middle of the past century, the first researcher to suggest the advantages of calculating a WQI [2].

Since then, many studies over various countries concerning water indexes have been reported to assess the overall status of their water bodies, such as United States, United Kingdom, Canada, India and Egypt. The concept is similar, where a few essential parameters are selected and compounded into numerical rating for the evaluation of the water quality.

2 Problem Statement

Presently, the crucial factor that is a lack in most countries WQI is biological parameters. The current WQI to ascribe water quality are mostly physio-chemical based, without consideration for microbial based indicators. Assurance that the water is microbial safe for drinking has traditionally been determined by measuring bacterial indicators of water quality, most commonly Total Coliform. Microbiological contaminant became a primary concern in both developing and developed countries as it has the greatest health impact. Therefore, the microbiological contaminant has the highest priority in water quality monitoring [3]. According to the survey conducted by USEPA, more than 9,000 Total Coliform maximum contaminant level (MCL) occurred each year from 2000 through 2004 [4].

2.1 Studies on Water Quality Index (WQI) of few countries without biological parameter

Following are WQI of few countries whereby biological parameter has been omitted as one of the key parameter. The Water Quality Index (WQI) was calculated based on the Weighted Arithmetic Index method. The quality rating scale for each parameter qi was calculated by using this expression: qi = (Ci/Si)×100. A quality rating scale (qi) for each parameter is assigned by dividing its concentration (Ci) in each water sample by its respective standard (Si) and the result multiplied by 100. Relative weight (Wi) was calculated by a value inversely proportional to the recommended standard (Si) of the corresponding parameter: Wi = 1/Si. The overall Water Quality Index (WQI) was calculated by aggregating the quality rating (Qi) with unit weight (Wi) linearly: WQI = $\left(\sum_{I=1}^{i=n} Wiqi\right)$.

2.1.1 Iraq

In Iraq, WQI studies are in a preliminary stage or non-existent; therefore, a study was conducted on the status of Tigris River water quality which has been used as raw water for the Water Treatment Plant (WTPs) within Baghdad, the capital of Iraq. A set of thirteen water quality parameters has been selected based on both importance of the parameters and availability of data to calculate the Water Quality Index. The thirteen parameters are as followed: pH value, Alkalinity, Turbidity, Total Dissolved Solids, Hardness, Calcium, Magnesium, Chloride, Sulphate, Ammonia, Fluoride, Iron and Aluminum. Then, the overall WQI was calculated using the method proposed by Ott and Harkins on the basis of weighting and rating of the different physico-chemical parameters, as follows: WQI= $\left(\sum_{i=1}^{i=n} WiQi\right)$ where, W_i = unit weight for various parameters, Q_i = quality rating [5].

2.1.2 India

The Noyyal River flows from Vellingiri Hills in the Western Ghats in Tamil Nadu, southeastern India and falls into the Kaveri River. The quality of Noyyal River became the concern of public and private sectors as the effluent from the textile industry dispose into the Noyyal River.Water Quality Index (WQI) with the following parameters has been used to evaluate the quality of this river :- DO, TDS, COD, sulphate, temperature, pH, chloride, hardness, iron, fluoride, calcium, magnesium, phosphate, nitrate, nitrite, manganese and sodium. WQI is calculated from the point of view of the suitability of ground water for human consumption. Wi = $\frac{wi}{\sum_{i=1}^{n} Wi}$ where w_i is the relative weight of each parameter and n is the number of water quality parameters. qi = (Ci / Si) x 100 where q_i is the quality rating scale, C_i is the concentration of each parameter in each sample water in mg/l and S_i is the Indian drinking water standard for each chemical parameter in mg/l according to the guidelines of the IS 10500:1991. $SI_i = W_i \cdot q_i$. WQI = $\sum SI_i$ where SI_i is the subindex of i^{th} parameter; qi is the rating based on concentration of i^{th} parameter and n is the number of parameters.

2.1.3 Nigeria

River Landzu, which is located in Nigeria, has become one of importance in the study of surface water pollution. This is because effluents from cottage industries, municipal sewage, agricultural and urban run-off are discharged into it bringing about considerable change in the water quality. The water samples were then analyzed for 17 parameters as followed: pH, turbidity, refractive index, total hardness, total acidity, total dissolved solids, total solids, chloride, sulphates, phosphate, nitrate, dissolved oxygen, chemical oxygen demand, manganese and iron using standard procedures of

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analysis. In this study, the WQI for drinking purposes is considered and permissible WQI for the drinking water is taken as 100. Overall WQI = $\frac{\sum qiwi}{\sum wi}$ where q_i = quality rating, w_i= relative weight [6].

2.1.4 Malaysia

The severe river pollution in Malaysia, has been attracted concern of various local authorities, government agencies as well as the public. The WQI primarily used in Malaysia is an opinion-poll formula that has been formulated after a panel of an expert is consulted on the choice of parameters and the weight age to each parameter [8]. Six parameters were chosen and the six resulting values are then entered into an established formula to arrive at the WQI scores:
WQI = (0.22xSIDO) + (0.19xSIBOD) + (0.16xSICOD) + (0.15xSIAN) + (0.16xSISS) + (0.12xSIpH) (1)
(where SI = subindex)
100 is the highest possible score and denotes a pristine river and zero are the lowest. Calculations are performed, not on the parameters themselves but their sub-indices. The Best Fit Equations used for the estimation of the six sub-index values are shown in equation (1). This has be followed in developing WQI for Malaysia[13].

2.1.5 Mexico

Water has become the most critical natural resource in the state of Chihuahua in northern Mexico. Conchos river is one of the rivers located in Chihuahua, Mexico and the Luis L. Leon dam is the downstream water reservoir that captures the water from the Conchos River. A study was conducted to develop a WQI for the water in the Luis L. Leon dam. A total of 38 parameters were detected and analysed in this study; yet only 11 parameters were considered in calculating the WQI using the formula as followed:- WQI = $\frac{\sum WiPi}{\sum Pi}$ where Wi = specific weight within a range of 1-4 according to the impact of that parameter in water quality and Pi = analysis performed on each single parameter. 11 parameters are as followed; pH, electrical conductivity (EC), dissolved oxygen (DO), color, turbidity, ammonia nitrogen, fluorides, chlorides, sulfates, total solids (TS) and total phosphorous (TP) [9].

3 Problem Solution

The microbial parameter that are typically of greatest concern because of their immediate health risk has been left out by many researchers. Following are some studies on Water Quality Index for few countries that included microbiological parameter as one of the key parameter.

3.1 Studies on Water Quality Index (WQI) of few countries with biological parameter

3.1.1 United States

The National Sanitation Foundation (NSF) has developed WQI by conducting a survey on 35 water quality tests through 142 water quality scientists and asked them to justify which test should be included as significant parameters in an index (Mitchell and Stapp, 2000). Based on this analysis, nine water quality parameters are as followed: dissolved oxygen (DO), faecal coliform, pH, biochemical oxygen demand (BOD)(5-day), temperature change, total phosphate, nitrate, turbidity, total solids were selected to include in the index to developed comprehensive WQI. WQI = [0.17(DO)] + [0.16(FC)]+[0.11(pH)]+[0.11(BOD)]+[0.10(T)] +[0.10(PO_4P)]+[0.10(NO_3)]+[0.08(Turbidity)]+ [0.07(TS)] equation (2). Among these parameters, faecal coliform found to be significant indicators as these parameters hardly meet the United States water guideline requirements and repetitive correction measures need to be conducted to eliminate this problem. [10].

3.1.2 Europe

A new index called the Universal Water Quality Index (UWQI) was developed based on the European water quality standard. UWQI has advantages as it is based on the national standards of any particular country and not limited their application to within the country of origin. The UWQI was developed on the basis set by the Council of the European Communities (EC, 1991) and Turkish water pollution control regulation - WPCR' (*Official Gazette*, 1988). The selection of the parameters for this UWQI development is based on the assessment of about 45 water quality parameters. These include physical, chemical, microbiological variables and Faecal Coliform has been included as an indicator parameter of microbial contamination. UWQI = $\sum_{i=1}^{n} WiIi$ where Wi = weight for i^{th} parameter and Ii = sub-index for i^{th} parameter. Among these 42 parameters, based on expert opinions and international experiences, 12 water quality parameters were considered as the significant indicator parameters of UWQI. The 12 water quality parameters are as followed:- cadmium, cyanide, mercury, selenium, arsenic, fluoride, nitrate, dissolved oxygen, BOD, phosphorus, pH and total coliform [11].

3.1.2 Iran

In East Azerbaijan, Aji Chai River is found to be one of the important river [12]. Aji Chai river has been highly polluted as the industrial and residential centers are built in the plains. Therefore, this research was conducted to analyse and evaluate the quality of Aji Chai River using water quality index (WQI) [13]. Sampling for the physiochemical parameters including acidity, dissolved oxygen, water temperature, water turbidity, electric conductivity and required oxygen for biological purposes, the total dissolved substances, phosphate, nitrate and gastrointestinal coliforms have being measured for four seasons of the year in 2008. The quality index of each station was calculated by WQI Calculator as followed:- WQI = WiQi where Wi = Weight or factor's precedence degree from 0 to1 and Qi = parameter's quality from 0 to 100.

3.1.3 Canada

Saskatchewan Watershed Authority in Canada has organised Lake Stewardship Program to develop Lake Stewardship Water Quality Guide. One of the tool the Saskatchewan Watershed Authority uses is a Water Quality Index (WQI) that provides an assessment of overall water quality. The Lake Stewardship Program uses sixteen parameters in its Water Quality Index. The parameters used in the Water Quality Index are as followed:- Total phosphorus, Total Ammonia, NO_3-N, Mercury, Aluminium, Chromium, Arsenic, Chloride, Sodium, Sulphate, MCPA, 2'4-D, E.Coli Bacteria, Dissolved Oxygen, pH and Chlorophyll *a*. The objectives used in the Water Quality Index are based on Saskatchewan's Surface Water Quality Objectives, the Canadian Environmental Quality Guidelines and target values established by the Saskatchewan Watershed Authority [14].

3.1.4 Serbia

Research were conducted on Water Quality Index based on Gruza Reseivor. The basic idea of this research was to integrate a number of microbiological parameters followed by comparing and coordinating them with the already established and accepted WQI system. Fuzzy groups were used as a tool for estimation of water quality. The parameter to evaluate the water quality of an artificial lake for the Gruza Reseivor was formulated using the elements of fuzzy logic based on the microbiological analyses on the lake itself. Following are the five microbiological parameters were measured to estimate water quality of Gruza Reseivor: Total number of bacteria, number of heterotrophs, *Escherichia coli*, intensity of phosphate activity and concentration of chlorophyll a. On the basis, of the performed computations, the author has concluded as follow:- A criterion is formulated that gives a quantitative estimate of water quality in a simple way from five important microbiological parameters [15].

4 UNIQ2008 and Water Quality Analyser Design

The software UNIQ2008 as shown in Figure 1 is burnt to hardware to ease the testing process. The hardware is a hand held or an on-site kit to determine WQI and the systerm diagram is presented in Figure 2. The software is developed for determining WQI as stated in secion 2.1.4 for Malaysia.

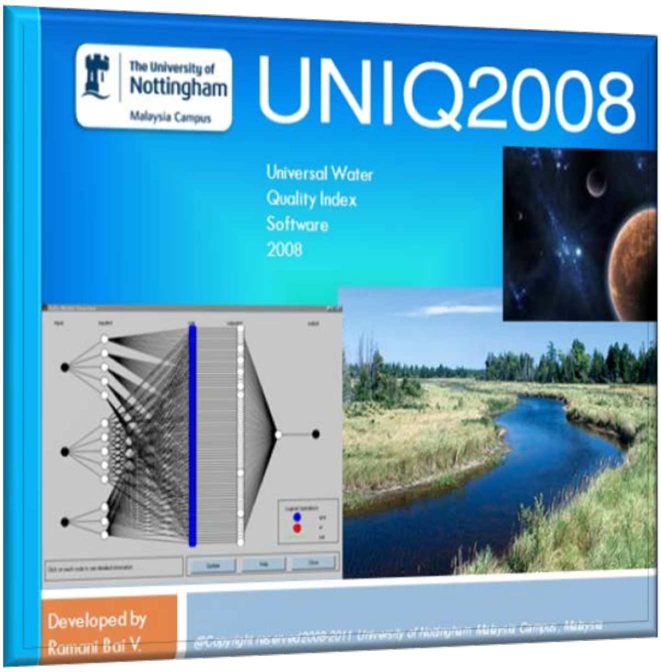

Figure 1 Universal Water Quality Index UNIQ2008- a Software to determine WQI

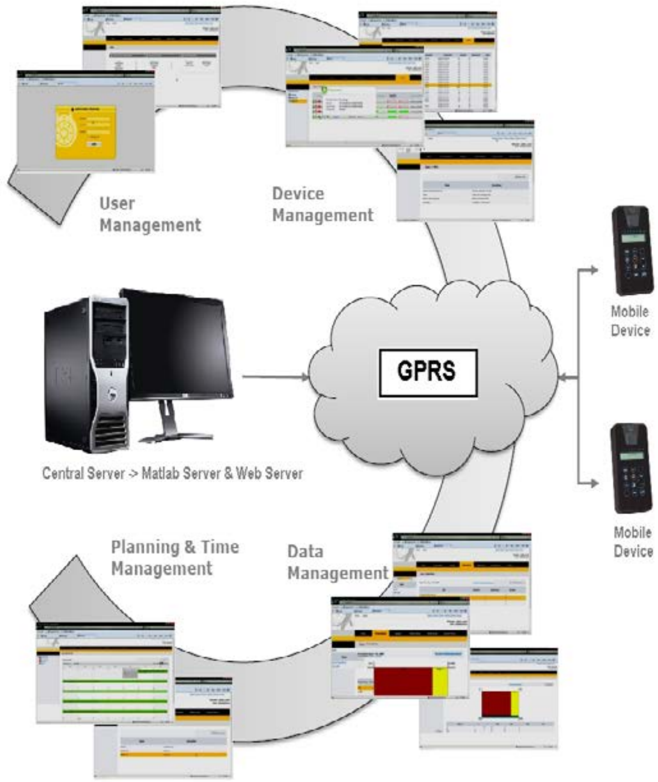

Figure 2 Water quality mobile monitoring & telemetry - System overview.

The Central Server serves as both the Web Server to communicate with the Mobile Devices as well as the Matlab Server, to compute the data receives from the Mobile Device. The Mobile Device functions as a data transmitter and receiver only. It does not contain any formula or algorithm in it. GPRS (general pocket radio service) network shall be the communication backbone for this system architecture. Reasons are for its network connection stability and cost-effectiveness. The operation is direct and straight forward. Input data is entered into the mobile device. The input data shall be fed back to the central server via GPRS for computation. The Matlab Server, which contains fuzzy model, which computes the input data received and provides the output data. The output data shall be transferred to the particular Mobile Device via GPRS.

With the system in place, the Web Server is equiped with four optional levels of Management Software:-

1. User Management – Security features with user id and login password in order to prevent unauthorized access to the data.
2. Device Management – To keep track of the status of the Mobile Devices.
3. Data Management – To record and safe the data collected from each Mobile Devices.
4. Planning & Time Management – For the second phase, whereby the mobile devices are installed along the river for automatic time-triggered data collection.

More details of software, hardware and the installation will be provided on demand by writing to the author for anyone interested in such developments.

5 Conclusion

Water quality index is good water quality tool, except for certain limitations. The main limitation identified are the index based on chemical and physical parameters only to evaluate its qualtiy status. The chosen parameters did not reflect all of the possible changes in water quality as biological parameter has been omitted from the Water Quality Index. Thus, further validation and detailed research of the index with biological parameter would be highly valuable. There is an urgent need for comprehensive biological monitoring of water quality at national and international level. A detailed approach and drastic efforts have been taken by countries such as the United States, Canada, Australia and member states of the European Union to amend their Water Quality Index by including different aspects of biological parameters of water quality. The current research of the author is also extending the current system to 8 or more parameter of water quality incluidng biological and its dependents. The United Nations Environment Programme / Global Environment Monitoring (UNEP/ GEMS) Water Programme recognizes the need for setting up a global database of biological monitoring data so that the water quality preservation efforts can be executed seamlessly.

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