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Development of Water Quality Index (WQI) for Gorganrood River

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ABSTRACT: There are several factors influencing the water quality based on its usage. The quality of drinking water is of the vital concern for human health and life. An essential attempt has to be done to develop a water quality index (WQI) corresponding with different conditions and characteristics of the relevant river or water body such as geographical, hydrological, discharge rate and pollution sources. The index is not specifically focused on human health or aquatic life regulations. However, a water index based on some very important parameters can determine a simple indicator of water quality. In the present study, the Gorganrood water quality has been evaluated by available NSF water quality index. Subsequently, the nine present NSF parameters' weights have been changed and modified using the analytical hierarchy process (AHP) method as well as experts' opinions in the field in a way to satisfy local conditions. In the newly developed WQI, more weights are given to relation with these parameters it can be said that the factors like dissolved oxygen (Do), fecal coliform (F.c) and biological oxygen demand (BOD) when compared with NSF-WQI.

Key words: Water quality index (WQI) , Analytical Hierarchy Process (AHP) , Team decision making , Expert choice software (EC)

INTRODUCTION

The access to "closer and cleaner drinking water" is still a distant dream for about one-sixth of humanity on this planet (Harvey *et al.,* 2002; Smedley and Kinniburgh, 2002). It is predicted that this increasing scarcity, and competition over water resources in the first quarter of the 21st century will dramatically change the way we value and use water (Mroczek , 2005; Maqbool *et al.,* 2011). The requirement of water in all forms of lives, from micro-organisms to man, is a serious problem today because many water resources have been reached to a point of crisis due to unplanned urbanization and industrialization (Singh *et al.,* 2002; Dixit and Tiwari , 2008). Water quality degradation through different sources as well as different monitoring methods have been widely considered in the literature (Ali *et al.,* 2004 ;Nakane and Haidary, 2010; Bhatnagar and Sangwan, 2009; Taseli, 2009; Najafpour *et al.,* 2008; Joarder *et al.,*2008; Rene and Saidutta, 2008; Monavari and Guieysse,2007; Jeong *et al.,* 2010). Surface waters are most exposable to pollution due to their easy accessibility for disposal of wastewaters (Samarghandi *et al.,* 2007). The consumption of different contaminants present in various industrial and agricultural sectors through biodegradation, or toxicity resistance to these pollutants by the microbial communities can provide information about pollutant exposure, metabolic diversity and the potential source of contamination and the potential for the ecosystem natural attenuation, thus may be a practical indicator of the water quality (Monavari and Guieysse , 2007). Both the anthropogenic influences such as urban, industrial and agricultural activities increasing exploitation of water resources as well as natural processes, such as precipitation inputs, erosion, weathering of crustal materials, degrade surface waters and damage their use for drinking, industrial, agricultural, reaction or other purposes (Jarvie *et al.,* 1998; Simeonov *et al.,* 2003; Mahvi *et al.,* 2005; Nouri *et al.,* 2008; Karbassi *et al.,* 2008). Rivers play a major role in assimilation or transporting the municipal and industrial wastewater discharge constitutes a constant polluting source, whereas surface run off is a seasonal phenomenon, largely affected by climate within the basin (Singh *et al.,* 2004; Karbassi *et al.,* 2007; Karbassi *et al.,* 2008; Najafpour, 2008). Due to increasing problem of deterioration of river water quality, it is necessary to monitor the water quality in order to evaluate the production capacity (Mishra *et al.,* 2009). Monitoring and Assessment of water has become environmental concern due to the contamination by mankind (Dixit and Tiwari, 2008). Over the past few years, a number of different tests have been developed to determine the organic content of wastewater (Sawyer *et al.,* 1994;

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Metcalf and Eddy, 1995; Rene and Saidutta , 2008). Water quality must be in the standard range for drinking uses. For this purpose the chemical, physical, microbiological and also superficial properties in water must have the standard value (Tabesh *et al.*, 2011). A water Quality Index (WQI) is a numeric expression used to evaluate the quality of a given water body and to be easily understood by managers (Adriano, 2006). In 1970 Brown *et al.,* used the Delphe technique to formulate a water quality index (WQI) for the National Sanitation Foundation (NSF) of the United States. Howevere, it has been observed that the procedure followed for the formulation of the index does not accurately represent the opinion of the experts who responded to questionnaries. For WQI formulation, the quality of the water in a specific river has to be investigated during the defenite period to determine the parameters' concentration and for any possible inclusion in an index. Finally nine factors were chosen and some were judged more important than the others, so a weighted mean was used to combine the values. In the case of weighting parameters for formulation; it is essential for the experts who want to give opinion about the amount of weights for each parameter, having informaton about the relevant basin (Gorganrood in this study) and being acquainted with the various specifications of the under study river. Different properties of basin, water application, discharge rate, present water quality, the pollution sources and finally the river hydrology cause dissimilar weights for each factor in drinking waters. This program requires skillful and knowledable experts to determine the weights based on their experiences and information.

Gorganrood basin is counted as a part of the Caspian sea. Many of ecologically significant rivers flowing into the Caspian Sea via its southern coast through the northern part of Iran (e.g. Haraz, Sefidrud, Chalus, Talar, Tadjan and Gorganrood rivers) are used as transport means for disposal of industrial, agricultural and urban wastes (Karbassi *et al.,* 2007). The main branch of this river with the length of 350 kilometers in the east-west extension ends to the Caspian sea. According to the regional classification of Emberger method, most of the study area has the semi-dry climate. Gorganrood has an area of 10200 square kilometers. An annual average discharge of this basin is about 920 million cubic meters. The amount of accessible water from surface and underground resources in the whole study area is about 4.10 million cubic meters per year. In general, river water quality is a function of land uses such as agriculture, urbanization and fish farms which in turn affects the receiving body (Taseli,2009). Gorganrood natural polluted sources include contaminations from geology constructions , mineral and geothermal springs and salty water resources. Human pollution sources are point sources like population effluent or industrial and manufacturing centers and also non-point sources such as agricultural pollution. The most important industrial factory, located in the Gorganrood area is the food producing firm which generates industrial sewages and causes wide range of effluents that discharge TSS and BOD in the water resources.

The objective of the present study is to develop a water quality index which is based on the characteristics and conditions of the Gorganrood basin in order to facilitate the managers' judgement and decisions makers about water quality.

MATERIALS & METHODS

The information and results of Gorganrood river project have been used in this section. This project was given to the Graduate Faculty of Environment, University of Tehran by the Department of Environment in the year 2008. In the mentioned project, 20 tations in the river course were selected for sampling. Samplings were done during 4 different seasons. In this paper only the result of one season (the Summer season) sampling is surveyed.

In general , Decisions involve many intangibles that need to be traded off. To do that, they have to be measured along side tangibles whose measurements must also be evaluated as to, how well, they serve the objectives of the decision maker. One thing is clear, numerical measurement must be interpreted for meaning and usefulness according to its priority to serve our values in a particular decision. It does not have the same priority for all problems. Its importance is relative. Therefore, we need to learn about how to derive relative priorities in decision making (Saaty , 2008).

The analytic hierarchy process (AHP) is a theory of measurement through pairwise comparisons and relies on the judgements of experts to derive priority scales. It is these scales that measure intangibles in relative terms. The comparisons are made using a scale of absolute judgements that represents, how much more, one element dominates another with respect to a given attribute. The judgements may be inconsistent, and how to measure inconsistency and improve the judgements, when possible to obtain better consistency is a concern of the AHP as the further strength of the AHP is its ability to detect inconsistent judgements . The derived priority scales are synthesised by multiplying them by the priority of their parent nodes and adding for all such nodes (Saaty , 2008).

The AHP methd has four basic principles which are ; reciprocal condition , homogeneity , dependency and expectation. Also has some privileges such as unity, complexity , interdependency , hierarchy structure , measurement , consistency , synthesis , tradeoff , judgment and consensus and repetition. The main advantage of the AHP is its ability to rank choices in the order of their effectiveness in meeting conflicting objectives. If the judgements made about the relative importance of , for example, the objectives of expense, operability, reliability and flexibility to satisfy the objectives, have been made in good faith, then the AHP calculations lead inexorably to the logical consequence of the judgements. It is quite hard , but not impossible to 'fiddle' the judgements to get some predetermined result . The essence of the AHP mathematics and it's calculation techniques is to construct a matrix expressing the relative values of a set of attributes. There should be a scale of numbers to make comparisons that indicates how many times more important or dominant one element is over another element with respect to the criterion or property with respect to which they are compared. One common scale which is adapted from Saaty is shown in Table 1 (Saaty, 2008).

The next step is the calculation of a list of the relative weights, importance, or value, of the factors, such as cost and operability, which are relevant to the problem in question (technically, this list is called an eigenvector). In addition AHP method is one of the group decision support system (GDSS) that can improve the reciprocative effect and participate people in a decision making program. The Analytic Hierarchy Process (AHPs) has been used in various settings to make decisions (Saaty, 2008).

The software used in this investigation is Expert Choice (EC) which is designed to analyze the multi criterion decision making problems by AHP technique. This software has many capabilities like priorities determination, final weights calculation, sensivity analyse and questions' designing. So a questionnair which contained 36 comparisons among every 2 parameters of the whole 9 NSF parameters was given to some selected skillful experts. After importing the experts' opinions, EC software calculates the nine parameters' final weights for each person. It is likelihood that some questionnair forms have an inconsistency factor more than the admissible limit. Inconsistency acceptable rate of a matrix or a system depends on the decision maker but Saaty submits 0.1 as admissible limit and believes that if inconsistency rate is more than 0.1, it will be better to revise in judgments (Ghodsipour, 2010). In this study inconsistency rate average at 0.15. Therefore questionnairs with inconsistency rate below 0.15 were considered in the group decision making.

RESULTS & DISCUSSION

Fig s 1 and 2 show EC's calculated weights. Results for the Gorganrood river WQI along with those derived from NSF WQI are shown in Table 2 and Fig. 3.

As it is apparent the above table describes the reclained water quality factors' weights for the Gorganrood river in comparison with the NSF WQI. Although they are to some extent looking alike, some changes are clear. In relation with these parameters it can be said that the factors like dissolved oxygen (Do), fecal coliform (F.c) and biological oxygen demand (BOD), have an increase in their weights. As an essential element for almost all aquatic life, the concentration of DO in a river provides a broad indication of its water quality (Taseli, 2009). Factors such as temperature change, total solids, nitrates, turbidity, total phosphate and pH, have respectively the most reduction in their weights' rate. As it can be seen the reduction priorities of the maney factors seem rational due to the importance of their role in water quality. Paying attention to the parameters that had increment, it can be concluded that these are as the same critical factors which influence undesirably on

Table 1. Rating Scale (Saaty, 2008)

Intensity of importance	Definition	Explanation
1	Equal importance	Two factors contribute equally to the objective
3	Somewhat more important	Experience and judgment slightly favour one over the other.
5	Much more important	Experience and judgment strongly favour one over the other.
7	Very much more important	Experience and judgment very strongly favour one over the other.Its importance is demonstrated in practice.
9	Absolutely more important	The evidence favouring one over the other is of the highest possible validity.
2,4,6,8	Intermediate values	When compromise is needed.

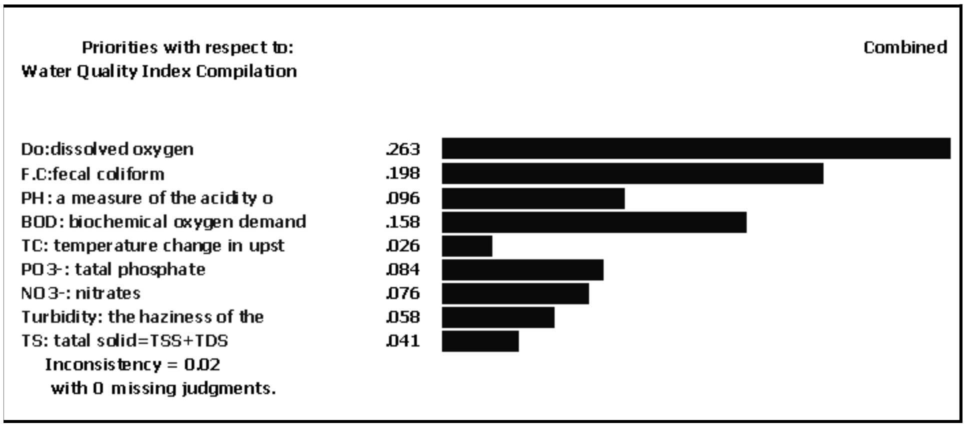

Fig. 1. Priorities derived from pairwise comparisons

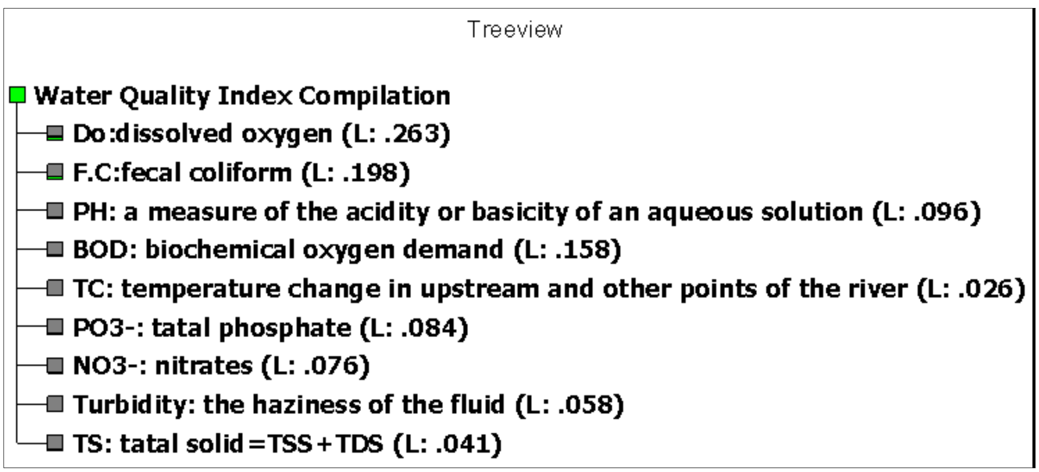

Fig. 2. The model view (tree view)

Table 2. NSF and Gorganrood WQI for the sampling stations in the Gorganrood River

Water Quality Factors	NSF Weights	Gorganrood Weights	Stations				
			Tamar	Ghalandar abad	Koorcli	Abpanir	Chinsibili
Do	0.17	0.263	7	3	7	3	8
F.c	0.16	0.198	22	22	22	22	29
pH	0.11	0.096	93	92	87	70	84
BOD	0.11	0.158	99	17	38	56	10
Temperature change	0.1	0.026	18	11	10	11	12
Total phosphate	0.1	0.084	96	24	33	2	96
Nitrates	0.1	0.076	97	95	96	94	3
Turbidity	0.08	0.058	81	74	72	69	52
Total solids	0.07	0.041	20	20	20	20	20
NSF WQI			77	45	59	41	57
Gorganrood WQI			53	32	37	34	30

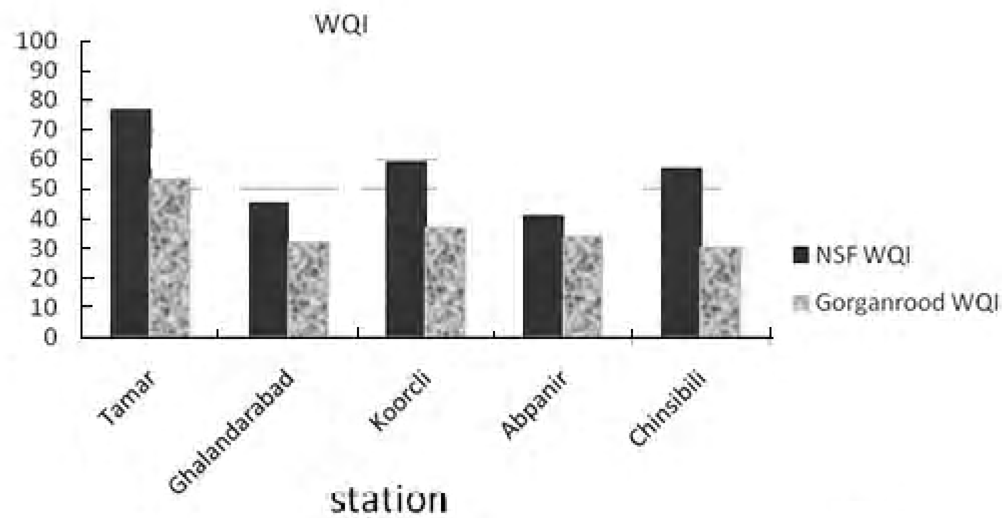

Fig. 3.Comparison of two NSF-WQI and Gorganrood WQI

the Gorganrood river water quality via the polluted resources. It should be emphasised that Gorganrood river receive manicipal sewage as well as food industries effluents. Therefore, higher concentrations of BOD originates from these two sources. The total number of coli form is also a major parameter for assessing possible sewage contamination in a water body. High bacterial levels can cause the closure of recreational facilities in the river, reduce its water quality, and cause sickness in wildlife using sea as a water source. Metabolic waste concentration reaches a high level in tanks thus producing pollution in a closed aquatic environment and they are considered to be a point source of pollution, affecting the receiving bodies (Taseli, 2009). So the weight of this parameter increased. Also it must be taken in to consideration that the results of this method excessively depends on the experts' views. It can be expressed that the NSF WQI results give a general view of water quality but if the research intends to study on the specific usage of water or any other qualitative problem, the discussed method application, will be valuable.

In this part the quality of water in the Summer is represented. Because of the dryness of this period, many stations were not been sampled. In the NSF WQI Water Quality assessment, 2 stations are in bad quality class and 2 stations are in the medium quality class and only one station is in the class with good quality. Referring to the new WQI obtained weights, one of the stations is in the medium class while the other ones' water qualities are bad.

CONCLUSION

The method used in this study is deserving for its merits. Because it provides managers with the capability that can have the better and more accurate judgements about the final weights of the parameters. Further more, the results are modified and corrected manipulately based on the comments and views of several experts familiar and well aware of the relevant water body conditions. Using the present method, one can consider all purposes and objectives defined in water quality projects by taking into account experts' opinions regarding the essential costs and economical, social and technical remarks. In this respect, the sensitivity of analyses can be changed and modified in relation to the spatial features. In other words, applying AHP method, confines the NSF utilization to a specific water quality project with the particular conditions.

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