Conference Paper

Developing a River Health Index: A Study in Ylang-Ylang River, Cavite, Philippines

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Abstract

This study explored the possibility of bridging the gap of inadequate assessment of rivers by considering the measurement of river health by developing a river health (RH) index. RH assessment is a crucial component of the strategy to protect, conserve and enhance the Philippine river systems. Through developing an integrative RH index, it can provide a systematic and standardized method of assessment which encompasses not only the physico-chemical aspects of rivers in terms of water quality but also their biological components. Participatory approach among experts was considered to come up with the weights and arrive with the scoring scheme for each identified indicators and sub-indicators of RH. Primary data from Ylang-Ylang River were gathered following standard sampling protocol and species identification. The study reveals that the current system of assessment of rivers in the Philippines focuses only on water quality and generally does not consider the assessment of biological indicators which are significant gauge of a river's ecological integrity – river health. The level of significance in indicating RH between physico-chemical and biological parameters is equally important based on experts' opinion.

The developed RH index is recommended to be utilized by several government agencies and private institutions to practice holistic river monitoring towards sustainability. The developed RH index can be applied to other rivers in the Philippines or even other countries. Improvement of this study may include the specification of the frequency of collecting the primary data and consideration of social aspects.

Keywords: river health, water quality, biological indicators, index

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1. Introduction

Approximately 36% of the Philippines' river systems are classified as sources of public water supply [1]. These water resources are considered the lifeblood of the economy of the country and considered the primary source of water for ecological and socio-economic development of the country [2], however, despite the vast ecological services the rivers provide to community, these are usually taken for granted and do not receive corresponding care. Their conditions are not assessed well. This reality is common to developing countries like the Philippines wherein rivers continue to degrade and proper assessment is inadequate to address this mounting problem. Lately, as river degradation becomes the primary problem faced by river ecosystem of all countries, more attention has been paid to river restoration and sustainable river management. The assessment of river health is the foundation of river management and monitoring. It is in this strategy that the timely prioritization of rivers in terms of conservation and protection can be fully realized.

The concept of "river health" is discussed both in simplicity and complexity. Comparing, it is easier to provide a response to the question "Is River X a healthy river?" than to respond to "What makes River X healthy?". With this, earlier studies, dating back to early 1990s, have attempted to determine and standardize factor/s that shall define River Health. Defining this concept, "river health" is an idea that incorporates both ecological principles and human values [3]. A healthy river has the capability to support and sustain a community of organisms, maintain its biodiversity, and continue to carry out key ecological processes that are as similar as possible to that of an unaltered river.

As far as the author knows, there are no existing guidelines and integrative indices to measure river health tailored for the Philippines and there are also gaps in performing river assessment in the country. The efforts of the Philippine Government through the Department of Environment and Natural Resources (DENR)-Environmental Management Bureau (EMB) focus only on water quality and water quantity. The establishment of Water Quality Management Areas (WQMA) by DENR-EMB includes consideration of water quality problems, potential sources of water pollution and measures to achieve improvement of water quality; however, the basis of this program fundamentally relies on water quality alone which is considered highly variable.

This study is a major step towards better and holistic assessment of rivers in the Philippines. Recognizing government efforts in monitoring water quality of water bodies throughout the country, river classification and establishment of WQMAs are being carried out, however, an integrative assessment of determining river condition is of utmost importance and very timely. The consideration of an integrative approach in assessing river health not only water quality as an indicator of river condition is a key pace towards better assessment of the country's rivers. Notably, no single variable can signify river's ecological condition explicitly but a set of complementary indicators is required to demonstrate a holistic definition of a healthy river.

As of 2009, the DENR-EMB has classified 632 principal and small rivers in terms of best usage and water quality. Of the 421 principal rivers, 283 or 67% of them have been classified. Principal river classification has been completed in three regions, namely, Regions 1, 7 and National Capital Region (NCR) [4].

2. Objectives of the Study

This study attempts to provide an integrative approach in assessing river health by developing river health index. The developed index is applied to Ylang-Ylang River in the Province of Cavite, Philippines by measuring not only the physico-chemical parameters but also the biological indicators of this river system. This study aims to identify the river health indicators and sub-indicators which can be used to measure health of rivers all over the Philippines or even outside the country. This study also aims to determine the level of importance / significance of the identified indicators relevant to the assessment of river health by assigning weights to indicators through a participatory and multi-sectoral approach.

3. Materials and Methods

The procedural activities involved in this study were divided into five (5) major steps: 1) Selection of river health (RH) indicators and sub-indicators based on review of related studies and research; 2) Assignment of weights to RH indicators based on experts' opinion using a questionnaire; 3) Assignment of scoring scheme for the selected RH sub-indicators; 4) Develop the RH index based on the assigned weights and scoring scheme of the RH sub-indicators; and 5) Apply the RH index to one of the rivers in the Philippines by gathering primary data through actual field surveys, sampling and analysis.

3.1. Sampling and analysis of water quality

Dissolved oxygen (DO) and temperature levels were measured in-situ using a pre-calibrated DO meter while the pH levels were measured in-situ using a portable pH meter. All meters were calibrated prior to the sampling activities to ensure validity and accuracy of the readings. Other parameters were tested from the water samples brought to the laboratory. Sampling and handling procedures were based on standard sampling techniques [5], [6]. Grab sampling of water samples was conducted by submerging the sampling containers against the flow/drift at a depth of 20 cm (whenever the depth of the stream permits). Samples were cool stored at about 4°C, as necessary, and brought to a DENR-accredited laboratory. Quality assurance and quality control procedures were observed.

3.2. Sampling of fish

Fish samples were collected at the sampling sites using a gill net and fish trap locally known as "bubo". The gill net ("*dala*") was utilized to trap pelagic fish and bubo was for fish that dwell at the bottom of the river. The collected specimens were documented for the identification and analysis. For waters that were too shallow, manual fish-catching and opportunistic sampling was employed.

3.3. Collection and analysis of algae

Algae were collected using plankton net, collecting at least one liter water sample from the designated study area. Duplicate samples were collected from each sampling station. One sample was preserved in a final concentration of 3% buffered formalin, while the other sample with Lugol's iodine solution. Preserved samples were decanted to at least 100ml after 24 hours and were brought to the laboratory for documentation and microanalysis. Specimens were observed and photographed using an electro photo microscope Olympus® CH20.

Using the algal genus pollution index of Palmer (1969) [7], the organic pollution level of the river was determined.

3.4. Scoring system

A participatory and multi-sectoral approach was conducted to reduce the possible biases inherent in any scoring scheme. The RH indicators were weighted by experts which included the following participants: water quality specialists, chemical engineers / chemists, biologists, environmental specialists / scientists, urban / environmental planners, sociologists, civil engineers, hydrologists, material engineer, wildlife biologists, geologists, forester, environmental researcher, GIS specialists, social development specialists, geodetic engineers, water supply engineers, sanitary engineer, project and quality managers and environmental researchers.

The weighted average determined the prioritization of indicator in terms of river health. A questionnaire was provided to the participants which asked them to weigh the RH indicators. The sum of the weights should sum up to 100%. This was finally used in the RH index that was developed.

3.5. River health sub-indicator scoring

Sub-indicators (i.e. water quality parameters, fish assemblage and algal community) were scored accordingly based on the degree of its determination towards river health.

Physico-chemical indicators were scored depending on their conformity to the threshold level set in the DENR Administrative Order (DAO) 2016-08 water criteria [8].

Biological indicators were scored based on the following: a) Fish were identified according to percent indigenousness. They were recorded as native / indigenous, native endemic, native but not endemic, exotic non invasive and exotic invasive. The proportion of recorded exotic invasive species versus the indigenous species will determine its score; and b) The algal community was scored based on the algal genus pollution index of Palmer (1969) [7].

4. Results and Discussion

The Physico-chemical (PC) Indicator is composed of ten Primary Water Quality Parameters indicated in Table 3 of the DENR Administrative Order (DAO) 2016-08, Water Quality Guidelines (WGS) and General Effluent Standards (GES) of 2016 [8]. The primary parameters are the required minimum water quality parameters that shall be monitored for each water body in the Philippines as specified in the mentioned DAO. The primary parameters include biochemical oxygen demand (BOD), chloride, color, dissolved oxygen (DO) fecal coliform, nitrate as NO_3-N, pH, phosphate, temperature and total suspended solids (TSS).

Classification of rivers and streams has been established by DENR-EMB. This classification of bodies of water is according to the degree of protection required. The guideline values for the Ten Primary Water Quality Parameters have been set for each classification which is the basis of the PC Indicator for this study.

4.1. PC indicator scoring scheme

The ten primary water quality indicators form the PC Indicator Sub-Index. Since these are the ten water quality parameters required by DENR-EMB to be measured as primary parameters, each parameter shall have equal weights. If all parameters measured from a river/ stream meets all the water quality guideline value set for its declared classification / assumed classification, then the river will get the highest score in terms of PC Indicator Score. If all parameters measured from a river/ stream failed to meet all the water quality guideline value set for its declared classification / assumed classification, then the river/stream will get the lowest score in terms of PC Indicator Score.

The PC Indicator Scoring Scheme is provided in Table 1.

Table 1: PC Indicator Scoring Scheme.

Number of Parameter/s Complied	PC Indicator Score	PC Indicator Sub-Index
10	5	Very good
7 to 9	4	Good
5 to 6	3	Moderate
3 to 4	2	Poor
0 to 2	1	Critical

In this scoring scheme, for instance, rivers which will meet 7 to 9 water quality parameters shall have a PC indicator score of 4 or a PC indicator sub-index of good, but this is not the overall rating of that particular river. Biological indicators shall be measured as well to come up with the overall RH rating.

4.2. Biological indicator sub-index

Two sub-indicators form the Biological Indicator. These are the Fish Assemblage (B_1) Indicator and Algal Community (B_2) Indicator. Based on judgement provided by 33 experts / practitioner of their fields, B_1 and B_2 have equal significance (50% each) in representing the Biological Indicator. This is primarily due to that experts believe that since fish species are located in the higher trophic level and are free-swimming, its existence / absence in a particular river can determine the health of such habitat.

High percent occurrence of native / indigenous fish species along a particular river is a positive determination of river's ecological integrity.

On the other hand, algae, a form of plankton, are considered base of the food chain. Determination of the type of assemblage of these algae can provide strong indication of organic pollution which is equally to that of the fish species.

The succeeding sections explain their scoring schemes.

4.3. Fish assemblage (B_1) scoring scheme

The Fish Assemblage (B_1) Indicator Scoring Scheme (Table 2) is primarily based on percent nativeness / indigenousness of fish species caught from the river/stream. The identification of the indigenousness of the fish species can be based on [9] – [10].

Table 2: Fish Assemblage (B_1) Scoring Scheme.

Percent Indigenousness	B_1 Indicator Score	B_1 Indicator Sub-Index
0.75 to 1.00	5	Very high
0.5 to 0.74	4	High
0.25 to 0.49	3	Moderate
0.15 to 0.24	2	Low
0.00 to 0.14	1	Very low

The higher the percent indigenousness of the total number of fish species caught, the higher the score. The lower the percent indigenousness is, the lower the score. The percent indigenousness can be computed by simply using the formula below:

$$\%\text{Indigenousness} = \frac{\text{Number of native or indigenous species}}{\text{Total number of fish species caught}}$$

For instance, there were five fish species caught from a particular river, but all of these species are considered introduced / exotic, the B_1 indicator shall be 1 or B_1 sub-index of very low.

4.4. Algal community (B_2) scoring scheme

The Algal Community (B_2) Indicator Scoring Scheme is based on the assemblage of algae found in the river/stream. The Palmer Algal Genus Pollution Index [7] was adopted for the B_2 Scoring Scheme. Following Palmer's Pollution Index, the algae are assigned a pollution index value of 1 to 6. When the microscopic analysis shows that these algae genera are present at a density of 50 or more individuals / cell in a one-ml sample, their index value will be recorded. Their values will be added. A score of 20 or more is considered to be a river/stream with high organic pollution.

The B_2 Indicator Scoring Scheme is provided in Table 3.

Table 3: Algal Community (B_2) Scoring Scheme.

Pollution Index	B_2 Indicator Score	B_2 Indicator Sub-Index
Less than or equal to 14	5	Very light organic pollution
15 to 20	3	Moderate organic pollution
More than 20	1	High organic pollution

4.5. River health (RH) indicator weighting

The RH Indicator weighting was developed by gathering the weights provided by 33 experts. The experts include environmental scientists, engineers (structural, civil, environmental, geodetic, chemical, sanitary, hydrologic, materials and water supply), geologists, environmental planners, socio-economist, social development specialists, GIS specialist, water quality specialists, project management officers, environmental assistants / researcher, hydrologists, foresters, and technical writer. The participants answered the questionnaire and generated the weights of the two RH indicators (PC and B).

Based on the weighting provided by experts, the percent significance of PC Indicator and B Indicator are 50% and 50%, respectively.

4.6. River health (RH) index

Table 4 presents the River Health Index which determines the status of the rivers / streams being investigated using integrative indicators.

Table 4: River Health (RH) Index.

River Health Score	River Health Index
5	Very Good
4	Good
3	Moderate
2	Poor
1	Critical

4.7. The study area

Ylang-Ylang River (YYR) (Figure 1) has a catchment area of approximately 1,334.85 hectares and is located at General Trias-Imus-Dasmariñas boundary. Based on the Inventory of Water Bodies from the website of DENR, the upper reach of Ylang-Ylang River is classified as Class B while the lower reach is Class C. Ylang-Ylang River has been designated as WQMA (included in the Imus-Ylang-Ylang-Rio Grande River System) by virtue of DENR Administrative Order No. 02 Series of 2013. Imus-Ylang-Ylang-Rio Grande River System is critically important in cleaning-up the Manila Bay.

The course of YYR was identified and the watershed where it belongs was also delineated based on National Mapping and Resource Information Authority (NAMRIA) maps and elevation maps generated from Interferometric Synthetic Aperture Radar (IFSAR). According to DENR – EMB Region 4A, Water Quality Monitoring Section, there are no clear basis or ruling of delineating the upstream from the midstream and downstream. It is logical that the upstream sections of a river are located on the rather higher elevation while the downstream portions are those located near the mouth of the river before it joins the sea. In the case of YYR, no significant variation in the elevations has been measured based on IFSAR. The more logical boundary identification among the three sections is to divide them into three equal parts from the headwaters down to the mouth of the river. This method of delineating the section boundaries, based on the interview and discussion with DENR-EMB is logical and acceptable.

Figure 1 presents the sampling stations along YYR.

4.8. Ylang-Ylang river health indicator scoring

4.8.1. Physico-chemical (PC) indicator

Table 5 presents the PC Indicator raw data collected along YYR and its corresponding score.

The upper reach of Ylang-Ylang River is classified as Class B while the lower reach is Class C. The technical description of the division between the upper and lower reaches was not specified hence, for this study, the water quality of upstream station, Station SW-YY-3 was compared to Class B while the midstream and the downstream stations, Stations SW-YY-2 and SW-YY-1, respectively were compared and assessed based on Class C water quality guidelines. Water bodies classified as Class B are intended for primary contact recreation such as bathing and swimming while Class C waters are

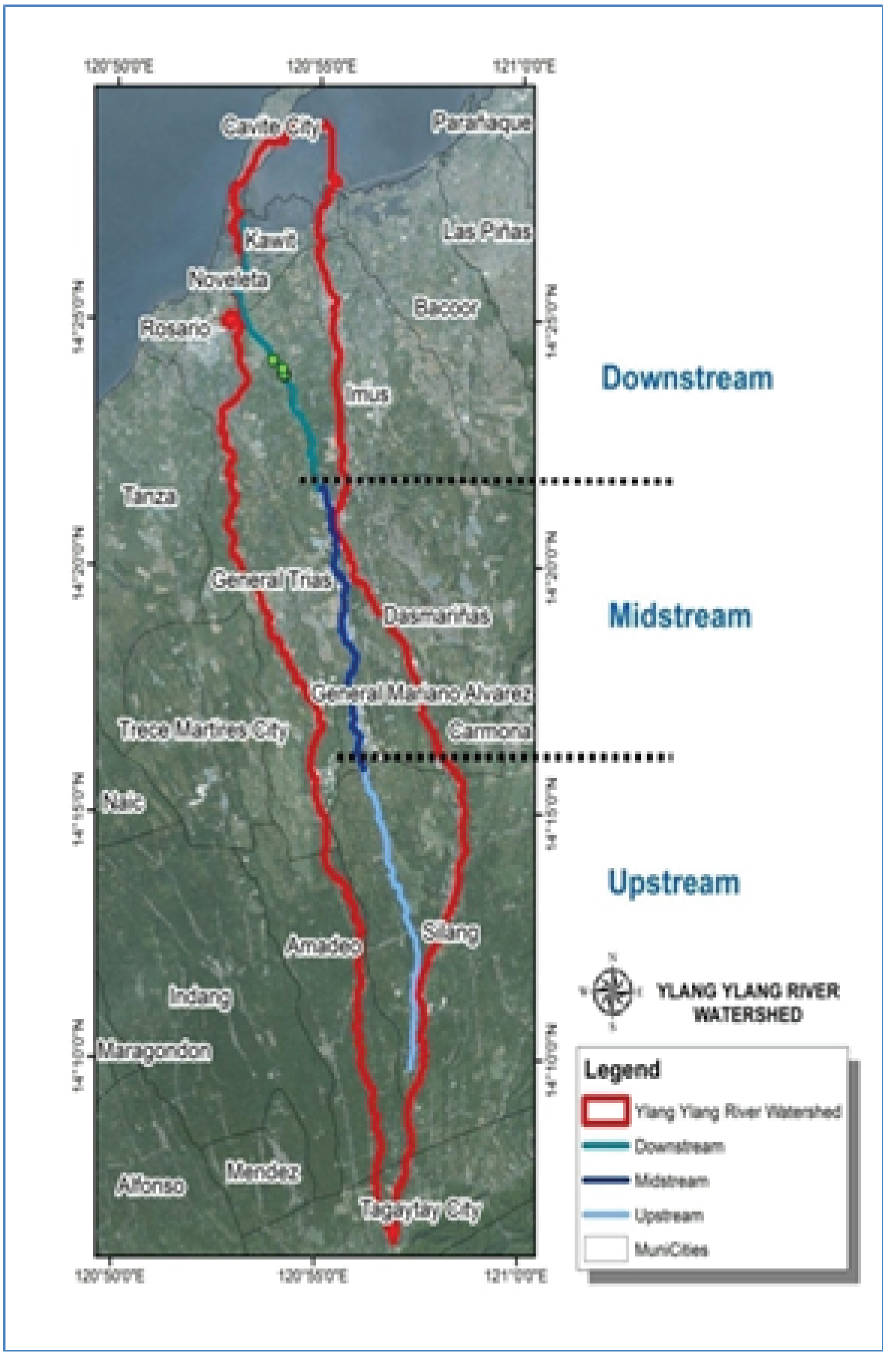

Figure 1: Ylang-Ylang River Sampling Stations.

intended for the propagation and growth of fish and other aquatic resources and as recreational water for boating, fishing, or similar activities as specified in the DAO 2016-08.

4.8.2. Biological indicator

Tables 6 and 7 present the B_1 and B_2 Sub-Indicator Assessments generated for YYR.

TABLE 5: YYR PC Indicator Data and Score and the Corresponding DAO 2016-08 Guideline Values.

Parameter	Station ID			Class B Waters	Class C Waters
	SW-YY-1	SW-YY-2	SW-YY-3		
BOD, mg/L	4.0	7.0	2.0	5	7.0
Chloride, mg/L	34.92	23.92	7	250	350
Color, PCU	30	25	20	50	150
DO, mg/L	5.61	4.4	5.5	Minimum of 5	Minimum of 5
Fecal coliform, MPN/100ml	220,000	54,000	160,000	100	200
Nitrate, mg/L	0.99	0.175	0.113	7	7
pH	7.8	7.5	7.7	6.5 to 8.5	6.5 to 9.0
Phosphate, mg/L	0.45	0.33	0.499	0.5	0.5
Temperature, °Celcius	31.7	30.5	25.7	25.0 to 30.0	25.0 to 31.0
TSS, mg/L	28	61	3	65	80
PC Raw Score	8	8	9		
PC Indicator Score	4	4	4		
PC Indicator Sub-Index	Good	Good	Good		

TABLE 6: YYR B_1 Sub-Indicator Assessment.

Name of Species Caught	Indigenousness	Indicator Index
Station SW-YY-1		Very low
Oreochromis niloticus niloticus	I/E	
Poecilia reticulata	I/E	
Poecilia sphenops	I/E	
Pterygoplichtys disjunctivus	I/E-Inv	
Sarotherodon melanotheron	I/E	
Trichopodus tricopterus	I/E	
Station SW-YY-2		Very low
Oreochromis niloticus niloticus	I/E	
Poecilia reticulata	I/E	
Pterygoplichtys sp.	I/Inv	
Station SW-YY-3		
Poecilia reticulata	I/E	Very low
Note: I –Introduced; E – Exotic; Inv - Invasive		

Table 7: YYR B_2 Sub- Indicator Assessment.

Algal Genus Found	Pollution Index
Station SW-YY-1	
Navicula	3
Gomphonema	1
Nitzschia	3
Closterium	1
TOTAL	8
B_2 Sub-Indicator Score	5
B_2 Indicator Sub-Index	Very light organic pollution
Station SW-YY-2	
Euglena	5
Navicula	3
Gomphonema	1
Nitzchia	3
Synedra	2
TOTAL	14
B_2 Sub-Indicator Score	5
B_2 Indicator Sub-Index	Very light organic pollution
Station SW-YY-3	
Euglena	5
Navicula	3
Gomphonema	1
Synedra	2
TOTAL	11
B_2 Sub-Indicator Score	5
B_2 Indicator Sub-Index	Very light organic pollution

4.8.3. YYR overall rating using RH index

Tables 8 to 10 present the Ylang-Ylang RH raw scores and the river health assessment using the developed RH Index

The RH assessment shall have a corresponding management implication measures to meet its objective. Table 11 below is proposed to be considered in the management of rivers in the Philippines.

Table 8: SW-YY-1 (Downstream) RH Score and Its Corresponding RH Assessment.

Indicators	Weight	RH Score
Physico-Chemical Indicator	50	2.0
Biological Indicator	50	1.5
Fish Assemblage (B_1) Sub-indicator (50%)	0.5	
Algal Community (B_2) Sub-indicator (50%)	2.5	
Total of B Indicator	3	
River Health		4.0*, Good
**River Health score is rounded off*		

Table 9: SW-YY-2 (Midstream) RH Score and Its Corresponding RH Assessment.

Indicators	Weight	RH Score
Physico-Chemical Indicator	50	2.0
Biological Indicator	50	1.5
Fish Assemblage (B_1) Sub-indicator (50%)	0.5	
Algal Community (B_2) Sub-indicator (50%)	2.5	
Total of B Indicator	3	
River Health		4.0*, Good
**River Health score is rounded off*		

Table 10: SW-YY-3 (Upstream) RH Score and Its Corresponding RH Assessment.

Indicators	Weight	RH Score
Physico-Chemical Indicator	50	2.0
Biological Indicator	50	1.5
Fish Assemblage (B_1) Sub-indicator (50%)	0.5	
Algal Community (B_2) Sub-indicator (50%)	2.5	
Total of B Indicator	3	
River Health		4.0*, Good
**River Health score is rounded off*		

5. Conclusion and Recommendation

Based on this study, the consulted experts are united that the physico-chemical indicators and biological indicators are equally important in assessing river health.

Table 11: Corresponding Management Measures of RH Index.

RH Index	Description of Possible Issue	Recommended Management Measures
Very Good (5)	Almost undisturbed river potentially located in the upstream portion or headwaters; Potentially located within protected areas.	Prioritize river protection by establishing policies against human disturbance; RH maintenance is considered low. Ecological assets shall be fully protected.
Good (4)	River is considered slightly to moderately disturbed; RH is at stake if succeeding RH assessment is getting low.	Ecological assets shall be fully protected although human disturbance is controlled. Set-up management measures to prevent further degradation; RH maintenance is low to moderate.
Moderate (3)	River is moderately to highly disturbed.	Not easy to balance human demands on water resources and river conservation. Improvement of RH shall consider budget, time and resource investment.
Poor (2)	River is severely disturbed. This could be a river in moderate health following a severe flood or dry season.	Immediate conservation measures shall be implemented to improve RH but much different from the river's original state. Resource investment is high to repair.
Critical (1)	River is entirely altered from natural state. This could be a river in poor health following a severe flood or dry season. This river may impact human health.	Consider intensive management cost and time to improve RH.

As shown by the river assessment conducted from the application of the developed index for Ylang-Ylang River, RH is the present state of the condition of the river. The developed RH index specifies clearly the translation of water quality parameters' conformity with existing local guidelines into simple diagnostic of river condition. Integrative indicators shall be considered to come up with a more reliable assessment of river in the country which may lead to appropriate implementation of programs for river improvement.

Corresponding management measures shall be clearly defined per RH index to allocate adequate resources such as budget, effort and time. Sustainability indices shall be considered to determine the predicted condition of the rivers in the future. This will allow better planning of river protection and conservation. Social aspect shall be considered in future researches.

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