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Eco-Heart Index as a tool for community-based water quality monitoring and assessment

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ABSTRACT

This study aimed to develop an economical, user-friendly, policy-relevant and impactful community-based water quality monitoring and assessment tool called Eco-Heart Index. Simple and economical water quality monitoring tools, such as Pact Test and LAQUAtwin, were used for Eco-Heart Index. The data was validated by comparing with those obtained using standard methods. Eco-Heart Index is a novel water quality indicator that draws a heart shape based on a result of 6 water quality parameters (pH, heavy metals, chemical oxygen demand, transparency, ammonia nitrogen and dissolved oxygen), which then indicates the water quality (*i.e.,* a full heart stands for clean water, while a broken heart stands for polluted water). This simplified tool was applied to the Langat River basin in Malaysia to generate a water quality map and to categorize the pollution trend based on the drawn figures. The water quality map showing the results of Eco-Heart Index clearly visualized the occurrence and distribution of the water pollution in the whole river basin. Specifically, a full heart shape appeared in upstream areas, whereas various broken heart shapes appeared in mid-stream and downstream areas, particularly in populated and land development areas. Eco-Heart Index was strongly correlated with the National Water Quality Index for Malaysia, suggesting that it could also be utilized as an alternative tool for water quality categorization. In conclusion, Eco-Heart Index has the great potential to be a community-based water quality indicator that could be understood through the universal symbol of peace and love.

1. Introduction

Many watersheds in the world have poor surface water quality that often negatively affects instream and near-stream ecologic integrity as well as water supply (Lee and Chung, 2007). Malaysia is no exception and water pollution is one of the most serious water resource management issues in the country. Water treatment plants have been frequently shut down in the capital region (*i.e.,* Klang Valley) due to high levels of ammonia, turbidity, phenolic compounds and smell (Santhi et al., 2012). High levels of *Escherichia coli* (*E. coli*) were detected in the surface water, particularly around populated areas in the capital region (Kondo et al., 2015). The main sources of the organic pollutants were suggested to be from domestic and industrial sewage as well as effluents from palm oil mills, rubber factories and animal husbandry (Juahir et al., 2011; Qadir et al., 2008). The surface water in the capital region is usually turbid and the turbidity exceeds 100 mg/L in most urban areas (Sakai et al., 2016). Mining operations, housing and road development, and logging and forest clearing were the major sources of suspended solids (Mohamed et al., 2015). According to the Department of Environment Malaysia (DOE), 36.6% of rivers in Malaysia were classified as slightly polluted, and 5.2% of rivers were classified as polluted (DOE, 2014). These facts mean that untreated municipal wastewater and the effluents from the extensive land development areas are directly discharged into rivers. The intermittent unsatisfactory discharges from combined sewer overflows might also worsen the situation (Rathnayake and Tanyimboh, 2015). The general public is highly aware of the water pollution since the issues are frequently reported in mainstream media, but they may think that it is not their concern or responsibility, or they may have no idea how to deal with the issues.

The DOE adopts the National Water Quality Index (WQI) for assessing surface water quality. The WQI consists of 6 parameters: pH, dissolved oxygen (DO), chemical oxygen demand (COD), biochemical oxygen demand (BOD), total suspended solids (TSS) and ammonia

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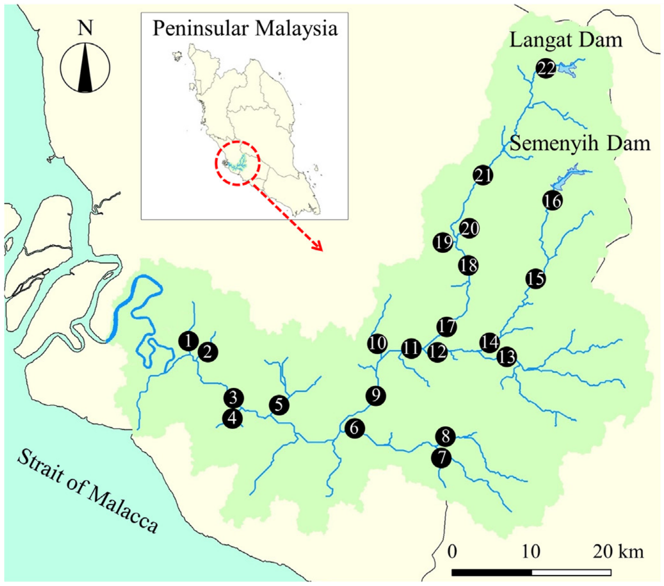

Site	Longitude	Latitude
S1	101’28”31E	2’53”34N
S2	101’29”22E	2’53”15N
S3	101’30”39E	2’48”56N
S4	101’30”29E	2’48”40N
S5	101’33”46E	2’49”34N
S6	101’41”27E	2’48”18N
S7	101’44”57E	2’46”49N
S8	101’45”05E	2’47”14N
S9	101’40”52E	2’51”20N
S10	101’41”03E	2’53”40N
S11	101’43”35E	2’53”49N
S12	101’44”57E	2’53”30N
S13	101’49”44E	2’53”17N
S14	101’48”32E	2’54”13N
S15	101’50”57E	2’57”31N
S16	101’52”17E	3’02”47N
S17	101’45”31E	2’55”06N
S18	101’47”05E	2’59”36N
S19	101’46”03E	3’00”54N
S20	101’46”28E	3’01”25N
S21	101’47”57E	3’05”41N
S22	101’53”01E	3’12”55N

Fig. 1. Watershed boundary of the Langat River basin and sampling sites. *2-column fitting image.

nitrogen (NH_3-N), and its value ($0 \leq WQI \leq 100$) is calculated by a single formula based on the subindex values of each parameter (DOE, 2014). The water quality in more than 470 rivers all over the country is regularly monitored by the DOE, and the results of WQI are annually published in the Malaysian Environment Quality Report (DOE, 2014).

The WQI provides the simplified results for local authorities and communities to acknowledge the overall river health of their interest, but this indicator has some disadvantages from the viewpoint of community engagement and participation. Firstly, the water quality monitoring is conducted by standard methods (Sidek et al., 2016), so only limited facilities and people can analyze all the parameters. Secondly, the 6 parameters are integrated into the WQI value (0–100) based on a specific formula and the annual reports only show the integrated value with a categorized pollution level (clean, slightly polluted or polluted) (DOE, 2014), which means that the water quality cannot be inferred from the WQI value because each parameter is masked by the integrated results. Thirdly, the numerical results of the WQI appears to not be attractive to local communities, particularly those who are not familiar with the index as well as those who are not interested in environmental conservation. Therefore, it is necessary to develop a community-based water quality monitoring and assessment tool that can be easily handled, can complement the comprehension of the WQI and can attract and inspire the heart of community so that local authorities and/or communities will be able to spontaneously monitor and assess the water quality at a local scale.

This study developed a novel community-based water quality monitoring and assessment tool called Eco-Heart Index that can depict the water quality by drawing a heart shape, which is a universally recognized symbol of peace and love (Hoystad, 2009). For instance, a full heart shape stands for clean water, while a broken heart shape stands for polluted water. The idea of using the heart shape was motivated by our theoretical and empirical work on the ‘Heartware’ approach in integrated watershed management (IWM) in Malaysia. The heartware is defined as the subjective, nebulous and humanistic dimension of the IWM that taps into the collective willingness of different stakeholders to continuously collaborate in solving complex problems for the attainment of a more sustainable IWM (Mohamad et al., 2015). The purpose of the heartware is to foster a foundation for continuous social learning and collaboration through the inclusion and acknowledgement of stakeholders’ values and perceptions, to promote meaningful dialogue and constructive exchanges, and to develop a mutually-accepted and well-informed course of action. It will lead to reducing conflicts as well as to increasing trust among stakeholders as they move to the next cycle of decision making. A good heartware foundation will begin an upwardly spiraling process toward effective and mutually acceptable solutions that are more politically sustainable in the long run (Mohamad et al., 2015).

In the present study, Eco-Heart Index was used to monitor and assess the surface water collected in the Langat River basin, which is located at the southern part of the capital region in Malaysia. The water quality results from using community-based monitoring kits were validated by those obtained using standard methods. A numerical evaluation of Eco-Heart Index was compared with the WQI in order to see whether the results were comparable. A water quality map in the Langat River basin was generated using the results of Eco-Heart Index, and the pollution trend in the whole river basin was spatially assessed accordingly. The drawn figures of Eco-Heart Index were categorized by the similarity of their appearances, and each category was associated with potential pollution sources based on land use in the catchment areas. Thus, this study aimed to develop Eco-Heart Index as a community-based water quality indicator to achieve a breakthrough in community engagement.

2. Materials and methods

2.1. Field experiment

2.1.1. Sampling sites and surface water collection

The locations of 22 sampling sites in the Langat River basin are shown in Fig. 1. A geographic information system (ArcGIS version 10.0, ESRI Inc., USA) was used to visualize the watershed boundary of the Langat River basin based on the digital elevation data (3sec GRID: Conditioned DEM in HydroSHEDS) that was downloaded from the United States Digital Service[1]. This data source is derived from the elevation data of the Shuttle Radar Topography Mission (SRTM) at a 3 arc-second resolution, and the original SRTM data have been hydrologically conditioned using a sequence of automated procedures. The selection of the sampling sites was based on the main stream (*i.e.,* the Langat River) and major tributaries visualized by GIS which substantially cover the entire river basin (Fig. 1). The sampling was conducted on 13th March, 2014, when the study area was in the inter

[1] Accessible at http://hydrosheds.cr.usgs.gov/dataavail.php1.