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Integrating biological aspects into river water quality research in Malaysia - an opinion

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ABSTRACT

Assessment on rivers and streams water quality should incorporate aspects of chemical, physical, and biological. The objective of this paper was to review the current primary concerned aspects and practiced method in river water quality research in Malaysia. The present day, method of determining river water quality in Malaysia is based mainly on physical and chemical parameters. Concentration on chemical and physical parameters is particularly surprising in judging natural waters where the main aim is often preservation of biological amenities. Numerous studies have indicated biological method has many advantages over chemical and physical method, such as; cheaper, easier, less time consuming, reliable, and can give indications of water quality for a long period of time. We do not advocate to abandoning physical and chemical assessments; rather, we note the inadequacy of the assessments to give complete information on river water quality. Therefore, Malaysia should start to anticipate and integrate the biological aspects into water quality studies and extensively make use of them to improve water quality monitoring in Malaysia. Successfulness on this will enhance water quality monitoring and management in Malaysia.

Introduction

Water quality research had gone more than 100 years and covers physical, chemical, and biological aspects of water quality. All these aspects had profound impacts on aesthetical and usability to consumers, they are linked and inseparable to ensure water quality kept at utmost (Viswanathan et al., 2010; Meybeck et al., 1996). Rivers and streams are very important natural's environment and linked to human lives, animals, and vegetations (Wu et al., 2010; Haase and Blodgett, 2009; Ghani, 2006).

Nowadays, the numbers of unpolluted streams are decreasing rapidly, parallel to rapid development process by man's (Niemczynowicz, 1999). Perhaps, that is the main reason why it's being considered by Malaysian professional as the main ecological problem in Malaysia when (Silverman and Silverman, 2000) conduct their survey back then. Description of development impact on natural environment in Malaysia has been discussed since 1970th by (Aiken and Moss, 1976), although their studies are based on case studies on different areal scale in Penisular Malaysia, their arguments are supported by strong fact. Former Director-general of Department of Irrigation and Drainage in Malaysia (Jabatan Pengairan dan Saliran Malaysia) also known as JPS or DID, Dato' Paduka Ir. Hj. Keizrul bin Abdullah in his speaking at the East Asia Regional Seminar on River Restoration in Kuala Lumpur in 2003 says, "we have exploited our rivers beyond sustainable level, and in many places, what is left is degraded river system. Rivers become polluted and devoid of aquatic life as it gets silted up and cannot perform its function as a drainage channel" (Star, 2003). A recent study by (Arsad, 2009) found, most of the rivers and streams in the city in Malaysia still possess water pollution related problem, and it has been identified to be caused by alteration on the physical properties of the rivers. Couple with the loss of riparian areas and land use practice along the rivers corridors, the effects are much greater than we could expect (DID, 2009).

Development related activities such as industrialization (Leung and Sell, 1982; Mangarillo et al., 2005), agricultural activities (Shamsudin, 1999; Vemula et al., 2004; Willardson, 1985; Espinosa-Villegas et al., 2005; Johns and Watkins, 1989), urbanization (Metsäranta et al., 2005; He et al., 2007; Gilbert, 2010; Weber et al., 2004) and channelization are well known to introduce stress to rivers and streams in the watershed. These development activities lead to nutrient enrichment to the rivers and streams with runoff related pollutants (Yusop et al., 2005) such as pesticides, toxic element (e.g. arsenic and chromium) (Abdullah and Nainggolan, 1991; Salim et al., 2009) and fertilizer (Dukes and Evans, 2006; Nazahiyah et al., 2007) as well as discharged effluent from wastewater treatment plants (Lung, 1986; Fulazzaky et al., 2010) and discharged of untreated wastewater or sullage from residential areas (Mamun et al., 2009; Lee et al., 2008). Chen et al. (2004), Arsdale et al. (2003) and Barbour et al. (1996) stated, development activities could cause reduction on biological functionality especially to the

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aquatic ecosystem and ecological values of the rivers compared to time when it's still in pristine condition. Coupled with bad antisocial habit such as wastes littering, the effects on rivers water quality are known to be negatives (Jennings et al., 2009; Arsad, 2009). Appropriate management and monitoring technique is then required to control and further offset the negative effects (Bowen, 1998; Deutschman and Leach, 1998; DID, 2009).

Rivers are generally heavily exposed to loads of polluting substances that can come from point sources (sewers, effluents from wastewater treatment plants) (Petersen et al., 2005) diffuse discharge sources (surface water runoff) (Mcleod et al., 2006; Petersen et al., 2005; Earles et al., 2008; Gurr and Nnadi, 2009; Lefkowitz et al., 2009). In order to evaluate the quality of running waters, chemicals and physicals (physicochemical) parameters such as *biological oxygen demand*, *chemical oxygen demand*, *organics and nitrogenous substance*, *suspended solids*, *alkalinity*, *temperature*, *electrical conductivity*, and *dissolved oxygen* are then assessed and evaluated. However, physicochemical analyses cannot yield enough information on the whole health of the river ecosystem (Viswanathan et al., 2010). In some case, chemical analyses may not detect the presence of a given contaminant due to the dilution phenomenon hence, integration of bioindicator is necessary to complete the information (Conti, 2008).

It is a concern in this paper to discuss more on biological aspect of water quality. In this context, aquatic biological communities (benthic macroinvertebrates, water plants, and fish) are the objects of safeguard actions and at the same time they are the markers for the health of water bodies. Although there are numbers of aquatic bioindicator, focus of this paper is primarily on the use of benthic macroinvertebrates as bioindicator for rivers and streams water quality monitoring.

The review reported in this paper was carried out to:

- Review the current practiced method of determining river water quality in Malaysia.
- Discuss the use of biological methods for assessing the river water quality.
- Suggest future direction for integrating biological aspect and implementing biological methods into river water quality studies in Malaysia.

Biological methods for assessing stream water quality have many attractions. For example, biological community can integrate many different environmental factors over a long time period, hence able to demonstrate environmental changes of the surrounding area (Wu et al., 2010; Hathaway and Hunt, 2010; Karr and Chu, 1999; Strobl and Robillard, 2008), and because biological community demonstrate ecological integrity as a whole (chemical, physical and biological) (Viswanathan et al., 2010), direct evaluation on the quality of the water bodies is possible (Boonsoong et al., 2009; DID, 2009).

Unfortunately, biological aspect in water quality often received little consideration in water resources research relative to physical and chemical aspects (James and Evison, 1979; Karr, 1991), where most national standards for assessment of water quality only include physical and chemical indicators relevant to specific pollutants and stressors (Boonsoong et al., 2009). This had also being a trend in Malaysia where most water quality related research and studies are focusing on physical and chemical parameters only e.g. (Ghani et al., 2009; Abdullah and Nainggolan, 1991; Lee et al., 2006; Latiff et al., 2009; Nazahiyah et al., 2007; Salim et al., 2009; Yunus and Nakagoshi, 2004; Deris, 2009; Suratman et al., 2009; Sarmani, 1989; Yusof et al., 1999; Yusop et al., 2005; Fulazzaky et al., 2010) with largely neglecting the biological parameters.

In selecting the appropriate bioindicator for freshwater quality monitoring, more knowledge is needed about the identification of species, how biological diversity is distributed, and what are the trends observed on short-term to long-term biodiversity changes. In many tropical countries (including Malaysia), there are lakes and rivers lacking even the most basic research on fauna and flora (Lévêque, 1998). Yule and Sen (2004) stated, the freshwater fauna of tropical regions is poorly known yet the tropics hold a large share of the world's freshwater resources and some extreme and unusual habitats. This should be taken as opportunity for scientist and biologist in Malaysia to explore and commence extensive research to study the surrounding environment ecosystem in Malaysia broadly for better understanding on the science behind bioindicator that could be used in Malaysia. Undoubtedly, successfulness in doing this will further hone our knowledge and understanding on bioindicator especially on benthic macroinvertebrates in Malaysia.

In late 1970, studies by (Sladécék, 1979) reveal, every aquatic organism can serve as indicator. The important part is, we must first know its environmental requirement, and then we are able to assess the water quality according to its presence, and in some cases, even according to its absence (Sommaggio, 1999). The benthic invertebrate community of streams in Malaysia regions may contain a variety of biota, including bacteria, protists, rotifers, bryozoans, worms, crustaceans, aquatic insect larvae, mussels, clams, crayfish, and other forms of invertebrates (Yule and Sen, 2004). Aquatic invertebrates are found in or on a multitude of microhabitats in streams including plants, woody debris, rocks, interstitial spaces of hard substrates, and soft substrates (gravel, sand, and muck). An invertebrate habitat exists, at all vertical strata including the water surface, the water column, the bottom surface, and deep within the hyporheic zone. The findings by (Sladécék, 1979) should open up the mind of scientists and researchers in Malaysia, hence start to put their intention on biological method in water quality research instead of traditional psychochemical based method.

Where studies on biological method in water quality research in Malaysia are still very limited, there has one study that should get prime attention. A study by (Salmah et al., 2006) reveals, odonate (dragonflies) larval communities are able to indicate the water quality of it habitats. The study was done in three small rivers in Penang, northern part of Malaysia. From the study, they found the distribution of dragonflies are higher in area with good water quality (high dissolved oxygen, low biological oxygen demand, low conductivity, and low turbidity) compared to area with bad water quality (low dissolved oxygen, high biological oxygen demand, high conductivity, and high turbidity). This relatively simple indication for water quality is a promising finding on the ability and validity of the biological method to be integrated into river water quality monitoring in Malaysia. With further research and widely use, biological method could soon have appropriate place in water quality research in Malaysia.

Benthic macroinvertebrate, particularly aquatic insect larvae and crustaceans, are widely used as indicators of waterbodies health and condition e.g. (Gewurtz et al., 2003; Haase et al., 2004; Meng et al., 2009; Barton, 1989; Conti, 2008; James and Evison, 1979; Iliopoulou-Georgudaki et al., 2003; Leonardsson et al., 2009; Canfield et al., 1996; Dlamini et al., 2010; Wu et al., 2010). Many fish species rely on benthic organisms as a food source (Longhurst, 1957; Shubina, 2006; Alheit and Scheibel, 1982) either by direct browsing on the benthos or by catching benthic organisms that become dislodged and drift downstream (Principe and Corigliano, 2006). The use of benthic macroinvertebrates to assess biological integrity of stream ecosystems has been well documented by (Resh et al., 1996) and with Rosenberg in (Rosenberg and Resh, 1992). On behalf of the United States Environmental Protection Agency (U.S EPA), Barbour et al. (1999) had revised the rapid bioassessment protocols with use of periphyton, benthic macroinvertebrates and fish as bioindicator. The protocols provide a practical technical reference for conducting cost-effective biological assessment of lotic systems and most suitable for streams and wadeable rivers.

According to Sladécék (1979), the right way of using aquatic organism is to use it according to where it stays in waterbodies: planktonic community about the water, benthic and littoral ones about the conditions on the bottom and shoreline. Combination of these is necessary because the result may not agree with one another and further clarification is therefore needed. It right to note the more species under consideration, the more accurate the result would be (Khan, 1990).

River water quality monitoring in malaysia

There are 189 river basins in Malaysia and 150 of them are main river basins. About 100 of main river basins in Malaysia are situated in Peninsular Malaysia, where 50 are situated in Sabah and Sarawak. It is estimated that there are 1800 rivers in Malaysia with total length of more than 38, 000km (DID, 2009). Currently Malaysia has 30 hydroelectric dam for power generation and water supply. Rivers and streams in Malaysia serve the purpose for agricultural, industry, water supply, transportation, aquatic habitats, water sport and recreational. Monitoring and management of rivers and streams water quality in Malaysia lies under the jurisdictions of two government agencies; one is The Department of Environmental in Malaysia (Jabatan Alam Sekitar Sekitar Malaysia), also known as JAS or DOE, and the other one is The Department of Irrigation and Drainage in Malaysia (Jabatan Pengairan dan Saliran Malaysia), also known as JPS or DID.

Yearly, DOE publishes Environmental Quality Report in Malaysia, to report the environmental status of air, water, and soil in Malaysia. In assessing and reporting the water quality status of river and streams in Malaysia, DOE uses physicochemical based method through their own developed Water Quality Index Malaysia (WQI Malaysia). The WQI Malaysia was developed in Malaysia by collaboration efforts between DOE and Universiti Malaya in 1985 (Arsad, 2009). WQI Malaysia consist of 6 parameters (chemicals and physical); Ammoniacal Nitrogen (NH3-N), Biochemical Demand (BOD), Chemical Oxygen Demand (COD), Dissolved Oxygen (DO), Suspended Solid (SS) and pH. Assessment and valuation of these parameters produced an index value ranging from zero to one hundred. According to the index value, the river water quality can be classified into three main classes as shown in table 1.0. Table 2.0 show the classification of WQI Malaysia and all the subindex parameters into five classes.

WQI Malaysia is one of the most effective ways to communicate information on the quality of water to concern citizen and the policy makers in Malaysia. Rating from the index reflects the composite influence of number of water quality parameters overall of water. Calculated index for a given river and stream will determine its quality status, which later will determine the management action needed by respective agencies.

Where DOE has their focus majorly on the quality of water and identifications of point and non-point sources pollution that polluted the freshwater in Malaysia, DID on the other hand focuses mainly on physical and design properties of rivers, streams, channel and drainage. Only recently, in 2009, DID has started to have their intention on water quality quite significantly when they made a collaboration effort with Universiti Sains Malaysia, and has successfully producing a Panduan Penggunaan Macroinvertebrata untuk Penganggaran Kualiti Air Sungai or also known as Guideline for Using Macroinvertebrates for Estimation of Streams Water Quality. DID has used Biological Monitoring Working Party Index's (BMWP) and Average Scor Per Taxon Index's (ASPT) in the guidelines. BMWP and ASPT were applied in the guidelines because these two indexes have been widely used in Europe and many parts of the world since 1976, and they require qualitative data which is easy to collect (DID, 2009). The guideline provides simple, cheap, and easy approach for estimating the river water quality through collecting and in identifying main species of aquatic macro invertebrates.

River water quality studies in Malaysia

Water quality was historically being evaluated using chemical-specific numeric water-quality standards and narrative criteria. While such criteria are based on scientific judgement about the potential for adverse effects to aquatic organisms, the causative relationship between chemicals and effect is only assumed (Ellis et al., 1997). The history of bioindicator systems for surface water quality assessment started more than a century ago by Kolenati (1848) and Cohn (1853), both quoted by Liebmann (1962) (Depauw and Vanhooren, 1983; Iliopoulou-Georgudaki et al., 2003) who observed that organisms occurring in polluted water are different from those in clean water. Discussion on bioindicator had run more than 100 years after Kolenati (1848) literally made first starting point when he concluded that the absence of caddis larvae from a stream can be caused by the presence of a city upstream (Liebmann, 1960 and SladeCek, 1973), both quoted in Mol (1980) and it was a very old and the very beginning of biological method used in river monitoring study conducted in Europe.

Observations and correlation between the distribution of certain aquatic invertebrate species and different water pollution levels are perhaps contrary to the expectation not very recent. One could even say that such observations are older than ecology itself; as early as 1848, it was correctly concluded that the absence of caddis larvae from a stream can be caused by the presence of a city upstream (Kolenati, 1848), quoted by Mol (1980). The term 'ecology' was blended in 1866 by German zoologist Ernst Haeckel (1834-1919), quoted by Lawrence (2003), together with a definition of the field to be studied by this new science. In the first decades of the 19th century these observations were more and more assembled into systems and methods to estimate water pollution levels and in 1908 to 1909 a first elaborated scheme for biological water quality assessment was published, the well known Saprobien system (Kolkwitz and Marsson, 1908; 1909), quoted in Tolkamp and Gardeniers (1988), and the system is still in use, especially in Central Europe. In saprobien system the range of organic pollution is divided into four levels and for every level a list of characteristic organisms is given; the invertebrate fauna is represented, but is only a fraction of all listed species. On basis of later investigations new indicative species were added to the list (Liebmann, 1960; Sladecek, 1973), quoted in Mol (1980).

In Europe, awareness on applying biological method for assessing water quality had emerged over the past century, and interest on using biological method had significantly increased over the past decade. As a result, there have many studies by interested party which lesson can be drawn. Biological quality can be assessed by different kinds of organisms: diatoms, riparian and aquatic vegetation, invertebrates and fishes. Many literature on these groups and methods are available (e.g. Dutka, 1979; Sladécék, 1979; Lockwood, 1979; Hawkes, 1979; Bellinger, 1979; Collingwood, 1979; Prince, 1979; Hellawell, 1986; Persoone and De Pauw, 1979; Descy and Micha, 1988). Quite recently, references on using freshwater biomonitoring and benthic marcoinvertebrate (aquatic insects, molluscs, crustaceans, and worms) in the biological assessment of water quality are well documented by Rosenberg and Resh (1992), they sum up the use of these organisms in both North America and Europe where their uses had dramatically increased in the past two decades.

In 1980, U.S. EPA had a thought that the traditional method for assessing water quality by using chemicals, physicals, and toxicity measure was not cost-effective and could not give full view on the ecological health of given waterbodies. U.S. EPA started to develop biological monitoring technique which they thought was more effectives, cheap, and fast for evaluating the biological integrity in all streams across United States without lack of scientific proves. Following that, U.S. EPA had made a collaboration works with few government agencies in United States to produce first Rapid Bioassessment Protocols in 1989. These protocols have being revised few times to accommodate present needs during the times. The latest revision was made in 1999 by Barbour et al. (1999), named Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrate and Fish, Second Edition. The protocols have been widely use by the local government agencies across United States, and were also accepted and widely used by several countries in Europe and were recently introduced in Thailand in 2008 (Boonsoong et al., 2009).

In the past, the presence or absence of a few indicator species, such as game fish, was used to assess watershed health. But scientists realized that the assessment was a little more complicated than just using indicator species. Eventually, length and weight measurements of fish were also used, and numeric indices for benthos were developed. Such indices were first called biotic indices because they assigned number scores to the pollution tolerance of many different biological indicator species. While biotic indices were expanding in use, other indices, such as diversity indices, grew in popularity and were used for many years. Recently, multiple metric indices, such as the Index of Biotic Integrity by Karr (1981) and Index of Well Being derived by Gammon's in 1980 have become the standard in the United States for accurately assessing watershed health (Barbour et al., 1999).

In the past 25 years, numerous biomarkers have been developed with the objective to apply them for environmental biomonitoring (Sanchez and Porcher, 2009). Recently, the Water Framework Directive (WFD) of the European Union has specified monitoring programs required to assess the achievement of good chemical and ecological status for all water bodies by 2015.

Whereby, in south East Asia (Thailand and Malaysia), example of studies on rivers and streams water quality monitoring using benthic macroinvertebrate can be found quite recently in (Boonsoong et al., 2010; Boonsoong et al., 2009; Mustow, 2002; Parnrong, 2002; Salmah et al., 2006; Lee et al., 2006).

Recently Malaysia has started to integrate biological technique for rivers and streams monitoring across the country, and this has been done by Department of Irrigation and Drainage in Malaysia (DID, 2009). However, the implementation is still too new compared to traditional physicochemical based technique. Hence, there are a lot to be studied before users (water authority, student, researchers, and scientist) can comfortably rely on the biological technique for river water quality monitoring. Until now the assessment on physicochemical parameters in water quality is still dominant in many river water quality studies in Malaysia e.g. (Bouza-Deaño et al., 2008; Bordalo et al., 2001; Yunus and Nakagoshi, 2004; Gopinath and Tamjis, 2008; Latiff et al., 2009). These concentrations on physical and chemical based method are particularly surprising in judging natural waters where the main aim is often the preservation of biological amenities.

One of the most striking features of past assessment procedures in Malaysia has been the reliance placed upon chemical and physical based techniques, with relatively full neglects on biological methods. Review on water quality standards and practices in Malaysia by Idris et al. (2003) reveals, chemical parameter such as Ammoniacal Nitrogen (NH_3-N) was identified as one of the main pollutants to Malaysian rivers. In the review, they suggested direct efforts in searching for others pollutants that frequently found in Malaysian rivers system. Although their suggestion would further enhance river water quality standard and practice in Malaysia, it lacks of biological amenities preservation which primarily important to the ends user (humans, animals and vegetations) of the water.

In Malaysia, studies on water quality with relations to bioindicator started relatively very late as the earliest and well documented one was in 1990 when Khan (1990) conducted a case studies in Linggi River Basin, Malaysia (tropical river basin) to assess water pollution using diatom community structure and species distribution. Khan found, a marked variation in species association exists between the unpolluted and polluted stations. In 1991, Khan expanded the studies where he investigated the effect of urban and industrial wastes on species diversity of the diatom community in a tropical river, Malaysia (Khan, 1991). Interest on this topic indicate a growth when Yap (1997) made a preliminary attempt to classify Malaysian river using biological indices; Shannon-Weaver diversity index and the Saprobic system, concept of Kolkwitz and Marsson. Yap found the Shannon-Weaver diversity index approach appeared to give interesting and interpretable classification results, compared to the Saprobic condition index. Only quite recently, in year 2000, the studies on biological method in river water quality studies started to increase, and example of the studies can be seen in (Al-Shami et al., 2010b, 2010a; Azrina et al., 2006; Lee et al., 2006; Maznah and Mansor, 2002; Salmah et al., 2006).

Research on biological methods in river water quality studies in Malaysia are still lack of quantity. Not very long, studies on this topic started to emerge after year 2000, and example of this kind of studies can be seen in (Maznah and Mansor, 2002) Aquatic pollution assessment based on attached diatom communities in the Pinang River Basin, Malaysia. Their study is on diatom community in relation with river water quality, and they had found certain diatom species is affected by the degree of water quality in the study area, thus the diatom community could be use as a bioindicator to measure the impacts of river pollution. A recent study by Al-Shami et al. (2010b) also agrees that pollutants discharged into a river can cause negative impact on aquatic macroinvertebrate (e.g. Diptera: Chairomidae). These two researches are very good example and gives us a strong proof that biological indicators (aquatic macroinvertebrate) can be use in Malaysia for assessing and evaluating streams and river water quality, therefore biological aspect is reliable to be an tool for river water quality monitoring in Malaysia (tropical climate country). The time is now that Malaysian should start to appreciate the importance of biological method in river water quality research agenda and stop neglecting it, hence scientists and researchers should start to integrate and manipulate every little advantages and benefits of biological method into river water quality research agenda in Malaysia.

Advantages of biological aspect

A typical question arises each time ones try to decide between biological method over physicochemical method in water quality analysis: Why biological water analysis at all? Or, more precisely: Why biological water analysis besides all other possibilities water analysis? And this means the biological analysis must offer important advantages over physical and chemical based method; otherwise, its uses could not be justified.

The use of biological methods may be justified by the following discussions. Biological assessment (Bioassessment) techniques have been developed to enhance the existing chemical-specific standards by providing direct measure of ambient aquatic life and overall biological integrity of a waterbodies (Wong and Dixon, 1995; Usepa, 1991). Better than chemical and physical criteria alone, biological criteria link human actions with their impacts on water bodies and societal goals which are expressed as designated uses (Karr and Yoder, 2004). Perhaps one of the bright sides of bioassessment techniques is it can be used across a range of biological systems, from the ecosystem down to the molecular level (Ellis et al., 1997).

One of the important values of biological indicators is that they give direct answer to the suitability of water for supporting aquatic life and agricultural irrigation, and to some extent it shows the suitability for direct consume by humans. The advantage of river water quality monitoring with use of bioindicator is that biological communities reflect overall ecological quality and integrate the effects of different stressors by providing broad measure of their impact and ecological measurement of fluctuating environmental conditions. According to Iliopoulou-Georgudaki et al. (2003), overall routine monitoring of river water quality using biological communities is reliable and relatively inexpensive compared to the cost of assessing toxicant pollutants.

Galassi et al. (1993) reveals another advantage of using biological method over chemical and physical method as they found biological method offers complete characterization of all parent compounds and their metabolites by employing aquatic organism on the basis of their toxicity. They also reveal biological method could save time due to its simplicity compared to physicochemical based method. A study by Tittizer and Kothe (1979) founds biological analysis yield relevant information on the quality condition of the waterbodies with relatively modest requirements and very quickly, they also found biological analysis provides information which cannot be obtained by other methods.

The crux of the problem in river water quality monitoring using biological community lies in finding reliable biological indication of water pollution which at the same time independent to natural variations in the environment.

The selection of proper bioindicator can provide additional benefits through their use in causal analysis of impaired waters and measurement of ecosystem (Barbour and Paul, 2010). Fortunately, there are now many case studies from which lesson can be drawn e.g. (Slooff and Zwart, 1983; Hawkes, 1979; Sladécék, 1979; Tittizer and Kothe, 1979). Sladécék had made his elaboration on continental system for the assessment of river water quality, Hawkes had found how to use invertebrates as indicator of river water quality, and Titizer and Kothe had shown the possibilities and limitations of biological methods in water analysis.

With the increased interest in biological surveillance, different data processing methods were tried. Since 1848 until early 1980, fifty different methods for biological water analysis have been developed (quoted in Depauw and Vanhooren (1983)). However the number is likely to continue increasing thereafter as U.S EPA had started their steps in biological monitoring in 1990 through development of Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition (Barbour et al., 1999).

In an ideal situation the quality of running waters should be assessed by the use of physical, chemical and biological parameters in order to get the complete spectrum of information for appropriate water management. However, such assessment needs much more time and expenses than assessment on the biological parameters (Iliopoulou-Georgudaki et al., 2003), which as it is widely accepted (Dolédec and Statzner, 2010) can give reliably about all the information.

A vast number of studies may cause fragmentation of method and results, especially if the new developed method is not shareable and linkable with one from the past and future to come. As wished in all water quality studies is to make not only the result is shareable, but also can be linked with any existing one at anywhere in the worlds from different parties.

When abundance of method had been developed, question is, does the developed method level with one another? Can we just use one particular method instead of another? The answer is yes, in late 1970, study by Tittizer and Kothe (1979) had proved the applicability of intercalibration developed earlier in 1976, where, it is possible to develop a comparative measuring system which allows the conversion of water pollution values from one type of measuring unit to another.

But, can the result from different method linked with one another? Is the result shareable? Houston et al. (2002) reveals, data or assessment information could be shared among agencies even though there was a difference in method and metric result. This shows that biological assessment is not sensitive to some changes in the method (Borja et al., 2008) thus offering flexibility to match with local condition and geographical area.

Challenge of biological aspect

A study by Duran et al. (2003) reveals biological and chemical results are in good agreement with respect to water quality in the stream. However, it is undeniable that they also suffer from disadvantages in failing to provide a numerical basis for remedial action (James and Evison, 1979). One of the primary goals of research on bioindicator is to identify species or other taxonomic units that would reliably indicate disturbances in the environment, and reflect the responses of other species or the overall biodiversity. According to Sladécék (1979) the biologist must be able to classify many species of aquatic organisms and be able to get the determination from specialists for the unknown ones. However, there is no perfect bioindicator and selecting the most suitable one depends to a great extent on the goal of the survey (Rainio and Niemelä, 2003).

In monitoring rivers and streams water quality, concerned parameters are largely on physicochemical parameters of the water itself. The use of bioindicator is as a tool for predicting the ranges of physicochemical contained in the water based on the tolerant value of the referred macroinvertebrates. Recent study by Al-Shami et al. (2010b) on rice fields in Penang, Malaysia found macroinvertebrate (Diptera: Chaironomidae) which is used as referred bioindicator did not significantly affected by physicochemical parameters such as pH, dissolved oxygen, daytime water temperature, total suspended solids, phosphate, and sediment total organic matter. Instead, the community of the referred biological indicator would follow the dynamic changes of the habitat area including agronomic practices, patterns of water availability, and phases of plant growth. This result appears to be a good indication on which biological method could also be linked with agricultural practice. However this finding actually revealed the disadvantage of biological method on reflecting the assessed water quality, whereby the finding could actually cause a doubt on the reliability of bioindicator in reflecting the actual status of water quality especially when one of the main objectives in biological method is to act as substitute of physicochemical method.

Khan (1990) found biological method (with use of diatom community) cannot give a marked variation between unpolluted and moderately polluted river, thus caused doubt on reliability of biological method especially when the river which ones try to assess is in fairly clean state. So there has a limited ability for biological method to distinguish the type and degree of pollution. In 1991, Khan got a result that could cause confusion to interpret the quality of assessed water especially to people without background on biological knowledge. Khan found the changes in species diversity can be related to changes in diatom community structure and thereby changes in water quality, however due to complexity to interpret the results he concluded that diatom community cannot be used as an index of water quality.

In order to get full view of the surrounding water quality, assessment on multiple species are needed because there is no single species on habitat composition of the community can reflects complex information (Sladécék, 1979). Before a particular bioindicator could be accepted to be used, there must have sufficient research to determine it suitability to be indicator. Until it is being extensively studied, they should be used with caution (Rainio and Niemelä, 2003). Disadvantages of biological method in lack of providing numerical basis compare to physicochemical based method in assessing water quality should not be seen as dead end for implementing it on water quality assessment, instead, it should be seen as challenge for scientists to commencing thoroughly research, hence foster the successfulness of biological method in river water quality research agenda.

Future Direction

Weng (2005) stated, the management of rivers and streams in Malaysia requires collaboration effort between government agencies, education institutions, scientist and all stakeholders. Holistic approach is then required with integration of sustainable agendas in the essence. Therefore future direction on river water quality research in Malaysia should integrate biological method in the agendas. Whether biological method (uses bioindicator i.e. macroinvertebrates) should be use alternatively or as a complementary approach for streams water quality monitoring in tropical climate country such as Malaysia, should be further investigated. The parallelism and relationship between bioindicator and water quality index established in Malaysia should be further studied to fully understand the science between these two different based methods. Understanding on the relationship will help to clear doubt pertaining biological method over physicochemical based method. The validity of biological method (using bioindicator) for assessing river water quality in Malaysia requires years of implementation to fully understand the information offered by the method (DID, 2009). In advance research, biological method could be applied to assess the recovery quality of river and streams related project (e.g. river restoration projects), especially when there has a number of river restoration project going on in Malaysia, such as; Sungai Pinang, Sungai Melaka, Sungai Tebrau, Sungai Skudai, Sungai Segget, and Sungai Muda.

Conclusion

In conclusion, the assessment of river water quality lies on the delicate interface between physics, chemistry and biology. Biological based methods have significant advantages over traditional analysis of physicochemical based methods. Besides providing information on the bioavailability of contaminants, it simplifies the physicochemical analysis, eliminating the problem of the assessment of very low levels of contaminants. It also prevent the risk of misinterpretations which might caused by sudden fluctuation in the environmental parameters at the time of sampling, thus providing a measurement over time on the level of environmental contaminations. However, we do not advocate abandoning physical and chemical assessments rather we note the inadequacy of the assessments which unable to give complete information on river water quality in complex ecosystem. A long history path in water quality research has produced many lessons that are very useful and beneficial for future to come. It is now that Malaysia should extensively make use of them to improve river water quality monitoring in Malaysia especially in term of biological aspects and for further research to be started. Biological and physicochemical qualities are inextricably tied to the viability of water resources availability and resilience. Integrating biological and physicochemical based method into holistic water resources research is essential for sustainable water resources. Therefore, a vibrant water resources research agenda must account for interdependencies between the quality and quantity of water. The water quality aspect in the agenda must be sustainable and should include consideration on findings and developing a viable system of regulation and incentive to promote interest on biological method. Succession in integrating the biological method in river water quality research agenda will contribute to one step further towards sustainability of the water resources in Malaysia and possibly in the world.

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Table 1.0: DOE water quality classification based on Water Quality Index Malaysia

Sub Index & Water Quality Index	Unit	Index Range		
		Clean	Slightly Polluted	Polluted
Biochemical Oxygen Demand (BOD)	mg/l	91 - 100	80 - 90	0 - 79
Ammoniacal Nitrogen (NH_3-N)	mg/l	92 - 100	71 - 91	0 - 70
Suspended Solids (SS)	mg/l	76 - 100	70 - 75	0 - 69
Water Quality Index (WQI)		81 - 100	60 - 80	0 - 59

Table 2.0: DOE Water Quality Index Malaysia classification

Parameters	Unit	Class				
		I	II	III	IV	V
Ammoniacal Nitrogen	mg/l	< 0.1	– 0.3	0.3 – 0.9	0.9 – 2.7	> 2.7
Biochemical Oxygen Demand	mg/l	< 1	1 – 3	3 – 6	6 – 12	> 12
Chemical Oxygen Demand	mg/l	< 10	10 – 25	25 – 50	50 – 100	> 100
Dissolved Oxygen	mg/l	> 7	5 – 7	3 – 5	1 – 3	< 1
pH	-	> 7.0	6.0 – 7.0	5.0 – 6.0	< 5.0	> 5.0
Total Suspended Solids	mg/l	< 25.0	25 – 50	50 – 150	150 – 300	> 300
Water Quality Index		> 92.7	76.5 – 92.7	51.9 – 76.5	31.0 – 51.9	< 31.0