Section II : Water Resources Management Tools

The Role of Biosensor Technology in Data Acquisition for Integrated Water Resource Management

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ABSTRACT

Data collection forms an important part of a successful integrated water resource management (IWRM) programme, particularly for the collection of water quality data. On site water quality data collection is useful in terms of both rapid interpretation of information as well as preservation of data quality. This is now made possible by a wide variety of sensors, including biosensors. Biosensors as user friendly devices can provide on-site, specific and rapid analysis for many water quality parameters. Biosensors based on DNA, microbial cells and enzymes have potential applications for the direct collection of water quality data from various water resources.

Keywords : Biosensor, Data Acquisition, Integrated, Water Resources, Management.

1. INTRODUCTION

The quality of a water resource is defined by a range of characteristics such as physical, chemical and biological parameters. Some examples of physical parameters are suspended solids, conductivity, redox potential, dissolved oxygen, temperature, turbidity, etc. While chemical parameters are pH, acidity/alkalinity, hardness, nutrients (phosphate, nitrate, ammonium), organic matter (TOC, COD, BOD etc.), major cations/anions, trace elements, organic micropollutants (pesticides, phenol, surfactants etc.). The biological parameters involved pathogens, e.g bacteria (E.coli, Salmonella, Shigella, etc) and enteroviruses (poliovirus, Coxsackie virus, etc).

The complicated nature of water quality interpretation makes it difficult for high level decision on water resource management if direct use of water quality data is involved. To address such a problem, other concepts of water resource management were explored. One approach is to employ indicator or index suitable for the type water resource involved. The indicator/index used may follow the Pressure-State-Response model of the OECD approach (Peterson, 1997). The PSIR (Pressure-State-Impact-Response) model from OECD has been suggested as a basic concept of developing a management tool for several life support systems in Malaysia, including water quality (Peterson, 1997). The model attempted to define the pressure (or stress) on the system and the current condition (state) of the system. Each of the pressure, state, impact and response sector can be represented by one or more indicators. As a result of the stress, the possible impacts are established and relevant responses to the stress and impact are evaluated. Each of the pressure, state, impact and response sector can be represented by one or more indicators (Figure 5.1)

PRESSURE	**STATE**
• Intensity of fertilizer/pesticide application in agriculture • Industrial/municipal effluent discharges to water • Sewage outfalls to water bodies	• % of population with access to safe water • Concentration of dissolve organic matter, BOD & COD in water. • Pesticide concentration in water • Number of faecal coliforms
IMPACT	**RESPONSE**
• Waterborne diseases. • Water rations. • Eutrophication of water bodies. • Degradation of recreational water	• Number of sewage plants • Number of rivers meeting classification standards • Expenditure on water abstraction, treatment and distribution. • Expenditure on waste water treatment

Figure 5.1 : The PSIR model for integrated water resource management

Based on the PSIR model, various indicators can be assigned with weights and values before an index related to water pollution can be derived. This will require input of data especially water quality data. The derivation of an index based on indicators will need some understanding of the relationships between various water quality indicators and non-water quality data especially socio-economic data source. The final aggregated index can be useful as a decision management tool for assessing water resource management based on multimetric indicators. An example of the use of indicators for the management of water bodies affect by sewage contamination is given by Lee et al. (2006).

The most important use of indicators in water quality managemnet was carried out in 1993 by the Department of Environment Malaysia (DOE) for communication on water quality decisions to the stakeholders and general publics. The DOE has set up a list of indices for water quality management such as the Malaysian Interim Water Quality Standards and the Malaysian Classification of River, which are based on a water quality index (WQI). WQI depends on six water quality parameters, i.e. BOD, COD, pH, DO, TSS, ammoniacal-nitrogen (DOE, 1993). The values of WQI determine the 4 classes of rivers: Class I (Conservation), II (Drinking & recreation), III (Irrigation) and IV (transport). The WQI currently used by the Department of Environment, Malaysia for management of river water resources is (DOE, 1993)

$$WQI = 0.22SIDO + 0.19SIBOD + 0.16SICOD + 0.15SIAN + 0.16SISS + 0.12SIpH$$

Where SI indicating a sub-index that is derived directly from a set of water quality data. The Interim Water Quality Standards and the WQI have now formed the main water pollution management and control tool in Malaysia.

2. PROBLEMS OF WATER QUALITY ANALYSIS

The creation of indicators will require water quality analysis to obtain the necessary data for indicators development. The usual procedures for obtaining water quality will include water sampling, sample preservation, sample pretreatment, chemical analysis using spectrophotometric methods and other instrumental methods

Many problems regarding collection of water quality data arise from sampling and analysis. When samples can not be analysed under field conditions, samples transport to laboratories are necessary but this eventually leads to delayed sample analysis, where the sample integrity is very often compromised. Most of these problems can be resolved if water samples are analysed on-site or when a system of continuous water quality monitoring is employed.

3. SENSOR TECHNOLOGY FOR CONTINUOUS WATER QUALITY MONITORING

Many of the conventional water analysis techniques hinder continuous water quality monitoring because samples are needed to be sent to laboratories for analysis. The use of sensor devices enables on-site water analysis and hence the integrity of the water samples can be preserved. On-site analysis with sensing devices also allowed the detection of rapid changes in water quality. Some sensor devices for on-site water analysis available currently are mostly physical sensors (e.g. conductivity, oxygen, temperature, salinity and turbidity) and chemical sensors (e.g. pH and ammonium ion). Such sensor technology has been applied by Alam Sekitar Malaysia (ASMA) for the direct collection of data from many rivers in Malaysia since 1993 (Tong, 1993).

Examples of the usefulness of continuous water quality monitoring in IWRM are the control of seawater intrusion into the Sarawak River that contaminated the Kuching town water resource (Tong, 1993), and the understanding/prediction of water quality changes in the Linggi River Basin during adverse climatic conditions such as draught and stormy weathers (Lee et al., 1993).

In terms of continuous water quality monitoring, advantages of sensor technology for water analysis include possible on-site analysis without sampling requirement and this avoids sample pretreatment and preservation but still maintains sample integrity. Since it is not necessary to send sample to a laboratory for analysis, direct, continuous and real time data can be obtained. With the possibility of data telemetry from the sampling site where the sensor is located, data can also be obtained online at anytime.

4. BIOSENSORS FOR CONTINUOUS WATER QUALITY DATA COLLECTION

One type of sensor is the biosensor. The potential of using biosensor is realized recently due to the rapid development of biotechnology. Th usage of biosensors is more promising in water analysis when compared with chemical sensors because of the higher specificity of the device and the larger range of water quality parameters that can be analysed. A biosensor is a device that contained an analyte recognition element, sometimes known as the bioreceptor. The biochemical interaction of the bioreceptor with an analyte generates a chemical or physical signal, which later processed by a transducer to electronic data. The electronic data is often concentration dependent and can be readout and understand by the user. Most often the signals generated are electrochemical (e.g. current) and optical (e.g. colour change). The bioreceptors used are enzymes, antibody-antigen system, DNA and living microbial cells (De Souza, 2001).

Current applications of biosensors are mostly for direct screening of water samples before detailed chemical analysis is performed. Biosensors are not only enabled on-site continous monitoring of water quality, they can performed quantitative analysis as well. Biosensors have now been developed for the analysis of phenolic compounds (Jaafar et al, 2006; Sharina et al, 2008), some nutrients, heavy metal detection, trace organics (Loh et al, 2008), water pathogens and water toxicity evaluations (Tay et al, 2005).

Many of the nutrients, metals/heavy metals and trace organics in water can be determined by the use of enzyme and antibody based biosensors. Enzymes and antibody that are specific or selective to these analytes can be immobilized onto the biosensor transducer and concentration of these analytes when presence can be measured directly. For DNA based biosensors, detection of DNA in water via hybridization is required. Thus, this class of biosensor is very useful in the direct detection of microorganism DNA that present in a water body. In the case of the pathogenic bacteria family such as the Enterobacteriaceae (enterics or coliforms, e.g *Escherichia coli*, Enterobacter and Klebsiella species) that can cause several water-borne illnesses, closing down of recreational facilities and seafood harvesting waters, DNA biosensors have been developed for direct and rapid analysis of pathogenic bacteria (Wang et al. 1997)

Water toxicity measurement is another important arsenal in IWRM. Very often analysis of individual chemical may not reflect the toxic nature of a cocktail of chemicals that are released to a water body. There is a general need of having procedures that can screen the effluent for toxicity before they are analysed chemically. Since water toxicity is very often influenced by the environment conditions and also the presence of other toxicants or chemicals, an ecotoxicity approach is normally adopted in water toxicity evaluation to compliment chemical analysis. This is particularly useful in the management of hazardous effluent.

Many of these procedures involved the use living organisms, especially microbial cells. The use of whole cell biosensors has been proven for the direct detection of water toxicity. Biosensor containing algae and cyanobacteria cells have been reported for the detection of many herbicides and toxic metals in water and also employed for toxic waste evaluation. The advantage is that these biosensors respond to broad-spectrum toxicity and they can yield results in less than 30 min when compared with the traditional toxicity testing methods that may require 24 to 36h. For example, using an electrochemical biosensor based on immobilized cyanobacteria, good linear detection ranges for Cu (0.3-4.5 mg/L), Pb(0.05-2.0 mg/L) and 2,4-D herbicide (0.05-0.5 mg/L) can be obtained (Tay, et al, 2005).

5. CONCLUSION

In conclusion, the use of indicators is important in IWRM where decision communication can be made easier between the management personnel and the stakeholders or general public. In order to achieve that, rapid, on-site and real time water quality data collection are essential. Biosensor technology has the potential in satisfying these requirements and they are already currently used as screening tools before detail chemical analysis for water. The use of biosensor devices in the future is expected to enable water quality data to be generated with minimum intervention from humans. Thus, they are future tools for building up a large quantity of data useful to IWRM.

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Environmental Flow Modelling as a Tool for Water Resources Management: A Study of Deia in Sungai Pelus River Catchment

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ABSTRACT

In Detailed Environmental Impact Assessment (DEIA), modeling of environmental flows is one of the main studies that need to be delivered in the final DEIA report. The model is important to the project proponent to engage suitable designs that can be suited to environmental needs, particularly on future water resources management. In this respect, Environmental Flow Assessment (EFA) is used to estimate the quantity and timing of flows to sustain the ecosystem values. The proposed of hydropower projects in Sg Pelus, Perak was studied aimed to evaluate existing river flow characteristics and to model EFA due to river diversion of Sg Pelus. Daily river flow (m3/s) recorded at Sg Pelus (Station No. 6035) and Sg. Yum (Station No. 6044) gauging stations were used to design the flow duration curve. The low flow then calculated using the 7Q10 equation to estimate the lowest 7-day average flow that occurred on average once every 10 years. The results indicate that the average daily flows for both stations (6035 and 6044) are 5.080 m3/s and 11.391 m3/s, respectively. The flow duration curve shows that 50 percent of 4 m3/s of discharge will be exceeded/ equaled in Station 6044 while 8.2 m3/s of discharge will be exceeded or equaled in Station 6035. The requirement environmental flows for both parameters are 0.613 and 0.426 m3/s for Environmental Flow Assessment, respectively. The results obtained in this model are important to managing the river at least in Class II after river diversion project.

Keywords: Environmental Flow Assessment; Detailed Environmental Impact Assessment; Low flow; Flow duration curve.

1. INTRODUCTION

Recent developments of legislation in Malaysia tend to consider environmental flows in the context of environmental sustainability. It is considered a basic principle in sustainable development and in the search for ways to reconcile multiple and competing water uses with environmental protection. One important tool for implementing this approach in the water allocation process is multi-criteria analysis, wherein an environmental flow assessment provides a way to quantify the environment criteria.

Practically, the concept of environmental flows was implemented for a very specific purpose, i.e. protecting the aquatic fauna downstream river diversion. Since then several different applications and interpretations have evolved that extend the original meaning. In some recent cases, it is considered to be an instrument to achieve water quality targets - together with other measures. In Malaysia, environmental flows are not prescribed in the national legislation in general terms, as framework laws. Current norms consider environmental flows only in the form of a minimum instream flows to be present downstream of water diversions. Eventually, this approach is part of the Detailed Environmental Impact Assessment (DEIA), to be presented by the developers in their Water Protection Plans.

This case study describes a scheme to integrate Environmental Flow Assessments (EFA) with hydrologic modeling tools in the Sg. Pelus, Perak. The purpose is mainly for hydropower generation. It shows how environmental objectives were incorporated in multi-criteria analysis to develop flow regulation policies, particularly the portion where the river flow will be diverted. Typically the main challenge in such circumstances is to define an environmental score that can be computed for different scenarios - one that is inaccessible to experimentation and measure. The approach described overcomes this problem by using existing low flow methodology, namely the 7Q10 equation to define EFA.

The main aim of this study was to study the flow characteristics of Sg Pelus and the development of environmental flows requirement as related to river diversion project. The information is important to stakeholder and project proponent to estimate how much waters can be diverted that also can fully supply at all times without deteriorating the water quality and quantity as a whole.

2. CONCEPTUAL FRAMEWORK

In Malaysia, the total available electricity generating capacity was estimated at 19.3 GW in 2003, a jump of 23 % from 15.6 GW in 2002 due to the commissioning of several coal and gas based independent power plants in Perak, Perlis and Perai (ABSE, 2005; Suruhanjaya Tenaga 2006). The electricity generation in 2003 was 82,406 GWh, which represented an increase of 6 % from 77,501 GWh in 2002. The electricity generation in 2003, which was basically from thermal generation, contributed about 87 %, while hydroelectric only contributed 13 %. Out of 87 % thermal generation, 65 % was from gas turbine/ combined cycle block, 11 % was from coal-fired plant and 11 % was from gas/oil plant, which suggested that our electricity generation was highly dependant on natural gas.

With increases in fuel (oil) prices, which was almost doubled in two years (2005 and 2006), hydropower is becoming increasingly appealing. Thus, hydropower is one of the alternatives to solve energy shortage in years to come. Despite the clean energy hydroelectric power plants can provide as an alternative of reducing dependence on non-renewable source, the government is constantly under criticisms for high cost of building dam, as well as environmental impacts of the dams (Annon, 2005).

In certain activities which involved natural environment, particularly river diversion project, Environmental Impact Assessment is required by Department of Environment (DOE) to protect water source areas in headwater regions from degradation. A detailed Environmental Impact Assessment (DEIA) study must be carried out by the consultant at various perspectives, i.e. physical, biological, socio-economic including tourism, archeology and health to ensure that the impacts from the project are minimal.

One of the main criteria in DEIA, particularly in hydrological section is the need to EFA requirement. The idea is to address acceptable water quality for flow diversion, and at a same time to protect flora and fauna below the downstream river diversion. In a case of river diversion project, dry season become a subject matter where by water level normally at a minimum level. Therefore, the need to study minimum or low river flow characteristics is essential so that full hydropower electric can be supply at all times.

The most common low flow analyses for streams are twofold, namely minimum annual minimum flow and 7Q10 model analysis. This study engages 7Q10 as this model is widely used throughout the world. In a case of Sg. Pelus, the 7Q10 was selected as a representative low streamflow value for regulatory and modeling purposes, particularly with respect to point-source pollution and concentration due to river flow diversion. Simply, the 7Q10 means *"seven-day, consecutive low flow with a ten year return frequency; [or] the lowest stream flow for seven consecutive days that would be expected to occur once in ten years," (*U.S. EPA 1997). According to the World Meteorological Organization, low flow is the "flow of water in a river during prolonged dry weather". Again, hydrologists use design flow statistics such as the 7Q10 or the lowest 7-day average flow that occurs on average once every 10 years to define low flow for the propose of setting permit discharge limits.

When the river is considered as unregulated natural river, the reliability of water availability is a function of the low flow characteristics. The three main characteristics of low flow are:

- Duration - reflect the tolerance of the user to periods of water deficits.
- Magnitude - Low flow for specific duration will determine the amount of water that is available to the user.
- Frequency of occurrence - The frequency of occurrence of low flow reflects the risk associated with the failure of water supply.

For this study, the 7Q10 flow was adopted as this method is the most commonly used single flow index (Table 6.1).

Table 6.1 : Uses of the 7Q10 Flow

» To protect/ regulate water quality (to prevent adverse biology/ ecological impacts)
» General indicator of prevalent drought conditions which normally cover large areas
» Total maximum daily load to assess aquatic life protection
» Minimum quantity of streamflow necessary to protect habitat during a drought situation
» Considered as the wroth case scenario in water quality modelling
» To compare the impacts of climate change and irrigation on low surface streamflows

3. STUDY AREA

The Sg. Pelus hydroelectric scheme is considered a mini-hydro utilizing Run-of-river type of hydroelectric power plant located within the Sg. Perak catchment. The scale of the project is considered relatively small, with minimal impact on already degraded natural environment of Sg. Pelus sub-catchment. The similar Sg. Perak catchment is currently exploited by hydroelectric power plants, such as Temengor, Bersia, Kenering and Chenderoh.

The Pelus river catchment is a sub-catchment of the Upper Perak River, which flows from its source near the Thailand boarder, southwards through Perak State. On the east site of the Perak River, lies the Sg. Piah Basin, this is part of the Kenering sub-catchment. The Pelus catchment is similar in size and physiographic characteristics to the Piah catchments and lies directly to the south. The Sg. Pelus discharges into the Perak River about 10km downstream of Chenderoh. Total catchments size for Yum and Pelus are estimated at 135 km2 to 170 km2, respectively (Figure 6.1).

The bifurcation ratios as the ratio of the number of streams of one order to the number of streams of next highest order (n + 1). In this catchment, the average value of bifurcation ratio was 5.35. This value is within the threshold for the upper catchment as studied by Mohd Ekhwan, (2002) for Peninsular Malaysia where mean bifurcation ratio of most of the catchment in the Peninsular Malaysia tends to be approximately 5-7.

The rivers of this catchment are relatively short courses. Their gradients in the upper courses are steep. Some river reach can drop to more than 50 m creating gorgeous waterfall.

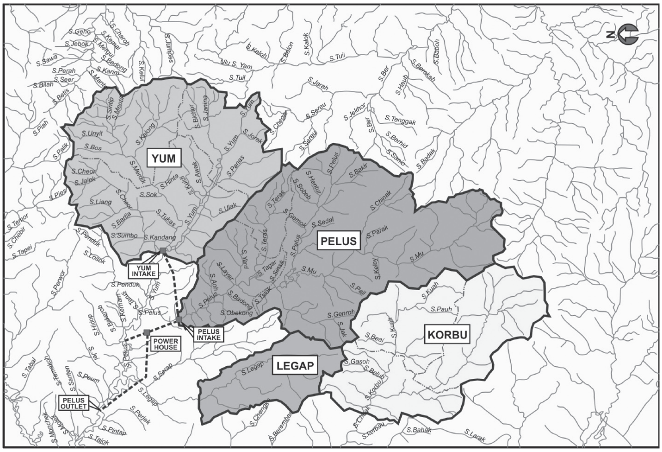

Figure 6.1 : Pelus, Yum, Korbu and Legap Sub-Catchments

4. METHODOLOGY

For this analysis, the stream flow was discussed at each single station. Stations 6044 (Sg. Yum at Kuala Yum) and 6035 (Sg Pelus below Kuala Yum) have a complete 13-year (Jan 1984-June 1997) and 14-year flow series, respectively (Jun 1985- October 1997). Meanwhile, the flow duration curve was developed by computing the percentage of time the various flow rates are equaled or exceeded and then plotting the discharge rates against the corresponding percentages of time.

Hydrological Procedure No. 12 (HPI2) 'Magnitude and Frequency of Low Flow in Peninsular Malaysia' describes a simple method to compute low flows. Like HP No.4, this procedure was developed based on regional frequency analysis. Four low flow regions (RC1; RC2; RC3 and RC4) were identified and using this procedure design low flows of return periods between 1, 10 and 25 years could be determined.

In the low flow frequency analysis, the total 7-day low flow for each year is identified. These total 7-days low flow value is then ranked starting with the lowest rank. Then, the percentage of ranking is computed for each rank. This is followed by plotting the log flow value against the respective percentage ranking on a probability paper.

Information on Biological Oxygen Demand (BOD) and Total Suspended Sediment (TSS) were obtained using standard laboratory procedures.

5. RESULTS AND DISCUSSION

The proposed scheme of Sg. Pelus hydropower project intends to abstract waters from Sg. Yum and Sg. Pelus which is then diverted to an underground power station (34.8 MW) at Kuala Legap (04° 56″ 47.8′E, 101° 15″ 45.4′N). The impact on water flow at the time the stream waters diverted into the tunnel is predicted - where the diversion will disrupt the flows, particularly the volume, velocity and water level especially stream section below the diversion intakes.

The channel platforms may also unstable in the early diversion period. Reducing flow can develop sediment deposition particularly in the inner bends of the river. At the same time with decreased in water levels causing bank materials to be exposed and finally may lead to lateral erosion especially those in the step banks. These impacts however are temporary and localized and not considered causing any significant effects further downstream.

5.1 Sg. Yum - Daily Flow

Daily Q was constructed from the Station 6044. The station receives water from Sg Yum sub-catchment. Based on the figure, the maximum Q (m^3/s) recorded was 26.3, while the mean and minimum Q is 5.080 and 2.0, respectively (Figure 6.2).

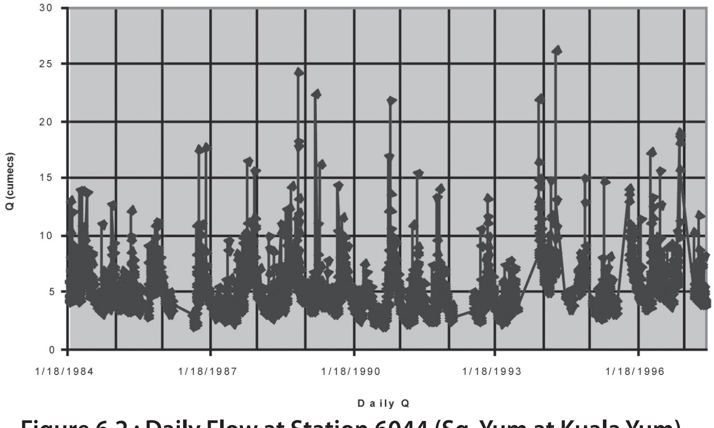

Figure 6.2 : Daily Flow at Station 6044 (Sg. Yum at Kuala Yum)

5.2 Sg. Pelus- Daily flow

Daily flows recorded at Sg Pelus below Kuala Yum are expected to be higher compared to Sg Yum as this station received both discharges from Pelus and Yum catchments. Based on the flow data, the maximum daily flow was 66.7 m^3/s. The average over 12 years record is 11.391 m^3/s and the minimum flow is 0.6 m^3/s (Figure 3).

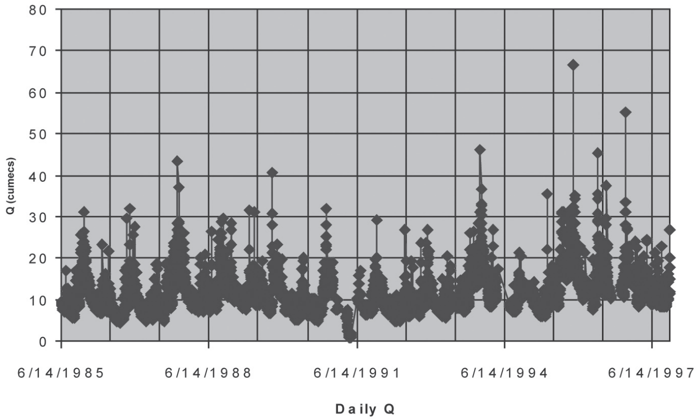

Figure 6.3 : Daily flow at Station 6035 (Sg. Pelus below Kuala Yum)

5.3 Flow Duration Curve

The flow duration curve is a plot that shows the percentage of time that flow in a stream is likely to equal or exceed some specified value of interest. For example, it can be used to show that the percentage of time river flow can be expected to exceed a design flow of some specified value (e.g., 5 m^3/s), to show the discharge of the stream, or to exceeded some percent of the time (e.g., 80% of the time).

The basic time unit used in preparing a flow-duration curve will greatly affect its appearance. For this study, mean daily discharges were used. The flow duration curve was developed by computing the percentage of time the various flow rates are equaled or exceeded and then plotting the discharge rates against the corresponding percentages of time.

Figures 6.4 and 6.5 show the daily flow duration curves calculated at Stations 6044 and 6035. It is estimated that for both stations, 50 percent of 4 m^3/s and

8.2 m^3/s of discharges will be exceeded or equaled. According to the figure to follow, minimum instream flow of approximate 2 m^3/s is likely to be available 100 % of the time for an average year. However, the demand of 5 m^3/s will only be available 25 % for Station 6044 and 80 % of the time. This implies that full supply will be available during a portion of the water year while a reduced supply will be available during other times of the year.

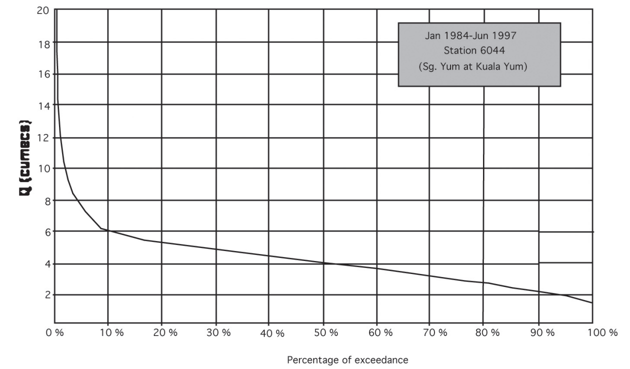

Figure 6.4 : Flow Duration Curve for Sg Yum at Kuala Yum

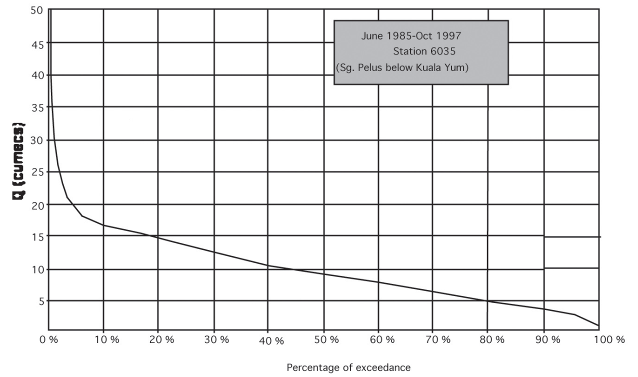

Figure 6.5 : Flow Duration Curve at Sg Pelus below Kuala Yum

5.4 Low Flow

In the low flow frequency analysis, the total 7-day low flow for each year is identified. Line fitting is drawn to provide the representative 7-days low flow probability line as shown in Figure 6. The value was re-calculated from the mathematical model,

$\hat{Y} = \acute{y} + Sy\,\dot{z}$ ……………………. [1]

Where ý is the population mean, S_y is standard deviation of the logarithms and ż is standard normal deviate. The estimated 7-day low flow for selected exceedence frequency (T) is tabulated in Table 6.2.

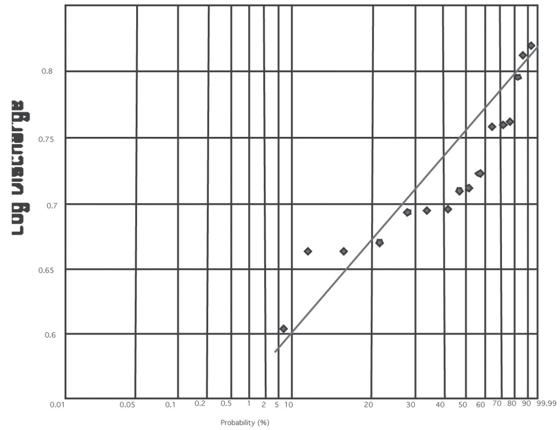

Figure 6.6 : 7-Day Low Flow Frequency Curve

Table 6.2 : 7-Day Low Flow Estimates for Sg. Pelus Catchment

T (Years)	*7-days low flow Q7, T(cumecs)*
01.5	2.413
02.33	1.602
05.0	1.175
10.0	**0.986**
20.0	0.890
50.0	0.801

5.5 Environmental Flow Assessment (EFA) For Water Resources Management

For Sg. Pelus river diversion project, the environmental group has adopted a suite of methods to determine environmental flows. These range from desktop studies in unstressed catchments to comprehensive studies of minimum flow requirements. The outputs from these assessments have been used to recommend Environmental Flow Assessment (EFA). EFA is a description of the flow regime required to maintain the ecosystem values, targeted by the assessment, at a low level of risk.

In this study, EFA is generally focused to those parts of the ecosystem and the specific times of the year that they are potentially at risk, particularly at the section where the stream will be diverted to the tunnel. For example, during the drought, the water use in a catchment may affect species that have particular requirements in these months (e.g. spawning, riparian germination and habitat availability). At other times outside the months, water use may not have a great impact on the ecological processes in a river diversion section. It is therefore critical to set the environmental flows during the planning stage of the project to ensure that this value is adhered to during operations of the diversions.

For environmental flow requirement, the measured water quality values for BOD (biochemical indicator) and TSS (physical indicator) for various locations at Sg Pelus and it tributaries taken during the field works showed BOD concentration is between 1.8 mg/l (Sg Menlik, a tributary of Sg Yum and upstream of the proposed Yum Intake) to 3.1 mg/l (Sg Pelus at 500 m downstream of the proposed Pelus Outlet) while TSS concentration is between 8.0 mg/l (Sg Menlik) to 48.8 mg/l (Sg Pelus). The average values for both BOD and TSS parameters are 2.45 mg/l and 28.4 mg/l, respectively. This means that, both parameters are under the Class II.

The required environmental flow for Sg Pelus is estimated. It is based on the average as represented by BOD and TSS against the 7-day low flows. The result is tabulated in Table 3.

Table 6.3 : Environmental Flow Assessment (EFA) Based on Mean Sampled Value of BOD and TSS under 7-Day Low Flow Conditions

	BOD	**TSS**
Mean (mg/L)	2.45	28.4
7-day Low Flow: *m^3/s* *L/s*	 0.986 986	 0.986 986
Estimated Loading (mg/s)	2415.7	28002.4
Required Environmental Flow (m^3/s)	0.279	0.280

NOTE : The estimated loading was computed by multiplying mean BOD and TSS (mg/L) load with mean daily flow (L/s)/ 7-Day Low Flow.

To maintain at least Class II waters, the minimum environmental flows required for BOD and TSS are 0.279 m^3/s and 0.280 m^3/s, under 7-day low flow. Based on Table 2, the 7Q10 was calculated at 0.986 m^3/s. Both values shown are below the 7Q10, meaning that even during the dry season, the values are still can maintain at Class II waters as water volume are plenty enough to cater both parameters.

6 CONCLUSION

In conclusion, the work presented here should convey the need for reporting of low flow confidence limits, and the value of using these limits in the decision making process, particularly when it involves with river diversion works. In summary, the results obtained from this study can summarized as follows:

- Total catchments size for Yum and Pelus are 135 km^2 and 170 km^2.
- Stations 6044 (Sg. Yum at Kuala Yum) and 6035 (Sg Pelus below Kuala Yum) are the gauged system used for the analyses.
- Mean daily flow for Sg. Yum is 5.080 m^3/s.
- Mean daily flow for Sg. Pelus is 11.391 m^3/s.
- 50 % of 4 m^3/s of discharge will be exceeded/ equaled in Station 6044
- 50 % of 8.2 m^3/s of discharge will be exceeded/ equaled in Station 6035
- BOD requirement for Environmental Flow Assessment (m^3/s) for Sg Pelus is 0.279 m^3/s.
- TSS requirement for Environmental Flow Assessment (m^3/s) for Sg Pelus is 0.280 m^3/s.

In conclusion, the work presented here should convey the need for reporting of low flow confidence limits, and the value of using these limits in the decision making process. Finally, the case study in Sg Pelus provides good exercise to identify acceptable limit threshold for the construction of the tunnel and at a same time maintaining the river water level for biotic and abiotic lives along the river system.

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Saving water through SRI: Implication for Sustainable Water Management in Malaysia

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ABSTRACT

The System of Rice Intensification (SRI) practiced by farmers in many parts of the world has proven to be water-saving and is more sustainable than the traditional method of rice planting. However, this method has yet to be practiced in Malaysia. This paper addressed the advantages of SRI in terms of water saving, cost reducing, sustainable land management, higher rice yield and policy for food security in Malaysia. In SRI management, the physiology of the rice plant is taken into account to avoid root trauma. The soil is aerated and allowed to alternate between wet and dry conditions for maximum tillering while reducing greenhouse gas production. The health of biological systems within plants and soils are maintained by the liberal use of large amount of compost. SRI has proven adaptable to many tropical soil types. The toxicity of aluminium and iron caused by acid sulphate soil condition is reduced, as SRI allows aerated condition to prevail. Such condition leads to the formation of insoluble Fe-Mn oxides which retain heavy metals in soils. The high incorporation of organic matter in soils as practiced in SRI also helps to reduce problems associated with acidity and increase nutrient availability. Malaysia's *commitment to improve its food security as stated in the fundamental objectives of the Third National Agriculture Policy 1998-2010 includes policies and strategies to increase its domestic food supply, especially rice while promoting sustainable land management. Sustainable rice production would be achieved with increased agricultural production and productivity through improved technologies. SRI provides the alternative to farmers to practice sustainable land management for rice cultivation while obtaining higher yield, reducing the cost of production, saving water and minimizing the damages to natural resources and environment, thus permitting sustainable rice production for national food security.*

Keywords: SRI; rice; sustainable; water; policy

1. INTRODUCTION

Rice cultivation traditionally requires a large amount of water through the practice of flooding and irrigation. Rice is the biggest consumer of water and with the poorest water productivity. In large irrigation systems, 4000-5000 litres of water are required to produce one kilogram of rice under current rice production practices. Water resources are becoming more limiting in many countries. In Malaysia, 68.2% of total water consumption is used for irrigation, the majority of which is used in rice production. The current irrigation efficiency is around 35-45 percent with a water productivity index for rice of about 0.2 kilograms per cubic meter (kg/m3). The national average yield for irrigated rice was 3.6 tonnes per hectare in 2008.

International Rice Research Institute (IRRI), for instant has developed varieties that resist water-stress and is currently having extensive research into aerobic rice. Water quality is also on the decline with rampant use of chemical fertilizers and pesticides. Application of large amount of fertilizers to increase rice yield have led to an increase of nitrogen and phosphorus in surface water and groundwater. Although a problem in some countries, the issues of salinity, waterlogging and water-borne diseases are not reported as being significant for Malaysia. Excessive use of pesticides have led to environmental problems such as soil and water pollution, diseases and reduced biological activity and biodiversity. There is an urgent need to address these issues for sustainable development. SRI, or System of Rice Intensification, practiced by farmers in many parts of the world has proven to be water-saving and through the use of organic fertilization is more sustainable than the traditional method of rice planting. SRI is a set of management practice which takes into account the physiology of the rice plant. SRI is now practiced in 34 countries. The spread of SRI around the globe has been credited to Norman Uphoff, director of the International Institute for Food, Agriculture and Development at Cornell University, Ithaca, New York. Farmers in Malaysia, however, have yet to begin the practice. This paper addresses issues of sustainable water management through the possible practice of SRI in Malaysia.

2. SRI PRACTICE AND WATER-SAVING ISSUES

Under SRI practice rice is transplanted as very young seedlings avoiding root trauma through specific method of transplanting or direct seeding and the soil is aerated and allowed to alternate between wet and dry conditions. This method allows for maximum tillering. The technique of "wetting and dry" not only results in water saving, but also conforms with the physiological water demand of rice, the essence of which is to rationally control the water supply, oxygen supply to the roots, adjust the ecological environment of rice and, in doing so, improve the water use efficiency, fertilizer, oxygen and thermal conditions necessary for high productivity. Wu (1999) studied a 21 year-long field experiments on water demands for various growth phases of paddy rice with respect to different areas, soils and climate conditions characterized as "shallowness, wetness and drying". Water-saving under "shallowness, wetness and drying" condition was achieved through 20-30% reduction in irrigation water and yield increases of 15-20% was observed when compared to submerged conditions as traditionally practiced by farmers. This entails shallow water depth for transplant recovery phase, being kept wet for pre-tiller phase, field drying for post-tiller phase, again shallow water depth during panicle formation or emulsifying phase, and finally being kept wet for yellow maturity phase.

Recognizing this different demand according to growth stage and its implication on water use efficiency, countries such as China and Japan have adopted specific water level control according to growth phases as part of their water management strategy for sustainable rice farming. In Japan, after rooting, the water is increased with rice growth at 1-3 cm. At tillering stage, water depth is kept shallow to enhance water temperature and promote tillering. When sufficient number of tillering is attained, the surface water is drained and the paddy is kept dry for 7-10 days to allow for fine shrinkage cracks to appear and promote subsurface drainage through them. This drainage practice supplies oxygen to the soil, promotes root growth and prevents ineffective tillering. At the beginning of panicle formation stage, the field is irrigated again, shallow at the young panicle stage and somewhat deep in the heading to flowering stage and again shallow at ripening stage. Wu's recommendation and the practice in Japan for water management are very similar to that proposed by SRI proponents. A comprehensive study by Horie et al (2004) on rice growing by Japanese farmers for the past 50 years supported the implementation of components of SRI, such as planting a single plant per hill, reducing transplanting injury, using large amount of compost, intermittent wetting and drying in order to increase yield. This practice increase roots in deeper soil layers, maintain their activities and presumably promote nitrogen (N) uptake at later stages. The general recommendations for SRI water management is that the soil is kept saturated under a very thin layer of water after transplanting. During tillering stage, the soil is allowed to dry until fine cracks can appear, and intermittently wet for short periods of time. The soil is again irrigated with 2 cm water at the beginning of panicle formation. The field is slowly drained, 20 days before harvest. From a farmer trial study in Eastern Indonesia comparing experience from 1363 ha under SRI management, water saving on irrigation was found to be about 40% (Sinha & Talati, 2007). Further, field study conducted in Purulia, India has shown that SRI could improve rice yields at 32% higher than conventional paddy cultivation (Sato, 2006).

Buoman & Tuong (2000) investigated cases of rice planted under saturated soil condition (SSC) and alternate wet and dry (AWD) and found that both led to decreased water input, but at the expense of decreased yield. However, from experiments conducted based on alternate submerged and non-submerged (ASNS) water management as practiced by farmers in China, Horie *et al* (2004) concluded that, for poorly drained irrigated lowlands in Asia ASNS can save water without affecting yield provided that the groundwater is maintained within 0-30 cm. In many instances, SRI rice fields have yields higher than conventional. With SRI methods, fertile tillers produce more grains per panicle whereas with rice grown under flooded, hypoxic conditions, the number of tillers per plant is negatively correlated with the number of grains per panicle (fertile tillers).

In Malaysia, the approach to addressing rice crop production has been to prove adequate irrigation water without any emphasis to educate the farmers

regarding the physiological demand for water component of rice growth. It is estimated that fees collected from farmers for irrigation provision cover only 10-12 percent of the actual operational cost. The government has since spent close to a billion USD for irrigation since the irrigation system was implemented.
SRI was introduced to rice farmers in 1980s in Madagascar by Father Henri de Laulanié. Farmers have noticed a substantial reduction in the use of water for their rice fields. Some claimed to have saved up to 30-50% of water. For instant, in Thailand, a study conducted to test the performance of rice planted under just moist condition using SRI practice have a reduction about 60% supplementary irrigation water use (Salokhe *et al, 2007)*.

Figure 7.1 : Serendah Kuning, a traditional rice cultivar at 58 days under SRI cultivation, Tanjung Karang, Selangor.

Typically, under SRI management practice, soil is kept moist with water level less than 2 cm after transplanting. During vegetative stage, the alternate wetting (<2 cm) and drying is practiced. During reproductive stage, the soil is kept under shallow water of slightly more than 2 cm. The soil is then drained 20 days before harvest. Methane emissions are reduced by keeping the fields unflooded, in doing so reduces greenhouse gas production and hence rendering SRI a more sustainable form of agriculture.

Furthermore, SRI gives hope to farmers who practice rain-fed systems without compromising on yield. Pathwardan & Patel (2008) demonstrated the potential of SRI in rain-fed conditions in Gujarat, India with a yield of 5.3 t/ha and an increase of 83-100% over the conventional method. In lowland rice, maximizing the utilization of water is imminent. Appropriate bund height around the rice fields, which is properly maintained to minimize surface drainage losses may help to store maximum amount of rainwater in the rice fields. In India, bund height, of about 22 cm were found to be able to capture 90% of the seasonal rain (Mishra et al 1997) thus greatly reducing irrigation requirement, and enhancing groundwater recharge. Rain-fed transplanted rice is generally delayed because of its dependence on intensive rainfall to facilitate soil puddling and transplanting.

3. SRI PRACTICE AND SUSTAINABLE MANAGEMENT

In traditional practice, rice straw is generally burnt in the field leading to loss of soil productivity due to reduction of biological and chemical fertility and atmospheric pollution. Under SRI, due to the inherent importance of maintaining the health of biological systems within the plant and soil, the rice is not burned but composted for the next season. The decomposition of rice straw is initially driven by aerobic respiration when oxygen is available. However, in traditional practices, anaerobic respiration prevails in flooded rice paddies and enhances more reducing conditions that may adversely affect rice growth and yield (Tanji et al, 2003). However, under SRI, the aerated soils and aerobic condition was maintained by minimal flooding, and therefore the rice straw can be left in the field under controlled composting management if the straws are left fallow. Hence, the practice of burning straw by traditional farmers to avoid this problem is common.

4. SRI AND LAND SUITABILITY ISSUES

The high temperatures, plenty of solar radiation and precipitation throughout the year experienced in most parts of Malaysia present a favourable agroclimatic condition for the practice of SRI. The extreme unevenness of rainfall, temporal and spatial as experienced in other tropical countries is not severe for Malaysia. In most cases, SRI have proven more superior than the conventional method on most tropical soil types. SRI is known to perform well on poor fertility, acidic soils. Since most Malaysian soils fall in this category, it is expected that there would be little problem in practicing SRI on Malaysian soils.

From our field trials currently being conducted, preliminary observation on the growth of SRI cultivated rice on acidic marine soil in Tanjung Karang and acidic loamy alluvial soil in Beranang may attest to this. No report, however, is available for SRI performance on highly acidic soils such as acid sulphate soils. Acid sulphate soils tend to have high soluble iron and aluminium which may compete with other nutrients (Shamshuddin, 1990). Aluminium toxicity or low Ca availability may pose a problem when the pH of the soil is less than 4.3. Furthermore, the wetting and drying as practiced in SRI may aggravate the situation as this would enhance the release of acid from the soil. However, with high incorporation of organic matter in the soil as practiced in SRI may help to reduce acidity and increase nutrient availability.

Soils exposure to reducing and oxidising condition, due to flooding and drying, during traditional paddy cultivation would influence metal uptake. Flooding in rice cultivation generates anaerobic conditions around roots for considerable periods of crop growth and causes many severe problems due to limited oxygen supply and accumulation of toxic substances, including iron (Kilcoyne *et al*. 2000). Such condition has caused the reduction and dissolution of Mn oxides, leading to the leaching of Cd in paddy soils (Wong *et al* 2002). Under SRI, the rice plant is mostly under aerated condition. Whenever submerged, mostly it is shallow and for short periods of time. SRI allows aerated condition to prevail, leading to the oxidation of iron and manganese (Fe-Mn oxide) in soils. Heavy metals which may be toxic to plants are retained by insoluble Fe-Mn oxide and therefore unavailable to the rice plants.

5. FOOD SECURITY POLICIES AND SUSTAINABLE RICE PRODUCTION

The National Food Security Policy of Malaysia implemented on 2 May 2008 aims to overcome the national food crisis situation (DOA, 2009) which steered the direction towards increasing rice self-sufficiency level from 73% (2006) to 90% (2010) (MADA, 2009). In general, strong commitment to meet the challenge of utilizing existing resources efficiency and optimally has been the fundamental objectives of the Third National Agriculture Policy (1998-2010) (EPU, 2009).

Malaysia's commitments to improve its food security level involves various strategies to increase its domestic food supply, particularly rice, through expansion of planting areas for long term measures, along with stockpiling for short term measures. In addition, the government also promotes sustainable utilizations of land for food production (Rohani Abdul Karim, 2008). Rice production under the new Food Security Policy also calls for sustainable management of agricultural inputs including agrochemical for pest and disease control. Selective breeding and production of high-quality seeds is further encouraged through several initiatives including the Certified Paddy Seeds Scheme. In order to sustain the growth in the agricultural sector, the government also seeks greater private and public investments to support its agricultural infrastructure and projects.

In developing new areas such as towards making Sarawak "The Second Rice Bowl of Malaysia" (Anon, 2008) or developing the "Rice Bowl of the East Coast" under the East Coast Economic Corridor, Malaysia has well-implemented its policy to increase rice production through area expansion. This is primarily accomplished by opening up of new areas or land conversions. With this strategy implemented, it is essential to offer farmers with sound and viable alternatives that not only can meet the demand of rice supply in the country, but also help to conserve the agro-biodiversity and natural resources. This should also mean preservation of the farming tradition and heritage of the community involved, particularly rural and indigenous rice farmers.

6. SRI AND SUSTAINABLE RICE PRODUCTION

Sustainable rice production has been suggested through various strategies such as integrated crop management (Clampett, 2002), integrated pest management (Gallangher, 2002) and integrated nutrient management (White *et al*, 1997) or integrated natural resources management (Kam, 2003). Ultimately, sustainability would be achieved with increased agricultural production and productivity through improved technologies that are eventually released to be utilized effectively and proficiently by the farming community.

As Malaysia embarks on its long term strategy to increase rice production through land expansion, where thousand hectares of land will be dedicated to rice, it is important to also provide alternatives to farmers of various scales with appropriate technology and projects that suit their capacities and local ecosystems.

Essentially, food security goals cannot be achieved without an increase in agricultural productivity and production capacity. (FAO, 2008) suggests that high rice yields are obtained only when water supply is adequate. To a large extend, rice production and productivity in Malaysia is still limited by water availability. Initial efforts through the establishment of the Muda Irrigation Scheme in the 1950's has successfully enable the planting of two crop cycles of rice per year through the drainage and irrigation system in West Kedah and Perlis. Currently, the Muda Agricultural Development Authority (MADA) scheme covers 96,000 hectares of paddy fields that produces about a million metric tonnes of paddy a year, accounting for 40 percent of the country's total rice production (John & Adib, 2008). Thus, it is important to note that a large percentage of the paddy planted areas (670,000 hectares in 2007) (AFSIS, 2009) outside the coverage of MADA or KADA or other assisted projects (Amin et. al, 2006) is still confronted with low production and productivity due to water management and productive resources issues. In Sabah, for example, irrigated paddy areas has increased from 1,600 ha from year 1967 to over 15,000 in year 1999 (DID, 2009). Total planted area for Malaysia was 692,400 hectares in 1999 (AFSIS, 2009).

In its report, (FAO, 2008) also suggests that integrated crop management systems need to be transferred to help farmers in effective cultivation of rice so that they could obtain higher yield, reduce the production cost, save water and minimize the damages to the natural resources and environment, thus permitting sustainable intensification of rice production for food security. With this projection, SRI technique could be offered to meet policy objectives, and an alternative to aerobic rice cultivation and alternate wetting-and-drying (AWD) cycles of irrigation management.

With great flexibilities of SRI, the technique can be applied and explored for potential gain in rice cultivation that could help to converse agro-biodiversity and the balance of local ecosystems. The challenge to mitigate climate change and manage natural resources could be facilitated through the water saving feature of SRI. Combined with the proven flexibilities and suitability for organic production (Nagrak Organic SRI Centre, 2009). SRI could also provide quality, safe and healthy crops for consumption, meeting the objectives of the National Food Security Policy.

Sustainable agriculture and natural resource management strategies seek to increase agricultural productivity through adoption of practices that maintain the long term ecological and biological integrity of natural resources. Activities in rice production cut across the rural, social and environmental issues of natural resource management to sustain significant increases in farm productivity through the efficient use of land and other resources. In some cases, increasing rice production through area expansion would be challenged in most parts due to water scarcity and competition for land from non-agricultural uses such as industrialization and urbanization.

Research efforts, such as on SRI should further be supported to help rice farmers boost their production efficiency through scientific knowledge and technologies in several key areas, including in optimizing utilization of available resources and reducing cost of production. In addition, policies should also encourage and offer one or more viable alternatives to protect the interests of farmers, consumers, environment and at the same time, empower farmers to participate in the decision-making process through informed choices.

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Utilizing the Tilapia Fish as A Bioindicator of the Accumulation of Potentially Toxic Metals in Ex-mining Lakes and Resevoirs

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ABSTRACT

Accumulation of heavy metals in fish has been studied in a polluted ecosystem, i.e. an ex-tin mining pool in Bidor, Perak as compared to an unpolluted ecosystem, namely Tasik Empangan Pangson, a water supply reservoir in Selangor. Tilapia (Oreochromis mossambicus) is the most dominant species in the freshwater ecosystem of the hot tropics, having been well adapted to both polluted and unpolluted waters. The accumulation of heavy metals in Tilapia was determined by the wet digestion method, using HNO_3 and $HClO_4$ (10:2), followed by Atomic Absorption Spectrometry (AAS) by Perkin Elmer. The results showed that the gut, gills and muscles of fish samples taken from the ex-mining pools in Bidor, Perak were polluted with heavy metals. The values of cadmium (Cd) in the muscles (3.13±0.03 mg/kg), gills (4.10±0.21 mg/kg), and gut (5.32±0.145 mg/kg) as well as lead (Pb) in the muscles (27.79±0.53 mg/kg), gills (41.20±0.82 mg/kg) and gut (50.91±0.51 mg/kg), respectively, were above the safety limits as stipulated under the Malaysian Food Act 1983 and Food

Regulations 1985. However, arsenic (As), nickel (Ni) and zinc (Zn) were below the standard permissible limits. In contrast, the heavy metals content in the water and also in the Tilapia samples collected from the Tasik Empangan Pangson, which represented a very clean unpolluted habitat were recorded to be lower than the stipulated permissible limits. Among the three body parts studied, muscles showed the lowest level of metal accumulation, followed by the gills and gut. In the aquatic environment, the food chain constitutes an important route for the accumulation of metals, especially for those organisms at the higher trophic levels because the effects of metal pollution is cumulative in nature. Fish provides the main source of protein for the local consumers, thus the utilization and management of ex-mining pools for aquaculture activities require close supervision and monitoring to ensure the safety of food source for local consumption.

INTRODUCTION

Water bodies such as fresh water lakes as well as artificial lakes such as dams and ex-mining ponds can function as sinks for various pollutants carried by runoffs from the surrounding areas. The rapid pace of urban development in Malaysia to date has given much stress upon the current land use such that those areas previously left idle or considered as marginal (for example, tin tailings), are now developed for agriculture, farming and aquaculture (Ang, 1994; Ramli & Ang, 1999; Ho, et al. 2008).

This study compares the levels of metals that are potentially toxic (PTEs) in fish, lakewater and bottom sediment of an unpolluted area (impounded lake, Tasik Empangan Pangson, Selangor) and a polluted area (ex-tin mining pool in Bidor, Perak). Monitoring of PTEs in the polluted area requires a detection method that is rapid, cost-effective and reliable to evaluate the acute and chronic effects of pollutant loads and toxic compounds in the water bodies as a precautionary measure in resource management involving public health and safety. Results of the study has health implications because the Tilapia (*Oreochromis* spp.) is a popular table fish that is cultured in large numbers in the ex-mining pools by the local farmers and the fish harvest is consumed by a large section of the local community (Abdullah, et al. 2000; Ang, et al. 2000).

The second objective of this study is to screen for suitable bioindicator candidates to be used in the monitoring of heavy metals accumulation, especially potentially toxic elements such as As, Hg, Cd and Pb. Studies by other researchers had identified fish as one of the significant bioaccumulating agents for PTEs, apart from rooted aquatic plants and benthic organisms such as gastropods and bivalves (Price, 1979; Salmijah, et al. 2000). Water from the ex-mining pools in Bidor reportedly contained trace or small amounts of PTEs (Ang, et al. 2000), however, sediments contained higher concentrations of PTEs compared to water. Organisms (biota) in the aquatic ecosystem can accumulate and concentrate specific pollutants such as heavy metals and persistent pesticides such as organochlorines, and these were subsequently accumulated through the food web, until they reached significant toxicity in organisms in the highest trophic levels such as large carnivores and humans.

Pollutants that enter the aquatic environment can cause acute toxicity that could result in death or mortality of the impacted organisms, or otherwise chronic morbidity effects that gradually affect growth, reproduction and general physiology of sensitive species. Thus, biological evaluation of the pollution levels can be used to identify changes in the habitat components such as the water quality and characteristics of the bottom sediment, which would affect the response of the biota and aquatic communities in the ecosystem.

Biological, toxicological and water quality data can measure directly the impact of one or several sources of stress upon the aquatic biota (Barbour, et al. 1997). Such data are very significant in the biocriteria to assess pollution impacts and the efficacy of mitigation and control measures in handling the water quality issues (Barbour, et al. 1997). Normally, local bioindicators and biocriteria are more suitable and relevant to the existing environment, whereby the structures and functions of biotic communities are much influenced by specific characteristics such as water quality and clarity, flow rate, types of substrate, vegetation, etc., which form part of the habitat (Inger & Chin, 1962, Lowe-McConnell, 1975). In Malaysia, suitable bioindicators can be identified among the main components of the freshwater ecosystem, i.e. macrophytes, fish, amphibians, plankton and benthic macroinvertebrates (Abas, et al. 2000). Although many studies have been reported (Badri, 1990; DOE, 1999), however, an integrated effort in the evaluation of PTEs and screening of pollutant loads in freshwater biota at the national and regional levels have not be implemented yet.

MATERIALS AND METHOD

Sampling of fish was conducted in three selected study sites, which were ex-mining pools (covering an area of 30 acres) in Bidor, Perak and Tasik Empangan Pangson, Selangor. Fish samples for determination of heavy metals were harvested by cast netting and fish traps. Water and sediment samples were also collected from the study sites. All the samples (fish, water and sediment) were immediately taken to the UKM laboratory in a cool box for further analysis. Each fish was rinsed thrice in distilled water, then separated into gills, gut and muscles. Each fresh body part was weighed, then dried in the oven at 80^{o}C to constant weight. The cooled dried samples were finely ground into powder with a pestle and mortar to facilitate digestion. Samples of sediment and fish body parts were digested with concentrated nitric acid and perchloric acid according to the AOAC standard methods (1984), whilst the water samples were filtered prior to metals analysis according to the AOAC standard methods (1984).

The heavy metals studied were Pb, Zn, Cu, Cd, As, Fe, Mn, Al and Ni, but the last four metals were only analysed for fish samples collected from Bidor because the latter represented a polluted ex-mining site. The metals content in all the samples were determined by atomic absorption spectrometry (Perkin Elmer model 4100). All samples were analysed at least in triplicates.

RESULTS AND DISCUSSION

The results are summarized in Tables 8.1 to 8.7 and Figures 8.1 and 8.2, and showed that the gills and gut of Tilapia collected from ex-mining pools in Bidor were tainted with certain heavy metals at high levels (Table 1). The mean concentration of Cd was highest in the gut (5.32±0.14 mg/kg), followed by the gills (4.10±0.21 mg/kg) and muscles (3.13±0.03 mg/kg), and the levels for Cd were above the safety limits as stipulated under the Malaysian Food Act 1983 and Food Regulations 1985. Likewise, the Pb level was highest in the muscles, followed by the gills and gut (27.79±0.53, 41.20±0.82 and 50.91±0.51 mg/kg dry weight, respectively). The accumulation range of Pb in fish from Bidor (Figure 8.1 and Table 8.1) was well above the stipulated minimum level of 2.0 mg/kg, and relatively high compared to the other heavy metals (i.e. As, Cd, Ni and Zn). However, levels of As, Ni and Zn were below the allowable limits (Table 8.2)(Abdullah, et al. 2000; Ang, et al. 2000). High levels of PTEs in the food source are associated with health risk implications to the consumers in the long term if the daily protein source is derived mainly from Tilapia consumed in substantial amounts on a regular basis.

Table 8.1 : Range of PTEs levels in Tilapia collected from ex-mining pools of Bidor

Fish samples	Composite Samples (n)	Lead (Pb)	Arsenic (As)	Cadmium (Cd)
Range of PTEs levels in Tilapia (mg/kg)	4	**27.26 - 28.32***	0.14 - 0.23	**3.10 - 3.16***
Allowable limits #		2.0	1.0	1.0

* PTEs values in fish that exceeded the allowable limit under the Malaysian Food Act 1983 and Food Regulations 1985

\# Allowable limit under the Malaysian Food Act 1983 for any type of foods

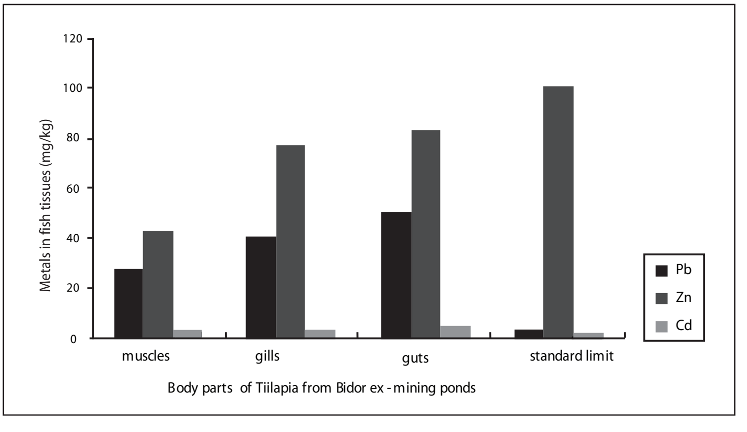

Figure 8.1 : Levels of PTEs in Tilapia from ex-mining pools in Bidor, Perak.

In contrast, analysis of Tilapia samples from Tasik Empangan Pangson in Selangor showed that the levels of heavy metal in the gills, gut and muscles were below the allowable maximum limit for food materials (Figure 8.2 and Table 8.2). The

PTEs levels in decreasing order in the fish gills are:

Pb >Cu >Zn >Cd (0.13±0.002, 0.009±0.0001, 0.001±0.0001 and 0.091±0.001 mg/kg, respectively, Figure 8.2).

For the fish gut, the PTEs levels in decreasing order are:

Zn >Cu = Pb >Cd (0.007±0.0001, 0.005±0.0001, 0.005±0.002 and 0.001±0.0001 mg/kg, respectively, Figure 8.2).

Likewise, in the fish muscles, the PTEs levels in decreasing order are;

Pb > Zn> Cu >Cd (0.008±0.002, 0.005±0.0001, 0.003±0.0001 and 0.001±0.0003 mg/kg respectively, Figure 8.2).

Table 8.2 : Concentrations of heavy metals in Tilapia (µg/g) from Tasik Pangson

Sampling Stations	Pb	Zn	Cu	Cd	As
Gills of *O. niloticus*	0.006±0.004	0.009±0.0001	0.030±0.000	0.001±0.0002	ND*
Gills of *O. mossambicus*	0.013±0.002	0.009±0.0001	0.091±0.001	0.001±0.0001	ND
Gut of *O. niloticus*	0.005±0.002	0.007±0.0001	0.005±0.0001	0.001±0.0001	ND
Muscles of *O. niloticus*	0.133±0.001	0.004±0.0001	0.009±0.0001	0.001±0.0001	ND
Muscles of *O. mossambicus*	0.008±0.002	0.005±0.0001	0.003±0.0001	0.001±0.0003	ND
Lake water mg/L	0.007±0.002	0.021±0.019	0.003±0.002	0.007±0.002	ND
Limit in food mg/kg #	2.0	100	30	1.0	

(#) Maximum allowable limit in foods by the Malaysian Food Act 1983 and Food Regulations 1985; * ND = not detectable

Heavy metals could be accumulated in the fish through intake of water and food mixed with sediment, especially for species that live and forage at the bottom of lakes, such as Tilapia (Mohsin & Ambak, 1991). Runoffs containing sediment loads enter the lake and form part of the bottom sediment that acts as a sink for the pollutant loads and a medium for heavy metals to enter the fish via its gills and gut. The availability of samples for bioaccumulation studies is very important of considering that previous studies (Price, 1979; Badri, 1990; Salmijah, et al. 2000) have reported that fish was a good bioindicator for PTEs. Further detailed studies should look into aspects of accumulation of metals in the local fish species and other aquatic organisms. In fact the U.S. Environmental Protection Agency has also recommended that biological data should be used to support enforcement of laws and in strategies for water resource management (Barbour, et al. 1997). Such data are considered invaluable in monitoring multiple and dispersed pollution sources such as agricultural effluents and surface runoffs.

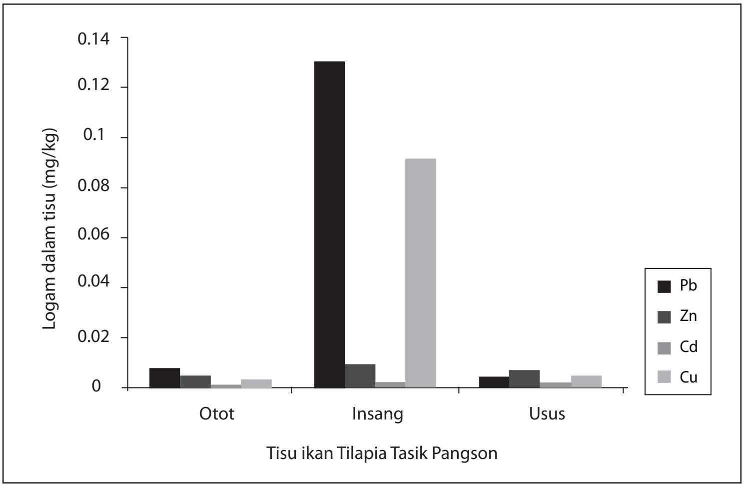

Figure 8.2 : Levels of PTEs in Tilapia from Tasik Empangan Pangson, Selangor

Table 8.3 : Concentrations of Pb, Cd and As in soils from tin tailings and water from ex-mining pools in Bidor, Perak

PTEs	Limits in mineral soils (mg kg^{-1})*	Sand (mg kg^{-1})	Agricultural sand (mg kg^{-1})	Sludge (mg kg^{-1})	Agricultural soil (mg kg^{-1})	Water (mg l^{-1})
Pb	300	3.91-21.82 (n=14)	3.57-18.21 (n=22)	13.97-18.27 (n=4)	8.92-22.41 (n=4)	<0.01-1.55 (n=8)
Cd	3	0.02-2.33 (n=23)	<0.01-2.62 (n=22)	0.10-1.33 (n=23)	0.10-0.97 (n=4)	<0.01-0.02 (n=8)
As	50	0.02-4.48 (n=18)	0.39-3.12 (n=26)	0.03-3.18 (n=8)	0.68-2.98 (n=4)	<0.001-0.132 (n=8)

Note: Source adapted from Smith (1996).* Allowable limits of PTE in mineral soils

Water from the ex-mining pools of Bidor contained low concentrations of Pb and Cd in the range of 0.01-1.55 mg/L for Pb and 0.01-0.02 mg/L for Cd. Values for both were higher than the Pb and Cd levels in water taken from Tasik Empangan Pangson (Table 8.3, 8.4 & 8.5). This showed that water from the latter habitat was free from Pb and Cd pollution. In general, the levels of Pb, Cd, Zn and Cu in the water of Tasik Empangan Pangson were still in the minimal range, and based on Sarmani (1989) the concentration ranges of Pb, Cd, Zn and Cu obtained were representative of natural values for such habitats.

Table 8.4 : Values of pH and heavy metals in the water and sediment collected from the ex-mining pools of Bidor, Perak.

Parameter	No. of samples (n)	Site 1	Site 2	Site 3
1. Water (mg/L)				
pH	2	5.0(4.9-5.1)	4.2(4.2)	4.3(4.2-4.4)
Pb	2	ND*	ND	ND
Mn	2	0.02(0.02)	0.01(0.01)	0.05(0.05)
Cu	2	ND	ND	ND
Cd	2	ND	ND	ND
Zn	2	0.12(0.12)	0.095(0.10-0.09)	0.05(0.05)
2. Sediment (mg/kg)				
pH	2	4.96(4.86-5.06)	5.12(5.12)	6.30(6.26-6.33)
Pb	2	43.65(42.09-45.24)	50.11(49.04-51.17)	37.66(37.30-38.01)
Mn		60.58(60.51-60.65)	25.60(25.26-25.93)	44.44(43.42-45.46)
Cu	2	7.93(7.79-8.07)	12.82(12.47-13.16)	14.41(14.04-14.78)
Cd	2	0.45(0.43-0.47)	0.86(0.83-0.88)	0.605(0.60-0.61)
Zn	2	82.76(82.19-83.32)	84.03(82.32-85.73)	40.65(39.76-41.53)

* ND = not detectable

Most potentially toxic elements in the surface water and tin-tailing soils are derived from geological rock formation and its sedimentation, except for Cd (Ramli & Ang 1999). For example, Pb originates from galena (PbS) and cerussite ($PbCO_3$), while As is probably derived from arsenopyrite (FeAsS) and Cobaltite (CoAsS). According to Ang, et al. (1999) PTEs could also be the by-products of mining and mineral extraction activities as well as the smelting of ores. Furthermore, some agricultural practices could also be a source of PTEs inputs, for example, the empty fruit bunches and chicken dung used as compost feed by farmers also contained substantial amounts of PTEs (Ang, et al. 2000).

In the aquatic environment, the fish communities were influenced by the habitat type, differentiated according to specific characteristics such as water quality, bottom substrate, depth and flow of the water (Mohsin, & Ambak, 1991). The species-habitat relationship is a fundamental aspect of community ecology including that of the fish population (Inger & Chin 1962). For any particular habitat, specialization in food source occurs so as to avoid niche competition among the various members of the community, and PTEs could be concentrated along the food chain in an ecosystem which is not too complex, such as that of a small river, pond or lake.

Table 8.5 : Concentrations of heavy metals in water (mg/L) from Tasik Pangson Selangor

Sampling station	Pb	Zn	Cu	Cd	As
1	0.006±0.004	0.053±0.040	0.002±0.001	0.004±0.003	# ND
2	0.003±0.003	0.011±0.009	0.003±0.003	0.001±0.000	ND
3	0.008±0.003	0.011±0.004	0.002±0.001	0.014±0.005	ND
4	0.008±0.001	0.035±0.022	0.007±0.001	0.002±0.001	ND
5	0.010±0.010	0.006±0.001	0.001±0.000	0.013±0.002	ND
6	0.005±0.003	0.008±0.021	0.001±0.001	0.002±0.001	ND
Average	0.007±0.002	0.021±0.019	0.007±0.005	0.003±0.001	ND
*Allowable limits	0.05	5.0	0.005	1.0	

* Maximum allowable limit in water by the Malaysian Food Act 1983 and Food Regulations 1985; #ND = not detectable

Note: sediment samples were not available because the bottom of Tasik Pangson was too deep.

The bioaccumulation studies of heavy metals conducted by Salmijah, et al. (2000) in Tasik Putrajaya and some other areas in Malaysia indicated that the heavy metals in water taken from most sampling stations were below the permissible limits stipulated by the Malaysian Interim National Water Quality Standards. Rooted macrophytes such as *Cyperus digitatus* that thrived in lakes and ex-mining ponds were able to accumulate large amounts of Fe and Mn in their tissues, especially the roots, while macrobenthos such as the aquatic snails were also efficient accumulators of metals such as Cu and Zn.

Table 8.6 : Physico-chenical parameters of water from Tasik Pangson Selangor

Water parameters	Sampling station (mean ±s.d.)		Average
	1	2	(mean ±s.d.)
Temperature ('C)	30.91±3.83	28.63±0.23	29.77±1.61
DO (mg/L)	5.35±0.32	7.45±0.49	6.40±1.48
pH	6.53±0.15	7.48±0.13	7.01±0.67
Conductivity (µS/cm)	36.83±3.89	34.45±0.08	35.64±1.68
Turbidity (FAU)	10.17±0.75	8.67±1.86	9.42±0.16
Clarity (m)	2.22±0.16	2.44±0.19	2.30±0.16
Clarity (m)	11.17±8.98	9.47±5.29	10.30±1.20
Nitrates (mg/L)	1.57±0.10	0.77±0.41	1.17±0.57
Phosphates (mg/L)	0.14±0.20	0.30±0.45	0.22±0.11

In the study of PTEs accumulation in the tissues of several species of wild fish from a mildly polluted natural lake, i.e. Tasik Chini in Pahang, Abas, et. al (2001) noted that the concentrations of metals were highest in the sediment, followed by those in the fish tissues. However, levels of Pb, Zn, Cu, Cd, Ni and Cr were lowest in the water compared to those in the fish and sediment, while the PTEs in the water samples were well below the permissible limits stipulated under the Malaysian Drinking Water Standards. The PTEs levels in the fish collected from unpolluted areas were also well below the maximum allowable limits for food materials in Malaysia (Legal Research Board, 1997).

Table 8.7 : Comparative levels of Cd and Zn in the tissues of Tilapia (mg/kg) collected from various areas

Species	Muscles	Gills	Head	Gut
Tilapia rendalli (Berg, et al. 1995)*	Cd:1.4 – 2.6 Zn: 20.9 – 26.9	- -	- -	- -
O. mortimeri (Berg et al. 1995)	Cd:1.2 – 1.3 Zn: 18.4 – 22.4	- -	- -	- -
O. mossambicus (Badri, 1988)	Cd: 1.08 Zn: 27.5	- -	Cd: 1.14 Zn: 43.77	Cd: 1.96 Zn: 56.26
O. mossambicus (Tasik Bidor)	Cd: 3.13 Zn: 43.26	Cd: 4.10 Zn: 43.26	- -	Cd: 5.32 Zn: 82.49

Note: *fish sampled from Kariba ex-mining pool, Zimbabwe.

Abas, et al. (2000) reported that most PTEs studied were positively correlated with pH, organic content and particle size of the sediment. Measurement of some abiotic parameters from Tasik Pangson, i.e. water temperature, dissolved oxygen, pH, conductivity, turbidity, nitrates and phosphates of the water (Table 8.6) indicated that the water quality was in class I-III for Pb and in class I-IV for Cu according to the Interim Classification for Rivers in Malaysia (Department of Environment, 2000). Denny, et al. (1995) noted that in general, the levels of Cu in freshwater was about 1.0 ug/L. The concentrations of Pb, Zn, Cd and Cu in water and tilapia fish in the Pangson Dam were lower than the stipulated permissible limits (Figure 8.2 & Table 8.2), therefore those fishes were safe for consumption and the levels of metals pollution were below the normal range for most areas (Table 8.7). Tilapia also showed good potential as a bioaccumulative organism for metals in the aquatic environment (Badri, 1990; Berg, et al. 1995; Salmijah, et al. 2000).

RECOMMENDATIONS AND CONCLUSION

Water bodies used for water supply and agricultural needs should be monitored regularly for the presence of pollutant loads and toxic compounds in amounts that can jeopardise the human health and that of other organisms (Price, 1979). This study is part of an effort to accumulate and update the database necessary for the proposed integrated management of water quality at the local and regional levels (Barbour, et al. 1997). Water resource management can utilize the study results from various sources and sectors in planning the administrative policies and assessing the potential risk to biological resources and human health, for example, in considering the benefits and risks of utilizing degraded and marginal areas such as tin tailings and ex-mining pools for aquaculture, farming and agricultural activities.

Toxic metals are usually accumulated in fish through filtration and ingestion of food and organic particles in the water and sediment. The lake water might contain only trace or small amounts of PTEs, however, higher concentrations are found in the sediment, which could be churned up and resuspended in the water by mechanical disturbance of the lake bottom. The metals As, Pb and Cd were found in the sludge and water of the ex-mining pools in Bidor (Table 3), however, none of those elements were found in levels that exceeded the permissible limits for water quality intended for agricultural use (Smith 1996). Aquatic plants and small fishes that may provide food for the larger fishes could also be polluted by the PTEs. This study found that the gut contents of Tilapia contained high levels of PTEs, indicating that filtration and ingestion processes were the main routes of PTE uptake and subsequent accumulation into the body tissues of the fish.

Should there be any risks of PTEs pollution in fish and other produce harvested from contaminated agricultural areas, then the authorities and stakeholders should adopt the judicious approach of safe practices and constant vigilance to ensure public health and safety. For instance, in ex-mining pools it would be more prudent to operate the floating cage culture system, that utilizes only the upper parts of the water bodies that are relatively unpolluted, while using commercial feedstock can reduce the risk of fish obtaining its food from the bottom sediment known to contain high levels of PTEs. Selection of suitable species of fish for cage rearing is also important, for example, to avoid mass rearing of bottom dwelling species such as the catfishes, while the rate of uptake and accumulation of heavy metals in fish and other aquatic resources should also be monitored to ensure the public health and safety of the consumers.

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