SEBERANG PERAI RICE SCHEME IRRIGATION WATER QUALITY ASSESSMENT

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ABSTRACT

Rivers are the main sources of water for agricultural purposes in Malaysia. The Seberang Perai Rice Irrigation Scheme in the state of Penang is one of the eight main rice growing areas in Malaysia. The scheme consists of five (5) sub-schemes and irrigation water for each sub-scheme are supplied from either the Muda river, Jarak river, Kulim river or the Kerian river with pumping or gravity intakes. Agricultural fertilisation entails significant economic and environmental costs. Nitrogen (N) is the most commonly applied nutrient in crop production. However, excess N inputs, pesticides, and herbicides for rice crop not only adds costs to crop production but can be environmentally damaging to the plant and the environment. This study was carried out to improve irrigation water quality in order to ensure that environmental concerns are built into the operation and monitoring activities of the rice irrigation scheme. Water quality data were used to determine the water quality status whether in clean waters (80-100), slightly polluted waters (60-<80) or very polluted waters (<60) category and to classify the rivers in Class I, II, III, IV or V based on existing Water Quality Index (WQI). From 18 years-data for the period from 1990 – 2007, Water Quality Index (WQI) was computed based on 6 parameters: Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Ammoniacal Nitrogen (NH_3N), pH, Dissolved Oxygen (DO) and Suspended Solids (SS) as a means for water quality assessment. Increasing DO concentration and concurrent low concentrations of BOD and COD is the trend in the scheme. WQI calculated in this study ranged from 69.9% to 82.2%. Two rivers (Kerian and Jarak River) were considered slightly polluted in comparison with the general rating scale of the water quality index. Agricultural activities may be contributing to this trend, but water quality nonetheless is also affected seriously by through industrial and domestic use. The data also showed that the Muda and Kulim River is relatively clean. However, there is not much difference in the water quality index of the four rivers, between upstream and downstream sections. Based on the results of this study and it must be qualified here that the results are only referring to the period of the data sourced, the water quality of the rivers can be classified into Class III and IV by on overall river classification based on the DOE-WQI. The results of this study can be a basis for future studies on irrigation water quality in the other projects.

Keywords: *Rice Irrigation, Seberang Perai Scheme, Water Quality Assessment, Water Quality Index*

1.0 INTRODUCTION

Water scarcity, pollution, and other water-related environmental and ecological problems have been increasing rapidly in many areas of the world. In some countries and regions, water is already being transferred out of irrigation and into urban industrial uses, putting additional stress on the performance of the irrigation sector [4]. Although the achievements of irrigation in ensuring food security and improving rural welfare have been impressive, past experience also indicates problems and failures of irrigated agriculture. In addition to large water use and low efficiency, environmental concerns are usually considered the most significant problem of the irrigation sector. Environmental problems include excessive water depletion, water quality reduction, waterlogging, and increase salinity. The marked reduction in annual discharge of some of the world's major rivers, evident in long-term hydrological records has been attributed, in part, to the large water depletion as a result of irrigated agriculture. In some basins, excessive diversion of river water for irrigation (and other uses) has brought environmental and ecological disasters to downstream areas. Groundwater pumping at unsustainable rates has contributed to the lowering of groundwater tables and to saltwater intrusion in some coastal areas. Many water quality problems have also been created or aggravated by changes in stream flows associated with agriculture's consumptive uses. Moreover, inappropriate irrigation practices, accompanied by inadequate drainage, have often damaged soils through over-saturation and salt build-up. The United Nations Food and Agriculture Organisation estimated that between 60 to 80 million hectares are affected to varying degrees by water logging and salinity [1]. Finally, these irrigation induced environmental problems threaten not only agricultural production systems but also human health and the environment.

Improved water management can help minimise offsite water quality impacts of irrigated production. Irrigated agriculture affects water quality in several ways, including higher chemical-use rates associated with irrigated crop production, increased field salinity resulting from applied water, accelerated pollutant transport with drainage flows, groundwater degradation due to increase deep percolation to saline formations, and greater in-stream pollutant concentrations due to flow depletion. Although agriculture is usually associated with its positive impacts on human life, irrigation practices may be associated with negative impacts on environmental conditions, which may eventually curtail the sustainability of irrigation projects. Environmental management of available rice water is essential for increased crop production. Environmental management that improves irrigation efficiency has the potential to greatly increase rice production as well as social livelihood. Irrigation projects have an imperative importance in third world countries to realise development policies like poverty reduction and food self sufficiency but such projects are usually given much societal considerations nevertheless they should be environmental friendly so as to assure their sustainability maintaining the existing productivity.

In the past, the environmental problems in Malaysia were largely due to discharges from the agro-based sector mainly rubber and palm oil industries, and domestic sewage. The control of pollution from processing of raw natural rubber and crude palm oil has proven to be very successful and resulting in the organic wasteload reduction of more than 90% of the total load generated. As the country progresses in industrialisation, a new set of environmental problem emerges.

Table 1: River water quality parameters for morning system

	Water Quality Classes*					
Parameter	**I**	**IIA**	**IIB**	**III**	**IV**	**V**
Ammoniacal Nitrogen (NH_3N) (mg/l)	0.1	0.3	0.3	0.9	2.7	2.7
BOD (mg/l)	1	3	3	6	12	12
COD (mg/l)	10	25	25	50	100	100
DO (mg/l)	7	5-7	5-7	3-5	3	1
SS (mg/l)	25	50	50	150	300	300
pH	6.5-8.5	6.5-9.0	6.5-9.0	5.0-9.0	5.0-9.0	–
Phosphorus (mg/l)	N.L	< 0.2	< 0.2	< 0.1	–	0.1 <
Nitrate (mg/l)	–	–	–	–	–	

N. L. = Natural levels

Source: Department of Environment, Malaysia

**Class I : (Water Supply I) No treatment necessary, (Fishery I) Acceptable for very sensitive aquatic species*

**Class IIA : (Water Supply II) Conventional treatment required, (Fishery II) Acceptable for sensitive aquatic species*

**Class IIB : Acceptable for recreational use with body contact*

**Class III : (Water Supply III) Extensive treatment required, (Fishery III) Acceptable for common and tolerant species. Acceptable for livestock drinking*

**Class IV : Acceptable for irrigation*

**Class V : None of the above*

Table 2:. Formulae for calculation of Water Quality Index (WQI)

Index	WQI Calculation	Ranges
NH_3N (SIAN)	$= 100.5 - 105\ x$ $= 94\ e^{0.573x} - 5 \mid x - 2 \mid$ $= 0$	For $x \leq 0.3$ For $0.3 < x < 4$ For $x \geq 4$
BOD (SIBOD)	$= 100.4 - 4.23\ x$ $= 108\ e^{0.053x} - 0.1\ x$	For $x \leq 5$ For $x > 5$
COD (SICOD)	$= - 1.33\ x + 99.1$ $= 103\ e^{0.0157x} - 0.04\ x$	For $x \leq 20$ For $x > 20$
DO* (SI DO)	$= 0$ $= 100$ $= - 0.395 + 0.03\ x^2 - 0.0002\ x^3$	For $x \leq 8$ For $x \geq 92$ For $8 < x < 92$
SS (SISS)	$= 97.5\ e^{0.00676x} + 0.05\ x$ $= 71\ e^{0.0016x} - 0.015\ x$ $= 0$	For $x \leq 100$ For $100 < x < 1000$ For $x \geq 1000$
pH (SIPH)	$= 17.2 - 17.2\ x + 5.02\ x^2$ $= - 242 + 95.5\ x - 6.67\ x^2$ $= - 181 + 82.4\ x - 6.05\ x^2$ $= 536 - 77\ x + 2.76\ x^2$	For $x < 5.5$ For $5.5 \leq x < 7$ For $7 \leq x < 8.75$ For $x \geq 8.75$
WQI	= 0.15 x SIAN + 0.19 x SIBOD + 0.16 x SICOD + 0.22 x SIDO + 0.16 x SISS + 0.12 x SIPH	

** = DO is in % saturation*
x = concentration in mg/l for all parameters except pH

The major sources of water pollution in the country remain as sewage disposal, discharges from small and medium-sized industries that are still not equipped with proper effluent treatment facilities and land clearing and earthwork activities. Based on 2005 records, 52 river basins (44%) were polluted with suspended solids (SS) resulting from poorly planned and uncontrolled land clearing activities; 18 river basins (15%) with high biochemical oxygen demand (BOD) resulting from industrial discharges; and 33 river basins (28%) polluted with ammoniacal nitrogen (NH_3N) from animal husbandry activities and domestic sewage disposal [5]. The objective of the study is to analyse irrigation water quality for better management and monitoring activities of a rice irrigation scheme, in this case the Seberang Perai Scheme.

2.0 STUDY AREA

Although irrigation in Malaysia is almost entirely devoted to rice cultivation, rice production still fall short of the demand of an increasing population. The eight designated granaries (granary areas are by law not allowed to be used for purposes other than rice growing) totaling 217,000 ha are located for rice cultivation in Malaysia producing 65% of the country's needs. However, with the addition of about 45,000ha of land put under rice cultivation in Sabah and Sarawak in 2009, it is expected to raise the level to some 85%. With the changing trends among the younger population going with less rice as a staple, the country may see a surplus for export in the near future. The Seberang Perai Rice Irrigation Scheme is located at about 100^0 8' ~ 100^0 32'E longitude and 5^0 8' ~ 5^0 32'N latitude. The scheme area covers an area of 10,999 ha of rice land. The scheme consists of five sub-schemes and has four main water sources. The irrigation water for the Sungai Muda and the Pinang Tunggal sub-schemes is taken from the Muda river through the Bumbong Lima pump station and the Pinang Tunggal pump station, respectively. A part of water pumped up at Pinang Tunggal pump station flows into the Kreh river, a tributary of the Jarak river and is then used as irrigation water for the Pokok Tampang Block in the Sungai Jarak sub-scheme. A headwork and the Padang Cempedak pump station on the Jarak river also supply water to the Pokok Tampang Block as well as the Padang Menora Block also in the Sungai Jarak sub-scheme. The Sungai Kulim sub-scheme is provided irrigation water from the Sungai Kulim headworks on the Kulim River. In the Sungai Acheh sub-scheme, water for irrigation is mainly supplied from a headwork on Kerian river.

Table 3: General rating scale for the water quality index (Percentage) in Malaysia

<table>
<tr><th>USAGE/INDEX (%)</th><th>10</th><th>20</th><th>30</th><th>40</th><th>50</th><th>60</th><th>70</th><th>80</th><th>90</th><th>100 %</th></tr>
<tr><td>GENERAL</td><td colspan="6">VERY POLLUTED</td><td colspan="2">SLIGHTLY POLLUTED</td><td colspan="2">CLEAN</td></tr>
<tr><td>PUBLIC WATER SUPPLY</td><td colspan="4">NOT ACCEPTABLE</td><td>DOUBTFUL</td><td colspan="3">NECESSARY TREATMENT BECOMING MORE EXTENSIVE</td><td>MINOR PURIFIC REQUIRED</td><td>PURIFICATION NOT NECESSARY</td></tr>
<tr><td>RECREATION</td><td colspan="2">NOT ACCEPTABLE</td><td>OBVIOUS POLLUTION APPEARING</td><td>NOT FOR BOATING</td><td>DOUBTFUL FOR WATER CONTACT</td><td colspan="2">BECOMING POLLUTED STILL ACCEPTABLE NEED BACTERIA COUNT</td><td colspan="3">ACCEPTABLE FOR ALL WATER SPORTS</td></tr>
<tr><td>FISH, SHELLFISH AND WILDLIFE</td><td colspan="3">NOT ACCEPTABLE</td><td>COARSE FISH ONLY</td><td>HANDY FISH ONLY</td><td>DOUBTFUL FOR SENSITIVE FISH</td><td>MARGINAL FOR TROUT</td><td colspan="3">ACCEPTABLE FOR ALL FISH</td></tr>
<tr><td>NAVIGATION</td><td colspan="3">NOT ACCEPTABLE</td><td>OBVIOUS POLLUTION APPEARING</td><td colspan="6">ACCEPTABLE</td></tr>
<tr><td>TREATED WATER TRANSPORTATION</td><td>NOT ACCEPTABLE</td><td colspan="9">ACCEPTABLE</td></tr>
<tr><td></td><td>10</td><td>20</td><td>30</td><td>40</td><td>50</td><td>60</td><td>70</td><td>80</td><td>90</td><td>100 %</td></tr>
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3.0 WATER QUALITY ANALYSIS

An environmental water management program requires information including the existing water quality, the influence of human activities on water quality and criteria for the present and planned uses. This information can be generated only from a record of long term water quality data and past experience of the use of water of known quality for the various purposes.

Parameters

A permanent water quality monitoring system that is designed particularly to check the quality of drainage water from the paddy fields as well as to monitor effectiveness of management actions such as controlling the use of agro-chemicals by farmers would be of utmost importance but however, currently is not available. Table 1 indicates a list of the parameters, which is a minimum requirement set required for a monitoring system. Other parameters can be included when it is necessary. The standard value of each parameter within the various water quality classes, which are defined by the Department of Environment, Malaysia (DOE) are also shown, and water quality should be maintained above the Class III classification at all times.

Water quality parameters were collected from DOE Pulau Pinang, during the field survey. The data from the DOE stations were analysed to give an overall picture of the water quality condition of irrigation water. In the interpretation of water quality data it is important to understand and acknowledged the spatial trends of parameters such as dissolved oxygen, biochemical oxygen demand and chemical oxygen demand. These spatial trends are especially important for water quality modeling as it will roughly indicate the assimilative capacity of the river. Changes in general water quality can also be evaluated with the water quality index (WQI) being adopted by the DOE. Using WQI values for the evaluation of drainage water allows for comparison with other water quality data.

Water Quality Index

The Department of Environment (DOE) has been conducting monitoring of rivers since 1978, primarily to establish the status of water quality, detect changes and identify pollution sources. Water quality data were used to determine the water quality status in clean, slightly polluted or polluted categories and to classify the rivers into Classes I, II, III, IV or V based on the all important WQI. The formula for the calculation of WQI is presented in Table 2, and is computed based on the six main parameters: Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Ammoniacal Nitrogen (NH_3N), pH, Dissolved Oxygen (DO) and Suspended Solids (SS). The general rating for the water quality index in Malaysia is presented in Table 3. At the moment there is apparently no systematic water quality monitoring system to particularly check a level of agro-chemicals in the water for irrigation. However, even if there is, sample sizes are expected to be rather small and data collection is not coherent and thus the data cannot be directly compared.

4.0 DATA

Technical and socio-economic field surveys were carried out in the study area. Drawing upon information identified in the literature and gathered from responses to the unstructured questionnaire, the main environmental impacts were identified, and assessed in terms of their current and likely future importance for agriculture and the environment. Much of this information was of qualitative in nature (for example, based upon expert opinion), the assessment has been a predominantly qualitative one. Data collection on rainfall, water quality parameters (BOD, COD, SS, NH_3N, DO, pH), were done during the field survey. The data covers the 18-year period of 1990 through to 2007 and was provided by DOE. Crop information relevant to the study such as fertiliser, pesticide, herbicide and yield was made available from the Department of Agriculture. Other crop information such as growth period, length of crop, agronomic practices were gathered from domain experts while a few were extracted from available publications. The knowledge on water management in the Seberang Perai Rice Irrigation Scheme was gathered from domain experts; the project engineer, assistant executives, irrigation engineers and field operation staff from the Department of Irrigation and Drainage through unstructured interviews or discussions, field visits, reports and documents available on the management aspects in the scheme.

5.0 AGRICULTURAL INPUTS

Application of Fertilisers

Urea at 100 kg/ha and compound fertiliser (17.5 : 15.5 : 10) of 200 kg/ha based on an agronomic recommendation of 80 kg of Nitrogen, 30 kg of P_2O_5 and 20 kg of K_2O are subsidised for each crop season. Most of farmers in the scheme depend on the subsidised fertiliser of about 80 kg/ha only while some farmers opted on their own to apply additional fertilisers at their own expense. Compound fertilisers are commonly used as additional fertilisers. The fertiliser application method according to the Malaysian Agricultural Research and Development Institute (MARDI) recommendation is adopted in the scheme. Average fertiliser application amounts in the scheme are as follows: Urea – 94.1 kg/ha, Compound – 156.5 kg/ha, Others – 48.9 kg/ha, Nitrogen Contents – 78.0. Applications of fertilisers by farmers who practice direct seeding are made between 14 to 75 days after seeding. Manual broadcast of fertilisers is the common practice where farmers use motor blowers. According to the "*Reconnaissance Soil Survey of Pinang and Province Wellesley*", the majority of soils in the scheme are classified as Class I or II of soil suitability class for agriculture. In general, it can be said that the scheme has the potential to support good plant growth with good yields. However, some cases of copper deficiency had been reported during the field survey.

Pesticide and Herbicide Use

Pests account for about 30% of agriculture crop losses in the field a further 10-12% in storage [3]. The pests include insects, plant diseases, weeds, mites, rats and others. Various techniques could be employed to control these pests; for example by destroying them directly (mechanical control), utilizing temperature or humidity to reduce the survival of pests (physical control), modifying the agriculture ecosystem in ways that makes it no longer suitable for pests to live in (cultural control), controlling the entry and movement of the pests (legislation control), utilizing the natural enemies of the pests (biological control), manipulating the immunity of the crop against the pest (host-plant control). The most common method used here to control pests is through chemical control using pesticide. A pesticide is known as the chemical tool used to manage all kinds of pests by controlling, preventing, repelling, destroying or mitigating any pest. The farmer's preference of using pesticides to control pests is due to pesticides being easy to obtain and use. They provide the result expected by the farmers and is probably the only tool available when there is an outbreak of the pest.

The shift to direct seeded rice in the country has aggravated the pest problem, especially weeds and insects. Apart from the impact on pest species, direct seeding has also affected the pest surveillance and forecasting techniques as the techniques were previously based on a transplanting modus operandi. Operations to control outbreaks have become more difficult to implement effectively, especially if the crop has reached the maximum tillering stage and beyond. Among the insects reportedly becoming more prominent as a result of implementing direct seeding are the brown plant hoppers and the leaf rollers.

The problem of weed competition with rice is of great economic importance in Malaysia because it causes a 10–35% reduction in grain yield. About RM14.5 million is spent annually on herbicides for rice alone, and this amounts to approximately 7% of the total expenditure on herbicides [2]. Weed management is critical to ensure good yields with the direct seeding method. Hence with the introduction and establishment of direct seeding emphasis was and is being given to weed control. It has been observed that 2 - 4 weed species are dominant in the scheme. The noxious weed, *E. crus-galli* is dominant in plots. Grassy weeds, especially *E. crus-galli* and *L. chinensis*, still remained dominant in direct-seeded rice fields. Graminicides, especially molinate, at the rate of 3.0 kg ai ha^{-1} is applied at 7 days before seeding or 14 days after seeding. Sulfonylurea herbicides such as bensulfuron, metsulfuron, pyrazosulfuron and cinosulfuron are often used for broad-leaved weed control, while chlorimuron is used in areas heavily infested by sedges in the scheme. Some farmers who adopted the practice with chemical control, usually used the phenoxy compound 2,4-D sufficiently to control the broad-leaved weeds. Farmers in the scheme are advised to prepare land well, practice good water management together with appropriate herbicide technology. The scheme stressed that water management is very important to keep weed population down in paddy field.

6.0 RESULTS AND DISCUSSIONS

6.1 Water Quality Parameters

Water pH

pH is important in natural waters and in water treatment. Aquatic organisms are sensitive to pH changes and require a pH value from 6 to 9. The pH measures in logarithmic scale 1-14, where 7 is neutral, 1 is extremely acidic and 14 are extremely alkaline. The pH values in the study area range from 5.10 to 8.15 with the average value of 6.63. The highest pH value was found in the Muda River while the lowest value in downstream of the Kerian River. The average pH values were 6.76, 6.39, 6.37 and 5.72 for the Muda, Kulim, Jarak and Kerian rivers, respectively. The pH values are slightly below neutral value. This indicates that only minimal amount of acidic industrial effluents had been discharged into the rivers. But all the pH values are within the permissible limit (Class IV) for irrigated agriculture.

Dissolved Oxygen (DO)

The DO test is one of the most important analyses in determining the quality of the natural waters. The effect of oxidation of wastes on streams, the suitability of water for fish and other organisms and the progress of self-purification can be evaluated from the dissolved oxygen content. The oxygen content of water depends on physical, chemical biological and microbiological processes.

The analysis for DO is a key test in water pollution and waste treatment process control. Oxygen is vital for the life cycle of living organisms in waterways. It is also essential to sustain species reproduction and development population. Standards for DO vary but the following recommendation serve as a guide for fresh water fish. Habitats for warm water fish population should contain DO concentrations of not less than 4.0 mg/L. Habitats for cold-water fish population should not be less than 5.0 mg/L. Rivers of the Seberang Perai Irrigation Scheme showed a wide range of DO levels ranging from 1.5 to 7.2 mg/L. The average value was found to be 4.35 mg/L which falls into Class III.

Chemical Oxygen Demand (COD)

Chemical Oxygen Demand test for natural water yields the oxygen equivalent of the organic matter that can be oxidised by a strong chemical oxidising agent in an acidic medium. For samples from a specific source, COD can be positively correlated to BOD, organic carbon or organic matter. The COD observed in natural streams and rivers may range from 2mg/L to 100 mg/L. Of the 4 DOE River sampling stations, one was found to have values greater than 50 mg/L, the standard for class III. The range of values for these four is 10-196 mg/L. But the average COD values are 8.4 mg/L, 31.36 mg/L, 13.33 mg/L and 21.88 mg/L for the Muda, Kulim, Jarak and Kerian rivers, respectively. BOD levels greater than 5 mg/L indicates the high positive correlation between BOD and COD values.

Biochemical Oxygen Demand (BOD)

The most widely used parameter in water quality analysis is the measure of the amount of oxygen used by the indigenous microbial population in water in response to the degradable organic material. The 5-day BOD (BOD5) is widely used. Typical reported concentrations of BOD5 for streams and rivers throughout the world range from 2 mg/L to 65 mg/L. BOD measures the amount of dissolved oxygen used by bacteria to oxidise organic matter in the water sample during a certain period of time. It indicates the amount of organic inputs from various sources into the rivers. Discharge from oil palm mills and rubber factories contribute to the BOD loadings in rivers of the scheme. Typical palm oil effluent and rubber effluent contain BOD ranging from 20,000-35,000 and 814-1,747 mg/L respectively. In this respect, the Kulim River falls into Class III of the DOE water quality standard, while the other 3 rivers fall into Classes I and II. The range of values for these four rivers is 1.05-6.60 mg/L.

Suspended Solid (SS)

The suspended solid test quantifies all the solids in the water, suspended and dissolved, organic and inorganic. This parameter is measured by evaporating a sample to dryness and weighing the residue. The total quantity of residue is expressed as milligrams per litre (mg/l) on a dry mass of solid basis. A drying temperature slightly above boiling (104°C) is sufficient to drive off the liquid and the water absorbed to the surface of the particles, while a temperature of about 180°C is necessary to evaporate the occluded water. SS is an important parameter to determine the level of concentration of domestic wastewater and it also affects the turbidity of water.

Solids refer to matter suspended or dissolved in water or wastewater. Solids may adversely affect water or effluent quality in a number of ways. Water high in suspended solids may be esthetically unsatisfactory for purposes such as bathing. Solids analysis is important in the control of biological and physical wastewater treatment processes and assessing compliance with wastewater effluent limits set by the regulatory agency. The highest SS value was found to be 387 mg/L in the Kulim River while the lowest value was recorded in the Kerian River.

Ammoniac Nitrogen (NH_3N)

The presence of ammonium ions in water is connected with the process of the biochemical decomposition of protein substances contained in household and industrial sewage. The presence of ammonia-nitrogen in surface water usually indicates domestic pollution. Data shows the value of NH_3N at all sampling station ranged from 0.1 mg/L to 7 mg/L. The highest NH3N value recorded at the Kulim River was 7 mg/L and the lowest NH3N value recorded at the Muda River was 0.1 mg/L. The highest value of NH3N was most probably due to the discharges from scattered industrial activities and a probable malfunctioning sanitation system.

6.2 Water Quality Indices

The water quality index is a mathematical instrument used to transform large quantities of water quality data into a single number which represents the water quality level while eliminating the subjective assessments of water quality and biases of individual water quality experts. The WQI is a method that combined numerous water quality parameters into one concise and objective value representing the state of water quality trends in a river. The WQI can be defined as a number on scale from 0 to 100 that is used to show the water quality.

The WQI of the four rivers of the scheme is presented in Figure 1. WQI calculated ranged from 69.9% (Jarak River)

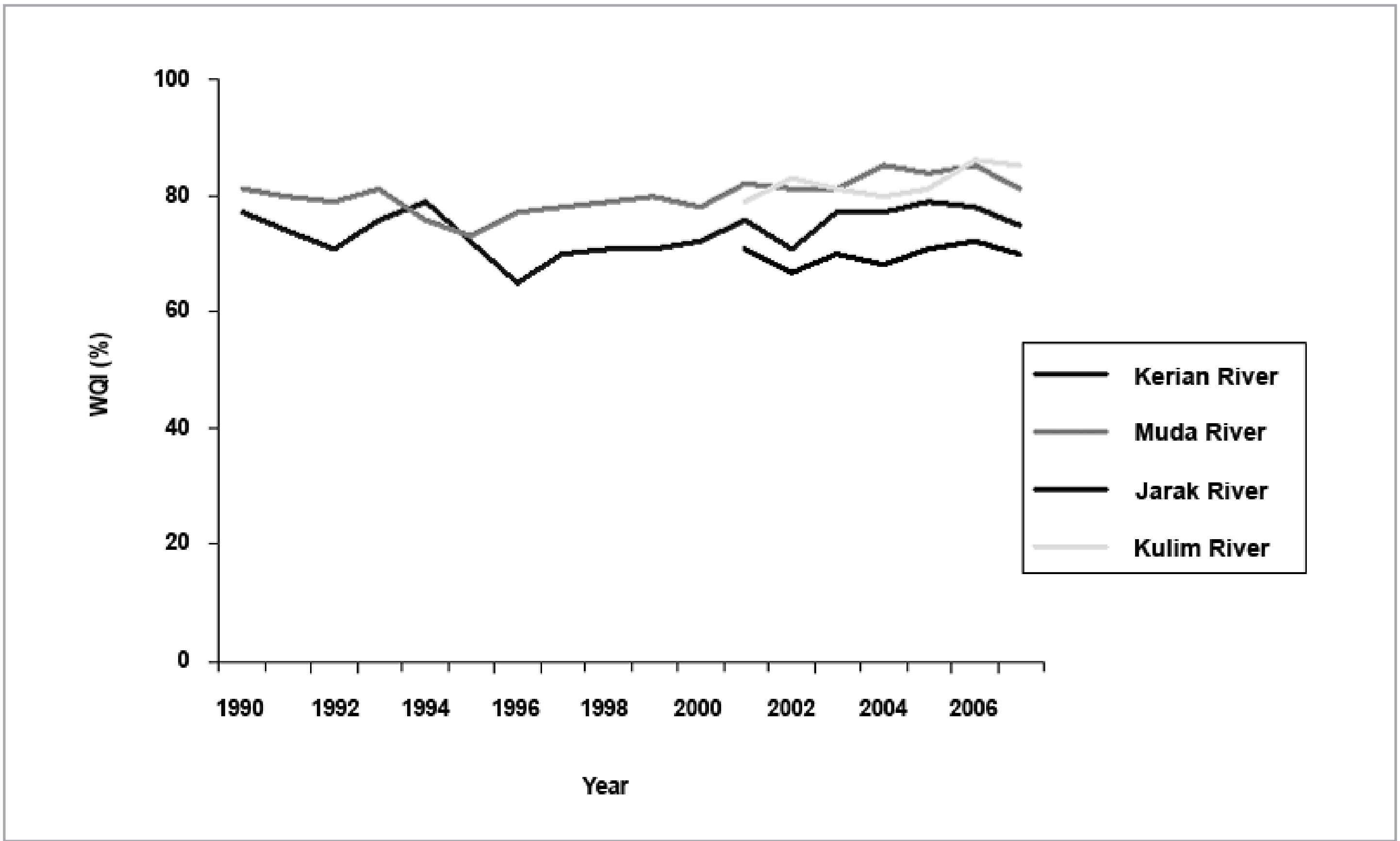

Figure 1: River Water Quality Indices in the Seberang Perai Rice Irrigation Scheme for data from 1990-2007

to 82.2% (Kulim River). This range is acceptable for wildlife including aquatic life, but waters with values less than 80% are considered as slightly polluted for general use. Two rivers (Kerian and Jarak rivers) were considered slightly polluted in comparison with the general rating scale of the water quality index. Agricultural activities may be contributing to this trend, but water quality nonetheless is also affected seriously by industrial use and domestic use. The data shows that the Muda and Kulim rivers are relatively clean. However, there is not much difference in water quality between upstream and downstream sections in each of the four rivers. The Sungai Muda sub-scheme is the largest irrigation area in this scheme, and its major source of water supply is the Muda River. Most of the drainage water from this rice field is discharged into the sea through various waterways. It is noted that the quality of water in this river had been gradually deteriorating during 1990 to 2000.

7.0 CONCLUSIONS

Seventy-five percent of the available surface water resources (river water) in Malaysia are used for rice irrigation. However, many of the rivers in Malaysia suffer from pollution. In this study, four rivers (with 18 years of data for the period from 1990 to 2006) were considered for irrigation water quality assessment. The following are the salient conclusions from this study and it must be qualified that the results are valid for the data period considered and they may have worsened or improved since then:

(i) The pH values in the study area ranges from 5.10 to 8.15 with an average of 6.63. The highest pH value was found in the Muda River while the lowest, downstream of Kerian River. The average pH values were 6.76, 6.39, 6.37 and 5.72 for the Muda, Kulim, Jarak and Kerian river respectively. The pH values are slightly below neutral value indicating only minimal amount of acidic industrial effluents had been discharged into the rivers. But all the pH values are within the permissible limit (Class IV) for irrigated agriculture.

(ii) A wide range of DO levels exist in the rivers in the irrigation scheme and the range is from 1.5 to 7.2 mg/L. The average value of 4.35 mg/L indicates the water is of Class III quality.

(iii) Of the four DOE sampling stations, one has readings greater than 50 mg/L, the standard for class III. The average COD values are respectively, 8.4 mg/L, 31.36 mg/L, 13.33 mg/L and 21.88 mg/L for the Muda, Kulim, Jarak and Kerian rivers.

(iv) The Kulim River falls into Class III of the DOE water quality standard, while the remaining 3 rivers fall into Classes I and II as far as the parameter 5-day BOD (BOD5) is of concern. The range of values for these four rivers is 1.05-6.60 mg/L.

(v) The highest SS value was found to be 387 mg/L in the Kulim River and the lowest value was recorded in the Kerian River. All SS values are still included within the acceptable range for agricultural purposes.

(vi) NH_3N readings at all sampling station ranged from 0.1 mg/L to 7 mg/L. The highest NH3N value was recorded at Kulim river with 7 mg/L and the lowest was recorded at Muda river, with 0.1 mg/L.

(vii) Water Quality Index (WQI) computed based on six parameters: Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Ammoniacal Nitrogen (NH_3N), pH, Dissolved Oxygen (DO) and Suspended Solids (SS), evaluated for the four rivers ranged from 69.9% (Jarak River) to 82.2% (Kulim River).

Water quality data indicated that two rivers (Kerian and Jarak rivers) in the scheme are slightly polluted due partially treated domestic waste and industrial pollution sources. It should be reiterated that the increasing level of pollutants in the rivers will remain an issue affecting human well being if proper attention is not given right at the very source of the problem. Efforts made must be adequate to ensure that river environment and water quality do not deteriorate further. Other human interferences include using chemicals (fertilisers, herbicides and pesticides) that cause surface and groundwater contamination and further water quality. Reducing fertiliser applications not only contributes towards lower production costs for rice cultivation but also less nitrogen (N) leaching into the soil and contamination of surface and ground water. Nevertheless, altered N fertilisation may also affect pests and their natural enemies. Remedial measures to be taken include the use of appropriate chemicals (the ones with low toxicity, biodegradable and mobility in soil) with appropriate application techniques and scheduling, and by maintaining unsprayed buffer areas near streams and applying chemical only during dry weather.

8.0 ACKNOWLEDGEMENT

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