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Managing River Water Quality Index: A Malaysian Case Study

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Abstract: The past few years have seen several issues that have led to the widespread concerns for the river environment in Malaysia. There has been inadequate supply of water in the big cities, unexpected floods threatening human lives and property, and the image of the country has been affected because of this recurring problem. This paper will discuss on the proposal to clean-up Penchala river in Kuala Lumpur. Penchala river is a tributary of the Klang River and passes through several important townships. Water Quality Index derived from parameters measured by the Department of Environment of Malaysia will be the bench-mark used to assess the severity of pollution condition in Penchala river. Proposed clean-up methods include public participation, engineering and river works and strict regulation by government. It is hoped that efforts from stakeholders can be harnessed to strive for a healthier Penchala River in the future.

Key words: Clean-up, Penchala river, proposal, polluted, water quality index.

Introduction

There are various reasons why river clean-ups are required in Malaysia especially in urban areas like Kuala Lumpur. First and foremost it is for the safety of water supply. Rivers are by far the cheapest form of water supply compared to other sources like groundwater, and seawater desalination. If polluting substances in rivers could be contained within the self-purification ability of rivers, then advanced treatment for water will not be required. However, this is not the normal case and many rivers are too polluted. In Kuala Lumpur, for instance, due to lack of understanding of environmental limitations, rivers around the area cannot provide enough water for the approximately five million consumers in the Klang Valley. It is currently necessary to supplement water supplies from the Klau River dam in the state of Pahang to channel water several hundred kilometres to Selangor, Kuala Lumpur and Putrajaya. This will open up to more biodiversity and environmental management complexity. Other reasons for the need for river clean-up are health, recreation and aesthetics that generally mirror the city's image and directly affect the quality of life in the urban community.

Penchala river is only 12 km long and is the shortest but most polluted tributary of the Klang River which is the main river running through the Klang valley. The Department of Environment (DOE) has been monitoring the river since the late seventies, 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 i.e whether it is in the clean, slightly polluted or polluted category. Classification is done on an annual basis by putting rivers in Class I, II, III, IV, or V based on the Water Quality Index (WQI) and the Interim National Water Standards for Malaysia (INWQS). WQI is computed based on six main chemical, biological and physical parameters. The six main parameters are: biological oxygen demand (BOD), chemical oxygen demand (COD), ammonical nitrogen (NH_3N), pH, dissolved oxygen (DO), and suspended solids (SS).

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In 1997, the river was already classified as Class IV based on the water quality parameters measured by DOE. Measurements made up to 2003 showed that the river had fallen gradually to Class V. There was a slight improvement for the years thereafter but it still remained in Class IV. The cause of pollution primarily has been attributed to rubbish, effluents from industries like iron and steel, saw-milling, battery production, clearing of land for development and overflows from manholes and septic tanks. Inefficient drainage system and the fencing along rivers that made the river unreachable to the residents to clean the river also contribute to the problem. The situation is made worse by the fast-growing population and industrialization within the river perimeter covering several townships.

Community-based groups like Residents Associations have been formed to discuss and carry out cleaning up activities for Penchala river. Global Environment Centre (GEC), an NGO, has also been running programmes for school children to instill a love for our rivers and educate them to care for the river's well-being as reported in *The Star*, 18 September. 2006. Under the GEC, a River Care Fund (RCF) was started to build the capacity of these community groups and disseminate information through the building of community skills on river monitoring and reporting and creating local action groups as recently reported in the local media, *The Star*, 6 January 2007. The main objectives of the proposal to clean-up Penchala river are to upgrade water quality classification, beautify the river, prevent potential health threats; instill feeling of ownership of the river among the residents in the river vicinity, and to review environmental regulations to prevent excessive discharges with overwhelming industrial effluent loading.

Materials and Methods

Studies of rehabilitation projects nationally and internationally were examined to determine how best the polluted state of rivers could be improved. Examples of sources of information were from books, reports from DoE and similar organisations, articles from journals and conference proceedings. Meetings and discussions with consultants from the industry and academia as well as representatives from relevant NGO's and residents living along the river were also arranged. Visits and personal inspection of the river itself at several stretches were also made to gain first-hand observation.

Results and Discussion

Water Quality Index

Tables 1 to 9 show the six parameters namely, biological oxygen demand (BOD), chemical oxygen demand (COD), ammonical nitrogen (NH_3N), pH, dissolved oxygen (DO), and suspended solids (SS) for each year from 1997 to 2005 taken throughout the year. The figures for WQI derived and the average value for the year are also given. It can be observed that for the period between 1997 and 2002 the annual average value for the WQI ranges from 30 to 33 with an overall average value of 31; while for the period from 2003 to 2005 the annual average value for the WQI ranges from 41 to a high of 51 with an overall average of 47. It may be concluded that the following efforts towards improving the river water quality have to a small measure seen a little improvement but have not been a roaring success.

Laws and Regulations

Compliance to laws and regulations is a common instrument used to combat environmental pollution. Experience have shown that significant failures have resulted when standards have been set too lenient or if they are set too stringent that they cannot be afforded for economic reasons as observed by Novotny and Somlyody, 1995.

Table 1: Parameters for 1997

DO mg/L	*BOD mg/L*	*COD mg/L*	*SS mg/L*	*pH unit*	*NH_3-NL mg/L*	*WQI*
0.7	9.04	80	58	7.15	1.04	47
0.2	12.43	63	184	6.13	8.64	35
1.8	14.32	42.0	43	6.90	3.10	46
0.6	42.52	122	126	6.58	5.55	24
1.2	7.0	28	113	10.5	5.38	39
1.0	58.0	74	12	9.8	5.80	26
0.2	59.1	102	48	7.5	6.48	26
1.5	78.52	111	190	7.0	2.3	26
1.81	39.18	119	206	7.22	3.99	26
0.56	68.6	133	256	8.95	8.04	15
0.26	56.19	94	159	6.47	7.40	23
0.96	20.93	44	30	4.48	4.61	45
1.55	34.28	114	62	4.48	0.24	64
0.72	44.41	77	220	5.33	10.70	21
0.61	55.4	109	117	4.59	10.16	17
0.7	37.4	113	137	4.19	20.23	17
1.74	42.83	82	34	9.49	6.38	44
1.88	20.12	32	291	8.56	21.28	36
2.49	27.84	73	180	7.65	6.51	34
0.8	11.34	50	43	6.53	5.44	42
3.2	16.73	53	68	6.16	3.43	46
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Public Awareness

There are many NGOs in Malaysia that are working towards the betterment of the environment but not many people are aware of what they are exactly doing. The *Berita Harian* newspaper also publishes opinions from professionals on the state of the environment every Tuesday.

Urgency and Commitment

One of the challenges in conducting community programmes was that there was no urgency and real commitment among the stakeholders to find solutions to the problem. This may be caused by the fact that relationship building and trust do take time, and because results cannot be achieved immediately as pointed out by Mokhtar, 2007.

Environmental Impact Assessment (EIA)

A project development of a certain size is required to conduct EIA under the Environmental Quality Act (EQA 1974).

Conclusions and Recommendations

Current approaches to improve the quality of the Penchala river have not been too successful. There was a sharp deterioration of river water quality beginning in year 2003 and persisted thereafter. Tools are available for cleaning up Penchala river and these must be utilized in order to arrest and reverse the worsening state. The following proposals could be considered, but much is needed in provisions of funds to buy land, install treatment facilities, and give incentives to volunteers. Awareness and attitude change is also a priority to be instilled in the authorities and the community. The entire clean-up process could take decades, but gradual improvement is better than nothing.

Implementation of Laws and Regulations

One of the ways to address the problem of compliance in a practical manner is to allow time to meet full compliance. The introduction of new regulations and amendments to existing regulations could be given enough time for states to achieve compliance, but they are required to demonstrate constant progress in reducing emissions and discharges. Provisions for sanctions on areas of the river that do not meet the required condition could be established as suggested by Schnelle and Brown, 2002. This is because full implementation of new effluent limitations would put undue burden on the industries,

Table 2: Parameters for 1998

DO mg/L	*BOD* mg/L	*COD* mg/L	*SS* mg/L	*pH* unit	*NH_3-NL* mg/L	*WQI*
1.23	26.3	77	88	10.88	1.93	27
0.36	3.9	6	11	5.80	2.81	58
0.81	70.6	134	68	6.65	6.28	24
1.87	27.8	51	168	10.37	3.45	28
1.24	<2.0	91	89	5.31	3.95	41
0.13	32.3	75	64	7.27	0.42	40
0.2	35.4	60	180	5.53	5.01	26
0.3	43.2	87	61	5.29	7.47	24
0.3	23.0	198	62	2.91	4.81	17
0.1	42.0	219	96	6.85	5.20	22
0.1	49.0	133	72	7.90	4.65	23
0.0	69.0	153	56	6.45	7.21	23
0	65.0	178	60	6.62	4.32	23
0.44	30.0	88	102	3.48	7.13	19
1.34	10.0	115	372	3.07	3.66	23
0.83	26.0	51	94	6.66	4.13	33
0.61	20.0	48	34	4.2	4.74	31
0.58	42.0	111	96	3.98	7.04	16
0.22	21.0	55	88	6.7	0.30	44
1.85	16.0	43	24	7.06	5.00	45
0.67	22	34	70	6.91	5.12	38
0.52	18	32	36	7	5.99	41
0.35	35	62	42	7.07	8.26	32
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Table 3: Parameters for 1999

DO mg/L	*BOD* mg/L	*COD* mg/L	*SS* mg/L	*pH* unit	*NH_3-NL* mg/L	*WQI*
1.15	26	79	152	8.04	5.34	29
1.8	59	98	120	9.47	4.47	21
0.93	26	60	50	6.96	5.18	35
2.02	10	88	422	5.02	5.01	31
0.17	6	45	20	6.16	4	47
0.13	36	94	51	6.11	3.76	28
0.72	52	116	659	3.64	5.39	7
2.8	14	67	34	9.49	5.26	41
2.46	22	78	40	4.83	4.06	34
0.51	19	106	66	6.93	5.16	32
0.26	13	106	172	6.72	6.18	32
0	37	94	69	6.49	5.65	27
0.07	32	110	100	6.07	5.6	25
0.16	78	96	131	5.71	4.97	22
0.27	36	89	182	5.03	6.54	21
0	81	688	41	6.79	3.23	25
0.94	68	191	63	6.05	3.5	23
2.04	19	60	35	6.68	2.26	45
0.45	19	66	47	7.35	4.43	36
0.22	43	106	59	4.6	3.55	20
0	24	79	67	6.5	4.53	31
4.62	36	78	68	6.2	3.43	41
0.13	43	154	72	6.93	2.41	27
0.65	31	108	39	7.05	3.27	31
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Table 4: Parameters for 2000

DO *mg/L*	*BOD* *mg/L*	*COD* *mg/L*	*SS* *mg/L*	*pH* *unit*	*NH_3-NL* *mg/L*	*WQI*
1.58	5.00	75.00	43.00	5.91	2.63	47
0.73	34.00	136.00	105.00	5.25	5.86	21
0.48	25.00	87.00	73.00	7.05	4.96	30
0.47	42.00	136.00	55.00	5.23	4.84	21
1.48	19.00	66.00	196.00	5.83	3.97	33
0.86	40.00	96.00	107.00	5.26	3.36	24
1.16	25.00	56.00	69.00	3.51	2.74	28
0.41	20.00	42.00	74.00	7.44	4.12	36
0.00	30.00	117.00	60.00	7.06	4.55	28
0.90	26.00	56.00	331.00	2.66	4.40	18
0.24	50.00	152.00	193.00	4.79	3.97	15
0.27	6.00	93.00	117.00	6.55	4.21	39
0.17	37.00	108.00	219.00	4.30	5.90	16
0.73	53.00	125.00	57.00	0.61	4.17	14
0.40	24.00	46.00	120.00	6.82	4.95	34
0.14	33.00	77.00	71.00	6.17	8.58	29
1.70	6.00	62.00	116.00	6.91	9.73	45
0.00	46.00	79.00	105.00	3.01	4.69	16
0.44	25.00	53.00	239.00	2.13	4.09	34
0.87	15.00	34.00	71.00	9.15	4.70	37
0.86	6.00	29.00	34.00	6.76	3.24	65
3.39	34.00	90.00	175.00	6.94	1.08	42
1.56	7.00	26.00	644.00	6.81	3.94	41
0.57	2.00	38.00	70.00	3.10	<0.01	53
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Table 5: Parameters for 2001

DO *mg/L*	*BOD* *mg/L*	*COD* *mg/L*	*SS* *mg/L*	*pH* *unit*	*NH_3-NL* *mg/L*	*WQI*
1.24	30	60	390	3.49	2.78	21
4.23	9	29	22	6.63	2.21	64
0.33	40	146	52	3.31	5.26	15
1.82	7	39	35	6.77	4.63	50
0.00	32	82	45	6.84	5.18	31
0.00	22	40	53	6.25	1.25	43
0.00	67	112	180	2.7	6.37	11
0.00	6	50	50	3.03	3.19	36
0.5	41	87	86	5.46	5.53	23
0.39	240	488	100	5.5	0.65	27
0.71	35	108	83	6.56	5	26
1.11	34	78	81	2.46	5.14	18
0.16	64	168	60	6.9	4.54	23
2.22	17	52	38	5.52	3.95	37
0.44	55	152	137	5.49	7.98	18
3.32	37	92	155	2.11	42.60	24
0.5	15	86	82	7.23	4.47	34
0.28	16	59	63	6.9	4.68	37
2.05	19	82	89	6.26	4.72	35
2.31	19	92	90	6.66	3.02	38
0.32	36	74	35	7.42	6.02	31
0.28	19	75	142	7.43	5.7	32
0.85	20	71	35	2.86	6.01	26
3.26	66	133	25	6.58	4.03	35
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Table 6: Parameters for 2002

DO *mg/L*	*BOD* *mg/L*	*COD* *mg/L*	*SS* *mg/L*	*pH* *unit*	*NH_3-NL* *mg/L*	*WQI*
0.82	13	83	41	3.13	7.06	28
0.28	18	86	43	4.33	0.104	41
0.15	28	155	95	6.68	4.53	25
0.7	40	97	120	2.43	11.9	15
0.26	43	87	49	7.33	4.97	28
0.15	37	151	54	7.3	5.3	26
0.55	53	107	59	7.04	4.47	25
0.72	40	103	50	6.91	11.13	28
0.69	18	72	38	4.35	10	29
0.45	36	100	80	6.3	4.3	26
0.68	38	133	92	6.63	4.72	24
3.88	5	46	99	7	2.1	59
2.37	13	63	164	6.77	4.33	41
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Table 7: Parameters for 2003

DO *mg/L*	*BOD* *mg/L*	*COD* *mg/L*	*SS* *mg/L*	*pH* *unit*	*NH_3-NL* *mg/L*	*WQI*
1.46	34	47	58	6.76	1.73	40
2.83	9	46	11	7.16	4.98	53
1.75	32	93	111	6.42	5.42	56
2.02	6	70	107	7.15	5.19	45
1.01	6	103	96	6.99	4.78	39
2.04	14	72	48	6.53	8.95	41
1.50	12	67	75	6.82	3.43	41
0.66	8	85	106	7.46	3.42	39
5.08	4	32	36	7.59	3.7	66
1.04	7	37	32	7.28	6.05	49
2.40	8	63	55	7.3	3.5	48
1.71	3	43	6	7.26	3.58	55
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economy and the community. New investors could be deterred from setting up industries in Malaysia and hence slow down the country's economic development. However, areas of extreme severity may be allowed more time to achieve attainment, but should receive increased federal scrutiny for new source review of major sources of pollution. Tightening standards is then scheduled over a period of time to assure affordability and allow dischargers to develop their adjustment plans in a realistic fashion.

Table 8: Parameters for 2004

DO mg/L	*BOD mg/L*	*COD mg/L*	*SS mg/L*	*pH unit*	*NH_3-NL mg/L*	*WQI*
2.19	3	56	14	7.28	3.99	53
2.75	20	129	22	7.55	4.82	40
4.91	5	27	26	7.44	3.52	67
1.98	14	80	34	7.55	4.17	41
1.56	7	41	24	7.77	4.61	49
2.16	11	102	28	7.54	8.83	44
2.31	9	55	33	7.84	3	49
3.2	13	66	81		8.2	42
0.7	21	68	12	7.37	5.63	38
2.71	8	61	27	7.26	2.76	53
5.66	8	39	11	7.41	2.04	70
6.16	20	53	30	6.46	3.56	58
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Table 9: Parameters for 2005

DO mg/L	*BOD mg/L*	*COD mg/L*	*SS mg/L*	*pH unit*	*NH_3-NL mg/L*	*WQI*
2.34	10	96	48	6.72	3.91	43
2.08	15	75	20	7.27	1.59	48
2.22	10	66	53	6.97	2.79	47
3.47	54	155	23	6.86	3.99	36
2.03	25	82	40	7.03	3.48	37
0.78	24	60	46	6.71	7.29	35
					Ave	41

Community Involvement

Citizen involvement in policy initiation and programme design decisions for their own community is vital. As pointed by Mohkeri and Parish (2003), basic policies to improve river environment and restoration which include protecting the hydrological cycle and diverse habitat in river basins can encourage better public participation. For example in previous research on solid waste recycling suggested that cities with higher rates of participation and waste stream diversion place more importance on citizen involvement in the policy initiation and programme design decisions. These findings offered modest empirical support that citizens are more likely to participate effectively in collective efforts when they are party to the policy decisions as observed by Folz and Hazlett, 1991.

Improved Awareness

The media focus should not only be on what the government could do but also on what the general public can do in their everyday lives towards preserving the river environment. The mass media can play an important part in reporting and giving information of clean-up activities around the world. They could highlight diseases that water pollution can cause, how these could happen, and how they could be prevented. Activities and views of NGOs can be published in daily newspapers.

Efficient Monitoring

Malaysia needs an effective national communication system which could track and monitor basic information on activities that are being organized that concern the environment. Projects could thus be prioritized based on what is known to work. There is also a need for a policy to support restoration standards, to promote the use of proven methods elsewhere in the world, and to provide basic data needed for planning and implementing restoration work. Although much is known about effective rehabilitation projects, this information has not been used in most projects as mentioned by Palmer and Allan, 2006. As pointed by Holmes, 2000, this could have arisen because of a lack of a national policy specifically aimed at river rehabilitation and the general lack of available finance which restricts the progress that can be made. The following are proposed solution to the problems:

- Government should ensure that restoration projects are credible by requiring recipients of federal funds to adhere to the standards for ecologically successful restoration projects. Requirements must be established for monitoring outcomes and tracking agency performance.
- Establish federal standards and guidelines to incorporate basic standards through revision of restoration manuals and design criteria which directly have implications for river welfare.
- The key elements, for example sound science of river rehabilitation, monitoring, restoration design that minimizes environmental impacts and demonstrate ecological improvement should be incorporated into the internal policies and guidelines of the new or reformed restoration programmes and be met before grants or contracts to fund restoration works are awarded.
- A coordinated tracking system for restoration projects must be implemented.

Sense of One with Nature

Many of the residents in Penchala river vicinity are denied any usage of the river in their daily lives. Communities in the early days have depended heavily on the existence of rivers. Today, people do not depend on rivers directly for water supply for drinking, cultivation or as a means

of transport. The value and importance of rivers have been lost. The traditional culture to safeguard against threat of rivers is forgotten and people have lost their relationship with rivers as indicated by Mohkeri and Parish, 2003. From the visits the author made to the river, it is observed that long stretches of the river are crossing roads and highways, which make the river inaccessible to the people. With proper walkways or stairs constructed on the banks of the river and parking lots provided, the river could be more reachable to the people who would feel more connected to it.

Effective Communication

Effective communication is required not only between the specialists like engineers, geologists and hydrologists, but also between the specialists and the general public. For example, the agencies directly involved in rehabilitation initiatives should include a combination of local authorities, nature conservation bodies, water authorities and resident associations.

Coordination

The level of technical understanding that differs among different government agencies and authorities will lead to perplexed control which could be upsetting each other's planned schemes. For example, the Department of Environment has the powers to control pollution of water resources in Malaysia; however the approval of development projects is still the prerogative of the State Government. As such, there are cases where projects which may have negative impacts to the sensitivity of river catchments are being approved in these areas. Therefore, water supply catchment areas should be gazetted by the State Governments and integrated management approach be practiced which involved the participation of relevant agencies to ensure that the water catchments are effectively controlled as suggested by Pillay and Talha, 2003.

A master plan is needed for river works to ensure comprehensive administration of the river system. For Penchala river, the master plan should contain policy and planning for water resources project, river environment improvement project, and other matters which will be the basis for executing river works. This can ensure that all aspects of concern are covered and avoid risking the financial investment for the rehabilitation projects through minimal coordination. In addition, river plans should be given highest priority in river management. Rivers should be managed systematically for the long-term benefits under suitable river plans. More stringent amendments are needed for the Environmental Quality (Sewage and Industrial Effluents) Regulations, 1979 for water courses discharging water into catchment areas. Most of the time, urban rivers cannot cope with the total load from the residents as well as factories in the industrial area especially for a river like Penchala which is only a stream as described by Mohamed, 1993.

Instilling a Sense of Urgency

Continuous motivation and incentives to participate in the programmes are needed. Among possible steps to enhance the chance of success in public involvement is given by Falk (1992), as follows:

a. Finding the right driving force.
b. Forging a partnership between the community and the authority.
c. Tapping professional expertise.
d. Showing early results.
e. Exploiting the media.

Technical Approaches

Technology and engineering approaches can be divided into two categories: nature development and physical construction. DOE recorded that the Penchala river water quality for the last few years has the value of WQI mostly in Class IV. With the value of WQI that are worrying, river works that tackle these six relevant parameters are proposed.

Aeration systems: Aeration is a water treatment process for river restoration which brings river water at the bottom of river up to the surface. The entire river is oxygenated by the atmosphere surface to bottom. Bottom toxic gases are also neutralized and foul odours quickly disappear. The result is a great improvement in fish health, number and growth rate. In any water body, when the bottom is oxygenated, phosphorus and nitrogen in the water column are bound to the sediment, where it becomes food for the beneficial bacteria and insects. Inversion and oxygenation will also reduce disease causing bacteria by exposing pathogenic bacteria to sunlight and these pathogens are weakened or killed as reported by Laing and Rausch, 1993. The proposed place for aeration is at the middle stream of Penchala river which is at the industrial area of the river.

Remove barriers: Some barriers should be removed so that the public can get down to the river, plant trees and take care of them. Vegetation can also control erosion the natural way. In Project Kingfisher for River Cole the sheet piling and reinforcements which were acting as barriers to easy access were removed and pools and wetlands were constructed instead as observed by Petts et al., 2002.

Wetland construction: Taking example from the Erh-Ren River project in Southern Taiwan where an effective and essentially free treatment of polluted water through a wetland system becomes a reasonable option used to purify the river water instead of an expensive treatment system as reported by Shub-Ren et al., 2001. Constructed wetlands were initially developed about 40 years ago in Europe and North America to exploit and improve the biodegradation ability of plants. The advantages of these systems include low construction and operating costs. It utilizes the ability of large aquatic plants to breakdown organic matter and removes disease-causing micro organisms and pollutants. A range of plants can be used, but the common reed (*Phragmites australis*) and the reed mace (*Typha latifolia*) are particularly effective. The performance of these systems is influenced by their area, length to width ratio, water depth, rate of loading and time to pass the wetland. Wetlands can also act as filters for pollutants and provide a landscape feature and varied recreational activities as well as creating wildlife habitat.

Rehabilitation of channel morphology: Where cover for fish is absent, rehabilitation efforts could focus on introducing boulders and logs, and planting suitable overhanging riparian vegetation.

River deepening and desilting: This is to remove accumulated sediment from the river and achieve a more uniform channel cross section and bed profile. Many river improvements depend on this method, but the cost is high. Proper maintenance by controlled activities in the upper and middle reaches of the river becomes important after the deepening and desilting has been done.

Other proposals: The following are some other measures that could be implemented within a reasonable time frame:

a. To set up built-in small wastewater treatment systems in high rise buildings. This will not only reduce the chances of pollution to rivers with several possibilities of leaking sewers, but also significantly reduce energy cost to pump wastewater to central treatment plants. The system has been successfully implemented in the USA and Thailand.
b. The use of organic instead of inorganic fertilizers for golf courses to curb the excessive flow of nutrients into the river water.
c. To install oil and grease traps at food outlets. It should be made compulsory even for small eateries to install filter systems to separate oil and other residues in their wastewater. This implementation has been initiated in 2005 by the Pahang State Government for Teluk Chempedak beach as reported in *The Star*, 13 January 2006.

Tighter EIA Requirement

The effectiveness of the EIA implementation needs to be examined because certain projects—no matter the size—require EIA to be conducted and this should be religiously implemented to ensure the well-being of Penchala river and other similar rivers. It is imperative that a detailed study be carried out with a focus on the water quality of the river system and the threats that the fragile river system will face.

Bio-engineering

Bio-engineering is a remediation method by using living plants, or plants combined with dead or organic materials. Project developments located in the vicinity of Penchala river should apply this method to maximize erosion control and to form permanent turf reinforcement. The method can be used wherever vegetation can be applied. This will minimize the use of Structural Erosion Control techniques that can significantly reduce the natural functions of land and water interface.

Environmental Reporting

Many countries like Denmark, Netherlands, United Kingdom and Japan have made environmental reporting mandatory for industries. This law has made companies' dealings on inputs and outputs to be more transparent to the authorities and the public. Companies need to show evidence of compliance to effluent limits and disposal of wastes. Inspection of industrial premises from time to time can be minimized because the report is self regulating and will become a stimulus for continuous environmental commitment to improvement.

It must be noted that pollution prevention is an excellent practice to cut clean-up costs and installing treatment systems. Environmental policies should promote economic development that will anticipate potential pollution problems and react to them by political and technological means before they occur. The following approaches could be applied as suggested by Muller and Hahn, 1995:

- Make it simple.
  Only five pollutants need to be controlled to strict threshold limits with uncomplicated rate structure. This method was done first in Germany. Efforts should be made to identify the best simple programme rather than the programme that is simply the best.
- Clean water costs money.
  Attract investment in sewage treatment and work with

national and regional environmental authorities as well as municipalities to identify financing schemes that are consistent with the existing institutional structure and facilitate the flow of capital into water quality improvements.

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