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Full Length Research Paper

Monitoring trends of nitrate, chloride and phosphate levels in an urban river

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Concerns for the river environment in Malaysia are highlighted. There had been occurrences of inadequate supply for water in big cities and unexpected floods over the last few years. This paper discussed the results of 'clean-up' efforts of Gombak River which passes through several industrial areas and the City of Kuala Lumpur. The trends in the levels of nitrates, chlorides and phosphates present in the river water were observed. Water quality index was also used to assess the general water quality of the river. Over the period of nine years from 1997 to 2005, results of efforts which included public participation, engineering, river works and strict statutory regulations by government had shown success in improving the river water quality. Continued efforts from stakeholders must be harnessed to enhance the health of the Gombak River.

Key words: Chloride, nitrate, phosphate, urban river pollution, water quality index.

INTRODUCTION

The safety and security of river water is of paramount importance since it is by far the cheapest form of water supply source. 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 by run-offs from agricultural and industrial activities loaded with nitrates, chlorides and phosphates up-stream of the river. These salts affect the general health of plant and animal life so the concentrations have to be monitored and controlled. In Kuala Lumpur, for instance, due to lack of understanding of environmental limitations; rivers around the area cannot provide enough water for the approximately 5 million consumers in the Klang Valley. It is currently necessary to suplement water supplies from the Klau River dam in the state of Pahang to channel water several hundred kilometers to Selangor, Kuala Lumpur and Putrajaya. This will open up to more biodiversity and environmental management complexity. Other reasons why river 'clean-ups' are required are for health, recreation and aesthetics that generally mirror the city's image and directly affect the quality of life in the urban community.

Gombak River is short but is considered a 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 that is, 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) as reported by Department of Environment (2008). The WQI is developed as follows:

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

where,
SIDO = Sub-Index DO (in % saturation):

SIBOD = Sub-Index BOD; SICOD = Sub-Index COD;

SIAN = Sub-Index NH_3N; SISS = Sub-Index SS;
SIpH = Sub-Index pH

Best fit equations for the estimation of the sub-index values are:

Sub-index for DO (in % saturation)

SIDO = 0 for a<= 8
= 100 for a >= 92
= $-0.395 + 0.030a^2 - 0.00020a^3$ for 8 < a < 92

Sub-index for BOD

SIBOD = 100.4 - 4.23a for a <=5
= 108* exp (-0.055a) - 0.1a for a > 5

Sub-index for COD

SICOD= -1.33a + 99.1 for a <=20
= 103*exp (-0.0157a) - 0.04a for a >= 20

Sub-index for AN

SIAN = 100.5 – 105a for a <= 0.3
= 94*exp (-0.573a) - 5 * | a - 2 | for 0.3 < a < 4
= 0 for a >= 4

Sub-index for SS

SISS = 97.5*exp (-0.00676a) + 0.05a for a<= 100
= 71*exp (-0.0061a) - 0.015a for 100 < a < 1000
= 0 for a >=1000

Sub-index for pH

SIpH = $17.2 - 17.2a + 5.02a^2$ for a < 5.5
= $-242 + 95.5a - 6.67a^2$ for 5.5 <= a < 7
= $-181 + 82.4a - 6.05a^2$ for 7 <= a <8.75
= $536 - 77.0a + 2.76a^2$ for a >= 8.75

In 1997, the river was classified as Class III based on the water quality parameters measured by DOE. Measurements made from 1999 to 2005 showed that efforts to improve the river water quality there had been some improvement shown. However, the river still remains in Class III. 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 up also contribute to the problem. The situation is made worse by the fast-growing population and industrialization within the river perimeter covering several highly industrialized areas. Monitoring the concentration levels of these salts have to be continued.

Nitrates

The major sources of nitrogen in water are municipal and industrial wastewater, septic tanks, feedlot discharges, animal wastes (livestock, birds, mammals, and fish), fertilized field and lawn runoff, and vehicle exhausts. Nitrogen-containing compounds act as nutrients in streams, rivers, and reservoirs. Nitrate levels in water fluctuate by season, and higher nitrate levels also occur following heavy rainfall. The major impact of nitrates and nitrites on fresh water bodies is that of fertilization of plants and weeds which can lead to low levels of dissolved oxygen.

Chlorides

Chlorides may enter surface water from sources such as rocks containing chlorides, agricultural runoff, industrial wastewater, oil well wastes and wastewater treatment plant effluents. Small amounts of chlorides are essential for normal cell function. Fish and other aquatic life forms cannot survive in high levels of chlorides.

Phosphates

Phosphates exist in forms with varying formulations involving phosphorus. Some are formed naturally and some are the result of breakdown of pesticides containing phosphorus. They are used in detergents and in the treatment of boiler water. Rainfall causes varying amounts of phosphates and phosphorus to wash from farm soils and soils treated with certain pesticides into waterways. Phosphates stimulate the growth of algae and aquatic plants that provide food for fish. Excess phosphates may cause an excessive growth in algae and aquatic plants, choking waterways. Phosphates are not directly toxic to humans or animals. Digestive problems can result from high levels of consumed phosphates.

MATERIALS AND METHODS

The data collected for this study were the secondary results of activities and initiatives to 'clean-up' the Gombak River carried out by DoE over the period from the beginning of 1997 to the end of 2005 taken over regular time intervals from three sampling stations referred to as 1K17, 1K18 and 1K24 along the river. Studies of rehabilitation projects nationally and internationally were examined. The methods used to determine and monitor the concentrations of the salts were ASTM D3867 for nitrates, ASTM D1411 for chlorides and ASTM D515-82 for phosphates. The WQI values were also collected and analyzed to examine if there were any trends in the parameters over the years. Two-hundred-sixty-three sets of data

Table 1. Sample set of results for 1998.

STA No.	Sample-Date (1998)	NO_3 (mg/l)	Cl (mg/l)	PO_4 (mg/l)	WQI
1K17	6 January	1.40	10.77	1.16	70
1K18	6 January	1.85	6.39	0.83	86
1K17	23 February	1.40	10.77	1.16	68
1K18	23 February	1.85	6.39	0.83	80
1K17	23 March	1.56	13.10	1.09	58
1K18	23 March	1.95	9.28	0.70	43
1K18	22 April	2.05	8.26	0.01	65
1K17	23 April	1.64	9.49	0.64	54
1K17	17 May	0.49	14.00	0.51	53
1K18	17 May	0.55	11.00	0.27	55
1K17	16 June	0.64	7.00	0.24	56
1K18	16 June	0.75	6.00	0.12	54
1K18	21 July	0.81	8.00	0.37	58
K17	22 July	0.46	11.00	0.45	58
1K17	18 August	0.69	5.00	0.17	52
1K18	18 August	0.83	6.00	0.09	50
1K17	11 September	0.70	5.00	0.01	72
1K18	11 September	0.62	3.00	0.01	79
1K17	9 October	0.39	11.00	0.36	61
1K18	9 October	0.53	5.00	0.07	66
1K17	18 November	0.56	6	0.16	66
1K18	18 November	0.72	6	0.04	67
1K17	16 December	0.73	10	0.27	60
1K18	16 December	0.83	9	0.22	53

were collected over the period. A sample set of results for 1998 is given in Table 1. The mean, the maximum, the minimum and the standard deviations of the concentrations of all the three ions were computed and recorded. The graphs of ionic concentration for each radical versus time in weeks were plotted in one graph for each ion over the entire period. The WQI's were also plotted over the study period. Discussions with consultants from the industry and academia as well as representatives from relevant NGO's and residents living along the river were made. Visits and personal inspection of the river itself at several stretches were also made to gain first-hand observation.

There are several projects which had been undertaken and several approaches that had been taken to improve the situation. Continuous motivation and incentives to participate in community programs had been given. Many NGOs are working towards the betterment of the river environment. The Berita Harian, a local daily newspaper, publishes opinions from professional on the general state of the environment every Tuesday of the week. The public had been directly involved in the policy and decision-making regarding their community. The authorities have been monitoring, communicating and coordinating on the restoration projects. The following are the summaries of the effectiveness of methods and approaches undertaken:

Human approach

The human approach can be considered as utilizing the people factors in organizations or projects. It involves motivation and incentives to participate, the driving force to forge a partnership between the community and the authority, tapping professional expertise, and exploiting the media as pointed out by Falk (1992). There must be urgency and commitment among the stakeholders to find solutions to the problem. Mokhtar (2007) showed that relationship building and trust take time, and results cannot be achieved immediately. Interest within the group of stakeholders need to be constantly nurtured and maintained.

The number of NGOs working towards the betterment of river environments is an indication of the effectiveness of this approach. The mass media can play an important part in reporting and giving information of 'clean-up' activities locally and around the world. Diseases related to water pollution could be highlighted.

Mohkeri and Parish (2003) observed that basic policies to improve river environment and restoration can encourage better public participation. The public could be directly involved in the initiation of policy and decision-making on matters of program design and related issues regarding the fate and welfare of their own community. Folz and Hazlett (1991) and Folz (1999) observed that citizens are more likely to participate effectively in collective efforts when they are party to the policy decisions.

Many residents in the vicinity of a river are denied any usage of the river in their daily lives. People do not depend on rivers directly for water supply for drinking, cultivation or as a means of transport anymore. Mohkeri and Parish (2003) observed that the value and importance of rivers have been lost and that the traditional culture to safeguard against threat of rivers is forgotten. With better provisions of facilities, the river could be more reachable to the people who would feel more connected to it.

Community-based groups like Residents Associations have been formed to discuss and carry out ‘cleaning up’ activities for Gombak River. Global Environment Centre (GEC), an NGO, has also been running programs for school children to instill a love for our rivers and educate them to care for the river’s well-being as was reported in the local newspaper, the Star (2006) on 18 September. 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 reported on 6 January 2007 in the same media (The Star, 2007).

Systems approach

An effective system and structural framework could track and monitor basic information on activities that are being organized which concern the environment needs. Projects could thus be prioritized based on what is known to work. Palmer and Allan (2006) pointed out that although much is known about effective rehabilitation projects, this information has not been used in most projects. Holmes (1999) suggested that 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. Government could ensure that restoration projects are credible and requirements must be established for monitoring outcomes and tracking agency performance. A coordinated monitoring system for restoration projects must be implemented. Effective communication is required not only between the specialists like engineers, geologists and hydrologists, but also between the specialists and the general public. Local authorities, nature conservation bodies, water authorities and resident associations must be involved.

The level of technical understanding between government agencies and authorities will lead to perplexed control systems and procedures. Projects which may have negative impacts to the sensitivity of river catchments could be approved in these areas. Pillay and Talha (2003) suggested that water supply catchments areas should be gazetted by the State Governments and integrated management approach be practiced for effective control. River plans should be given highest priority in river management. Urban rivers cannot cope with the total load from the surrounding industrial activities. More stringent amendments are needed for the environmental quality (Sewage and industrial effluents) regulations of 1979 for water courses discharging water into catchment areas.

Regulatory approach

Compliance ‘with’ laws and regulations is a common instrument used to combat environmental pollution. However, Novotny and Somlyody (1995) observed that this approach have resulted in significant failures when standards were too lenient or if they were too stringent. Developers would purposely stay within the size limits just to avoid having to conduct an EIA study. The introduction of new regulations and amendments to existing regulations should be given enough time to achieve compliance. Schnelle and Brown (2002) suggested that ‘they’ are required to demonstrate constant progress in reducing emissions and discharges. Areas of extreme severity could be allowed more time to achieve attainment. Tightening standards could be scheduled over a period of time. It is imperative that a detailed study ‘should’ be carried out with a focus on the water quality of the river system and the threats that the fragile river system will face. The introduction of new regulations and amendments to existing regulations had been given enough time for states to achieve compliance. Tightening standards had been scheduled over a period of time to assure smooth implementation. The EIA requirements have been implemented.

Technical approach

The technical approach is involved in the application of the appropriate and affordable hardware. Use of aerators is an example. The entire river is oxygenated by the atmosphere surface to bottom. Bottom toxic gases are also neutralized and foul odors quickly disappear. Laing and Rausch (1993) pointed out that inversion and oxygenation will also reduce disease by exposing pathogenic bacteria to sunlight and these pathogens are weakened or killed. Accumulated sediment can be removed from the river ‘thereby achieving’ a more uniform channel cross section and bed profile, but ‘at a high cost’. Proper maintenance by controlled activities in the upper and middle reaches of the river becomes important after the deepening and desilting has been done. Another remediation method is by using living plants, or plants combined with dead or organic materials to maximize erosion control and to form permanent turf reinforcement. Where cover for fish is absent, rehabilitation efforts could focus on introducing boulders and logs, and planting suitable overhanging riparian vegetation.

Aeration facilities were installed at the middle region of Gombak River which is at the industrial area of the river. River deepening and desilting to remove accumulated sediment had also been done. Plants and overhanging riparian vegetation had been planted. More organic instead of inorganic fertilizers had been applied to golf courses. Some oil and grease traps at food outlets had been installed as reported in The Star (2006) on 13 January 2006. The main objectives of the proposal to ‘clean-up’ Gombak 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.

Other methods of improvement are to set up small built-in 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. 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 barriers were removed and pools and wetlands were constructed instead (Petts et al., 2002). More organic instead of inorganic fertilizers could be used for golf courses to curb the excessive flow of nutrients into the river water; and oil and grease traps could be installed at food outlets to filter and separate oil and other residues in their wastewater.

RESULTS

The results of monitoring the three parameters namely, nitrates, chlorides and phosphates which were taken at regular time intervals and the corresponding values of the WQI for the year show that for nitrates the mean concentration was 0.78 mg/l with a maximum of 12.27 mg/l, a minimum of 0.01 mg/l and a standard deviation of 1.19 mg/l. Corresponding values for chlorides were 8.45, 102.22 l, 1.00 and 12.68 mg/l. The values for phosphates were 0.33, 9.74,, 0.01 and 0.75 mg/l. The corresponding values for the WQI were 68, 95, 28 and 15.85.

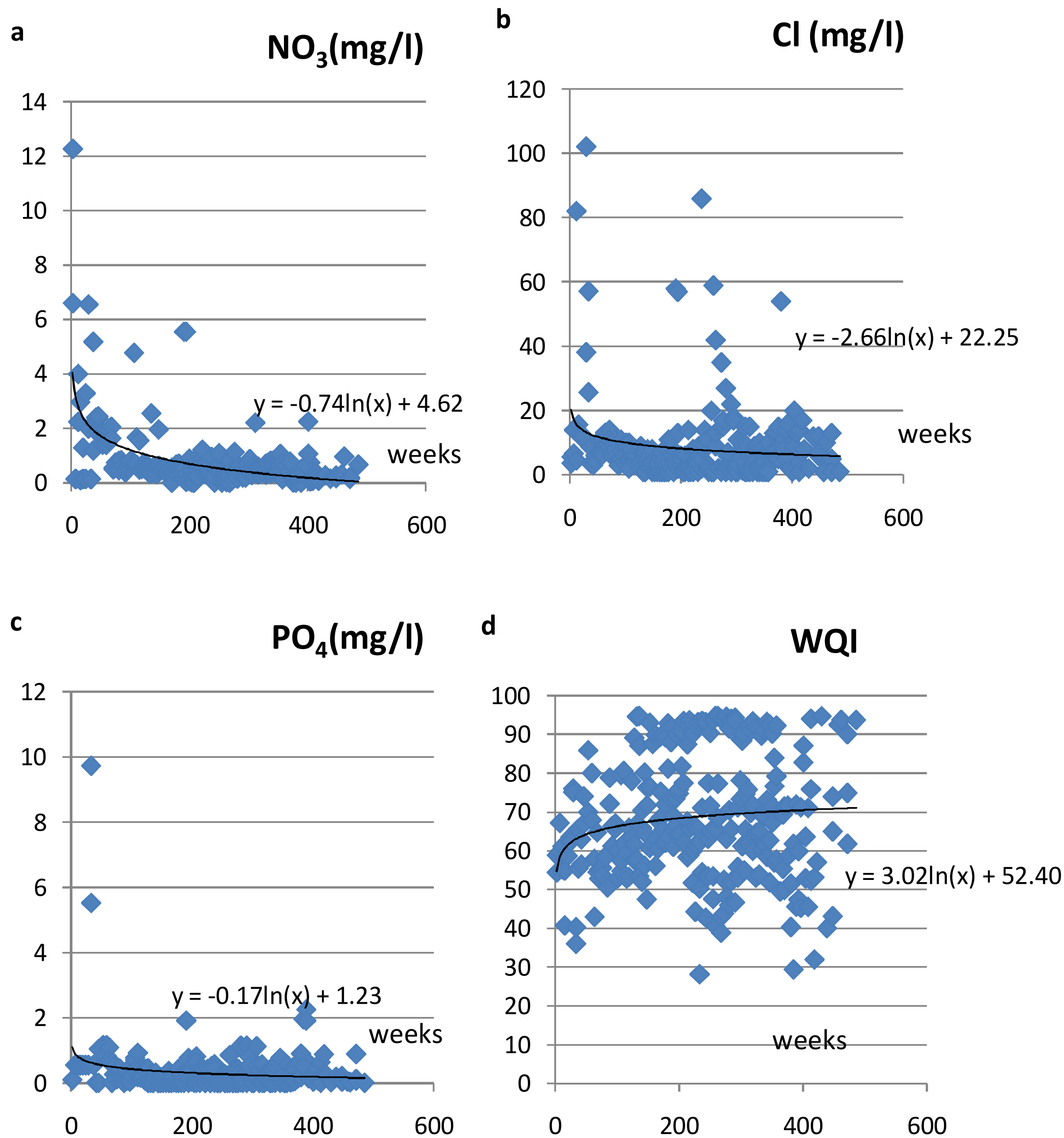

Figure 1. Salt concentration and WQI trends.

The ionic concentrations for all the salts were regressed with weeks from the starting date to examine the trends for these parameters over the study period. Analysis using the linear, polynomial, exponential and the natural log relationships were tried and it was found that the natural log relationship gave the strongest correlation. The correlation was not strong. For the case of nitrates R^2 was 0.37. This relationship was used for all other parameters.

Nitrates

The ionic concentration regressed against weeks over the nine-year period for nitrates can be expressed as $y=4.62 - 0.74\ln(x)$ where y=concentration in mg/l and x=time in weeks. This is shown in Figure 1a. It started with a value of 4.62 mg/l at the beginning of the study period ending with a level of 0.03 mg/l at the end of the period.

Chlorides

The ionic concentration regressed against weeks over the nine-year period for chlorides can be expressed as y=22.43 – 2.66ln(x) where y=concentration in mg/l and x=time in weeks as shown in Figure 1b. It started with a value of 22.25 mg/l at the beginning of the study period ending with a concentration level of 5.80 mg/l at the end of the period.

Phosphates

The ionic concentration regressed against weeks over the nine-year period for phosphates can be expressed as y=1.23 – 0.17ln(x) where y=concentration in mg/l and x=time in weeks as shown in Figure 1c. The concentration started with a value of 1.23 mg/l at the beginning of the study period ending with a level of 0.16 mg/l at the end of the period.

Water quality index

The values of WQI regressed against weeks over the nine-year period can be expressed as y=52.40 + 3.02ln(x) where y=WQI and x=time in weeks. This is shown in Figure 1d. It started with a value of 52 at the beginning of the period ending with a value of 71 at the end of the study period.

DISCUSSION

The final ionic concentration of nitrates showed a reduction of 99.27% compared to the beginning of the study period. This could be the combined effect of reduced agricultural activities as a result of urban migration and a tighter control of discharges from industrial activities. The final ionic concentration of chlorides showed a reduction of 73.93% compared to the beginning of the study period. Levels of chlorides are affected by rainfall and floods which occur frequently around the river basin. Sea water intrusion also happens sometimes. The final ionic concentration of phosphates showed a reduction of 87.27% compared to the beginning of the study period. As in the case for nitrates this could be the combined result of reduced agricultural activities and a better control of industrial and domestic discharges. The WQI showed an overall improvement of 36%. The WQI depends on other parameters which are out of the scope of the current study.

Muller and Hahn (1995) suggested that because clean water costs money simple and effective improvement approaches be applied. National and regional environmental authorities as well as local or state municipalities should cooperate to identify financing schemes that are consistent with the existing institutional structure and facilitate the flow of capital into these water quality projects. It is apparent that from the monitoring exercise that these simple approaches to control pollution have been successful.

CONCLUSIONS AND RECOMMENDATIONS

Current approaches to improve the quality of the Gombak River in terms of nitrates, chlorides and phosphates have been quite successful. There is still room for improvement. The current activities must be continued and enhanced in order to continue improving the conditions. The above 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 'attitudinal' change is also a priority to be instilled in the authorities and the community. Malaysia needs an effective national communication system which could track and monitor basic information on activities that are being organized that concern the environment. A master plan is needed for river works to ensure comprehensive river administration in the river system. For Gombak 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. The effectiveness of the EIA implementation needs to be examined because certain projects no matter the size requires EIA to be conducted and this should be religiously implemented to ensure the well-being of Gombak River and other similar rivers. Environmental reporting could be made mandatory for industries. Barriers should be removed to make the river accessible to the public. The entire improvement process could take decades, but gradual progress is better than no progress at all. The progress has to be continually monitored.

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