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Full Length Research Paper

Monitoring and management issues of heavy metal pollution of Gombak River, Kuala Lumpur

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There had been concerns about related issues on urban river pollution in Malaysia. These included inadequate supplies of water in big cities and unexpected floods threatening human lives and property. The results of efforts to improve the Gombak River water quality in Kuala Lumpur were presented. The Gombak River is a tributary of the Klang River that passes through the populous and important city of Kuala Lumpur. Special focus on metals content was given following reports by the Department of Environment of Malaysia to assess the state of metal contamination of the river. The effectiveness of government efforts through engineering and river works and public awareness campaigns to strive for a healthier Gombak River was observed over a period of nine years from 1997 to 2005. Results showed that the pollution status in relation to concentrations of metals in the river water had essentially remained at the same levels over the study period for all metals investigated.

Key words: Heavy metal pollution, pollutant source, remedial method, urban river.

INTRODUCTION

Gombak River

The Gombak River (Malay: *Sungai Gombak*) is a river which flows through Selangor and Kuala Lumpur. It is a tributary of the Klang River. The point where it meets the Klang River is the origin of Kuala Lumpur's name. Gombak River was used to be called Sungai Lumpur. Kuala Lumpur's name was taken as it was located in Sungai Lumpur's confluence or "Kuala Lumpur". The Gombak 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 river holds a special significance as the river associated with the capital city of Kuala Lumpur. Figure 1 shows the confluence of the Gombak River and the Klang River in the heart of the city.

Pollution issues

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. Organic loading in the Klang River has not improved significantly over the years. 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 then follows by putting rivers in Class I, II, III, IV, or V based on the Water Quality Index (WQI) and Interim National Water Standard for Malaysia (INWQS) on an annual basis. The WQI is computed based on six main chemical, biological and physical parameters. In 1997, the river was classified as Class III based on the water quality parameters measured by DOE. Measurements made in 2005 showed that the river had fallen gradually to Class IV.

Sources of contaminants

Heavy metal contamination of sediments can critically degrade aquatic systems. Monitoring the concentration levels would provide the preliminary baseline data for control of pollution. Natural as well as human activities

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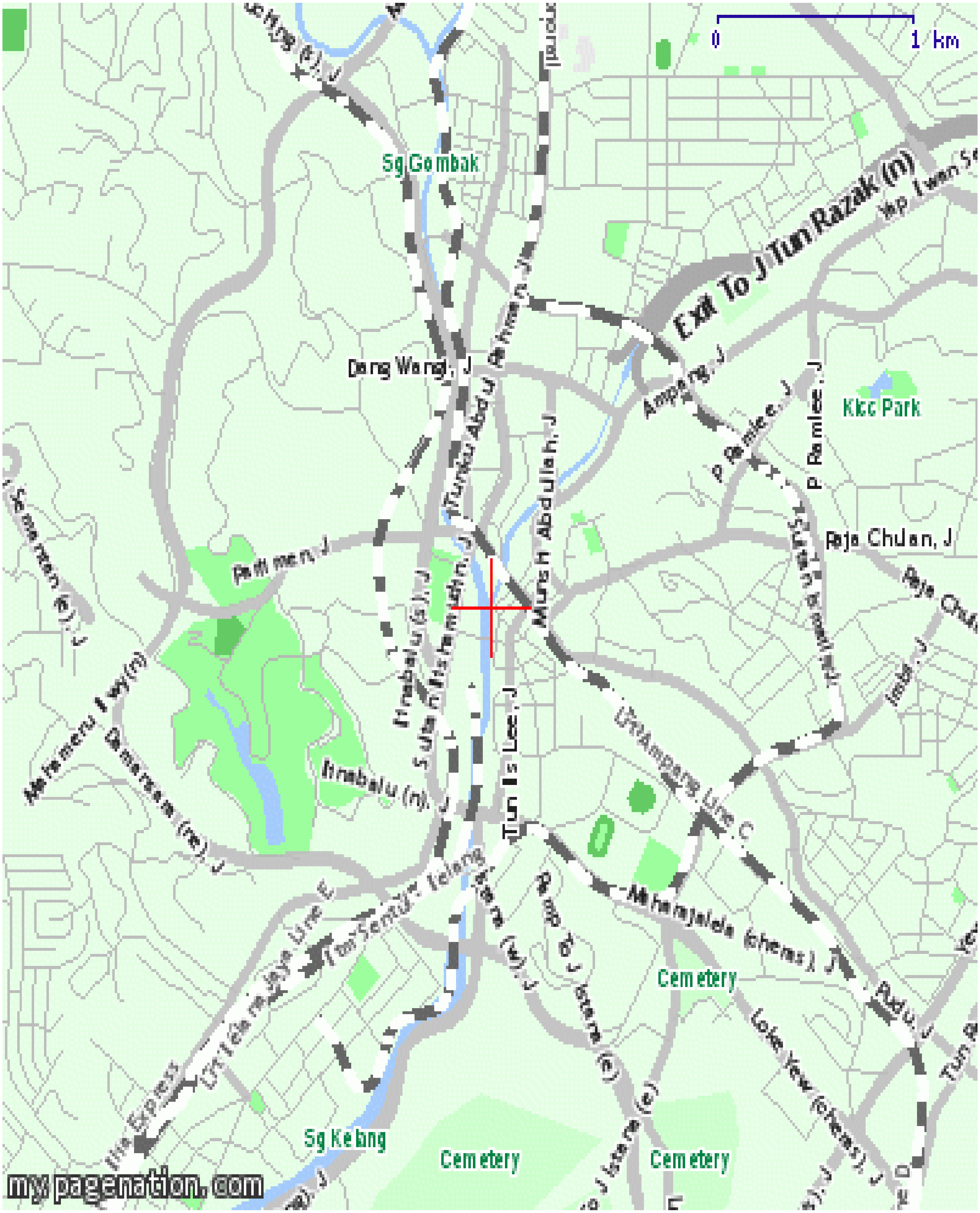

Figure 1. Gombak River (Sg Gombak) location map.

have caused river water pollution. Important contributors are heavy metals. Arsenic contamination of groundwater occurs naturally with higher concentration of arsenic at deeper levels. Mercury is generated naturally from volcanic emissions and the degassing of the earth's crust. The substance exists in the form of elemental mercury, organic and inorganic mercury. Significant producers of mercury are the mining operations, chloralkali plants, and the paper industries (Goyer, 1996). Mercury is dispersed across the globe by winds and returns to the earth through rainfall, accumulating in aquatic food chains and fish in lakes (Clarkson, 1990). Mercury compound additives were used in paints as fungicides until 1990. These compounds are now banned; however, old paint supplies and surfaces painted with these old supplies still exist. Mercury is still used in thermometers, thermostats, and dental amalgams. Chromium is a carcinogen. It is a byproduct of the mining and smelting of lead and zinc. The leather industry produces chromium and other toxic substances. Cadmium may be found in reservoirs containing shellfish. Cadmium is also present in tobacco. It can be found in soils originating from cadmium-bearing insecticides, fungicides, sludge, and commercial fertilizers used in agriculture. Lead is present in water sources. Lead and silver in river waters are commonly found together and associated with lead mining. Impacts from very old mines can be very long-lived. In the River Ystwyth in Wales for example, the effects of silver and lead mining in the 17th and 18th centuries still causes unacceptably high levels of zinc and lead in the river water right down to the estuary.

Causes of pollution

The cause of pollution primarily has been attributed to rubbish, effluents from industries like iron and steel, saw-milling, battery production etc., and clearing of land for development and overflows from manholes and septic tanks. Inefficient drainage systems and the fencing of rivers have made the river unreachable to the residents for cleanup. The situation is made worse by a fast-growing population and industrialization within the river perimeter covering several townships.

Rivers provide a convenient means of drainage, and are used for the discharge of domestic, commercial, industrial and agricultural effluents resulting in severe pollution. Rapid development has produced great amounts of human wastes as well as wastes from all of man’s activities, including agriculture, industrial, commercial and transportation wastes. This has resulted in large number of polluted rivers, some are beyond rehabilitation as pointed by Abdullah (2002). Agriculture expansion and industrialization have also rapidly changed the land use from one of mainly forest and food industrial centers (Government of Malaysia, 2001).

Detrimental effects

Exposure to heavy metals can be gauged by the accumulation of the metals in various organs. Common test samples are the hair, nails and bones. Analysis of metal contamination of soils collected from four different sites along the lower Diep River, Cape Town, South Africa, conducted by Ayeni et al. (2010) showed that this is a common area of concern the world over.

Khudzari et al. (2011) successfully measured the heavy metals accumulation in the hair of sanitary workers using X-ray fluorescence (XRF). Concerns over the heavy metal exposure has also attracted the attention of health workers looking at the consumers of open wells (Ochieng et al., 2010) regarding sanitary features, pollutions and water qualities.

Arsenic is the most common cause of acute heavy metal poisoning in adults. Arsenic is released into the environment by the smelting process of copper, zinc, and lead, as well as through the manufacture of chemicals and glasses. Arsine gas is a common byproduct in the manufacture of pesticides that contain arsenic. Arsenic may be also be found in water supplies worldwide, leading to exposure of shellfish, cod, and haddock. Other sources are paints, rat poisons, fungicides, and wood preservatives. Target organs are the blood, kidneys, and central nervous, digestive, and skin systems (Roberts, 1999). Arsenic is a carcinogen which causes many cancers including skin, lung, and bladder as well as cardiovascular disease and diabetes prevalence. Arsenic in drinking water may also compromise immune function.

Mercury and cadmium are still used in batteries though some now use other metals instead. Many researchers suspect dental amalgam is a possible source of mercury toxicity (Omura et al., 1996; O'Brien, 2001). Medicines, such as mercurochrome and merthiolate, are still available. Algaecides and childhood vaccines are also potential sources. Inhalation is the most frequent cause of exposure to mercury. The organic form is readily absorbed in the gastrointestinal tract (90 to 100%); lesser but still significant amounts of inorganic mercury are absorbed in the gastrointestinal tract (7 to 15%). Target organs are the brain and kidneys (Roberts, 1999).

Cadmium is used in nickel-cadmium batteries, PVC plastics, and paint pigments. Lesser-known sources of exposure are dental alloys, electroplating, motor oil, and exhaust gases. Inhalation accounts for 15 to 50% of absorption through the respiratory system; 2 to 7% of ingested cadmium is absorbed in the gastrointestinal system. Target organs are the liver, placenta, kidneys, lungs, brain, and bones (Roberts, 1999). Cadmium is a metal in sludge-derived fertilizer and present in water sources.

Lead was once commonly used in gasoline (petrol), though its use is now restricted in some countries and is present in water sources. Lead accounts for most of the cases of pediatric heavy metal poisoning (Roberts, 1999).

It is a very soft metal and was used in pipes, drains, and soldering materials for many years. Millions of homes built before 1940 still contain lead (e.g., in painted surfaces), leading to chronic exposure from weathering, flaking, chalking, and dust. Every year, industry produces about 2.5 million tons of lead throughout the world. Most of this lead is used for batteries. The remainder is used for cable coverings, plumbing, ammunition, and fuel additives. Other uses are as paint pigments and in PVC plastics, x-ray shielding, crystal glass production, and pesticides. Target organs are the bones, brain, blood, kidneys, and thyroid gland (International Occupational Safety and Health Information Centre, 1999).

Zinc toxicity is rare but is more likely to occur in adults than in children. It is usually related to occupational hazards and has been reported to occur in metal workers exposed to fumes containing zinc. A few instances of zinc toxicity have been reported in people who consumed acidic food or beverages that had been stored in galvanized zinc containers. Taking excessive supplemental zinc can result in nausea, vomiting, and diarrhea. The chronic intake of excessive zinc supplements can result in copper deficiency, as zinc inhibits the absorption of copper.

Calcium and phosphate are closely related nutrients. Calcium toxicity is rare, but overconsumption of calcium supplements may lead to deposits of calcium phosphate in the soft tissues of the body. Phosphate toxicity can result from the overuse of laxatives or enemas that contain phosphate. Severe phosphate toxicity can result in hypocalcemia and in various symptoms resulting from low plasma calcium levels. Moderate phosphate toxicity occurring over a period of months may result in the deposit of calcium phosphate crystals in various tissues of the body.

Discussion of iron toxicity is limited to ingested or environmental exposure. Iron overload disease (hemochromatosis) is an inherited disorder. Iron is a heavy metal of concern, particularly because ingesting dietary iron supplements may acutely poison young children (e.g. as few as five to nine 30-mg iron tablets for a 30-lb child). Ingestion accounts for most of the toxic effects of iron because iron is absorbed rapidly in the gastrointestinal tract. The corrosive nature of iron seems to further increase the absorption. Most overdoses appear to be the result of children mistaking red-coated ferrous sulfate tablets or adult multivitamin preparations for candy. Fatalities from overdoses have decreased significantly with the introduction of child-proof packaging. In recent years, blister packaging and the requirement that containers with 250 mg or more of iron have child-proof bottle caps have helped reduce accidental ingestion and overdose of iron tablets by children.

Other sources of iron are drinking water, iron pipes, and cookware. Target organs are the liver, cardiovascular system, and kidneys (Roberts, 1999).

Remedial methods

The biggest contributors to pollution of the groundwater are activities related to waste disposal, mining, logging, transportation, shipping and aviation, Agriculture and the automobile industry are also big contributors. The vulnerability of soil and groundwater in relation to agriculture activities and drinking water supply was presented by Mohamed et al. (2009).

There are various reasons why river water quality needs to be maintained especially in urban areas. First and foremost it is for the safety of the 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. Other reasons for the need for river cleanups are health, recreation and aesthetics that generally mirror the image of the location and directly affect the quality of life in the community. Strategic stretches of the river could be beautified for recreational purposes as suggested by Abdullah (2002).

Rivers cannot provide enough water for the consumers because of the high levels of contaminants and other reasons including lack of understanding of environmental limitations. It is frequently necessary to supplement water supplies from sources several hundred kilometers away. This could bring about more biodiversity and environmental management complexity. There is a need to start taking proactive actions to protect, conserve and restore the rivers so that their waters can be sustained for future use as noted by Chan (2004). Chop and Jusoh (2002) reported that currently, there have been some fragmented efforts from the authorities for river restoration and rehabilitation.

MATERIALS AND METHODS

For each metal, including arsenic, mercury, cadmium, chromium, lead, zinc, calcium and iron, 263 ionic concentrations based on data collected twice a month from three sampling stations referred to as K17, K18 and K24 along the river by DOE were examined for the period from 1997 to 2005.

Sampling

Surface sediment samples were collected at three sites each time. Three surface sediment (0 to 5 cm) samples were collected and each sample was placed in polyethylene plastic bag and labeled. They were then kept in an ice box. As soon as the field work was finished, samples were preserved at 10°C. To prevent uncertain contaminations, all laboratory equipments used were washed with phosphate-free soap, double rinsed with distilled water and left in 10% HNO_3 for 24 h and all equipments were then rinsed two times with double distilled water and left semi-closed to dry at room temperature.

Table 1. Metal concentration range and average for the period from 1997 to 2005.

Metal	Mean (mg/L)	Max (mg/L)	Min (mg/L)	Std dev
Arsenic	0.007391	0.094	0.001	0.010758
Mercury	0.000339	0.005	0.0002	0.00046
Cadmium	0.001224	0.009	0.001	0.000878
Chromium	0.002939	0.032	0.001	0.004147
Lead	0.01016	0.051	0.001	0.003658
Zinc	0.042481	0.710	0.0004	0.061285
Calcium	13.08902	204.36	0.1	21.2523
Iron	0.548914	10.05	0.001	0.916411

Certified Reference Material (CRM) (International Atomic Energy Agency, Soil-5, Vienna, Austria) was determined as a precision check. Percentage of recoveries (n=5 for each metal) for certified and measured concentration of those metals ranged from 94% for Cu to 98% for Pb. Calibration curves for each trace element were determined with 1,000 mg/L (BDHSpectrosol®) stock solution. The reagent and procedural blanks were monitored for each fraction after five samples during the analysis as part of the quality accuracy program.

All statistical analyses were computed by using Package for Social Science (SPSS) version 16. The graphs were performed with Microsoft Excel for Windows.

Analytical methods

The appropriate ASTM methods were used for the analyses. The mean, maximum and minimum values together with the standard deviations were computed and recorded. These are shown in Table 1. Figure 3a to h give the scatter-grams of the results for the metals.

Consultation

Studies of rehabilitation projects nationally and internationally were examined to see the relevance of the methods applied to combat and improve the polluted state of rivers. 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

Heavy metal concentration profiles

Figure 2 shows the concentrations metals in the river water. Figure 2a shows the results for arsenic over the years from 1997 to 2005. All data recorded as <0.001 mg/l were taken as 0.001 mg/L for the purpose of determining the overall trend. The regressed value was found to be 0.006 mg/L with a slight indication of an increasing trend but this was not easily noticeable.

For mercury, Figure 2b shows the concentration over the years from 1997 to 2005. All data recorded as <0.001 mg/L were taken as 0.001 mg/L for the purpose of determining the overall trend. The regressed value was found to be 0.0007 mg/L with an indication of a slight decreasing trend over the study period.

Figure 2c shows the concentration for cadmium over the period from 1997 to 2005. All data recorded as <0.001 mg/L were taken as 0.001 mg/L for the purpose of determining the overall trend. The regressed value was found to be 0.0015 mg/L. There was an indication of a slight decreasing trend over the entire study period. Again, like the case for mercury, this trend was not easily noticeable.

For the case of Chromium, Figure 2d shows the concentration over the period 1997 to 2005. All data recorded as <0.001 mg/L were taken as 0.001 mg/L for the purpose of determining the overall trend. The regressed value was found to be 0.0037 mg/L with an indication of a slight decreasing trend over the study period but again this trend was not easily noticeable.

Figure 2e shows the concentration for lead over the period 1997 to 2005. All data recorded as <0.001 mg/l were taken as 0.001 mg/L for the purpose of determining the overall trend. The regressed value was found to be 0.0103 mg/L. The concentration stayed almost at a constant level over the entire study period.

Figure 2f shows the concentration of zinc for the period 1997 to 2005. All data recorded as <0.0004 mg/L were taken as 0.0004 mg/L for the purpose of determining the overall trend. The regressed value was found to be 0.0525 mg/L. There was an indication of a slight decreasing trend over the study period but like in the other cases, this trend was not easily noticeable.

Figure 2g shows the concentration of calcium for the period 1997 to 2005. The regressed value was found to be 20.799 mg/L. There was an indication of a slight decreasing trend over the study period but this trend was not easily noticeable.

Figure 2h shows the concentration of iron for the period 1997 to 2005. All data recorded as <0.001 mg/L were taken as 0.001 mg/L for the purpose of determining the overall trend. The regressed value was found to be 0.9292 mg/L. There was an indication of a slight decreasing trend over the study period but this trend was not easily noticeable.

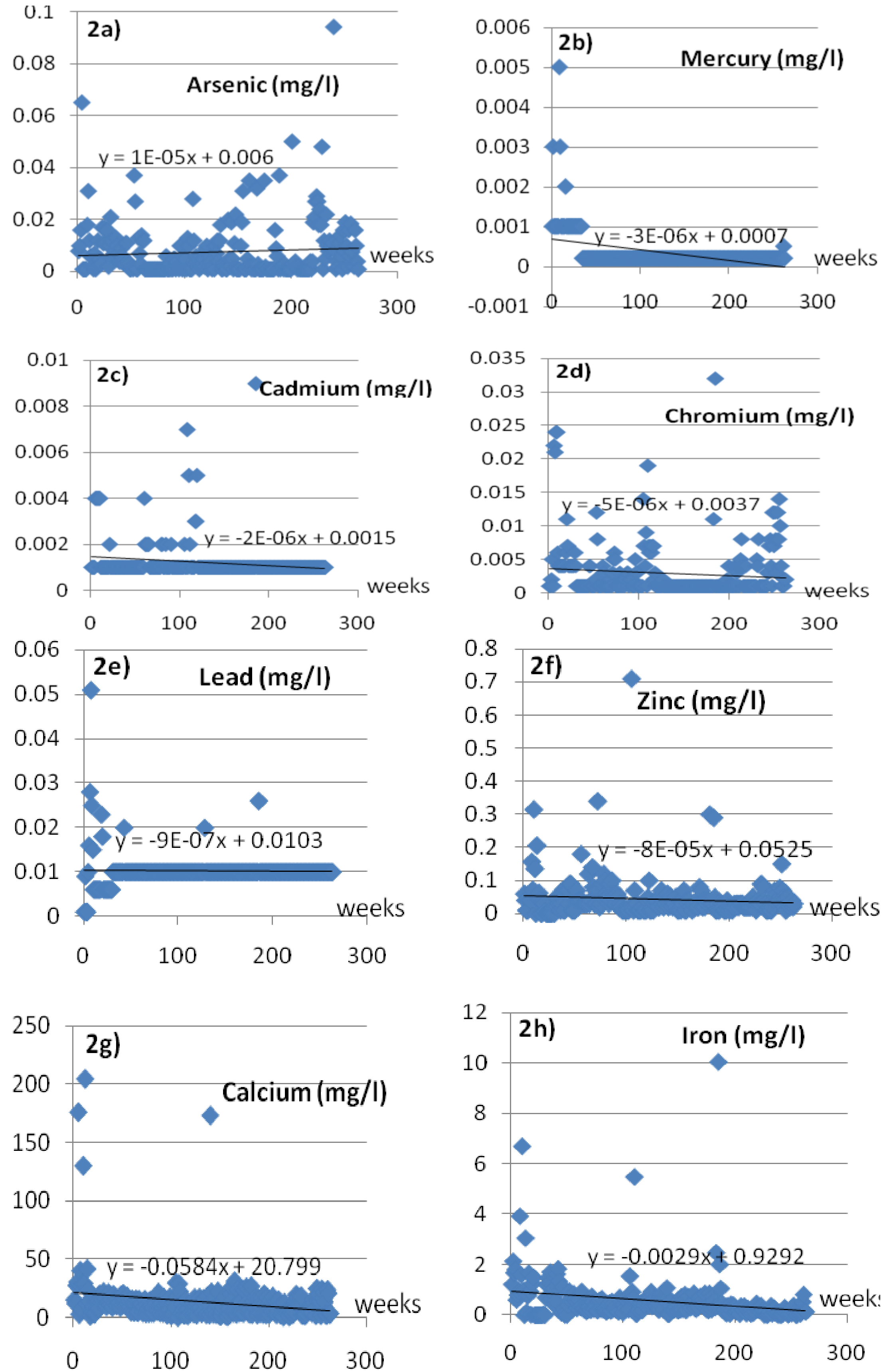

Figure 2. Metals concentration profiles from 1997 to 2005.

Management and improvement issues

The DOE has reported that the Gombak river water quality has a WQI mostly of Class IV. Technology and engineering approaches can be utilized for remedial action as indicated by Embi (2004). Aeration as described by Laing and Rausch (1993) has been practiced. Some barriers have been removed and trees planted which help to control erosion the natural way. Boulders and logs have been introduced which also act as cover for fish. Dredging and desilting are on-going in order to achieve a more uniform channel cross section and bed profile. Munusamy (2010) reported that between 500 and 800 tones of solid waste enters the Klang River basin system daily with only 80 tones (15%) picked out by existing trapping and removal mechanism. The solid waste composition in 2006 was reported at 36% from factories, 25% from squatters, 17% from hawkers, 10% as debris and 18% from individuals. In order to prevent sedimentation and maintain the quality of the river water from further deterioration, the strategy must lie in controlling and reducing the amounts of contaminants getting into the system especially from the upper and middle reaches of the river.

Institutional issues are also major stumbling blocks for effective management of rivers as observed by Chan (1998). The level of technical understanding differs among government agencies and authorities which lead to inconsistent and contradictory approaches to the problem may have negative impacts to the sensitivity of river catchments are being approved in these areas. Abdullah (2002) acknowledged that there is no formal mechanism to integrate and coordinate activities within a river basin. It is suggested that water supply catchments areas should adopt an integrated management approach which involves the relevant agencies to ensure the water catchments are effectively controlled as proposed by Pillay and Talha (2003).

Government support is vital but the general public can do in their everyday lives towards preserving the river environment. Mass media can play an important part in reporting and giving information on successful cleanup examples around the world. Issues that could be highlighted are diseases that water pollution can cause, how they can happen and how they could have been prevented. This information has not been used in most projects or policies as observed by Palmer and Allan (2006). This could be due to an absence of a national policy specifically aimed at river rehabilitation and the general lack of available finance which restricts the progress that can be made (Holmes 2000). As mentioned by Low (2003), government can still play a pivotal role and responsibility in setting the overall policies and laws for river development and management, but it is inevitable that people must be involved.

Significant failures have resulted when standards are too lenient or, if they are too stringent (Novotny and Somlyody, 1995). More time can be given to achieve compliance as suggested by Schnelle and Brown (2002). Tightening standards could then be scheduled over a period of time to assure affordability and allow dischargers to develop realistic plans. As observed by Raman and Sangaralingam (2002), despite the presence of many laws which protect rivers in one way or another, enforcement is still a problem.

Citizen cooperation and involvement in policy initiation and program design decisions for their own community are vital. Basic policies to improve river environment and restoration can encourage better public participation as noted by Mohkeri and Parish (2003). Higher rates of participation and waste stream diversion place more importance on citizen involvement in the policy initiation and program design decisions as noted by Folz and Hazlett (1991). Chan (2003) and Low (2003) indicated that river restoration and rehabilitation could only be successful with a combined effort between government, NGOs and the local communities working together to ensure the cleanliness of the rivers. The authorities are now inviting NGOs and local communities to play an active role in river management as observed by Low (2003). The role of NGOs and ordinary citizens is becoming increasingly important as pointed out by Rasagam and Chan (2002). The objective of this study is to analyze the results of the efforts to clean up the Gombak River with a special focus on the metals content of the river water over a nine year period from 1997 to 2005. Steps are recommended to further upgrade the water quality classification for aesthetic sight and preventing potential health threats; instill feeling of ownership of the river to the residents in the river vicinity; and to review environmental regulations to prevent additive and overwhelming industrial effluent loading. The overall results showed that the concentrations of metals in Gombak River water have remained within the schedule limits for all metals considered.

Effective communication is required not only between the specialists like engineers, geologists, hydrologists etc., but also between the specialists and the general public. The agencies directly involved in rehabilitation initiatives should include a combination of these specialists with technical knowledge and know-how and local authorities, nature conservation bodies, water authorities and resident associations as suggested by Muyibi et al. (2008).

Relationship building and trust do take time, and because results take a long time and cannot be achieved immediately. Means of continuous motivation and incentives to participate in the programs are needed. There is a need to improve the cooperation between the private sector and the government agencies as indicated by Muyibi et al. (2008). Steps to enhance the chance of success in public involvement has been shown by Falk (1992) to be finding the right driving force, forging a partnership between the community and the authority, tapping professional expertise, showing any early results and exploiting the media.

Conclusions

The metal contents in the Gombak River are not yet critical. The concentrations of all metals considered have stayed almost at constant levels over the study period. Tools are available for further cleaning up of the river, but much is needed in the provision of funds to buy the 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 society as a whole. To enhance the cleanup process could take decades, but gradual improvement is better than none at all.

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