Port Klang

Initial Risk Assessment

Port Klang Integrated Coastal Management
National Demonstration Project

Selangor Waters Management Authority
(Lembaga Urus Air Selangor or LUAS)
Ahah Alam, Selangor, Malaysia

GEF/UNDP/IMO Regional Programme on
Partnerships in Environmental Management
for the Seas of East Asia

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MISSION STATEMENT

The Global Environment Facility/United Nations Development Programme/International Maritime Organization Regional Programme on Building Partnerships in Environmental Management for the Seas of East Asia (PEMSEA) aims to promote a shared vision for the Seas of East Asia:

> "The resource systems of the Seas of East Asia are a natural heritage, safeguarding sustainable and healthy food supplies, livelihood, properties and investments, and social, cultural and ecological values for the people of the region, while contributing to economic prosperity and global markets through safe and efficient maritime trade, thereby promoting a peaceful and harmonious co-existence for present and future generations."

PEMSEA focuses on building intergovernmental, interagency and intersectoral partnerships to strengthen environmental management capabilities at the local, national and regional levels, and develop the collective capacity to implement appropriate strategies and environmental action programs on self-reliant basis. Specifically, PEMSEA will carry out the following:

- build national and regional capacity to implement integrated coastal management programs;
- promote multi-country initiatives in addressing priority transboundary environment issues in sub-regional sea areas and pollution hotspots;
- reinforce and establish a range of functional networks to support environmental management;
- identify environmental investment and financing opportunities and promote mechanisms, such as public-private partnerships, environmental projects for financing and other forms of developmental assistance;
- advance scientific and technical inputs to support decision-making;
- develop integrated information management systems linking selected sites into a regional network for data sharing and technical support;
- establish the enabling environment to reinforce delivery capabilities and advance the concerns of nongovernmental and community-based organizations, environmental journalists, religious groups and other stakeholders;
- strengthen national capacities for developing integrated coastal and marine policies as part of state policies for sustainable socioeconomic development; and
- promote regional commitment for implementing international conventions, and strengthening regional and sub-regional cooperation and collaboration using a sustainable regional mechanism.

The twelve participating countries are: Brunei Darussalam, Cambodia, Democratic People's Republic of Korea, Indonesia, Japan, Malaysia, People's Republic of China, Philippines, Republic of Korea, Singapore, Thailand and Vietnam. The collective efforts of these countries in implementing the strategies and activities will result in effective policy and management interventions, and in cumulative global environmental benefits, thereby contributing towards the achievement of the ultimate goal of protecting and sustaining the life-support systems in the coastal and international waters over the long term.

Dr. Chua Thia-Eng
Regional Programme Director
PEMSEA

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List of Abbreviations and Acronyms

AN	–	ammoniacal nitrogen
API	–	Air Pollution Index
ASEAN	–	Association of Southeast Asian Nations
BOD	–	biochemical oxygen demand
CO	–	carbon monoxide
COD	–	chemical oxygen demand
CPUE	–	catch per unit of effort
DO	–	dissolved oxygen
DOE	–	Department of Environment
Geomean	–	geometric mean
IRA	–	initial risk assessment
ISQV	–	interim sediment quality values of Hong Kong
IWQS Malaysia	–	Index Water Quality Standard Malaysia
IMWQS Malaysia	–	Interim Marine Water Quality Standard Malaysia
INWQS Malaysia	–	Interime National Water Quality Standard Malaysia
LESTARI	–	Institute Alam Sekitar dan Pembangunan/Institute for Environment and Development — Universiti Kebangsaan Malaysia
LC_{50}	–	concentration of toxicant that causes death in 50 percent of an exposed population
LOAEL	–	lowest observable adverse effect level
LOC	–	level of concern
LUAS/SWMA	–	Lembaga Urus Air Selangor/Selangor Waters Management Authority
MEC	–	measured environmental concentration
MEL	–	measured environmental levels
MEY	–	maximum efficiency yield
MFR	–	mangrove forest reserves
MPP-EAS	–	GEF/UNDP/IMO Regional Programme for the Prevention and Management of Marine Pollution in the East Asian Seas
MPN	–	most probable number
MSY	–	maximum sustainable yield
NAHRIM	–	National Hydraulic Research Institute of Malaysia
NH_3	–	ammonia
NO_2	–	nitrogen dioxide
NO_3	–	nitrate
O_3	–	ozone
PAH	–	polycyclic aromatic hydrocarbon

PCB	–	polychlorobiphenyls
PEC	–	predicted environmental concentration
PEL	–	predicted environmental levels
PEMSEA	–	GEF/UNDP/IMO Regional Programme on Building Partnerships in Environmental Management for the Seas of East Asia
PM_{10}	–	particulate matter having a diameter smaller than 10 micrometer
PNEC	–	predicted no-effects concentration
PNEL	–	predicted no-effects level
PO_4	–	phosphate
ppm	–	parts per million or mg/l
PSP	–	paralytic shellfish poisoning
RQ	–	risk quotient: MEC (or PEC)/PNEC (or Threshold)
RQ_{Ave}	–	mean/average risk quotient: MEC (or PEC) $_{Geomean}$/PNEC (or Threshold)
RQ_{Max}	–	maximum risk quotient: MEC (or PEC) $_{Max}$/PNEC (or Threshold)
SEMP	–	strategic environmental management plan
Sg	–	*sungai* (Malaysian) or river
SO_2	–	sulfur dioxide
TBT	–	tributyltin
TDI	–	tolerable daily intake
TOC	–	total organic carbon
TSS	–	total suspended solids
UKM	–	Universiti Kebangsaan Malaysia
UPM	–	Universiti Putra Malaysia
U.S.EPA	–	United States Environment Protection Agent
U.S.FDA	–	United States Food and Drugs Administration

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Executive Summary

An environmental risk assessment estimates the likelihood of harm being done to identified targets as a result of factors emanating from human activity but which reach the targets through the environment. This combines knowledge about the factors that bring about hazards, their levels in the environment, and the pathways to the targets.

The potential harm to human and environmental targets may arise from exposure to contaminants in the environment. These contaminants come from activities that bring economic growth and contribute benefits to society. The potential harm to environmental targets may also arise from indiscriminate extraction of resources and physical destruction of habitats. The environmental impacts of these activities stem from the loss of ecological functions and the consequent disruption of ecological balance. The impacts may not be as evident as impacts from pollutants but these could be irreversible and may lead to greater losses.

There can be two approaches to protecting the environment and human health. The first approach is to eliminate the contaminant or stop the activities that produce it (hazard-based approach). Another approach is to prevent the contaminant level from exceeding an allowable level that presents acceptable risk (risk-based approach).

There has been a gradual shift in environmental policy and regulation from hazard-based to risk-based approaches, and this was partly due to the recognition that "zero discharge" objectives are unobtainable and that there are levels of contaminants in the environment that present "acceptable" risks (Fairman, et al., 2001). Aiming for "zero discharge" levels or using the best available technology may not be cost-effective and could result in excessive economic burdens to society and adversely affect the provision of goods and services that contribute to human welfare. Risk assessment is a systematic and transparent process that provides comprehensive and logical information to environmental managers and decisionmakers for identifying rational management options. Identifying areas of concern through the risk assessment also prevents the pitfalls of wasting effort and resources on minor concerns.

Various methodologies and techniques for ERA have been developed and different organizations are presently involved in further improving this management tool (ADB, 1990; UNEP-IE, 1995; UNEP-IETC, 1996; Fairman, et al., 2001).

The approach adopted by PEMSEA attempts to answer the two questions: "What evidence is there for harm being done to targets in the environment?" (referred to as a retrospective risk assessment) and "What problems might occur as a consequence of conditions known to exist, or to possibly exist in the future?" (referred to as a prospective risk assessment).

Retrospective risk assessment aims to determine significant causes of adverse effects observed on human and/or ecological targets. In many circumstances, however, it is never possible to identify cause with certainty after an effect is observed. Retrospective risk assessment does not provide a definite formula for enabling this to be done but it provides a transparent and logical series of steps for collecting and evaluating evidence that can help increase confidence in judgments about a suspected causal agent.

Prospective risk assessment involves predicting likely effects on targets from knowledge of a particular agent. It basically involves some comparison of exposure and effect concentrations. Depending on the level of detail, it can be carried out in a variety of sophisticated ways, but the starting point will often be a comparison of measured environmental concentrations (MECs) and predicted no-effect concentrations (PNECs) in order to obtain risk quotients (RQs). The prospective risk assessment starts by using worst-case and average scenarios and progresses if the results show the need for more refined assessment and more sophisticated ways of assessing and addressing the uncertainties associated with the RQ technique.

Both the retrospective and prospective risk assessments can be carried out independently. Alternatively, these two approaches can be performed concurrently and used to strengthen the individual assessments.

RETROSPECTIVE RISK ASSESSMENT

In the retrospective risk assessment, qualitative and quantitative observations on the resources and habitats were assessed, it was not possible to determine changes in fisheries as a result of the increased fishing intensity. It was also observed that establishing decline in fisheries using fish landing data may be difficult as fishes are caught from neighboring countries, particularly Indonesia, such that high fish landings are not really reflective of the status of fisheries in the Port Klang coastal waters. The results of the risk assessment show that data on other indicators of fisheries conditions such as catch per unit of effort (CPUE) will have to be gathered to enable more appropriate assessments to be carried out. Estimates of the maximum sustainable yield (MSY) will also be important to determine if the fishing effort is within sustainable levels or if this may eventually lead to adverse impacts on local fisheries.

For aquaculture, decline in production from 1,011.63 to 543.89 metric tons was observed from 1990 to 1993 while increase in production to 1,579.34 metric tons was noted in 2000. The decline in production in 1990–1993 was attributed to unsuitability of the areas for aquaculture, water contamination and diseases while the following increase in production was attributed to aquaculture technology improvements and control of water contamination and diseases. Areas of fish and prawn ponds were also reported to have increased from 1993 to 2000 although no quantitative information was provided. The development of aquaculture, which is recognized as an alternative way of coping with the increased demand for fish and shellfish, came however at the expense of mangrove and peat swamp areas, which were converted to culture ponds. The mangroves and peat swamps are important for the survival and reproduction of numerous aquatic organisms and the loss and degradation of these areas resulting from aquaculture development may adversely affect their ecological functions. The risk assessment indicates the need to evaluate the impacts of existing aquaculture practices on the natural ecosystem, identify environment-friendly aquaculture practices, balance the need to meet the increasing demand for marine food products and protect the natural environment.

Decline in mangrove cover was established for the Kapar and Klang Islands mangrove forest reserves (MFR). In the Kapar MFR as of 1998, only 410 ha (8 percent) remains of the 4,865 ha mangrove cover in 1970. Also in 1998, the remaining mangroves in the Klang Islands MFR was estimated to be 10,871.4 ha (88 percent) of the 12,301 ha in 1984. The identified primary cause of decline in mangrove cover in the forest reserves was the degazettement or removal from legal protection of certain portions of the forest reserves and subsequent land reclamation to accommodate developments in the vicinity of the Klang coastal area. The extensive loss of mangroves especially in the Kapar area may have had adverse ecological impacts arising from the impairment of ecological functions and services provided by the mangroves including shoreline protection, habitat for marine life, and carbon storage. Economic losses may also have occurred from reduced fisheries productivity and loss of large areas of the mangrove forest for sustainable forestry activities. The lack of adequate mangrove buffer strip also threatens agricultural areas near the coast. A better understanding of the ecological and economic impacts of the decline of mangrove areas in the Klang District will be valuable in formulating future development plans that will integrate ecological as well as economic considerations.

The retrospective risk assessment on three major groups of wildlife namely mammals, birds and freshwater fish in primary (dipterocarp), mangrove and peat swamp forests showed decline due primarily to loss or degradation of habitats as a result of changes in land use for various socioeconomic activities and in some cases, pollution.

The data used in the assessment were, however, very few, not comprehensive and in some cases, non-quantitative. The interrelatedness between the suspected agents and targets were not clearly defined most of the time, and it was difficult to correlate between the agents and the resources within the specified habitats. More research need to be undertaken to verify the reported decline in mammal, bird and fish species in the three forests. This research should be more comprehensive and should allow sufficient time to detect changes in the number of species and population. Studies to determine exposure, correlation and cause-effect relationships between potentially significant agents should also be undertaken.

PROSPECTIVE RISK ASSESSMENT

In the prospective risk assessment, potential stressors in the site were identified and the MECs of these stressors were compared with threshold values or PNECs to obtain RQs. An RQ less than 1 indicates acceptable risk and suggests little concern while an RQ greater than 1 signifies cause for concern. The level of concern increases with the increase in RQ.

The data for the prospective risk assessment came primarily from the Department of Environment – Selangor Monitoring Reports while the threshold values came from the Interim National Water Quality Standards (INWQS) and Interim Marine Water Quality Standards (IMWQS) for Malaysia. Some criteria values from the ASEAN Marine Water Quality Criteria (ASEAN, 2003) and other countries in the region were also used.

The risk assessment was carried out for selected coastal stations near the Klang and Langat Rivers and within the two rivers. Although the risk assessment was prescribed for marine waters, sediments and biota, the RQ approach was extended to the assessment of risk from major contaminants in ambient air.

Risk Assessment of Coastal Areas in the Klang ICM Area

The risk assessment for coastal waters in selected coastal areas near the Klang and Langat Rivers demonstrated cause for concern in all areas for oil and grease, *Escherichia coli* and suspended solids. For oil and grease, the highest cause for concern was found at Jugra, an important aquaculture zone, followed by Selat Klang Utara and Pantai Morib. For *E. coli*, higher cause for concern was found at Pantai Morib and Kuala Klang. The lowest RQs for *E. coli* were found at Jugra although these RQs still exceeded 1. Acceptable risk was shown for other parameters such as heavy metals. The concern for oil and grease was corroborated by the RQs exceeding 1 for sediment polycyclic aromatic hydrocarbons (PAHs), which are among the various constituents of oil and grease and which are found in petroleum hydrocarbons.

Adverse effects on reproductive and developmental processes have been observed in fish exposed to sublethal levels of petroleum (even similar to those observed under normal field conditions). PAHs in petroleum have also been linked to the formation of tumors in fish and mollusks (IMO, 1988). Suspended solids can have adverse effects on coastal aquaculture, primary production (by reducing light penetration and impairing photosynthesis), and aesthetics.

Human health risk arises from bathing in *E. coli*-contaminated waters and consumption of potentially contaminated aquaculture products.

The high levels of suspended solids (SS), *E. coli* and oil and grease in coastal waters were attributed to various socioeconomic activities such as industrial, agricultural and domestic activities and changes in land use that lead to improper discharge of wastes and habitat loss/degradation in the areas surrounding the Klang and Langat Rivers.

Evaluation of temporal trends of risk for a coastal station close to Langat River showed RQs for dissolved oxygen (DO), SS, turbidity, chemical oxygen demand (COD), oil and grease and ammonia (NH_3) consistently exceeding 1, thus confirming the preceding results and strengthening the premise that Langat River is a significant contributor to the contamination of coastal waters. Risk from the levels of organic matter was indicated by the RQs for COD and DO. No data on *E. coli* was evaluated.

Risk Assessment of the Klang and Langat Rivers

The risk assessment of selected stations along the Klang and Langat Rivers showed risk from organic contamination as indicated by the average RQs exceeding 1 for biochemical oxygen demand (BOD), COD, DO and NH_3 especially for the middle stretch and estuary stations; risk from sedimentation and siltation of rivers as indicated by the average RQs for SS and turbidity for all except the catchment stations; and risk from pathogen contamination as indicated by the enormously high RQs for coliforms especially *E. coli*. In the catchment areas where water is used for drinking, risk from *E. coli* must be carefully evaluated and immediately addressed.

The priority concerns identified in the risk assessment of Klang and Langat Rivers are consistent with the priority concerns for selected coastal areas, showing the strong influence of the two rivers on the water quality of these coastal areas.

Risk Assessment of Ambient Air

The assessment of human health risk from exposure to the major contaminants in ambient air, such as suspended particulate matter having a diameter smaller than 10 micrometer (PM_{10}), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO) and ozone (O_3), from December 1996 – March 2000 showed that except for CO, all worst-case RQs (RQ_{Max}) exceeded 1 although all parameters gave RQ_{Ave} values that were less than 1. The average Malaysian Air Pollution Index (API), which is computed using the major contaminants presented here, exceeded the limit of 50 (API_{Max} = 291 and API_{Ave} = 54), and PM_{10}, which exhibited the highest potential to pose risk to the ecosystem of Klang (RQ_{Max} = 5.72 and RQ_{Ave} = 0.52), may have contributed significantly to the high API.

During the haze phenomenon which affected the Southeast Asian region in 1997, the RQ_{Ave} for PM_{10} and the RQ_{Max} for O_3 exceeded 1 but RQ_{Ave} for other gases during this period remained below 1.

Malaysian urban and industrial areas are increasingly being affected by air pollution due primarily to automobiles, industrial activities, domestic combustion and thermal power plant operation (DOE, 1998). A large portion of the population may also be exposed to hazards in the atmosphere due to the location of housing areas near industrial parks. Stationary and non-stationary emissions, if not properly managed and controlled, may cause serious air pollution episodes like haze and smog phenomena, acid rains, greenhouse effect, and transboundary pollution, and can affect public health (Hashim, 2000). In the 1997 haze episode, the main factor for the high concentration of suspended particulate matter in ambient air was forest fire aggravated by contributions from soil dust, motor vehicles and industrial processes.

Link between Identified Risks and Socioeconomic Drivers

In developing and implementing a holistic and integrated environmental management system, it is very important for managers, implementers and stakeholders to understand what really drives the adverse changes and creates the risk to the ecosystem and human health. In Klang and Kuala Langat, socioeconomic activities are the key factors that influence pollution levels and degradation of the ecosystem, thus posing risk to flora and fauna and human health and welfare. Among these socioeconomic factors are the development process for industrialization and urbanization. In order to ensure that risk management efforts will effectively minimize the risk posed to the coastal zone of Klang and Kuala Langat, these should not be limited to isolated and merely remedial approaches, but should involve management of the risk from the source.

In this report, the risk posed by the socioeconomic development in Klang and Kuala Langat was made more clear through a retrospective assessment of the changes that have occurred in key socioeconomic factors such as land-use change, demography, agriculture and waste management.

Rapid development growth in both the Klang and Kuala Langat districts was driven by the development policy and strategy of the state and the local government. Well-built infrastructure and utilities sped up the development. Availability of ports, highways, rail tracks, business and finance centers, a power plant and manual labor attracted investors to Klang and Kuala Langat districts. This is in line with the State Government of Selangor and local government development plans, which aimed to make Selangor a developed state by the year 2005.

However, rapid changes of land use, especially the conversion of mangroves and peat swamp forests for other uses, affected important ecosystem functions. Reduction of mangrove and peat swamp areas reduced the functions and services provided by these habitats, which are important to animals and humans. There have also been cases of peat swamp fires caused by illegal farmers who practice the slash and burn method for cash crops. Other development and economic activities also created stress to the coastal ecosystem, which will continue to adversely affect the quality of the environment and impair ecosystem health if not properly addressed.

The assessment of agriculture showed that the main problems in the agriculture sector are not associated with the capabilities in increasing crop yields but the adverse impacts of agricultural activities to the ecosystem from pesticide and fertilizer use, as well as waste generated from processing activities. Another threat is illegal clearing of land and forests, which often leads to forest fires and air pollution.

The rapid development in Klang and Kuala Langat also attracted more people as industrialization and economic growth created employment and business opportunities. With well-equipped infrastructure, such as highways, better roads, rail tracks and public transport, and wide coverage of utilities to the public, businesses and institutions, Klang and Kuala Langat attracted the migration of people from other districts, states and countries as well as local and foreign investors. The high population density, which translates to more energy and resource requirements to cater to the needs of the population, created stress on the Klang ecosystem. It is estimated that more infrastructure, energy and resources will be needed if the population of Klang continues to increase at its current rate. For 2005, the Klang population is expected to increase to 816,705, which will then increase the density to 1,303 people per km^2. On the other hand, the Kuala Langat population growth rate, which is higher than the national growth rate of 2.8 percent per year, will have lesser population than Klang. For 2005, the Kuala Langat population is expected to increase to 229,636 people with a density of 261 people per km^2.

Waste generation in Klang and Kuala Langat had also increased significantly. From 1994, waste generation in Klang increased from 360 tons/day to 472.36 tons/day, while in Kuala Langat it increased from 90 tons/day to 119.1 tons/day. The availability of a landfill is one of the problems in waste management as Klang and Kuala Langat are experiencing problems in determining areas for a new landfill. The landfill area in Klang has decreased from 5.2 ha to 3.66 ha while the Kuala Langat landfill area decreased from 6.1 ha to 4.1 ha. It is expected that waste generation will increase by four percent per year. Therefore, it is estimated that by the year 2005 waste generation in Klang will reach 576.9 tons/day, while in Kuala Langat it is estimated to increase up to 145.5 tons/day. The state and local governments, therefore, have to develop strategies and plans to minimize waste generation through an efficient waste management system that involves waste recycling, reduction and reuse.

A retrospective assessment of human health problems was also carried out, which showed that, like many developing countries, food and water-borne diseases are among the most common health problems in the area. The identified diseases include cholera, dysentery, food poisoning and typhoid infection. The infections are mostly due to poor hygienic practices during food preparation in food stalls, restaurants, hotels and even at home. Food poisoning can also be caused by chemical contamination by heavy metals and pesticides. These two groups of contaminants, however, have not been investigated thoroughly in food products. The elevated levels of coliform in coastal and river waters, as reported in the prospective risk assessment, also indicate potential human health risks from coliform-contaminated seafood.

Vector-borne diseases such as dengue fever, dengue hemorrhagic fever and malaria are still troublesome health problems in this area. Unhealthy environment and poor sanitation will allow the vector to breed, multiply and later become a dangerous vehicle for the dengue virus and malaria protozoa. Comprehensive research to be carried out in this area is very crucial.

Data Gaps

Data that were not available when the risk assessment was undertaken, which could enhance future assessments, include:

1. More appropriate indicators to determine the status of capture fisheries with regard to sustainability of existing fishing practices and fishing effort such as CPUE, estimates of the MSY, changes in species composition and size, presence or absence of endemic species, etc.;
2. For aquaculture, data on production per unit area, which are more useful than production estimates in establishing changes in aquaculture productivity;
3. For the assessment of biodiversity, more comprehensive and quantitative information on flora and fauna, focusing systematically on key indicator species and their responses to habitat loss and various environmental factors;
4. Information showing the impacts of habitat loss and degradation and environmental pollution to living aquatic resources particularly the economically valuable species;
5. Data gaps in the prospective risk assessment such as nutrients in coastal water; oil and grease in river water; coliform in seafood tissue; heavy metals in sediment and biota; and pesticides and organotins in all media (water, sediment, biota);
6. Data on oil fractions from petrogenic and biogenic sources. Local standards for different components of total oil and grease are actually available (e.g., mineral oil; emulsifiable and edible oil) but the only available data are on total oil and grease. Identification of the oil fractions from petroleum and biological origins will allow a more precise assessment of risks from various oil components;
7. More suitable standards for marine water quality. The IMWQS for Malaysia is for limited parameters only and some values (e.g., heavy metals) are not very protective compared with standards from other jurisdictions;
8. More information to determine the linkages of some of the most common food and water-borne diseases to potential contamination of aquatic food products from pathogens and chemical compounds; and
9. More information that would specifically link particular socioeconomic activities to the identified priority environment concerns, to provide a basis for the formulation of more specific management interventions.

Uncertainties

Uncertainties in the results of the retrospective and prospective risk assessments for certain parameters are associated primarily with the data gaps.

The RQ approach was also found unsuitable for dealing with risks posed by solid waste, poor sanitation and increased population (crowding). These are problems that require attention and better understanding, particularly with regard to the sources/causes, distribution and impacts.

In some instances, models may need to be developed to gain better understanding of the risks. This may include modeling shipping accidents, effluent discharges, changes in the ecosystem and disease outbreaks. This model will help in identifying the type and level of risk, as well as, in developing emergency response procedures.

The initial risk assessment (IRA) was based on worst-case and average scenarios. For some parameters, ecological components or socioeconomic sectors, it is very important to conduct the assessment in greater detail, which might need other perspectives of assessment. This will also enable the distinction between localized and coastal-wide conditions and corresponding risk assessment results.

Other possible sources of uncertainty in the results of the IRA are mostly associated with the quality, comparability and adequacy of the measured concentrations and the suitability of the threshold concentrations used. The PNECs used have been derived primarily from the national standards for water quality and air quality, and supplemented by criteria or standards from other areas in the region. Values derived from other countries, however, might not be suitable to Klang conditions. Even the suitability of some of the marine water quality standards for Malaysia needs to be evaluated.

Further quantification or clarification of the uncertainties associated with the risk assessment may be done through the application of quantitative uncertainty analyses using appropriate software packages (e.g., Monte Carlo simulation using the Crystal Ball software).

SUMMARY OF RECOMMENDATIONS

Results for both the retrospective and prospective risk assessments point to the need for the conduct of a refined risk assessment although some results already indicate the need for management interventions. The detailed recommendations are presented in the section on Recommendations and Proposed Actions.

These recommendations, in brief, are as follows:

On Socioeconomic Drivers

1. Undertake further assessment of socioeconomic drivers and their linkages to the identified environmental concerns in order to allow the development of suitable and cost-effective management plans that are focused on the sources/ causes of risk. Recommended focus areas include:

    - Waste: focus on waste generation, types, source of waste and implication to coastal ecosystems. The source of waste will be identified according to activity such as urban, industry, shipping, hospital and agriculture.

    - Industrial development: focus on determining the number, types and location of factories in Klang and Kuala Langat. Implications of industrial activities towards the coastal ecosystems will be determined.

    - Agriculture: to determine the implications of agricultural activities on water and sediment quality of the coastal ecosystem in Klang and Kuala Langat as well as on the aquaculture products in the area. Main agriculture activities such as palm oil production, pig farms and aquaculture will be assessed in greater detail.

    - Land Use: to evaluate impacts of land conversion with respect to the various ecological functions and services provided by the areas being converted. Evaluation of benefits to be derived from the land conversion and development activity and the costs incurred including the ecological losses may aid in assessing the suitability of the selected land use and in the formulation and approval of future development plans that will require land conversion or reclamation.

On Ecological and Human Health Risks

Identified contaminants of concern

2. Prioritize contaminants for risk management, i.e.,

   - Coastal waters: *E. coli* > oil and grease, SS, turbidity

   - Klang River water: *E. coli* > total coliform > BOD, Fe (catchment, middle stretch and estuary) > NH_3, COD, DO, SS, turbidity, PO_4 (middle stretch and estuary) and As (estuary)

   - Langat River water: *E. coli* (catchment, middle stretch and estuary) > total coliform (catchment and middle stretch), SS, turbidity, BOD, COD, NH_3 (middle stretch and estuarine areas), Fe, Cr, Pb

   - Sediment: Oil and grease in Port Klang > oil and grease in Morib, PAHs in Klang estuary and coast

3. Prioritize the management of sewage discharges that pose human health risks from bathing in *E. coli*-contaminated waters and consumption of potentially contaminated aquatic food products.

4. Develop and implement comprehensive control programs for preventing direct and indirect discharges of untreated or partially treated wastes in the coastal areas and tributaries starting from the catchment areas.

Potential human health risk from aquatic food products

5. Conduct systematic monitoring and research studies concerning human health risks from consumption of contaminated aquatic food products and exposure to contaminated waters.

Evaluation of risk from persistent contaminants

6. Undertake systematic data collection for heavy metals, pesticides and tributyltin (TBT) in the water column as well as in the sediment and aquatic products in the Klang and Langat estuaries and nearby coastal areas.

Detailed assessment of risk throughout the river basin

7. Strengthen the use of risk assessment in risk management by extending its application throughout the whole river basin in order to ascertain the risk implications of particular river systems on the Klang coastal environment.

8. Identify sources of risk agents by relating identified risks for a particular stretch of the river to specific land uses or activities.

9. Formulate risk reduction measures that are focused on managing the identified sources of risk agents.

Wider application of the RQ approach

10. Apply the RQ approach to carry out a more detailed risk evaluation of rivers and coastal waters in Selangor. Although there are limitations associated with the simplified RQ approach, this IRA has yielded meaningful results that may be useful for river basin and coastal management. Depending on available information, a more detailed assessment of risks using RQs can be carried out.

Review of the Interim Marine Water Quality Criteria

11. Review the interim standard values and assess their effectiveness as one of the important decision factors in managing the coastal and marine environment. The evaluation should focus on the standards for heavy metals which are regarded as "unprotective" relative to those specified by the ASEAN and other countries in the region. Standards for other parameters such as DO, BOD and nutrients should also be specified. Specific scientific research required in relation to the review of the standards needs to be identified.

On Resources and Habitats

Fisheries

12. Collect information on important indicators for monitoring and assessment of fisheries conditions, such as CPUE, stock density and demersal biomass, and changes in catch composition (e.g., decline in economically-important species).

13. Estimate the MSY to determine if the current fishing effort is still within sustainable levels.

14. Evaluate the fisheries management framework in the area to determine areas that need to be strengthened for the sustainable development of the fisheries sector (e.g., inter-agency and inter-sectoral coordination, community participation, conservation efforts, use of responsible fishing methods, enforcement of existing laws and regulations on fisheries, and protection of fisheries resources from pollutant discharges).

Aquaculture

15. Evaluate existing aquaculture practices and their impacts on the natural ecosystem and develop management guidelines in accordance with environmental quality management plans and land and sea-use plans.

16. Designate coastal aquaculture zones.

17. Minimize adverse environmental impacts arising from aquaculture activities through environment-friendly practices.

18. Formulate measures to control adverse impacts of other activities on coastal aquaculture activities.

19. Collect data on indicators that can provide better assessment of the status of aquaculture (e.g., production/area).

Mangroves

20. Conduct systematic studies to assess the economic value of mangrove forests and the ecological, economic and social effects of the reduction or degradation of mangrove ecosystems.

21. Evaluate the practice of degazettement or removal from legal protection of some portions of the forest reserves to allow other uses of the area in relation to effects on the overall integrity of the ecosystem and other potential benefits from the existing mangrove area.

22. Evaluate benefits and costs associated with both public and private development plans, particularly those that involve reclamation and mangrove conversion, as part of the government approval process.

23. Promote mangrove reforestation in areas with high potential for mangrove rehabilitation and encourage community participation in protection and rehabilitation efforts.

24. Improve and/or strengthen the enforcement of laws, rules, and regulations on utilization and conservation of coastal resources.

Wildlife

25. Carry out more comprehensive and systematic research to verify the reported decline in mammal, bird and fish species and the attributed causes of decline, allowing sufficient time to detect significant changes in the number of species and population and determining exposure, correlation and cause-effect relationships between targets and potentially significant agents.

On Air Quality

26. Conduct more detailed temporal assessment for all air quality parameters in order to verify the results of the risk assessment. Moreover, although average RQs for all parameters were < 1, the average air pollution index (API) still exceeded 1, indicating potentially significant contribution of other parameters not assessed in this report.

Other Data Gaps

27. Verify identified concerns and fill data gaps through primary data collection (i.e., monitoring or research). Recommended research areas include:

    - Sediment load study which will be conducted through a hydrodynamics study;
    - Determination of level of impacts in specific pollution hotspots;
    - Toxicology study through market-basket study by using certain types of fish and shellfish species;
    - Poverty and its implication towards the environmental management strategy; and
    - Industrial development in the Klang area and the linkage to environmental pollution.

Risk management

28. The results of the risk assessment show the need to develop long-term strategies and action programs to address environmental issues related to resource exploitation, pollution and various land and coastal uses, including:

    - *Integrated Land- and Water-Use Zoning*, which should be aimed at managing conflicting uses of land and water resources, promoting the most beneficial uses of specific areas, and preventing adverse effects to ecological and human targets. Corresponding institutional arrangements should also be developed to implement the zoning scheme.

- *Environmental Investments* that will provide environmental services and facilities and clean technologies in order to achieve a balance between continuing economic growth in Klang and environmental protection and management (e.g., facilities to manage industrial wastes, solid wastes and sewage), and the use of innovative approaches to facilitate the participation of various sectors in providing such services and facilities.

- *Integrated Environmental Monitoring Program* that will provide scientific basis for management decisions and actions, which should be systematic and cost-effective, and developed and implemented through multi-agency and cross-sectoral coordination.

- *Collaboration and Institutional Arrangements* that will support the development and implementation of risk management strategies and action programs that require multi-agency and cross-sectoral approaches, and may involve evaluation and strengthening of policies, rules and regulations, implementation frameworks and enforcement capabilities on resource utilization and environmental protection.

Background

Introduction

The GEF/UNDP/IMO Regional Programme on Building Partnerships in Environmental Management for the Seas of East Asia (PEMSEA) identified Port Klang, which includes Klang and Kuala Langat districts as one of the six national demonstration sites in the region to develop and implement integrated coastal management (ICM) as a strategic environmental management framework in partnership with the national government and local stakeholders in the public and private sectors. This pioneering effort is in line with Agenda 21 of the Selangor State Government. The Memorandum of Agreement between the State Government of Selangor and PEMSEA for the implementation of this project was signed on 19 July 2001. The Selangor Waters Management Authority (Lembaga Urus Air Selangor or LUAS) has been designated by the State Government of Selangor to be the Project Management Office (PMO) for the ICM Project.

This report presents the findings and outcome of the initial risk assessment (IRA) of Port Klang, Malaysia, which is one of the component activities of the Port Klang ICM Project. The assessment was undertaken by an inter-agency, multi-disciplinary Technical Working Group composed of experts and technical personnel from various government agencies and institutions involved in the Port Klang ICM Project. The IRA of Port Klang was started during the Training Course on Environmental Risk Assessment, held from 23–28 July 2001 at Burapha University in Chonburi, Thailand, and subsequently completed at the project site. Comments from various institutions were used to refine the initial drafts.

Objectives

The IRA of the Port Klang ICM project site aimed to determine the effects of factors derived from human activities on human and ecological targets in the Port Klang area.

Specifically, it aimed to:

1. Evaluate the impacts of various pollutants in the Port Klang project site on human and ecological targets and identify the priority environmental concerns;

2. Identify activities that contribute to pollution in the Port Klang project site;

3. Identify gaps and uncertainties that will require more effort in a refined risk assessment;

4. Make recommendations for a refined risk assessment that is focused on the identified areas of concern;

5. Identify agencies and institutions that can play significant roles in the refined risk assessment and in the long-term management of the Port Klang area; and

6. Identify priority concerns to be addressed under risk management.

Sources of Information

Data for the risk assessment were taken mostly from the Department of Environment–Selangor, Department of Fisheries–Selangor, Klang Municipal Council (2000), Majlis Perbandaran Klang (2000) and Universiti Pertanian Malaysia (2000).

Other materials used are also cited in the text. A detailed list of the sources of data for each parameter/resource is given in Appendix 1, which also includes descriptions of the data. Sampling stations are shown in Appendix 2. The criteria used, which were also taken from various sources, are found in Appendix 3–4.

Most of the data used were presumed to be accurate and reliable, although preliminary screening was done for some data for which ranges of concentrations in different environmental conditions are known. Ideally, the reliability of data should be more systematically assessed based on the sampling design and laboratory techniques used to produce the data as well as the period when these were obtained. A more thorough assessment of data should be made in the refined risk assessment.

The choice of criteria was based on what were available (locally and in other locations) with the assumption that these values were suitable for Port Klang.

DEFINITION OF KEY TERMS

The following are key terms used in risk assessment (a more comprehensive list of terms, as modified from U.S. EPA (1997), U.S. EPA (1998) and IUPAC (1993) is found in the Glossary:

Effects assessment – The component of a risk analysis concerned with quantifying the manner in which the frequency and intensity of effects increase with increasing exposure to substance.

Exposure assessment – The component of a risk analysis that estimates the emissions, pathways and rates of movement of a chemical in the environment, and its transformation or degradation, in order to estimate the concentrations/doses to which the system of interest may be exposed.

Hazard assessment – Comparison of the intrinsic ability of a substance to cause harm (i.e., to have adverse effects for humans or the environment) with its expected environmental concentration, often a comparison of PEC and PNEC. Sometimes referred to as risk assessment.

Hazard identification – Identification of the adverse effects that a substance has an inherent capacity to cause, or in certain cases, the assessment of a particular effect. It includes the identification of the target populations and conditions of exposure.

Risk – The probability of an adverse effect on humans or the environment resulting from a given exposure to a substance. It is usually expressed as the probability of an adverse effect occurring, e.g., the expected ratio between the number of individuals that would experience an adverse effect in a given time and the total number of individuals exposed to the risk factor.

Risk assessment – A process which entails some or all of the following elements: hazard identification, effects assessment, exposure assessment, and risk characterization. It is the identification and quantification of the risk resulting from a specific use of occurrence of a chemical including the determination of exposure/dose-response relationships and the identification of target populations. It may range from largely qualitative (for situations in which data are limited) to fully quantitative (when enough information is available so the probabilities can be calculated).

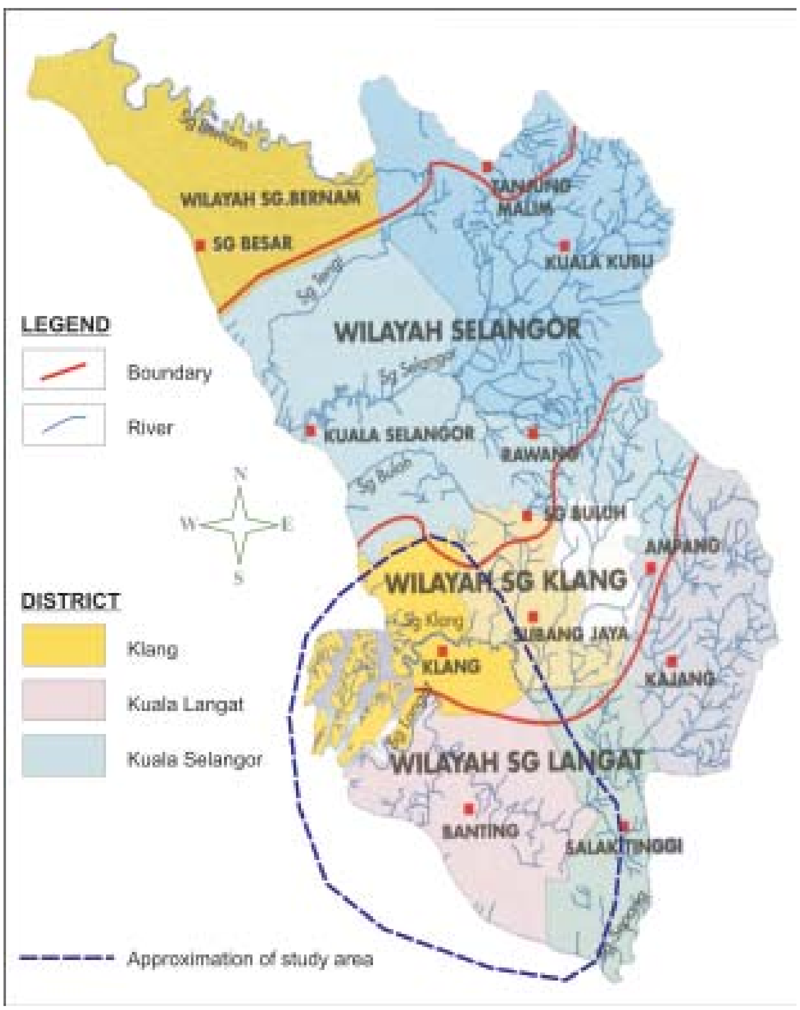
Risk characterization – The step in the risk assessment process where the results of the exposure assessment (e.g., PEC, daily intake) and the effects assessment (e.g., PNEC, NOAEL) are compared. If possible, an uncertainty analysis is carried out, which, if it results in a quantifiable overall uncertainty, produces an estimation of the risk.

Risk classification – The weighting of risks in order to decide whether risk reduction is required. It includes the study of risk perception and the balancing of perceived risks and perceived benefits.

Description of the Study Area

The Port Klang ICM project area (Figure 1) covers 1,484.53 km^2, including 626.78 km^2 in Klang and 857.75 km^2 in Kuala Langat, and has a population of 742,837 (Year 2000), and a population density of 500 people per km^2. Initially, the project area was restricted to Port Klang and the adjacent coastal area as an "influencing zone." However, with consideration and realization that ICM is basically an environment management project, the project boundary has been broadened to include pollution sources (basin/catchments areas) that eventually lead to Port Klang. There are two main river mouths or sungal, Sg. Klang and Sg. Langat, which drain into the nearby coastal area. These two rivers cover 1,300 km^2 and 2,400 km^2 of catchment areas, respectively. The sea area within three nautical miles (5.5 km) from the shoreline during spring tide towards the sea is 169.40 km^2. The coastlines for both Klang and Kuala Langat are 53.75 km and 48 km, respectively.

Figure 1. The Administrative (LGUs) and Study Area of the Port Klang ICM Site.



Source: Unit ICT-GIS, Selangor Waters Management Authority (LUAS).

The project area also includes the main islands of Pulau Klang, Pulau Ketam, and Pulau Carey. Conflicts of use are expected within the project boundaries particularly in the future, thus there is a great need to harmonize economic development and environmental conservation while recognizing the social aspects in harmonizing the two. Control and reduction of pollution from upstream sources are crucial for the proper management of the environment in the project area. There are several developments in the upstream areas including industrial and housing projects which greatly contribute to the pollution of Sg. Klang and Sg. Langat. Port Klang (North Port and South Port) and West Port (Pulau Indah) are busy ports handling millions of metric tons of cargo which increase every year.

Economic development and environmental conservation in the area need to be harmonized in order to ensure sustainable development. Identifying priority environmental concerns through the risk assessment will aid in formulating management plans that will balance the environmental, economic and social aspects of development.

The Risk Assessment Approach

Risk is the probability of an adverse effect on humans or the environment resulting from a given exposure to a substance. Risk assessment can be carried out either as retrospective or prospective. For the retrospective risk assessment, the fundamental question concerns the extent to which conditions are likely to have caused adverse effects observed in specific targets. A prospective risk assessment considers the extent to which current conditions, and/or those likely to pertain to the future due to new developments, would likely cause harm. Both can be used as a basis for environmental management and imply the desire to control activities and conditions to levels that do not cause harm and which are likely to be nonzero.

In the Klang Environmental Management Project, a combination of retrospective and prospective approaches is used. A retrospective approach is applied to explain observed deterioration in ecological targets and/or the occurrence of human health problems in terms of likely levels of exposure and their causes. A prospective approach is applied to consider and compare the likely adverse effects emanating from observed environmental concentrations of chemicals. The approaches converge to indicate the relative importance of different adverse effects and their causes. This should lead to appropriate, cost-effective management programs.

The fundamental features of both retrospective and prospective risk assessments are that they identify problems and their causes based on systematic and transparent principles that can be justified in public and can be revisited as more information and understanding become available. The key concept for risk assessments is the comparison between environmental conditions (e.g., environmental concentrations of chemicals) and threshold values likely to cause adverse effects in the targets under consideration. In a prospective risk assessment, this is made explicit as a risk quotient (RQ), which is the ratio of an environmental concentration that is either predicted (PEC) or measured (MEC) with a predicted no-effect concentration (PNEC) for the target of concern ($RQ = P(M)EC/PNEC$). An $RQ < 1$ indicates a low, and thus acceptable risk, and an $RQ > 1$ indicates a level of concern and possibly the implementation of appropriate management programs.

The basic principles and techniques for both retrospective and prospective risk assessment are described in *Environmental Risk Assessment Manual: A Practical Guide for Tropical Ecosystems* (MPP-EAS, 1999a).

The simplified risk pathways in the Klang project area (Figure 2) brings together the possible sources of hazards to human health and the environment and shows the possible effects on the economy. It also indicates the relationships between the sources of hazards and various economic and social drivers. This qualitative illustration draws attention to specific activities that may cause problems to human health and the environment and aids in the prioritization of concerns for risk assessment and, ultimately, risk management, especially when human health and environmental protection will need to be weighed against economic realities.

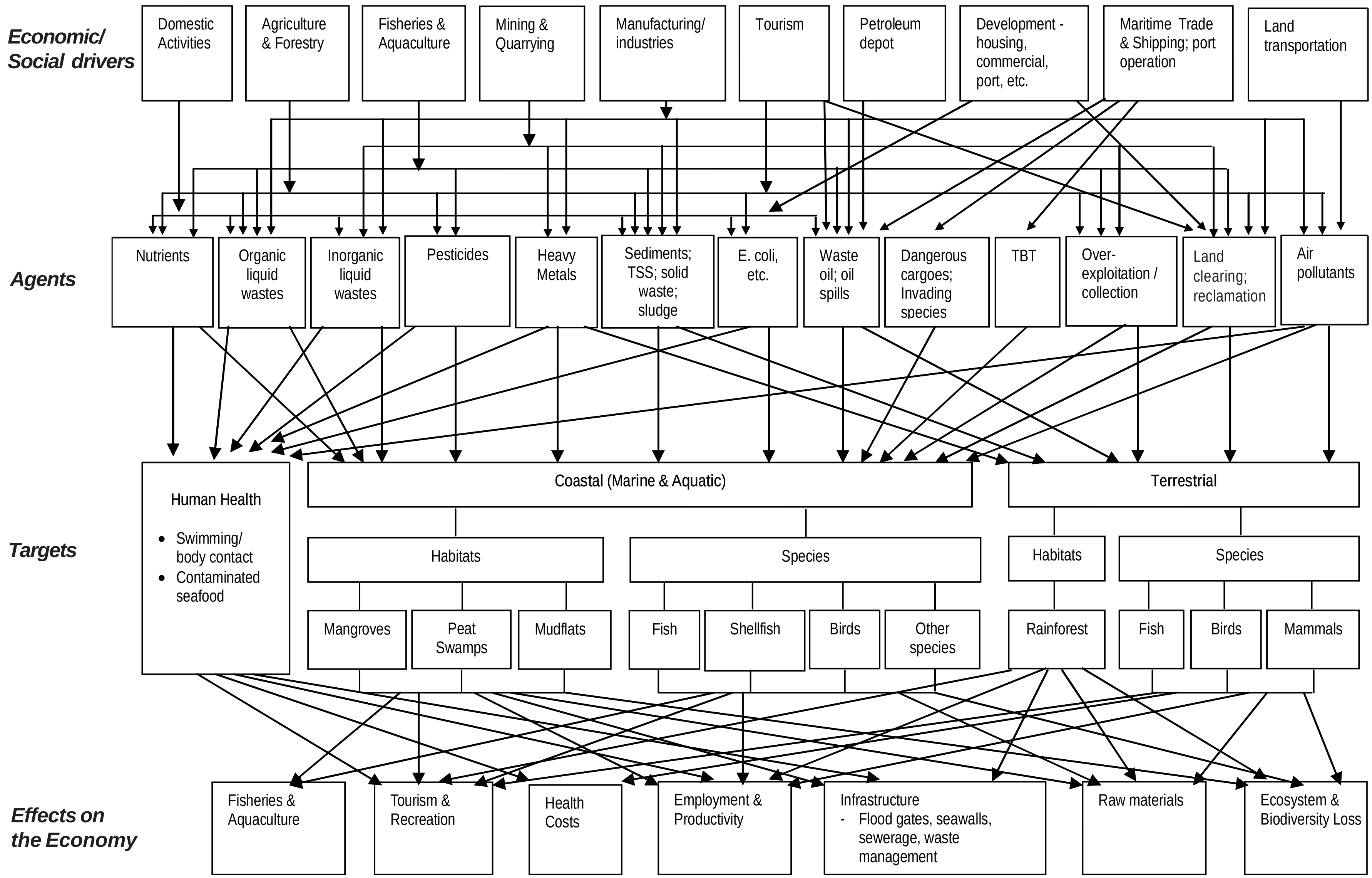


Figure 2. Simplified Risk Pathway for Port Klang (Klang–Kuala Langat).

Retrospective Risk Assessment

Introduction

Retrospective risk assessment is an evaluation of the causal linkages between observed ecological effects and stressor(s) in the environment. It addresses risks from actions that began in the past and can therefore be assessed based on measurements of the state of the environment (Suter, 1998). It attempts to answer the question: "What evidence is there for harm being done to targets in the site?" (MPP–EAS, 1999b). In retrospective studies, it is important to identify significant effects (targets and endpoints) and ascribe causation. The approach involves making inferences about the causes of observed effects (Suter, 1998) and this often requires temporal and spatial series of data for comparative purposes. Comparison facilitates the ascribing of risks to a particular source.

The retrospective approach employed for Port Klang was of the "effects-driven assessment" type that addresses apparent ecological effects that have uncertain magnitudes and causes (Suter, 1998). Under this perspective, risk is viewed as the likelihood that current impacts are occurring and that demonstrating these existing impacts confirms that a risk exists. It is important to note that impacts have primary or secondary effects — as these may cause direct or indirect changes in identified targets. These impacts range from those occurring inland and near the coast to those occurring in the bay itself as consequences of developments and ecosystem exploitation.

Methodology

A considerable volume of materials on Port Klang, from various studies, reports, and projects, were reviewed and relevant data on identified targets (habitats and resources) in the bay were put together for the retrospective risk assessment. Steps prescribed in the *Environmental Risk Assessment Manual: A Practical Guide for Tropical Ecosystems* (MPP-EAS, 1999a) were likewise applied.

Problem Formulation

The problem formulation phase involved defining the target and the way it is impaired by recognizing that an undesirable effect on an ecological system or human population has already occurred, identifying suspected (or known) agents, and considering the links between the agents and the adverse effects on the targets with an aim to eventually manage these agents in order to reduce harm.

It is also important to determine the assessment and measurement endpoints in the targets. Assessment endpoints are features related to the continued existence and functioning of the identified targets (e.g., production, density changes and mortality), which may not be easy or would take much time to measure. So measurement endpoints, which are features related to the assessment endpoints but are easier to measure, are used instead, such as biomass (for production), abundance (for density changes) and LC_{50} or biomarkers (for mortality).

To elaborate on the interrelatedness of agents and targets, a simplified risk pathway (Figure 2) was used.

The suspected agents for the different resources and habitats include: a) overexploitation/collection; b) land clearing/

reclamation; c) nutrients; d) organic liquid wastes; e) inorganic liquid wastes; f) pesticides; g) heavy metals; h) sediments; i) total suspended solids (TSS); j) solid wastes; k) coliform; l) waste oil; m) oil spills; n) dangerous cargoes; o) invading species; p) tributyltin (TBT); and q) air pollutants.

The ecological targets assessed include marine resources and habitats such as fisheries; shellfisheries; and mangroves, and associated fauna (e.g., birds and mammals) in selected terrestrial habitats (rainforest and peat swamps).

Retrospective Risk Assessment

Under the retrospective risk assessment phase, a set of questions, answerable by yes (Y), no (N), maybe (M), unknown (?) or no data (ND) was formulated in order to establish evidences of decline, and the causes and consequences of the decline. The following questions were adapted from MPP-EAS (1999a).

1. Is the target exposed to any of the agents?
2. Was there any loss/es that occurred following exposure? Was there any loss/es correlated through space?
3. Does the exposure concentration exceed the threshold where adverse effects start to happen?
4. Do the results from controlled exposure in field experiments lead to the same effect? Will removal of the agent lead to amelioration?
5. Is there specific evidence in the target as a result of exposure to the agent?
6. Does it make sense (logically and scientifically)?

In order to facilitate the assessment, all the abovementioned questions were tabulated in a matrix where each of the targets was subjected to the series of questions. The answers to the questions were based on available information on the targets and agents. The matrices are termed here as decision tables. Using these tables, agents that were likely to have caused adverse effects have been systematically screened by assigning the likelihood of these agents to have caused the decline in resources and habitats.

The different categories of likelihood of harm are as follows:

1. Likely (L) – based on knowledge of exposure to the agent and either established effect concentrations (i.e., criteria used in prospective analyses) or other evidence (such as knowledge about intentional harvesting, field observations (e.g., of infestation), the agent is considered to be a likely cause of decline in the resource or habitat.
2. Possibly (P) – based on available information about exposure and effect levels, this agent cannot be excluded as a cause of decline in the resource or habitat;
3. Unlikely (U) – based on available information about exposure and effect levels, this agent is unlikely to have caused decline in the resource or habitat. However, agents in this category may have indirect effects on the resource. For example, nutrients, themselves, would not have a negative effect on benthos (defined here as unlikely), but by enhancing primary productivity (algal blooms), increased nutrients could lead to lowered DO, which is likely to have a negative impact on benthos; and
4. Unknown (?) – there is not enough information available on exposure and/or effect levels to assess whether agents in this category have led to decline in the resource.

Deciding the likelihood of harm based on the answers to the decision table was aided by the decision criteria as presented in Appendix 5.

After establishing evidences of decline in the resources and habitats, linkages of the observed decline with various socioeconomic activities/drivers in the area were evaluated.

RESOURCES

Fisheries

The coastal region in the Klang and Kuala Langat districts are important areas for fisheries and aquaculture activities. Fish landing facilities and other modern infrastructure contribute to the economic growth of the fishing industry.

Evidence of Decline

There was a decline in landing from 164.43 metric tons in 1990 to 57.55 metric tons in 1993 (Table 1), but fish landing subsequently increased to 141.37 tons then 1,579.34 tons between 1993 and 2000.

Attributed Causes

The decline in fish landings at Port Klang from 1990 to 1993 was attributed to the use of low-end technology for fish trawling. However, from 1993 to 2000, fish landings have increased mainly due to an increase in the number of fisherfolks and the use of more/highly efficient fishing equipment, which both reflect the increased intensity in fishing effort, and potential adverse impacts to fishery resources. Establishing decline may also be quite difficult as fishes are caught from neighboring countries (usually imported), especially from Indonesia. High fish landings are thus not reflective of fish caught in the Port Klang coastal waters.

Since decline in fisheries was not adequately established, there was no point in carrying out the detailed retrospective risk assessment to determine significant causes of decline. Other indicators of fisheries conditions such as CPUE will have to be gathered to enable more appropriate assessments to be carried out. MSY estimates will also be important to determine if the fishing effort is within sustainable levels or if this may eventually lead to adverse impacts on local fisheries. Effects of other factors such as marine water pollution, particularly the incidence of oil spills, and mangrove exploitation on fisheries productivity will also have to be evaluated.

Table 1. Retrospective Analysis for Fisheries.

Results		Remarks
Changes Observed	Identified Agents	
Decline in fish landing from 164.43 (1990) to 57.55 metric tons (1993)	**Likely:** – Technology used did not allow high catch – Number of fishing gears reduced **Possibly:** – Marine water pollution and incidence of oil spills – Exploitation of mangroves for economic activities	The current condition of the fisheries in Klang could not be adequately assessed using the available information CPUE and MSY can be used to enhance the assessment
Increase in fish landing from 57.55 (1993) to 141.37 to 1,579.34 metric tons from 1993–2000	**Likely:** – Technology used enhanced – Number of fishing gears increased – Number of fishing folks increased	
Five species caught from fishing gear from 1990–2000		

Sources: Fisheries Department of Malaysia, 2000;DOE–Selangor, 2000.

Consequences

The increase in fishing effort is driven by the increasing demand for marine fishes. Overfishing, however, leads to reduction in fish stocks as well as ecological stress due to improper fishing practices. Such unsustainable fishing practices imperil local fisheries and economy, with the adverse effects to be felt most by the small-scale fisherfolks who primarily depend on fishing for livelihood.

Aquaculture

Aquaculture has been identified as an alternative technique to cope with the increased demand for marine fish and shellfish and Klang coastal zone was identified as an area with potential for aquaculture activities. In the process of aquaculture development, huge areas of mangroves and peat swamps were converted to fish and prawn ponds. Production of fish and prawns from the aquaculture ponds increased from 1993 to 2000.

Evidence of Decline

For aquaculture, decline in production from 1,011.63 to 543.89 metric tons was observed from 1990 to 1993 while increase in production to 1,579.34 metric tons was noted between 1993 and 2000 (Table 2). The number of cultured species also increased from four species in 1990–1996 to six species in 1997–2000.

Attributed Causes

The decline in production in 1990–1993 was attributed to unsuitability of the areas for aquaculture, water contamination and diseases while the following increase in production was attributed to improvements in aquaculture technology and control of water contamination and diseases. Increase in the areas of fish and prawn ponds may also have contributed to the increased production. It was thus difficult to assess risks posed by various factors to aquaculture based on the information available on production since these increased with increase in culture areas. Production per unit area would be a more appropriate indicator of aquaculture productivity. Since decline in aquaculture was not adequately established, the detailed retrospective risk assessment to determine significant causes of decline was not carried out anymore. The potential environmental consequences of aquaculture was instead evaluated.

Consequences of Aquaculture Development

The implications of aquaculture development in the Port Klang coastal zone towards the mangrove and peat swamp forest ecosystems has been found significant. In addition to conversion of mangrove and peat swamp areas into culture ponds, existing practices, which make use of many types of chemicals, may lead to pollution of the coastal ecosystem and impairment of the functions and services provided by mangroves and peat swamp forests. There is, therefore, a need to determine best practices which will allow aquaculture to continue and produce high quality and quantity of fish and prawns while maintaining the coastal zone ecosystem functions and services.

HABITAT

Mangroves

Evidence of Decline

Table 3 presents the evidences of decline in the areal cover of mangroves in the Port Klang ICM area. Mangrove clearance was largely concentrated in the Kapar Mangrove Forest Reserve (MFR) and the Klang Islands Mangrove

Table 2. Retrospective Analysis for Aquaculture.

<table>
<tr><th colspan="2">Results</th><th rowspan="2">Remarks</th></tr>
<tr><th>Changes Observed</th><th>Identified Agents</th></tr>
<tr><td>Decline in production from 1,011.63 to 543.89 metric tons from 1990–1993</td><td>– Soil of areas used were not suitable for aquaculture
– Water contamination
– Diseases</td><td rowspan="2">Current status of aquaculture was not sufficiently assessed using the available information; data on production/area can be used to enhance the assessment

Impacts of aquaculture development:
– Loss and degradation of mangrove and peat swamp areas due to conversion into culture ponds
– Water quality deterioration (self-polluting characteristic of aquaculture activities)</td></tr>
<tr><td>Increase in production from 543.89 metric tons to 1,579.34 metric tons from 1993-2000

Four species produced from1990 to 1996

Two additional species produced from 1997 to 2000</td><td>– Technology used enhanced
– Water contamination and diseases controlled
– Increase in pond areas</td></tr>
</table>

Sources: Fisheries Department of Malaysia, 2000; DOE–Selangor, 2000.

Table 3. Retrospective Analysis for Mangroves in Klang Islands and Kapar.

<table>
<tr><th colspan="2">Results</th><th rowspan="2">Impacts</th></tr>
<tr><th>Changes Observed</th><th>Identified Agents</th></tr>
<tr><td>Klang Islands

Decline from 12,301 to 11,799 ha from 1984 to 1995

Decline from 11,799 ha to 10,871.4 ha from 1995–1998</td><td>Likely:
Land reclamation and other development activities

Possibly:
Suspended solids

Unknown:
Pollution
Sedimentation</td><td rowspan="2">Degradation and/or loss of habitat and nursery grounds

Reduced biodiversity therefore loss of economically viable timber

Loss of natural protection — Coastal erosion and siltation

Loss of carbon storage

Reduced detritus</td></tr>
<tr><td>Kapar

Decline from 4,865 to 410 ha from 1970 to 1998</td><td>Likely:
Land reclamation, Other development activities, e.g., construction of bunds

Possibly:
Suspended solids

Unlikely:
Illegal timber extraction

Unknown:
Sedimentation
Pollution</td></tr>
</table>

Sources: Wetlands International–Malaysia Programme, 2000; PERHILITAN, 1987; Majlis Perbandaran Klang, 2000; Klang Municipal Council, 2000; Chan, et al., 1993.

Forest Reserves. Kapar MFR is a coastal mangrove forest system, while the Klang Islands consists of more than nine mangrove islands associated with large mudflat and sandflat areas (information on mudflat areas in the Klang Islands were not available).

Continuous developments in the areas surrounding and adjacent to Port Klang have been extended to the Kapar Forest Reserve and the Klang Islands. By the late '90s, both these forest reserves have dwindled by as much as 92 percent and 12 percent, respectively through degazettement (removal from legal protection) and subsequent reclamation works. Presently, the Kapar MFR stands at only 410 ha from 4,865 ha in 1970 while at the Klang Islands, around 10,871.4 ha of mangrove area remains intact from the 12,301 ha in 1984 (Majlis Perbandaran Klang, 2000). Eight out of the nine islands are mangrove forest reserves (classified under Class VII – as Wildlife Reserves under the Forest Classification System implemented by the Selangor State Forestry Department) (Wetlands International – Malaysia Programme, 2000).

Attributed Causes

Demand for new land to accommodate new developments in the vicinity of the Klang coast resulted in the degazettement of forest reserves in Kapar and to a smaller extent in the Klang Islands. These degazetted forests were reclaimed and converted to various development projects and agricultural activities. A bund or artificial embankment was constructed along the coast of Kapar to protect farmland from seawater intrusion, but instead this resulted to further degradation of the remaining mangroves. Mangroves failed to accrete due to the presence

Table 4. Details of Retrospective Risk Assessment for Mangroves of Klang Island.

Mangroves	Sedimentation	TSS	Pollution	Land Reclamation	Other Development Activities
1. Is the target exposed to the agent?	M	Y	M	Y	Y
2a. Was there any loss/es that occurred following exposure?	M	Y	M	Y	Y
2b. Was there any loss/es correlated through space?	M	ND	M	Y	Y
3. Does the exposure concentration exceed the threshold where adverse effects start to happen?	M	Y	M	M	M
4a. Do the results from controlled exposure in field experiments lead to the same effect?	ND	ND	ND	NR	NR
4b. Will removal of the agent lead to amelioration?	Y	Y	Y	Y	Y
5. Is there an effect in the target that is known to be specifically caused by exposure to the agent (e.g., biomarkers)?	ND	Y	ND	Y	Y
6. Does it make sense (logically and scientifically)?	Y	Y	N	Y	Y
Likelihood	?	P	?	L	L

Legend: Y – Yes, N – No, M – Maybe, ND – No Data, NR – Not Relevant, ? – Unknown, L – Likely, P – Possibly of the bund. Other potential causes of decline such as illegal timber extraction, high sedimentation and water pollution from inland and from the sea were identified but, despite paucity of data, may be insignificant in this area compared to the impacts arising from conversion of mangrove areas for development purposes (Tables 4 and 5).

Consequences

Destruction of mangrove forests in the Klang district has led to the loss of the economic value of sustainable forestry in a large portion of the mangrove forest and to the loss of ecological functions including shoreline protection; spawning, breeding and nursing grounds for marine life; and carbon storage. The loss of mangrove forests may also have led to a decline in the biodiversity value of the remaining mangrove forests and associated mudflats. Consequent adverse effects on fisheries productivity may in turn have affected the livelihood of local fishers. The lack of adequate mangrove buffer strip may also threaten agricultural land beyond the bund.

Wildlife

The wildlife component is divided into three major groups namely mammals, birds and aquatic fauna. These groups are also identified as targets that are potentially affected by environmental risk agents. For wildlife, the interrelatedness with the suspected agents is not clearly defined most of the time, thus it is quite difficult to correlate between the agents and the resources within the specified habitat.

In this retrospective risk assessment of wildlife, emphasis is given to three most important

Table 5. Details of Retrospective Risk Assessment for Mangroves in Kapar.

Mangroves	Sedimentation	TSS	Pollution	Land Reclamation	Other Development	Illegal Timber extraction
1. Is the target exposed to the agent?	M	Y	ND	Y	Y	Y
2a. Was there any loss/es that occurred following exposure?	M	Y	M	Y	Y	M
2b. Was there any loss/es correlated through space?	M	ND	M	Y	Y	N
3. Does the exposure concentration exceed the threshold where adverse effects start to happen?	M	Y	ND	M	M	N
4a. Do the results from controlled exposure in field experiments lead to the same effect?	ND	ND	ND	NR	NR	ND
4b. Will removal of the agent lead to amelioration?	Y	Y	Y	Y	Y	Y
5. Is there an effect in the target that is known to be specifically caused by exposure to the agent (e.g., biomarkers)?	ND	Y	ND	Y	Y	ND
6. Does it make sense (logically and scientifically)?	Y	Y	N	Y	Y	N
Likelihood	?	P	?	L	L	U

Legend: Y – Yes, N – No, M – Maybe, ND – No Data, NR – Not Relevant, ? – Unknown, L – Likely, P – Possibly, U – Unlikely habitats within the specified study sites (Klang and Kuala Langat districts): peat swamp, Dipterocarp forest (primary forest) and mangrove forest. The urbanized habitat can be included here in the risk assessment but this habitat may be seen as an outcome arising from some suspected agents identified in the risk assessment.

The retrospective risk assessments of these resources are as follows:

1. Mammals

In general, mammals in Malaysia are found in the primary forests. Among the three major forest reserves left in the Klang Project area, the primary forest is much more exploited compared to the mangrove and peat swamp forests.

Evidence of Decline

Data gathered indicate evidences of decline in the number of mammal species in all forest types found in the project area (Table 6). Detailed evidence, however, cannot be provided since the data are very few and not comprehensive. More research needs to be undertaken to verify the decline in the number of mammal species in these three forests. These researches should be more comprehensive and may require more time to detect changes in the number of species and population.

Attributed Causes

Decline in mammal population and species in the Klang project area is suspected, based on evidence that several large mammal species such as elephants, tigers and rhinos are locally extinct. Based on reports some 20–30 years ago, these species still existed and were found in some areas especially at the southern part of the project area. The cause of extinction is due to loss of habitats, especially primary forests, as a result of various factors which include land clearing for mining; aquaculture, agriculture and other development activities. For mangrove and peat swamp forests, much of the areas were lost due to reclamation projects either for housing or agriculture activities (Table 7). Hunting is another likely cause for the decline in mammal species. The contribution of other factors like pollution, pests and diseases could not be evaluated due to lack of data.

Consequences

Loss of habitat can result to a decline in the population of mammals in all types of forests in

Table 6. Retrospective Analysis for Terrestrial Mammals in Three Different Habitats.

Results		Remarks
Changes Observed	Identified Agents	
Peat Swamp Forest (1998– 2001): Decline in number of species and population of selected species	Land clearing, reclamation, selective logging, mining, agriculture, development activities, and hunting	Available information indicate a decline in the number of species and population but no quantitative data were provided. More data need to be collected from other studies or from new researches.
Primary Forest (1956–2001): Decline in number of species	Land clearing, selective logging and other agriculture and development activities and hunting	
Mangrove Forest: Decline in number of species	Land clearing, reclamation, selective logging, acquaculture, agriculture and development activities, and hunting	

Sources: Heang and Lim, 1998; Lim, et al, 2003; PERHILITAN, 1998.

the Klang area. Reduction in forest area will initially affect large mammals, followed by medium-sized mammals and finally small mammals.

2. Birds

In general, birds can be grouped into water birds and forest birds. Since this project covers the three forest types, both groups were considered.

Evidence of Decline

Data gathered indicated evidences of decline in the number of bird species (forest and water birds) in all forest types and selected areas found in the Klang project area (Tables 8–10). Detailed count is provided only for water birds (Tables 9–10) since a detailed study was conducted by several researchers in the past. For forest birds, detailed evidences cannot be provided since the data are very scarce and not complete. More researches are needed to verify the decline in the number of bird species in the three forest types. These researches should be more comprehensive and may require more time to detect changes in the number of bird species and population.

Attributed Causes

The decline of bird population and species in the Klang project area is suspected based on evidences that several large shore and migratory bird species were not seen in the last several years. Although the absence of these species might be associated with a sampling error, the possibilities are high that these species are no longer using the

Table 7. Details of Retrospective Risk Assessment of Terrestrial Mammals.

Terrestrial Mammals	Pollution	Diseases	Pests	Hunting	Selective Logging	Land clearing for mining	Aquaculture, Agriculture and Other Development Activities
1. Is the target exposed to the agent?	M	M	M	Y	Y	Y	Y
2a. Was there any loss/es that occurred following exposure?	M	M	M	Y	Y	Y	Y
2b. Was there any loss/es correlated through space?	M	M	M	Y	Y	Y	Y
3. Does the exposure concentration exceed the threshold where adverse effects start to happen?	ND	ND	M	Y	Y	Y	Y
4a. Do the results from controlled exposure in field experiments lead to the same effect?	M	M	ND	M	M	M	M
4b. Will removal of the agent lead to amelioration?	ND	Y	M	Y	Y	Y	Y
5. Is there an effect in the target that is known to be specifically caused by exposure to the agent (e.g., biomarkers)?	ND	ND	M	Y	Y	Y	Y
6. Does it make sense (logically and scientifically)?	Y	Y	Y	Y	Y	Y	Y
Likelihood	?	?	?	VL	VL	VL	VL

Legend: Y – Yes, M – Maybe, ND – No Data, ? – Unknown, VL – Very Likely area because of the absence of the required habitats such as mudflats and other forested areas. Loss and degradation of habitats were brought mostly by land clearing, reclamation and logging activities (Table 11). Hunting is another likely agent for the observed decline.

Consequences

The absence of certain bird species is primarily due to the absence of required habitats. Further loss of habitat will lead to greater decline in migratory and waterbirds in all types of forests in the Klang area since these sea and migratory birds may move to more suitable locations.

3. Aquatic Fauna

Assessment of aquatic fauna is only on freshwater fishes found in peat swamp and primary rain forests. No assessment was made on other aquatic organisms because not much data was available.

Table 8. Retrospective Analysis of Birds in Three Different Habitats.

Changes Observed	Identified Agents	Remarks
Peat Swamp Forest: Decline in number of species (1998–2001)	Land clearing, reclamation, selective logging and other agriculture and development activities; hunting	Needs further reports and references for detailed analysis. The data available are sketchy.
Primary Forest: Decline in number of species (2001)	Land clearing, selective logging and other agriculture and development activities; hunting	A decline in the number of species is the predicted outcome from a change of land use especially in primary forest within the study sites.
Mangrove Forest: Decline in number of species	Land reclamation and other development activities	A decline in number of species is the predicted outcome from a change of land use especially in mangrove forest within the study sites.

Sources: PERHILITAN, 1998; Shukor, et.al.,2001.

Table 9. Retrospective Analysis of Waterbirds in Kapar Power Station.

Changes Observed	Possible Agents
Number of species increased from 25 to 40 (1999-2000)	**Most Likely:** Better coverage of survey **Likely:** Weather factor, resurgence in migrating species **Unlikely:** Habitat conditions improved
No. of species decreased from 40 to 26 (2000-2001)	**Likely:** Weather factor, lack of migrating species **Possibly:** Disturbance from operational activity within the plant **Unlikely:** Poor conditions in the ash ponds

Source: Wetlands International-Asia Pacific, n.d.

Table 10. Retrospective Analysis of Waterbirds in Paya Indah Wetland Sanctuary.

Changes Observed	Possible Agents	Remarks
No. of species decreased from 131 to 15 (1996-1999)	**Most Likely:** Bird observations concentrated primarily on waterbirds in recent years; diversity of forest birds outnumber waterbirds; time of count did not coincide with bird migratory period **Possibly:** Illegal hunting of birds **Unlikely:** Environmental pollution	• Generally, the diversity of waterbirds in inland freshwater systems of Peninsular Malaysia is low as compared to forest birds. • Illegal hunting of waterbirds do occur occasionally and diminish certain species.
No. of species decreased from 15 to 11 (1999-2000)	**Most Likely:** Bird observations concentrated primarily on waterbirds, time of count did not coincide with bird migratory period **Likely:** New environment needs time to re-establish **Possibly:** Illegal hunting of birds **Unlikely:** Environmental pollution	• Generally, the diversity of waterbirds in inland freshwater systems of Peninsular Malaysia is low as compared to forest birds. • Illegal hunting of waterbirds do occur occasionally and diminish certain species. • Paya Indah will attract more birds as the ecosystem strives to achieve stability.
No. of species maintained at 11 (2000-2001)	**Most Likely:** Bird observations concentrated primarily on waterbirds; time of count did not coincide with bird migratory period **Likely:** New environment needs time to re-establish **Possibly:** Illegal hunting of birds **Unlikely:** Environmental pollution	• Generally the diversity of waterbird in inland freshwater systems of Peninsular Malaysia is low as compared to forest birds. • Illegal hunting of waterbirds do occur occasionally and diminish certain species. • Paya Indah will attract more birds as the ecosystem strives to achieve stability.

Source: Giesen and Sebastian, 1996; Wetlands International-Asia Pacific, n.d.

Evidence of Decline

Available data gathered (Table 12) indicated evidences of decline in the number of fish species in the primary rain forest and peat swamp forests. Detailed evidence however cannot be provided since the data are very scarce and not complete. More research works are needed to verify the decline in the number of fish species in these habitats. These researches should be more comprehensive and may require more time to detect any change in the number of species and population.

Attributed Causes

Decline in fish population and species in the Klang project area is suspected based on evidence that several predator species are locally rare and that several exotic species such as *Tilapia* are increasing in the river system. This is a sign of a disturbed or polluted river system. The loss of species is not only due to the loss of habitat such as the peat swamp areas that are converted into farmland and housing, but also potentially pollution of organic and inorganic substances in the water channels (Table 13).

Consequences

Loss of habitat and pollution of the water channels may lead to decrease in the local species and increase in invader (exotic) species. Indirectly, the reduction of the fish population would influence the economic condition of the local people.

Table 11. Detailed Retrospective Risk Assessment of Birds in Three Different Habitats.

Birds	Pollution	Disease	Land Clearing	Hunting	Selective Logging	Land Reclamation
1. Is the target exposed to the agent?	M	M	Y	Y	Y	Y
2a. Was there any loss/es that occurred following exposure?	ND	M	Y	Y	Y	Y
2b. Was there any loss/es correlated through space?	ND	M	Y	Y	Y	Y
3. Does the exposure concentration exceed the threshold where adverse effects start to happen?	ND	ND	Y	Y	Y	Y
4a. Do the results from controlled exposure in field experiments lead to the same effect?	ND	M	M	M	M	Y
4b. Will removal of the agent lead to amelioration?	ND	Y	Y	Y	Y	Y
5. Is there an effect in the target that is known to be specifically caused by exposure to the agent (e.g., biomarkers)?	ND	ND	Y	Y	Y	Y
6. Does it make sense (logically and scientifically)?	?	Y	Y	Y	Y	Y
Likelihood	?	P	VL	VL	VL	VL

Legend: Y – Yes, M – Maybe, ND – No Data, ? – Unknown, L – Likely, P – Possibly, U – Unlikely, VL – Very Likely

Table 12. Summary of Information for Aquatic Fauna Decline in Three Different Habitats.

Changes Observed	Agents	Remarks
Peat Swamp Forest: Decline in number of species (1998–2001)	Land clearing, reclamation, selective logging, mining and other development activities	Needs more data either from reports and other references or further study for detailed analysis. At present the data available are sketchy.
Mangrove Forest: Decline in number of species	Land clearing, selective logging and aquaculture and other development activities	
Inland Streams: Decline in number of species (2000)	Logging, pollution and other agriculture and development activities	

Sources: Ng, et al., 1994; Abdullah and Wang, 1996.

Table 13. Detailed Retrospective Risk Assessment of Freshwater Fishes.

Freshwater Fishes	Sedimentation/TSS	Oil & Grease/oil spills	Heavy Metals	Pesticides	Toxic Algae	Organic Matter	Nutrients	Disease	Development Activities
1. Is the target exposed to the agent?	Y	Y	Y	M	M	M	Y	M	Y
2a. Was there any loss/es that occurred following exposure?	M	Y	M	M	ND	ND	Y	Y	Y
2b. Was there any loss/es correlated through space?	M	M	M	M	M	ND	ND	ND	Y
3. Does the exposure concentration exceed the threshold where adverse effects start to happen?	M	M	M	M	M	ND	ND	ND	Y
4a. Do the results from controlled exposure in field experiments lead to the same effect?	ND	Y	ND	ND	ND	ND	ND	ND	Y
4b. Will removal of the agent lead to amelioration?	M	Y	M	M	M	M	M	ND	Y
5. Is there an effect in the target that is known to be specifically caused by exposure to the agent (e.g., biomarkers)?	ND	Y	M	M	ND	ND	ND	ND	Y
6. Does it make sense (logically and scientifically)?	Y	Y	Y	M	M	M	M	M	Y
Likelihood	?	P	?	?	?	?	P	P	VL

Legend: Y – Yes, M – Maybe, ND – No Data, ? – Unknown, L – Likely, P – Possibly, U – Unlikely, VL – Very Likely

SUMMARY OF THE RETROSPECTIVE RISK ASSESSMENT

For marine capture fisheries, it was difficult to relate the changes in production to environmental factors due to insufficiency of data and other confounding factors such as fish catch from other areas.

Fish and shellfish culture activities, on the other hand, have been shown to have significant impacts on mangrove ecosystems due to the conversion of mangrove areas to culture ponds, while in the Kapar and Klang MFRs, the observed decline in mangrove cover was linked to the conversion of mangrove areas to accommodate developments in the vicinity of the Klang coastal area.

Decline was also established, based on the limited information available, for mammals, birds and fish in tropical rainforests, peat swamp forests and mangrove forests, and the most important factors identified to have contributed to the decline were habitat loss and hunting. For freshwater fishes, water pollution is an important factor influencing the population and diversity but land clearing and land reclamation directly destroys suitable habitat for aquatic organisms.

The results of the retrospective risk assessment have linked the decline in natural resources and habitats to various development activities in the Klang ICM area. Specifically, over-exploitation of natural resources such as forest products and changes in land use such as for housing, aquaculture, agriculture, mining and other development activities have resulted to habitat loss and degradation and decline in biodiversity. Changes in environmental conditions due to pollution have also been implicated in the decline although more information is required to sufficiently establish correlation and cause-effect relationships.

The retrospective risk assessment emphasizes the need to balance economic development and the conservation and protection of the natural environment and resources in order to ensure that ecological functions and services will be sustainably provided while maintaining economic activities that also provide goods and services that benefit society.

The retrospective risk assessment also emphasized the need to gather information on appropriate indicators especially for fisheries in order to allow more quantitative and reliable assessments to be made.

Prospective Risk Assessment

Introduction

A prospective risk assessment aims to determine if measured or predicted levels of environmental parameters are likely to cause harm to targets of interest. This is accomplished by identifying the likely targets then comparing the measured or predicted environmental concentrations (MECs or PECs) with appropriate threshold values (PNECs) to get risk quotients (RQs). For human health, risk through seafood ingestion is estimated by comparing measured or predicted environmental levels (MELs or PELs) with levels of concern (LOCs) as PNECs.

In an ecological point of view, different thresholds should be specified for different targets, and if these are not available, as is often the case, ecotoxicological endpoints can be extrapolated to ecosystem endpoints using appropriate application factors (MPP-EAS, 1999a).

For Port Klang, a simplified ecological risk assessment was carried out using standards and criteria values from the literature as thresholds to estimate the risk to the entire ecosystem. The principles and techniques applied are described in MPP-EAS (1999a).

For the ecological risk assessment, RQs are the ratios of MECs (or PECs) and PNECs. For human health, RQs are the ratios of MELs (or PELs) and LOCs. LOCs are obtained by dividing the tolerable daily intakes (TDIs) by the consumption rates. When an RQ is less than 1, it is presumed that the likelihood of adverse effects is low. When an RQ is greater than 1, there is a likelihood of adverse effects the magnitude of which increases with increase in RQ.

For ecological risk assessment:

$$RQ = \frac{MEC\ (or\ PEC)}{PNEC}$$

For human health:

$$RQ = \frac{MEL\ (or\ PEL)}{LOC}$$

Where RQ	<1	Low risk
	≥ 1	High risk

The reliability of the assessment depends largely on the quality of the data used as MECs and on the quality and relevance of the threshold values used as PNECs. Although there may be uncertainties associated with the MECs and PNECs used in the risk assessment, the utility of the RQs in signaling potential areas of concern is significant. The uncertainties can be minimized through the careful selection of good quality data and relevant thresholds or these can be described so that future use of the results of the risk assessment would take the possible effects of the uncertainties into consideration.

Uncertainties can also arise from the variability in the RQs obtained. An initial measure of uncertainty was obtained by taking the average and worst-case (maximum) RQs. A more quantitative measure of uncertainty can be carried out using the Monte Carlo simulation, a re-sampling technique which randomly re-samples pairs of MECs and PNECs to come up with the percentage of the measured values exceeding the threshold.

Data for the IRA of Port Klang came primarily from the DOE–Selangor, 2000 (Appendix 1). The threshold values used as PNECs came primarily from the Interim National Water Quality Standards for Malaysia (INWQS) and Interim Marine Water Quality Standards for Malaysia (IMWQS) (Appendix 3). Marine water quality criteria and standards from other sources were also used to supplement the local marine water quality standards.

In the preliminary risk assessment carried out during the Regional Training Course on Environmental Risk Assessment in Chonburi, Thailand on July 23–28, 2001, data for selected parameters in the water column from various stations were combined and the best-case, worst-case and average RQs were estimated. The RQs generated using this simplified approach provided a glimpse of ecological and human health risks in the area, which became the basis for a more detailed assessment of risk for specific areas along the coasts and two major rivers, Klang and Langat.

Assessment of risk in sediments was carried out only for oil and grease and polycyclic aromatic hydrocarbons or PAHs. There were no data on contaminants or pathogens in seafood tissue that could be used to assess direct risk to human health associated through consumption of contaminated seafood, but risk to human health associated with water contact was assessed.

Although the risk assessment focuses on marine ecosystems and their components as targets, the RQ approach was extended to the assessment of risk posed by various contaminants in the air using air quality monitoring data as MECs and air quality standards for Malaysia as PNECs (Appendix 3).

Following are the results of the preliminary risk assessment (during the training) and the IRA for coastal areas, river areas and ambient air in Port Klang, Malaysia.

PRELIMINARY RISK ASSESSMENT

The data used for the analysis were taken from the reports from DOE–Selangor with monthly monitoring observations from 24 stations (Appendix 1–2) representing mostly Klang River, Klang River estuary and Straits of Klang (one station). Sampling was conducted observing DOE–Malaysia guidelines for sampling methods for surface water. The PNECs used, as appropriate, were from the INWQS for Malaysia, Class II, and the IMWQS for Malaysia. For oil and grease, the PNEC used was 1 mg/l, which was the recommended standard for Malaysia as reported in Abdullah and Wang (1996) and applied in MPP-EAS (1999b). Initial estimates of RQs were obtained by using the geometric mean and worst-case measurements from the combined data from various sampling stations and sampling periods. This was aimed at screening parameters that present acceptable concern, and hence may not require detailed risk analysis, and to identify priority parameters for which detailed spatial and temporal analysis will be carried out as the data permit. Sources of uncertainty and data gaps in the risk assessment were also identified and recommendations for filling the data gaps and verifying the uncertainties were provided.

Table 14 shows that except for arsenic, all parameters in the water column gave average RQs (RQ_{Ave}) that exceeded 1. For biochemical oxygen demand (BOD) and ammonia (NH_3), even the best-case RQs (RQ_{Min}) exceeded 1, indicating general cause for concern for levels of these parameters in the water column. Only average values were available for the other parameters, thus only average RQs were obtained, which exceeded 1 for *Escherichia coli*, Hg, and oil and grease. Since the PNECs used were specified for the protection of waters used for recreation and body contact, RQs that exceed 1 also indicate human health risk associated with bathing in contaminated waters. The high RQs for *E. coli*, in particular, pose human health risks.

It is clear that for BOD, ammoniacal nitrogen (AN), total suspended solids (TSS), *E. coli*, mercury (Hg) and oil and grease in the water column, there is a need to conduct a more detailed risk assessment in order to verify and/or update the results, conduct more detailed spatial and/or temporal assessment of risks and identify primary sources of these risk agents. Oil and grease requires closer examination using additional data. Data for heavy metals in the water were also limited to Hg and arsenic (As), which were taken from the monthly monitoring activities of DOE–Selangor in the year 2000 only, thus Hg, As, and other heavy metals should also be examined more closely using additional data. All the PNECs used were from the Interim Water Quality Standards for Malaysia (IWQS), Class II. The analysis involved data for fresh water as well as seawater (e.g., *E. coli*, As, Hg and oil and grease were measured in seawater from the Straits of Klang.

In the sediment (Table 15), only one set of data for oil and grease from Port Klang, which was taken from Chua Thia-Eng, et al., (1997) and from Abdullah (1995), was available at the time of the assessment. The PNEC used (3 mg/kg) was the critical concentration for both oils and hydrocarbons in sediment, as applied in MPP-EAS (1999b) after consideration of the variability in criteria and standards for oil and grease in Malaysia and other locations.

For oil and hydrocarbons in the areas assessed, both RQ_{Min} and RQ_{Max} exceeded 1 (Table 20), indicating general cause for concern for their levels. The uncertainty associated with the limited data (from three stations in 1995) used in the analysis is well recognized, but given the level of both land-based (domestic, industrial and automotive activities; palm plantations and refineries) and sea-based (shipping, port

Table 14. Prospective Risk Assessment for Water Column Contaminants.

Agent	MEC_{Ave}	MEC_{Min}	MEC_{Max}	PECs	PNECs	RQ_{Max}	RQ_{Min}	RQ_{Ave}	Remarks/Notes on Uncertainty
BOD (mg/l)	81.48	46	82		3	27.33	15.33	27.16	RQ_{Min} > 1 (general cause for concern); risk reduction actions needed
AN (mg/l)	13.52	5.4	17		0.3	56.33	18	45.1	RQ_{Min} > 1 (general cause for concern); risk reduction actions needed
TSS (mg/l)	64	39.5	65.29		50	1.31	0.79	1.28	RQ_{Ave} > 1 but RQ_{Min} < 1, need refined RA to determine areas of concern
E. coli (MPN/ 100 ml)	7300				100			73	RQ_{Ave} > 1 (area-wide concern); risk reduction actions needed
As (mg/l)	0.007				0.1			0.007	RQ_{Ave} < 1 but RQ_{Max} is not available; need refined RA using more data
Hg	0.002				0.001			2	RQ_{Ave} > 1 but RQ_{Min} and RQ_{Max} are not available; need refined RA
Oil and Grease (mg/l)	1.5				1			1.5	RQ values slightly above 1 but RQ_{Min} and RQ_{Max} are not available; need refined RA

operations and fishing) activities that can contribute oil and related substances to the marine environment, oil and grease is recommended for further assessment. It is also recommended that other available data on oil and grease and other parameters in the sediment (e.g., heavy metals, pesticides, PAHs) be collected and used for the risk assessment and/or that oil and grease and other parameters be integrated into future environmental monitoring programs in the Port Klang ICM project area.

COASTAL AREAS IN KLANG

Based on the results of the preliminary risk assessment, a more detailed risk assessment was carried out specifically for various areas along the coast of Klang and selected rivers. Trends in risk through time were also evaluated for some areas.

Major parts of the Selangor coastal areas are under the influence of two major rivers, i.e., Langat and Klang. Both of these rivers are polluted and hence there may be water quality deterioration at the estuaries and coastal areas where both rivers discharge their water. In view of the strong influence of these two rivers on the coastal areas, the risk assessment of the coastal zone focused on areas that are situated near both of these rivers. And in order to confirm the risk posed by contaminant discharges from the rivers, risk assessment was also carried out for the two rivers.

The coastal zones in Selangor that may be affected by possible contamination of the Langat and Klang rivers are:

- Pantai Morib
- Kuala Langat at Jugra
- Kuala Langat
- Kuala Klang
- Selat Klang Utara

These coastal areas are situated close to both of the two rivers and are important areas for aquaculture (Jugra) and recreation (Morib). The risk assessment of marine water in several coastal zones was aimed at evaluating the potential impacts of water quality on these economic activities.

The data used (MECs) in calculating RQs came from the DOE–Selangor, while the thresholds (PNECs) came primarily from the IMWQS for Malaysia. RQ > 1 indicate adverse impacts associated with use of the water for human body contact and for aquaculture.

The IMWQS, however, has been specified for a limited number of parameters only and values for dissolved oxygen (DO), pH and turbidity are not available. For oil and grease, the standard value is zero (0), which cannot be used to quantitatively estimate RQs. The values for some parameters are also not stringent and are at least one order of magnitude higher than the INWQS for rivers in Malaysia, the ASEAN marine water

Table 15. Prospective Risk Assessment for Oil and Grease in Sediment.

Agent	MEC_{Ave}	MEC_{Min}	MEC_{Max}	PNECs	RQ_{Max}	RQ_{Min}	RQ_{Ave}	Remarks/Notes on Uncertainty
Oil and Grease (mg/l)		83	704	3	234.7	27.7		RQ_{Min} > 1 but limited data; needs further assessment

quality criteria (2003), and criteria or standards from other areas within and outside the region (Table 16). Use of these higher standard values will underestimate the risk that the agents pose to ecological and human targets.

In view of the limitations of the IMWQS and the inappropriateness of applying freshwater standards for marine areas, PNECs for the risk assessment of coastal waters were chosen, as deemed appropriate, from the IMWQS, ASEAN criteria, and other areas in the region, in this order of priority. The protectiveness of the threshold values was also an important consideration. Table 17 presents the standards/criteria applied to specific parameters and the respective sources.

For oil and grease in water, the PNEC used was 1 mg/l, which was the value applied for total oil and grease in Malaysia in MPP-EAS (1999b) based Abdullah and Wang (1996). This value is the same as the Philippine criteria and Vietnamese standard for oil and grease.

For pH, standard values are not available from the INWQS and the ASEAN criteria while ranges

Table 16. Comparison of the Water Quality Standards of Malaysia with Other Criteria and Standards.

Agent	IMWQS	INWQS	ASEAN[1]	Philippines[2]	Thailand[3]	Vietnam[4]	Bali, Indonesia[5]	U.S. EPA[6]
DO (mg/l)		5–7	4	5	4	> 5	4	
SS (mg/l)	50	50	< 10% increase over seasonal avg. conc.	< 30% increase	50	80		
pH		6.5–9		6.5–8.5	7–8.5	6.5–8.5	6–9	
Turbidity (NTU)		50					30	
As (mg/l)	0.1	0.05		0.05		0.01	0.01	0.036 (III)
Hg (mg/l)	0.001	0.001	0.0016	0.002	0.0001	0.005	0.003	0.000025
Cd (mg/l)	0.1	0.01	0.01	0.01	0.005	0.005	0.01	0.0093
Cr (mg/l)	0.5	0.05	0.05 (VI)	0.05 (VI)	0.05 (VI)	0.05 (VI)	0.01	0.05
Cu (mg/l)	0.1	0.01	0.008	–	0.05	0.01	0.06	0.0029
Pb (mg/l)	0.1	0.05	0.0085	0.05	0.05	0.05	0.01	0.0056
E. coli (CFU/100ml)	100	100	100	nil	nil	1,000		
Oil & Grease (mg/l)	0	1	0.14	1	Not visible	1	5	
BOD (mg/l)	–	3	–	3	–	10	45, 10 (for bathing)	
COD (mg/l)	–	25	–	–	–	–	80, 20 (for bathing)	
NH_3 (mg/l)	–	0.3	0.07	- 0.4	0.5	1		

[1]ASEAN Marine Water Quality Criteria (ASEAN, 2003), Criteria for protection of aquatic life
[2]Philippine Marine Water Quality Criteria (DAO 34, 1990), Class SA (propagation, growth and harvesting of shellfish for commercial purposes)
[3]Coastal Water Quality Standard of Thailand (PCD, 1994), Class 4: propagation of marine life
[4]Vietnamese Standards for Seawater Quality (MOSTE, 1995), VNS 5943 –1995, Class B (Aquaculture)
[5]Bali Province Seawater Quality Criteria (2000), Indonesia (for marine biota and fisheries)
[6]U.S.EPA Marine Chronic Criteria for Regulatory Purposes (U.S. EPA, 2000)

of permissible pH values were specified for other countries in the region. Using criteria values for Class SA waters in the Philippines (suitable for propagation, survival and harvesting of shellfish for commercial purposes), RQs were assigned either as < 1 or > 1 depending on whether the value falls within the range of PNECs.

In calculating RQs for DO, it should be noted that, unlike with other parameters, a measured value lower than the standard value indicates deteriorating conditions (i.e., worst-case MEC is the lowest value). Thus, for DO, RQ = PNEC/MEC and the worst-case RQ (RQ_{Max}) is equal to PNEC/lowest MEC.

In addition to the data on oil and grease in sediments from Port Klang which were used in the preliminary risk assessment, a range of oil and grease values from three stations in Morib were also obtained from Chua Thia-Eng, et al. (1997) and Abdullah (1995). The PNEC used was 3 mg/kg, as applied in MPP-EAS (1999b).

Results and Discussion

Tables 18-22 present the results of the risk assessment for the five identified coastal areas. A general trend is seen with regard to the contamination of these five coastal zones, as demonstrated by the parameters SS, *E. coli* and oil and grease in the water column, and PAH and oil and grease in the sediment (Table 23), for which all RQ_{Ave} exceeded 1, indicating cause for concern for the levels of these parameters. However, other parameters such as heavy metals still showed acceptable risk as the RQs were all < 1. The RQ values for these parameters remain < 1 even for worst-case conditions. There were no data on COD or BOD but the high utilization of DO could be deduced from RQ_{Ave} values > 1 for DO at Kuala Klang and Kuala Langat. RQ_{Ave} for DO in Selat Klang Utara was also very close to 1.

Obviously, the contamination of the marine water by pathogenic *E. coli*, oil and grease and SS, as indicated by RQ_{Ave} exceeding 1, is a cause for concern.

Table 17. PNECs used for the Prospective Risk Assessment for Coastal Waters.

Agent	PNECs	Sources
DO (mg/l)	4	ASEAN, 2003
SS (mg/l)	50	IMWQS (Malaysia)
pH	6.5–8.5	Philippines (DAO 34, 1990, Class SA)
Turbidity (NTU)	30	Bali, Indonesia (for marine biota & fisheries) (2000)
As (mg/l)	0.05	Philippines (DAO 34, 1990, Class SA)
Hg (mg/l)	0.001	IMWQS (Malaysia)
Cd (mg/l)	0.01	ASEAN, 2003
Cr (mg/l)	0.05	ASEAN, 2003
Cu (mg/l)	0.008	ASEAN, 2003
Pb (mg/l)	0.0085	ASEAN, 2003
***E. coli* (CFU/100ml)**	100	IMWQS (Malaysia)
Oil and Grease (mg/l)	1	MPP-EAS, 1999b
BOD (mg/l)	3	Philippines (DAO 34, 1990, Class SA)
COD (mg/l)	20	Bali (for bathing) (2000)
NH_3 (mg/l)	0.07	ASEAN, 2003

Risk from Pathogenic Bacteria

RQ_{Ave} for *E. coli* exceeded 1 in all stations, with the highest RQ values obtained from Kuala Klang (RQ_{Ave} = 23.3) followed by Pantai Morib (RQ_{Ave} = 15.3), and the lowest at Kuala Langat at Jugra (RQ_{Ave} = 1.8) (Figure 3).

The presence of *E. coli* poses risk to human health because these bacteria may contaminate the aquaculture products from these coastal areas, especially at Jugra, which is an important aquaculture area. When consumed, these products may lead to public health problems. The use of this marine water for recreational purpose with body contact also poses human health problems especially in Pantai Morib, which is a recreation area.

Risk from Sedimentation and Siltation

RQ_{Ave} for SS exceeded 1 in all the coastal stations. The magnitude of RQ values show that the five areas are almost equally affected by

Table 18. RQs for Water Quality Parameters at Pantai Morib.

Agent	MEC_{Ave}	MEC_{Max}	PNECs	RQ_{Max}	RQ_{Ave}
DO (mg/l)	4.70	4			0.85
SS (mg/l)	198.8	240	50	4.8	3.98
pH	7.5		6.5–8.5		< 1
Turbidity (NTU)	44.9	82	302.73		1.5
As (mg/l)	0.005	0.007	0.05	0.14	0.1
Hg (mg/l)	< 0.001	< 0.001	0.001	< 1	< 1
Cd (mg/l)	< 0.001	< 0.001	0.01	< 0.1	< 0.1
Cr (mg/l)	0.001	< 0.001	0.05	< 0.02	< 0.02
Cu (mg/l)	0.002	0.003	0.008	0.38	0.25
Pb (mg/l)	< 0.001	< 0.001	0.0085	< 0.1	< 0.1
E. coli (CFU/100ml)	1,532	2,400	100	24	15.32
Oil and Grease (mg/l)	2.17	8	1	8	2.17

Table 19. RQs for Water Quality Parameters at Kuala Langat at Jugra.

Agent	MEC_{Ave}	MEC_{Max}	PNECs	RQ_{Max}	RQ_{Ave}
DO (mg/l)	5.02		4		0.8
SS (mg/l)	73	108	50	2.16	1.46
pH	7.7		6.5–8.5		< 1
Turbidity (NTU)	12.88	82	30	2.73	0.43
As (mg/l)	0.006	0.007	0.05	0.14	0.12
Hg (mg/l)	< 0.001	< 0.001	0.001	< 1	< 1
Cd (mg/l)	< 0.001	< 0.001	0.01	< 0.1	< 0.1
Cr (mg/l)	< 0.001	< 0.001	0.05	< 0.02	< 0.02
Cu (mg/l)	0.003	0.004	0.008	0.5	0.375
Pb (mg/l)	< 0.001	< 0.001	0.0085	< 0.1	< 0.1
E. coli (CFU/100ml)	179.6	542	100	5.42	1.8
Oil and Grease (mg/l)	5.5	6	1	6	5.5

suspended solid particulates in the water column (Figure 3). For turbidity, RQ_{Ave} exceeded 1 for Pantai Morib, Kuala Langat and Selat Klang Utara while RQ_{Max} exceeded 1 for Kuala Langat at Jugra.

Elevated levels of SS can affect the aquaculture industry especially the culture of shrimps. It can also affect the aesthetic nature of the water and hence recreational use. High levels of SS can also reduce light penetration in the water and inhibit photosynthetic processes with consequent effects on organisms at higher trophic levels.

Although suspended solids are contributed by natural biological, physical and chemical processes, various land-use practices in the watershed areas and along the coast are also significant contributors. These activities include land reclamation projects, aquaculture, agriculture, upland forestry, mining, discharge of wastes from various sources, dredging, trawling, mangrove conversion and so on. Relative contributions of these various sources of SS also need to be determined.

Table 20. RQs for Water Quality Parameters at Kuala Klang.

Agent	MEC_{Ave}	MEC_{Max}	PNECs	RQ_{Max}	RQ_{Ave}
DO (mg/l)	3.20		4		1.25
SS (mg/l)	108.3	230	50	4.6	2.17
pH	6.59	6.5–8.5			< 1
Turbidity (NTU)	8.9	18	30	0.6	0.3
As (mg/l)	0.006	0.011	0.05	0.22	0.12
Hg (mg/l)	< 0.001	< 0.001	0.001	< 1	< 1
Cd (mg/l)	< 0.001	< 0.001	0.01	< 0.1	< 0.1
Cr (mg/l)	< 0.001	< 0.001	0.05	< 0.02	< 0.02
Cu (mg/l)	< 0.001	< 0.001	0.008	< 0.125	< 0.125
Pb (mg/l)	< 0.001	< 0.001	0.0085	< 0.01	< 0.01
E. coli (CFU/100ml)	2,326	3,428	100	34.28	23.26
Oil and Grease (mg/l)	1.5	2	1	2	1.5

Table 21. RQs for Water Quality Parameters at Kuala Langat.

Agent	MEC_{Ave}	MEC_{Max}	PNECs	RQ_{Max}	RQ_{Ave}
DO (mg/l)	3.66		4		1.09
SS (mg/l)	192.6	348	50	6.96	3.852
pH	7.28	6.5–8.5			< 1
Turbidity (NTU)	80.6	240	30	8	2.69
As (mg/l)	< 0.001	< 0.001	0.05	< 0.02	< 0.02
Hg (mg/l)	< 0.001	< 0.001	0.001	< 1	< 1
Cd (mg/l)	< 0.001	< 0.001	0.01	< 0.1	< 0.1
Cr (mg/l)	< 0.001	< 0.001	0.05	< 0.02	< 0.02
Cu (mg/l)	< 0.001	< 0.001	0.008	< 0.125	< 0.125
Pb (mg/l)	< 0.001	< 0.001	0.0085	< 0.118	< 0.118
E. coli (CFU/100ml)	885.6	3,480	100	34.8	8.86
Oil and Grease (mg/l)	1.6	2	1	2	1.6

Risk from Oily Wastes

RQ_{Ave} for oil and grease in the water column exceeded 1 in all stations, with the highest RQ_{Ave} obtained for Jugra followed by Selat Klang Utara and Pantai Morib (Figure 3).

In the sediments (Table 21), RQ_{Min} for oil and grease in Port Klang and Morib also exceeded 1, indicating general cause for concern in all the areas sampled.

Oil and grease pollution can have adverse impacts on marine flora and fauna. Laboratory studies, some of which have been supported by field observations, have shown that fish exposed to sublethal levels of petroleum (even similar to those observed under normal field conditions) experienced negative effects on reproductive processes and aberrations in development, behavior, subcellular structure and biochemical processes that could lead to premature death through increased susceptibility to predation and disease. PAHs in petroleum have also been linked to formation of tumors in fish and mollusks (IMO, 1988).

The RQs exceeding 1 for PAHs in sediment (Table 23) in two out of three areas (Klang Estuary and Kuala Langat) confirm the concern for oil and

Table 22. RQs for Water Quality Parameters at Selat Klang Utara.

Agent	MEC_{Ave}	MEC_{Max}	PNECs	RQ_{Max}	RQ_{Ave}
DO (mg/l)	4.16	4			0.96
SS (mg/l)	157.4	234	50	4.68	3.15
pH	7.02		6.5–8.5		< 1
Turbidity (NTU)	56.25	150	30	5	1.88
As (mg/l)	0.002	0.003	0.05	0.06	0.04
Hg (mg/l)	< 0.001	< 0.001	0.001	< 1	< 1
Cd (mg/l)	< 0.001	< 0.001	0.01	< 0.1	< 0.1
Cr (mg/l)	< 0.001	< 0.001	0.05	< 0.02	< 0.02
Cu (mg/l)	< 0.001	< 0.001	0.008	< 0.125	< 0.125
Pb (mg/l)	< 0.001	< 0.001	0.0085	< 0.118	< 0.118
***E. coli* (CFU/100ml)**	416.8	542	100	5.42	4.17
Oil and Grease (mg/l)	3	6	1	6	3

Table 23. RQs for Oil and Hydrocarbons in Sediment at the Klang–Kuala Langat Coastal Zone.

Agent	MEC_{Min}	MEC_{Max}	MEC_{Ave}	PNECs	RQ_{Max}	RQ_{Min}	RQ_{Ave}
Total PAHs (ng/g)							
Klang Estuary	19	431	233. 4	200	0.095	2.155	1.167
Klang Coast	9	39	24	200	0.045	0.195	0.12
Kuala Langat	55	615	232	200	0.275	3.075	1.16
Oil and Grease (µg/g dry wt.)							
Port Klang	83	704		3	234.7	27.7	
Morib	5.6	26		3	8.7	1.9	

related substances in the water column since PAHs are constituents of oil and grease which represents a large group of chemicals including biogenic and petrogenic hydrocarbons as well as biological lipids. PAHs are found in petrogenic hydrocarbons and indicate the contribution of petroleum sources to the oil and grease in the marine environment.

The relative contribution of biogenic and petrogenic sources in the levels of oil and grease in the Klang coastal area therefore need to be evaluated in order to enhance the assessment and develop appropriate risk reduction measures.

Conclusions

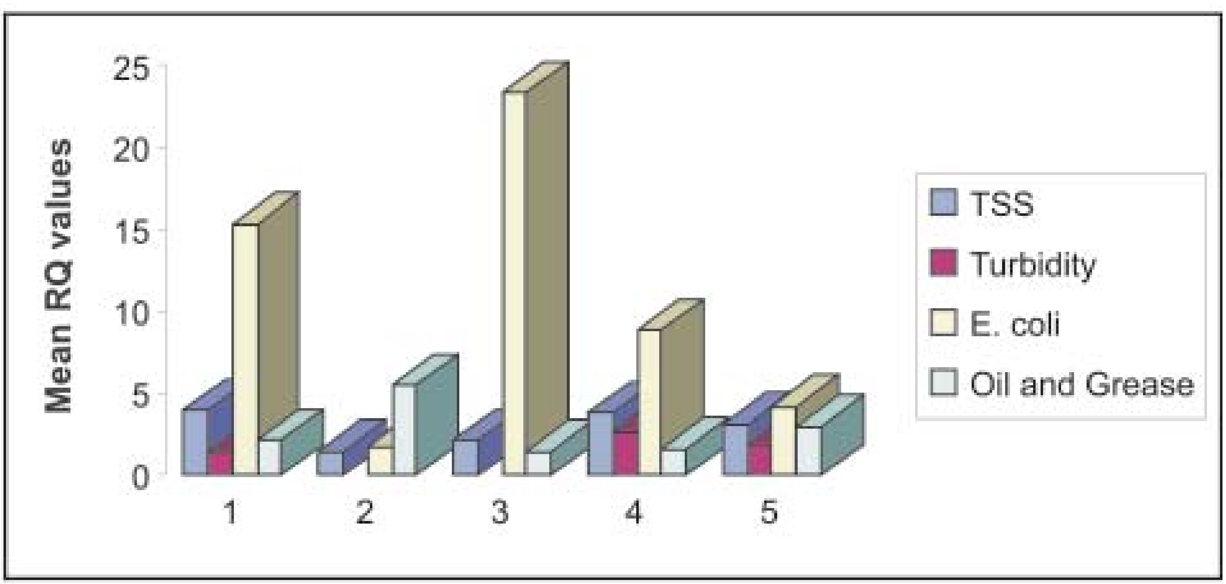
Among all five coastal zones examined, based on the RQ_{Ave} values, Jugra showed the highest RQ_{Ave} for oil and grease followed by Selat Klang Utara and Pantai Morib, while Pantai Morib and Kuala Klang are the priority risk areas for *E. coli*. For SS, most zones are equally affected. Jugra is an important aquaculture zone while Morib is a recreation area. Attention must be given to the presence of pathogenic bacteria and high levels of oil and grease in the water especially at these areas, with particular consideration on the sources.

Evaluation of Temporal Trend of Risk for the Coastal Station in Langat River

Changes in the average level of risk for some parameters throughout a six-year period was evaluated for the coastal station in Langat River. The MEC_{Ave}, taken from DOE–Selangor, are shown in Table 24. The RQs which were calculated using the MECs and corresponding PNEC values (from Table 17) are presented in Table 25.

As shown in Table 25, the RQ values for DO, SS, turbidity, chemical oxygen demand (COD), oil and grease and NH_3 consistently exceeded 1 while some of the RQs for BOD and NH_3 also exceeded 1. For most parameters, the RQs fluctuated and did not show clear trends, potentially due to variability associated with sampling areas and periods, although there has been little reduction in risk (Figure 4).

Figure 3. RQ_{Ave} Values for Selected Water Quality Parameters (with RQ > 1) in the Coastal Stations



The RQs for oil and grease exceeded 1, indicating cause for concern for this parameter in the coastal areas. The RQs for COD also indicate risk from excessively high organic loads. Very frequently, however, analysis of COD in marine water is subjected to high chloride ion interference. Therefore the data obtained here must be viewed with caution and calls for further verification. The RQs exceeding 1 for DO, however, confirm the results for COD since decline in DO indicates an increased oxygen demand in the bay for the decomposition of organic loads. The high RQs for NH_3 also indicate anoxic conditions thus further confirming the concern for low DO levels and high organic loads. The RQs for SS and turbidity are also complementary and both indicate risk from siltation and sedimentation at the coastal area close to the river and at some points along the stretch of the river.

Table 24. The Average MEC Values for Various Water Quality Parameters at a Coastal Station near Langat River (1993-1998).

Parameter	Average MECS					
	1993	1994	1995	1996	1997	1998
	(n = 6)	(n = 5)	(n = 5)	(n = 3)	(n = 4)	(n = 6)
DO (mg/l)	2.36	2.02	2.1	2.53	2.65	2.78
SS (mg/l)	547.4	416.4	212	192.33	249	216.67
pH	6.11	6.74	6.69	7.18	6.26	6.6
Turbidity		(n = 3)	(n = 2)			
BOD (mg/l)	3.36	0.9	1.52	1.9	40.28	4.08
COD (mg/l)	110.11	199.32	249.72	91	151.72	754.5
Oil and Grease (mg/l)	3.66	2.38	5.26	5.33	ND	1.08
NH_3 (mg/l)	0.29	2.97	0.53	1.73	ND	ND

ND: No Data

Table 25. RQs for Various Water Quality Parameters at a Coastal Station near Langat River (1993-1998).

Parameter	PNEC	RQ_{Ave}					
		1993	1994	1995	1996	1997	1998
DO (mg/l)	4	1.69	1.98	1.90	1.58	1.51	1.44
SS (mg/l)	50	10.9	8.32	4.24	3.85	4.98	4.33
pH	6.5-8.5	> 1	< 1	< 1	< 1	> 1	< 1
Turbidity	30	5.63	4.03	4.56	7.30	14.07	9.24
BOD (mg/l)	3	1.12	0.3	0.51	0.63	13.4	1.36
COD (mg/l)	20	5.54	9.97	12.49	4.55	7.59	37.73
Oil and Grease (mg/l)	1	3.66	2.38	5.26	5.33	ND	1.08
NH_3 (mg/l)	0.07						

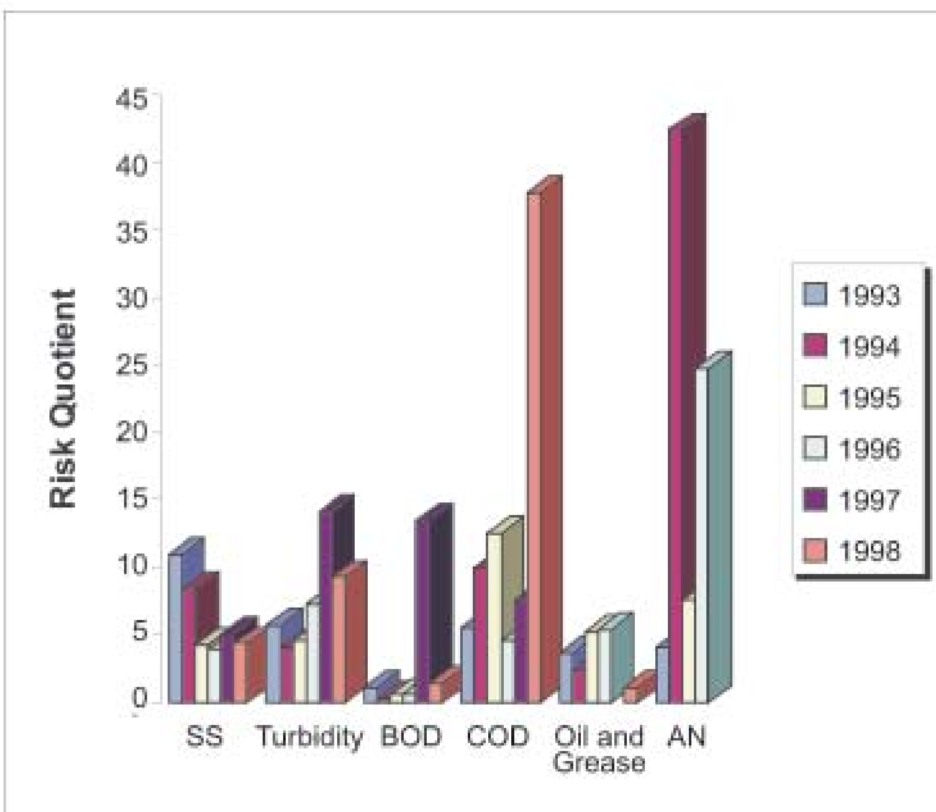
ND: No Data

Sources of Uncertainty

It is noteworthy that RQs have been estimated separately for the different stations assessed, thereby providing an indication of spatial variability of potential risks. In this initial assessment, however, data collected from each station at different periods were combined to provide single estimates of mean and worst-case RQs, which do not demonstrate temporal variability. This process, however, allowed the identification of priority areas and parameters of concern for which more detailed analysis of seasonal or annual trends could be carried out (such as the one done for the coastal area near Langat River). Information on seasonal and annual trends in risks will aid in understanding the sources/causes and distribution of risk agents and in developing appropriate management interventions.

Another potentially significant source of uncertainty in the risk assessment is the use of standards and criteria from other locations (such as PNECs) since these might not be totally suitable for Port Klang. These values were, however, applied because of the recognized limitations of the Malaysian marine water quality criteria. These limitations therefore need to be given attention in order to improve the effectiveness of the standards as one of the decision factors in marine and coastal management and enhance the reliability of future risk assessments.

Figure 4. The Variation of the RQs for Some Water Quality Parameters throughout 1993–1998.



KLANG AND LANGAT RIVERS

To confirm the risks identified in the risk assessment of coastal areas and the linkage with the major river systems, risk assessment was also carried out for the water column of the Klang and Langat Rivers. The data used in the risk assessment were taken from reports (1990–2000) of DOE–Selangor (Appendix 1) while the standards used as PNECs came from IWQS for Malaysia. The class of standards selected was Class II, a minimum standard quality for drinking purposes. Class II was chosen to reflect the stringent nature of the standards and hence the seriousness of the risk assessment. RQs > 1 indicate adverse impacts associated with use of the water for human body contact and for aquaculture.

For oil and grease in water, the standard values in the INWQS are specific for different types of oil such as mineral oil (0.04 mg/l for Class II water) and emulsifiable and edible oil (7 mg/l for Class II water). Since the oil and grease data used in the Klang IRA do not distinguish between the different oil types, the standard used was 1 mg/l, which was the standard applied for total oil and grease in Malaysia in MPP-EAS (1999b).

For DO and pH, ranges of standard values were specified in the INWQs for Malaysia. For pH, RQs were assigned either as < 1 or > 1 depending on whether the value falls within the range of PNECs. For DO, since anoxic conditions over short periods may have considerable impact on fauna, particularly benthic animals, RQs were computed using the lower value in the range (5 mg/l), which is comparable with standard values from other locations (Appendix 4). For DO, unlike with other parameters, a measured value that is lower than the standard value indicates deteriorating conditions (i.e., worst-case MEC is the lowest value) such that RQ = PNEC/MEC.

Tables 26 to 31 present the results of the assessment for three areas in Klang River and another three areas in Langat River, representing the catchment (Tables 26 and 29), middle stretch (Tables 27 and 30), and estuarine (Tables 28 and 31) areas.

Risk from Organic and Nutrient Contamination

Risk from nutrients and organic materials in the water column was assessed by using RQ_{Ave} values for the parameters NH_3, NO_3 and P and BOD, COD and DO. For both Klang and Langat Rivers, risk of contamination from organics is evident especially for the middle stretch and estuary of these rivers where RQ is very much > 1. The risk from organic load in these areas were confirmed by the RQs > 1 for DO, indicating utilization of DO for decomposition of organic matter. Even the highest or best-case DO values generated RQs > 1. Among the nutrients evaluated, NH_3 poses risk to both rivers for the middle stretch and estuary stations. However, for phosphorus (P), only one out of five stations examined indicated average RQ > 1. For NO_3, there was no risk established. Considering the low risk posed by P and NO_3 contamination, the risk for river eutrophication is probably also low.

Risk from Contamination by Metals/Toxic Metals

Assessment for heavy metals involved the following MECs of the seven metals As, Hg, cadmium (Cd), chromium (Cr), lead (Pb), zinc (Zn), and iron (Fe). Except for Zn, Cr, and Fe that are normally considered as trace essential elements for humans and most aquatic organisms, other metals are toxic and can endanger health.In general, the RQ values for Zn, Cr and all the toxic metals are < 1, which indicates low or acceptable risk from levels of toxic metals in the two rivers

Table 26. Prospective Risk Assessment of Water Quality in Klang River at Ulu Klang.

Agent	MEC_{Ave}	MEC_{Max}	PNECs	RQ_{Max}	RQ_{Ave}
DO (mg/l)	6.03	7.55	5.0–7.0	0.66 (best-case)	0.83
BOD (mg/l)	3.00	4	3	1.33	1
COD (mg/l)	22.00	26	25	1.04	0.88
SS (mg/l)	18	34	50	0.68	0.36
pH	6.68	7.11	6.5–9.0	< 1	< 1
NH_3-N (mg/l)	0.24	0.43	0.3	1.43	0.8
Turbidity (NTU)	27	390	50	7.8	0.54
NO_3 (mg/l)	0.28	0.38	7	0.05	0.04
P (mg/l)	0.01	0.5	0.2	2.5	0.05
As (mg/l)	0.011	0.032	0.05	0.64	0.22
Hg (mg/l)	0.0002	0.0005	0.001	0.5	0.2
Cd (mg/l)	0.001	0.003	0.01	0.3	0.1
Cr (mg/l)	0.001	0.009	0.05	0.18	0.02
Pb (mg/l)	0.01	0.01	0.05	0.2	0.2
Zn (mg/l)	0.02	0.04	5	0.008	0.004
Fe (mg/l)	0.39	0.55	0.3	1.83	1.3
E. coli (counts/100 ml)	58,000	200,000	100	2,000	580
Coliform (counts/100 ml)	130,000	200,000	5,000	40	26

Table 27. Prospective Risk Assessment of Water Quality in Klang River at Petaling.

Agent	MEC_{Ave}	MEC_{Max}	PNECs	RQ_{Max}	RQ_{Ave}
DO (mg/l)	2.43	4.44	5.0–7.0	1.1 (best-case)	2.1
BOD (mg/l)	10.00	16	3	5.33	3.33
COD (mg/l)	48.00	119	25	4.76	1.92
SS (mg/l)	49	1,390	50	27.8	0.98
pH	7.23	7.52	6.5–9.0	< 1	< 1
NH_3-N (mg/l)	6.75	9.79	0.3	32.6	22.5
Turbidity (NTU)	42.5	1,620.2	50	32.4	0.85
NO_3 (mg/l)	0.14	0.39	7	0.06	0.02
P (mg/l)	0.52	1.05	0.2	5.25	2.6
As (mg/l)	0.031	0.93	0.05	18.6	0.62
Hg (mg/l)	0.0002	0.0002	0.001	0.2	0.2
Cd (mg/l)	0.001	0.001	0.01	0.1	0.1
Cr (mg/l)	0.001	0.01	0.05	0.2	0.02
Pb (mg/l)	0.01	0.01	0.05	0.2	0.2
Zn (mg/l)	0.03	0.04	5	0.008	0.006
Fe (mg/l)	0.59	0.9	0.3	3	1.97
E. coli (counts/100 ml)	200,000	200,000	100	2,000	2,000
Coliform (counts/100 ml)	200,000	200,000	5,000	40	40

Table 28. Prospective Risk Assessment of Water Quality in Klang River at Pelabuhan Klang.

Agent	MEC_{Ave}	MEC_{Max}	PNECs	RQ_{Max}	RQ_{Ave}
DO (mg/l)	2.97	4.3	5.0–7.0	1.2 (best-case)	1.7
BOD (mg/l)	3.00	7	3	2.33	1
COD (mg/l)	43.00	93	25	3.72	1.72
SS (mg/l)	128	226 50	4.52	2.56	
pH	7.36	8.06	6.5–9.0	< 1	< 1
NH_3-N (mg/l)	2.84	4.41	0.3	9.5	1.47
Turbidity (NTU)	56	153.2	50	3.06	1.12
NO_3 (mg/l)	0.01	0.11	7	0.02	0.0014
P (mg/l)	0.03	1.03	0.3	3.43	0.1
As (mg/l)	0.007	0.28	0.05	0.56	0.14
Hg (mg/l)	0.0002	0.0002	0.001	0.2	0.2
Cd (mg/l)	0.001	0.001	0.01	0.1	0.1
Cr (mg/l)	0.001	0.01	0.05	0.02	0.02
Pb (mg/l)	0.01	0.01	0.05	0.2	0.2
Zn (mg/l)	0.03	0.09	5	0.018	0.006
Fe (mg/l)	0.02	10.2	0.3	34	0.067
E. coli (counts/100 ml)	30,000	200,000	100	2,000	300
Coliform (counts/100 ml)	5,000	200,000	5,000	40	1

Table 29. Prospective Risk Assessment of Water Quality in Langat River at Batu 18.

Agent	MEC_{Ave}	MEC_{Max}	PNECs	RQ_{Max}	RQ_{Ave}
DO (mg/l)	7.60	7.96	5.0–7.0	0.63 (best-case)	0.66
BOD (mg/l)	1.00	2	3	0.67	0.3
COD (mg/l)	17.00	22	25	0.88	0.68
SS (mg/l)	13	92	50	1.84	0.26
pH	7.05	7.49	6.5–9.0	< 1	< 1
NH_3-N (mg/l)	0.02	0.14	0.3	0.47	0.07
Turbidity (NTU)	7.4	14.2	50	0.28	0.148
NO_3 (mg/l)	0.35	0.42	7	0.06	0.05
P (mg/l)	0.01	0.01	0.2	0.05	0.05
As (mg/l)	0.002	0.002	0.05	0.04	0.04
Hg (mg/l)	0.0002	0.0002	0.001	0.2	0.2
Cd (mg/l)	0.01	0.01	0.01	1	1
Cr (mg/l)	0.001	0.001	0.05	0.02	0.02
Pb (mg/l)	0.01	0.01	0.05	0.2	0.2
Zn (mg/l)	0.02	0.02	5	0.004	0.004
Fe (mg/l)	0.25	1.2	0.3	4	0.83
E. coli (counts/100 ml)	4,000	21,000	100	210	40
Coliform (counts/100 ml)	16,000	200,000	5,000	40	3.2

Table 30. Prospective Risk Assessment of Water Quality in Langat River at Kajang.

Agent	MEC_{Ave}	MEC_{Max}	PNECs	RQ_{Max}	RQ_{Ave}
DO (mg/l)	4.05	5.74	5.0–7.0	0.9 (best-case)	1.2
BOD (mg/l)	8.50	17	3	5.67	2.83
COD (mg/l)	35.50	62	25	2.48	1.42
SS (mg/l)	321.5	496	50	9.92	6.43
pH	6.89	7.11	6.5–9.0	< 1	< 1
NH_3-N (mg/l)	0.92	1.73	0.3	5.77	3.07
Turbidity (NTU)	218.75	853	50	17.06	4.375
NO_3 (mg/l)	0.64	0.77	7	0.11	0.091
As (mg/l)	0.006	0.008	0.05	0.16	0.12
Hg (mg/l)	0.0002	0.0002	0.001	0.2	0.2
Cd (mg/l)	0.001	0.001	0.01	0.1	0.1
Cr (mg/l)	0.001	0.001	0.05	0.02	0.02
Pb (mg/l)	0.01	0.01	0.05	0.2	0.2
Zn (mg/l)	0.035	0.05	5	0.01	0.007
Fe (mg/l)	0.49	1.19	0.3	3.96	1.63
E. coli (counts/100 ml)	68,000	113,000	100	1,130	680
Coliform (counts/100 ml)	91,500	200,000	5,000	40	18.3

Table 31. Prospective Risk Assessment of Water Quality in Klang River at Kg. Air Tawar.

Agent	MEC_{Ave}	MEC_{Max}	PNECs	RQ_{Max}	RQ_{Ave}
DO (mg/l)	2.21	2.26	5.0–7.0	2.2 (best-case)	2.3
BOD (mg/l)	2.00	14	3	4.67	0.67
COD (mg/l)	38.00	59	25	2.36	1.52
SS (mg/l)	266.5	1,150	50	23	5.33
pH	6.54	6.89	6.5–9.0	< 1	< 1
NH_3-N (mg/l)	0.42	0.91	0.3	3.03	1.4
Turbidity (NTU)	150.2	2,544	50	50.88	3.004
NO_3 (mg/l)	0.18	0.36	7	0.05	0.026
P (mg/l)	0.01	0.01	0.2	0.05	0.05
As (mg/l)	0.001	0.001	0.05	0.02	0.02
Hg (mg/l)	0.0002	0.0002	0.001	0.2	0.2
Cd (mg/l)	0.001	0.001	0.01	0.1	0.1
Cr (mg/l)	0.001	0.15	0.05	3	0.02
Pb (mg/l)	0.01	0.01	0.05	0.2	0.2
Zn (mg/l)	0.035	0.09	5	0.018	0.007
Fe (mg/l)	0.02	0.7	0.3	2.33	0.067
E. coli (counts/100 ml)	400	1,100	100	11	4
Coliform (counts/100 ml)	2,350	4,800	5,000	0.96	0.47

examined. For Cd, the RQ exceeding 1 in the catchment area of Langat River needs further verification. For Fe, however, RQ_{Ave} exceeded 1 in three out of six stations surveyed including the catchment area of Klang River while RQ_{Max} exceeded 1 in all six stations, indicating cause for concern particularly for the Klang River.

Risk from Sedimentation and Siltation of Rivers

Except for the catchment stations, both Klang and Langat rivers showed risk from sedimentation and siltation problems. This is demonstrated by high RQ values (> 1) for the SS and turbidity parameters, which indicate risk on the flora and fauna in these aquatic habitats. Particularly affected are the sensitive species such as those that carry out photosynthetic activities, e.g., plankton.

Risk from Pathogen Contamination

The RQs for *E. coli* and total coliform bacteria showed serious cause for concern for the level of these pathogens in all river stations including the catchment areas. The RQ values computed were enormously high and imply severe contamination.

In the catchment areas where water is used for drinking, such risk must be carefully evaluated.

Conclusions

The priority concerns identified in the risk assessment of Klang and Langat Rivers are consistent with the priority concerns for selected coastal areas, showing the strong influence of the two rivers on the water quality of these coastal areas. Assessment of risk from oil and grease in river waters was, however, not carried out due to lack of data.

RISK ASSESSMENT OF AMBIENT AIR

Malaysian urban and industrial areas are increasingly affected by air pollution to a considerable extent. This is due primarily to automobiles, industrial activities, domestic combustion and thermal power plant operations (DOE, 1998). A large portion of the population may be exposed to hazards in the atmosphere due to the location of housing areas near industrial parks. The large number of automobiles adds to the amount of suspended particulates and gaseous pollutants. Stationary and non-stationary emissions, if not properly managed and controlled, may cause serious air pollution episodes like haze and smog phenomena, acid rain, greenhouse effect, and transboundary pollution, and can affect public health and intensify public complaints (Hashim, 2000).

There are a number of air pollutants in ambient air but only some parameters were considered for the assessment, in particular the major air pollutants which are also used to determine the Malaysian Air Pollution Index (API), and these include suspended particulate matter having a diameter smaller than 10 micrometer (PM_{10}), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO) and ozone (O_3) (DOE, 1989).

Data for the assessment of air quality were taken from the database of Alam Sekitar Malaysia Sdn. Bhd. station located at Sekolah Menengah Perempuan Raja Zarina, Klang. The MEC of each parameter is an average data collected from December 1996 to March 2000. The PNEC values are based on air quality standards recommended by the DOE of Malaysia.

The results of the initial risk assessment (Table 32) show that except for CO, all worst-case RQs exceeded 1 although all parameters gave RQ_{Ave} values that were less than 1. RQ_{Ave} for PM_{10}

recorded the highest value among the parameters selected (0.52). The average API was shown to have exceeded the limit and PM_{10}, which exhibited the highest potential to pose risk to the ecosystem of Klang, may have contributed significantly to the high API.

A more detailed evaluation of data is needed to determine the temporal variability of risk from various contaminants in ambient air.

However, during the haze phenomenon which affected the South East Asian region in 1997 (Table 33), the RQ_{Ave} for PM_{10} exceeded 1 while the RQ_{Max} for O_3 also exceeded 1. RQ_{Ave} for other gases during this period were still below 1. The main factor for the high concentration of suspended particulate matter in ambient air during the haze episode was forest fire although soil dust, motor vehicles and industrial processes from local areas aggravated the situation.

Table 32. Prospective Risk Assessment of Air Quality.

Agent	MEC_{Ave}	MEC_{Min}	MEC_{Max}	PNEC	RQ_{Max}	RQ_{Min}	RQ_{Ave}
PM_{10} (µg/m^3)	77.81	8	858	150	5.72	0.05	0.52
NO_2 (ppm)	0.02	0	0.2	0.17	1.18	0	0.1
SO_2 (ppm)	0.01	0	0.13	0.13	1	0	0.1
CO (ppm)	1.32	0	12.07	30	0.4	0	0.04
O_3 (ppm)	0.02	0	0.17	0.1	1.71	0	0.16
API	54.11	4	291	50	5.82	0.08	1.08

PNECs: Used Interim Standards for Air Quality in Malaysia, Class 1.

Table 33. Prospective Risk Assessment of Air Quality During the Haze Phenomenon in September 1997.

Agent	MEC_{Ave}	MEC_{Min}	MEC_{Max}	PNEC	RQ_{Max}	RQ_{Min}	RQ_{Ave}
PM_{10} (µg/m^3)	214	27	624	150	4.16	0.18	1.43
NO_2 (ppm)	0.022	0	0.069	0.17	0.40	0	0.1
SO_2 (ppm)	0.018	0	0.077	0.13	0.59	0	0.1
CO (ppm)	2.04	0.12	6.3	30	0.21	0.004	0.07
O_3 (pm)	0.03	0	0.11	0.1	1.1	0	0.3

PNECs: Used Interim Standards for Air Quality in Malaysia, Class 1.

Comparative Risk and Uncertainty Assessment

Introduction

Comparative risk assessment for the range of agents considered to be of potential concern in the Klang project area have been carried out separately for the water column in the coastal areas and rivers as well as in sediment and ambient air. The results of these analyses are summarized in Tables 34–43. An initial indication of uncertainty in the risk assessment is provided by comparing differences between average and worst case (i.e., MEC_{Max}) conditions. In addition, the comparative risk assessment highlights data gaps, considering the lack of MECs and criteria (local standards).

For all targets, average and maximum MECs for the range of agents are shown (lower and higher ends of horizontal bars). MEC_{Ave} were calculated as geometric mean since data of this nature most often follow a log-normal distribution, and in such cases geometric mean will provide a less biased measure of the average than the arithmetic mean.

Risks to the Ecology of Port Klang from Water-Borne Substances in Coastal Areas

Table 34 presents the summary of RQs for water column parameters for the five coastal stations evaluated in the prospective risk assessment. Table 35 presents the comparative information on risks in the five coastal stations in the form of horizontal bars representing the average and maximum RQs.

The comparative RA table easily shows a trend in risk factors for all sites assessed, highlighting *E. coli*, oil and grease, SS, turbidity and DO as priority concerns and heavy metals as low concerns (RQ_{Max} < 1). Relative degrees of risk among sites are also shown. Almost comparable risk was shown for SS for the five areas, with the

Table 34. Summary of RQs for the Prospective Risk Assessment of Water Quality in Coastal Areas.

Agent	Pantai Morib		Kuala Langat at Jugra		Kuala Klang		Kuala Langat		Selat Klang Utara	
	RQ_{Max}	RQ_{Ave}	RQ_{Max}	RQ_{Ave}	RQ_{Max}	RQ_{Ave}	RQ_{Max}	RQ_{Ave}	RQ_{Max}	RQ_{Ave}
DO		0.85		0.8		1.25		1.09		0.96
SS	4.8	3.98	2.16	1.46	4.6	2.17	6.96	3.85	4.68	3.15
Turbidity	2.73	1.5	2.73	0.43	0.6	0.3	8	2.69	5	1.88
pH		< 1		< 1		< 1		< 1		< 1
As	0.14	0.1	0.14	0.12	0.22	0.12	< 0.02	< 0.02	0.06	0.04
Hg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Cd	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Cr	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Cu	0.38	0.25	0.5	0.38	< 0.12	< 0.12	< 0.12	< 0.12	< 0.12	< 0.12
Pb	< 0.1	< 0.1	< 0.1	< 0.1	< 0.01	< 0.01	< 0.12	< 0.12	< 0.12	< 0.12
E. coli	24	15.32	5.42	1.8	34.28	23.26	34.8	8.86	5.42	4.17
Oil and Grease	8	2.17	6	5.5	2	1.5	2	1.6	6	3

highest RQs found in the Kuala Langat coastal area. For *E. coli*, the piority areas are Kuala Klang and Pantai Morib ($RQ_{Ave} > 10$) followed by Langat. The lowest RQs for *E. coli* were found at Jugra, an important aquaculture area, although RQ_{Ave} still exceeded 1. The highest RQ_{Ave} for oil and grease was, however, found at Jugra followed by Selat Klang Utara and Pantai Morib while the lowest RQs (although still > 1) for oil and grease came from Kuala Klang and Kuala Langat. There were no measurements for nutrients and pesticides so these were not assessed.

RISKS TO THE ECOLOGY OF PORT KLANG FROM WATER-BORNE SUBSTANCES IN KLANG RIVER

Table 36 shows the summary of RQs for the three stations along the Klang River while Table 37 illustrates comparative information. The comparative table shows that RQ_{Max} were less than 1, indicating acceptable risk, in all sites assessed for all the heavy metals except Fe and As, and NO_3 and pH. General cause for concern (RQ_{Ave} > 1) at the middle stretch (Klang River at Petaling) and estuarine areas (Klang River at Pelabuhan

Table 35. Comparative Risk Assessment of Water-Borne Substances in Coastal Areas.

RQ	< 1	1 – 10	1 – 100	100 – 1,000	> 1,000
DO					
SS					
pH					
Turbidity					
As*					
Hg					
Cd*					
Cr*					
Cu*					
Pb*					
E. Coli					
O il and Grease					

Legend:

Pantai Morib

Kuala Langat at Jugra

Kuala Klang

Kuala Langat

Selat Klang Utara

* *Single bar for all sampling sites*

Klang) are shown for organics as indicated by DO, BOD and COD; and sedimentation and siltation as indicated by SS and turbidity. High cause for concern ($RQ_{Ave} > 1$) is shown for coliforms especially fecal coliform at all sites including the catchment area (Klang River at Ulu), signifying the need for immediate management interventions starting from the catchment area. Cause for concern was also shown for the nutrient NH_3 and metal Fe at the middle stretch and estuarine areas and for the nutrient P and metal As at the middle stretch of Klang River. There was no data on oil and grease so this was not assessed.

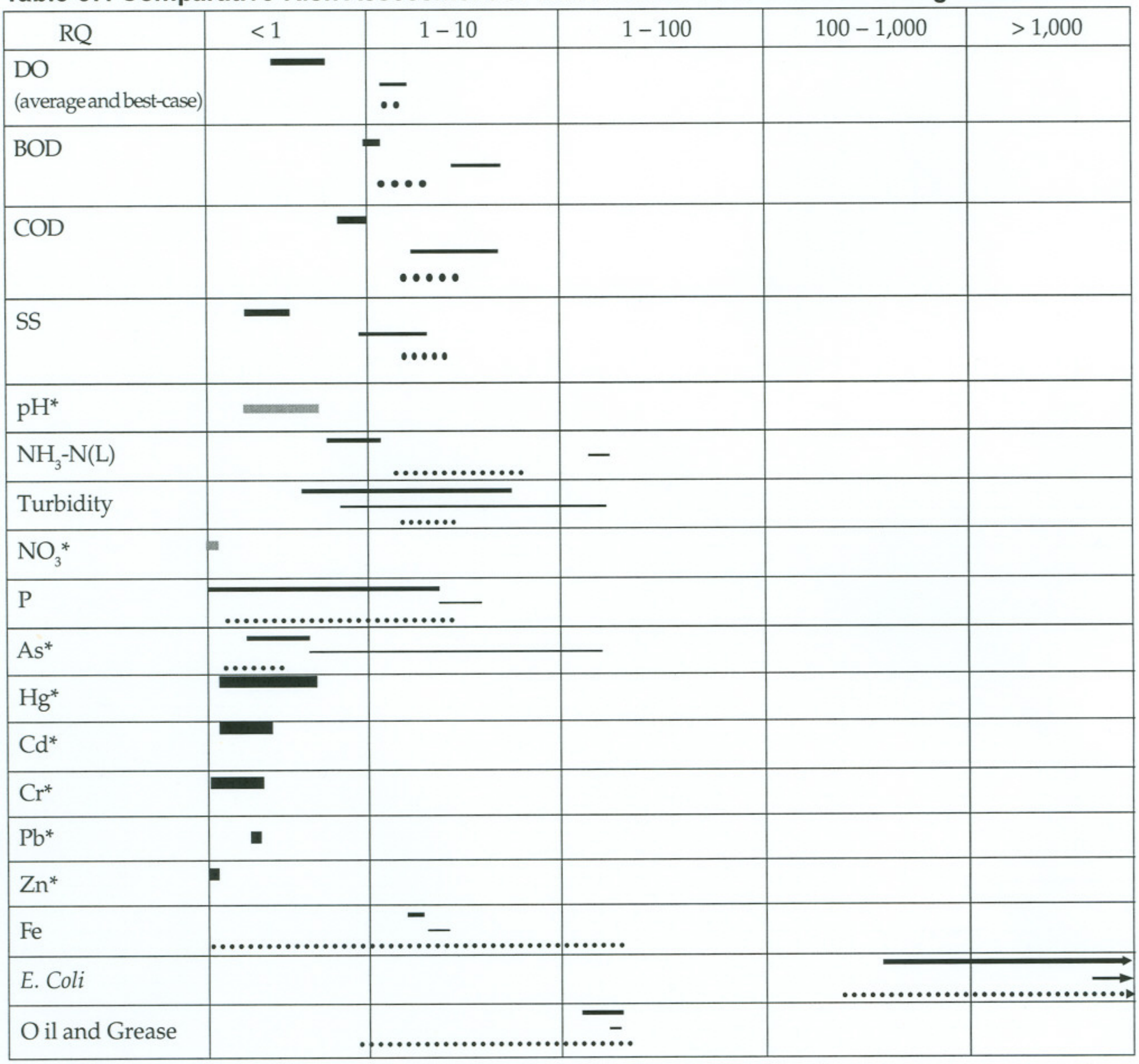
RISKS TO THE ECOLOGY OF PORT KLANG FROM WATER-BORNE SUBSTANCES IN LANGAT RIVER

Similar to Klang River, a general cause for concern ($RQ_{Ave} > 1$) was also shown (Tables 38–39) at the middle stretch (Langat River at Kajang) and estuarine areas (Langat River at Kg. Air Tawar) in Langat River for organics (indicated by BOD, COD and DO); sedimentation/siltation (indicated by SS and turbidity); and NH_3, indicating anoxic (oxygen-deficient) conditions and confirming the risk from high organic load. Corresponding RQs for these parameters at the

Table 36. Summary of RQs for the Prospective Risk Assessment of Water Quality in Klang River.

Agent	Ulu Klang		Petaling		Pelubuhan Klang	
	RQ_{Max}	RQ_{Ave}	RQ_{Max}	RQ_{Ave}	RQ_{Max}	RQ_{Ave}
DO	(best-case)		(best-case)		(best-case)	
BOD	1.33	1	5.33	3.33	2.33	1
COD	1.04	0.88	4.76	1.92	3.72	1.72
NH_3-N	1.43	0.8	32.6	22.5	9.5	1.47
NO_3	0.05	0.04	0.06	0.02	0.02	0.0014
P	2.5	0.05	5.25	2.6	3.43	0.1
SS	0.68	0.36	27.8	0.98	4.52	2.56
Turbidity	7.8	0.54	32.4	0.85	3.06	1.12
pH	< 1	< 1	< 1	< 1	< 1	< 1
As	0.64	0.22	18.6	0.62	0.56	0.14
Hg	0.5	0.2	0.2	0.2	0.2	0.2
Cd	0.3	0.1	0.1	0.1	0.1	0.1
Cr	0.18	0.02	0.2	0.02	0.02	0.02
Pb	0.2	0.2	0.2	0.2	0.2	0.2
Zn	0.008	0.004	0.008	0.006	0.018	0.006
Fe	1.83	1.3	3	1.97	34	0.067
E. Coli	2,000	580	2,000	2,000	2,000	300
T. Coliform	40	26	40	40	40	1

Table 37. Comparative Risk Assessment of Water-Borne Substances in Klang River.



Legend:

* ▬ *Single bar shows range of RQs for three sites (approximated for pH: RQs<1)*

— *Range of RQs for Klang River at Ulu*

— *Range of RQs for Klang River at Petaling*

····· *Range of RQs for Klang River at Pelabuhan Klang* catchment areas (Langat River at Batu 18) were all less than 1 except for sedimentation (RQ_{Max} > 1). However, for coliform, higher cause for concern was shown for the catchment area than the estuarine area, indicating the need to manage coliform levels starting from the watershed area. Low cause for concern (RQ_{Max} < 1) is shown for the nutrients P and NO_3 and almost all heavy metals except Fe.

Between Klang and Langat Rivers, slightly higher RQs for sedimentation were obtained for Langat River, but much higher RQs were obtained for *E. coli* in the Klang River.

RISKS TO THE ECOLOGY OF KLANG FROM SEDIMENT-BORNE SUBSTANCES

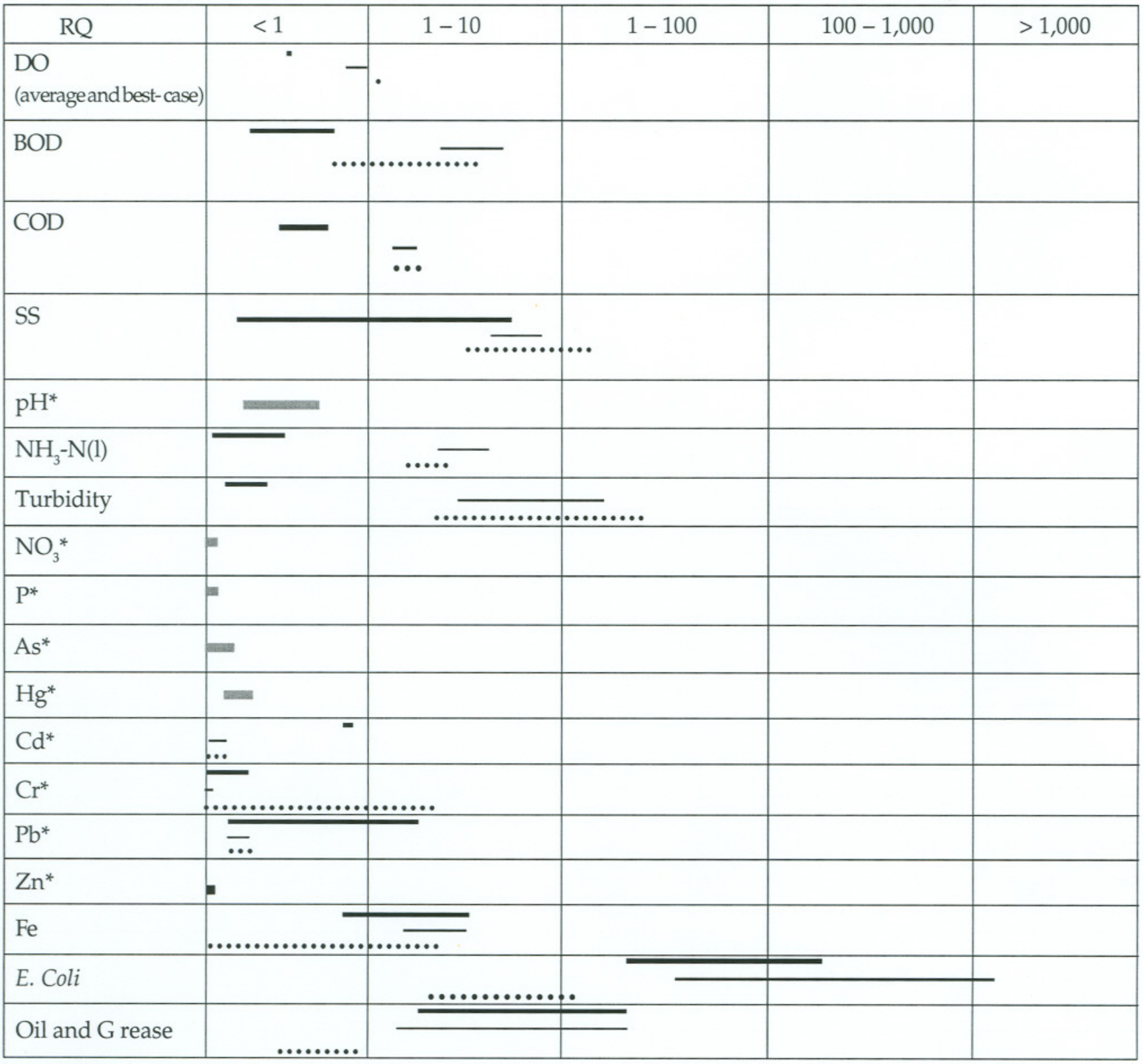
Only data on oil and grease and total PAHs were available for the sediment compartment. The RQ_{Ave} derived from available data (Table 40) show cause for concern for the levels of oil and grease in Port Klang and Morib and PAHs in the Klang Estuary and Kuala Langat, as shown clearly in Table 41.

PAHs indicate the concentration of crude oils and oil products in the aquatic environment, including PAHs that arise from combustion and

Table 38. Summary of RQs for the Prospective Risk Assessment of Water Quality in Klang River.

Agent	Batu 18		Kajang		Kg. Air Tawar	
	RQ_{Max}	RQ_{Ave}	RQ_{Max}	RQ_{Ave}	RQ_{Max}	RQ_{Ave}
DO	0.63 (best-case)	0.66	0.9 (best-case)	1.2	2.2 (best-case)	2.3
BOD	0.67	0.3	5.67	2.83	4.67	0.67
COD	0.88	0.68	2.48	1.42	2.36	1.52
NH_3-N	0.47	0.07	5.77	3.07	3.03	1.4
NO_3	0.06	0.05	0.11	0.091	0.05	0.026
P	0.05	0.05			0.05	0.05
SS	1.84	0.26	9.92	6.43	23	5.33
Turbidity	0.28	0.148	17.06	4.375	50.88	3.004
pH	<1	<1	<1	<1	<1	<1
As	0.04	0.04	0.16	0.12	0.02	0.02
Hg	0.2	0.2	0.2	0.2	0.2	0.2
Cd	1	1	0.1	0.1	0.1	0.1
Cr	0.02	0.02	0.2	0.02	0.02	0.02
Pb	0.2	0.2	0.2	0.2	0.2	0.2
Zn	0.004	0.004	0.01	0.007	0.018	0.007
Fe	4	0.83	3.96	1.63	2.33	0.067
E. Coli	210	40	1130	680	11	4
T. Coliform	40	3.2	40	18.3	0.96	0.47

Table 39. Comparative Risk Assessment for Water-Borne Substances in Langat River.



Legend:

Single bar shows range of RQs for three sites (approximated for pH; RQ<1)

Range of RQs for Langat River at Batu 18

Range of RQs for Langat River at Kajang

Range of RQs for Langat River at Kg. Air Tawar incomplete oil combustion processes such as in internal combustion engines and industrial processes. Aromatic hydrocarbons are of concern since these are highly toxic and PAHs in particular are known to be carcinogenic.

The results therefore show that oil and related substances may be posing direct risk to the benthic and related ecosystem of Klang. However, due to the limited data employed, a more comprehensive risk assessment should be conducted as soon as new data/information becomes available. Data on other potential contaminants in the sediments such as heavy metals, pesticides and organotins should also be included in future assessments.

Table 40. Summary of RQs for the Prospective Risk Assessment of Sediment-Borne Substances in the Klang Langat Coastal Zone.

Agent	MEC_{Min}	MEC_{Max}	MEC_{Ave}	PNECs	RQ_{Min}	RQ_{Max}	RQ_{Ave}
Total PAHs (ng/g)							
Klang Estuary	19	431	233.4	200	0.095	2.155	1.167
Klang Coast	9	39	24	200	0.045	0.195	0.12
Kuala Langat	55	615	232	200	0.275	3.075	1.16
Oil and Grease (µg/g dry wt.)							
Port Klang	83	704		3	234.7	27.7	
Morib	5.6	26		3	8.7	1.9	

Table 41. Comparative Risk Assessment for Sediment.

RQ	< 1	1 – 10	10 – 100	100 – 1,000	> 1,000
Total PAHs (ng/g)					
Klang Estuary					
Klang Coast	-				
Kuala Langat					
Oil and Grease (µg/g dry wt.)					
Port Klang					
Morib					

RISKS FOR AIR QUALITY

RQ_{Ave} were less than 1 for all parameters while maximum RQs exceeded 1 for all parameters except for CO, indicating cause for concern in some specific areas (Tables 42–43). The mean API, however, still exceeded 1, signifying other important contributors to the API in addition to the agents assessed in this report. The RQ_{Ave} for PM_{10} exceeded 1 during the haze episode in the 1997. Future assessments should identify specific areas or periods for which RQs exceeded 1.

Table 42. Prospective Risk Assessment of Air Quality.

Agent	MEC_{Ave}	MEC_{Min}	MEC_{Max}	PNECs	RQ_{Max}	RQ_{Min}	RQ_{Ave}
Data from 1996–2000							
PM_{10}	77.81	8	858	150	5.72	0.05	0.52
NO_2	0.02	0	0.2	0.17	1.18	0	0.1
SO_2	0.01	0	0.13	0.13	1	0	0.1
CO	1.32	0	12.07	30	0.4	0	0.04
O_3	0.02	0	0.17	0.1	1.71	0	0.16
API	54.11	4	291	50	5.82	0.08	1.08
Data During the Haze Phenomenon in 1997							
PM_{10}	214	27	624	150	4.16	0.18	1.43
NO_2	0.022	0	0.069	0.17	0.40	0	0.1
SO_2	0.018	0	0.077	0.13	0.59	0	0.1
CO	2.04	0.12	6.3	30	0.21	0.004	0.07
O_3	0.03	0	0.11	0.1	1.1	0	0.3

Table 43. Comparative Risk Assessment for Air Quality.

RQ	< 1	1 – 10	10 – 100	100 – 1,000	> 1,000
Agent					
PM_{10}					
NO_2					
SO_2					
CO					
O_3					
API					

RQs during the haze phenomenon in 1997.

Assessment of Socioeconomic Drivers

Introduction

Four sectors were selected for risk assessment of socioeconomic factors/drivers, namely land-use change, demography, agriculture and waste management. These sectors are the key factors that influence the development process in Klang and Kuala Langat. Assessing the risks posed by these factors to the existing ecosystem is crucial to determine the level of impact or effect of each sector on the environment and how these adverse impacts can be addressed.

Land-use Change

The development process in Klang has undergone rapid growth. Historically, Klang has been the center of economic activities since the 17th century. Port Klang, previously named Port Swettanham, is the major port for Peninsular Malaysia. Land-use changes involved development of more urban and industrial areas. In 2000, 54.98 percent of land area were agricultural lands while 7.2 percent and 3.5 percent were urban and industrial areas, respectively. The district of Kuala Langat is also taking advantage of the development in Klang, although land-use changes in Kuala Langat were rather slower in rate compared with Klang district. Kuala Langat is still dominated by agriculture land covering 55.3 percent of total area, while urban area and industry cover 1.1 percent and 0.99 percent respectively. Forest cover in Kuala Langat has, however, decreased from 3,954.14 ha to 2,383 ha from 1992 to 2000 (Table 44).

The rapid economic growth in both districts was driven by the development policy and strategy of the state and local government. Well-built infrastructure and utilities also sped up the development. Availability of ports, highways, rail tracks, business and finance center, power plant and labor attracted investors to Klang and Kuala Langat. This is in line with the State Government of Selangor and local government development plans, which aim to achieve for Selangor the status of a developed state in 2005.

Rapid changes of land use have, however, affected the functions of the ecosystem, especially the conversion of mangroves and peat swamp forests for other uses. There are cases of peat swamp fires caused by illegal farmers who practice the slash and burn

Table 44. Land-use Changes in Klang and Kuala Langat.

Area (hectares)	District (1992)		District (2000)	
	Klang	Kuala Langat	Klang	Kuala Langat
Agriculture	ND	72, 293.9	34, 457.53	48, 465.14
Urban	ND	450.4	4, 516.70	980.5
Industry	ND	212.8	2, 184.41	869.68
Mines	ND	1, 649.9	0	335.25
Forest	ND	3, 954.19	10, 608.00	2, 383.0
Others	ND	9,142.81	10, 911.36	33, 099.24
Total	62, 678.00	87, 704.00	62, 678.00	87, 704.00

Source: Klang Municipal Council, 2000; Kuala Langat District Council, 1994; Kuala Langat District Council, 2000.

method for cash crops. Other development and economic activities have also created ecological stress for the coastal ecosystem. Shrinkage of mangroves and peat swamps reduce the function and services that they provide, which are important to animals and humans. Habitat loss and degradation, loss of shoreline protection, increase in sedimentation rates, and reduced biodiversity are among the adverse impacts arising from changes in land use and these have been identified as among the issues of concern in the ICM area.

DEMOGRAPHY

The fast economic growth through industrialization in Klang and Kuala Langat has created jobs and business opportunities and has attracted more people, leading to an increase in local population. With well-equipped infrastructure such as highways, better roads, rail tracks, public transport, wide coverage of utilities for the public, businesses and various institutions, Klang and Kuala Langat have become attractive for migration of people as well as investors from other districts, states and countries.

The population in Klang is three times larger than in Kuala Langat (Table 45). The population growth rate in Klang was 4.6 percent from 1991 to 2000 while it was 3.8 percent in Kuala Langat during the same period. The population density in Klang is also higher at 1,035 persons/km^2 compared to Kuala Langat's density of 216 persons/km^2.

High population density, which translates to more energy and resource requirements to cater to the needs of the population, has created stress to the Klang ecosystem. It is also estimated that more infrastructure, energy and resources will be needed as the population of Klang continues to increase at the current rate. It is expected that in the year 2005, Klang population will increase to 816,705 people, which will then increase the population density to 1,303 persons/km^2. On the other hand, the Kuala Langat population growth rate, which is higher than the national growth rate of 2.8 percent per year, will still have a lesser population number than Klang. By 2005, Kuala Langat population is estimated to increase to 229,636 people with a density of 261 persons/km^2.

AGRICULTURE

Economic activities in Klang and Kuala Langat in the 1960s and 1970s were focused more on agriculture. Agriculture activities were divided to five types of crops namely plantation, cash crops, fruits, vegetables and herbs. Palm oil dominated, compared to rubber, in plantation crops. Agriculture development was driven by government policies, where under the five-year Malaysian Plan (MP) for 1971–1975 (MP2) and 1976–1980 (MP3), more land was developed for agriculture. These plans came with strategies to enhance capability of farmers to produce more and better crops.

Under MP8 (2001– 2005), land for agriculture will be reduced, and focus will be on technology

Table 45. Population of Klang and Kuala Langat.

District	1991	2000
Klang	406,900	648,900
Kuala Langat	130,100	189,900

Source: Universiti Teknologi MARA, 2000.

to use less land for higher yields. As a result of this policy, agriculture areas in Klang have decreased from 20,941 ha to 6,668.5 ha while Kuala Langat has maintained its agriculture areas at 67,689 ha.

The problems in agriculture activities, however, is not the capabilities in increasing crops yield But the ecological stress brought by the agricultural activities through the use of pesticides and fertilizers as well as generation of wastes from processing. Another threat is illegal clearing of land and forest, which leads to forest fire. There were cases where peat swamp forests in Kuala Langat were cleared illegally and farmers who used slash and burn technique inadvertently set up forest fires which also led to air pollution.

Agricultural activities, especially those that involve clearing of forest areas also contribute to habitat loss and degradation, reduced biodiversity, and sedimentation and siltation in water bodies.

WASTE MANAGEMENT

The rapid development in Klang and Kuala Langat has increased its population. Industrialization and expansion of urban areas have created more wastes. The wastes generated in Klang and Kuala Langat can be categorized as domestic, market, commercial, industrial, construction, institutional, landscaping and street wastes. With a population of 648,900 people in Klang and 189,900 in Kuala Langat and with the variety of industrial and agriculture activities, waste generation in 2001 in Klang was 472.36 tons/ day while it in Kuala Langat it was 119.1 tons/ day. Waste generation in Klang and Kuala Langat have increased significantly, from 360 tons/day in 1994 in Klang and 90 tons/day in Kuala Langat to the amounts given for 2001. Landfill availability is one of the main problems in waste management.

Klang and Kuala Langat are experiencing problems in determining areas for a new landfill. Landfill areas in Klang have decreased from 5.2 ha to 3.66 ha while in Kuala Langat the decrease was from 6.1 ha to 4.1 ha. It is expected that waste generation will increase by 4 percent per year.

For 2005, the rate of waste generation is estimated to increase to 576.9 tons/day in Klang and 145.5 tons/day in Kuala Langat. The state and local governments, therefore, have to determine strategies and plans to reduce waste generation. An efficient waste management system which focuses on waste recycling, reduction and reuse might be able to reduce the rate of waste generation.

In addition to solid wastes, management of organic and inorganic liquid wastes from land-based (i.e., domestic, commercial, industrial, institutional and agricultural) and sea-based

Table 46. Areas of Crops in Klang and Kuala Langat.

Crops (hectares)	1998		2000	
	Klang	Kuala Langat	Klang	Kuala Langat
Plantation	20,941	67,689	6,668.5	67,689
Cash Crops	50.4	293.2	45.8	314
Fruits Orchards	683.3	2,221.4	683.2	2,150.9
Vegetables Farms	28.3	111.5	30.3	145.7
Herbs Crops	18.2	71.5	18.2	87.6

Source: Department of Agriculture–Selangor, 2000.

activities should also be given attention as indicated by the results of the prospective risk assessment.

HUMAN HEALTH

A retrospective assessment of common health problems using information from the Ministry of Health showed that food and water-borne diseases are the most common health problems faced by many countries especially developing countries like Malaysia. The diseases include cholera, dysentery, food poisoning and typhoid infection. Incidence of these infections is still not well controlled, and cholera and food poisoning in particular still occur in the Klang ICM area. The illnesses have mostly been associated with poor hygienic practices during food preparation at food stalls, restaurants, hostels, and even at home. Food poisoning, however, may also be caused by contamination of food by chemicals (e.g., heavy metals and pesticides) and pathogens (e.g., coliforms) from production processes and from exposure in the natural environment. These factors, however, have not been thoroughly investigated, and the results of the prospective risk assessment show that aquatic food products are exposed to various contaminants, thus consumption potentially poses human health risks.

Conclusions, Data Gaps and Uncertainties

Retrospective Risk Assessment

For capture fisheries, conclusive evidence of adverse impacts as a result of environmental factors or fishing effort was not adequately established from the available information during the assessment. Based on available data, decline in fish landing from 164.43 metric tons to 57.55 metric tons was observed from 1990 to 1993, while from 1993 to 2000, fish landing records showed an increase from 57.55 to 141.37 to 1,579.34 metric tons. Using data on fish landing alone, it was not possible to explicitly relate the changes in fisheries yield to the level of fishing intensity, and to determine whether this yield is sustainable. Fish landings are also not really reflective of the status of fisheries in Port Klang coastal waters since fishes are caught from neighboring countries, particularly Indonesia. The results of the risk assessment show that data on other indicators of fisheries conditions such as CPUE will have to be gathered to enable more appropriate assessments to be carried out. Estimates of the MSY will also be important to determine if the fishing effort is within sustainable levels or if this may eventually lead to adverse impacts on local fisheries.

The areas utilized for aquaculture activities have increased from 1993 to 2000, with corresponding increase in fish and prawn production. This development, however, came at the expense of mangrove and peat swamp areas, which were converted to culture ponds. These mangroves and peat swamps are important for the survival and reproduction of numerous aquatic organisms and the loss and degradation of these areas resulting from aquaculture development may adversely affect their ecological functions. The risk assessment indicates the need to evaluate the impacts of existing aquaculture practices on the natural ecosystem, identify environment-friendly aquaculture practices, and balance the need to meet the increasing demand for marine food products and protect the natural environment.

Decline in mangrove cover was adequately established for the Kapar and Klang Island mangrove forest reserves (MFR), with 8 percent remaining in Kapar and 88 percent in Klang as of 1998. The identified primary cause of decline in mangrove cover in the forest reserves was the degazettement or removal from legal protection of certain portions of the forest reserves and subsequent land reclamation to accommodate developments in the vicinity of the Klang coastal area. The extensive loss of mangroves especially in the Kapar area certainly will have effects on the various ecological services and functions provided by the mangroves, with corresponding economic losses. A better understanding of the ecological and economic impacts of the decline of mangrove areas in the Klang District will be valuable in formulating future development plans that will integrate ecological as well as economic considerations.

The retrospective risk assessment on three major groups of wildlife namely mammals, birds and freshwater fish in the primary (dipterocarp), mangrove and peat swamp forests showed decline in these species due primarily to loss or degradation of habitats due to changes in land use for various socioeconomic activities and in some cases, pollution.

The data used in the assessment were, however, very few, not comprehensive and in some cases, not quantitative. The interrelatedness between the suspected agents and targets were also most of the time not clearly defined, and it was difficult to correlate between the agents and the resources within the specified habitats. More researches need to be undertaken to verify the reported decline in mammal, bird and fish species in the three forests. These researches should be more comprehensive and should allow sufficient time to detect changes in the number of species and population. Studies to determine exposure, correlation and cause-effect relationships between potentially significant agents should also be undertaken.

A retrospective assessment of common health problems also showed that food and water-borne diseases such as cholera and food poisoning still occur in the Klang ICM area. These illnesses have mostly been associated with poor hygienic practices during food preparation although contamination of food by chemicals (e.g., heavy metals and pesticides) and pathogens (e.g., coliforms) from production processes and from exposure in the natural environment may also be important factors. Thorough investigation of these factors, however, has not been carried out, while the results of the prospective risk assessment show that aquatic food products are exposed to various contaminants and consumption potentially poses human health risks.

PROSPECTIVE RISK ASSESSMENT

Risk Assessment of Coastal Areas and Rivers

The prospective risk assessment of selected coastal areas and the Klang and Langat Rivers showed consistent results with regard to priority concerns, showing the strong influence of the two rivers on the water quality of the coastal areas.

For coastal waters in selected areas near the Klang and Langat Rivers, human health risk arises from bathing in *E. coli*-contaminated waters and consumption of potentially contaminated aquaculture products. Higher cause for concern was found at Pantai Morib, a recreation area, and Kuala Klang. The lowest RQs for *E. coli* were found at Jugra, an important aquaculture zone, although these RQs still exceeded 1.

Ecologically, cause for concern was shown in all the coastal areas assessed for oil and grease and suspended solids. Greatest cause for concern for oil and grease was found at Jugra followed by Selat Klang Utara and Pantai Morib. There were no data on COD or BOD but the high utilization of DO could be deduced from the RQ_{Ave} values > 1 for DO at Kuala Klang and Kuala Langat while RQ_{Ave} for the other three sites were approaching 1. Acceptable risk was shown for other parameters such as heavy metals, while the concern for oil and grease was corroborated by the RQs exceeding 1 for sediment PAHs, which are among the various constituents of oil and grease and which are found in petroleum hydrocarbons.

For the Klang and Langat Rivers, human health risk from pathogen contamination was indicated by the enormously high RQs for coliforms especially *E. coli*. In the catchment areas where water is used for drinking, risk from *E. coli* must be carefully evaluated and immediately addressed. Ecologically, risk from organic contamination was indicated by the average RQs exceeding 1 for BOD, COD, DO and NH_3 especially for the middle stretch and estuary stations; and risk from sedimentation and siltation of rivers as indicated by RQ_{Ave} for suspended solids and turbidity for all except the catchment stations. No assessment was carried out for oil and grease in river waters.

The high levels of SS, *E. coli*, and oil and grease in coastal waters were attributed to various socioeconomic activities such as industrial, agricultural and domestic activities and changes in land use that lead to improper discharge of wastes and habitat loss/degradation in the areas surrounding the Klang and Langat Rivers.

Evaluation of temporal trends of risk for a coastal station close to Langat River showed RQs for DO, SS, turbidity, COD, oil and grease and NH_3 consistently exceeding 1, thus confirming the preceding results and strengthening the premise that Langat River is a significant contributor to contamination of coastal waters. Risk from the levels of organic matter was indicated by the RQs for COD and DO. No data on *E. coli* was evaluated.

Risk Assessment of Ambient Air

The extension of the RQ approach to the assessment of human health risk from major contaminants in ambient air such as suspended particulate matter (PM_{10}), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO) and ozone from December 1996–March 2000 showed that although the RQ_{Ave} for all parameters still indicate acceptable risk (all $RQ_{Ave} < 1$), there were instances when the contaminant levels presented cause for concern (except for CO, all RQ_{Max} exceeded 1). The average Malaysian API, which is computed using the major contaminants presented here, also exceeded the limit of 50 (API_{Max} = 291 and API_{Ave} = 54). PM_{10}, which exhibited the highest potential to pose risk to the ecosystem of Klang (RQ_{Max} = 5.72 and RQ_{Ave} = 0.52), may have contributed significantly to the high API.

Assessment of the contaminant levels during the haze phenomenon which affected the South East Asian region in 1997 showed that the RQ_{Ave} for PM_{10} and the RQ_{Max} for O_3 also exceeded 1 although RQ_{Ave} for other gases during this period were still below 1.

Factors that contribute to air pollution in Malaysia especially in urban and industrial areas include automobiles, industrial activities, domestic combustion and thermal power plant operation. Further economic development in the ICM area is expected to further enhance these factors and increase the level of air pollution. Location of housing areas near industrial parks may also expose the population to various atmospheric hazards. Proper management and control of stationary and non-stationary emissions need to be developed and implemented in order to mitigate air pollution, prevent associated events like haze and smog, acid rain, greenhouse effect and transboundary pollution, and protect public health.

LINK BETWEEN IDENTIFIED RISKS AND SOCIOECONOMIC DRIVERS

The retrospective risk assessment of key socioeconomic drivers related to the industrialization and urbanization in the ICM project area shows the linkage between these activities and the observed adverse environmental changes and resource and habitat degradation/ losses.

The rapid economic growth in both the Klang and Kuala Langat districts was driven by the development policy and strategy of the state and local government, which aimed to make Selangor a developed state by the year 2005. Well-built infrastructure and utilities sped up the development, and the availability of ports, highways, rail track, business and finance centre, power plant and labor attracted investors to Klang and Kuala Langat districts.

Land and resource requirements to support industrialization and urbanization have, however, resulted to rapid changes in land use including conversion of mangroves and peat swamp forests for other uses; increase in population due to migration; and increase in waste generation. Efforts to increase agricultural yields through the use of pesticides and fertilizers also presented ecological and human health risks. Illegal clearing of forests for farming is another damaging practice that has led to forest fires.

These changes have led to increase in energy and resource requirements and reduction/loss of the functions and services provided by the natural ecosystem. Further development and economic activities could bring additional stress to the coastal ecosystem unless better understanding is achieved regarding the interactions between development activities and the environment and management interventions that aim to balance these two aspects are put in place.

Data Gaps

Data that were not available when the risk assessment was undertaken, which could enhance future assessments, include:

1. More appropriate indicators to determine the status of capture fisheries with regard to sustainability of existing fishing practices and fishing effort such as CPUE, MSY estimates, changes in species composition and size, presence or absence of endemic species, etc.;

2. For aquaculture, data on production per unit area, which are more useful than production estimates in establishing changes in aquaculture productivity;

3. For the assessment of biodiversity, more comprehensive and quantitative information on flora and fauna, focusing systematically on key indicator species and their responses to various environmental factors;

4. Information showing the impacts of habitat loss and degradation and environmental pollution to living aquatic resources particularly the economically valuable species;

5. Data gaps in the prospective risk assessment such as nutrients in coastal water; oil and grease in river water; coliform in seafood tissue; heavy metals in sediment and biota; and pesticides and organotins in all media (water, sediment, biota);

6. Data on oil fractions from petrogenic and biogenic sources. Local standards for different components of total oil and grease are actually available (e.g., mineral oil; emulsifiable and edible oil) but the only available data are on total oil and grease. Identification of the oil fractions from petroleum and biological origins will allow a more precise assessment of risks from various oil components;

7. More suitable standards for marine water quality. The IMWQS for Malaysia is for limited parameters only and some values (e.g., heavy metals) are not very protective compared with standards from other jurisdictions;

8. More information to determine the linkages of some of the most common food and water-borne diseases to potential contamination of aquatic food products from pathogens and chemical compounds; and

9. More information that would specifically link particular socioeconomic activities to the identified priority environment concerns, to provide basis for the formulation of more specific management interventions.

Uncertainties

Uncertainties in the results of the retrospective and prospective risk assessments for certain parameters are associated primarily with the data gaps.

The RQ approach was also found unsuitable for dealing with risks posed by waste, poor sanitation and increased population (crowding). These are problems that require attention and better understanding, particularly with regard to the sources/causes, distribution and impacts.

In some instances, models may need to be developed to gain better understanding of the risks. This may include modeling shipping accidents, effluents flows, changes in ecosystem, and disease outbreaks. This model will help in identifying the type and level of risk, as well as, in developing emergency response procedures.

The initial risk assessment was based on worst-case and average scenarios. For some parameters, ecological components or socioeconomic sectors, it is very important to conduct the assessment in greater detail, which might need other perspectives of assessment. This will also enable the distinction between localized and coastal-wide conditions and corresponding risk assessment results.

Other possible sources of uncertainty in the results of the IRA are mostly associated with the quality, comparability and adequacy of the measured concentrations and the suitability of the threshold concentrations used. The PNECs used have been derived primarily from the national standards for water quality and air quality, and supplemented by criteria or standards from other areas in the region. Values derived from other countries, however, might not be suitable to Klang conditions. Even the suitability of some of the marine water quality standards for Malaysia needs to be evaluated.

Further quantification or clarification of the uncertainties associated with the risk assessment may be done through the application of quantitative uncertainty analyses using appropriate software packages (e.g., Monte Carlo simulation using the Crystal Ball software).

Recommendations and Proposed Actions

Results for both the retrospective and prospective risk assessments point to the need for the conduct of a refined risk assessment although some results already indicate the need for management interventions. Based on the results of the assessment, the following are recommended:

On Socioeconomic Drivers

Further assessment of the socioeconomic drivers assessed in this report and their linkages to the identified environmental concerns need to be undertaken to allow the development of suitable and cost-effective management plans. Assessment should be carried out on the following:

1. Waste: This will need to focus on waste generation, types, source of waste and implication to coastal ecosystems. The source of waste will be identified according to activity such as urban, industry, shipping, hospital and agriculture.

2. Industrial development: This will need to focus on determining the number, types and location of factories in Klang and Kuala Langat. Implications of industrial activities towards the coastal ecosystems will be determined.

3. Agriculture: Further evaluation will aim to determine the implications of agricultural activities on water and sediment quality of the coastal ecosystem in Klang and Kuala Langat as well as on the aquaculture products in the area. Main agriculture activities such as palm oil production, pig farms and aquaculture will be assessed in greater detail.

4. Land Use: The impacts of land conversion for other uses need to be evaluated with respect to the various ecological functions and services provided by the areas being converted (e.g., mangroves and peat swamps). Evaluation of the benefits to be derived from the land conversion and development activity and the costs incurred including the loss/decline in the ecological functions and services of the natural environment may aid in assessing the suitability of the selected land use and in the formulation and approval of future development plans that will require land conversion or reclamation.

On Human Health

It has been shown that food and water-borne illnesses particularly cholera and food poisoning still occur in the Klang ICM area. These illnesses have mostly been associated with poor hygienic practices during food preparation at food stalls, restaurants, hostels, and even at home, while linkages with contaminated aquatic food products and exposure to contaminated waters has not been adequately studied. Based on the results of the prospective risk assessment, aquatic food products are exposed to various contaminants and consumption potentially poses human health risks. It is recommended therefore that human health risks from consumption of contaminated aquatic food products and exposure to contaminated coastal waters be determined through systematic research studies to allow determination of measures to protect public health. Hygienic food handling practices at various stages from production/collection to preparation should also be promoted.

ON THE QUALITY OF WATER, SEDIMENT AND AQUATIC FOOD PRODUCTS

On Identified Contaminants of Concern

In the risk assessment for the coastal areas and the Klang and Langat Rivers, common concerns were highlighted such as pathogens, oil and grease, organic load and siltation of water bodies. Risk from coliform, in particular, is a cause for concern even in the catchment areas of both rivers. Temporal trends in risk also showed that these contaminants would continue posing risk to the coastal areas unless risk reduction measures are implemented These contaminants are introduced to the water bodies through the direct and indirect discharge of untreated or partially treated liquid wastes as well as solid wastes from land-based and sea-based sources. A comprehensive control program for preventing direct and indirect discharges of untreated or partially treated wastes in the coastal areas and tributaries starting from the catchment areas should be developed and implemented.

Evaluation of Risk from Persistent Contaminants

Persistent contaminants such as toxic metals and pesticides/organochlorines pose higher risk than any other pollutant because of their accumulation behavior. Most of these contaminants in the water column will be deposited in the bottom sediment once the rivers that carry them enter the sea. Unfortunately at the river estuary, particularly the Klang and Langat estuaries, aquaculture activities are important economically. Aquaculture produce from these estuaries are likely to accumulate these toxicants and the subsequent risk to seafood contamination is high.

The risk associated with pesticides was not assessed at all due to lack of data in the water column, sediment and biological tissue. There were also no data on heavy metals in the sediment and biota. It is recommended that a systematic data collection be undertaken to determine the levels of these toxic metals and pesticides in the water column as well as in the sediment and aquatic products in the Klang and Langat estuaries and nearby coastal areas. There was also no assessment done on tributyltin (TBT) due to lack of data. Given the level of shipping activities in the area, TBT should be considered for data collection and monitoring.

Detailed Assessment of Risk throughout the River Basin

The information from the risk assessment of various parameters in the water column will be useful for risk management only when the whole river basin is examined and its risk implications on coastal water is ascertained. Therefore, the next phase of the risk assessment should be extended throughout the whole river basin. This is unlikely to be a problem because data are available for many water sampling stations along particular rivers, e.g., Klang or Langat. The risk evaluated for a particular stretch of the river will be related to land use or activities occurring surrounding that stretch. This will thus enable the source of risk factors to be identified and remedial actions can be taken to reduce the risk.

Wider Application of the RQ Approach

Risk from organics, siltation, oil and grease and pathogens in the coastal areas and Langat and Klang Rivers were determined through the RQs generated in the prospective risk assessment. Future trends in risk were also deduced based on the temporal trends in RQs. These results show that although there are limitations associated with the simplified RQ approach applied, this IRA based on RQs (and the comparative assessment of risks based on order of magnitude differences in RQs) appeared to be adequate for providing insights into relative risks in river and coastal waters. This process has yielded meaningful results that may be useful for river basin and coastal management. Thus, such procedure may be extended to carry out a more detailed risk evaluation of rivers and coastal waters in Selangor.

Review of the Interim Marine Water Quality Criteria

In this risk assessment, the limitations of the IMWQS for Malaysia were highlighted particularly with regard to the standard values which were regarded as "unprotective" relative to those specified by ASEAN and other countries in the region. This emphasizes the need to take a closer look at the interim standard values and assess their effectiveness as one of the important decision factors in managing the coastal and marine environment. The limited number of parameters included in the IMWQS also limits its usefulness for the risk assessment and other evaluation tools. Specific scientific researches required in relation to the review of the standards need to be identified.

ON RESOURCES AND HABITATS

Fisheries

The retrospective risk assessment of capture fisheries was not able to conclusively establish adverse changes in fisheries as a consequence of environmental factors much less identify causative agents for observed changes since the only available data was on fish landing, which was influenced by increase in fishing intensity and use of more efficient fishing methods. It was also observed that fish landings are not really reflective of the status of fisheries in the Port Klang coastal waters since fishes are caught from neighboring countries, particularly Indonesia.

The results of the risk assessment for fisheries show that indicators for monitoring and assessment of fisheries conditions such as CPUE, stock density and demersal biomass, and changes in catch composition (e.g., decline in economically-important species) will have to be gathered to enable more appropriate assessments to be carried out. Estimates of the MSY will also be important to determine if the current fishing effort is within sustainable levels or if this may eventually lead to adverse impacts on local fisheries.

Concurrent with data gathering efforts, evaluation of the fisheries management framework in the area may be carried out to determine areas that need to be strengthened for the sustainable development of the fisheries sector such as inter-agency and inter-sectoral coordination, community participation, conservation efforts, use of responsible fishing methods, enforcement of existing laws and regulations on fisheries, and protection of fisheries resources from pollutant discharges.

Aquaculture

Aquaculture in the Port Klang ICM area is considered as an alternative way of coping with the increased demand for fish and shellfish, but aquaculture development has involved conversion of mangrove and peat swamp areas to culture ponds, which may lead to adverse ecological effects. Pollution may also result from intensive aquaculture practices.

It is recommended that use of indicators that can provide better assessment of the status of aquaculture such as the production/area should be collected and used in future risk assessments. Existing aquaculture practices and their impacts on the natural ecosystem should also be evaluated and management guidelines should be developed in accordance with environmental quality management plans and land and sea-use plans. Coastal aquaculture zones should be designated and adverse environmental impacts arising from aquaculture activities should be minimized through environment-friendly practices. Measures should also be developed to control adverse impacts of other activities on coastal aquaculture activities.

Mangroves

Various development activities have resulted in the reduction of mangrove forest areas in the Klang ICM area, particularly at the Kapar and Klang Island MFRs. The extensive loss of mangroves may have had adverse ecological, economic and social impacts due to the impairment of ecological functions and services provided by the mangroves.

Systematic studies should be carried out to assess the ecological, economic and social effects of the reduction or degradation of mangrove ecosystems. A better understanding of the adverse impacts of mangrove decline will be valuable in formulating future development plans that will integrate ecological as well as economic considerations. Economic valuation of mangrove forests will provide valuable information for management programs.

The practice of degazettement, in particular, to allow other uses of the protected area should be assessed thoroughly in relation to effects on the overall integrity of the ecosystem and other potential benefits from the existing mangrove area. Benefit-cost analysis of proposed public and private development plans, particularly those that involve reclamation and mangrove conversion, should be conducted as part of the government approval process. Mangrove reforestation in areas with high potential for mangrove rehabilitation should be promoted and community participation in protection and rehabilitation efforts should be encouraged. Improvement and /or enforcement of laws, rules and regulations on utilization and conservation of coastal resources should also be strengthened.

Wildlife

Using limited data, decline in mammals, birds and aquatic fish were established. It was, however, difficult to clearly establish causes for the decline due to insufficient information, and in most cases, the assessments were made based on unpublished observations and certain assumptions. There are very few cause-effect studies, which try to relate the effects of prescribed agents on resources within a specified habitat. For wildlife especially terrestrial species (mammals and birds), the most important factors identified for the decline were habitat loss and hunting. For aquatic fauna, considering not only the aquatic mammals but also vertebrates and invertebrates, water pollution may also be an important factor. More comprehensive researches, however, need to be undertaken to verify the reported decline in these species and the attributed causes, allowing sufficient time to detect significant changes in the number of species and population and determining exposure, correlation and cause-effect relationships between targets and potentially significant agents.

ON AIR QUALITY

Except during the haze phenomenon in 1997 when RQ_{Ave} for PM_{10} exceeded 1, RQ_{Ave} for all parameters were all < 1, indicating acceptable concern in general. The RQ_{Max} for all parameters, however, exceeded 1, indicating cause for concern in some specific areas. The average API also exceeded 1, indicating potentially significant contribution of other parameters not assessed in this report. It is recommended that more detailed temporal assessment be conducted for all parameters and that other potentially-important parameters be included in the assessment.

OTHER DATA GAPS

In order to refine the IRA, it is recommended that the identified concerns be verified and data gaps be filled through primary data collection (i.e., monitoring or research).

Following are some recommended studies:

- Sediment load study which will be conducted through hydrodynamics study;
- Determination of level of impacts in specific pollution hotspots;
- Toxicology study through market-basket study by using certain types of fish and shellfish species;
- Poverty and its implication towards the environmental management strategy; and
- Industrial development in the Klang area and the linkage to environmental pollution.

RISK MANAGEMENT

The results of the risk assessment show the need to develop long-term strategies and action programs to address environmental issues related to resource exploitation, pollution and various coastal uses, including:

a. Integrated Land and Water-Use Zoning

The existing land and water uses in Klang, which are linked with recent economic developments, have been attributed to contribute to environmental concerns such as pollution, increasing resource utilization and habitat loss and degradation. Considering Klang's goal for further development and the impending adverse impacts on its natural coastal resources, it is recommended that an integrated land- and water-use zoning scheme with associated institutional arrangements be developed. This should be aimed at managing conflicting uses of land and water resources, promoting the most beneficial uses of specific areas, and preventing adverse effects to ecological and human targets.

b. Environmental Investments

The risk assessment shows the need for environmental services and facilities and clean technologies in order to achieve a balance between continuing economic growth in Klang and environmental protection and management. This includes facilities to manage industrial wastes, hazardous wastes, solid wastes and sewage. These present investment opportunities that are expected to create income, employment and livelihood. Such facilities will, however, require large financial investments and technological resources such that innovative approaches that will facilitate the participation of various sectors will have to be employed.

c. Integrated Environmental Monitoring Program

The risk assessment identifies the need for a systematic, cost-effective and coordinated environmental monitoring program that will focus on identified priority areas of concern and potentially-important data gaps. An integrated approach in the monitoring of priority pollutants, monitoring of human health impacts of priority pollutants, and monitoring of resource and habitat conditions is recommended in order to enhance the assessment of the impacts of human activities on the environment, impacts of environmental factors on human and ecological targets, as well as the effectiveness of management measures to address these adverse impacts. The integrated environmental monitoring program (IEMP) will be developed and implemented through multi-agency and multi-sectoral coordination and cooperation and characterized by sharing of technical, financial and information resources. Capacity-building requirements for implementing the IEMP will also be identified, and the linkage between environmental monitoring and environmental management will be enhanced through application of the risk assessment/risk management framework.

d. Collaboration and Institutional Arrangements

Sustainable environmental management cannot be achieved by governments or specific agencies unaided but should be undertaken through collaboration between different agencies, universities, research institutions, local government, communities and the private sector. Presently, there are limited efforts on setting up this kind of collaboration, but development and implementation of strategies and action programs to address the environmental concerns highlighted in the risk assessment require multi-agency and cross-sectoral approaches. To facilitate and ensure sustainable collaboration, appropriate institutional arrangements will have to be put in place, which will involve evaluation and strengthening of policies, rules and regulations, implementation frameworks and enforcement capabilities on resource utilization and environmental protection.

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Glossary

Accuracy. The degree to which a measurement reflects the true value of a variable.

Adverse ecological effects. Changes that are considered undesirable because they alter valued structural or functional characteristics of ecosystems or their components. An evaluation of adversity may consider the type, intensity, and scale of the effect as well as the potential for recovery.

Agent. Any physical, chemical, or biological entity that can induce an adverse response (synonymous with stressor).

Assessment endpoint. An explicit expression of the environmental value that is to be protected, operationally defined by an ecological entity and its attributes.

Attribute. A quality or characteristic of an ecological entity. An attribute is one component of an assessment endpoint.

Benthic community. The community of organisms dwelling at the bottom of a pond, river, lake, or ocean.

Bioaccumulation. General term describing a process by which chemicals are taken up by an organism either directly from exposure to a contaminated medium or by consumption of food containing the chemical.

Bioconcentration. A process by which there is a net accumulation of a chemical directly from an exposure medium into an organism.

Biomagnification. Result of the process of bioaccumulation and biotransfer by which tissue concentrations of chemicals in organisms at one trophic level exceed tissue concentrations in organisms at the next lower trophic level in a food chain.

Bund. A land built along coastal area to prevent sea water intrusion to the land area during the high tide.

Community. An assemblage of populations of different species within a specified location and time.

Comparative risk assessment. A process that generally uses a professional judgment approach to evaluate the relative magnitude of effects and set priorities among a wide range of environmental problems.

Concentration. The relative amount of a substance in an environmental medium, expressed by relative mass (e.g., mg/kg), volume (ml/L), or number of units (e.g., parts per million).

Contaminant of concern. A substance detected at a hazardous waste site that has the potential to affect ecological receptors adversely due to its concentration, distribution, and mode of toxicity.

Correlation. An estimate of the degree to which two sets of variables vary together, with no distinction between dependent and independent variables.

Degazettement. Annulment or revocation of the proclamation of gazettement.

Degradation. Conversion of an organic compound to one containing a smaller number of carbon atoms.

Disturbance. Any event or series of events that disrupts ecosystem, community, or population structure and changes resources, substrate availability, or the physical environment.

Ecological component. Any part of an ecosystem, including individuals, populations, communities, and the ecosystem itself.

Ecological entity. A general term that may refer to a species, a group of species, an ecosystem function or characteristic, or a specific habitat. An ecological entity is one component of an assessment endpoint.

Ecosystem. The biotic community and abiotic environment within a specified location and time, including the chemical, physical, and biological relationships among the biotic and abiotic components.

Ecotoxicology. The study of toxic effects on nonhuman organisms, populations, or communities.

Effects assessment. The component of a risk analysis concerned with quantifying the manner in which the frequency and intensity of effects increase with increasing exposure to substance.

Environmental risk assessment. The likelihood that an environmental condition caused by human activity will cause harm to a target. It involves estimating the likelihood of harm being done to human health and/or ecosystems through factors emanating from human activities that reach their natural targets via the natural environment.

Exposure. Co-occurrence of or contact between a stressor and an ecological component. The contact reaction between a chemical and a biological system or organism.

Exposure assessment. The component of a risk analysis that estimates the emissions, pathways and rates of movement of a chemical in the environment, and its transformation or degradation, in order to estimate the concentrations/doses to which the system of interest may be exposed.

Fate. Disposition of a material in various environmental compartments (e.g., soil or sediment, water, air, biota) as a result of transport, transformation, and degradation.

Food-chain transfer. A process by which substances in the tissues of lower-trophic-level organisms are transferred to the higher-trophic-level organisms that feed on them.

Habitat. Place where a plant or animal lives, often characterized by a dominant plant form and physical characteristics.

Hazard. The likelihood that a substance will cause an injury or adverse effect under specified conditions.

Hazard assessment. Comparison of the intrinsic ability of a substance to cause harm (i.e., to have adverse effects for humans or the environment) with its expected environmental concentration, often a comparison of PEC and PNEC. Sometimes referred to as risk assessment.

Hazard identification. Identification of the adverse effects that a substance has an inherent capacity to cause, or in certain cases, the assessment of a particular effect. It includes the identification of the target populations and conditions of exposure.

Ingestion rate. The rate at which an organism consumes food, water, or other materials (e.g., soil, sediment). Ingestion rate usually is expressed in terms of unit of mass or volume per unit of time (e.g., kg/day, l/day).

LC_{50}. A statistically or graphically estimated concentration that is expected to be lethal to 50 percent of a group of organisms under specified conditions.

Lowest-observable-adverse-effect level (LOAEL). The lowest level of a stressor evaluated in a toxicity test or biological field survey that has a statistically significant adverse effect on the exposed organisms compared with unexposed organisms in a control or reference site.

Measurement endpoint. A measurable ecological characteristic that is related to the valued characteristic chosen as the assessment endpoint. Measurement endpoints often are expressed as the statistical or arithmetic summaries of the observations that make up the measurement. Measurement endpoints can include measures of effect and measures of exposure.

Population. An aggregate of individuals of a species within a specified location in space and time.

Precision. A measure of the closeness of agreement among individual measurements.

Predicted or estimated environmental concentration (EC). The concentration of a material predicted/estimated as being likely to occur in environmental media to which organisms are exposed.

Primary effect. An effect where the stressor acts on the ecological component of interest itself, not through effects on other components of the ecosystem (synonymous with direct effect; compare with definition for secondary effect).

Prospective risk assessment. An evaluation of the future risks of a stressor(s) not yet released into the environment or of future conditions resulting from an existing stressor(s).

Reference site. A relatively uncontaminated site used for comparison to contaminated sites in environmental monitoring studies, often incorrectly referred to as a control.

Representative samples. Serving as a typical or characteristic sample; should provide analytical results that correspond with actual environmental quality or the condition experienced by the contaminant receptor.

Retrospective risk assessment. An evaluation of the causal linkages between observed ecological effects and stressor(s) in the environment.

Risk. The probability of an adverse effect on humans or the environment resulting from a given exposure to a substance. It is usually expressed as the probability of an adverse effect occurring, e.g., the expected ratio between the number of individuals that would experience an adverse effect in a given time and the total number of individuals exposed to the risk factor.

Risk assessment. A process which entails some or all of the following elements: hazard identification, effects assessment, exposure assessment and risk characterization. It is the identification and quantification of the risk resulting from a specific use of occurrence of a chemical including the determination of exposure/dose-response relationships and the identification of target populations. It may range from largely qualitative (for situations in which data are limited) to fully quantitative (when enough information is available so the probabilities can be calculated).

Risk characterization. The step in the risk assessment process where the results of the exposure assessment (e.g., PEC, daily intake) and the effects assessment (e.g., PNEC, NOAEL) are compared. If possible, an uncertainty analysis is carried out, which, if it results in a quantifiable overall uncertainty, produces an estimation of the risk.

Risk classification. The weighting of risks in order to decide whether risk reduction is required. It includes the study of risk perception and the balancing of perceived risks and perceived benefits.

Risk Pathways (Exposure Pathways). A diagrammatic representation of the course that all agents take from a source to exposed organisms (target) (Modified from U.S. EPA). In the diagram, each exposure pathway includes a source or release from a source, an exposure point, and an exposure route. If the exposure point differs from the source, transport/exposure media (i.e., air, water) also are included. For the particular use of the report, the major categories found in the diagram include economic/social drivers (sources), hazards, resources and habitats (targets), and the effects on the economy. It may also sometimes be referred to as the *conceptual model* that describes ecosystem or ecosystem components potentially at risk, and the relationships between measurement and assessment endpoints and exposure scenarios.

Sample. Fraction of a material tested or analyzed; a selection or collection from a larger collection.

Secondary effect. An effect where the stressor acts on supporting components of the ecosystem, which in turn have an effect on the ecological component of interest (synonymous with indirect effects; compare with definition for primary effect).

Sediment. Particulate material lying below water.

Source. An entity or action that releases to the environment or imposes on the environment a chemical, physical, or biological stressor or stressors.

Species. A group of organisms that actually or potentially interbreed and are reproductively isolated from all other such groups; a taxonomic grouping of morphologically similar individuals; the category below genus.

Stressor. Any physical, chemical, or biological entity that can induce an adverse response (synonymous with agent).

Threshold concentration. A concentration above which some effect (or response) will be produced and below which it will not.

Trophic level. A functional classification of taxa within a community that is based on feeding relationships (e.g., aquatic and terrestrial plants make up the first trophic level, and herbivores make up the second).

Uncertainty. Imperfect knowledge concerning the present or future state of the system under consideration; a component of risk resulting from imperfect knowledge of the degree of hazard or of its spatial and temporal distribution.

Uptake. A process by which materials are transferred into or onto an organism.

APPENDICES

Appendix 1. Sources of Data for the Initial Risk Assessment of Port Klang.

Retrospective Risk Assessment

Resource/Habitat	References
Fisheries	
Aquaculture	
Mangroves	
Land-use, Agriculture, Demography, Waste	Klang Municipal Council, 2000. Majilis Perbandaran Klang, 2000. Kuala Langat District Council, 1994. Kuala Langat District Council, 2000.
Wildlife	Wildlife, 1998; Shukor et al., 2001.
Data on Human Health and Sanitation	Ministry of Health Malaysia, n.d.

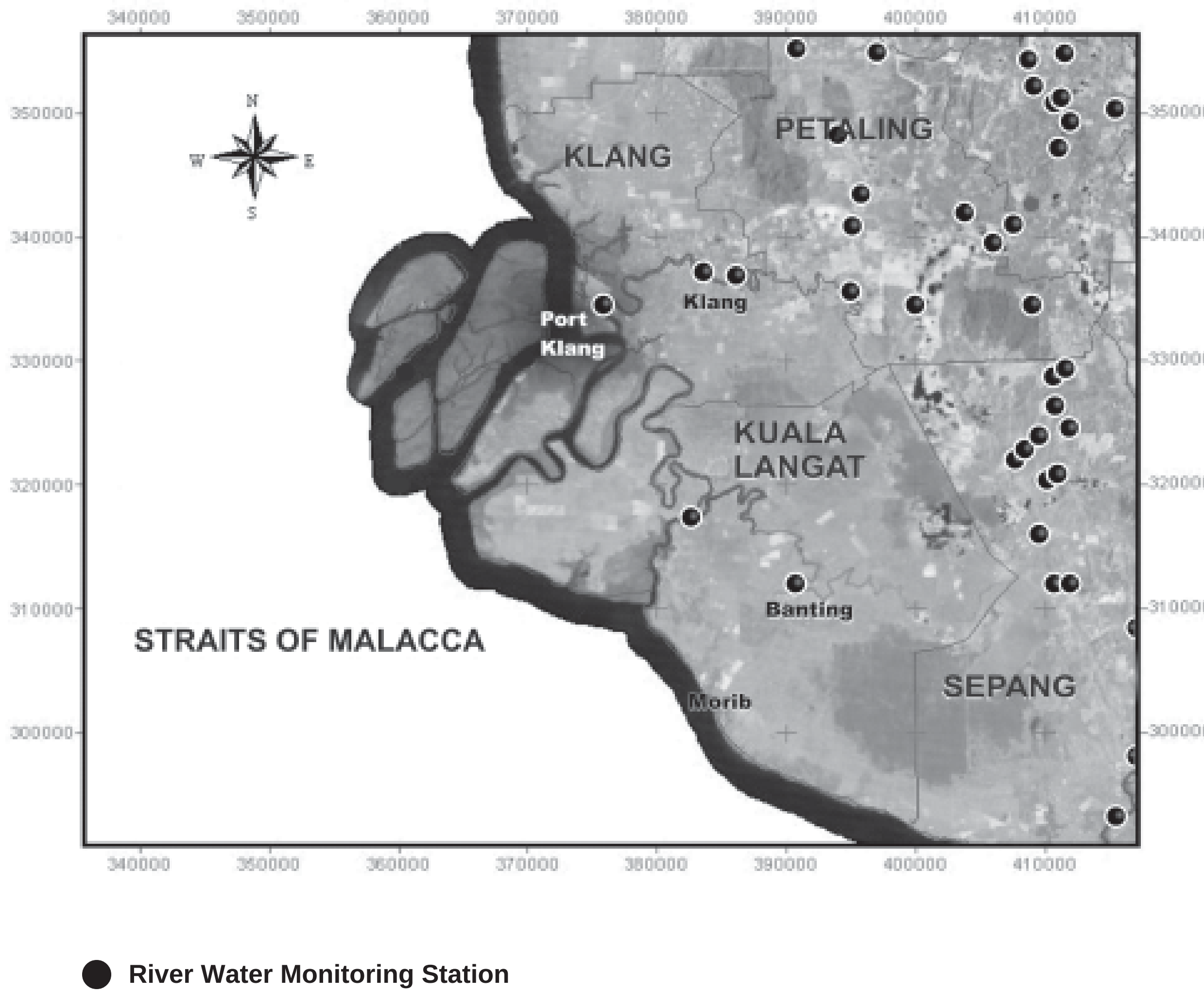
Data Used in the Prospective Risk Assessment (conducted in Chonburi, Thailand)

Agent	Compartment	Description of data	Location	Reference
BOD	Water	Raw data: 1990 - 2000, monthly, 24 stations, sampling methods follows DOE Malaysia guidelines (surface water).	Stations represent Klang Riverwater quality. 2 stations located at the Klang river estuary and 1 station in Straits of Klang.	DOE–Selangor, 2000
AN (ammonical nitrogen)	Water	Raw data: 1990 - 2000, monthly, 24 stations, sampling methods follows DOE Malaysia guidelines (surface water).	Stations represent Klang River water quality. 2 stations located at the Klang river estuary and 1 station in Straits of Klang.	DOE–Selangor, 2000
TSS	Water	Raw data: 1990 - 2000, monthly, 24 stations, sampling methods follows DOE Malaysia guidelines (surface water).	Stations represent Klang Riverwater quality. 2 stations located at the Klang river estuary and 1 station in Straits of Klang.	DOE–Selangor, 2000
E. coli	Water	Raw data: year 2000, monthly, 1 station, sampling methods follows DOE Malaysia guidelines (surface water).	Straits of Klang	DOE–Selangor, 2000
As	Water	Raw data: year 2000, monthly, 1 station, sampling methods follows DOE Malaysia guidelines (surface water).	Straits of Klang	DOE–Selangor, 2000
Hg	Water	Raw data: year 2000, monthly, 1 station, sampling methods follows DOE Malaysia guidelines (surface water).	Straits of Klang	DOE–Selangor, 2000
Oil and Grease	Water	Raw data: year 2000, monthly, 1 station, sampling methods follows DOE Malaysia guidelines (surface water).	Straits of Klang	DOE–Selangor, 2000
Oil and Grease	Water	Data collected for year 1995	Port Klang	MPP-EAS, 1999b

Data Used in the Initial Risk Assessment

Parameters	Description of Data	Location	References
DO	data collected from 1990 to 2000	Klang River and Langat River estuary	DOE–Selangor 2000
BOD	data collected from 1990 to 2000	Klang River and Langat River estuary	DOE–Selangor 2000
COD	data collected from 1990 to 2000	Klang River and Langat River estuary	DOE–Selangor 2000
SS	data collected from 1990 to 2000	Klang River and Langat River estuary	DOE–Selangor 2000
pH	data collected from 1990 to 2000	Klang River and Langat River estuary	DOE–Selangor 2000
NH_3-N(L)	data collected from 1990 to 2000	Klang River and Langat River estuary	DOE–Selangor 2000
Turbidity	data collected from 1990 to 2000	Klang River and Langat River estuary	DOE–Selangor 2000
NO_3	data collected from 1990 to 2000	Klang River and Langat River estuary	DOE–Selangor 2000
As	data collected from 1990 to 2000	Klang River and Langat River estuary	DOE–Selangor 2000
Hg	data collected from 1990 to 2000	Klang River anf Langat River estuary	DOE–Selangor 2000
Cd	data collected from 1990 to 2000	Klang River and Langat Tiver estuary	DOE–Selangor 2000
Cr	data collected from 1990 to 2000	Klang River and Langat River estuary	DOE–Selangor 2000
Pb	data collected from 1990 to 2000	Klang River and Langat River estuary	DOE–Selangor 2000
Zn	data collected from 1990 to 2000	Klang River and Langat River estuary	DOE–Selangor 2000
Fe	data collected from 1990 to 2000	Klang River and Langat River estuary	DOE–Selangor 2000
E. coli	data collected from 1990 to 2000	Klang River and Langat River estuary	DOE–Selangor 2000
T. Coliform	data collected from 1990 to 2000	Klang River and Langat River estuary	DOE–Selangor 2000
PM_{10}, NO_2, SO_2, CO, O_3, API	December 1996 to March 2000	station located at Sekolah Menengah Perempuan Raja Zarina, Klang	Alam Sekitar Malaysia Sdn. Bhd., 2000

Appendix 2. The Water Quality Monitoring Stations in Klang and Kuala Langat.



Appendix 3. Environmental Quality Standards for Malaysia.

Appendix 3a. Interim National Water Quality Standards for Malaysia.

PARAMETERS	I	IIA	IIB	III	IV	V	RAW WATER CRITERIA	DRINKING WATER STANDARD
Conventional Parameters								
DO (mg/l)	7	5-7	5-7	3-5	3	1		
COD (mg/l)	10	25	25	50	100	100	10	
BOD (mg/l)	1	3	3	6	12	12	6	
NO_2 (mg/l)	N	0.4	0.4	0.4 (0.03)	5	+	10	10
NO_3 (mg/l)		7	-				1	
P (mg/l)	N	0.2	0.2	0.1	-	+		
Total Suspended Solids (mg/l)	25	50	50	150	300	300		
Total Coliform (counts/100 ml)	100	5,000	5,000	5,000	5,000	5,000		
Fecal Coliform (counts/100 ml)	10	100	400	5000	5,000 (2,000)@	– (2,000)@		
Metals								
As (mg/l)	N	0.05	0.05	0.4(0.05)	0.1	+	0.05	0.05
Cd (mg/l)	N	0.01	NR	0.01 # (0.001)	0.01	+	0.005	0.005
Cr (IV) mg/l	N	0.05	0.05	1.4(0.05)	0.1	+	0.05	0.05
Cu (mg/l)	N	1	1	0.01 (0.012*)	0.2	+	1	1
Zn (mg/l)	N	5	NR	0.4#	2	+	1.5	5
Pb (mg/l)	N	0.05	NR	0.02# (0.01)	5	+	0.01	0.05
Hg (mg/l)	N	0.001	NR	0.004 (0.001)	0.002	+	0.001	0.001
Ni (mg/l)	N	0.05	NR	0.9#	0.2	+		
Ag (mg/l)	N	0.05	0.05	0.0002	-	+		0.05
Sn (mg/l)	N	NR	NR	0.004	-	+		
Zn (mg/l)	N	5	NR	0.4#	2	+	1.5	5
Oil and Grease (Mineral) (mg/l)	N	40;NF	NR	NL	NR	+	0.3	0.3
Organics								
Aldrin	A	0.02	NR	0.08	NR	NR		
Dieldrin (ug/l)	A	NR	(0.2) (0.13)	NR	NR			
BHC (ug/l)	A	2	NR	(9.9)	NR	NR		
Heptachlor /	A	0.05	NR	0.06	NR	NR		
Epoxide (ug/l)	A	-	NR	(0.91)	NR	NR		

a - PAHs b - Pesticides and others

Appendix 3b. Interim Marine Water Quality.

No	Parameters	Unit	Interim Standard
1	E. coli	MPN/100 mL	100
2	Oil and Grease	mg/L	0
3	TSS	mg/L	50
4	As	mg/L	0.1
5	Cd	mg/L	0.1
6	Cr (total)	mg/L	0.5
7	Cu	mg/L	0.1
8	Pb	mg/L	0.1
9	Hg	mg/L	0.001

Source: Malaysia Environmental Quality Report, 2002; DOE, n.d; MOSTE, 1995.

Appendix 3c. Air Quality Standard for Particulate Matter (PM_{10}), Sulphur Dioxide ($S0_2$), Nitrogen Dioxide (NO_3), Ozone (O_3) and Carbon Monoxide (CO).

Parameter	PM_{10} (24 hours)	SO_2 (1 hour)	NO_2 (1 hour)	O_3 (1 hour)	CO (1 hour)
Unit	gm^{-3}	ppm	ppm	ppm	ppm
Concentration	150	0.13	0.17	0.10	30.00

Appendix 4. Environmental Quality Standards from Other Locations.

Appendix 4a. Water Quality Criteria

	U.S. EPA Quality Criteria for water for regulatory purposes (U.S. EPA, 2000)		Water Quality Criteria for coastal and marine waters in the Philippines (DAO 34, 1990)				ASEAN Marine water quality criteria (ASEAN, 2003)	Chinese Standards for Different Classifications (National Standards of PR China, 1995)			
	Marine acute criteria	Marine chronic criteria	Classes					Classes			
			SA	SB	SC	SD		I	II	III	IV
Physico-chemical parameters											
DO (mg/l)			5	5	5	2	4.000	6	5	4	3
COD (mg/l)								2	3	4	5
BOD 5 (mg/l)			3	5	7	-		1	2	3	4
Nitrate (mg/l)							0.060				
Nitrite (mg/l)							0.055				
Phosphate (mg/l)							0.015-0.045 (coastal - estuaries)				
TSS (mg/l)							50.000 (Malaysia)				
Cyanide (ug/l)	1	1	50	50	50	-	7.000	5	5	100	200
Ammonia (ug/l)							70.000 (unionized)				
Heavy Metals (µg/l)											
Cadmium	43.0	9.300	10	10	10	-	10.00	1	5	10	10
Copper	2.9	2.900	-	20	50	-	8.00	5	10	50	50
Lead	140.0	5.600	50	50	50	-	8.50	1	5	10	50
Mercury	2.1	0.025	2	2	2	-	0.16	0.05	0.2	0.2	0.5
Nickel	75.0	8.300						5	10	20	50
Chromium	1,100.0	50.000	50	100	100	- (VI)	50.00 (VI)	50	100	200	500
Silver	2.3	-									
Zinc	95.0	55.000					50.00	20	50	100	500
Arsenic	69.0 (Tri)	36.000 (Tri)	50	50	50	-	120.00	20	30	50	50
Selenium	410.0	54						10	20	20	50

Appendix 4a. (continued) Water Quality Criteria

	U.S. EPA Quality Criteria for water for regulatory purposes (U.S. EPA, 2000)		Water Quality Criteria for coastal and marine waters in the Philippines (DAO 34, 1990)				ASEAN Marine water quality criteria (ASEAN, 2003)	Chinese Standards for Different Classifications (National Standards of PR China, 1995)			
	Marine acute criteria	Marine chronic criteria	Classes					Classes			
			SA	SB	SC	SD		I	II	III	IV
Trace Organics (µg/l)											
Chlordane	0.090	0.0040	3	-	-	-					
DDT	0.130	0.0010	50	-	-	-		0.05	0.1	0.1	0.1
Malathion	-	0.1000						0.5	1	1	1
Endosulfan	0.034	0.0067									
Pentachlorophenol	13.000	7.9000									
Heptachlor	0.053	0.0035			-						
Endrin	0.037	0.0023			-						
Aldrin	1.300	-	1	-	-	-					
Dieldrin	0.710	0.0019	1	-	-	-					
Lindane			4	-	-	-					
Toxaphane			5	-	-	-					
Methoxychlor	-	0.0300	100	-	-	-					
Benzene	5,100.000	700.0000									
Phenol							120				
PCBs	10.000	0.0300	1	-	-	-					
PAHs	300.000	-									
Benzo[a]pyrene								2.5	2.5	2.5	2.5
HCHs								1	2	3	5
Organometallics											
TBT (µg/l)							0.01				
Oil & grease(mg/l)	0.09	0.004	1	2	3	5	0.14	0.05	0.05	0.3	0.5
			(Petroleum ether extract)				(Water soluble fraction)				

Appendix 4b. Sediment Quality Criteria

Heavy Metals	HK-ISQVs (µg/kg) (EVS, 1996)		CANADA (µg/kg) Environment Canada, 1995)		NOAA (µg/kg) Long, et al., 1995)		NETHERLANDS (µg/kg) (MTPW, 1991)	
	Contamination Classification		Threshold/Probable Effects Level		Effects Range		Provisional Test/ Warning Value	
	Lower limit	Upper Limit	Threshold	Probable	Low	Median	Test	Warning
Cadmium	1.50	9.60	[0.68]	4.21	1.20	9.60	7.5	30
Copper	65.00	270.00	[18.70]	108.00	34.00	270.00	90.0	400
Lead	75.00	218.00	30.20	112.00	46.70	218.00	530.0	1,000
Mercury	0.28	1.00	0.13	0.70	0.15	0.71	1.6	15
Nickel	40.00	N/A	[15.90]	42.80	20.90	51.60	45.0	200
Chromium	80.00	370.00	52.30	160.00	81.00	370.00	480.0	1,000
Silver	1.00	3.70	[0.73]	[1.77]	1.00	3.70	-	-
Zinc	200.00	410.00	124.00	271.00	150.00	410.00	1,000.0	2,500
Arsenic	8.20	70.00	7.24	[41.60]	8.20	70.00	85.0	150

Appendix 4b. Sediment Quality Criteria

	HK-ISQVs (µg/kg) (EVS, 1996)		CANADA (µg/kg) (Environment Canada, 1995)		NOAA (µg/kg) (Long, et al., 1995)		NETHERLANDS (µg/kg) (MTPW, 1991)	
	Contamination Classification		Threshold/Probable Effects Level		Effects Range		Provisional Test/ Warning Value	
	Lower limit	Upper limit	Threshold	Probable	Low	Median	Test	Warning
Organics (µg/kg)								
Acenaphthene	16.00	500	[6.71]	[88.90]	16.00	500.0	-	-
Acenaphthylene	44.00	640	[5.87]	[245.00]	44.00	1,100.0	-	300
Anthracene	85.30	1,100	[46.90]	[128.00]	85.30	640.0	80	-
Fluorene	19.00	540	21.20	[144.00]	[19.00]	540.0	-	-
Naphthalene	160.00	2,100	34.60	[391.00]	160.00	2,100.0	-	-
Phenanthrene	240.00	1,500	86.70	544.00	240.00	1,500.0	[80]	[300]
Low mol. wt. PAHs	552.00	3,160	-	-	552.00	3,160.0	-	-
Benzo[a] anthracene	261.00	1,600	[74.80]	693.00	261.00	1,600.0	80	[300]
Benzo[a]pyrene	430.00	1,600	88.80	763.00	430.00	1,600.0	80	[300]
Chrysene	384.00	2,800	108.00	846.00	384.00	2,800.0	[80]	[300]
Dibenzo[a,h] anthracene	63.40	260	[6.22]	[135.00]	63.40	260.0	80	300
Fluoranthene	600.00	5,100	[113.00]	1,494.00	600.00	5,100.0	200	[700]
Pyrene	665.00	2,600	153.00	1,398.00	665.00	2,600.0	[80]	[300]
High mol. wt. PAHs	1,700.00	9,600	-	-	1,700.00	9,600.0	-	-
Total PAHs	4,022.00	44,792	-	-	4,022.00	44,792.0	[460]	[1,700]
Total PCBs	22.70	not stated	21.50	189.00	22.70	180.0	[20]	[40]
p,p′-DDE (4,4′-DDE)	2.20	not stated	[2.07]	374.00	2.20	[27.0]	-	-
Total DDT	1.58	not stated	3.89	51.70	[1.58]	[46.1]	2	50
Bis(2-ethylhexyl) phthalate			182.00	2,647.00				
Chlordane			2.26	4.79				
Lindane			[0.32]	0.99				
Organometallics								
TBT in interstitial water (µg/l)	0.15	not stated						

Appendix 5. Decision Criteria for Determining the Likelihood of Harm.

Case	Result Decision Tables	Conclusion
A	No 1 & 2 = unlikely (U)	No correlation
B	Yes 1 & 2, ND for 3 – 6 = possibly (P)	Just correlation
C	Yes 1 & 2, but No 3 = unlikely (U)	Correlation but negative evidence for cause-effect
D	Yes 1 & 2, but No 6 = unlikely (U)	Spurious correlation
E	Yes 1, 2, & 3 = likely (L)	Correlation with some evidence of cause-effect
F	Yes 1, 2, & 3, but no 4a = unlikely/possibly (U/P)	Correlation but negative evidence for cause-effect; if good experimental design (e.g., low Type II error = unlikely), with poor experimental design (e.g., high Type II error = possibly).
G	Yes 1, 2, & 3, ND for 4a, but no 4b = possibly (P)	Correlation but lack of evidence for cause-effect
H	Yes, 1, 2, 3, & 4a, but no 4b = likely (L)	Correlation with evidence for cause-effect and recovery does not always occur
I	Yes, 1, 2, 3, 4a, & 5 = very likely (VL)	Correlation with strong evidence for cause-effect
J	Yes, 1, 2, 3, & 4a, but no 5 = likely (L)	Correlation with evidence for cause-effect (a lack of biomarker response is inconclusive evidence)
K	Yes, 1, 2, 3, 4a, 5, & 6 = very likely (VL)	Correlation with very strong evidence for cause-effect
L	Yes, 1, 2, 3, but maybe 6 = possibly (P)	Correlation but scientific/logical justification lacking
M	Yes 6 but no data for 1 & 2 = unknown (?)	Cause – effect relationship known to be possible in principle, but no evidence in this case
N	Yes 1, but no 2	Target is exposed but there is no evidence for decline; if there is good evidence for no decline then no need to take risk assessment further; if evidence for no decline is weak or questionable seek more evidence.