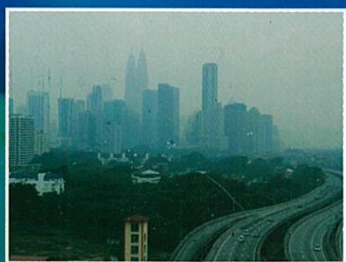
GUIDANCE DOCUMENT ON HEALTH IMPACT ASSESSMENT (HIA) IN ENVIRONMENTAL IMPACT ASSESSMENT (EIA)





Department of Environment
Ministry of Natural Resources and Environment
Malaysia
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ISBN : 978-983-3895-37-3

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LIST OF ABBREVIATIONS

ADD	:	Average daily dose
ATSDR	:	Agency for Toxic Substances and Disease Registry
CDI	:	Chronic daily intake
CSF	:	Cancer slope factor
DOE	:	Department of Environment
EC	:	Exposure air concentration
EIA	:	Environmental impact assessment
FDA	:	Food and Drug Administration
HIA	:	Health impact assessment
HQ	:	Hazard quotient
IRIS	:	Integrated Risk Information System
LADD	:	Lifetime average daily dose
LCR	:	Lifetime cancer risk
MRL	:	Minimal risk level
MSDS	:	Material safety data sheet
NAS	:	National Academy of Sciences
RfC	:	Reference concentration
RfD	:	Reference dose
URF	:	Unit risk factor
U.S. EPA	:	United States Environmental Protection Agency
WHO	:	World Health Organization
ZOI	:	Zone of impact

GLOSSARY OF TERMS

Average daily dose (ADD) is the total intake of a toxicant into a human body over the duration of exposure and averaged over that duration. ADD reflects the body burden of the toxicant.

Dose-response relationship describes the increase in the probability of an adverse effect with a corresponding increase in the exposure dose to the hazard in question.

Environmental health comprises of those aspects of human health, including quality of life, that are determined by physical, chemical, biological, social, and psychosocial factors in the environment. It also refers to the theory and practice of assessing, correcting, controlling, and preventing those factors in the environment that can potentially affect adversely the health of present and future generations.

Environmental Impact Assessment (EIA) is a study to identify, predict, evaluate and communicate information about the impacts on the environment of a proposed project and to detail out the mitigating measures prior to project approval and implementation.

Hazard quotient (HQ) is a ratio of the average daily dose (ADD) to the reference dose (RfD) for ingestion exposure; or the ratio of the exposure air concentration (EC) to the reference concentration (RfC) for inhalation exposure.

Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity.

Hazard identification is the process of determining whether exposure to an agent can cause an increase in the incidence of a health condition (cancer, birth defect, etc.). It involves characterizing the nature and strength of the evidence of causation

Health impact assessment (HIA) is the process of estimating the potential impact of a chemical, biological, physical or social agent on a specified human population system under a specific set of conditions and for a certain timeframe.

Health risk assessment is a methodological approach in which the toxicities of a chemical are identified, characterized, analyzed for dose-response relationships, and the data generated are applied to a mathematical model to produce a numeric estimate representing a guideline or decision concerning allowable exposure.

Lifetime average daily dose is the total intake of a toxicant into a human body over the duration of exposure and averaged over a lifetime of 70 years. ADD reflects the lifetime body burden of the toxicant.

Minimal risk level is an estimate of the daily human exposure to a hazardous substance that is likely to be without appreciable risk of adverse, non-cancer health effects over a specified duration of exposure.

Oral reference dose is an estimated daily oral exposure of a toxicant, with uncertainty spanning perhaps an order of magnitude, to the human population including sensitive subgroups, that is likely to be without an appreciable risk of deleterious effect during a lifetime of 70 years.

Risk assessment is the use of the factual base to define the health effects of exposure of individuals or populations to hazardous materials and situations.

Reference concentration is an estimated daily concentration of a toxicant in air, with uncertainty spanning perhaps an order of magnitude, of which an inhalation exposure to the human population including sensitive subgroups, is likely to be without an appreciable risk of deleterious effect during a lifetime of 70 years.

Risk management is the process of weighing policy alternatives and selecting the most appropriate regulatory action, integrating the results of risk assessment with engineering data, and with social, economic and political concerns to reach a decision.

Qualitative risk assessment is risk assessment that merely characterizes or compares the hazard of a chemical relative to others, or defines the hazard in only qualitative terms, such as mutagen or carcinogen, which connotes certain risk or safety procedures, and as such may not necessarily require a numerical assessment of risk.

Quantitative risk assessment is risk assessment that generates a numerical measure of the risk or safety of a chemical exposure. The numerical measure of the risk generated is compared against a guideline value or an acceptable risk level.

Risk characterization is the process of estimating the incidence of a health effect under the various conditions of human exposure described in exposure assessment. It is carried out by combining the dose response and exposure assessment steps.

Zone of impact (ZOI) is the area of environmental impact around a proposed project. This ZOI is arbitrarily taken as an area of 5 km radius from the centre of the project site. Depending on the source strength and the pollutant dilution effect, the ZOI for health may be less or more than the 5 km radius boundary.

Preface

Health impact assessment (HIA) is a very critical component of the Environmental Impact Assessment (EIA) process. EIA is deemed mandatory for all prescribed activities under the Environmental Quality (Prescribed Activities) (Environmental Impact Assessment) Order, 1987, which comes under the purview of the Environmental Quality Act, 1974.

Presently, the conduct of HIA in Malaysia is not standardized even though all practicing HIA consultants are registered under the EIA Consultant Registration Scheme. Hence, there is a need to make HIA practice more uniform through the introduction of a guidance document. This Guidance Document on HIA in EIA aims to provide information to stakeholders such as consultants, industries and government agencies on the assessment of health impacts from development projects.

There are overwhelming evidences that infrastructural development can have beneficial impacts on human health and well-being through the creation of employment, promotion of economic activities and growth, and improvement of welfare and living standards. However, development can also generate adverse impacts through outcomes such as noise, water and air pollution, as well as increased risks to injury, accidents and diseases. Development may also impact on the social and emotional status of individuals and communities through alienation, inequity and disempowerment. Some community members such as children and the elderly may be particularly susceptible to both the physical and social impacts.

HIA is a process and a planning tool that systematically identifies and examines, in a balanced way, both the potential positive and negative health impacts of an activity or development project. In this planning context, the outcome of an HIA provides the ideal platform to implement efforts to maximize positive health impacts and prevent or minimize negative health impacts.

This Guidance Document specifically addresses the use of HIA when conducting an EIA. This form of HIA is sometime referred to as prospective HIA. It is prospective because the HIA is done before the activity or project has actually started. Other forms of HIA are concurrent and retrospective HIA. Every form of HIA has its own strengths and weaknesses. HIA in EIA refers to health impacts arising from environmental impacts of the project, not from the overall process of development.

CHAPTER 1

Introduction

Chapter 1

Introduction

1.1 Health and its Determinants

The World Health Organization (2006) defines health as a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity. The enjoyment of the highest attainable standard of health is one of the fundamental rights of every human being without distinction of race, religion, political belief, economic or social condition. The health of all peoples is fundamental to the attainment of peace and security and is dependent upon the fullest cooperation of individuals and States. This means that as health is a fundamental human right, it is the responsibility of the state to ensure that every resident of the state enjoys a basic level of health status and accessibility to basic health services.

In 1974, Blum (1981) proposed the "Environment of Health" model which was later referred to as the "Force Field and Well-being Paradigms of Health" (Figure 1.1). According to Blum, 4 major determinants contributed to health and well-being of humans. These determinants or "force fields" are heredity, health care services, behavior or lifestyles and the environment; all of which must be taken into account when addressing the health status of an individual and his community.

The size of each determinant signifies its relative significance in influencing human health. Thus, the most important determinant is the environment, followed by lifestyles and heredity. Medical care, which is a major focus of public expenditure and intervention, has the least impact on health and well-being. An argument can be made here that the greatest impacts on the improvement of general health of the masses can be more effectively and efficiently achieved through improvement in environmental health conditions such as sanitation, safe water supply, food hygiene and disease vector control, than through improving public access to the latest medical care technology. At least, this statement is undeniably true for many developing countries like Malaysia.

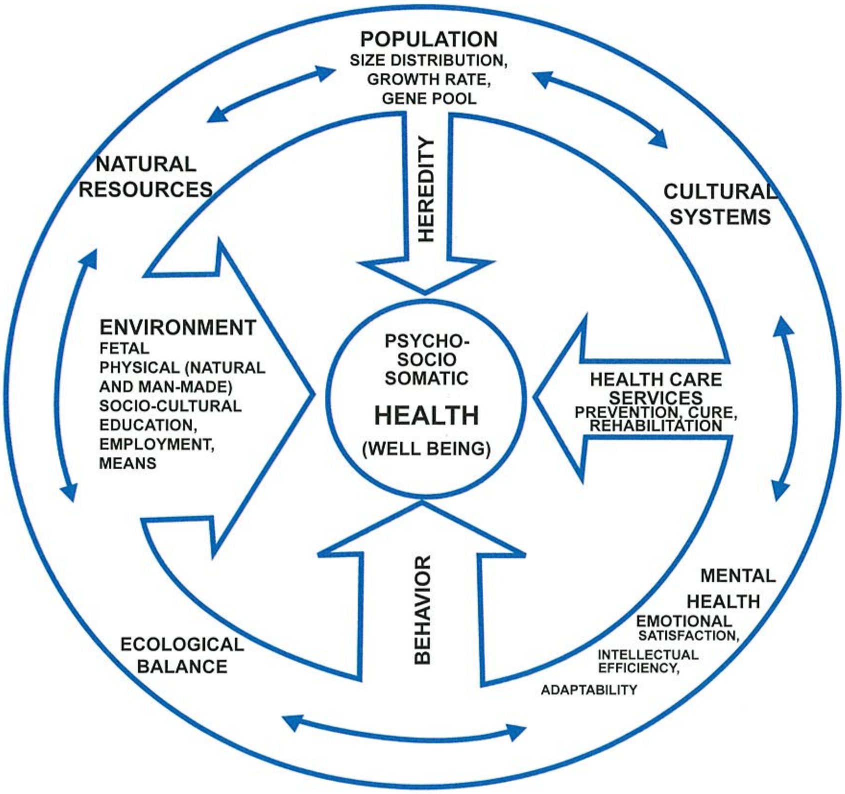


Figure 1.1 : The Environment of Health Model by H.L. Blum.

The main setback in combating issues of public health significance is that the intervention programmes usually come a bit too late. For example, by the time we would want to provide a safe water supply to a community, their children are already dying from diarrheal diseases; and by the time we want to reduce community exposure to air pollution, it has already taken its toll on asthmatics individuals. Our approaches have mainly been reactive and curative in nature. Through HIA in EIA, we are bringing public health intervention a step forward by making it more proactive and preventive. The health impacts are yet to be realized but we are already proactively prescribing mitigation measures to help alleviate the health problems even before they become a reality.

1.2 Defining Environmental Health

According to the World Health Organization (WHO), Environmental health comprises of those aspects of human health, including quality of life, that are determined by physical, chemical, biological, social, and psychosocial factors in the environment. It also refers to the theory and practice of assessing, correcting, controlling, and preventing those factors in the environment that can potentially affect adversely the health of present and future generations (WHO, 1993).

Assessing health impacts from the environment, and correcting, controlling and preventing the impacts from being realized, is the main strategy and approach in environmental health. All these tasks are embodied in HIA for the purpose of EIA. Environmental health is regarded as one of the sub-disciplines of public health. It is closely associated with occupational health which is another sub-discipline of public health. Both environmental health and occupational health deal with health threats originating from man's environment. While the former deals with man's ambient or general environment, as well as his home environment, the latter deals with man's work environment.

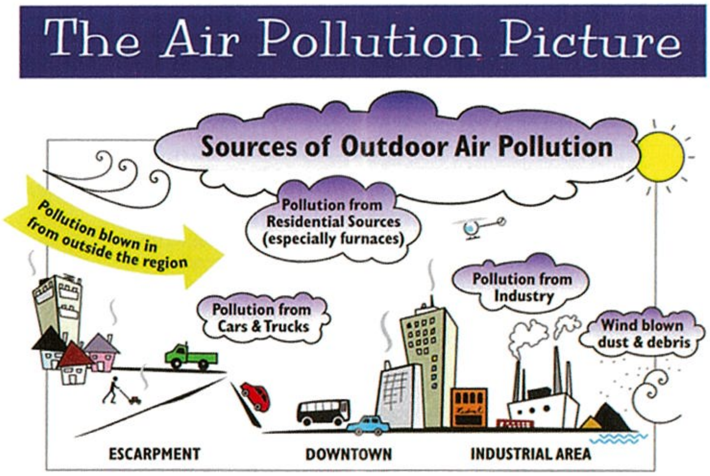
1.3 What is Health Impact Assessment ?

Health impact assessment (HIA) is the process of estimating the potential impact of a chemical, biological, physical or social agent on a specified human population system under a specific set of conditions and for a certain timeframe (EnHealth Council, 2001). HIA has also been defined as a combination of procedures, methods and tools by which a policy, programme or project may be judged as to its potential effects on the health of a population, and the distribution of those effects within the population (WHO European Centre for Health Policy, 1999). Thus, HIA may be applied for assessing the health impacts of policies, programmes or projects. It may also be conducted retrospectively, concurrently or prospectively. In this Guidance Document, we will focus specifically on HIA as it applies to EIA. Therefore, we will be restricting our discussions to project type HIA which is normally carried out prospectively.

The main approach in HIA for EIA is to assess the impacts of the proposed project on the health of the affected communities who reside within the vicinity of the project, that emanate from environmental impacts. However, because of the potential to transport pollutants over a distance, downwind or downstream of the project site, the affected communities may not be physically close. Nevertheless, human communities are the sensitive receptors in HIA that should be the focus of concern by the HIA consultant.

The assessment of health impacts may be complicated by the multiplicity of the sources of impacts. For example, the health impacts due to particulate in the atmosphere which can impact a particular community may be due to the emissions from a proposed coal-fired power plant, but they may also be related to the emissions from an existing cement plant or granite quarry or from vehicular traffic and wind blown dust from a neighbouring location (Box 1).

Box 1.1 : Multiplicity of the sources of pollution.



Source : www.cleanair.hamilton.ca/images/...ture.jpg

When assessing the potential health impacts of air pollution from a proposed development project, the HIA consultant must be able to appropriately apportion the air pollutants coming from the proposed project under consideration, relative to the other existing sources of air pollutants. This can be done by first modeling the potential release of incremental air pollutants from a proposed project. The existing air pollution in the area where the proposed project will be sited is taken as the baseline air pollution. Both the baseline and incremental air pollution are taken into account when assessing the non-carcinogenic effects of air pollution, but only the incremental air pollution is considered when assessing carcinogenic effects.

HIA in EIA in the Malaysian context refers to a health impact assessment of a development project or prescribed activities that are related to impacts on the environment, using a prescribed scientific methodology and applied in the process of an EIA; with the purpose of assessing the short and long term impacts of project activities on the health of the impacted communities, so that mitigation measures can be incorporated to minimized the adverse impacts.

1.4 Aims of Guidance Document

This HIA Guidance Document is intended to guide all stakeholders who include DOE officers, HIA and EIA consultants, project initiators and review panel members, on the purpose and format for conducting and reporting HIA studies as part of the EIA submission. However, it is not meant to provide a detailed step-by-step protocol for conducting HIA studies as this can be referred to literatures elsewhere. Nevertheless, it is meant to streamline the HIA approach so as to make HIA studies in Malaysia more uniform and comparable. The reason for not providing a detailed protocol in this Guidance Document is because HIA protocol is case-specific, there can be more than one acceptable protocol in each case, and that detailed HIA protocols have been published elsewhere and can be easily referred to. The main aims of this Guidance Document are :

i. To provide general guidance and information on the conduct of a health impact assessment in an EIA study.

ii. To provide information on the sources of health hazards arising from environmental impacts of development activities and their potential health impacts.

iii. To introduce a uniform and comparable methodology for health impact assessment in EIA.

iv. To provide examples of control and mitigation measures that can be taken to minimize the health impacts of a development project.

1.5 Scope of Health Impact Assessment

Health impact assessment (HIA) is becoming an increasingly important tool for assessing the health impacts of policies, programmes and projects. There are several guidelines on HIA, both general and specific, that has been published to describe the procedure. However to date, the authors have not encountered any HIA guideline that has been published to specifically address an EIA study. The aim of this Guidance Document is to specifically do that.

The application of HIA in Malaysia has been mainly in the context of an EIA study. However, due to the absence of a formal guideline on its implementation, various methodologies and formats have been employed by HIA consultants resulting in inconsistency in the HIA reports generated.

This HIA Guidance Document focuses only on health impacts that are related to environmental impacts and changes brought about by the project activities. It therefore, does not include occupational health impacts on workers or health impacts due to social changes brought about by the development project.

1.6 Why Undertake Health Impact Assessment

Prevention is always better than cure. HIA in EIA is an attempt to prevent the manifestations of adverse health impacts that may emanate from the environmental impacts of a proposed project. HIA not only help avoid unnecessary hardships due to negative health consequences, but preventing a health effect is certainly less costly than treating it.

While pollution control is reactive, EIA and thus HIA are proactive in nature. Pollution has to occur before we can implement pollution control through the use of pollution control equipments and treatment processes. EIA and HIA on the other hand are initiated well in advance of a pollution episode. In other words, HIA preempts a pollution event and its consequent health impacts.

Some health impacts or damages, especially long-term chronic effects, are usually irreversible. Such health impacts can be categorized as residual impacts. Irreversible health impacts such as end-stage renal failure, chronic obstructive airway disease, congenital malformation and advanced cancers are not only costly to manage but also debilitating to the victims. They may also trigger costly legal battles between the victims and the perpetrators which now seem to be a developing trend in developed countries.

CHAPTER 2

Principles of HIA

Chapter 2

Principles of HIA

Health impact assessment (HIA) may be conducted as a substudy or component of an EIA when the purpose of the HIA is to assess the health impacts of a proposed development project. In circumstances other than EIA, HIA may also be carried out as a separate process to assess the health impacts of a policy, programme or project. When HIA is conducted in the context of an EIA, the strategy and approach taken in the 2 assessments should be in concert as the former is part of the latter. For example, the steps involved in an HIA should synchronize with those of the EIA.

Health impacts of a development project can be expressed either as positive or beneficial impacts, or as negative or detrimental impacts. Ideally, both beneficial and detrimental health impacts should be taken into account in HIA. However, the preoccupation of HIA is to explore all possible detrimental health impacts and to propose effective mitigation measures for each of those impacts. Therefore, for the purpose of HIA in EIA in Malaysia, efforts should be focused on the detrimental impacts.

2.1 The EIA Process

Environmental Impact Assessment (EIA) is a study to identify, predict, evaluate and communicate information about the impacts on the environment of a proposed project and to detail the mitigating measures prior to project approval and implementation (DOE, 2009). EIA when integrated into the existing planning and decision-making structure, provides additional information towards a better decision-making process.

In Malaysia, Section 34A of the Environmental Quality Act, 1974, empowers the Minister of Natural Resources and Environment after due consultation, to prescribe any activity which may have significant environmental impact as a Prescribed Activity. The section further requires the Project Proponent of a Prescribed Activity to submit an EIA report to the Director General of Environmental Quality, before approval for the proposed activity is granted by the relevant approving authority. Activities subjected to EIA are prescribed under Environmental Quality (Prescribed Activities) (Environmental Impact Assessment) Order, 1987.

The EIA report must be in accordance with the guidelines issued by the DOE, contains an assessment of the impact of the Prescribed Activity on the environment, and details the proposed measures that shall be instituted to prevent, reduce or control adverse impacts on the environment. Depending on the nature of the Prescribed Activity, the potential adverse impacts that are usually addressed in an EIA are air quality impacts, water quality impacts, impacts on flora and fauna, traffic impacts, noise impacts, soil erosion impacts, fire and explosion risks, socioeconomic impacts, and of course, health impacts. Each category of impacts or risks will require a focused assessment effort. For health impacts, a HIA and a HIA report is called for. Thus, the preparation of this Guidance Document on HIA is to facilitate the conduct of an HIA for an EIA and the preparation of the report.

2.2 The HIA Process

The health impact assessment (HIA) process to be described here will be that undertaken for the purpose of an EIA. The HIA report generated from this process will be incorporated into and submitted together with the EIA report. Thus the HIA process detailed in this Guidance Document may share some similarities, but may also be different from other HIA processes described in the literature elsewhere. The HIA process described here will be in accordance with the general EIA process as prescribed for in the EIA Guideline published by the DOE.

2.2.1 Step 1 : Screening

The purpose of this first step in the HIA process is to screen the potential project for the need to conduct an HIA. HIA may not be necessary for the EIA of some development projects and prescribed activities. As a general rule, Detailed EIA tends to require an HIA, unless it can be objectively argued that an HIA is not necessary. HIA in EIA will be required for prescribed activities whose environmental impacts will pose significant adverse health impacts on the affected communities. The onus would be on the Project Initiator to objectively justify why an HIA would be necessary or otherwise.

To assist the Project Initiators and the Department of Environment in screening potential projects or prescribed activities that would require an HIA, a screening checklist as given in Appendix I has been developed.

2.2.2 Step 2 : Scoping

In the second step of scoping, the task would be to list the potential health impacts that may accrue from a proposed development project. The HIA consultant should begin by listing the project activities. The project activities are usually classified into 4 phases, namely the site preparation phase, project construction phase, project operational phase and project decommissioning or abandonment phase.

These project activities are very specific for each type of prescribed activity or project and for each project phase. The HIA consultant will need to scope for these specific project activities as well as their potential health impacts with the EIA consultant. As the project activities and potential health impacts will be project specific, it will not be practical to list out all of these in this guidance document.

2.2.2.1 Potential Health Impacts

The HIA consultant should first obtain a complete list of the project activities from the project initiator or the project management consultant. This task is normally undertaken by the lead EIA Consultant or the EIA Team Leader as a detailed description of the project activities and processes are required for the main EIA report. The EIA Team Leader should also provide information to the HIA consultant as to the major hazards or pollutants that may be released from these project activities and processes. For example, when coal is burned in a thermal power plant, we should expect air pollutants such as PM10, sulfur dioxide, nitrogen dioxide, hydrogen chloride, and heavy metals such as lead, arsenic, cadmium and nickel, to be released from the smoke stack. The HIA consultant should then decide which of the identified hazards or pollutants can pose as a health threat to a community who might be exposed to them.

Table 2.1 lists some generic project activities and their potential health impacts. It should be cautioned that there can be other health impacts that may emanate directly or indirectly from these project activities which have not been listed in Table 2.1. Occupational health impacts are not included in this table, for e.g. ergonomic problems from forestry and agricultural activities. Also excluded are health impacts due to social changes brought about by the development project, for e.g. sexually-transmitted diseases due to increased negative socialization from workers' in-migration and increased income. The reason for this is that we are focusing only on health impacts that are related to environmental impacts and changes brought about by the project activities.

Table 2.1 : Examples of potential health impacts by project activities.

Project activity	Potential health impacts
Land clearing/site preparation	• Accident injuries due to heavy vehicles. • Vector-borne diseases like dengue, chikungunya and malaria. • Respiratory and cardiovascular effects due to air pollution from heavy vehicles. • Nuisance due to noise from heavy vehicle use.
Deforestation/forestry	• Accident injuries due to logging. • Injuries due to animal attacks. • Poisoning from toxic plants and animals. • Vector-borne diseases like malaria and filariasis.
Agricultural activities	• Accident injuries due to agricultural machineries. • Health effects due to pesticide and chemical exposures. • Vector-borne diseases like malaria and filariasis. • Zoonotic diseases like Japanese B encephalitis, schistosomiasis, leptospirosis, avian flu, swine flu, etc. • Respiratory diseases like asthma and hay fever due to open burning and pollens. • Poisoning from toxic plants and animals.
Transportation	• Road traffic accidents. • Noise-induced hearing impairment from exposure to vehicle noise. • Respiratory and cardiovascular effects due to air pollution.

Table 2.1 (cont.) : Examples of potential health impacts by project activities.

Project activity	Potential health impacts
Construction of physical infrastructure	• Respiratory and cardiovascular effects due to construction dusts. • Noise-induced hearing impairment form exposure to piling and construction noise. • Accident injuries from falling objects and motor vehicles.
Dam impoundment	• Vector-borne diseases like malaria and filariasis. • Zoonotic diseases like schistosomiasis and leptospirosis. • Animal attacks and snake bites due to fleeing animals. • Injuries due to boat accidents. • Drowning.
Quarrying	• Accident injuries due to heavy vehicles, explosion, flying objects and landslides. • Noise-induced hearing impairment from explosion and quarrying noise. • Respiratory effects including silicosis due to quarry dusts.
Mining	• Accident injuries due to heavy vehicles and mining activities. • Poisoning from chemicals used in mining (e.g. sodium cyanide in gold mining), heavy metals and radionuclides. • Respiratory effects due to mining dusts. • Contamination of groundwater and rivers by heavy metals and radionuclides.
Petroleum refining	• Accidents and explosion from refining activities. • Respiratory effects from exposure to gaseous and particulate pollutants from flaring. • Respiratory effects from accidental release of air pollutants.

Table 2.1 (cont.) : Examples of potential health impacts by project activities.

Project activity	Potential health impacts
Emissions from combustion/incineration of fuel or wastes	• Respiratory effects due to PM10, nitrogen dioxide and sulfur dioxide (respiratory and cardiovascular morbidity, respiratory symptoms, asthma and reduced lung function). • Neurotoxic effects from inhalation exposure to neurotoxicants such as lead, mercury and arsenic. • Nephrotoxic effects from inhalation exposure to nephrotoxicants such as lead, mercury, arsenic, cadmium, nickel and chromium (VI). • Cancer from inhalation exposure to carcinogens such as cadmium, arsenic, nickel and chromium (VI).
Effluents from industrial discharge	• Health effects from ingestion exposure to various chemicals in the effluents. • Cancer effects from ingestion exposure to carcinogens such as cadmium, arsenic, nickel and chromium (VI).
Solid and hazardous wastes handling, storage, transportation and disposal	• Accidents due to sharp objects in wastes. • Health effects related to inhalation of volatile and gaseous wastes. • Health effects related to accidental ingestion of chemicals in wastes. • Health effects related to skin contact and penetration of liquid wastes. • Diseases related to vector/pest breeding such as dengue, chikungunya and leptospirosis.
Commercial and residential development	• Road traffic accident. • Annoyance and anxiety from traffic noise. • Respiratory effects from traffic air pollutants. • Vector-borne diseases like dengue and chikun-gunya. • Water and food-borne diseases like cholera and typhoid. • Rodent-transmitted diseases like leptospirosis.

2.2.3 Step 3 : Description of Existing Public Health Status

One of the steps in EIA is describing the existing environment prior to project implementation. This will provide us with a pre-project baseline environmental status which would include existing flora and fauna, existing air and water quality and current socioeconomic status. The impacts of the proposed project will be the change or the departure from the baseline environmental status brought about by the identified project activities.

Similarly, we can also define an existing public health status associated with the project. What is meant by this is the current health status or conditions of the community that may be vulnerable to the impacts of the project. These communities are termed as human receptors of the identified environmental threats. It should be made clear that the project area and the impact area of the human receptors may be closely situated or very removed from one another. For example, a human receptor area will be downwind from a stationary air pollutant source (e.g. a smoke stack) or downstream from an effluent release point.

2.2.3.1 Zone of Impact

The area of environmental impact around a proposed project is normally termed as the zone of impact (ZOI). This ZOI is arbitrarily taken as an area of 5 km radius from the boundary of the project site. Depending on the source strength and the pollutant dilution effect, the ZOI for health may be less or more than the 5 km radius boundary. For example, a municipal water treatment intake point that is 6 km downstream of an industrial effluent discharge point can still be considered as within the ZOI for health. Thus the ZOI for health must be defined on a project by project basis.

The potential human receptor locations in the vicinity of the project will practically define the ZOI for health. For an air pollution source, potential human receptor locations include residential areas, food premises and establishments, schools, hospitals, public parks and recreational areas, and food crop farms or plantations. For a water pollution source, potential human receptor locations include downstream villagers who consume raw water directly, water treatment plant intake points, food crop irrigation water intake points, water recreational areas with possible body contact activities and aquaculture farms.

In the case where there is no human receptor location identified within the ZOI of a proposed development project, then a HIA may not be necessary, even if the requirement is for a Detailed EIA study. This means that the conduct of a Detailed EIA study does not automatically make an HIA mandatory for the project. Likewise, this also mean that an HIA may be deemed mandatory when human receptor locations are identified within the ZOI of a proposed project, even when the assessment is only for a Preliminary EIA.

2.2.3.2 Morbidity Statistics

One reliable source of data on the existing public health status of the impacted community will be patient morbidity for selected environmentally related disease cases seen at nearby government health facilities. These are usually the District Hospital and the District Health Clinic. Environmentally related disease cases should include respiratory, cardiovascular, food-borne, water-borne, vector-borne, zoonotic diseases, and skin diseases, especially those related to atopy and hypersensitivity.

Preferably, the patient morbidity data should be obtained for a period of at least a year. Normally, request for such data must be made to the State Health Director. Upon approval, the District Hospital Director and Medical Officer of Health can be contacted to retrieve data from the District Hospital and District Health Clinic, respectively.

2.2.3.3 Community Health Survey

A community health survey is very useful in assessing the current health status of a community. However, it is labor intensive, time consuming and quite expensive to conduct. To minimize the time and resources needed, the survey is usually conducted in collaboration with the socio-economic survey conducted by the socio-economic study team. The two surveys will utilize the same sample of population.

The survey tool would be a health questionnaire. Assessments that should be included in the health questionnaire are :

i. Respondent's background information

ii. Household demographic information (age structure and gender)

iii. Sanitation facilities (toilet, solid waste disposal and drinking water source)

iv. Household members' morbidity profile of environment-related diseases (for e.g.: respiratory, cardiovascular, food-borne, water-borne, vector-borne, zoonotic and skin diseases).

2.2.4 Step 4 : Health Risk Assessment

Health risk is an outcome of health hazard and exposure to that hazard. In order for risk to be expressed, a health hazard must first be present. A health hazard may be biological, chemical or physical in nature. However, the presence of a hazard alone may not translate into an expression of risk. The other condition that is necessary for the expression of risk is exposure. This means that even if a hazard is present but exposure is prevented or averted, risk will not be realized. Thus, the first step in risk prevention is to eliminate the hazard. An example of this is the substitution of benzene, a leukemia-causing agent, with xylene or toluene. As such, the risk of leukemia among workers using solvents is effectively prevented. However, such a preventive measure is not always possible or practical. When elimination of hazard is impractical, exposure minimization is the alternative approach to minimize risk. Table 2.2 presents the risk of mortality experienced by a Malaysian due to various causes in 1998.

Regulatory actions are based on two distinct elements; risk assessment and risk management. Risk assessment is the use of the factual base to define the health effects of exposure of individuals or populations to hazardous materials and situations. Risk management is the process of weighing policy alternatives and selecting the most appropriate regulatory action, integrating the results of risk assessment with engineering data, and with social, economic and political concerns to reach a decision (NAS, 1996).

Risk minimization is a product of risk management. Risk must first be assessed before an attempt to minimize it can take place. Therefore, the goal of health risk assessment would be to identify and describe the risk, and subsequently, to assess the extent of exposure to the risk. With the information on hazard and exposure, risk can be adequately assessed and characterized.

Health risk assessment can also be defined as a methodological approach in which the toxicities of a chemical are identified, characterized, analyzed for dose-response relationships, and the data generated are applied to a mathematical model to produce a numeric estimate representing a guideline or decision concerning allowable exposure James (1985a). Health risk assessment is risk assessment applied for the assessment of health hazards from the environment.

Table 2.2 : Individual risk of mortality in Malaysia due to various causes in 1998.

Cause of mortality	Individual risk
Cardiovascular disease	5.7×10^{-4}
Cancers	2.2×10^{-4}
Motor vehicle accidents	1.7×10^{-4}
Pneumonia	8.7×10^{-5}
Kidney disease	4.8×10^{-5}
Chronic obstructive pulmonary disease	4.6×10^{-5}
Liver disease	3.6×10^{-5}
Drowning	2.5×10^{-5}
Falls	2.0×10^{-5}
Asthma	1.9×10^{-5}

Table 2.2 (cont.) : Individual risk of mortality in Malaysia due to various causes in 1998.

Cause of mortality	Individual risk
Suicide	1.3×10^{-5}
Homicide	9.0×10^{-6}
Fires and flames	7.1×10^{-6}
Accidental poisoning	4.2×10^{-6}
Accidents due to firearms and explosive	4.0×10^{-6}
Dengue Fever	2.1×10^{-6}
Railway accidents	2.1×10^{-6}
Natural disasters	1.7×10^{-6}
Struck by falling objects	8.9×10^{-7}

Adapted from Department of Statistics, Malaysia. 1999. *Vital Statistics Malaysia.* Estimated mid-year population in 1998 was 21,466,031.
Source : Jamal H.H. and Zailina H. 2004. Assessing cancer risks from chemical carcinogens. *Environmental Health Focus*, 2(2): 11-20.

There are two forms of health risk assessments, namely quantitative and qualitative health risk assessment. Quantitative risk assessment generates a numerical measure of the risk or safety of a chemical exposure. The numerical measure of the risk generated is compared against a guideline value or an acceptable risk level (James, 1985a). When conducting a quantitative risk assessment, there are two categories of risks being assessed, namely non-carcinogenic and carcinogenic health risk. Quantitative risk assessment is the preferred assessment for HIA in EIA whenever this is possible.

Qualitative risk assessment merely characterizes or compares the hazard of a chemical relative to others, or defines the hazard in only qualitative terms, such as mutagen or carcinogen, which connotes certain risk or safety procedures, and as such may not necessarily require a numerical assessment of risk (James, 1985a). Certain health risk that may be associated with risk due to communicable diseases may not lend well to quantitative risk assessment. Therefore, qualitative risk assessment may only be the assessment method possible. For example, the clearing of jungle land for agriculture activities may result in the propagation of certain disease vectors which in turn trigger the spread of vector-borne diseases.

2.2.4.1 Quantitative Health Risk Assessment

The outcome of a quantitative health risk assessment (HRA) should generate a numerical measure of the risk or safety of a chemical exposure. Quantitative HRA should contain some or all of the 6 steps, namely issues identification, hazard identification, dose-response assessment, exposure assessment, risk characterization and uncertainty analysis. The application of quantitative health risk assessment is mainly limited to the assessment of chemical hazards. Biological and physical hazards do not lend themselves well to quantitative assessment. In such cases, qualitative assessment should be applied.

Before we begin describing quantitative HRA, it should be understood from the beginning what it does and does not do. Quantitative HRA is an assessment and a decision-making tool that models the real human exposure to a hazard and the risk associated with it. However, it cannot depict what will actually occur in reality. It is a best estimate of reality which will guide us towards making the best decision on human exposure and risk. This means that it cannot preclude proper monitoring and auditing of the actual outcomes during project implementation.

I. Issues Identification

The purpose of this first step is to develop a Conceptual Site Model for the proposed project. This is done by exploring the Source-Pathway-Receptor link, the component of each is essential in the expression of risk. When even one component in this link is missing, risk will not eventuate. Hazard is the first component in the link without which, no risk will be posed. There can be one or more hazards associated with a proposed project. The next step of hazard identification is solely for the purpose of describing these hazards in detail.

These hazards will reach human receptors through one or several pathways, these being the inhalation, ingestion and direct contact pathways. The role of each of these pathways will in turn be dependent upon the magnitude of contamination of the associated environmental media. For example, an air pollution source like a coal-fired power plant will release the hazards cadmium, arsenic and dioxins amongst others, to the atmosphere. The exposure pathways to humans can be multiple. One is through direct inhalation of the hazards in air by the exposed humans. The other is through dry and wet depositions of the air pollutants onto food crops in the vicinity. Yet another is through wet deposition into the aquatic environment. These depositions will finally lead to contamination of the drinking water sources and human food chains. This can result in human exposure through the ingestion pathway.

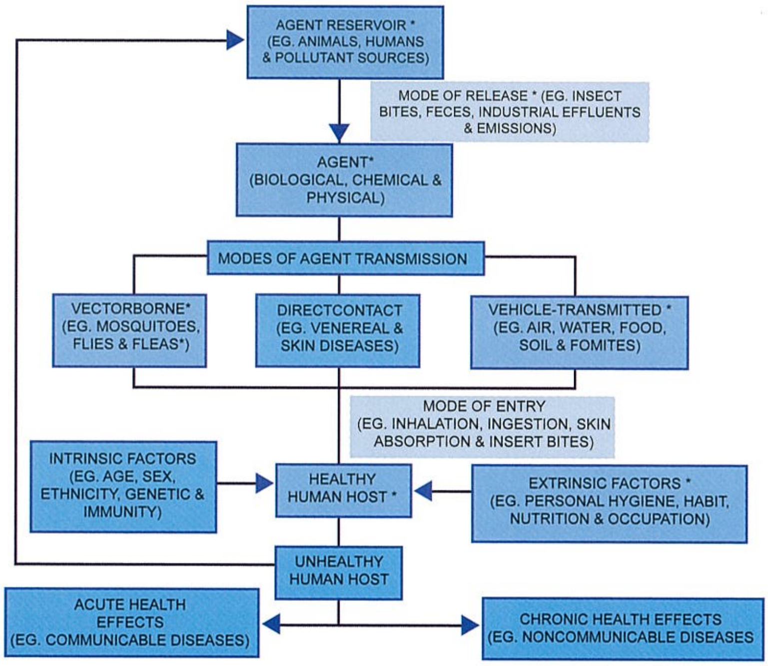
Human receptors are the final component in the link without which, health risk cannot be realized. Therefore, it is important to assess whether there are potential human receptors currently present in the area or there will be new human receptors moving into the area in the future. Both existing and potential human receptors can result in realization of health risk and must be taken into consideration in the assessment.

Box 2.1 gives a conceptual model in environmental health which can be used to assess the potential Source-Pathway-Receptor link. In the context of environmental health, the hazard is defined as the agent that may be associated with an adverse health effect. The agent that can be biological, chemical or physical in nature, originates from a source known as the reservoir. Upon release from its reservoir, transmission of the agent occurs through several pathways, either through direct contact, a vector or a vehicle.

II. Hazard Identification

This second step is the most easily recognized in the actions of regulatory agencies where information about a potential hazard is diligently sought in order to properly compile adequate information about the hazard in question. As mentioned earlier in this document, a health hazard can take the form of a biological, chemical or physical hazard. Hazard identification is defined as the process of determining whether exposure to an agent can cause an increase in the incidence of a health condition (cancer, birth defect, etc.). It involves characterizing the nature and strength of the evidence of causation (NAS, 1996).

Box 2.1 : Agent transmission pathway from reservoir to host in an environmental health conceptual model (source-pathway-receptor)



The Source-Pathway-Receptor link is depicted here in the movement of a hazard or agent from its source or reservoir, to the receptor or a healthy human host. Depending on the agent, which may be biological (e.g. *vibrio cholerae*), chemical (e.g. lead) or physical (e.g. noise) in nature, the reservoir may be an animal host, a human patient, or a factory. Once the agent is released into the environment though various means such as an insect bite or an industrial discharge, it is free to be transmitted to a healthy human host through direct contact, animal vector or inanimate vehicles such as air, water and food. The agent may be inhaled, ingested or skin absorbed by the host, and this completes the pathway link from the source (reservoir) to the receptor (human host).

Source : Jamal H.H. and Zailina H. 2004. Assessing cancer risks from chemical carcinogens. *Environmental Health Focus*, 2(2): 11-20.

Well-conducted epidemiological studies indicating a statistically significant association between exposure to the hazard and corresponding health effect will provide the most convincing evidence about human health risk from the hazard. Evidence about the hazard may be sourced from local as well as foreign epidemiological studies which have been scientifically published, preferably in refereed scientific journals. Alternatively, the information may be extracted from scientifically reliable databases such as the U.S. EPA's Integrated Risk Information System (IRIS), Agency for Toxic Substances and Disease Registry's (ATSDR) Toxic Substances Portal, or from other reliable published literature. For example, the association between carbon monoxide and neurotoxicity through the formation of the carboxy-haemoglobin complex is a well known fact and can be referenced from any of the literature mentioned above. Information from the U.S. EPA's IRIS and ATSDR's sites will provide adequate information on both the carcinogenic and non-carcinogenic health effects of a chemical hazard.

III. Dose-response Assessment

Once a chemical hazard has been adequately identified, the third step would be to assess its toxicological profile in terms of its dose-response relationship. A dose response-relationship describes the increase in the probability of an adverse effect with a corresponding increase in the exposure dose to the hazard in question. Therefore, some forms of toxicological parameters must be used to describe this relationship in order to enable us to assess the health risk that would be associated with a particular exposure dose of the hazard.

The first parameter is the oral Reference Dose (RfD). The oral RfD is an estimated daily oral exposure of a toxicant, with uncertainty spanning perhaps an order of magnitude, to the human population including sensitive subgroups, that is likely to be without an appreciable risk of deleterious effect during a lifetime of 70 years. The unit of oral RfD is in mg/kg-day, which means that a certain dose in mg of the toxicant can be ingested safely by an exposed person for every kg of his body weight, over his entire lifetime of 70 years, without showing the health effect in question. The protection accorded by an oral RfD is against a specific health effect and not for all potential health effects of a toxicant. However, the health effect in question is usually the most sensitive health effect known at any particular point in time (adapted from U.S. EPA, 2002 and IRIS, 2009).

For inhalation exposure, an inhalation RfD may also be prescribed in the unit of mg/kg-day. However, a more commonly used parameter is the Reference Concentration (RfC). The RfC is an estimated daily concentration of a toxicant in air, with uncertainty spanning perhaps an order of magnitude, of which an inhalation exposure to the human population including sensitive subgroups, is likely to be without an appreciable risk of deleterious effect during a lifetime of 70 years. The unit of RfC is usually in mg/m^3. Therefore, while the oral RfD is described in the form of an oral dose, the RfC is described in the form of an air concentration which may be safely inhaled by an exposed person over his entire lifetime of 70 years (adapted from U.S. EPA, 2002 and IRIS, 2009).

Oral RfD and RfC are dose-response parameters used by the U.S. EPA to describe a safe oral ingestion dose and a safe air concentration for inhalation exposure, respectively, for non-carcinogenic health effects. The Agency for Toxic Substances and Disease Registry (ATSDR) also publishes a dose-response parameter in the form of the Minimal Risk Level (MRL). The MRL is an estimate of the daily human exposure to a hazardous substance that is likely to be without appreciable risk of adverse, non-cancer health effects over a specified duration of exposure. (ATSDR, 2009a). The information in the MRL serves as a screening tool to help public health professionals decide where to look more closely to evaluate possible risk of adverse health effects from human exposure.

Oral RfD and RfC can also be referred to as threshold dose and threshold concentration, respectively. What this means is that there is a threshold or safe level on the dose-response curve, below which a non-carcinogenic health effect will not be observed or detectable. When such a threshold is crossed or exceeded, health effect related to the toxicant exposure will begin to appear. Since both oral RfD and RfC refer to a lifetime exposure to the toxicant, exposure at these prescribed level over a lifetime of 70 years will not elicit a non-carcinogenic health outcome.

For carcinogenic health effect, a threshold level cannot be determined. This means that at any dose above zero, there is some probability of a cancer occurrence. In other words, the dose-response curve for carcinogenic effect begins at the origin. For carcinogenic effect, the applicable dose-response parameter is the cancer slope factor or the cancer potency factor. The cancer slope factor is defined as the probability of cancer per unit dose in mg/kg-day

$$\text{Cancer slope factor} = \frac{\text{Probability of cancer}}{\text{Dose in mg/kg-day}}$$

IV. Exposure Assessment.

The two main components of risk are hazard and exposure. In order to experience health risk, a health hazard, be it biological, chemical or physical, must first be present. Without a hazard, there can be no risk. Therefore, the preferred approach for risk elimination is hazard elimination or substitution. However, this preferred approach of hazard elimination is usually impractical.

The next best available approach would be risk minimization which can be achieved through minimizing exposure. When we limit or minimize exposure to a specific hazard, the subsequent health risk will be minimized. Risk minimization rather than risk elimination is the practical goal in risk management. Proposed mitigation measures are part of risk management strategy which are aimed at minimizing risk.

Exposure assessment is the fourth step in risk assessment and is a prelude to risk management through exposure minimization. In the previous section, we have elaborated on dose-response assessment which describes the relationship between exposure dose and an adverse health effect. Therefore, if the exposure dose is known or can be predicted, we can describe the adverse health effect that will be manifested. If exposure has already taken place, we can measure the exposure and correlate it with the health effect outcome. When exposure is yet to be experienced, then the adverse health effect will have to be predicted through health risk assessment. Since EIA is meant to be carried out before the commencement of a project, then HIA in EIA is of this nature.

For the purpose of applying HIA in EIA, human exposure to an environmental hazard has to be predicted or modeled. This is normally done by other EIA team members in consultation with the HIA consultant, namely the air quality modeler or the water quality modeler. In modeling human exposure to an environmental hazard, the following guidelines should be observed

a. The modeling should reflect the most likely human exposure. For example, when the downwind concentration of an air pollutant coming out of a smoke stack is being modeled and predicted, its concentrations should be predicted at the nearest downwind human receptor locations like residential areas, schools and hospitals. When the downstream concentration of a water pollutant released in an effluent is being modeled and predicted, its concentrations should be predicted at water intake points or locations of recreational activity downstream.

b. The prediction of pollutant concentrations downwind and downstream of the pollutant source should be done under two exposure scenarios. One scenario is the "normal operation" exposure scenario when all pollution control equipments are functioning properly. The other scenario is the "worst-case or abnormal operation" exposure scenario when there is a breakdown of the pollution control equipments.

V. Risk Characterization

Risk characterization is the final step in the risk assessment process. It is the process of estimating the incidence of a health effect under various conditions of human exposure described in exposure assessment. It is carried out by combining the dose response and exposure assessment steps. In other words, if we know the exposure dose, we can use the dose-response relationship to estimate the incidence of the health effect. Risk characterization also represents an estimate of the magnitude of the public health problem (NAS, 1996).

Risk characterization is carried out differently for non-carcinogenic and carcinogenic risks. A chemical hazard can have either a non-carcinogenic or carcinogenic risk or even both. The reason for this different treatment of non-carcinogenic and carcinogenic risk is for the same reason as explained earlier that a threshold level exists for non-carcinogenic risk but not for carcinogenic risk.

The first step in risk characterization is to compute the total intake of a toxicant into a human body, which reflects the body burden of the toxicant. The total toxicant intake can be termed as the average daily dose (ADD) for non-carcinogenic risk and lifetime average daily dose (LADD) for carcinogenic risk. The computation of the ADD and LADD need to take into account :

Route of intake – The route of toxicant intake into the human body can be through inhalation, ingestion or skin absorption. This will depend on the state or nature of the toxicant. If the toxicant is in the form of a gas, vapour, mist or respirable particulate (PM10), it may be inhaled and absorbed through the lungs and enters the bloodstream. If it is a liquid or a solid, it may be ingested, absorbed by the linings of the stomach and intestines and enters the bloodstream. If the toxicant is a vapour, mist or liquid, it may enter a person's body through skin absorption. For some exposure scenarios, there can be more than one routes of exposure. For example, when a person swims in a contaminated river, the toxicant may enter his body through accidental ingestion of the contaminated water as well as through absorption through his skin.

Magnitude of intake – This refers to the rate of intake of the toxicant into the human body, in term of mg/day. It is a function of one, the concentration of the toxicant in the contaminated media (air, water or food) at the point of contact with the exposed person; and two, the intake rate of the contaminated media per day. The concentration of toxicant in air is usually expressed as mg/m^3, while its concentration in water is usually expressed as mg/L. Default values are used to prescribe the intake rate of contaminated media per day. For example, the default air intake or inhalation rate is 20 m^3/day, while the default water ingestion rate is 2 L/day. A less commonly encountered default intake value is for leafy vegetables which has been suggested as 10 g/meal (Louvar and Louvar, 1998).

Frequency of intake – Frequency of intake describes the frequency with which intake of the toxicant into the human body takes place. For example for inhalation exposure, the frequency should be 365 days/year since a person never stop breathing while alive. However, we normally only apply a frequency of 350 days/year, as we assume that a person will be away from his place of residence for 15 days or 2 weeks in a year. For other exposure events like swimming or ingestion of a certain food item, the frequency has to be arbitrarily determined by the HIA consultant. For example for swimming, it can be set at 1 swim per month or 12 swims per year. For consumption of leafy vegetables, it can be set at once or twice per week.

Duration of exposure – Risk is indeed a function of the dose and total duration of exposure. The magnitude of intake determines the dose of exposure. The total duration of exposure is in turn a product frequency of intake and duration of exposure. The duration of exposure can reach a maximum human lifetime of 70 years. However, a more appropriate duration of exposure will be related to the lifespan of the project.

a. Acute Health Risk

Health risks or effects can be categorized as acute and chronic health risks. An acute health risk is one producing a usually reversible response characterized by a sudden onset of short duration, following a short exposure period to a high pollutant or toxicant dose. Examples would be the release of air pollutants during an abnormal operation of a thermal power plant. However, reversibility of an acute health risk is an arbitrary descriptor as death can also be termed as an acute health risk, which is clearly not reversible.

Acute health risks from exposure to a specific toxicant may be described by simply comparing an exposure concentration or dose to a guideline level set by a regulatory or non-regulatory authourity. For example, the Department of Environment Malaysia issues the Malaysian Ambient Air Quality Guideline (MAAQG) (Appendix III). Most of the MAAQG values prescribing averaging exposure durations of 1, 8 and 24 hours, primarily refer to acute health risks. Therefore, to avoid acute health risks from exposure to the prescribed air pollutants, their MAAQG concentrations should not be exceeded. For example, the MAAQG concentrations for sulfur dioxide over 10 minutes, 1 hour and 24 hours are 500, 350 and 105 $\mu g/m^3$, respectively. Another reference guideline is the US National Ambient Air Quality Standards (US NAAQS) (Appendix IV). For example, while both the MAAQG and the US NAAQS prescribe a 24-hour PM10 guideline concentration of 150 $\mu g/m^3$, only the US NAAQS prescribes a 24-hour PM2.5 guideline concentration of 35 $\mu g/m^3$.

Another reference for acute health risks is the Agency for Toxic Substances and Disease Registry's minimal risk levels (MRL) (ATSDR, 2009b). For example, the acute inhalation levels for benzene, toluene and ammonia are 0.009, 1 and 1.7 ppm, for immunological, neurological and respiratory health risks, respectively. Therefore, to prevent acute neurological effect from inhalation exposure to toluene, the air exposure concentration of toluene should not exceed 1 ppm. The acute oral ingestion dose for heptachlor, arsenic and xylene are 0.0006, 0.005 and 1 mg/kg.day, for reproductive, gastrointestinal and neurological health risks, respectively. Therefore, to prevent acute gastrointestinal effect from ingesting arsenic, the ingested dose of arsenic should not exceed 0,005 mg/kg.day.

b. Chronic Health Risk

A chronic health risk is one producing a usually irreversible response characterized by a gradual onset of long duration, following a constant or continuous exposure period to a low pollutant or toxicant dose. Examples of these would be organ damage like the kidneys and lungs, as well as cancers. A chronic health risk culminating in a non-cancer endpoint is known as a non-carcinogenic risk, while that leading to a cancer endpoint is known as carcinogenic risk.

i. Non-carcinogenic Risk

The non-carcinogenic risk is expressed using the hazard quotient (HQ). For ingestion exposure of a specific toxicant, HQ is a ratio of the average daily dose (ADD) to the reference dose (RfD). For inhalation exposure, HQ is the ratio of the exposure air concentration (EC) to the reference concentration (RfC). The formula are given below :

For ingestion : $HQ = \frac{ADD}{RfD}$

For inhalation : $HQ = \frac{EC}{RfC}$

Where,

HQ = Hazard quotient (unitless)
ADD = Average daily dose (mg/kg-day)
RfD = Reference dose (mg/kg-day)
EC = Exposure air concentration (mg/m^3)
RfC = Reference concentration (mg/m^3)

Below is an example of how ADD can be calculated for a food ingestion exposure.

$$ADD = \frac{C_F \times Ri \times Fi \times EF \times ED}{BW \times AT}$$

Where, ADD = Average daily dose of pollutant through ingestion of food (mg/kg.day)
C_F = Pollutant concentration in a food item (mg/kg)
Ri = Food item ingestion rate (e.g. 0.01 kg/meal for leafy produce)
Fi = Fraction ingested from contaminated source (unitless) (e.g. 0.2 for leafy produce)
EF = Exposure frequency (e.g. 26 meals/yr)
ED = Exposure duration (e.g. 20 yr)
BW = Body weight (70 kg)
AT = Averaging time (days); for non-carcinogenic effects; AT = ED = 20 years or 7,300 days

For further reference on the calculation of the ADD through various inhalation, ingestion and body contact routes, please refer to the Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities by the U.S. EPA (2005), and the Exposure Factors Handbook by the U.S. EPA (2007 and 2009).

In determining the concentration of a pollutant in an environmental media (air, water or food item), it is taken as the existing, baseline concentration in the environmental media plus the incremental concentration to be contributed by the proposed project. While the baseline environmental concentration will come from environmental monitoring of the existing environment, the incremental concentration will be determined through environmental modeling.

ii. Carcinogenic Risk

For ingestion exposure, the lifetime cancer risk (LCR) is estimated by the product of the lifetime average daily dose (LADD) and the cancer slope factor (CSF). For inhalation exposure, LCR is estimated by the product of exposure air concentration (EC) and the unit risk factor (URF). The formula are given below :

For ingestion : LCR = LADD x CSF

For inhalation : LCR = EC x URF

Where,

LCR = Lifetime cancer risk (unitless)
LADD = Lifetime average daily dose (mg/kg-day)
CSF = Cancer slope factor $(mg/kg\text{-}day)^{-1}$
EC = Exposure air concentration (mg/m^3)
URF = Unit risk factor $(mg/m^3)^{-1}$

Calculating for the LADD is almost similar to calculating for the ADD, except for some differences. Firstly for LADD, the averaging time (AT) is always taken as 70 years, even when the exposure duration (ED) is less than that. The reason for the 70 years averaging time is that even though the exposure to carcinogen is lesser than a person's lifetime, the risk of developing cancer from that exposure extends over a person's lifetime. For example when a smoker stops smoking, even though his risk of developing lung cancer due to smoking will diminish, it will not be as low as that of a non-smoker. It means that his risk of developing lung cancer from his previous exposure to smoking is now spread over his entire lifetime of around 70 years. Secondly, the pollutant concentration in the environmental media should be the incremental pollutant concentration that will be contributed by the proposed project only, without adding the existing, baseline environmental concentration.

Below is an example of how LADD can be calculated for a food ingestion exposure.

$$LADD = \frac{C_F \times Ri \times Fi \times EF \times ED}{BW \times AT}$$

Where, LADD = Lifetime average daily dose of pollutant through ingestion of food (mg/kg.day)
C_F = Incremental pollutant concentration in a food item (mg/kg)
Ri = Food item ingestion rate (e.g. 0.01 kg/meal for leafy produce)
Fi = Fraction ingested from contaminated source (unitless) (e.g. 0.2 for leafy produce)
EF = Exposure frequency (e.g. 26 meals/yr)
ED = Exposure duration (e.g. 20 yr)
BW = Body weight (70 kg)
AT = Averaging time (days); for non-carcinogenic effects; AT = 70 years or 25,550 days

For further reference on the calculation of the LADD, please refer to the Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities by the U.S. EPA (2005) and the Exposure Factors Handbook by the U.S. EPA (2007 and 2009).

iii. Acceptability of Risk

As events or activities in life are never risk-free, society must identify a level of risk they consider as acceptable or tolerable. Government agencies and the courts sometimes refer to this acceptable risk as reasonable risk. Acceptable risk is a societal acceptance of a level of risk, which those who are being subjected to the risk, consider as tolerable or as something they can live with comfortably. Thus, acceptable risk may vary from society to society or from community to community. A consensus on acceptable risk should be reached by comparing costs, benefits and alternative risks, especially those that have previously been accepted as tolerable (Louvar and Louvar, 1998). Therefore, a community which tends to benefit from a particular project or activity in their neighborhood, such as employment opportunity will be willing to accept a higher level of risk from that project when compared to a community which does not seem to benefit much.

The one in a million or 10^{-6} acceptable risk level for a potentially fatal event such as cancer is a societal guideline rather than a norm. The Food and Drug Administration (FDA) in the United States was the first government agency to use risk assessment to make regulatory decisions. They first proposed a method for the regulation of carcinogenic drugs used in food producing animals in 1973 with an acceptable lifetime risk level of 10^{-8}. Later, this acceptable risk level was revised to 10^{-6}. This minimal risk level came to be known as *de minimis* risk, which means that the risk is so small that it should be beyond concern. The phrase *de minimis* was derived from the Latin phrase *de minimis non curat lex*, which is a well established principle in American common law, meaning that the court should not concern itself with trifles (Peterson, 2002).

The U.S. EPA does not make any definitive stand on the acceptable risk level. However, with respect to cleanup of hazardous waste sites, the agency requires a cleanup that would bring the level of public risk to below 10^{-6} (Hallenbeck, 1993). The first use of acceptable risk in any environmental guidance appears to have been a part of the Superfund Public Health Evaluation Manual, issued in 1986 and now superseded by the National Contingency Plan (1990) for hazardous waste sites. The plan specifically states that 10^{-6} should not be presumed to be the final target risk for hazardous waste sites, but instead a "point of departure" for deciding an appropriate target level. Levels of 10^{-6} to 10^{-4} are given as a range of "generally acceptable risk," with the option that even 10^{-4} may be exceeded in some circumstances (Kelly, 1991).

Table 2.3 shows the cumulative or lifetime risk of selected cancers among Peninsular Malaysians in 2006 whereby the overall risk for both sexes was 1.4 x 10^{-1} or between 1 to 2 cancers for every 10 persons (Zainal *et al.*, 2006). This represents the background cancer risk level for Peninsular Malaysians due to all causes of cancers. By ethnicity, the Chinese have a slightly higher risk of developing cancers compared to the Malays and Indians. While breast cancer is most common among females, colorectal and lung cancers are most prevalent among males. In comparison to this, the 10^{-6} to 10^{-4} acceptable risk range would seem very small.

Table 2.3 : Cumulative risk of selected cancers among Peninsular Malaysians in 2006.

Cancers by sex, ethnicity and sites	Cumulative Risk
By sex	
Males	1.4×10^{-1}
Females	1.4×10^{-1}
Both sexes	1.4×10^{-1}
By ethnicity and sex	
Malay males	1.1×10^{-1}
Malay females	1.0×10^{-1}
Chinese males	1.6×10^{-1}
Chinese females	1.6×10^{-1}
Indian males	1.1×10^{-1}
Indian females	1.5×10^{-1}
By cancer sites and sex	
Breast in females	4.2×10^{-2}
Colorectal in males	2.7×10^{-2}
Lung in males	2.5×10^{-2}
Colorectal in females	1.8×10^{-2}
Prostate gland in males	1.4×10^{-2}
Cervix uteri in females	1.4×10^{-2}
Lung in females	1.0×10^{-2}
Nasopharynx in males	0.9×10^{-2}
Liver in males	0.9×10^{-2}
Ovary in females	0.8×10^{-2}
Bladder in males	0.8×10^{-2}
Stomach in males	0.8×10^{-2}
Thyroid gland in females	0.7×10^{-2}
Lymphoma in males	0.6×10^{-2}
Corpus uteri in females	0.5×10^{-2}
Stomach in females	0.5×10^{-2}

Source : Zainal A.O., Zainudin M.A. and Nor Saleha I.T. 2006. Malaysian cancer statistics – Data and figure, Peninsular Malaysia 2006. Kuala Lumpur : National Cancer Registry, Ministry of Health Malaysia.

Therefore, as a guideline, the acceptable lifetime carcinogenic risk range will be taken as a range between 10^{-6} to 10^{-4}, or between 1 cancer for every million of exposed population to 1 cancer for every 10,000 of exposed population, over a lifetime duration of 70 years. Carcinogenic risk smaller than 10^{-6} will be deemed as "clearly acceptable" while that larger than 10^{-4} will be deemed as "clearly unacceptable."

VI. Uncertainty Analysis

Quantitative HRA requires several input parameters which are usually taken as default values. These default values are used in the calculation of average daily dose (ADD) and lifetime average daily dose (LADD). Examples of such default values are inhalation rate of 20 m^3/day, water ingestion rate of 2 L/day, exposure duration of 350 days/year and body weight of 70 kg. These default values represent average values or that of an average person. However, we know that in reality each of these parameters spans a range of possible values. For example, the actual inhalation rate will vary between a male and a female, and between a child and an adult.

Quantitative HRA is also not a tool that can emulate or model "reality" with unquestionable accuracy and precision. The model it generates is a representation of reality which the scientific tools of today will render. Therefore, there is always a certain degree of uncertainty involved in the quantitative HRA process. This uncertainty is internalized in the form of assumptions made by the HIA consultant. These assumptions made, in term of the various default values used, should be clearly interpreted by the HIA consultant as it applies only to the assessment under consideration and not under all circumstances.

2.2.4.2 Qualitative Health Risk Assessment

Quantitative health risk assessment is mainly applicable to the assessment of chemical and physical hazards like ionizing radiation. For most biological hazards like infectious disease agents and physical hazards like noise and electromagnetic frequency, quantitative assessment may not be possible due to the lack of quantitative dose-response parameters such as the reference dose and cancer slope factor. Therefore, qualitative method is the only mean available to assess the health risk from exposure to these hazards.

For qualitative health risk assessment, there is no prescribed methodology to abide by. Basically, it would be merely listing and describing the probable change in health outcomes or endpoints that would be realized due to a prescribed activity. For example, the construction of a sanitary landfill may lead to potential breeding of pests like rodents and disease vectors like mosquitoes and flies. We cannot effectively predict the quantum of increase in the populations of rodents or mosquitoes or the subsequent increase in the prevalence of diseases associated with them. Thus, the prediction of the health impacts will be qualitative in nature in term of the potential increase in the prevalence of diseases or health outcomes without mentioning of the quantum of increase. An example of a qualitative risk assessment tool in the form of a qualitative risk assessment matrix is presented in Appendix V.

2.3 Residual Health Impacts

A health impact may be categorized as residual when a measurable impact remains even after prescription of mitigation measures. For example when addressing a carcinogenic risk, the assessed risk will not approach zero as a threshold does not exist for carcinogenic risk. However, the residual carcinogenic risk may still fall within the acceptable risk range.

Another example of a residual health impact is when a significant health impact is realized but over a short duration of time. For example, during an abnormal thermal power plant operation when the air pollution control equipment such as an electrostatic precipitator malfunctions, the particulate pollutant released will be maximized. However, as a power plant usually has an automatic shutdown system during an abnormal operation, the duration of exposure to this maximum level of air pollutant will be minimized. This maximum exposure level to an air pollutant can be considered as a residual health impact. However, this residual health impact can be considered as acceptable if the duration of exposure is minimized. This assumption takes into account the fact that health risk is a function of the dose and duration of exposure to a health hazard. Therefore, even if the dose of exposure to a health hazard may be high, health risk can be acceptable if the duration of exposure to the health hazard can be minimized.

Nevertheless, whenever a residual health impact is identified by an HIA consultant, regardless of whether the residual health impact is deemed acceptable or not, the HIA consultant must give due consideration and attention to a residual health impact. The HIA consultant must reassure stakeholders that a residual health impact will not turn into a significant adverse health outcome. One form of reassurance is to draft up an emergency response plan.

2.4 Mitigation Measures

Mitigation measures represent measures to be taken by the Project Initiator that will help overcome or alleviate the adverse impacts from a proposed project. Since health impacts are mostly secondary impacts that stem from primary impacts on the physical and biological components of the environment, mitigation measures are usually prescribed to address these primary impacts first. In mitigating these primary impacts, the consequential health impacts will also be mitigated. Therefore, mitigation measures are usually not prescribed to address health impacts directly.

Health impacts that may be directly generated are occupational health impacts. Examples of these would be occupational diseases like noise-induced hearing loss and work accidents. In such cases, health specific measures will have to be proposed. However, occupational health impacts are not within the scope of this Guidance Document, and therefore will not be dealt with here. Table 2.4 gives examples of potential health impacts and proposed mitigation measures.

Table 2.4 : Potential health impacts and proposed mitigation measures.

Potential health impacts	Proposed mitigation measures
• Vector-borne diseases like dengue, chikungunya, malaria and filariasis.	• Vector control through elimination of breeding sites, larviciding and adulticide fogging.
• Water-borne and food-borne diseases like cholera, typhoid and hepatitis A due to improper sewage and solid waste disposal.	• Good sanitation which include hygienic toilet, clean water supply and proper solid waste disposal.
• Air-borne and skin diseases due to overcrowding.	• Proper housing and living quarters.
• Health effects due to pesticide and chemical exposures.	• Proper storage, use and disposal of pesticides wastes. • Proper training of pesticide applicators. • Regular medical examinations and biomonitoring of pesticide exposure.
• Respiratory effects from exposure to dusts from heavy vehicles, construction and mining activities.	• Wet method to control dusts and good traffic management.
• Road traffic accidents.	• Proper traffic management.
• Accidents from explosion, flying objects and landslides from quarrying, mining and refining activities.	• Implementation of adequate buffer zones and safe work practices.
• Noise-induced hearing impairment from exposure to vehicle noise.	• Installation of sound barriers and proper traffic management

Table 2.4 (cont.) : Potential health impacts and proposed mitigation measures.

Potential health impacts	Proposed mitigation measures
• Noise-induced hearing impairment from exposure to piling, construction noise, explosion and quarrying noise.	• Reduced operational hours and implementation of adequate buffer zones
• Respiratory effects including silicosis from exposure to quarry dusts.	• Wet method to control quarry dusts.
• Respiratory effects from exposure to gaseous and particulate pollutants from flaring and accidental release.	• Proper flaring conditions and adequate stack height.
• Respiratory and systemic effects including cancers from inhalation exposure to particulate, gaseous and chemical pollutants from stack emissions.	• Installation of proper air pollution control equipment such as baghouse, electrostatic precipitator and flue gas desulfurization
• Poisoning from chemicals used in mining (e.g. sodium cyanide in gold mining).	• Proper transportation, storage and use of chemicals.
• Health effects including cancers from ingestion exposure to various chemicals in effluents.	• Adequate treatment of wastewater.

Table 2.4 (cont.) : Potential health impacts and proposed mitigation measures.

Potential health impacts	Proposed mitigation measures
• Accidents, health effects due to accidental ingestion and contact with solid and hazardous wastes.	• Proper handling, transportation, storage and disposal of solid and hazardous wastes.
• Health effects related to chemical contamination of the groundwater from landfilling.	• Proper lining of landfills. • Proper management and treatment of leachate.

CHAPTER 3

Implementation Issues

Chapter 3

Implementation Issues

3.1 HIA Team

The conduct of an HIA involves several tasks which may need to be executed by several individuals. These tasks should be coordinated by an HIA Consultant. The other team members may include other EIA consultants in-charge of other tasks in EIA such as a socio-economic consultant, air quality modeler, water quality modeler and survey enumerators.

3.1.1 HIA Consultant

The HIA consultant should be a registered EIA consultant or a subject consultant with the DOE. He should be formally trained in the field of environmental health or public health at a tertiary education level, and has acquired relevant experience in health impact and quantitative health risk assessment. Basic knowledge in the medical or health sciences, epidemiology, toxicology, environmental health and occupational health is vital. Without such knowledge, an HIA consultant may be able to conduct an HIA exercise but will not be able to appreciate its human health relevance and interpret the assessment results appropriately.

3.1.2 Environmental Quality Modelers

The information input for an HIA will normally come from the EIA on air and water quality. This information will be used by the HIA consultant to model the non-carcinogenic and carcinogenic health risks associated with community exposure to the health hazards. This information will be generated by environmental quality modelers, namely air and water quality modelers. Therefore, they are very much part of the HIA Team.

To ensure that the environmental quality modelers generate relevant information for HIA, the HIA consultant should properly enlighten them on the type and details of information required, as well as the locations of human receptors for modeling hazard or pollutant dispersion in the environment.

3.1.3 Quantitative Risk Assessment Consultant

Quantitative risk assessment (QRA) in EIA assesses mainly fatality risks associated with untoward incidences such as explosions and fires. An outcome of this assessment is fatality risk contours to assess the potential risk of death to workers within the project site as well as to the public outside the project boundary, and to compare this risk with risk guidelines established by the DOE. QRA in EIA is done as a separate exercise from HIA as QRA deals with fatality due to accidents, while HIA dwells on the acute and chronic health effects from exposures to hazards related to the proposed project activities.

3.2 Ethical Issues

Ethical issues are an overriding concern among EIA consultants. As registered and regulated professionals, they should exhibit professional and exemplary conduct of utmost quality when performing EIA tasks. For HIA consultants, this professional ethics is doubly important as the outcome of their work will affect human lives and have human health implications for many years into the future.

Even though HIA and other EIA consultants are financially compensated for their work by the Project Initiator, it should be clearly emphasized that their responsibility rests with ensuring the health, welfare and safety of the community impacted by the proposed project. On top of that, HIA consultants are accountable for their work not only to the Project Initiator, but more so to the Department of Environment, the impacted community, the public at large, as well as other relevant stakeholders.

3.3 Limitations of HIA

HIA consultants must be aware of the limitations of HIA and its assessment outcomes. The modeling of exposure to a hazard in quantitative health risk assessment is based on a number of assumptions like the frequency and duration of exposure, average human body weight, rate of respiration and rate of food ingestion. In deterministic modeling, these parameters are taken as a single value or point estimate. Therefore, the outcome of the modeling may not be representative for all individuals in the community but more for an average individual.

CHAPTER 4

Case Study

Chapter 4

A Case Study

4.1 A Local Case Study

The case study presented here does not represent the entire scope of a health impact assessment (HIA) in environmental impact assessment (EIA). It however focuses on the application of the quantitative health risk assessment (HRA) methodology for HIA of a proposed small-scaled municipal solid waste incinerator. It also focuses on chronic health risks where the quantitative health risk assessment applies. The HIA report was incorporated into a Detailed Environmental Impact Assessment (DEIA) report which was submitted to the Department of Environment (DOE). The HIA and DEIA reports were subsequently approved by the ad-hoc DEIA review panel convened by the DOE.

4.1.1 Hazard Identification

This initial step in EHRA involves the characterization of the innate adverse toxic effects of the suspected environmental hazards. The purpose was to scope for potential environmental and health hazards that may emanate from the operation of the proposed project. The review indicated that the major environmental hazards from the proposed project will be mainly air pollutants during its operational phase.

4.1.1.1 Air Pollutants during the Project Construction Phase

According to the air quality assessment as reported in a section of the DEIA report, the project construction phase is not foreseen to be a contributor to air pollution for this proposed project.

4.1.1.2 Air Pollutants during the Project Operational Phase

The actual air pollutants that will be emitted from the smoke stack of the solid waste incinerator will depend on the actual composition of the solid waste being burned. The major air pollutants will be respirable particulates (PM10); gases such as nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon monoxide (CO) and hydrochloric acid (HCl); heavy metals such as lead, mercury, arsenic, cadmium and chromium; as well as dioxins.

4.1.1.3 Health Hazards of the Air Pollutants Generated

Particulate matter, especially the fraction known as respirable particulate (PM10), with an aerodynamic diameter of 10 μm, have a great impact on human health as they can penetrate beyond the nasopharyngeal region and reach the lower human respiratory tract (Dockery and Pope, 1994; Dockery and Pope, 1996).

Nitrogen dioxide may cause proliferative lung damage, methemoglobinemia, bronchiolitis or viral infections of the lower respiratory tract. Sulphur dioxide may

Table 4.1 : Predicted community ambient concentrations, RfD, RfC and HQ for non-carcinogenic health effects of air pollutants for a lifetime community exposure during a normal (with control) project operational phase at Ladang Blue Valley.

Air pollutant	Predicted community ambient concentration (µg/m^3)	RfD (mg/kg/day)	RfC (µg/m^3)	HQ	Non-carcinogenic health effects
Nitrogen dioxide	9.0	1 [(a)]	3500 [(e)]	2.6×10^{-3}	Proliferative lung changes & methemoglobinemia
Hydrochloric acid	2.17	N.A.	20 [(d)]	0.11	Hyperplasia of nasal mucosa larynx and trachea
Arsenic	7.5×10^{-3}	3.0×10^{-4} [(b)]	1.05 [(e)]	7.1×10^{-3}	Cardiovascular, nervous systems and developmental effects
Cadmium	4.0×10^{-3}	5.0×10^{-4} [(b)]	1.75 [(e)]	2.3×10^{-3}	Significant proteinuria
Chromium as chromium (VI)	0.01	N.A.	0.008 [(b)]	1.25	Nasal septum atrophy
Lead	0.12	N.A.	1.5 [(d)]	0.08	Neurotoxicity and nephrotoxicity
Mercury	2.2×10^{-4}	N.A.	0.3 [(b)]	7.3×10^{-4}	Hand tremor and memory disturbance
Dioxins as 2,3,7,8-TCDD	1.0×10^{-9}	1.0×10^{-9} [(c)]	3.5×10^{-6} [(e)]	2.9×10^{-4}	Developmental toxicity

N.A. – Not available/not applicable

Sources : [a] Louvar and Louvar, 1998.

[b] USEPA's Integrated Risk Information System (accessed 30 July 2008).i

[c] ATSDR's Minimal Risk Level (accessed 8 August 2008).

[d] USEPA's Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities, 2005.

Note : [e] RfC was estimated from oral RfD.

Table 4.2 : Pollutant emission rate (Q), unitized dry deposition rate (Dydp), unitized wet deposition rate (Dywp), predicted pollutant concentration in produce (Pd), ADDp, RfD and HQ at Ladang Blue Valley.

Pollutant	Emission rate (Q) in g/s	Unitized dry deposition rate (Dydp) in s/m²-yr	Unitized wet deposition rate (Dywp) in s/m²-yr	Pollutant conc. in produce (Cp) in mg/kg DW	ADDp (mg/kg.day)	RfD (mg/kg.day)	HQ
Arsenic	0.054	0.0039	0.0039	2.07	4.2×10^{-6}	3.0×10^{-4} [a]	1.4×10^{-2}
Cadmium	0.032	0.0045	0.0045	1.41	2.9×10^{-6}	5.0×10^{-4} [a]	5.8×10^{-3}
Chromium as chromium (VI)	0.108	0.0044	0.0044	4.66	9.5×10^{-6}	5.0×10^{-3} [b]	1.9×10^{-3}
Mercury	0.022	0.0001	0.0001	0.022	4.4×10^{-8}	3.0×10^{-4} [b]	1.5×10^{-4}
Dioxins as 2,3,7,8-TCDD	2.2×10^{-10}	0.0044	0.0044	3.2×10^{-9}	6.5×10^{-15}	1.0×10^{-9} [c]	6.5×10^{-6}

Sources : [a] USEPA's Integrated Risk Information System (accessed 30 July 2008)
[b] Louvar and Louvar, 1998.
[c] ATSDR's Minimal Risk Level (accessed 8 August 2008).

Table 4.3 : Combined hazard quotient of pollutant exposure from inhalation and produce ingestion at Ladang Blue Valley.

Pollutant	HQ from inhalation	HQ from produce ingestion	Combined HQ
Arsenic	7.1×10^{-3}	1.4×10^{-2}	2.1×10^{-2}
Cadmium	2.3×10^{-3}	5.8×10^{-3}	8.1×10^{-3}
Chromium as chromium (VI)	1.25	1.9×10^{-3}	1.252
Mercury	7.3×10^{-4}	1.5×10^{-4}	8.8×10^{-4}
Dioxins as 2,3,7,8- TCDD	2.9×10^{-4}	6.5×10^{-6}	2.97×10^{-4}

Table 4.4 : Predicted community incremental concentrations, LADDi, CSF and LCR of air pollutants for a 20 years community exposure during a normal (with control) project operational phase at Ladang Blue Valley.

Air pollutant	Predicted community incremental concentration (μg/m^3)	Lifetime average daily dose (LADDi) (mg/kg.day)	Cancer slope factor (CSF) (mg/kg.day)$^{-1}$	Lifetime excess cancer risk (LCR)
Arsenic	2.5×10^{-3}	2.0×10^{-7}	50 [(a)]	1.0×10^{-5}
Cadmium	1.5×10^{-3}	1.2×10^{-7}	6.1 [(a)]	7.3×10^{-7}
Chromium as chromium (VI)	5.1×10^{-3}	4.0×10^{-7}	42 [(b)]	1.7×10^{-5}
Dioxins as 2,3,7,8-TCDD	1.0×10^{-11}	7.8×10^{-16}	1.5×10^{5} [(c)]	1.2×10^{-10}

Source : [a]Risk Assessment Information System, Toxicity Profiles. Oak Ridge National Laboratory, U.S. Department of Energy. http://rais.ornl.gov/tox/rap_toxp.shtml (accessed 100808).
[b]Eschenroeder A. and von Stackelberg K. 1999. Health risk of landfilling versus combustion of municipal waste : An Illinois comparison. Paper submitted to the Air & Waste Management Association's 92nd Annual Meeting and Exhibition.
[c]Oral slope factor from USEPA's Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities, 2005.

Table 4.5: Predicted pollutant concentration in produce (Cp), LADDp, CSF and LCR of contaminated produce ingestion exposure over 20 years during a normal (with control) project operational phase at Ladang Blue Valley.

Pollutant	Predicted pollutant concentration in produce (Cp) in mg/kg DW	Lifetime average daily dose (LADDp) (mg/kg.day)	Cancer slope factor (CSF) $(mg/kg.day)^{-1}$	Lifetime excess cancer risk (LCR)
Arsenic	2.07	1.2×10^{-6}	50 [(a)]	6.0×10^{-5}
Cadmium	1.41	8.2×10^{-7}	6.1 [(a)]	5.0×10^{-6}
Chromium as chromium (VI)	4.66	2.7×10^{-6}	42 [(b)]	1.1×10^{-4}
Dioxins as 2,3,7,8-TCDD	3.2×10^{-9}	1.9×10^{-15}	1.5×10^{5} [(c)]	2.8×10^{-10}

Source : [a]Risk Assessment Information System, Toxicity Profiles. Oak Ridge National Laboratory, U.S. Department of Energy. http://rais.ornl.gov/tox/rap_toxp.shtml (accessed 100808).
[b]Eschenroeder A. and von Stackelberg K. 1999. Health risk of landfilling versus combustion of municipal waste : An Illinois comparison. Paper submitted to the Air & Waste Management Association's 92nd Annual Meeting and Exhibition.
[c]Oral slope factor from USEPA's Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities, 2005.

Table 4.6 : Combined lifetime excess cancer risks (LCR) due to pollutant exposure from inhalation and produce ingestion at Ladang Blue Valley.

Pollutant	LCR from inhalation	LCR from produce ingestion	Combined LCR
Arsenic	1.0×10^{-5}	6.0×10^{-5}	7.0×10^{-5}
Cadmium	7.3×10^{-7}	5.0×10^{-6}	5.7×10^{-6}
Chromium as chromium (VI)	1.7×10^{-5}	1.1×10^{-4}	1.3×10^{-4}
Dioxins as 2,3,7,8-TCDD	1.2×10^{-10}	2.8×10^{-10}	4.0×10^{-10}

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Appendix I : Health impact assessment (HIA) screening checklist.

Instruction : Circle your answers and give a point for each answer circled. Add all your points for each column. A higher point for the left column means that HIA is necessary, while a higher point for the right column means otherwise.

Questions about the project being proposed		
Inclined towards HIA	**Questions**	**Inclined against HIA**
Yes	Is the project the first of its kind in Malaysia? (e.g. a municipal waste incinerator or a nuclear power plant).	No
Yes	Does the literature mention health impacts that may emanate from the project?	No
Yes	Has previous EIA studies on similar projects indicate significant health impact?	No
Yes	Are there human receptors (residential area, school, hospital, water intake point) located in the vicinity, downwind or downstream of the project site?	No
Yes	Does this project require a detailed EIA?	No
Yes/don't know *	Are the potential negative health impacts likely to be serious?	No
Yes *	Are there communities concern about potential health impacts?	No
Yes/don't know *	Are the potential negative health impacts likely to be disproportionately greater for some groups in the population, e.g. because of age?	No

* When even one such answer is chosen, HIA must be conducted.

Appendix I (cont.) : Health impact assessment (HIA) screening checklist.

Instruction : Circle your answers and give a point for each answer circled. Add all your points for each column. A higher point for the left column means that HIA is necessary, while a higher point for the right column means otherwise.

Questions about the nature of the potential health impacts		
Inclined towards HIA	**Questions**	**Inclined against HIA**
Yes	Are the affected community or population regarded as marginalized (poor, aborigines)?	No
No/don't know	Is there a robust evidence/experience base readily available to determine the health impacts and suggest measures to mitigate the impacts?	Yes
Yes/don't know	Are the consequent health impacts tend to be chronic and irreversible in nature (e.g. cancer) rather than acute and reversible (e.g. respiratory irritation)?	No
Yes	Could any of the mitigation measures for the potential health impacts actually have a subsequent impact on health?	No
No/don't know	If allowed to occur, could the potential health impacts be easily remedied through current health service provision?	Yes
Yes	Is there a need to increase social capital in the affected community or population?	No
Total = ____		Total = ____

* When even one such answer is chosen, HIA must be conducted.

Appendix II : Health impact matrices by project activities (adopted from the Canadian handbook on health impact assessment, Vol. 4 : Health impacts by industry sector (Health Canada, 2004).

Table II-1

Hydro-electric Dam Structure[1]: Matrix of Health Impacts: Health Component

STRESSOR/ EXPOSURE	Nature of Stressor	Effects on Health	Population at Risk	Probability of Occurrence	Biological/Environmental Monitoring Indicators
Technological Disaster	dam failure	injury, trauma, death	communities downstream from the dam, particularly those on the banks	very rare	public safety reports; regular inspections
Gas Emissions or Emissions to Air	CO_2 and CH_4 (decomposition of vegetation)	climate change	global	frequent	atmospheric CO_2 and CH_4 concentrations
Liquid Emissions or Emissions to Water	organic mercury (methylmercury)	poisoning (behavioural and neurological disorders)	consumers of large quantities of fish	rare to frequent	mercury levels in blood and hair (15-30 mg/kg in hair[2])
	decomposing organic material	N/A	N/A	N/A	N/A
	floating debris	unhealthy conditions, quality of life	neighbouring communities, people using the area	occasional	visual appearance of the area
Solid Emissions or Emissions to Soil	varied construction debris (rock, sand, etc.)	N/A	N/A	N/A	N/A
Nuisances	upstream flooding	quality of life	local communities	occasional to frequent	complaints/perception
	downstream drying	quality of life	local communities	occasional to frequent	complaints/perception
	noise, dust (during construction)	quality of life	local communities	occasional	complaints/perception

[1] Applies to the construction of a concrete or rockfill dam that creates a reservoir flooding terrestrial habitats.

[2] This concentration is three times the limit recommended by WHO, which is impossible to apply to Quebec Aboriginal communities for whom fish is the dietary mainstay.

Table II-2
Co-generation Power Plant: Matrix of Health Impacts: Health Component

STRESSOR/ EXPOSURE	Nature of Stressor	Effects on Health	Population at Risk	Probability of Occurrence	Biological/Environmental Monitoring Indicators
Technological Disaster	fires, explosions	respiratory irritation, burns	workers and vicinity	very rare	public safety reports; regular inspections
Gas Emissions or Emissions to Air	suspended particles	irritation of respiratory tract, asthma	vicinity (especially asthmatics)	rare	epidemiological monitoring, level of atmospheric particulate matter
	NO_x	respiratory tract irritants	vicinity	rare	level of atmospheric NO_x
	VOCs	none at predicted concentrations	N/A	N/A	mass of VOC emissions
	$CO_2 + CH_4$	climate change	global	frequent	determination of CO_2 emissions
	SO_2	respiratory problems	vicinity (especially asthmatics)	rare	concentration of atmospheric SO_2; monitoring of hospital admissions for asthma
	CO	none at predicted concentrations	N/A	N/A	N/A
	PAHs	possibility of cancer	vicinity	very rare	level of benzo[a]pyrene and other ambient air PAHs
Liquid Emissions or Emissions to Water	suspended solids	unhealthy conditions, no direct effects	users of polluted water (swimmers, boaters, etc.)	rare	suspended solids measurements
	anticorrosive substances and biocides (cooling water)	unknown	N/A	N/A	N/A
Solid Emissions or Emissions to Soil	N/A	N/A	N/A	N/A	N/A
Nuisances	noise and vibrations	quality of life and sleep, stress	vicinity	unknown	complaints, ambient noise measurements
	vapour plume	quality of life	vicinity	unknown	complaints
	odours	quality of life	vicinity	unknown	complaints

Table II-3
Roads and Highways: Matrix of Health Impacts: Health Component

STRESSOR/ EXPOSURE	Nature of Stressor	Effects on Health	Population at Risk	Probability of Occurrence	Biological/Environmental Monitoring Indicators
Technological Disaster	toxic spills	numerous, depending on contaminant	vicinity	rare to occasional	depending on the contaminant involved
Gas Emissions or Emissions to Air	suspended particles	respiratory irritation and problems, infections	primarily workers	rare to occasional	suspended particles in ambient air
	NO_x	irritation of respiratory tract	urban area residents	rare to occasional	ambient air NO_2 measurements
	VOCs	irritants; carcinogenic benzene; possible carcinogenic formaldehyde	urban area residents, pump attendants (gasoline pumps)	rare or unknown	ambient air VOC measurements (particularly benzene and formaldehyde)
	photochemical smog	ozone: pulmonary tissue inflammation	residents of urban and peri-urban areas	occasional in large cities	ground-level (tropospheric) ozone measurements
	CO_2	climate change	global	frequent	atmospheric CO_2 measurements
	CO	increase in % of carboxyhemoglobin	people working with vehicles in enclosed spaces	rare	atmospheric CO measurements
	PAHs	some compounds are carcinogenic	particularly people living near roads	unknown	measurements of certain PAHs, such as benzo[a]pyrene
Liquid Emissions or Emissions to Water	heavy metals, particularly Cu, Fe, Pb, and Zn	various toxic effects (no carcinogenic metals in this case)	consumers of polluted water	unknown	levels of heavy metals in drinking water
	oil and grease	if PAHs present: possible carcinogenic and mutagenic effects	consumers of polluted water	unknown	levels of PAHs in drinking water
	chlorides	no significant effects	consumers of polluted water	N/A	levels of chlorides in drinking water
Solid Emissions or Emissions to Soil	N/A	N/A	N/A	N/A	N/A
Nuisances[1]	noise	sleep quality, stress	vicinity	frequent to very frequent	dB measurements at various distances from the road network
	dust	stress, hearing problems	workers	occasional to frequent	

[1] BAPE reports; Lévesque and Gauvin (1996).

Table II-4
Airport Construction/Operation: Matrix of Health Impacts: Health Component

STRESSOR/ EXPOSURE	Nature of Stressor	Effects on Health	Population at Risk	Probability of Occurrence	Biological/Environmental Monitoring Indicators
Technological Disaster	plane crash	trauma, injury, death	aircraft passengers and residents on the ground	rare	reports on mortality and morbidity; Transportation Safety Board[1]
Gas Emissions or Emissions to Air	CO	increase in % of carboxyhemoglobin	local residents	very rare	% blood carboxyhemoglobin
	CO_2	climate change	global	frequent	ambient air measurements
	NO_x	irritation of respiratory tract	urban area residents	occasional during summer	air measurements, epidemiological studies
	VOCs	irritation of respiratory tract, inflammation by smog	urban area residents	occasional during summer	air measurements, epidemiological studies
	suspended particles	various respiratory problems	urban area residents	rare to frequent, depending on location and environment	ambient air measurements
Liquid Emissions or Emissions to Water	diversion and drainage of watercourses	N/A	N/A	N/A	state of fish populations
	suspended solids	N/A	N/A	N/A	state of fish populations
	ethylene or propylene glycol	toxic if ingested (lethal dose: 1.4 mL/kg for ethylene glycol)	none	N/A	levels in watercourses or sewers
	urea	toxic if ingested or methemoglobin	none	N/A	levels in watercourses or sewers
	sodium hydroxide	toxic if ingested	none	N/A	pH measurements
Solid Emissions or Emissions to Soil	domestic waste	hygiene and health problems	primarily airport visitors and users	very rare	public complaints
	international waste	spread of exotic diseases	aircraft passengers	very rare or unknown	complaints, medical monitoring after incidents
	hazardous waste (oil, PCBs, etc.)	toxic and potentially carcinogenic effects	airport workers	rare	medical monitoring of workers
Nuisances	noise	quality of life, sleep disturbance, stress, aggressiveness, hypertension	residents around airport perimeter and under approach corridors	occasional to frequent	measurements of interior and exterior ambient noise, epidemiological monitoring studies

[1] Consult Transportation Safety Board (Ottawa).

Table II-5
Gold Mining: Matrix of Health Impacts: Health Component

STRESSOR/ EXPOSURE	Nature of Stressor	Effects on Health	Population at Risk	Probability of Occurrence	Biological/Environmental Monitoring Indicators
Technological Disaster	rupture of pond dams	see "cyanides" and "heavy metals"	riparian population (watercourses)	very rare	cyanide and heavy metal concentrations in the water
	collapse and flooding of tunnels	injury, death	workers	occasional	morbidity/mortality reports
Gas Emissions or Emissions to Air	suspended particles	various respiratory problems	workers, vicinity	rare to occasional	complaints, levels of atmospheric particulate matter
	cyanides	headaches, vomiting, arrhythmia, and coma	primarily workers	rare	monitoring of plasma concentration of cyanides
	arsenic	hyperkeratosis, possibly carcinogenic	primarily workers	rare	monitoring of plasma concentration of arsenic
Liquid Emissions or Emissions to Water	cyanides	weakness, headaches, tachycardia, coma, and possible death	consumers of contaminated water	very rare	monitoring of concentration of toxic elements in mine effluents and watercourses; levels of certain elements in risk groups (blood, urine)
	heavy metals	various toxic effects	consumers of contaminated water	very rare	pH monitoring of mine effluents
	pH reduction (sulphuric acid)	none	N/A	N/A	N/A
Solid Emissions or Emissions to Soil	overburden	none	N/A	N/A	N/A
	waste rock and mine tailings	see "cyanides" and "heavy metals" in water	vicinity and consumers of contaminated water	rare to occasional	levels of toxic elements
Nuisances	dust	hygiene, respiratory problems	vicinity and workers	rare to occasional	complaints
	noise (mobile and fixed sources)	sleep disturbance, stress, quality of life	vicinity and workers	occasional to frequent	complaints

Table II-6

Uranium Mining: Matrix of Health Impacts: Health Component

STRESSOR/ EXPOSURE	Nature of Stressor	Effects on Health	Population at Risk	Probability of Occurrence	Biological/Environmental Monitoring Indicators
Technological Disaster	dike failure	none or uncertain	workers and population downstream	infrequent	monitoring of water quality
	water flooding	severe injury or death	workers	rare	morbidity and mortality
Gas Emissions or Emissions to Air	dust radon gas	respiratory and lung cancer	workers and population in the vicinity	infrequent	air monitoring for dust and radioactivity
Liquid Emissions or Emissions to Water	heavy metals	toxic effects	people drinking water, eating fish	infrequent	monitoring downstream for heavy metals and pH levels
	acid leachate				
Solid Emissions or Emissions to Soil	heavy metals, radium, thorium	minimal	workers	infrequent	soil analyses
Nuisances	dust	respiratory	workers	chronic	dust sampling
	noise	minimal	people along transportation routes	periodic	public complaints
Indirect Impacts or Other Exposure	radiation	lung or other cancers	workers	low	radiation dosimetry for workers and the environment

Table II-7

Pesticide Spraying in Orchards: Matrix of Health Impacts: Health Component

STRESSOR/ EXPOSURE	Nature of Stressor	Effects on Health	Population at Risk	Probability of Occurrence	Biological/Environmental Monitoring Indicators
Technological Disaster	fire in pesticide storage facility	injury, poisoning, burns, death	workers, firefighters, vicinity	rare	morbidity and mortality reports
	accidental spill of concentrated pesticides	acute: blurred vision, stomach pains, nausea, loss of consciousness; chronic: neuropathy, various central nervous system disorders	handlers of concentrated solutions	rare	medical, public safety reports
Gas Emissions or Emissions to Air	organophosphorus insecticides[1]	cholinergic effects of varying intensity depending on extent of exposure	workers and producers' children most at risk; nearby population less at risk	occasional to frequent among groups at risk	measurements of alkylphosphates in urine: 5.3 mg/g creatinine equals the NOAEL for workers; 2.2 mg/g creatinine equals the NOAEL for children
	fungicides[2]	captan: dermatitis, allergies, potentially teratogenic and mutagenic	same as above	same as above	no data for captan
Liquid Emissions or Emissions to Water	organophosphorus insecticides[1]	same as above; acute lethal dose in humans: 5-50 mg/kg body weight	consumers of contaminated water	unknown	same as above
	fungicides[2]	same as above; NOAEL: 12.5 mg/kg body weight per day (rat) for captan	consumers of contaminated water	unknown	no data for captan
Solid Emissions or Emissions to Soil	organophosphorus insecticides[1]	same as above	consumers of ground water	unknown	N/A
	fungicides[2]	same as above	consumers of ground water	unknown	N/A
Nuisances	odours	stress, anxiety concerning health	vicinity	rare to frequent	complaints, perception studies
	noise (spraying)	quality of life, disturbance	vicinity	rare	complaints

[1] Azinphos-methyl is the typical substance considered for reference purposes; however, it is to be phased out in 2005.
[2] Captan is the typical substance considered.

Table II-8

Sanitary Landfilling: Matrix of Health Impacts: Health Component

STRESSOR/ EXPOSURE	Nature of Stressor	Effects on Health	Population at Risk	Probability of Occurrence	Biological/Environmental Monitoring Indicators
Technological Disaster	fire	irritation, asphyxia, burns	vicinity and workers	unknown	fire and injury reports
	explosion	trauma, death	vicinity and workers	31 cases in the USA between 1967 and 1987	morbidity/mortality, explosibility
Gas Emissions or Emissions to Air	biogas	asphyxia, injury	workers, nearby residents	rare	explosibility (CH_4) (<1.25% by volume)
	CH_4, CO_2	climate change (CH_4 and CO_2)	global	frequent (greenhouse effect)	atmospheric CH_4 and CO_2
	VOCs	various types of poisoning, tumour-producing potential	landfill workers and nearby residents	unknown	benzene and VOC levels
Liquid Emissions or Emissions to Water	leachate BOD, COD[1]; heavy metals, organic compounds, and microorganisms	for leachate: unhealthy conditions, acute or chronic poisoning; possible carcinogenic, teratogenic, or mutagenic effects	primarily consumers of contaminated water; children most vulnerable	acute poisoning: very rare chronic poisoning: unknown	monitoring of the various pollutants in the leachate and in the natural receiving water bodies
Solid Emissions or Emissions to Soil	N/A	N/A	N/A	N/A	N/A
Nuisances	noise	quality of life and of sleep	vicinity and community	occasional	L_{eq}[2] 45 dBA, (night) and 55 dbA (day) WHO guidelines
	odours	quality of life	vicinity and community	occasional to frequent	complaints/perception
	airborne waste	quality of life, hygiene	vicinity and community	occasional to frequent	site inspection
	vermin	spread of disease	primarily children	rare	complaints from residents

[1] COD = chemical oxygen demand.

[2] L_{eq} = Equivalent sound pressure level.

Table II-9

Wastewater Treatment Plant Construction and Operation: Matrix of Health Impacts: Health Component

STRESSOR/ EXPOSURE	Nature of Stressor	Effects on Health	Population at Risk	Probability of Occurrence	Biological/Environmental Monitoring Indicators
Technological Disaster	fires and explosions	trauma, injury, death	workers, persons on site	very rare	morbidity and mortality; fire department reports
Gas Emissions or Emissions to Air	CO	increase in % carboxyhemoglobin, death	primarily workers	rare	% blood carboxyhemoglobin
	NO_x	irritation of respiratory tract	urban and periurban areas	rare to moderate	ambient air measurements
	dioxins, furans	some carcinogenic compounds	unknown	rare or unknown	ambient air measurements if possible; epidemiological studies
	heavy metals (Hg, Cr, Cd)	some types of cancer, renal or hepatic toxicity	workers and those near emission sources	rare or unknown	ambient air measurements, epidemiological studies
	VOCs	irritation of respiratory tract, tissue inflammation caused by smog	urban and periurban areas, exposed workers	rare to moderate, in major urban centres	ambient air VOC and ozone measurements at ground level, epidemiological studies
	PAHs	some carcinogenic compounds	workers and local population	unknown	ambient air benzo[a]pyrene and other PAH concentrations
Liquid Emissions or Emissions to Water	heavy metals (Cd, Cr, Hg, Pb)	some types of cancer, renal or hepatic toxicity	consumers of fish or crustaceans	unknown or rare	levels in fish and crustacean flesh; epidemiological studies
	PCBs	possible carcinogenic effects	primarily eaters of fatty fish	unknown or rare	levels and epidemiological studies
	endocrine disruptors	reproduction effects, reduced sperm count?	unknown	unknown	epidemiological studies
	suspended solids	unhealthy conditions, no direct effects	recreational use	occasional to frequent	suspended solids measurements in recreational waters
	enterobacteria and *Enterococcus* spp.	gastroenteritis, other infections	recreational use, drinking water	rare to moderate, depending on location	coliform, enterobacteria, and *Enterococcus* levels, medical reports
	Picornaviridae and hepatitis A	encephalitis, meningitis, pericarditis, and hepatitis	recreational use, drinking water	rare to moderate, depending on location	epidemiological monitoring, public health reports
	Cryptosporidium and *Giardia*	gastroenteritis	recreational and drinking water	rare to moderate, depending on location	epidemiological monitoring, public health reports
Solid Emissions or Emissions to Soil	decantation/sedimentation sludge	possible carcinogenic effects, pathogenic micro-organisms	workers, sludge handlers	rare or unknown	medical monitoring
	bottom ash	possible toxicity	workers, ash handlers	rare or unknown	medical monitoring
Nuisances	odours	quality of life	vicinity	rare to moderate	complaints, perception

Table II-10

Incineration or Land Application of Municipal Sewage Sludge: Matrix of Health Impacts: Health Component

STRESSOR/ EXPOSURE	Nature of Stressor	Effects on Health	Population at Risk	Affected Area	Biological/Environmental Monitoring Indicators
Technological Disaster	N/A	N/A	N/A	N/A	N/A
Gas Emissions or Emissions to Air	a number of pollutants resulting from the incineration of sludge: see grid on waste incineration	see grid on waste incineration	see grid on waste incineration	see grid on waste incineration	see grid on waste incineration
Liquid Emissions or Emissions to Water	heavy metals (Cd, Cr, Hg, Pb)	various toxic effects and neurotoxicity	consumers of polluted water	rare or unknown	all pollutants in this section: determination of concentration of contaminants in runoff from application sites; water analysis of individual wells
	organic compounds: surfactants, PCBs, etc.	disturbance of the reproductive system, possibility of cancer	consumers of polluted water	rare or unknown	
	eggs and cysts of protozoans: *Giardia, Toxoplasma, Cryptosporidium, Taenia*	various parasitoses	consumers of polluted water	rare or unknown	epidemiological monitoring of local populations near sites on which applications are frequently made (primarily cases of gastroenteritis)
	enteric bacteria: *Salmonella, Shigella, Vibrio*	primarily gastroenteritis	consumers of polluted water	rare or unknown	
	enteric viruses	gastroenteritis	consumers of polluted water	rare or unknown	
Solid Emissions or Emissions to Soil	heavy metals	variable toxicity	primarily workers	unknown	all soil pollutants: determination of concentration, monitoring of workers if necessary
	organic compounds (PCBs, PAHs, dioxins, etc.)	possible carcinogenic effects	primarily workers	unknown	
	eggs and cysts of parasites (see above)	various parasitoses	primarily workers	unknown	
	bacteria and viruses	gastroenteritis	primarily workers	unknown	
Nuisances	odours, insects, vermin	quality of life	vicinity and community	rare or unknown	complaints, perception studies

Appendix III : Malaysian ambient air quality guidelines (MAAQG)

RECOMMENDED MALAYSIAN AMBIENT AIR QUALITY GUIDELINES (AT 25 °C / 298 °K AND 101.13 kPa / 760 mmHg)

POLLUTANT	AVERAGING TIME	MALAYSIAN GUIDELINES	
		(ppm)	(μg/m³)
Ozone	1 Hour 8 Hours	0.10 0.06	200 @ 120
Carbon Monoxide	1 Hour 8 Hours	30 9	35 * 10 * @
Nitrogen Dioxide	1 Hour 24 Hours	0.17 0.06	320 113 @
Sulphur Dioxide	10 Minutes 1 Hour 24 Hours	0.19 0.13 0.04	500 350 105 @
Total Suspended Particulate (TSP)	24 Hours 1 Year		260 90
Respirable Particulate (PM10)	24 Hours 1 Year		150 @ 50
Lead	3 Month		1.5

* mg/m³
@ API = 100

API : 0 – 50 (Good)
51 – 100 (Moderate)
101 – 200 (Unhealthy)
201 – 300 (Very unhealthy)
301 – 500 (Hazardous)

(Source: DOE)

Recommended Malaysian Secondary Guidelines.

Pollutant and method	Averaging Time	Malaysian Guidelinesn (mg/m²/day)
Dustfall AS 2724.1	1 year	133

Appendix IV : US National ambient air quality standards

Pollutant	Primary Standard	Averaging Time	Secondary Standard
Carbon Monoxide	9 ppm (10 mg/m³)	8-hour	None
	35 ppm (40 mg/m³)	1-hour	None
Lead	1.5 µg/m³	Quarterly Average	Same as Primary
Nitrogen Dioxide	0.053 ppm (100 µg/m³)	Annual (Arithmetic Mean)	Same as Primary
Particulate Matter (PM_{10})	Revoked	Annual (Arithmetic Mean)	Revoked
	150 µg/m³	24-hour	Same as Primary
Particulate Matter ($PM_{2.5}$)	15.0 µg/m³	Annual (Arith. Mean)	Same as Primary
	35 µg/m³	24-hour	Same as Primary
Ozone	0.08 ppm	8-hour	Same as Primary
	0.12 ppm	1-hour (Applies only in limited areas)	Same as Primary
Sulfur Oxides	0.03 ppm	Annual (Arith. Mean)	-
	0.14 ppm	24-hour	-
	-	3-hour	0.5 ppm (1300 µg/m³)

Appendix V : A qualitative risk assessment matrix

Severity of Consequences					
CATERGORY / DESCRIPTIVE WORD	PERSONAL ILLNESS / INJURY	EQUIPMENT LOSS ($) **	DOWN TIME	PRODUCT LOSS	ENVIRONMENTAL EFFECT
I CATASTROPHIC	Death	> 1M	>4 months	Values as for Equipment Loss	Long-term (5 yrs or greater) environmental damage or requiring >$1M to correct and/or in penalties
II CRITICAL	Severe injury or severe occupational illness	250K to 1M	2 weeks to 4 months		Medium-term (1-5 yrs) environmental damage or requiring $250K - $1M to correct and/or in penalties
III MARGINAL	Minor injury or minor occupational illness	1K to 250K	1 day to 2 weeks		Short-term (<1 yr) environmental damage or requiring $1K - $250K to correct and/or in penalties
IV NEGLIGIBLE	No injury or illness	<1K	<1 day		Minor environmental damage, readily repaired and/or requiring <$1K to correct and/or in penalties

Provide stepwise scaling of SEVERITY levels for each potential TARGET

Probability of Mishap**		
LEVEL	DESCRIPTIVE WORD	DEFINITION
A	FREQUENT	Likely to occur repeatedly in system life cycle
B	PROBABLE	Likely to occur several time in system life cycle
C	OCCASIONAL	Likely to occur sometime in system life cycle
D	REMOTE	Not likely to occur in system life cycle, but possible
E	IMPROBABLE	Probability of occurrence cannot be distinguished from zero
F	IMPOSSIBLE	Physically impossible to occur

Provide stepwise scaling of PROBABILITY levels for all potential TARGETS.

PROBABILITY is a function of EXPOSURE INTERVAL.

Decide on potential TARGETS.

*Adapted from MIL-STD-882C **Life cycle = 25 yrs.

Source : Clemens P.L. and Simmons R.J. 1998.

Appendix V (cont.) : A qualitative risk assessment matrix

Severity of Consequences	Probability of Mishap**					
	F IMPOSSIBLE	E IMPROBABLE	D REMOTE	C OCCASIONAL	B PROBABLE	A FREQUENT
I CATASTROPHIC					1	
II CRITICAL				2		
III MARGINAL			3			
IV NEGLIGIBLE						

- Code 1 : Imperative to suppress risk to a lower level.
- Code 2 : Operation requires written, time-limited waiver, endorsed by management.
- Code 3 : Operation permissible.
- Personnel must not be exposed to hazards under risk codes 1 and 2.

Appendix V (cont.) : A qualitative risk assessment matrix

How to use the qualitative risk assessment matrix

This qualitative risk assessment matrix which is often applied to a work environment can assess risks related to personal illness and injury, equipment loss, process downtime, product loss and environmental effect. It assesses a risk with respect to the severity of its consequences and the probability of the mishap, as shown in the first matrix. For example, a risk which can culminate in a death is catastrophic in severity. If this risk is likely to occur several times in a system life cycle, its probability is probable.

Looking at the second matrix, a risk of which the severity is catastrophic with a probability that is probable is termed as code 1. Code 1 means that it is imperative to suppress risk to a lower level. In other words, the risk is too high and is unacceptable. Code 2 means that operation requires written, time-limited waiver and endorsement from management. This means that the risk needs to be closely assess and monitored. Code 3 means that operation is permissible or the risk is clearly acceptable.

Acknowledgement

Acknowledgement

The Department of Environment Malaysia would like to thank the following individuals on their involvement in the preparation of this Guidance Document on HIA in EIA.

Consultants :

Prof. Dr Jamal Hisham Hashim	International Institute for Global Health, United Nations University and Universiti Kebangsaan Malaysia
Prof Dr Zailina Hashim,	Department of Environmental and Occupational Health Universiti Putra Malaysia

Government Agencies

Malaysian Association of Environmental Health (MAEH)
Jabatan Kesihatan Awam, Ministry of Health Malaysia
Division of Engineering Services, Ministry of Health Malaysia
Environmental Health Research Centre, Ministry of Health Malaysia
Jabatan Perlindungan Alam Sekitar Sabah
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ISBN 978-983-3895-37-3

9 789833 895373

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