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Environmental Hazard and Risk Assessment

Many types of development supported by the Bank involve environmental risk. For example, dam construction or remedial action to clean up pollution may pose risks to human health or the natural environment. Under such conditions, the potential environmental impacts are often subject to uncertainties. Where these uncertainties are significant, for example in the case of a potential release of toxic material in a densely populated area, a quantitative assessment of hazards and risks may be appropriate.

The techniques of hazard and risk assessment have been developed to help determine the degree of uncertainty associated with development activities. These techniques may be used independently from or in support of environmental assessment (EA) and environmental auditing, which they compliment. This Update *provides an introduction to hazard and risk assessment, outlines some available methodologies, and discusses the use of these techniques in assessing environmental liability.*

Background

The origins of risk assessment lie in military operations research during World War II and thereafter in the avoidance of chemical and nuclear plant failure. More recently, notorious industrial accidents such as the 1976 dioxin release in Seveso in northern Italy and the 1984 methyl-isocyanate incident in Bhopal, India, have accelerated an extension of risk assessment to the control of major industrial hazards. Legislative and procedural developments in response to these disasters have supported this trend, including the European Economic Community (now European Union) Directive for Major Accident Prevention of 1982 and the United States National Research Council's risk assessment framework of 1983 for the Environmental Protection Agency (USEPA).

The focus of risk assessment on acute human health issues arising from major industrial hazards was broadened to encompass chronic health concerns. These include occupational health risks associated with the use of potentially harmful materials (such as carcinogens or teratogens), and broader chronic health concerns linked to environmental pollution. The pollutants of concern in the wider environment include: potentially harmful industrial materials; emissions from automobiles, energy production and other industrial processes (such as particulates, radionuclides, estrogen mimickers and hydrocarbons); and biological agents. More recently, the concept of risk assessment has been extended to natural systems. Such approaches include assessing risks to ecological resources, or investigating the risks arising from natural disasters such as floods and earthquakes.

In the context of Bank development projects, risk assessment deals with three basic questions:

1. *What can go wrong?* What impacts might affect human health and the natural environment, and what are the reasonable project scenarios (cause and effect) that might result in damage to health, the environment or the financial viability of the project.

2. *What is the range and magnitude of these adverse impacts?* What number of people or geographical area could be affected, what is the maximum credible accident that could occur during the lifetime of the project, and what are the risks of routine operations.

3. *How likely are these adverse consequences?* With what frequency might they occur, what evidence is available to judge their likelihood, and what data are

available. For example what data exist for failure rates of processes and technological components, or occurrences of natural disasters.

The first two questions are partially addressed in EAs, whereas the third question is addressed by risk assessment. The main objective of risk assessment is to identify hazards and assess risks associated with development projects, and to recommend appropriate risk management strategies. The interactions between hazards, risks and risk assessment are described in box 1.

Box 1. What is hazard and risk assessment?

In simple terms, *hazards* refers to sources of potential harm, whereas *risk* considers frequency and severity of damage from hazards. A risk assessment involves evaluating actual and perceived risks as the basis for decisionmaking.

Hazard denotes a property (of substances, microorganisms, and so on) or a situation that in particular circumstances could lead to harm. If these circumstances occur, they result in adverse consequences. *Hazard assessment* is thus the identification of hazards, their potential receptors (people, natural resources, plants or animals) and the determination of the consequences.

Risk is a function of the probability (or frequency) of a *hazard* occurring, and the magnitude of the consequences; *risk* therefore represents the likelihood of a potential hazard being realized. *Risk estimation* involves identifying the probability of harm occurring from an intended action or accidental event. *Risk evaluation* determines the significance of estimated risks, including risk perception (involving subjective appreciation and judgment), which will more often than not bear little relation to a statistical probability of damage.

Risk Assessment is a combination of risk estimation and risk evaluation. The technique of risk assessment may be used to assess the relative costs and benefits of a situation, development proposal or regulatory approach. Risks that are under voluntary control are considered less potentially hazardous than those over which there can be no control, such as seismic events.

Risk management is the process of implementing decisions about accepting or controlling, based usually on cost-benefit analysis. Risks may be controlled through the application of technology, procedures or alternative practices. The iterative nature of risk management requires that control technologies or alternative practices be re-evaluated for associated risk.

When should risk assessment be used?

Where uncertainties associated with Bank investments are large and important to the outcome of an environmental assessment (such as the potential release of toxic materials in a densely populated area, or likelihood of seismic damage to a hydropower dam), a quantitative assessment of risks is appropriate. The Bank requires risk assessment for projects involving certain inflammable, explosive, reactive, and toxic materials when they are present at a site in quantities above a specified threshold level (for guidance, see Technica, Ltd., 1988).

The Bank has also employed risk assessment to evaluate the linkages between environmental pollution and other health determinants. In addition, risk assessment has been used to assist developing countries in allocating limited resources to pollution prevention, control and management, for example in Bangkok and Manila.

Bank Group involvment with existing private enterprises (either through privatization loans, lending via financial intermediaries, or investment by the IFC) increases the likelihood of project environmental liability. This is most commonly associated with historical contamination arising from past activities at industrial or utility locations. A risk management approach is increasingly advocated for site investigation and assessment for the definition and identification of contaminated land (see box 2). Other relevant project contexts are described below in conjunction with a description of the types of risk assessment.

Stages in risk assessment process

Many formal and informal methodologies have been developed for risk assessment. These vary from reliability assessment to mathematical and statistical modeling techniques. The general methodological sequence described below applies in most situations. This is illustrated in figure 1, which also highlights the iterative nature of risk assessment.

Hazard assessment

Following the description of an intended action (for example, a development proposal, regulatory approach or policy intervention) and relevant assumptions, hazards can be identified. This is similar to the qualitative prediction of impacts in EA. The first step in the identification of hazards is to define the practical boundaries for the assessment taking into consid-

Box 2. Risk assessment and contaminated land remediation: Argentinian oil refinery

The main concerns with historical land contamination or remediation works are human and ecological exposure to contaminants, and associated remediation costs and liabilities. Risk estimation methods, in combination with analysis of soils and other environmental media, are used to assess probabilities of the relevant harm occurring (or having occurred). Following privatization in 1993 of the YPF oil refinery in San Lorenzo, Argentina, a company (Refinsan San Lorenzo S.A.) was established to assume ownership and operation of the refinery. Refinsan is committed to cleaning up severe land contamination resulting from poor operational practices during 48 years of public ownership of the refinery.

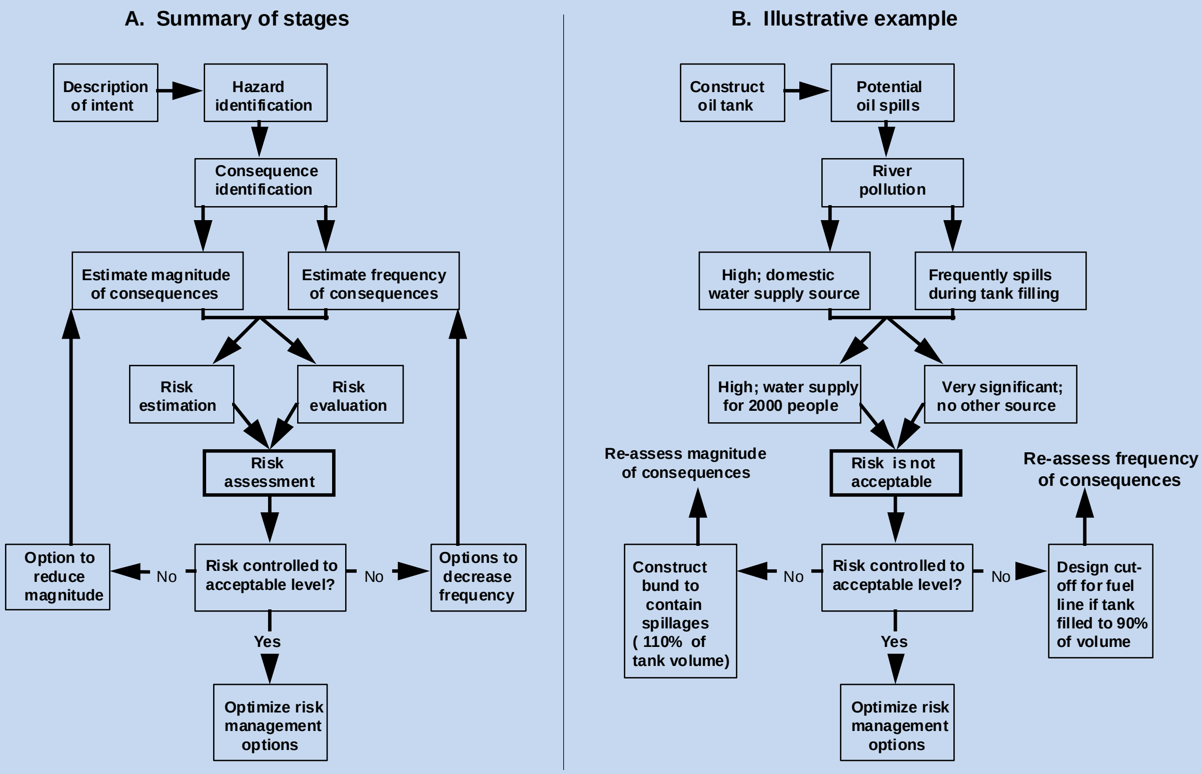
A contaminated land assessment and remediation program was agreed with the Local Authority prior to privatization. Refinsan considered some of the time frames for completing remedial actions to be unrealistically short; however, proposals for rescheduling have not been critically evaluated due to the absence of appropriate expertise or institutional capacity within the Local Authority.

IFC is currently financing expansion of Refisan's refining capacity and gas station network as well as the remediation program. One of IFC's conditions of disbursement is implementation of a plan for final decontamination of the site. IFC is monitoring compliance with this condition including the time schedule of implementation.

eration the potential receptors (people, natural resources, plants, or animals) and their social and natural environments. Hazards associated with developments may include: the presence of toxic, flammable or explosive materials; failure of dams or storage vessels; accidents during transportation of hazardous materials, flooding, and other natural disasters or wetlands drainage.

Uncertainties may arise due to a lack of procedural or mechanical controls, insufficient knowledge regarding cause and effects relationships, the inherent variation in natural systems or insufficient baseline data. Examples of uncertainties are the potential for release of hazardous materials, equipment failure rates, human error or frequency of natural disasters. It is important to identify uncertainties in parallel with

Figure 1. Stages in the risk assessment process



hazards, as these can influence the scale of the consequences. The types of consequences which may be identified through a hazard assessment include death or injuries, pollution of water resources, or damage to crops or infrastructure.

Probability (frequency) estimation

This element of risk assessment is concerned with the likely occurrence of hazards—for example, how often would flooding occur in a given area causing damage to crops and infrastructure, or what is the failure rate for a type of pressure vessel containing flammable materials. For Safety Risk Assessment (SRA) this might involve a review of historical records for a given industry or the application of predictive methods. For human health or ecological risk assessments, the concern is often with evaluating potential exposure through identification of pathways and receptors.

Risk estimation

Estimation of risks based on magnitude and frequency of hazards may either be qualitative or quantitative. Important considerations in the estimation of risk include relative toxicity of materials, duration of exposures, dose responses of people or plants and animals affected, extent of resources affected, and errors in assumptions.

A qualitative approach might involve the adoption of a matrix format. More quantitative approaches are usually based on predictive modeling techniques. Combined risks for different environmental aspects may be estimated by additive or multiplicative methods, for qualitative or semi-quantitative information.

Risk evaluation

Risk evaluation involves an appraisal of the significance of the estimated risks, and typically involves evaluating differing perceived risk and benefit scenarios. The outcome of such evaluations should be reviewed as further data become available, or as the balance between economic benefits and environmental harm changes. Risk evaluation should therefore be seen as an iterative process with alternative risk reduction strategies being subjected to comparative assessments.

Risk management

Risk management involves making decisions regarding the acceptability of risks, and implementing mitigation measures to minimize or eliminate risks as part of an iterative cycle. The implementation of actions to control risks should be integrated with monitoring activities. In considering the effectiveness of risk management measures, it is important to evaluate the extent to which stakeholder concerns have been satisfied as well as the efficacy of risk control measures.

Monitoring and supervision

Monitoring is a tool to ensure adherence to agreed actions, to assess compliance, and to provide enhanced data for refined risk management purposes. The types and frequency of monitoring depend upon specific circumstances. However, monitoring should generally be directed towards identifying the:

- Implementation of agreed actions
- Compliance with World Bank standards or guidelines (or country standards, whichever is the more stringent)
- Accuracy of assumptions used in the estimates and analyses undertaken as part of the risk assessment
- Changes in stakeholder perceptions of risk.

The level of supervision effort will depend upon the complexity of the project and the scale of potential impacts (see *Update* no. 14: *Environmental Performance Monitoring and Supervision*).

Risk perception and public involvement

Risk perception reflects the concerns of stakeholders. There is frequently a gap between the level of assessed risk and stakeholder concerns. This heightened perception of risk significance can have real potential consequences in creating resistance amongst stakeholders or decision makers to otherwise potentially positive projects. The most effective means of bridging this gap is through involving stakeholders in the risk assessment process.

To be effective, public involvement needs to be based on identification of stakeholders who perceive that they are directly affected by a development proposal, and relevant regulatory authorities and NGOs. Consultation plans should include NGOs and affected populations both during risk assessment and project implementation. In particular the supervision system should provide for responses to their concerns. Full disclosure of information is an important element of the consultation process, otherwise stakeholders are unlikely to be satisfied with the results of the risk assessment. Information from risk assessment, mitigation or monitoring activities should therefore be made available to the public in a clear and readily accessible format. Additional guidance may be obtained from *Update* no. 5: *Public Involvement in Environmental Assessment: Requirements, Opportunities and Issues*.

Types of risk assessment and applications

A number of risk assessment types have been developed. The main examples are described below with examples of typical applications. Guidance on how to conduct each assessment type is given to assist task managers and borrowers in understanding the requirements and in establishing terms of reference for risk assessments.

Safety risk assessment

Safety risk assessment (SRA) is primarily concerned with control of risk within the chemical manufacturing or petroleum industries, although it also applies to industrial, utility or other sites where large volumes of chemicals or petroleum or petrochemicals are stored. The concern is typically with low probability accidental releases of hazardous materials having severe consequences which give rise to acute adverse effects. The focus of SRA is on the safety of the workforce and adjacent communities, and on loss prevention and control.

The *hazard identification* component of SRA requires clear definition of the scope of work. Typical hazards associated with industrial developments might include the presence of toxic or explosive materials, accidents during transportation of hazardous materials, natural disasters or failure of mechanical equipment. Uncertainties may arise due to a variety of reasons which might trigger a risk assessment, for example the potential for release of hazardous materials, equipment failure rates, human error, incidence of natural disasters or frequency of power outages. The Bank issued a manual on *Techniques for Assessing Industrial Hazards* in 1988.

Common methods for hazard identification include Hazard and Operability studies (HAZOP), Failure Mode and Effect Analysis (FMEA), what-if checklists and historical data on similar processes. The end result of the hazard identification process should be an explicit list of failure cases for subsequent analysis (see box 3). Examples of such failure cases might include an instantaneous release of 10,000 liters of solvent from a storage tank due to stress corrosion cracking, or a 3 inch diameter hole on a high pressure gas main which is isolated within one hour.

The next stage in SRA is *estimating the probability* of the hazards identified occurring. In the context of industrial risk assessment this involves a review of historical records and / or predictive methods. Generic industry average data are available for many processes and may compliment historical data for existing sites. Predictive methods are based on techniques such as fault tree analysis (FTA) or event tree analysis (ETA). FTA focuses on the primary and secondary causes that can result in a system failure, and is particularly useful in identifying combinations of events that may lead to an accident. ETA focuses on the possible outcomes of the primary cause which initiates an accident, before the final outcome is realized. Such predictive methods require specialist knowledge of the techniques and processes under consideration. Most SRAs are qualitative or semi-quantitative, and quantitative approaches are reserved for the most significant risks due to the level of effort involved.

Box 3. Safety risk assessment (SRA) of a petrochemical complex, India

An extensive SRA was carried out in 1990 of the Indian Petrochemicals Corporation LTD's (IPCL) Baroda complex, focusing on the potential hazards and risks arising from processes, and materials stored and handled in the aromatics, ethylene-propylene copolymer, acrylic fiber, and gas turbine power plants. Design changes and procedures to minimize risks to personnel and local communities were recommended.

In 1994 an additional SRA was carried out of expansion plans to include a polypropylene and poly butadiene rubber plant at the complex. The SRA was carried out in conjunction with an EA, with the objective of estimating public risk (individual and societal) from major accident hazards, and recommending risk reduction measures. The combined population of villages and towns within a 5 kilometer radius of the Baroda complex was approximately 57,000.

A hazard assessment identified 39 major hazard scenarios, such as catastrophic rupture of the polypropylene feed tank, chlorine cylinder, or butene storage tank. Damage criteria were calculated for these scenarios, to assess the percentage of the local populations that would be killed due to heat radiation, explosions or toxic effects. EFFECTS and RISKCURVES software (TNO, Netherlands) and HEGADAS of Shell international were used for the SRA.

Specific risk reduction measures included: reducing storage capacity for propylene and butadiene; installing sprinkler systems to protect storage vessels from fire; fitting non-return valves in transfer lines to storage vessels to prevent loss of stored materials in the event of line rupture; and development of a Safety Management System. While the combined effects of these measures reduces risks to adjacent communities to an acceptable level, relocation of the nearby Dhanora Village (population 3,750) was thought to be desirable.

Risk is estimated by combining the outcomes of the probability estimation with the predicted magnitude of the consequences. For SRA, important considerations in estimating risk include the hazardous properties of materials, quantities involved, duration of exposures and number of people involved.

The next stage of *safety risk evaluation* is an appraisal of the significance of the estimated risks, which should include differing perceived risks and benefit scenarios. These may be process and / or site specific. The same operation at two locations could have differing risks (both real and perceived), a factor rarely considered by financial and insurance institutions. While some materials would be immediately considered of risk, others that are seemingly innocuous may be a hazard in certain situations or after a long (and often unknown) period of time, or when used in conjunction with other substances.

Safety risks are typically expressed in terms of the number of additional deaths or injuries in a population over a specified time frame or economic losses.

Health risk assessments

The focus of health risk assessments (HRAs) is the well-being of humans in the wider population, or occupational health concerns of a chronic nature. HRAs are typically concerned with high probabilities of low-level exposures. The effects are frequently delayed and causes are not readily established. The principal concern lies in estimating risks of contracting cancers or other diseases from exposure to toxic agents, and the implications for the life span of the affected individuals.

HRA has its origins in epidemiological studies of, for example, asbestos workers. Concerns over health and safety at work where acute exposures are most likely, have lead to the establishment of threshold limits for perceived “safe” exposure to various chemicals over specified time periods. The World Health Organization (WHO), for example, have established criteria for “Internationally accepted” air emission standards and guideline limits for human health (and recently also environmental health) for various parameters. Standards need regular review as scientific evidence of accepted or tolerated risk levels evolves.

Common health concerns which might prompt HRAs are concentrations of lead, dust, sulfur dioxide, pesticides, chlorine or ozone in the various environmental media. For example, the Bank has evaluated linkages between environmental pollution and other health determinants in Central and Eastern Europe (see box 4). HRA can also be directed towards, *inter alia*, deciding how best to deploy limited resources to site cleanup or pollution control (see box 5), or to assess the health risks versus benefits of pesticide control programs and chlorination or fluoridation of water supplies.

The *hazard identification* component of HRA involves an assessment of the quantities, concentrations and toxicity of chemicals, dusts or other agents in

Box 4. Health risks of environmental pollution in Central and Eastern Europe

In response to concerns regarding the risks to human health from environmental pollution in Central and Eastern Europe (CEE), the Bank commissioned a study to:

- Evaluate the influence of pollution on human health in comparison with other health determinants
- Collate and evaluate data on locations where pollution had influenced human health
- Identify the principal environmental hazards affecting human health which could be remediated.

The study concluded that health damage from pollution, while significant, was one of a series of competing health determinants, which included poor healthcare provisions and lifestyle factors such as diet, smoking and exercise. The most common pollution-related health problems were the result of exposures to lead, airborne dusts and sulfur dioxides, nitrates in drinking water, and contaminants in food and water. Airborne pollution was concluded to be a greater threat than waterborne pollution, with respirable dust frequently being the primary problem.

Due to the scarcity of resources for environmental improvement, the study made recommendations for priority setting to control risks to human health from pollution. The immediate investment priorities include:

- Installation of dust abatement equipment to non-ferrous metal smelters located upwind of significant population centers
- Installation of abatement equipment to control smoke, dust and carbon monoxide emissions from iron and steel plants
- Investments to replace coal by gas or to permit burning of smokeless fuels in cities with high ambient particulates concentrations during winter
- Assistance to facilitate proper installation of domestic septic tanks and appropriate disposal of manures to protect rural drinking water sources with high nitrate levels.

Box 5. Cost effective risk reduction strategies for Bangkok

The Bank commissioned a study in 1994, aimed at identifying cost-effective health risk reduction strategies for the Bangkok Metropolitan Region, Thailand. Of particular concern, were the inevitable escalation of social costs associated with pollution from energy production and use, transportation and manufacturing as a result of continued economic expansion.

Prioritization of environmental problems was based on the efficiency criterion (maximizing net social benefits). The highest priority was assigned to air pollution by particulate matter, lead, and traffic congestion, followed by microbiological contamination of water. The latter was not addressed in the study because it would not be exacerbated by economic growth. The next priority was water pollution due to organic and toxic wastes.

The study made recommendations for policy and institutional reforms including to:

- Alter fuel taxes to remove price distortions which favored lignite over less polluting fuels
- Establish emission standards for particulates and SO_2 from power generation facilities
- Implement programs to phase out lead in gasoline and reduce sulfur content of diesel
- Establish a presumptive charging system for wastewaters to replace a standards-based system (to shift the monitoring onus to firms)
- Establish an incentive framework to encourage better management of hazardous wastes
- Streamline and clarifying institutional responsibilities for pollution management.

Because Thailand is in the early stages of pollution control, it should be possible to reduce the impacts of the main pollutants in Bangkok at relatively low cost. The country's recent remarkable economic growth should also support the necessary investment.

environmental media at a site or study area and identification of the main chemicals of concern. In common with SRA, the scope of HRA should be clearly defined based on the underlying objective, e.g., development of a control plan for airborne lead in an urban environment.

The next stage in HRA is *exposure assessment*, i.e. who is likely to be exposed to an identified hazard and to what extent. Assessment of exposures involves identification of pathways and migration routes for transport of the pollutants of concern; identification of potential receptors and sensitive subgroups (e.g., children in the context of lead or asthmatics in the case of airborne dusts); and exposure rates and durations.

The pathways for transport of hazardous material from source to receptor might include air, water, or soil. The routes of transfer to the receptor are inhalation, ingestion, or absorption through the skin. Exposure assessment frequently involves the application of environmental modeling to predict concentrations of hazardous materials available for transfer to receptors. Air and groundwater pollution dispersion modeling techniques which evaluate the fate of toxic chemicals in the wider environment have become highly sophisticated.

Estimation of risk in HRA involves a *dose-response or toxicity assessment*. This characterizes the relationship between the dose and the effects on human health. A variety of information sources are available on the toxicity of environmental hazards, based on their potential to cause cancer or other diseases. These include dose-response curves developed by the US Environmental protection Agency and the UK Health and Safety Executive.

The final stage in HRA is *risk characterization*, who is affected and what are the likely effects. This integrates the results of exposure assessments and toxicity assessment to derive quantitative estimates of cancer risks and hazard indices. Cancer risk is expressed as the likelihood of an individual developing cancer from lifetime exposure to cancer-causing hazards. Non-cancer risks are expressed as hazard quotients based on the estimated daily exposure or intake of hazardous material relative to the acceptable daily intake.

For further information on human health impacts and EA, see *Update* no. 19: *Health Aspects of Environmental Assessment*.

Ecological risk assessment

The concern with ecological risk assessment (ERA) is with the response of ecosystems to human induced environmental threats. ERA compares expected environmental impacts and predicted ecosystem responses to assess the safety of a proposed action or release. Uncertainties regarding the value of ecosystems, frequency of adverse impacts, and the severity of response to diverse anthropogenic stresses are identified and evaluated. The techniques of ERA are less well developed and internationally accepted than for SRA or HRA. This is due in part to the uniqueness of ecological systems. Experience to date with the application of ERA is limited, and typically linked to evaluating human and ecological impacts of natural disasters or global warming (see box 6).

Hazard identification in the context of ERA involves an assessment of the causes of ecological risks, known

Box 6. Risk assessment and planning for global climate change: Caribbean

The members of the Caribbean Community are primarily small island states with fragile coastal ecosystems. Agriculture and tourism are the principal sources of employment and foreign exchange earnings. Coastal zones support a wealth of biological resources, and are vital to the prosperity of these countries. In recent years, these resources have come under increasing stress, in the absence of an institutional structure to enable integrated management.

Anticipated global climate change (GCC) may seriously compound these problems. Sea level rise, in particular, will likely affect freshwater supply, increase beach and coastal erosion, and aggravate the impact of tropical storms. The Intergovernmental Panel on Climate Change (IPCC) has estimated first order costs for protection against rising sea levels as $11.1 billion, which is well beyond the combined investment capacity of their economies. Other adaptation measures are therefore needed.

The project's overall objective is to support Caribbean countries in coping with the adverse effects of GCC through *vulnerability assessment*, adaptation planning and capacity building. It will be executed through a cooperative effort and by a combination of national pilot programs, regional training and technology transfer linked to adaptation planning. This relates to planning of adaptation to GCC through measures such as:

- Establishing a sea level/climate monitoring network for the Caribbean
- Preparing an inventory of physical and biological resources of coastal areas, current uses, users, and associated values
- Developing a coral reef monitoring network for evaluating the impacts of temperature stresses on reefs and their adaptive capacity
- Assessing the vulnerability of coastal areas to GCC using the tropical storm hazard assessment model of the OAS
- Formulating a framework for integrated coastal and marine planning
- Identifying low-cost implementation measures.

as ecological stressors. These may be chemical, physical or biological agents. In addition to toxic materials such as pesticides or oxides of nitrogen, logging, wetlands drainage, erosion, introduction of non-native species or climate change may all present ecological hazards.

The *exposure assessment of ERA* involves cataloging pathways and migration routes for transport of chemical or biological agents, and the spread of physical stressors such as logging, erosion or rising sea levels. Potential receptors might include habitats or sensitive subgroups such as endangered plant and animal species. The magnitude and duration of stressors are also identified. For example, logging may occur incrementally over a long time frame, whereas pesticide applications are typically discrete events. The pathways for transport of stressors from source to receptor include air, water, soil, host organisms or direct human intervention .

The next stage in ERA is to identify *stress-response relationships*, i.e. estimating the relationship between exposure, dose, and response. The ecological level of organization to assess the impacts of exposures may range from ecosystem, through communities to populations.

Risk characterization involves integrating the results of field surveys, toxicity and exposure data to evaluate the ecological risk. This should be complemented by an assessment of the uncertainties involved in the risk estimation, such as variations in toxicity responses of test populations of fish or cumulative effects of more than one stressor. A variety of methods may be employed including screening calculations and physical or mathematical models.

Where baseline ecological data are not available for all seasons, ERA can help to determine the potential significance of the impacts in the absence of such data, and inform the user of the relative importance of obtaining additional data; the outcome may be that additional data collection is essential, or that the risks are so trivial or so significant that decisions can proceed without additional data. ERA may also be used to test the efficacy of a range of mitigation measures. A simple example of this is the use of river hydrology and water quality assessments, to determine the receiving capacity of a watercourse.

Scientific understanding of dose response relationships and the environmental safety (or otherwise) of chemicals is continuing to evolve. For example, recent data suggest that some chlorofluorocarbon (CFC) replacements are environmentally harmful, and estrogen levels in watercourses are reputedly affecting fish reproduction. Much work remains to be resolved concerning toxic equivalent exposures and the short-term or long-term effects of chemicals on the environment, particularly in developing countries.

Natural disasters and global challenges

While the primary focus of risk assessment is the hazards and risks arising from human activities, the Bank is also concerned with risks arising from natural disasters such as floods, typhoons and earthquakes.

The Bank frequently finances emergency projects to alleviate the effects of natural disasters. The Bank has also played a leading role in expanding the understanding of the links between poverty, economic development and natural disasters. Poverty limits the resilience of developing countries to natural disasters. It constrains implementation of protective measures to control or limit damage in anticipation of disaster, exacerbates the severity of impacts, and hinders recovery.

Environmentally unsustainable development can undermine key ecological functions and increase the frequency of natural disasters and associated risks. The challenge is therefore to foster development that protects natural systems which buffer communities (such as wetlands), while investing in cost-effective measures to control risks from natural occurrences.

In the area of climate change, the impacts of sea level rise and disturbed weather patterns are of concern to both human and ecological communities. The Bank is also associated with a number of studies which address the risks associated with climate change, for example in the Caribbean where the Bank is the implementing agency for an Organization of American States (OAS) study on climate change adaptation and vulnerability (see box 6).

Links to the project cycle

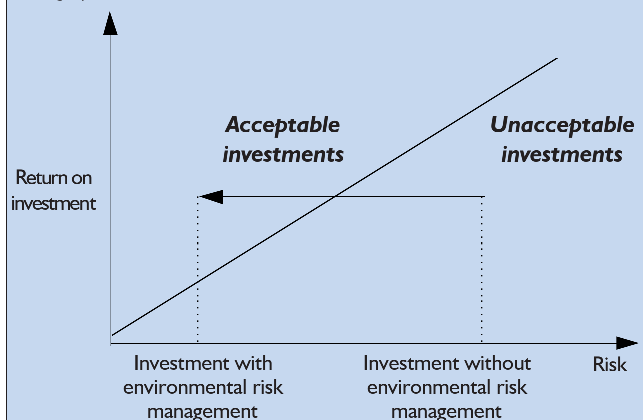
Hazard and risk assessment can be used during initial project screening, preparation of EA studies or detailed project appraisal. Financial intermediaries working with the Bank will also benefit from taking a risk assessment approach to their appraisal of investment opportunities (see box 7).

Some projects will require hazard identification and screening in the initial concept stage. If risk scenarios are considered unlikely to be acceptable, then TORs for risk assessments should be prepared. SRA is typically applied iteratively during project implementation when detailed designs are prepared. However, for industrial upgrades or privatization projects, HAZOP or land contamination studies might form part of an audit process during project preparation (see also *Updates* no. 6: *Privatization and Environmental Assessment: Issues and Approaches* and no. 11: *Environmental Auditing*).

HRA or ERA may be the primary focus of a loan, for example the study of health risks associated with environmental pollution in Central and Eastern Europe (see box 4). Alternatively, they may be required during project preparation to determine investment priorities.

Box 7. Risk management for financial intermediaries

Environmental risk in defined broadly by the International Finance Corporation (IFC) to encompass risks to the natural environment, risks to a company, and as a consequence, risks to the company's financiers. Risk management for financial institutions is thus the process of assessing and managing risks. The major environmental issues affecting the companies in which financial intermediaries (FIs) invest include: site contamination, major hazards, special concerns (such as logging within tropical rainforests) and violations of regulations. The increasing importance of FI lending in IFC's portfolio, prompted the production of guidance to assist FIs to assess and manage risk.



At the heart of IFC's *Environmental Risk Management for Financial Institutions* guidance document is a corporate environmental checklist which poses a series of questions designed to:

- Identify risks to the environment associated with a company's current operations, such as potential site contamination
- Identify risks to the environment associated with a company's planned investment, such as major hazards
- Assess liabilities associated with current or future environmental risks.

Guidance is provided on when more detailed risk assessments are required, and on managing risks throughout the investment project cycle. A program of training financial officers within IFC's lending partners in the application of risk management techniques is ongoing.

Conclusions

A structured methodology has advantages for improved analysis and judgment of environmental risk, especially if there is a high degree of uncertainty involved and effects are potentially significant. Adopting a precautionary approach is frequently cost-effective in the longer term, and can be reviewed as knowledge regarding inherent risks improve.

Despite the opportunities presented by a risk management approach, the limitations must be remembered. If a robust sensitivity analysis cannot be conducted in conjunction with a risk assessment, then a more qualitative appraisal is required.

The hazard and risk assessment field is still developing. It must be re-emphasized that risk assessment methodologies need adapting to each situation to allow implementation of risk reduction measures, and institution of a risk management program.

For further reading

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This *Update* was prepared by Aidan Davy. Some background information was provided by Christine Cowley, and expert technical review was undertaken by Paul Hollywell of WS Atkins Consultants. The *EA Sourcebook Updates* provide guidance for conducting environmental assessments (EAs) of proposed projects and should be used as a supplement to the *Environmental Assessment Sourcebook*. The Bank is thankful to the Government of Norway for financing the production of the *Updates*. Please address comments and inquiries to Olav Kjørven and Aidan Davy, Managing Editors, EA Sourcebook Update, ENVLW, The World Bank, 1818 H St. NW, Washington, D.C., 20433, Room No. MC-5-111, (202) 473-1297, or send E-mail to: eaupdates@worldbank.org.