ENVIRONMENTAL RISK ANALYSIS- CONCEPT OF RISK, RISK ASSESSMENT AND RISK MANAGEMENT

INTRODUCTION

Dear Friends, Environmental problems are serious and we have seen that there are different types of policy instruments that government operates and implements, ranging from command and control to uniform standards to tradable pollution permits. Now, we are interested in investigation that *how* such policies are designed and implemented in practice. It is a complex process that how government involves in controlling environmental degradation and what response it gets. The plea is that government must use scientists' evaluation of an environmental hazards to formally assess the environmental problem and the risk it poses to society - a procedure referred to as *risk assessment*. On the other hand the public officials must decide an appropriate course of action or policy response to reduce the risk-part of the process known as *risk management*. Hence, in this module we shall try to understand and analyze three important things; (1) the concept of risk, (2) the assessment of risk and (3) the management of risk that we encounter while designing and implementing the policy to controlling the environmental damages and hazards.

In matters of risk assessment and risk management we have to take decision and decision making is difficult since there involves uncertainty about environmental hazards and the implications for human health and the ecology, particularly in the long run. Moreover there is no clear consensus about the government's response to given hazard. In reality all environmental risks cannot be eliminated, hence policy makers have to determine how much risk society can tolerate and what-policy to use to achieve whatever risk level is deemed acceptable.

If we take an economic approach, then the management of environmental risks must be guided by the costs and benefits associated with abatement. However sufficient data to assess the costs and benefits are not available, hence the policy-makers have to rely on the best available estimates or to use an alternative risk management strategy.

(A) CONCEPT OF RISK

We know that risk is very important concept in economics especially in the study of entrepreneurship, but it is an obscure concept, and in real world we take some intuitive sense of what it is. It can be reckoned as the chance of something bad happening when we say that things are risky, we mean that some positive or favorable outcome is not always possible, the negative event phenomenon and action where in loss is incurred is a situation of risk. We know that risk is a pervasive phenomenon and also know that some risks can be minimized or avoided, provided they have been recognized. This suggests that dealing with risk involves two tasks; (1) identifying the degree of risk and (2) responding to it. These two tasks are evolved in individual activities. Individuals make perceptive of risk in unscientific way and guided by instinct or subjective element. A person might choose to accept risk as is, but also find ways to reduce it and avoid it tactfully.

This shows that dealing with risk is strictly private exercise, but the risk analysis is also an important part of public policy development. The government devises it by taking in to consideration of society and the social interest. The policy maker must use a systematic assessment of risk before devising a policy response.

Classifying Risk: Voluntary and involuntary risk

One of the more common approaches is to consider two broad risk categories; voluntary risk and involuntary risk.

Voluntary risks

These risks are those that are deliberately assumed at an individual level and it is a result of a conscious decision. Most voluntary risks are from personal activities, such as driving a car, flying an airplane or taking drug. These risks are self-imposed and individual can make decision to respond to them. Then they adjust their exposure level to underlying hazards.

Involuntary Risks

When people are exposed to hazards that are beyond their control, then such risk is involuntary. These risks do not arise from a willful decision e.g., likelihood of property damage and personal injury cause by a natural disaster. The risk of being harmed by natural calamity is not self-imposed environmental hazards, such as air pollution on toxic waste sites, are another source of involuntary risk. All these risks and hazards are causing problems of human health and ecology and they cannot be reduced to zero.. Such risks are beyond the control of private individuals, they are the threats and a public problem and government intervenes to remove such risks.

Distinguishing between voluntary and involuntary risks

The distinction between the voluntary and involuntary risks is that the voluntary risk turn in to involuntary for e.g. smoking is a voluntary risk but the bystander or the companion is adversely affected by it which he cannot control it. In this regard Government has to take some measures to avoid such risk by advertisement and by caution or by anti-smoking posters etc.

Defining Environmental Risk

Environmental risk is an involuntary risk of exposure to an environmental hazard which is an important concerns of environmental decision makers. This risk is involuntary and it appears in the form of pollutant emissions and toxic substances. The two elements, the hazard itself and the exposure to *hazard* determine the extent of environmental risk. (Hazard means a source of the environmental damage) It is a form of negative externality such as poisonous factory emissions or toxic chemicals dumped in to a river *exposure* refers to the pathway, between the source of the damage and the affected population or resource. Both hazard and exposure define environmental risk, and each can independently affect the outcome.

Since risk analysis is central to environmental decision making, the policy makers have devised methods to assess, characterize and respond to environmental risk. These interdependent methods are referred to as *risk assessment and risk management*. We can discuss them separately in detail.

(B) RISK ASSESSMENT

Risk assessment refers to the quantitative and grand quantitative evaluation of the risk posed to health or the ecology by an environmental hazard. In practice, environmental risk assessment is conducted by scientists who gather, analyze and interpret data about a given contaminant we can briefly examine each of these assessment processes in turn.

(1) Human Health Risk Assessment

The risk assessment model usually takes in to account evaluations of human health risks. It helps to know that this risk assessment model is part of a three-phase framework of risk-based decision making *phase I*-problem formulation and scoping

Phase II- Risk Assessment

Phase III Risk Management

The risk assessment phase is comprised of four steps hazard identification, dose-response assessment, exposure assessment and risk characterization. We shall discuss these steps one by one and represent them in figure.

<u>(a) Hazard Identification</u>

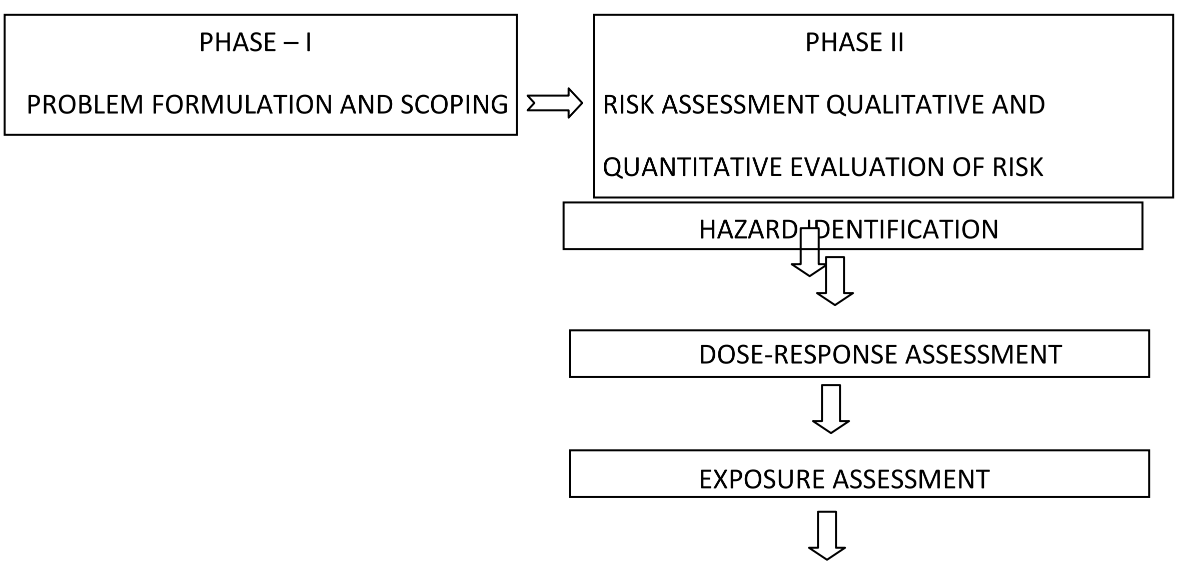
In this step, we determine whether a caused relationship exists between a pollutant and an increased incidence of adverse effects on human health and whether there effects are likely to arise. This determination is based on available data, using several scientific methods together evidence about any association between human health and exposure to a pollutant. Three common methods are case clusters, animal bioassay and epidemiology, which we will show in a tabular form.

<u>(b) Dose-Response Assessment</u>

This technique is a quantitative relationship between dose of contaminant and corresponding reaction. Once a substance has been identified as a hazard, scientist must investigate its potency by quantifying the human response to various dose this element of risk assessment determines the *dose-response relationship*. At the hazard identification stage, dose-response assessment attempts to develop a complete profile of the effects of an environmental pollutant. An important aspect of this assessment is determining whether some range of exposures to the hazards from zero to some specific level to tolerated scientists call this a *threshold level* of exposure which is the point up to which no response exists based on scientific evidence.

Estimating a dose-response relationship requires to make initial assumptions. These include which factors are being controlled when defining the relationship and what the underlying relationship looks like figure - 2 (a), (b) and (c) illustrate three hypothetical dose-response functional forms.

<u>Figure - 1</u> <u>Human Health Risk Assessment Process</u>



RISK CHARACTERIZATION

PHASE – III

RISK MANAGEMENT

FORMULATING POLICY RESPONSES RISK

Table - 1 Scientific Methods to identify an Environmental Health Hazard

Scientific Method	Definition
Case Cluster	A study based on the observation of an abnormal pattern of health effects within some population group
Animal Bioassay	A study based on the comparative results of laboratory experiments on living programs both before and after exposure to a given hazard
Epidemiology	The study of the causes and distribution of disease in human populations based on characteristics such as age, gender, occupation and economic status.

Graph

NO LINK

to each graph is positive relationship between dose level and response. What differs among them is the rate at which the response increases with the dosage.

Panel (a) shows a linear dose-response function, meaning that the rate of increase between dose and response is constant. Because the function starts at the origin, no threshold level is co-observed. The function in panel shows a constant rate of change between dose levels and response beyond dose level up to and including that point there is no response, meaning that there is a threshold panel (c) depicts a cubic relationship (increasing at increasing rate and then increasing at diminishing rate) drawn from the origin, showing that the response level increases at an increasing rate up and then increasing at a decreasing rate thereafter.

The scientific results derived from hazard identification and dose response assessment provide general information about an environmental risk based on some known population defined by the laboratory or test conditions. This information can then be used as a basis for assessing the risk to a potentially exposed population on a specific context. The EPA (Environmental Protection Act) has established a database of identified environmental hazards and their relationship estimated dose-response relationships for use by both researchers and the general public referred to as the *Integrated Risk Information System* (IRIS). This database is designed to improve risk assessment by lending consistency to what is a difficult and time intensive process.

(C) Exposure Assessment

The process through which a generalized dose-response relationship is applied to specific conditions for an affected population is called exposure assessment. This evaluation measures or estimates the following:

1. The magnitude , frequency and duration of exposure
2. The pathways from the source to the affected population and the routes in to the body
3. Any sensitivities within the population group

The sources of leads are factory emissions, lead-acid, batteries and lead water pipes.

(d) Risk Characterization

Risk characterization communicates the nature of the expected risk, information on how risk was assessed along with underlying assumption and uncertainties and areas where policy decisions are needed. It include the individual characterization of the three prior steps as well as an integrated analyses of the overall process. The description includes both a quantitative and a qualitative risk evaluation.

The quantitative component identifies the magnitude of the risk and provides a way to compare one risk with another. Drawn from the dose-response assessment, risk can be measured as a probability that an event will occur or as a reference dose.

Environmental risks, such as no carcinogenic health risks, are quantified as the exposure level to a hazard that can tolerated a life time with harm. This is communicated as a reference dose (RFD) expressed as:

RFD = Milligram of a pollutant per body weight (in kilograms) per day.

The qualitative component of risk characterization gives content to the numerical risk value. It gives a description of the hazard, an assessment of exposure that notice any susceptible population groups an identification of the data used, the scientific uncertainties, data gaps, or measurement error that distinguish the findings are pointed out as well. All this information characterizes the reliability of the results and facilitates further research.

(2) Ecological Risk Assessment

An ecological risk assessment evaluates the probability of changes to the natural environment that are linked to such stressors as pollution exposure or climate change, e.g. crop damage and soil contamination. The figure-2 can give some insight in to the ecological risk of climate changes under most-public policies; there economical changes are viewed as secondary to human health effect. However, ecological effects and human health effects are not independent. Over time, human health is adversely affected if ecological health deteriorates, e.g. damage to soil and crops may negatively affect economic productivity, human fitness, and the quality of life. A report on environmental risk by EPA devotes more attention to reducing ecological risk and to recognizing the link between ecological health and human health.

The EPA has developed guidelines aims specifically at ecological risk assessment. These guidelines help with the implementation of three phases comprising ecological risk assessment. These phases are identified as *problem formulation, Analysis and Characterization,* which can be represented by this figure.

Figure -3 Ecological Risk Assessment Process

PHASE - 1

Problem formulation

Information Gathering

About What Is at Risk

PHASE - II

Analyses

Determination of What Is Exposed,

Degree of Exposure and Likelihood of

Harmful Ecological Effects

PHASE - III

Risk Characterization

Description and Estimate of

Risk Based on Information

Collected in Phases I and II

(a) <u>Problem Formulation</u>

In problem formulation, the ecological entity or assessment endpoint identifies the potential risk. This entity could be either individual plant or annual species, and ecological community, an entire ecosystem, or a habitat. The assessment determines that which characteristic of the entity may be at risk and what is its importance, such as its role in ecosystem such model shows the possible links between the ecological entity and the environment stressor with an accompanying description that include the assessment endpoint, i.e. the predicted effects on the ecological entity.

(b) Analysis

The *analysis phase* identifies all the information necessary to predict ecological responses to environmental hazard under various exposure conditions. It includes that a determination of which ecological entities are exposed, the degree of the exposure, and the likelihood, that harmful effects will arise because of that exposure. To support the analysis, calculations are made to quantify the risk, such as a hazard quotient, which forms the ratio of a contaminant concentration to some screening benchmark, and a bio accumulation rate, which measures how pollutants are taken up by an ecological species.

(c) Risk Characterization

This final phase of ecological risk assessments is a description of risk based on the information gathered in the previous phases. This description provide the degree of confidence in the risk estimate any evidence that supports the findings and an interpretation of the predicted ecological effects. It includes the risk descriptions as the severity of the damage, the time over which the damage occurs, and the extent of damage in terms of numbers and types of species.

(C) RISK MANAGEMENT

Risk management is the decision-making process of evaluating and choosing from alternative responses to environmental risk.

The objective of risk assessment is to identify risk and the goal of risk managements to respond to it. The risk management is concerned with evaluating and selecting from alternative policy instrument to reduce society's risk of a given hazard. To evaluate various policy options, the decision maker must consider not only, the information given by the risk characterization but also such factors as technological feasibility, implementation cost and other economical implications.

Implementation of the risk management process involves a series of decisions aimed at two major tasks:

1. To determine what level of risk is 'acceptable to society'
2. To evaluate and select the 'best' policy instrument to achieve that risk level

Since the decisions are not one-dimensional and cannot be made with complete objectivity, we use strategic approaches to guide the decision making and some of them are mandated by law. A brief discussion of these two tasks of risk management, gives us the groundwork for an analysis of risk management strategies.

(1) Tasks of Risk Management

(a) Determining 'Acceptable' Risk

The General objective of all risk management strategies is to reduce risk. The policy maker has to decide as to how much risk reduction is appropriate. Since risk is a function of both hazard and exposure, we need to select any one, say exposure and then control it. So when the risk manager decides on the risk reduction to be achieved, the exposure level is implicitly determined. In setting the level of 'acceptable' risk, the policy maker confronts a difficult but necessary question: should the policy, eliminate the risk by reducing exposure to zero or should some compromise be struck at some positive risk level and if so, where?

‘Acceptable’ risk is the amount risk

determined to be tolerable for society

If the acceptable risk level is set at zero, the policy must reduce society's exposure to zero. Although this action eliminates the associated health and ecological damages, but the factory or plant would be closed and lead to unemployment.

If some positive level of risk of deemed acceptable, then the decision maker is setting, policy that allows exposure and therefore some amount of damage. To help guide this difficult decision, policymakers sometimes use the concept of *de minimis risk*. De minims risk refers to a negligible level of risk such that reducing it further would not justify the costs of doing so. This concept is sometimes equated to the risk of a natural hazard; for e.g. earthquake once the baseline is established, the decision maker might use *comparative risk analysis* to evaluate how the positive risk level compares to other currently faced and accepted by society. This type of analysis can be useful to communicate the relatively unfamiliar risks associated with exposure of naturally occurring gas that can be harmful.

(b) Evaluating and selecting a policy Instrument

After ascertaining the degree of risk and the need of a required policy is determined the next task of risk management is to decide the type of policy useful for that. Here the question of evaluation of alternative policies arises. The policy that gives the "acceptable" risk level and can serve the purpose is selected. We know that there are two policy options; either to go for command and control or to go for market-based policy. Here the risk manager takes in to consideration the magnitude of risk and the cost benefits related to each available control instrument and hence in this situation the risk management strategies enable us to evaluate a policy instrument.

(2) Risk Management strategies

Executing the two tasks namely, determining the "Acceptable" risk level, and choosing the appropriate. Policy instrument requires a systematic evolution of available options. From an economic perspective, the most important considerations are:

(1) The level of risk established

(2) The benefits that accrue to society from adopting the policy.

(3) The associated costs of implementing the policy

Many risk management strategies have been developed over time, each of which outline how these factors are to be evaluated. The most prevalent of these are *comparative risk analysis, risk-benefit analysis and benefit-cost analysis.*

(a) Comparative Risk Analysis

This analysis helps the risk manager to select an ‘acceptable’ risk level as well as to officials to identify which risks are most in need of an official response. The EPA'S science Advisory Board (SAB) has prepared a ranking of environmental problems by degree of risk, shown in the table.

Table - 1 Scientific Ranking of Environmental Problems

Relative Risk Ranking	Environmental problem

High risk to human Health	- Ambient air pollution
	Worker exposure to chemicals in industry and agriculture
	- Indoor pollution
	- Contamination of drinking water
High risk to natural ecology and human welfare	- Habitat alteration and destruction
	- Species extinction and loss of biodiversity
	- Stratospheric ozone depletion
	- Global climate change
Medium risk to natural ecology and human welfare	- Herbicides/Pesticides
	- Contamination of surface water
	-Acid deposition
	- Air borne toxics
Low risk to natural ecology and human welfare	- Oil spills
	- Ground water contamination
	- Radio nuclides
	- Thermal pollution
	- Acid run off to surface waters

The SAB specifically advises that EPA programs should be guided by the principle of relative risk reduction, meaning the agency should order its policy decisions to reduce the most severe environmental risks first.

The difficulty with setting risk-based priorities is the difference between the government's risk setting and the risk perceives by the society which is depicted in table -2 to see a ranking of environmental problems based on general public perception in U.S.

Table - 2 Public perception of Environmental Problem in United States

Environmental problems	Percentage Responding That Problem is very or extremely serious
Hazardous waste	89
Oil Spells	84

Air pollution	80
Solid waste disposal	79
Atmospheric damage	79
Nuclear waste	78
Contaminated water	77
Forest destruction	76
Ocean pollution	75
Endangered species	67
Threat to wildlife	65
Pesticide use	60
World population	57
Poor energy use	56
Global warming	56
Reliance on coal/oil	53
Wetland Development	50
Radon gas	35
Indoor air pollution	27
Electromagnetic Fields	19

Notice that public perception of environmental risk is generally not aligned with the SAB's ranking given in this table.

Such dichotomy of views between public perception and scientific evidence presents a dilemma to officials attempting to gain support for policy proposal. In this condition government should communicate scientific findings to the public to improve its understanding of environmental risk.

Comparative risk analysis enables us to select appropriate control instrument from given alternatives. This approach is often called risk-risk analysis. This strategy involves a comparison of the estimated risk probabilities or risk ranking scores from two or more policy options. This also gives access to the decision maker to compare the relative risks involved in given hazards and choose the instrument which is more effective in reducing risk. It implies that the objective of a risk - risk strategy is risk minimization, with no explicit consideration allowed for associated costs.

(b) Risk Benefit Analysis

Risk - benefit analysis deals with an assessment of risk of hazards along with the benefits to society if not regulating the hazards. In this approach, risk is taken as a cost and is compared with the benefits of the usage of risk hazardous resource, for example the use of gasoline, creating gas is health wise a risky hazard for the society but at the same time the usage of gasoline provides a source of fuel to society. In this situation the risk manager compares the risk reduction strategy with the benefits. He would maintain the balance between the two. He would consider that how a reduction in gasoline usage would diminish society's well being. In this analysis, in short, the risk manager has to keep in mind while selecting the instrument, the degree of exposure to the substance and the benefits the substance provides to society in use.

(c) Benefit - Cost Analysis

This analysis can identify an 'acceptable' risk level based on the criterion of *allocative efficiency*. For incremental risk reductions, the decision maker would compare the monetized value of social benefits with the associated costs to find the efficient risk level, where the marginal social benefit (MSB) and the marginal social cost (MSC) of risk reduction are equal. This corresponds to the risk level that maximizes the difference between total social benefits (TSB) and the total social costs. (TSC)

Environmental law is meant to achieve risk reduction to the associated benefits which are predetermined. In such cases, the risk manager still can use benefit-cost analysis but with different objectives in mind. Here, the goal would be to select a policy instrument that meets the legislated risk objective at least cost. If the selection is made properly, initiative will achieve the economic goal of *cost-effectiveness* rather than allocative efficiency. If the risk manager finds that at risk level the MSB and MSC are not equal, then he would think to amend to correct the resource misallocation.

CONCLUSION

We have seen in this module, the concept of risk, risk assessment and risk management in the context of environmental policy to overcome risk hazards. In fact the environmental decisions are difficult and controversial. However, the environmental policy makers struggle as to how to bring objectively and fairness with the risks posed by environmental hazards. It is a point effect of scientist researchers and official to get information about the nature of environmental hazards and the risk exposure. Risk management strategies enable to determine the 'acceptable' level of risk and appropriate policy instrument to equate MSB and MSC.

The use of benefit cost analysis as a decision rule is becoming more prevalent in public policy decision making. Monetizing environmental costs and benefits is an attempt to provide an impartial guideline to the risk manager.