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ISSUES IN ENVIRONMENTAL RISK ASSESSMENT

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ABSTRACT

Environmental risks are multiorder, interactive, irreversible, and long term risks. Major issues in generating impartial risk assessments are identified as well as the probably and possible distortions in deriving them using systems theory. A six step process is suggested which will strengthen the linkages of the policy system with the components of the risk assessment. A new behavioral world order achieved through a multidisciplinary action research program involving academics, politicians, administrators, planners, and environmentalists is needed.

INTRODUCTION

Environmental risk is becoming a concern in the developed countries [1-8] as well as in the developing world [9-13]. Environmental risk is a new kind of risk and information support for environmental risk assessment is currently very meagre. This study is an attempt to look into the problems of environmental risk assessment, using systems theory and to identify the ways and means of increasing our capability to undertake comprehensive environmental risk assessments.

ENVIRONMENTAL RISK

Environment risk is a new form of risk that has to be identified, assessed and then managed. Using a morphological matrix the uniqueness of environmental risks can be explained. In conventional economics risk covers situations where the probability distribution of outcomes are uncertain [14] but environmental risk includes situations covering genuine uncertainity due to lack of information

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concerning the outcomes as well as of the alternative consequences arising from the actions. Environmental risk has six dimensions—the impact, magnitude of the risk, intensity of the impact, information concerning the risk, number of levels of impact the risk has and the public acceptance. Most of the environmental risks come under column 4 in Table 1. A large number of combinations can occur complicating the environmental risk assessment. Environmental risk assessment is complex because of the following reasons. Environmental risks have:

1. impacts which are long term oriented and not clearly known;
2. intensity, which may be uncertain, uncontrollabe, catastrophic and/or irreversible;
3. large magnitude, which may be global;
4. poor knowledge or information base since they are new risks;
5. multiple dimensions which may be difficult to perceive, compared to economic risks which are simple, and
6. very complex public acceptance behavior.

Six examples of environmental risks are analysed before going into the assessment issues.

Low Level Radiation

The risks of low level radiation are a complex and contradictory area [15-19]. Our knowledge base about the long term effects of low level radiation is very inadequate. The experimental evidence is very scant to make conclusive observations. To determine at the 95 per cent confidence level, by a direct experiment whether 150 millirems will increase the mutation by 0.5 per cent requires about 8,000,000,000 mice, the number is so staggeringly large that, as a practical matter, the question is difficult to prove by direct scientific investigation [20]. At low radiation doses, of the order permitted by the radiation standards, the evidence is not clear as to whether radiation is harmful, harmless or even beneficial—these are not necessarily mutually exclusive [21]. The risk of inducing cancer at low doses of radiation is far greater than we once thought it to be and it may be as great or greater for the human race than the genetic risk [17]. Another contrary view also has been expressed as, the average genetic risk of low level radiation would be of 30 or 40 effects per million person rad or about one third the value which appears likely for the somatic risk of fatally induced cancer [22], i.e., the hazards of low level radiation has been grossly overplayed. Low level radiation is an environmental risk which needs detailed assessment since: 1. we do not know very clearly about the effects of these in the absence of long term data; 2. the experimental evidence is inconclusive; 3. if there is a serious genetic risk it can cause irreversible harm; 4. the public acceptance of low level radiation risk is a very intricate problem because people link radiation with nuclear weapons.

Table 1. Characteristics of Environmental Risks

	Alternatives			
Characteristics	*1*	*2*	*3*	*4*
Impact	Unknown	Known	Long term	Secondary and multiple order impacts
Intensity	Small	Uncertain	Catastrophic	Irreversible
Magnitude	Very localized	Regional	Mixed	Global
Information	Knowledge base poor	Fairly known	Interactions not known	Very compartmentalized and poor information base
Interaction	Single order	Multiple order	Unpredictable	Multiple order and highly interactive
Public Acceptance	Poor	No role	Depends on knowledge level	Emotional or biased

Carbon dioxide build-up

Increase in the concentration of atmospheric carbon dioxide is another risk which has been reported widely [23-31]. Burning of only 20 per cent of the world's fossil fuel would lead to an ice free arctic and an ice free Arctic would profoundly change the entire world's climate, and once a climate change begins, its ecological consequences could be manifested over a few decades [28]. Since both developing reliable models to estimate future atmosphere carbon dioxide concentration and possible radiative balance of the atmosphere [23] are very complex and it will never be possible to establish models which are absolutely true. What makes this environmental risk unique is its second order consequences. The consequences of climatic alteration reside not in any direct sensitivity of humans to moderate changes in temperature or moisture, but rather in the great sensitivity of food production to such changes and perhaps in the possible climate related spread of diseases into populations with no resistence against them [24]. The particulate matter and dust appears to have a balancing effect on the carbon dioxide buildup. The earth's temperature regulating mechanism involves a number of beautifully interrelated mechanisms that are not completely understood but it appears, however, that atmospheric carbon dioxide variations such as those occurring at present are likely to have only a minor effect on overall global temperature [25]. Here the choice is between a rapid cooling of the globe and maintaining the radiative balance and greenhouse effect due to carbon dioxide. This environmental risk is again unique because: 1. we are not sure of the atmospheric interactions; 2. the probability of temperature buildup is low but if it occurs the consequences will be global and catastrophic; 3. a small increase in atmospheric temperature may be tolerated but the secondary interactions triggered by this change may be more detrimental and uncontrollable; 4. public acceptance of this risk is again complex since changes in carbon dioxide concentration cannot be perceived easily; and 5. the multidimensional changes that are likely to be initiated may involve food production, ocean levels, precipitation, melting of ice caps, human health, and climate all over the globe.

DDT in the Environment

In certain third world countries the concentration of DDT in the food chain or food residues has been increasing. The secondary consequences have been observed in certain areas [32]. The withdrawal of DDT at this time from public health use could give rise to immense problems and expose large populations to malaria [33]. The use of DDT cannot be stropped for a long time to come, but by then the secondary consequences would have become severe. This is more serious in the third world because people use pesticides without much care, Further, it has been reported that a large number of species of mosquitos have become resistant to DDT. Increased use of DDT thus increases the incidence of resistance, as well as residue in food materials, whereas withdrawal of DDT also will have very serious consequences. Thus, this is an example of yet another type of environmental risk. In this, the deleterious secondary consequences get severe, yet the primary action cannot be withdrawn since this results in another risk, i.e., if DDT is withdrawn the endemic and epidemic malaria will reappear. Thus, to suppress the malaria, the usage of DDT has to be continued resulting in pesticide resistance or other deleterious consequences.

Urbanization

The rate of urbanization in the developing countries is twice that observed in the developed world [34-36]. Poverty, and rural unemployment causes migration into already over-crowded and unclean environments where physical infrastructure is already under severe strain. The migration of the rural poor and unemployed into the cities causes severe pressure on the physical facilities forcing the migrants to inhabit that unhygenic slums. Lack of hygenic conditions and lack of sanitary facilities and severe malnutrition prevalent among the poor results in mental stress and social conflicts. This is yet another major environmental risk since: 1. the trend of urbanization cannot be reversed easily; 2. the population increase and the increasing unemployment levels will only further increase the rates of urbanization; 3. already the second order consequences of urbanization like overcrowding and increased mental stress have been felt; 4. the urban life styles are more energy intensive compared to rural life styles and increased urbanization will intensify the second order risk of widening the disparities between rural and urban poor, creating a very unstable social conflict situation; 5. resources are becoming scarce and costlier, at this time promoting migration to urban areas will catalyze the energy and resources crises in the resource starved developing countries; and 6. the health risk of urbanization due to overcrowding in the already overcrowded unhygenic slums will be severe. Environmental risks or urbanization are turning serious as environmental conditions determine the inidividual behavior. Severe, second order risks like mental depression, crime and violence will make the life of poor in urban areas more insecure further increasing the existing mental anxiety, and severe mental stress conditions.

Deforestation

Deforestation is yet another very serious environmental risk. Forests have productive regulatory and protective functions at the ecosystems level [37-44]. There is severe deforestation in the third world countries and the second order effects like flash floods, erosion, laterization, denudation, sedimentation, and desertification have been on the increase in the recent past. Deforestation and its consequent ecological disorders are nonhomeorhetic i.e., after a disturbance the system is not able to come to the same stabilized chreodic or pathway that they have been following previous to the disturbance. This makes the risk of deforestation irreversible, catastrophic [24, 42], and unpredictable, i.e., after a threshold value, deforestation causes climatic changes or ecological catastrophes.

The second order risks of deforestation are also irreversible. Firstly, the vanishing of biological species [45-50] is the most imminent risk posed by the loss of certain species. This reduces plant genepools available to agricultural scientists and farmers for breeding and evolving new strains. This happens not due to direct decimation of species but due to other indirect activities like agriculture in tropical forests, plantation croppings, irrigation projects, paper industries, fuelwood usage, etc. The serious risk of deforestation is the possibility of impairing water resources systems in the developing world and thereby affecting the food production and agriculture adversely. The linkage between food production, soil and water resources [24, 51, 52] is more delicate in those countries where population sizes are large and agricultural systems are more at the mercy of nature. An examination of land and soils shows much of the hunger in Africa and Asia results from a shortage of water and not of land. The destruction of tropical forests may become our ecodisaster, i.e., a catastrophe involving severe, perhaps irreparable damage to the ecosystems. The risk of deforestation has another grave dimension. Deforestation is a phenomena with a large time lag [53, 43] and this means that when the symptoms finally appear, corrective action is ineffective or impossible.

Bilharzia

Bilharzia or bilharziasis or schistosomiasis is a health risk caused by waterborne snail that infects humans on contact [32, 54-56]. About 200 million persons are affected by it currently and another 600 million persons are likely to be endangered by this environmental risk in Asia, Africa, the Caribbean and Latin-America. Bilharzia is caused by snails from man-made lakes and reservoirs. There is unequivocal evidence that schisosomiasis is spreading fast and its severity is increasing in many regions of the third world. Migration of population, nomadism, insanitary living conditions, lack of protected water supply and spread of irrigation, all still common in the developing world, are likely to increase the prevalence of the disease, since the snail hosts are generally more widespread than the infection. The disease was identified in the early 1970's, and since then a number of United Nations agencies are regarding this as a serious risk, affecting a large number of farm workers, seriously impairing this productive capability.

These examples given about explain the multidimensionality, interactiveness, unpredictability, irreversibility and catastrophic nature of environmental risks. With these in view, this paper analyzes the risk assessment problems which are possible, probable, prevalent, incident and recurrent. (Table 2)

Using concepts of general systems theory, six hierarchical levels of issues can be identified, namely:

1. issues concerning inputs into risk assessment,
2. issues relating to techniques,
3. issues relating to the problems,
4. issues concerning the analyst and risk preferences,
5. issues concerning the result and public acceptance, and
6. issues concerning the linkages and system as a whole.

ISSUES CONCERNING INPUTS

Environmental risk assessments consist of risk registration, identification, impact analysis and evaluation [1, 2, 4, 8]. Risk registration is a perceptive process and hence highly subjective, value loaded and hence, biased. What one describes depends on what one wants [57]. Human perception is highly susceptible to emotionally loaded stimuli. Hence environmental risks get discounted on both sides. For example, the assessor of impact of nuclear energy, who favors nuclear energy discounts the undesirable risks whereas opponents of nuclear energy magnify the negative consequences. In a way, the first step itself is value dependent hence we have bias even before the assessment process. The next step in risk assessment is the identification of impact and estimation of the likelihood of occurrence of various alternative impacts. Identification of impact is a strong function of prior experience

[1, 4, 58, 59] and belief [60]. Previously unexperienced risks are discounted spatially and temporally. Further, belief distorts the cognitive processes depending on the value bias and prior experience. This may explain why most nuclear technologists discount the undesirable components of impacts of nuclear energy.

The next step following impact analysis is evaluation of the various possible impacts. The human cognitive mechanism requires a very large information base [61], when complex problems are involved. Environmental risks are highly complex, multiple order, and multidisciplinary. In the case of these risks, the knowledge base, information base, experimental base and academic base are yet to be fully developed. It has been shown that our knowledge about factors connecting public health and air pollution is still in the formative stages [62] and long range policy questions on public health should not be based on the very limited data which we have today. This problem is further magnified since our forecasting ability or anticipatory capability weakens as we look into higher orders of impact. Compartmentalization of education, administrative and professional activities force human beings to consider only parts, but mere collection of parts do not reproduce the whole. For example, though deforestation has been alarming in tropical Asia, Africa and Latin America, no integrated assessments have originated on this till recently. When a very large hydroelectric reservoir was built in Nagarjunasagar, India, nobody anticipated the environmental impacts it generated in totally unrelated areas. Construction of large water reservoirs in areas endemic for fluorosis have resulted in the appearance of cases of knock knees. Similar cases have been detected in the vicinity of two other large reservoirs in India. Environmental risks are quite complex and perceiving the impact dimension is extremely difficult. When complex risks are assessed [63, 64], we lack the cognitive capacity of combining the large amount of information involved in many decisions. Combination of various dimensions to derive an integrated risk assessment is another problem area.

In the case of multidimensional uncertainty, the subject often over-simplifies the cognitive structure by focusing on one or two elements [65]. The mind operates in such a way as to keep internal belief relationships both hierarchical and lateral, consistent with one another, a constraint which affects both the organization of memory and the processing of new information [66]. Also, multidimensional judgments have limitations at a second level of complexity in the combinatory operations [67]. Increasing the number of dimensions decreases the information extracted from each. These two constraints reduce the capacity for integrating multidimensional risks. The integrations of risks, thus, is an area requiring conceptual research before any meaningful combination of multidimensional risk can be attempted. Inhaber has attempted to integrate risks in energy production using accidents, disease and deaths per unit output [68-70]. But the biological risks of hydroelectric power and loss of genepool resources are not considered explicitly. Haefele has compared risks by normalizing the possible pollution [71]. But ecological irreversibilities or negative externalities have not been explicitly considered in this. Pochin combines risks and compares them using the number of accidents per unit output [72]. In all these we find a certain compartmentalization. Vanishing of genetic resources may be one risk which may not involve any deaths but biological extinction is truely irreversible. Hydroelectric reservoirs may not directly cause deaths but do cause deforestation and ecological damage. Risks of deforestation measured in terms of lives lost or human accidents will not really reflect the environmental damages of deforestation operations.

Since our knowledge, data and information base regarding environmental risks are insufficient fixing acceptable environmental standards are difficult. For example, fixing standards which will not generate any risk to aquatic organisms from toxic substances is a much more complex task. Firstly, aquatic systems are quite complex and elude the reductionist approach that has proven so useful in laboratory experiments [73-75]. Secondly, acceptability level of risks to aquatic organisms is in itself a subjective judgment. Thirdly, without a continual flow of information about the response directly from the ecosystem at risk, our response is likely to be inappropriate. Fourthly, different aquatic organisms have different toxic limits. Smaller fishes can tolerate only lower limits. Fifthly, combined toxicity of a number of chemicals is not linearly additive since certain trace chemicals enchance the toxity exponentially. Few toxicity-test procedures are available for microcosms and these are comparatively expensive and infrequently used. To conclude, our present state of knowledge regarding toxicity interactions and relatively primitive methodology [76] are insufficient to make any decision whatsoever, and therefore it is unreasonable to do so until more precise and refined methods have been developed. This indicates how intricate environmental risks are. It may be too late if we wait until we have comprehensive information on all the possible risks. Here risk anticipation and anticipatory control assumes importance.

Our education system, administration system and political system are highly fragmented, specialized, short term biased and compartmentalized. These groups in general, produce only stratified risk assessments. This problem may be acute because of another discounting phenomena observed widely [65]—the extremity of judgment—i.e., the tendency to use the end categories of a scale rather than the middle. Thus, the perception of risk as well as its identification and evaluation are highly value biased. Situational risk perception is influenced by a number of factors which are difficult to define including: interpretation of environmental clues, observed action of others, experience, amount of breathing time, socio-economic status, race, ethnicity, cultural background, primary group context, role conflict, perceived escape alternatives and training in statistical skills [58, 63]. Ignorance of actions and outcomes results in highly simplified risk assessment far removed from reality. For example, in the case of nuclear energy, opponents consider different aspects as more harmful, theft of plutonium [77-79], proliferation of weapons [79-81], nuclear waste disposal and storage [82-84] and accident hazards [85-87]. Whereas proponents of nuclear energy emphasizes the merits of nuclear option, like avoidance of carbon dioxide buildup [88,89], reducing dependence on oil resources [90], reducing sulphur dioxide [22, 28], etc. We must aim at integrated risk assessments based on basic data encompassing all multidisciplinary impacts without discounting any dimensions.

ISSUES RELATED TO TECHNIQUES

Anticipation or forecasting of risks and their impacts and assessing the risks, require anticipatory skills and technique skills. In the case of multidimensional risk each group amplifies one aspect of risk, discounting others, because people react differently to the prospect of exposure to different types of risks [8], like real risks. This happens because there are large variations between individuals in the rate of adjusting to changes or scales or, stimuli. This can be seen in a number of risk assessments where one dimension is amplified; to the exclusion of the other dimensions. Opponents of nuclear energy overemphasize the toxicity aspect of plutonium [77] whereas the proponents emphasize the depletion of fossil fuels and air pollution [91].

The next area of concern is the estimation of risks or evaluating, comparing, and assessing the impacts. Without statistical knowledge cognitively complex situations cannot be compared. The main problem is additivity of risks. Linear addition of risks does not necessarily correspond to realistic risk integration. Inhaber, in a study on risks of energy production had compared the risk using a linearly additive model [68-70].. The conventional energy systems are more risky in this sense and nuclear option the least risky. Similarly Haefele [71] in his model has linearly compared the output ratios of different energy systems as does Pochin's model [72]. All of these risk assessments favor the nuclear option. These assessments neglect risks of proliferation of weapons, and diversion of plutonium. And the establishment of nuclear parks under the authority of an agency like IAEA, UNIDO, UNDP, IBRD may reduce the diversion or proliferation. We need detailed assessments to show whether such alternative systems are at less risk. Before doing away with the nuclear option completely, we may also find out alternative ways of making nuclear options less risky. Risk assessment has little use unless it leads to the identification of lower risk options.

The next group of issues concern the quantifications of risks. We estimate risks in terms of probability. Human judgments of probability are affected by irrelevant factors and the figures obtained may be grossly misleading [60]. Secondly, it has been noticed that low probabilities are often overestimated and high probabilities are underestimated [65]. This explains why nuclear critics underestimate probabilities of nuclear reactor safety. Coming to the complex issue of small subjective probability measurements, prone to a large number of biasing factors, even under the best of conditions, it seems highly unlikely that people make any valid and reliable, intuitive distinctions between very small probabilities. This has been one of the objections raised against the most comprehensive nuclear safety study conducted [92] apart from the other reactor accident studies [93]. This suggests why nuclear proponents usually discount nuclear accidents, and core burndown. Thirdly, it has been found that a small amount of information available in ambiguous stimuli is sufficient to confirm a very strong hypothesis whereas a weaker hypothesis may not be confirmed even when a considerable amount of information is available [94]. Fifthly, mixing of utility and probability assessments are very common, and hence risk becomes a function of desirability of the consequence and the probabilities of consequences through their mutual dependence [80]. This is a major reason for discounting undesirable consequences and overestimating desirable outcomes. Possible climatic changes due to carbon dioxide buildup has been discounted even though there is no evidence to conclude what is most probable. Sixthly, conceptual bias, estimate bias, and task bias, prevail in all situations involving uncertainty, since assessment procedure is one of mapping the cognitive structure into a consistent probability distribution function [67, 95, 96]. Finally, these distortions arise out of lack of integrated models for risk assessment. Any aggregation model of risks contains value judgment and therefore there is no objective procedure for comparison of risks [97]. Thus we come to a paradoxical situation. Without quantification we cannot have objective assessments but quantification brings its own bias and distortions. Integrating undimensional models without real multidimensional cross linkages only produces distorted or biased assessments. Uncertainty, negativity, extremity, redundancy, context effects, inconsistency and idiosyncratic effects distort information integration in decision making. So, we need forecasting and assessment model capable of anticipating and estimating multidimensional risks without strong technique and task bias.

ISSUES RELATED TO THE PROBLEM

The error of the third kind, namely, solving the wrong problem, is a more fundamental and involved issue compared to technique and information bias. Incomplete understanding of the situation, cognitive simplifications like trivialization, fragmentation and dissociation of problems enhance the occurrence of these kinds of task biases. Consider the deforestation problem in the third world [41, 42, 94, 95], it has been wrongly conceived as an agricultural issue. In many of these countries [40] more than eighty per cent of the total wood extraction is for fuel purposes. To our dismay we find that illegal forest cuttings are much more than the legal extraction of forest resources in India. Merely enacting more laws cannot stop illegal extraction, since people who extract forests illegally are precisely those who do not have any other options for fuel. Deforestation could not be stopped in Haiti by mere legislation, since population whose needs are not satisfied continue to degrade their environment for mere subsistance. Hence deforestation is the effect of a serious basic cause–lack of cheap and economic domestic fuel. Hence risks of deforestation will continue until the poorer sections of the third world population are provided with alternative biomass fuels. Forest legislation exists in different forms in various countries but this has not arrested deforestation.

Problem distortions also occur: 1. when black box models are used instead of casual models; 2. when insignificant parameters take prominence over the real issues; or 3. when the problem or situation is not fully known; or 4. when the solution is not known; or 5. when uncorrect and unrealistic assumptions are used in deriving solutions. In the case of environmental risks, the incidence of all these distortions and their combinations occur because our knowledge about certain new risks are meagre. This also happens because of the hazy connection people make between hazard and risk. It has been shown that the hazards of nuclear bombs have been displaced to nuclear power generation through such incorrect link-up. These link-ups are difficult to separate. Tubiana in a study on risk, has shown how educating people about nuclear risks has caused more worry, anxiety and concern [100, 101].

The assumptions are a major distorting factor and wrong assumptions may make an impact assessment irrelevant, even if sophisticated techniques and reliable data are used. Our knowledge about environmental interactions are still in the formative stages, since information on these are not available and uncertainty is of a higher degree regarding outcomes. Hence, using wrong assumptions is more probable in the environmental situations [102]. The carbon dioxide buildup issue is an area where only black box models are available for risk assessment since our knowledge about the meteorological interactions is only elementary, partial, and fragmentary.

Long-term and short-term risks or impacts cannot be explicitly differentiated in many techniques. The cost/benefit criteria is almost ubiquitous in quantitative assessments, but is worthless for medium and long range planning in spite of the elaborate time preference theories discussed in economics [103]. This problem is compounded since most formal forecasting devices that are currently used were originally derived for short-term forecasting often for business or industry. Take the example of continuous short-term sulphur dioxide pollution vs the small possibility of serious accident in a nuclear power station. A statistically minimal risk, if perceived as being threatening, may generate anxieties that are no less real than if the situation actually were threatening [7].

A major issue is foreclosing of the options because of incorrect assessments. Wildavsky identifies this as "no risk is the highest risk of all." [5] Consider a situation where we identify a potentially deleterious consequence of an option.

In the future, two may happen i.e., 1. the option may not result in the deleterious consequence because of corrective action and 2. the option was wrongly stopped considering potential hazards, which turned out to be imaginary. In the second case, we unnecessarily discountinued the option to find that we have foreclosed our future options. So, we have to be extra sure before censoring any options. Suppose we halt the nuclear option and then find in the future that we were wrong in our choice, and have produced a higher risk? Clearly we do not have the option of a risk-free energy system and hence a wise choice in these circumstances will require both an open, unbiased decision process and a calculus that enables us to distinguish risks to survival form those to particular interests or to various social patterns [102, 104]. Here one major conclusion can be drawn, any high energy consumption alternative is likely to be risky one way or the other. We may have to go in for steady state options which in the long run are likely to bring the least risk. To sum up: 1. detailed understanding of the system; 2. availability of contained models concerning the system; and 3. consideration of feasible, desirable and probable options are needed to derive the best alternative to maintain ecological equilibrium.

ANALYST AND RISK PREFERENCE ISSUES

Risk preference, knowledge and desirability of outcomes are an integrated set of concepts not really separable from personality [57]. The perception of riskiness of options is subjective and dependent on risk preferences [6] i.e., the amount of risk one is willing to take is very intricately linked to a large number of value dependent factors. In short, intensive training programs must be planned on risk assessment to reduce the personal bias in risk estimation and evaluation. The conditionality assessment of impact is very subjective and depends on perceptive skills. But perceptive skills are in turn functions of attitude [105, 106], values [105], beliefs [60], prejudices [100], emotions [100, 107] and aspirations. As far as environmental risks are concerned, given the holes in our knowledge regarding these and the value laden nature [63] of environmental issues it is impossible to recommend a best response to the problems posed by the limits of human judgment. There is a tendency among members of a group to over-value their group's product and actions of several agencies have caused severe damage in many governments because of the rigidity of group thinking [108]. Further, decision makers under complexity rely heavily on negative logic [15]. Group rigidity and negative logic affects risk preferences and hence assessment.

Risks are overlooked when they go against strong, irrational motivations [100]. This is because belief has strong bearing on risk estimation and beliefs are perceptual, sensory, intuitive and experiential in nature and sometimes ambiguous. Further, belief distortions are acute and chronic since cognition gets weakened under stress and brings about shortsighted and twisted reasoning. In the case of environmental risk assessment stress, belief and emotions are common and often fear and unfounded beliefs distort the whole judgment. Possible future impacts or outcomes are nothing but projections of aspirations [106] and desirable scenarios. Social preferences are driven by the social motives and are dependent on self interest, self sacrifice, altruism, aggression, cooperation and competition [57]. Thus, assessments become biased and the biases become amplified because of our lack of knowledge, experience and information concerning multidimensional–multiorder–long term and uncertain risks. Because, data available for defining relationships and specifying coefficients are grossly deficient, some of the more ambitious of the ecological models are clearly doomed to be costly failures [109]. Each individual develops techniqeus for integrating feelings and experiences and hence perceptual vividness of stimuli are highly individualistic and unique. Perceptual vividness and beliefs introduce, thus, highly distorting conceptual biases in evaluative judgments.

Even among the environmentalists there are two schools of thought: ecocentric and technocentric [110]. Hence obtaining bias free future impacts is very difficult in a value loaded world. Risk assessments have to imbibe more of behavioral interactions so as to develop an integrated method of assessment devoid of purely subjective issues. The nuclear critics, pro solar groups, proponents of breeders, soft energy futurists, etc. first become fixed to a one-sided value system and then derive the assessments. Value changes occur only slowly or never, hence obtaining integrated risk assessments may be a time consuming and slow process in societies oriented towards short-term reward structures and groups with fixed value orientations. Assessments of risk of nuclear power done by nuclear establishments have never been critical of the nuclear option itself. The worth of an assessment lies not merely in identifying a deleterious impact but in prescribing ways to reduce the undesirable consequences. Hence in assessment groups opponents and proponents have to be made to sit together to derive a lower risk option, than merely abbrogating the high risk actions. The accident hazards of nuclear reactors may be higher than what has been anticipated by the proponents but risk assessment should help us in reducing the psychological fears of opponents, which may be real, imaginary or partial, by corrective actions.

Differences in time preferences and risk preferences of the analyst are other factors which determine the orientation of assessments. Utility differences, uncertainty differences, long-term versus short-term objectives and latent values [6, 57] determine risk preferences. Paradigms of perception are different in different societies and cultures. Hence assessors may need to be subjected to a process of changing paradigms to get a bias free assessment, even though this may be a slow process. In the case of environmental risks, the assessors who identify the risk are often unable to suggest remedies or risk lessening measures.

For example, low level radiation risks or climatic variation projections cannot be easily averted. Human tendency is such that threatening prospects are likely to be ignored no matter how serious, if no means of reducing that threat are defined along with the emergency warning. This clearly indicates the need for an integrated anticipatory or early warning and risk assessment system. The risk assessments have to include a strong normative component, if it has to be accepted by the decision makers and public, along with the early warning components.

Another issue regarding risk preference is the link between perceptive skills and reward structure in societies. The reward structure in industry and government, make the assessors discount certain risk [111, 112]. Administrators are assessed by their short-term contributions and activities like forest conservation, preservation of ecological stability, population control, protection of archeological monuments, wild life protection, etc. Long-term significance gets lowest priority in the eyes of the administrators as well as the politicians. With elections to win, wars to fight, dams to build and hungry mouths to feed it is hard for any politician and administrator to concentrate funds and attention on a problem which is multidimensional and seemingly long-term in nature [41]. The assessments have to be debiased by putting a large number of opponents and proponents to work in an innovative mode of problem solving. Further, there is an urgent need for research that will lead to a better understanding of the factors that determine the perception of environmental risks and risk preferences of assessors, decision makers and the public.

ISSUES CONCERNING PUBLIC ACCEPTANCE

The next hierarchical level in risk assessment is the public acceptance of the assessments. Thorough factual educational campaigns regarding certain risks not only have failed to give a better understanding but have hightened uncertainty and confusion in certain cases [101]. When negative consequences and fears are prevalent in assessments, public acceptance issue becomes extremely prejudiced. The public acceptance of risk is poor [2], when the uncertainty associated with risks is great, when data concerning the uncertainty is not forthcoming and when expert opinion is apparently divided. The sources of anxiety about nuclear power are complex, extending well beyond concerns of physical health and safety because of the contradictory postures of experts. The uneasiness about nuclear power represents the most fundamental, primal fears about the integrity of the human body, as threatened by the invisible poison of irradiation. Thus the public opposition to nuclear is in a way a kind of displacement process involving the extension of fear of nuclear weapons to nuclear power [113-117]. The public reaction to nuclear power also reflects mistrust of governmental bureaucracies and concern about the extent of citizen participation in policies concerning technology. Site related opposition and procedure related opposition act in unison because of the unique nature of specific nuclear risks [116]. All these show that public acceptance is a very complex issue involving fear, value judgment, beliefs, and mass media postures. In the case of nuclear power, the hostility to nuclear energy is partly based on myths and fears; active opponents and proponents of nuclear energy are not speaking the same language. In other words, emotions, fears, beliefs, linkages, etc. control public acceptance.

Unless the risk assessments are given widest possible publicity to the public and to the politicians at large, the administrators and politicians discount the highly complex and involved issues. Delusions and subjectivity influence the political decision process as well. Conventional political machinery discounts long-term impacts, uncertainities, negative consequences and second order effects. The decision makers who receive the impact or risk assessment statement may distort, discount, neglect, interpret or modify the results since in many countries bureaucracies are very powerful. Though the population explosion is a real issue in the third world it gets discounted by the politicians since they give little importance to long-term issues. Groups are usually not cautious in the face of uncertain information. Groups frequently ignore something which is uncertain just because it is uncertain [15].

Another major and probably the most difficult issue concerns the interaction of risk assessment and corruption. Assessors because of personal motives may distort or amplify or cover up or discount assessments to suit their own viewpoint. Organized technology and difficult energy paths may have institutional supporters. Nuclear power has been reported to be a lopsided partnership between the private and public sectors, in which the rewards have been private and the huge risks–the hazards to life, the waste of billions of dollars, the rising cost of power, the impending collapse of the nuclear program and the ensuing economic chaos, have been assigned to the public [118]. Another example is deforestation in the third world. Often forest contractors and officials collude and clear large areas of superior rain forests neglecting the long term risks. The softness in administration is a widely prevalent malaise in the third world [119]. This makes it difficult to implement impartial risk assessment procedures.

SYSTEM RELATED CONCERNS

This is the highest level of issue in risk assessment. This determines the boundaries and interfaces of the legal, economic, political, technological, social and ecological system. When conflict arises due to a disagreement over the level of risk rather than the value assigned to that risk, efforts to reduce the conflict by incorporating risk/benefit values will not be successful [2]. Unless, we allow the technical process of the risk assessment task to work, it becomes enmeshed in the political process, which is always larger than the technical process. When the political process and the technical process become intermeshed, all of the technical information becomes biased, becomes labelled as prejudicial, it becomes mistrusted and further more, the people who purvey it become identified with the issues and they are tagged as being either for it or against it depending on the nature of technical evidence they have come up with [120]. Risks have structural features which put them in a class, being capable of effective control neither by a purely scientific analysis nor on a personal, conservative type of authority [121]. In the case of environmental risk, the outcomes are too ambiguous and uncertain and when in the midst of social complexity, there is doubt about where the steering controls lie. Latent tendencies to avoid risk [113] that are present in all institutions are conspicuously reinforced.

Organizations resist internal as well as external pressures on them to change. Risk assessment get discounted if they go against the sytem or if the internal linkages are poor or if the system managers feel that assessments go against the stability of the system. There are practical limits to human rationality and these limits are not static but depend upon the organizational environment in which the individuals make decisions [122]. Bureaucracies resist change by keeping a check on information (i.e., by secrecy). The opposition of nuclear power in a way is the displaced fear of strong secret bureaucratic procedures [114, 116]. The public reaction to nuclear power will harden further, if the governments do not reach solutions on waste disposal and nuclear reactor safety acceptable to the public. Attitudes harden very quickly but reversal is slow since bureaucracies by nature are not participative or information sharing. Further, lethargy regarding change, unfamiliarity and improper institutional linkages weaken environmental risk assessments and this is further weakened because of the lack of information sharing. Even in the case of developed countries, there is a strong tendency to discount, long-term risks because of strong commercial, economic and production oriented pressures.

Corruption is another factor which introduces system oriented bias as does the collusion of analyst with the system manager. Most people in the world will compromise his or her altruistic or ethical values for survival or money [123]. Corruption not only nullifies the assessments but also distorts them to the detriment of the subsystems. Certain internal impact assessments, thus, are only self-fulfilling forecasts. Unless the assessment agency is independent of the system manager this cannot be rectified. This may be a serious issue, in the case of developing countries and more so, if the governmental form is nondemocratic or public participation is very poor.

Hierarchically, this is the sixth and highest level in the risk assessment process. As one goes up in the hierarchy the prevalence of distortions also rises. Because indeterminate problems tend to emerge at the apex or highest level of a decision process, errors made at that level will have the highest catenation factor and therefore carry the highest absolute cost [124]. The distortions can be removed only slowly and generally from the lowest level. The developed countries like USA, Sweden, France, Britain, etc. have already reached higher levels of environmental planning skills. Since complex skills, too, have a hierarchic structure [125], in the third world countries, this will percolate to the higher levels only slowly and with difficulty.

In order to make risk assessment a part of the environmental planning process, it is necessary to develop the following subsystems.

INITIATING STEPS FOR ENVIRONMENTAL PLANNING

Information Support

The major support sytem necessary to sustain an unbiased risk assessment, is a comprehensive environmental monitoring and information system. The necessity of having a comprehensive information net-work, such as INFOTERRA, which has been established by UNEP and other UN agencies [126, 127]. But this information support system is likely to be grossly insufficient, since without nationwide and statewide linkages these are likely to be a one-sided network without means for enforcement. If INFOTERRA is to be of help in environmental decision making, environmental education and research has to be properly linked to the administrative and research information networks.

These networks must also provide information on alternatives for risk reduction. In effect, if the environmental information network is to be used in different sectors of national planning, such a system requires a disproportionately large increase in the number of information processing and decision making components. So we find that if environmental information is to be utilized there must be a proper and wide academic and research base to accept it.

Training and Imparting New Skills

As specialists we can handle effectively only specialized problems and lack the overall grasp required to overcome the environmental and social difficulties for which specialized approaches are highly inadequate. This arises partly because the organization of the university along disciplinary lines [128] does not provide a good match to the technological, political, social, ecological and cultural problems we face. The educative process must cultivate the future through creative, ecosystematic planning and learning paradigms by being value sensitive, by reversing time casuality, by adopting an ecosystemic hierarchy and by shifting to a system balance orientation [129]. To do this the training process must inculcate five kinds of skills [130], quantitative, decision, relationship, empirical and conceptual skills. The task dimension of these skills has been given in detail in Table 3.

Table 2. Environmental Risks

Risk	*Special Characteristics*
Low level radiation	1. Evidence inconclusive 2. Experimental verification impossible 3. Long term effects not known clearly 4. Genetic vs somatic risk difficult to predict 5. People have adapted to low level radiations for centuries 6. Possibility of genetic damage is very small 7. More experimental evidence and detailed analysis needed
Carbon dioxide buildup in the atmosphere	1. Interactions not clearly known 2. Existing models are not truely representative 3. Climatic changes will have impact on food production and health 4. If there is any tilt of balance no control possible 5. Severe damages throughout the world in the event of change 6. Dust and particulates are likely to be balancing factors, but effects not clearly known
DDT in the environment	1. Buildup of residues 2. Cannot be withdrawn since severe damages will result 3. Currently no other viable alternative available 4. By the time alternatives are developed, delayed consequences would have become severe
Deforestation	1. The effects are likely to be catastrophic 2. Biological extinction irreversible 3. Food production system will be seriously impaired 4. Micro-climate will change 5. Secondary effects have already become severe 6. Returning to original state not possible 7. Risks of deforestation occurs because a large number of development activities indirectly cause depletion of forest resources
Bilharzia	1. Incidence has become severe 2. Rate of spreading is growing 3. New irrigation systems cannot be stopped 4. Solution is very complicated 5. Illiteracy major constraint in spreading knowledge 6. Poor people are affected more
Urbanization	1. The rates are increasing 2. No action to reverse the trend is attempted 3. Social and cultural tension in cities to continue 4. Any changes in resource prices are likely to have catastrophic effects 5. Secondary effects are likely to become severe due to overcrowding

Table 3. Skills Needed for Risk Assessment

Assessment Activity	*Quantitative Skills*	*Decision Skills*	*Relationship Skills*	*Empirical Skills*	*Conceptual Skills*
Risk Registration	Magnitude and intensity of impact	Selecting major potential risks	Identification of second-order and delayed effects	Identifying interactions	Anticipatory capability
Risk Identification	Relevance trees, fault trees, impact trees	Objective decision making approach	Impartial observation of links	Perceptual clarity	Cognitive clarity
Impact Analysis	Probability and stochastic modelling	Multiple criteria decision making	Mode of assessing impact	Multidimensional balanced view	Integrating multi-dimensional risks or impact
Evaluation	Risk analysis and network methods	Depending on data select the method to evaluate	Organizational linkages of risk assessment	Deriving integrated assessments	Avoid overemphasis and bias
Acceptance	Presentation of impacts	Identifying alternative courses of action	Avoid internalizing assessments	Developing newer alternatives	Reduce discounting the impacts
Implementation	Risk/benefit analysis	Alternative ways of implementing as well as reorganizing	Organizational acceptance as well as public acceptance	Anticipating road blocks in implementation	Corrective and risk reducing alternatives to be found

Intensive training on impact and risk assessment as a part of environmental management, has to be initiated. Risk assessment, impact analysis and evaluation of alternatives must be incorporated in engineering, technology and management curricula. The most crucial step in the area of risk assessment is educating government administrators and policy makers. Without changes in bureaucratic attitudes, nothing can change in governmental machinery [131]. Another constraint is spreading valid assessment techniques is the lack of successful cases and examples in the third world.

Public Participation

Without serious, technical and open public participation, risk reduction is not possible except perhaps in countries where non-democratic forms of government prevail. One of the major reasons why people reject nuclear power is the secrecy involved in all procedures as well as lack of information. In essence, countries have to develop public groups, citizen forums and strong professional societies with independent assessment capabilities. We cannot expect people to support strong environmentally protective actions by governments until they perceive a clear and present danger. The process of public participation should be one which is continuous, open, informing, iterative, responsive, evocative and tied to decisions. Further, defective public participation increases the danger of the outcomes being manipulated in favor of certain interests [132] and hence maximum direct and active participation must be stimulated. Public participation has to be followed by consensus decision making. The consensus approach will be helpful in deriving multiorder, multidisciplinary approaches. In the third world the danger of risk assessment being degraded into a political consensus is strong and this has to be resisted. Yes–no votes have no place in assessment and the process of decision making must be interactive and consensual.

Early Warning Systems

A supernational early warning system to anticipate new environmental risks must be initiated under the United Nations [133]. In critically irreversible processes immediate and constant monitoring is urgently needed. The early warning system on environmental risk has to have very strong impact anticipation and monitoring capabilities. The incidence of Bilharzia is on the increase in Asia and Africa due to spread of irrigation and no one had anticipated such an impact [54]. Since environmental risks are new forms of risk, impact anticipation must be highly futuristic, multidisciplinary, cross sectoral, multidimentional and broad based.

Environmental Policy Links

An unbiased environmental risk assessment can be sustained only if it is properly linked to environmental policy. Linking of risk assessment with the decision making and public policy system requires research directed to: 1. the interplay of values in risk assessment and preference; 2. public response to risks; 3. public acceptance of risks; 4. bureaucratic and political response and reaction to risks; and 5. the relationship between perceptual skills and decision making in the case of environmental risks. If the risk assessment system is to be properly linked with public policy, then policy generation and impact analysis methodologies have to be properly coupled with conventional techno-economic evaluation criteria. This may not be possible without dovetailing public policy analysis, environmental planning, resource planning, perception research, long-range modelling, futures research and technology assessment systems. If any one of these links in public policy, in the supporting system is weak, the entire chain will be constrained. The integration of these subsystems has to be done with mutual respect and openmindedness. Finally, the linkages will be effective only if the existing short range reward system is thoroughly overhauled and reformulated to support a perceptive outlook which will not irreversibly harm future options.

Behavioral Revolution

Risk assessment skills can be improved only through intensive training in statistical reasoning, transparadigmatic approaches, epistemological changes [134], sensitivity training, gestalt therapy, etc. People are overconfident of how much they know and some of the judgmental biases have the psychological status of optical illusions and only through training, can decision making [64], relationship, quantitative, empirical and conceptual skills be improved. To be effective, risk assessment, as the first step, has to move from the technique area to the behavior interaction area. This will be possible only by integrating planning, training in creativity, epistemological change, futures research, transactional analysis and risk assessment into one action oriented research module. In the second step, the first step module has to be integrated with policy sciences, environmental planning, resource management, and systems management to obtain the next higher level module. In the third step, creative futuristic paradigms must be extended to the behavioral sciences—policy planning realm through joint research by forecastors, environmentalists, politicians, technologists, bureaucrats, planners and behavioral scientists to yield a new behavioral world order. Much research will be needed to reach this state.

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