A Discussion of Public Health Issues From a Severe Nuclear Reactor Accident

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INTRODUCTION

Any strategy for implementation of protective actions for the general public following a nuclear power reactor accident must be based on justification and optimization of the imposed actions to produce a maximum benefit by reducing the total harm. This paper discusses the influence of some of the factors affecting the analysis of risk and assignment of priorities in the creation of a rational and flexible strategy for post-emergency periods. The issues discussed include: radiation-induced risks, the impact of protective actions, and psychologically induced illnesses.

DISCUSSION

Radiation-Induced Risks

The risks induced by exposure to radiation have been catalogued, analyzed, and quantified by national and international agencies.[1] Procedures for emergency preparedness for response to the emergency phase of a nuclear reactor accident have been fully documented.[2] The levels of radiation-induced risk have been correlated with both rates and duration of exposure.[3] The radiation risks during the post-emergency periods are principally from chronic irradiation due to inhalation of contaminated airborne radionuclides, ingestion of contaminated food and water, and external exposure to the contaminated ground. The principal radiation-induced effects are somatic late effects, which include stochastic effects such as leukemia, sarcoma, and carcinoma. Each one of these late effects has a period of latency, which is the time period between irradiation and manifestation of the cancers. The latency period may be from several years to decades long.

A particular protective action may decrease the radiation dose, but the long-term decrease in somatic effects of the exposure may not be uniformly distributed for all age cohorts in the demographic distribution. This non-uniformity in protective effect is a consequence of a non-linear age-dose-response distribution. For example, for older adults whose remaining life span is less than the latency period for induction of a somatic effect, the effect of the radiation-induced risk may not be realized.[3]

The Impact of Protective Actions

Among the most common emergency and intermediate protective actions are evacuation, relocation, and restriction of the intake of contaminated food and water. All have associated impacts and risks, as described below.

Some actions, such as evacuation and administration of potassium iodide (KI), could be intrusive and may induce unintended harm. Evacuation under adverse climatological conditions, such as a severe winter storm, could prove far riskier than the dose to be avoided. Evacuation of medical facilities can pose high risks to the elderly or critically ill. Adverse reactions to KI resulting from hypersensitivity to iodide, although uncommon, are not unknown.

Furthermore, while local emergency plans thoroughly address the use and implementation of early protective actions like evacuation and sheltering, they commonly fail to address the consequences of later actions; i.e., those involving potentially contaminated food, water, animals, etc. Evacuation decisions will likely be based on science (reactor stability, accident sequences, dose assessments), while food chain decisions will more likely bow to public perception. For example, following the Chernobyl accident, some foodstuffs grown in the Ukraine were sampled, analyzed, and found to contain minimal amounts of radioactive contamination, far below cut-off levels. Although science verified the safety of such products, the public perception of risk was skewed, and these items were driven from the market. The economic consequences were considerable.

Likewise, long-term actions for environmental cleanup can have drawbacks. One long-term protective action for a contaminated area is the option of "no action," permitting natural removal of the radioactivity by surface runoff and by mechanical mixing of the contamination into deeper soil matrices by wind and precipitation.[4] Another option is surface stabilization using surface active chemicals to reduce resuspension. This may also reduce relocation of the radioactivity by surface wash off. Finally, deep tilling of the moist, agricultural land can be performed to reduce resuspension of the radioactivity. All of these options reduce availability of the land for an extended period of time and would increase the potential for plant uptake and leaching of radionuclides into the groundwater.

Psychologically Induced Illnesses

Psychologically induced illnesses include both psychosomatic illnesses and the induction of anxiety, depression, and helplessness. Some of the induced psychological effects are created by overestimating the magnitude of the risks beyond the reality of the potential hazards. An apprehension about risks of unknown events and lack of control, fed by misinformation and poor comprehension of reality, increases the anxiety and its consequences.

The psychological effects of major accidents, such as car, train, and airplane crashes, or natural disasters, such as floods, tornadoes, and earthquakes, have been studied and understood better than nuclear accidents. The public has become aware of the dangers and consequences of natural disasters on the affected individuals and the environment; thus the public has developed a reasonable comprehension of risks and realities. In contrast, our experience with nuclear reactor accidents is embedded in the Hiroshima and Nagasaki bombings. The consequences of the atomic bombs have created an unrealistic apprehension about non-military sources of radiation. The horror of events in unscientific fiction and movies about monstrous genetic mutations are etched into our memories. Radiation phobia (or radiophobia) is an expression for an exaggerated perception of radiation risks. This phobia has been nurtured by decades of misinformation while the real and significant risks in our daily life are downplayed. Although we are all affected by any event that deviates from the daily routine--coping[5] with evacuation or food restrictions would be stressful enough--the prospect of additional actions such as whole body counting and decontamination could induce even more anxiety and stress.

These psychological effects are physically real and are usually disproportionate to the magnitude of the radiation exposure. These syndromes are classified as post-traumatic stress disorder (PTSD)[6] and chronic stress disorder (CSD). A major difference between these two disorders is the duration of the stress itself. Whereas the duration of the stress may be brief for the onset of PTSD, lasting up to several days, the stress would be chronic for CSD. In Chernobyl, the continuity of the stress among the population created CSD, similar to that found among victims of war and prolonged occupation. A review of the Three Mile Island[7] (TMI) and Chernobyl[8] accidents indicates that the PTSD and CSD contribution to the total risk is significant. The impact of induced psychological risks on the public health is difficult to analyze and quantify using standard risk analysis techniques. Because these effects are hard to quantify, they often are not included in the traditional methods of risk analysis. This is a serious omission.

A major objective following a severe nuclear reactor accident is allocation of regional and national resources to reduce any potential public health risks. These allocations should be cost-effective and based on realistic objectives for reduction of total harm. Unfortunately, this is difficult in practice because of multiple factors affecting the decision process.

An optimum risk management structure would include elimination of interference among several parallel imposed actions. Not all of the parameters for the evaluation are amenable to digitalization (assignment of cost to a particular risk factor). In addition, some of the risk parameters are subjective and many carry a large uncertainty in their value.[9] These include biotic uptake coefficients, resuspension coefficients, and the accuracy of measured radiation concentrations in the environment. Nevertheless, expert evaluation of these risks, including some attempt at quantization, may permit the creation of scales for trade-off among several risks. In contrast to the emergency and early post-emergency periods, a more systematic evaluation of each of the input parameters could permit a more accurate estimation of the accident's psychological, social, and economical impacts upon the society, and thus assist in the development of longer-term strategies.

The trade-off among several risk factors has to be weighed against the long-term benefits and cost-effectiveness of the actions to be taken. Assigning an economic weight to each risk increment is fraught with difficulty, because it is non-linear in functional structure. For example, the cost of the reduction of a particular risk from 50% to 10% may be economically worthwhile; however, the corresponding cost of reductions from 10% to 1% may not be cost-effective. Cost analysis relative to the associated baselines (no protective action) for different risks may not be additive.

Risks may also be shared unequally across a population. The psychological and economic consequences of some protective actions may affect the members of older cohorts in the population more than younger ones. A uniform imposition of actions for all ages may be robust and practicable; however, the consequences of the action may be non-uniform. Segregation based solely on age for any protective action would impose its own psychological effects, adding anxiety and stress particularly to young families.

Any analysis of risks based solely on reduction of the radiation risks could easily underestimate the total risk and cause more harm than good. History bears this out: protective actions following the Chernobyl accident were a brute exercise in relocation. The second wave of evacuation, in 1990 and 1991, did reduce radiation exposure, while exacerbating and extending the chronic environmental disorder. What were the merits of the evacuation in terms of reduction of total impacts on public health? In some cases, especially when the whole body radiation doses were less than 10 rem, the psychological and social consequences of evacuation on those older than 60 years of age may have exceeded the potential radiation-induced biological effects. An evaluation of an optimum procedure for the management of risks must, by necessity, be flexible and based on inputs from multiple disciplines: radiation protection, agriculture, conservation, economics, psychology, sociology, and political science. The analysis should draw from each discipline using techniques such as multi-attribute utility analysis.[10] The perception of risk would be the dominant force affecting the process.

CONCLUSION

Finally, good public information and education are essential for effective risk reduction. Systematic programs to educate the public through participation and interaction must be initiated before any severe nuclear reactor accident. Negative public reactions following an accident should be expected and planned for. Emergency planners must integrate the effect of psychological factors into the response planning and training in order to optimize the benefits of public protective actions.

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REFERENCES

1. United Nations Scientific Committee on the Effects of Atomic Radiation, Sources, Effects and Risks of Ionizing Radiation, United Nations, New York (1988).

2. Shleien, B., Preparedness and Response in Radiation Accidents, US Department of Health and Human Services, Rockville, Maryland (1983).

3. Momeni, M.H., Williams, R.J., and Rosenblatt, L.S., "Dose, Dose Rate and Age Parameters in Analysis of Risks from Bone Seeking Radionuclides: An Extrapolation to Low Levels." In International Atomic Energy Agency Symposium: Biological Effects of Low-level Radiation Pertinent to Protection of Man and His Environment, v. II, IAEA, Vienna (1976).

4. Momeni, M.H., Yuan, Y., and Zielen, A.J., The Uranium Dispersion and Dosimetry (UDAD) Code, NUREG/CR-0553, ANL/ES-72, US Nuclear Regulatory Commission (1979).

5. Lazarus, R., Psychological Stress and the Coping Process, New York, McGraw-Hill (1966).

6. American Psychiatric Association, Diagnostic and Statistical Manual of Mental Disorders, Washington, DC (1987).

7. Prince-Embury, S., and Rooney, J.F., "Psychological Symptoms of Residents in the Aftermath of the Three Mile Island Nuclear Accident and Restart", The Journal of Social Psychology, v. 128(6), pp. 779-790 (1988).

8. Renn, O., "Public Responses to the Chernobyl Accident", Journal of Environmental Psychology, v. 10, pp. 151-167 (1990).

9. Vesely, W.E., and Rasmuson, D.M., "Uncertainties in Nuclear Probabilistic Risk Analyses", Risk Analysis, v. 4, pp. 313-322 (1984).

10. Merkhoffer, M.W, Conway, R., and Anderson, R.G., "Multiple Utility Analysis as a Framework for Public Participation in Siting a Hazardous Waste Management Facility", Environmental Management, v 21, pp. 831-839 (1997).