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Control of Radioactivity from Nuclear Industry in India

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Abstract—Interest in harnessing nuclear energy for the service of mankind has been continuously growing since the first atomic reactor was built in late 1950s, but the industry grew in strength with the wave of new build in the 1970s. The management and control of radioactivity from a nuclear industry is an integrated and intricate problem with no single, unique solution. Whereas existing research and experience provide useful guidelines, each situation has to be explored in itself and a good amount of scientific research and engineering judgment put in before a satisfactory solution is found. We cannot eliminate radiation from our environment. We can, however, reduce our risks by controlling, to some extent, our exposure to it. The best procedure for Indian situation is to first make a detailed engineering and economical evaluation and choose the best suitable process for a particular project. All extraneous factors eliminated it might be easier to assess the safety aspect. This paper presents one view of the prospects of using advancements in nuclear industry to control and manage radiation and the issues involved in radiological health and nuclear safety.

Index Terms— Decontamination factor, Glass fiber filter, Membrane filters, Nuclear energy, Power reactor, Radiation, Radio-nuclides, Thorium, Uranium.

1. Introduction

INTEREST in harnessing nuclear energy for the service of mankind has been continuously growing since the first atomic reactor was built in late 1950s, but the industry grew in strength with the wave of new build in the 1970s. Several nuclear power stations are now in operation in USA, USSR, India, China and the Western Europe and nuclear power has been applied to power submarines and ships in some cases. The global nuclear capacity reached 330 GWe by 1990, but confidence in the industry ebbed with accidents and safety concerns and very little capacity was added in subsequent years. Today, nuclear power capacity of 370 GWe provides 14% of the world's electricity generation, which is far less than that imagined in the early development years of the industry.

Although designs, research and experience so far have demonstrated that with adequate care it is possible to manage and operate the nuclear industry without jeopardizing in any way the health, environment and economic values of the human population, the scare of radiation hazard in the uneducated and even the generally educated population is a fact. To alleviate these fears it is of great importance that the facts regarding radiation exposure and damage and the controlmeasures provided in nuclear industry be widely publicized.

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The management and control of radioactivity from a nuclear industry is an integrated and intricate problem with no single, unique solution. Whereas existing research and experience provide useful guidelines, each situation has to be explored in itself and a good amount of scientific research and engineering judgment put in before a satisfactory solution is found.
Some of the basic principles and devices used in control of radioactivity from nuclear industry at the moment and those under development and trial are listed and briefly described in the following pages. Whereas the list in no way complete nor the brief discussion indicative of the vast amount of knowledge already available on the subject, it is intended to bring out to notice;

1. The large number of alternative devices for control, available or feasible;
2. The high efficiencies of decontamination attainable and hence the vainness of any fears;
3. The philosophy of acceptable risk without which no development would ever be possible.

2. Nuclear Industry and Radiation Hazards

The main operations may be broadly classified into following groups:

1. Mining and milling
2. Processing and fuel fabrication
3. Power reactor
4. Fuel reprocessing
5. Research activity at various stages

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It will be a rare situation where all of the above operations are concentrated together. Thus in India whereas Thorium mining and some milling and processing may be carried out in Kerala beaches, the ore may be shipped to a central processing plant and the fuel elements fabricated shipped to nuclear power stations in different parts of the country. Reprocessing of the fuel elements could be done at the central processing plant when necessary. The research activity would perhaps be much more widely distributed. Thus a general awareness of radiation risks and radiation safety is of great importance over widely distributed areas. It is easily seen that adverse radioactive exposures from nuclear industry could result as under,

1. Direct In-plant Exposure which includes mines and labs; and
2. Indirect Exposure via environment contaminated by various waste products from the industry.

3. Direct In-plant Exposure

Nuclear industry has developed in the age of distant electronic controls, and in a well-equipped installation a man would rarely be required to take undue risks. Adequate lead or other shielding and handling safety standards are prepared and applied by the Atomic Energy Commission or other regulatory agency. The U.S. regulations provide detailed instructions for general safety, handling of contaminated clothing, and equipment as also for emergencies like spills, dusts, fumes and major disasters like fire or explosion.

It has to be remembered that in spite of all shielding and precautions, anybody going inside the plant exposes himself to some radioactivity, however small in magnitude. It is for this reason that admission to nuclear installations has to be controlled and has to involve a certain acceptable risk however minimal. Based on the results of extensive research and allowing for possible uncertainties a maximum permissible exposure limit for the whole body and critical organs has been provided at a cumulative MPD of 5 rems multiplied by the number of years beyond age 18, the dose in any consecutive 13 weeks not exceeding 3 rems. The plant personnel are desired to carry pocket dose meters to maintain a cumulative record of the exposure. The above specified MPD is expected to produce no adverse genetic, somatic or other effects but the numbers should be and are subject to revision either way if further knowledge deems it necessary. The exposure considered so far was external exposure and did not involve ingestion of radionuclides. Internal exposure involves contaminated air, water or food. Connected with direct or external exposure is the problem of disposal of contaminated clothing, equipment, garbage etc. These can be decontaminated by laundering, scrubbings, solvent action, or storage or they can be disposed by burial at sea or land after their bulk has been suitably reduced by incineration or pressure-bailing. The general problems connected with disposal of contaminated solid wastes are briefly referred to later.

4. Environment Contamination

Waste products from various phases of the industry, if not properly managed would contaminate the environment and may cause health and/or economic hazard to man. The wastes obviously can be divided into gaseous, liquid and solid wastes. The alternative techniques of handling the wastes are briefly mentioned below separately for each category. It may be noted that radioactivity decays only with time and no known or economically feasible factor can either accelerate or delay this decay with time. Thus the final treatment in case of all radioactive wastes is to let the activity decay at its own rate while the waste is so stored that no adverse effects on the environment result.

The handling methods thus all revolve around,

1. Concentration of the waste for economical storage, and
2. Dilution to an extent that the diluted waste is no more hazardous.

Generally the two seemingly opposite processes go hand in hand and a small volume of concentrated wastes plus a large volume of presumably safe diluted waste are the result of any of the treatment processes.

5. Contamination of Air-Gaseous and Particulate Wastes

Gaseous and particulate radio-nuclides emits at each stage of the nuclear industry. Among the particulates, Uranium and Thorium dust could be let off during mining, milling and processing, while more hazardous radio-nuclides like Sr90, Cs_{137}, Ce_{144} and Ru_{106} could be let off in small quantities from the production and power reactors. Among the dusts experience has shown that Uranium and Thorium dusts are not as much a problem as Silica dusts in the mining and milling operations. Hence general dust control and other mining precautions would be adequate. For the more hazardous particulate radio-nuclides control, total containment of the air and suitable treatment before the waste gases are let off from a well-designed high stack for diffusion in the air are essential.

Among gases the Radon released from mining and processing operation is rather small compared to the Radon given off naturally from earth's surface and not considered to be a hazard at the time. Of the several gaseous radio-nuclides produced in reactors radio-iodine I_{131} is supposed to be most critical and hazardous. Besides N_{13}, Kr, Xe could also be present. The half-life of I131 is the greatest among these and hence also its greater significance besides its concentration in thyroid being a factor.

5.1 Treatment and Disposal Devices

5.1.1 High Efficiency Filters

High efficiency membrane filters are used to remove particulate matter. At Hanford (USA), fixed bed, glass fiber filter systems have operated for several years with an efficiency of over 99.9% to remove sub-micron level particles.

5.1.2 Activated Charcoal

This is used to adsorb radio-iodine. Later research has shown sharp decline in efficiency of activated charcoal to remove radio-iodine when organic or inorganic Iodine compounds are present or when other particles cause mechanical blocking of the filter. The latter could cause a decline in efficiency from 99.9% to 58%. In spite of these pit-falls, activated charcoal is the most popular treatment for I131.

5.1.3 Silver Nitrate Columns

Columns packed with beads impregnated with AgNO3 have removed I131 with an efficiency of 99.5% at Hanford (USA).

5.1.4 Diffusion Board Device

The board is fabricated by placing a honeycomb material packed with solid absorbent, between two high efficiency filters. The arrangement is almost impervious to I131 and particulates but pervious to air.

5.1.5 Foam Encapsulation

Aqueous high expansion foam is used to encapsulate halogens and particulate matter. Upto 95% efficiencies are reported from Harvard.

The gaseous waste treatment systems generally comprise a dense water spray for cooling and some removal of halogens and particulate matter, a high efficiency filter, and activated charcoal to absorb I_{131}. The system has been proved adequate in both UK and USA The filters charged with particulates, the activated charcoal charged with I_{131}, and the spray water in themselves become radioactive wastes and have to be disposed of as discussed further.

6. Contamination of Water and Food-Liquid Wastes

Large quantities of water are used in all operations in the nuclear industry in processing, cleaning and as coolant. The contaminated water-wastes can be significant hazard to man's environment both in terms of water supplies directly as also through various food chains, plants and plant products; fish, milk etc. which tend to concentrate certain radio-nuclides. Radioactive waste waters are broadly divided into,

1. Low level wastes: In range of 1 micro-curie/gallons
2. High level wastes: 102-104 curie/gallons.

6.1 Low Level Wastes

The bulk of these are comprised by cooling waters. Under irradiation by neutrons some of the impurities present in water are converted to radio-nuclides. Prominent among those of importance are H_3, N_{16}, N_{17}, O_{19}, Na_{24}, Co_{60}, Fe_{55}, Fe_{59}, Sr_{90} etc. Some of these (e.g. N_{16}, N_{17}, O_{19}) have very short half lives and detention would remove them completely others (e.g. Fe_{55}, Co_{60}, Sr_{90}) have very long half lives and are potential hazard. To keep the formation of these activation products low, highly treated water with low dissolved solids is used. Currently some auxiliary systems e.g. HTO coolant system or Sodium coolant system have also been tried but are not in economic feasible domain.

6.1.1 Treatment Devices

6.1.1.1 Dilution

The most important and ultimate disposal of low level wastes is dilution with some river, lake, ocean or other body of water. Occasionally a big enough body of water to dilute the waste to safe concentrations is not available and other treatments have to be provided to partially reduce the activity until the waste can be disposed of by dilution.

6.1.1.2 Lime Soda Process

The conventional softening process has been adopted to removing radioactive impurities and at ORNL (USA) gives 62% removal of Sr_{90} and 72% removal of Cs_{137}.

6.1.1.3 Ion Exchange Columns

Cation exchange resins of the strong acid type have proved to be highly efficient in removal of Sr90, Cs137 etc. and ingenious devices such as used at U. C. Davis Laboratories could treat even intermediate to high level wastes.

6.1.1.4 Scavenger Precipitation

This is basically flocculation with $FeSO_4$ used as the flocculating agent after adjusting the pH with N/10 NaOH. The solution and iron floc flow through a sludge blanket in an upflow clarifier and a big part of radio-nuclides are removed with the floc. When followed by a single ion exchange column, this could give 99.99% removal.

6.1.1.5 Foam Separation Process

Dodecyl Benzene Sulfonate foam has been satisfactorily used to remove Sr_{90}, Cs_{137} and rare earths in foam. Countercurrent type foam columns at ORNL have given Sr_{90} decontamination factors of upto 8500 in conjunction with scavenger precipitation. Cs_{137} is not removed in foam to any large extents and Ca++ ions interfere with Sr90 removal.

6.1.1.6 Adsorption by Natural Minerals

Several natural clays and Zeolites show strong affinities to absorb the ions of interest in radioactive wastes. Thus the clay Grundite strongly adsorbs Cs137 while Clinoplilolites in the U.S. and Canada and Vermiculites in Western Europe have been used to great advantage for removal of Sr90 & other ions. Efficiencies of 99% and over are noted and the processes are cheap, the minerals not being regenerated several other minerals including basalts could prove useful for such purpose.

6.1.1.7 Other Exchange Materials

Zirconium Phosphate, Ferrous Cyanide Molybdate and Ferrous Cyanide Tungstate among other materials have proved especially effective in removing Cs_{137} and Sr_{90}.

6.1.1.8 Desiccation of Frozen Material at Low Temperatures

Developed at Scalay Laboratories this gives decontamination factors of upto 106 and is especially effective for Ru_{106}.

6.1.1.9 Evaporation

A lot of work has been done in Japan, Belgium and Italy to design economical evaporations.

6.1.1.10 Biological Treatment

This is not especially suited to radioactive wastes because of low nutrient content but in especial circumstances could be of use. Thus a large type of possible alternatives exists and more can be found to suit any conditions.

6.2 High Level Wastes

These result mainly from chemical processing units and contain daughter products from Uranium extraction besides impurity activation products. These wastes are very hazardous, may have activity of thousands of curies per gallon and may be self boiling for several years. Fortunately they are produced only at the central processing plant and then only in small volumes. Research has helped develop technology by which the volume of such wastes per ton of Uranium processed has reduced by a factor of 10 since 1945 and is still reducing. The general handling of these wastes follows further concentration and storage.

6.2.1 Final Disposal of Solid and Concentrated Liquid Wastes

6.2.1.1 Burial at Sea

This is not favored by most nations, yet may be feasible in some cases.

6.2.1.2 Burial in Concrete Underground

Precautions have to be taken to insure monitoring and avoiding any leakages or tank failures over long periods.

6.2.1.3 Bed Rock Storage

As envisaged for Savannah River Project USA, the wastes could be stored in huge tunnels drilled in suitable rock.

6.2.1.4 Storage in Salt Beds

Where available this is the most favored solution because of absolute dryness of salt beds.

7. Philosophy, Economy and Safety

Realizing that from a technological point of view it is feasible to control radioactivity exposures from a nuclear industry to any desired levels and that such a wide choice of alternatives are available, it is the policymakers dilemma as to what criteria to apply? What levels of decontamination to be considered safe? It is this area where most doubts from public are bound to arise.

The maximum permissible body burdens and MPCs for air and water for various radio-nuclides have a number of assumptions which may or may not be true for a particular situation. Thus an Indian consumes more and generally untreated wastes, his food habits are different, his resistance to various physiological damages might be different. Whereas in US food habits oysters, shell fish and fish form an important part of food and major factor for stream protection, in Ireland a certain type of kelp which is used as food was more significant and in India at least in certain areas none of those may be significant. In USA, it is estimated that average exposure due to medical and dental X-rays is 4.5 rems over 30 years, in India a major portion of population never faces X-ray in life. The natural background levels may also be lower being nearer to the equation. Thus the average radio exposure of an Indian is perhaps much lower than in USA.

Is it still safe and philosophically alright to accept same MPC levels for India as in USA or should they be lower? Or can they be much higher because of low exposures due to other causes? Economy of course enters at all steps because of our limited resources we may be keen to get away with the least possible research and the most economical equipment.

8. Conclusion

It appears that the best procedure for Indian situation is to first make a detailed engineering and economical evaluation and choose the best suitable process for a particular project. All extraneous factors eliminated it might be easier to assess the safety aspect. After all it is a question of acceptable risks and a poor man has often to take greater risks particularly if he wants to improve his financial status fast. As the economy improves more straight measures for safety could be possible.

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