Mitigation of Radioactive Waste by Sampling and Analyzing the Affected Area and Efficient Use of Different Detectors – 17139

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ABSTRACT

The paper describes the ways by which the mitigation of the radioactive waste during events like decommissioning of nuclear plants, mines, other nuclear-related facilities and also in event of nuclear disaster is done, so that the rehabilitation process for flora and fauna can begin in a natural manner. There are many parameters that have to be kept in mind during the planning stage of environmental remediation (ER), as there are many hindrances and snags that might occur during environmental remediation and rescue operation. The paper describes the problems faced during ER operations in the developing countries and needs of international committees. The paper emphasizes proper site characterization and suggestions for it, and suggests simultaneous detection of various activity of radionuclides dispersed and the need for proper knowledge and handling in ER operations. It describes how the radioactivity can be an interference in detection and the importance of low-level activity. The paper describes why site characterization should be quick and prior to other important key points during rescue operations. Also, it gives a description of various detectors used widely and their related significance in ER. The paper describes the strategy on how after site surveying the input can be used to map an area, as to provide easy operation and working conditions for personnel, and how it can be helpful in the evaluation of other parameters. The paper also gives suggestions on the use of bio-indicators in above described events and their benefits.

INTRODUCTION

Remediation of radionuclides after decommissioning of nuclear facilities or nuclear accidents is one of the great tasks in the nuclear industry. Radionuclides can affect a large region surrounding the main epicenter of nuclear sites. As the nuclear industry has grown from production of nuclear bombs to power production in the last sixty years, so has the unwanted effects on the environment. Environmental damage can be related to any incident including testing of nuclear weapons, nuclear accidents or decommission of nuclear facilities around the world. As these activities take place in a small areas, the large surroundings regions are affected in various ways. The technologies employed today to investigate the affected area and then carrying out remediation has been done in different ways depending on the site. There have been the deployment of various detection systems to selectively select the affected region and work on the process of regeneration and isolate the contaminants if above the maximum permissible limits. Large scale nuclear industry operations are related to the development of nuclear weapons in WW-II which gave rise to notable research and testing of nuclear weapons. Then in the 1950s, nuclear industry made a step towards the commercial operations of plants leading to power productions in various countries. This led to exploration and significant mining at various regions. This over time has resulted in the accretion of naturally occurring radioactive material (NORM) [1]. In the path of nuclear history 1960s and 1970s saw subsequent growth in various countries over the nuclear program and development of various nuclear facilities. It was seen until the Chernobyl accident in Russia, in 1986, that made humans to think over the development of nuclear industry from the perspective of safety and security. Many nations curtailed their nuclear program due to public protest and policies. This led to the decline of nuclear power and fear in the mind of public, which can be seen until today in many developed countries even. The higher cost related to the building of nuclear plants also led some nations to rethink their energy development plan and eventually shutting down of these power plants. This led to decommissioning of many power plants used for both military and civilian purpose and closing of uranium mines and enrichment and reprocessing plants for production of nuclear weapons at times of cold war [1]. This led to a large area having contamination from the years of operation of those facilities, which left and will leave in future risk to the environment (both to flora and fauna) and to human beings. It is of foremost importance to investigate these sites and apply procedures that are efficient and economical to mitigate the effect of long-lived radionuclides and those with short half-life but in large concentrations and help regenerate the region naturally. Besides this during nuclear accidents there occurs large dispersion of radioactivity over a large area, affecting public and posing potential threat to environmental. These incidents can many times leave the site unfit for further use for several years. The Chernobyl accident is one of them. The effect of the accident is well-known today. The paper discuss methodologies used and proposes that could be employed in these events and the discussion on the effect of local and national bodies in extending the ER and rescue operations in nuclear accident or minor incidents in developing countries and the mitigation through efficient and fast surveying of the area and characterizing them into different levels of radioactivity.

METHODOLOGY AND DISCUSSION

Environmental remediation (ER) is a process that comes into the picture at regions or sites that have been affected in a way that the natural process is hampered and there is a negative impact is on the environment. Planning then commences, the start of this long-term process. It is to be figured out what steps will be taken in the course of time so that they could be justified with the national and international agencies and be in the favor of the general public [2]. Some of the points that should be considered in planning stage are as follows [3]:

1. The impact on the ecosystem and human beings.
2. The risk of spreading of the radionuclides released in the incident or event.
3. The financial aid in hand for environment remediation.
4. The availability of the skilled human labor and technical equipment.
5. The present status of ground situations with measures of dose level to humans.

As the planning stages develop, the very first thing is the survey of the site. For environmental remediation, site surveys are indispensable prerequisites. They offer us with valuable data that is helpful to carry out the plan sketched out at the start. Site investigation should be carried out in all aspects including meteorology, geology and hydrology, seismicity, geomorphology and the other aspects depending on site for a certain period of time [4]. These studies play a significant role when the waste has to be disposed of in the nearby area. They let us make an estimation for leaching of waste into nearby ponds, rivers and soil which may over time induce into the food chain. Many often existing data are taken as the reference, but this paper places emphasis on the use of fresh values as data from the past do not commonly compensate to the quality of values required to carry on the work. As there are chances of human error and also with the incoming new efficient and precise detection systems, the values taken in past never remain the same as before, even for the same site. The high level of accuracy makes for better options and cut costs on using heavy machinery. Though historical data gives a sense that the same errors are not produced [5], it has been often that cases relating to cold war times and other guarded facilities do not often easily produce existing data. This leads to government negotiations, and slacken the process. As foretold, site surveying yields data, which helps quick decisions to be made during ER or in event of a nuclear accident. A site characterization often takes the following key points into conversation [3]:

1. The amount of damage occurred to the environment and the human society in the nearby region or farther in the case of large incidents.
2. The distribution, character and the extent to which radioactivity has been dispersed.
3. The amount of risk that will be involved for personnel working in the field.
4. The precision of data collection that is collected to be used as input for further processes.

The important feature that is intertwined in every aspect of site characterization is to know the amount of transported radionuclides into the biological components. These components should contain surface water reservoirs, like pond, lake, rivers etc.; vegetation; waste from animals; ground water; and the dispersion into the air. During an event of nuclear site decommissioning, or in an event of nuclear accident, the national bodies play an important role in determining how the task will be managed, and their role starts from the beginning stage. The central governmental bodies in developing countries play a very deep role, as it is often seen that the state bodies do not have sufficient resources to carry out the work properly. So, central bodies play at a pivotal point to provide the funds and technical help through other states or internationally. This affects a lot in the progress of work. It is often that corruption and slow decisive power of the people involved hamper the process and make an agitation for the people who really work on the field. Many times ministers modify work for their election benefits and do politics over financial and environment damage. Criticism and pin-pointing of the occurrence of the accident between the party in rule and opposition often occurs. Though it is often that international funds are made available to developing countries, completion time plays a major role. The paper proposes to allow more time in such situations and also emphasize in working of international bodies with local governments so that standard ER rules are followed. This will not only save their funds, but also allow local bodies involved to learn the proper remediation process that is carried out during an ER. Though in developing countries major bodies involved in ER take their way out from politics and work in

the real progress for completion of work, the efficiency of work decreases. This may lead to more spending of funds on the site, but the time spent cannot be retained and remains a big loss in such situations. Such situations can be solved if international bodies work more closely with these bodies.
The time spent, being proportional to the effect on the environment and human being, causes a lot of future problems. These can be summarized as follows:

1. Leakage of radionuclides to nearby water bodies, which could have been stopped earlier.
2. The absorption of low-level liquid waste to shallow roots.
3. More exposure of higher dose to the nearby public.
4. More air contamination and dispersion of radionuclides (such as I-131, which are dangerous in nuclear accidents).

If proper methodology and proper allocation of funds and resources are done in such regions, then such consequences can be mitigated and the threat across national borders can be minimized. The scenarios are worsened when mitigation and environmental remediation after the nuclear accident have to be conducted with rescue operations. Due to lack of technical knowledge within committees of developing countries and government bodies, the scenario sometimes comes as contradictions between the technical teams and governmental bodies [5]. The time to explain the real scenario and the critical points in the accident that can occur in more loss of radioactivity into the public domain, can be burdensome to the ER strategies and comes as an incoming point in developing countries, during the planning stage.
The paper describes the use of strategies that can be employed during an event of nuclear accidents. As site characterization is an important aspect, the choice of use of proper detection system plays a key role. The following Table I summarizes the main aspects of the type of detectors used.

TABLE I: COMMONLY USED DETECTORS

Type of Detector	**Principle material used**	**Detection**	**Advantages**	**Disadvantages**	**Applications**
GM	Helium, Neon or Argon	Detect alpha, beta, gamma and neutrons	Cheap	Does not differentiate between particles directly, high dead-time. Low sensitivity.	In nuclear power plants to maintain a safe environment. Useful for public in event of nuclear accident. So that they can monitor their food and

					water.
Scintillators					
Inorganic	NaI(Tl), CsI(Tl), $LaBr_3$(Ce) BaF_2, CaF_2(Eu) High-Z material.	Gamma rays, neutrons, electrons, heavy ions. The photoelectric effect is prominent.	High detection efficiency, low energy radiation detection, linearity, good light output	Large crystal size is not easily manufactured, hygroscopic, slow scintillation.	X-ray, gamma-ray spectroscopy with good efficiency and acceptable resolution for radionuclides having gamma energies at a good difference.
Organic	Anthracene, Stilbene, Naphthalene	Gamma rays, neutrons, electrons. Not suitable for heavy ions. Compton scattering is prominent.	Very durable, organic crystals can be used to increase neutron efficiency using ^{10}B.	The output is anisotropic if the source is not collimated. Cannot be grown in large sizes.	Short scintillation decay time makes them fit for low energy particle detection.
Plastic scintillators	Here the fluorescent emitter ‘fluor’ is suspended in the base. Flour-oxazole, polyphenyl hydrocarbons and oxadiazole aryls.	Gamma rays, neutrons, electrons.	Fair light output, cheap, fast scintillation, ability to be shaped. Large volume detectors.	When energy density is large it shows light output saturation. Not suitable for low energies X-ray and γ-rays.	For gross counting of gamma rays above 100 Kev. Used in the portal and waste monitors. Rugged used for densitometry, level gauging.

	Base-aromatic plastics, polymers with aromatic rings.				
HPGe	Germanium	Gamma, X-rays, particle detection.	The high density of the material, excellent resolution. Larger crystals than NaI(Tl)	Radiation damage, needs to be cooled, expensive.	Used for gamma spectroscopy, in portal monitors to distinguish between false alarm.
Silicon detectors	Si(Li)	Gamma, X-rays, particle detection.	High density of material and high resolution.	Radiation damage, expensive.	Used in environmental remediation to sample continuously [6] and detect small quantities of aerosol carrying radioactivity. They can be employed to detect Pu aerosols which can't be done by gamma measurements.

We can see that each detector has its own specific characterization and should be allowed during site surveying only when required. Though the list does not contain all the detectors, it shows how many of the detectors differ from each other. They all have signature characteristics. Also, it should be kept in mind that one detector cannot be used for all the situations and detection of particles. This should be kept in mind especially by the planners in developing countries as they try to bring down the cost used in detection, by using only some certain detectors. Detectors must be used according to situations and the personnel should have the knowledge of the detector used for less error measurements. This increases the efficiency of the outcome work. The paper proposes to keep an emphasis on establishing more survey points on the site and using the variety of detectors efficiently for the particular region established. Since in the start of operation there will be activity present all over the place, the method is to narrow the area of different level of activity and mark the boundaries at certain radius for different dose readings. This will help in mapping the area into different sockets of different radioactivity. Now, according to the manpower and remediation process available at hand, a proper selection of tool for the particular region can be suggested. This will help in distributing the resources wisely and help in saving time, which is crucial in such cases, especially in developing countries. Mapping is an important aspect that should be given consideration during such events. They not only allow easy detection of sources but also give an overall view to personnel working in the field. Source detection is a game changer in such situations as seepage of radioactivity can be controlled at the start. Mapping can be done on computer models, where the region of the radioactive area can first be defined and then the site readings can be used to mark the locations of different activity [7]. As this is done one can mark physical boundaries for the personnel working, which can be instructed to personnel working as for how long they are allowed to work. This will allow easy dosimetry of personnel after work and reduce the chances of error. As one much as might be known of the radioactive doses one should have got from the particular marked area. So, if there occurs an increment or decrement in values it will help in knowing the change in radioactivity in the marked region. If changes occur, it leads to one conclusion i.e. movement of the dispersed source. It can then help in evaluating how well the plans are working as proposed and in ensuring that contamination is bound to the region.

This may not be an easy task, as first priorities lie in giving medical aid to the affected ones and simultaneously making a clear ground for work, which may use heavy machinery. These heavy machines can lead to dispersion of radioactive sources or waste which would be dispersed over a bigger surrounding region. This can exaggerate the problem of contamination of water sources, which are primarily present near nuclear reactors. The characterization of the site and differentiating area prior to such operations are very important, and in a way that they are completed early, as human lives and environmental risks are much higher in nuclear accidents. The methods employed to hustle through such difficulties and complete site surveying are very important for future work to be done. The use of surveying technologies to test the soil and water must be done as to get a clear estimate of the how much seepage has occurred since beginning of the incident. The method of detection of low, intermediate and high-level waste should be done simultaneously, rather than focusing on a certain point and pouring down all the resources at a certain path. During low-level activity detection, the background can create errors in measurement systems. Also, the high radiation from radionuclides having high-level of activity can cause interferences and may overlap the photo-peaks of radionuclides with energies

close-by. This calls for use of highly sophisticated and precise detection systems like HPGe detectors to ratify the errors and give a clear view of the dispersed radionuclides with concentration.
As dispersion occurs in the system, natural indicators of such incidents can be of great help. There have been studies on how biological indicators can be of real value. They can show the long term effect of events, like the discharge of radioactive waste of low levels into water bodies, or decommissioning of the old site, or the effects of nuclear accidents. Paper [8] shows how salmon was used as bioindicator for the Hanford site for the discharge of hexavalent chromium used in the coolant of the reactors. Such examples show that the use of bioindicators can provide a long term reliable source of successful environmental remediation work. They also create a decisive factor evaluating the success of ER programs. Such bioindicators depending on the site can be used from the beginning of ER process, by incorporating people from all over the fields having expertise on that bioindicator. Their work simultaneously with the site characterization can help in producing a clear picture of the damage of ecosystem in overall including all life forms.

CONCLUSIONS

One of the important issues during an environmental remediation is site characterization. In the author’s view, there is no single paved path for every situation that can lead to a successful ER. The planning should be done in such a way that the future work is not disturbed due to technical problems. Though details like cost, technical use of detection system, and mitigation methods remain as important aspects every time an ER is planned, in developing countries time remains a critical issue. As often international funding agencies are involved, time provided is often less than required. Lack of knowledge and resources within the state and the political problems between ruling and opposition parties, and many other reasons, causes unwanted delays in the ER operation. The close involvement of international agencies in providing sources and help to carry out the work in the proper manner will reduce the cost and also bring more success to ER operation.
During nuclear accident times, the scenario changes a lot more than the normal ER. The first priority becomes to save human life, then the cleaning of dispersed radionuclides. The paper discusses the greater use of determining the radionuclides doses before the rescue operations begin. If the site characterization is done before the rescue operation, that way it can save more lives and also simultaneously work for ER operation. Also, the use of machinery can be directed, which leads to less dispersion of radionuclides. By using such methodologies, working personnel can be significant indicators of movement of radionuclides. The further work in mapping the site and marking the physical boundaries will reduce pouring all the resources in one direction. The paper proposes the use of skilled labor which has the knowledge of detectors. This is significant, because errors can make significant changes in the outcome during such conditions. The use of the detector required helps in saving time and cost. The planners should not compensate the cost of others ER methods by reducing the cost for detectors, which leads to the use of only certain kind of detectors. Not using the proper detector as required can build the cost of ER during or after the completion of the operation. During such operations, low-level waste is of significant importance. High level and intermediate waste are easily detectable and

contained, but low level waste remains as a worry, due to low detection and containment problems. The paper also proposes the use of bioindicators from the start of ER missions. Bio-indicators can be a very helpful source for detection and dispersion of radionuclides. They also, provide an evaluating factor for the success of an ER operation.

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