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PERFORMANCE ASSESSMENT - RISK ASSESSMENT VIVE LA DIFFERENCES *

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Abstract

In the sister worlds of radioactive waste management disposal and environmental restoration, there are two similar processes and computational approaches for determining the acceptability of the proposed activities. While similar, these two techniques can lead to confusion and misunderstanding if the differences are not recognized and appreciated. In the case of radioactive waste management, the performance assessment process is used to determine compliance with certain prescribed "performance objectives." These objectives are designed to ensure that the disposal of radioactive (high-level, low-level, and/or transuranic) waste will be protective of human health and the environment. The environmental link is primarily through assuring protection of the groundwater as a resource. The performance assessment process has its genesis in several Department of Energy (DOE), Nuclear Regulatory Commission (NRC), Environmental Protection Agency (EPA) Orders, Regulations and the like. In particular, for the disposal of low-level radioactive waste at a DOE facility, the requirements for a performance assessment are found in DOE Order 5820.2A entitled "Radioactive Waste Management." In the case of environmental restoration, the risk assessment process is used to determine the proper remedial action response, if any, for a past hazardous waste release. The process compares the "no action" or "leave as is" option with both carcinogenic and noncarcinogenic values for human health to determine the need for any action and to help determine just what the appropriate action would need to be. The carcinogenic and noncarcinogenic values have been selected to provide assurance that if met there will be no adverse health effects or unacceptable cancer risks to humans. The impacts to the ecological system are evaluated in a slightly different but similar fashion. The risk assessment process has its genesis in the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) and subsequent regulation known as the National Contingency Plan (NCP). Now the common objectives between these two processes notwithstanding, there are some key and fundamental differences that need to be answered that make direct comparisons or a common approach inappropriate. Failure to recognize this can lead to confusion and misunderstanding. This can be particularly problematic when one is faced with an active disposal facility located within the boundaries of an environmental restoration site as is the case at the Idaho National Engineering Laboratory (INEL). Through a critical evaluation of the performance assessment and risk assessment processes, highlighting both similarities and differences, it is hoped that greater understanding and appreciation of these two approaches will be had by regulators, analysts, and the public alike.

INTRODUCTION

In the areas of waste management disposal and environmental restoration, there are available two different yet similar approaches for determining the acceptability of the proposed actions. These two approaches arise from the fact that a lot of times, even when the proposed/resultant action is the same, the question of acceptability can be looked at either forward or backward. Because of this, while there are similarities between the two approaches, there are and should be differences. This paper will critically examine the two processes, highlighting the similarities and the differences. From this examination, it will become clear why there need to be two processes and why one should appreciate the appropriateness of each.

BACKGROUND - PERFORMANCE ASSESSMENT

Let's begin with looking an area, low-level radioactive waste management disposal. Here is a situation where one needs to know if the particular environmental setting that is being considered for the disposal is suitable or can be made suitable (by engineering designs, etc.) for disposal of the specific waste being considered. By suitability, it is meant that the disposed waste will pose an acceptable risk to humans and the environment now and in the future. The method that is commonly selected to demonstrate the acceptability is typically called a "performance assessment". Essentially one is assessing the performance of the environmental setting and any engineering enhancements with respect to the waste and its release and effect. A Webster-like definition would read something like: Performance Assessment - n. A systematic analysis of the potential radiological doses posed by the low-level management system to workers, the public, and environment, and a comparison of those doses to established performance objectives. Now even though these descriptions seem fairly straightforward and somewhat simple they can in fact be most complex and difficult. Even the words themselves can involve much deliberations. For example the expression "performance objectives" must be location, receptor and activity specific in addition to being time dependent to provide the necessary assurance that the disposal will pose no unacceptable risk.

The specific requirements associated with the disposal of low-level radioactive waste and supporting guidance documents vary according to the regulatory agency responsible for approving the disposal and the entity that is performing the disposal as well as in some cases the generator of the waste. For the situation where the generator is the DOE and is disposing of waste in a DOE facility, then the regulation that specifies the requirement for a performance assessment is DOE Order 5820.2A entitled "Radioactive Waste Management."

Regardless of which specific requirements are to be imposed, the computational process is essentially the same. Also the information and data needed to perform the calculations are essentially the same. This can vary somewhat based on the specific computational tool and its algorithms but for the most part the needed inputs are not vastly different. For example, in all cases, the activity, radioactivity that is, by nuclide is needed, the chemical and physical form, any packaging, etc. would be needed to initiate any subsequent computations. Also, there are common environmental setting values that would be the same. For example, average precipitation, cover thickness, soil moisture content, and depth to water table, would be typical inputs needed in all cases.

Briefly, the performance assessment involves a series of steps. These steps will include a determination of the inventory; its rate and release from the waste form; the fate and transport of the radioactivity in the subsurface; the fate and transport in the aquifer, surface water, surficial soil, and air; the exposure and dose to a receptor at a particular location and point in time; and a comparison of the doses to the performance objectives. Now obviously, this is a simplification of the process but does give a sense of the steps and what the outcome will be. If the doses are less than the prescribed performance objectives, then the disposal would be acceptable. If the doses are greater than the performance objectives than any one of several things would need to be done. These things could range from reducing the inventory, to adding engineered features such as a robust cap, to moving to a different site. The particular step that is ultimately taken will depend on what factors led to the evaluation exceeding which performance objective.

BACKGROUND - RISK ASSESSMENT

Now, let's turn our attention to the environmental restoration and its associated risk assessment process for determining the need for action. Environmental restoration is a very diverse area that can encompass a wide range of actions. For the purposes of this discussion, let's look at the situation of trying to determine if an abandoned low-level radioactive waste disposal area needs to be remediated. If this facility were located in the United States, there is a good chance the regulatory authority would be the EPA and the statutory reference would be the CERCLA. Were this to be the case, then the exercise one would undertake would be what is referred to as a "baseline risk assessment" or more simply a risk assessment. Here one is essentially trying to determine the health risk to humans and the environment from the disposed radioactive contamination if no action is taken. A textbook definition for this assessment might look something like this: n. an analysis of the potential adverse health effects (current or future) caused by hazardous substance releases from a site in the absence of any actions to control or mitigate these releases (i.e., under an assumption of no action). As in the case of performance assessment, the words seem fairly straightforward, but the assessment itself can be most complex and difficult. These analyses typically require a multidisciplinary team, much time and plenty of money.

The specific requirements for a baseline risk assessment are found in the National Contingency Plan (NCP) (40 CFR 300). The NCP is the implementing regulation for the Superfund Law also known as CERCLA. This requirement is supplemented with many guidance documents to provide necessary details on how to conduct a baseline risk assessment. The major document is the Risk Assessment Guidance for Superfund (RAGS) which consists of two volumes. The first volume deals with human health, while the second volume entitled "Environmental Evaluation Manual" addresses ecological health.

There are typically four steps that would be taken to conduct this assessment. The first step is commonly called "hazard identification". It is here that the identity and characteristics of the low-level radioactive waste are determined. Information pertaining to each isotope, such as the concentration, chemical and physical form, the packaging, etc. is gathered in preparation for the subsequent steps. It is also here that the identify and characteristics of any hazardous non-radioactive contaminants would be determined. Heavy metals such as lead, and cleaning solvents such as carbon tetrachloride are common examples of non-radioactive hazardous substances that are found in older disposal facilities.

The second step which can be done in parallel with step three is commonly referred to as exposure assessment. This can be a very complex and time consuming step. It is here where the time dependent fate and transport of the contaminants is determined usually with the help of powerful computational models. The outcome of this substep is the time dependent media contaminant concentrations. For example, 4 pCi/l of Cs-137 in the aquifer 100 meters downgradient from the disposal site 50 years from the present would be an example of one output. These time-dependent contaminant media concentrations are coupled with intake variables based on the receptor and the associated activity to determine the pathway specific exposures. Here, one may have a worker who drinks 2 l/day, 5 days a week for 50 weeks a year for 20 years. These would be the drinking water pathway intake variables.

The third step in this baseline risk assessment process is called the toxicity assessment. It is in this step that the determination of toxicity values for both noncarcinogenic and carcinogenic effects is performed. This step is sometimes referred to as the dose-response evaluation. The numerical expressions for the dose-response relationships are called "reference doses" for noncarcinogenic effects and "slope factors" for carcinogenic effects. This is yet another step that, depending upon the available information, can be very arduous and contentious.

The fourth and last step is called the risk characterization step. This is the step where the results from the previous steps are brought together and synthesized into qualitative and quantitative expressions of risk. Here the toxicity values are combined with the pathway specific exposures. As appropriate, these pathway specific risks are combined across pathways to give the overall risk from an associated activity. These results are then usually compared against two constraints. For carcinogenic risk, the constraint is typically defined as a range, 10^{-4} to 10^{-6} incremental risk of cancer incidence. Risks above the range are usually deemed unacceptable. Risks below the range are considered acceptable. For noncarcinogenic risk, the constraint is usually defined as a hazard quotient or hazard index (for multiple contaminants) equal to 1. That is, if the hazard quotient/index is less than one than it is not likely there will be any adverse noncarcinogenic health risks. If the hazard quotient/index is greater than one, then there is a chance of an adverse health effect and some response action may be in order.

The previous paragraphs have given a brief overview of the two processes of interest to set the stage for the following discussion on the similarities and the differences. While it might be clear that there are some similarities as well as some differences a more critical eye is needed to identify them all. As a matter of fact, after a listing of the similarities and differences it will become clearer why there really needs to be two separate approaches.

SIMILARITIES

Let's begin with a look at what is generally alike. In the first case, both tools, the performance assessment and the risk assessment, have as their overarching goal to provide the information needed to help assure protection of human health from the waste in question. Secondly both tools must address fate and transport of the radioactive contaminants through the environment. Thirdly, both the performance assessment and risk assessment require a description of the environment setting. Items like soil type, depth to water table, average infiltration rates, cover thickness, etc. are values necessary to describe the physical conditions. Fourthly, both tools require a description of the radioactive constituents. Characteristics like concentration, chemical and physical form, and packaging are needed to adequately describe the hazard. Fifthly, exposures to human receptors from hazardous substances are determined in both efforts. A cursory look at these general similarities would seem to indicate that they are essentially the same analyses requiring the same inputs. However, one does not have to look too deeply to identify a whole multitude of differences.

DIFFERENCES

The first of many differences is that the CERCLA baseline risk assessment considers the impacts from both radioactive and nonradioactive hazardous substances while the performance assessment only considers the radioactive constituents. Depending of the composition of the waste in question this can have a major impact. For instance, having highly mobile carcinogenic solvents in the waste matrix can sometimes drive the overall risk. Secondly, even in the case of radionuclides, the CERCLA risk assessment considers both the carcinogenic and noncarcinogenic adverse health effects, while the performance assessment only considers the carcinogenic impact. For certain heavy metal contaminants, like uranium, this can also have significant influence. It is not uncommon to find the effect from the metal toxicity of uranium to exceed its radiotoxicity. Thirdly, the CERCLA risk assessment process addresses potential impacts to the environment in a much more robust manner than the performance assessment does. There is an entire separate guidance manual and supporting documents devoted to the evaluation of ecological health. In the case of the performance assessment, the only performance objective that is related to the environment is the one which states "protect groundwater resources, consistent with Federal, State and local requirements." Fourthly, the exposure scenarios that are evaluated are typically much different. In the case of the performance assessment there are a suite of standard scenarios that are required to be evaluated. These scenarios include both intrusive (e.g. drilling a well) and non-intrusive scenarios. In the case of CERCLA, the scenarios to be evaluated are based on likely use of the land and agreement with the regulatory agencies and the public. As such, there can be a whole range of scenarios to be evaluated ranging from recreational use to residential use to industrial use. Another difference is the time of compliance. Neither of the processes have a definitive specified time period during which compliance or acceptability is required. In the case of the performance assessment, the tradition has been to calculate to the time of peak dose with the window of compliance being 10,000 years. For CERCLA risk assessments the time period can range from just present day to 10,000 years and beyond. Typically the time period is much shorter than for a performance assessment. Yet another difference relates to the acceptance levels or performance objectives. For performance assessments the objective is a dose, not a risk. For risk assessments, to no surprise, the result is a risk. It is not that one cannot convert the dose to a risk, but even the conversion can raise some differences in not only just how to do it, but what dose conversion values to use. One could go on and on listing differences but the important point now is to discuss why there are differences and why that is good.

DISCUSSION

The best way to understand the differences is to recognize that the two processes are really trying to answer two very different questions. In the case of the performance assessment, one is really trying to decide if the site where the disposal is planned, is suitable for the waste. It really is a preventive type of question. That is, what is it that one must do or what is it that can be buried without the likelihood of creating a site whose releases at some time in the future might require corrective action. In the case of the risk assessment process, the contaminants have already been disposed. To use an old axiom the horse is already out of the barn. For this instance, one is really trying to determine if there is a need to cleanup or if the past disposal will not result in any releases that would exceed protective criteria. Because the questions are different and because the timing of the activities are different it is only fitting there are different tools to help answer the questions.

In the case of the performance assessment, one is usually in an excellent position to know a great deal about and/or control the inventory of hazardous material being considered for disposal. Additionally, control over the packaging, disposal arrangement, etc. are possible. Further, depending on the situation, one can possibly even change the location and find a more favorable site if need be. This is not the case for a risk assessment, where the cards have already been dealt, that is the waste has already been disposed, the location already chosen. As a result, the inventory can be highly uncertain, and the packaging and disposal arrangement may not be well known either. Couple this with the usual situation of having highly uncertain knowledge about the environmental setting and associated fate and transport of the contaminants and the resultant risk picture has great uncertainty. The recognition of this inherent uncertainty manifests itself somewhat in the metric against which the results are compared. In the case of the performance assessment there are bright lines if you will. Specific numbers, like 25 mRem/yr. If one is below the number then the disposal is acceptable. In the case of the risk assessment, the metric is a range of two orders of magnitude. That is, depending on the particular circumstances, an acceptable answer can be 10^{-4} while in another case an acceptable answer can be 10^{-6}, two orders of magnitude different.

One other way to look at the two situations metaphorically, is to think of two patients. One, who is healthy and another one who has a tumor. In the case of the first patient, one needs to take the necessary steps to keep the patient healthy. Diet and exercise would be key preventive measures. Here, the diet would relate to the inventory and exercise would correspond to the engineered features incorporated into the facility design. Eating carefully is very important for a healthy patient just as a carefully selected inventory is critical to an acceptable (healthy) disposal facility. Likewise, just as exercise makes the patient more robust and resistant to disease and illness, engineered features do the same for a disposal facility.

With respect to the patient with a tumor, the need is to determine whether the tumor is benign or malignant. This is the similar to trying to determine whether a hazardous waste site needs to be cleaned up or not. If the tumor is benign, then no further action is required. If the tumor is malignant then an operation or some other "remedial action" is needed. This corresponds to the case when the baseline risk assessment indicates either an acceptable risk and no further action is required (benign) or an unacceptable risk and therefore a need to cleanup or take some action (malignant).

Now let's look at the special case where one has an active disposal area inside a CERCLA Superfund site. The INEL has such a situation that is presently being evaluated. This indeed poses a unique set of circumstances. There can be one of several outcomes some of which at first glance would appear inconsistent. Of the possible outcomes there are four general ones. The first is the case where the past disposal poses an unacceptable risk but one could continue to dispose of radioactive waste. The second case is where the past disposal poses an acceptable risk but one could not dispose of any additional radioactive waste. The third case is where the past disposal poses an unacceptable risk and so does any additional waste disposal. The last case is where the past disposal poses an acceptable risk and one can continue to dispose of additional radioactive waste.

Let's examine the two outcomes that appear to be inconsistent more closely. In the first case, one conducts a baseline risk assessment for the past waste disposed and finds that the resultant risk exceeds the acceptable risk range. Now if this is the case, how is it possible that one could continue to dispose of radioactive waste? Well, the answer lies in just what contaminants are driving the unacceptable risk, when the unacceptable risk takes place, and what contaminants are planned to be disposed and when they might affect the risk results. As an example one might determine that the past waste disposed poses an unacceptable risk during the 100 to 350 year time frame. And that for all other times the risk is below the acceptable risk range. Now armed with this information, one can conduct a performance assessment on the planned waste disposal and if the modeled releases do not impact the risk window and meet the performance objectives for all times then it is quite appropriate to consider continued disposal. Now of course there may be other reasons not to continue disposal. These reasons could range from political to continued disposal will inhibit effective remediation on the past waste. But also it could be the most appropriate and cost-effective place to dispose of the waste and should not necessarily be ruled out solely on the basis of the risk assessment results.

How about the case where the past waste disposed poses an acceptable risk but future disposal is unacceptable? Here one can envision the baseline risk assessment indicating a long-term risk that is right on the edge of acceptability. For example the waste could be slowly yet continually releasing into the environment resulting in a risk level at the upper end of the acceptable risk range for the next 1,000 years. Now when one conducts a performance assessment and finds any exposure during the next 1,000 years then it would not be considered prudent to continue to dispose. Also it might not be cost effective to institute engineered barriers to delay the exposure for 1,000 years.

CONCLUSION

In summary, there are many other possible scenarios and variables for the complex issues of waste disposal and environmental restoration. Suffice it to say that one needs to be most careful in how one goes about evaluating the situation at hand. There are two important tools at one's disposal, no pun intended. The risk assessment process is the proper tool to use to help determine the need to cleanup past disposed waste. The performance assessment process is the proper tool to use to ensure that any planned disposal can be done in a safe manner. Between these two efforts one can provide the assurance that environmentally sound decisions are being made.

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