Questions

1. A threat analysis of a particular reactor emergency scenario establishes radiological consequences as RBE-weighted values for radiation exposure to an individual outside the site boundary for the entire duration of the emergency, which includes a release of radioactive material from the reactor facility, and expected maximum dose rates in an area beyond the site boundary. The analysis of the radiological consequences includes consideration of both external and internal exposure (inhalation), but excludes consideration of internal exposure from ingestion of potentially contaminated food, milk and water. For each case below and considering only the off-site consequences:

   - what is the appropriate emergency class for the event,
   - what protective actions would be appropriate,
   - what are the medical consequences of the exposure if no protective action is implemented, and
   - what other information would you need to determine appropriate protective actions and how would that information be obtained?

   Discuss your answers in terms of the IAEA information presented in this course for recommended protective actions and emergency class. Assume normal background at the site boundary is 0.05 μSv/h.

   Case 1:

   Whole body exposure (external) – 2 mGy (7-day), 3 mGy (30-day)

   Whole body exposure (internal) – 0.3 mGy (7-day), 0.5 mGy (30-day)

   Thyroid (7-day) – 1 mGy

   Maximum gamma dose rate – 65 μSv/h

   Case 2:

   Whole body exposure – 20 mGy (7-day), 30 mGy (30-day)

   Whole body exposure (internal) – 3 mGy (7-day), 5 mGy (30-day)

   Thyroid (7-day) – 10 mGy

   Maximum gamma dose rate – 650 μSv/h

   Case 3:

   Whole body exposure (external) – 90 mGy (7-day), 125 mGy (30-day)

   Whole body exposure (internal) – 50 mGy (7-day), 110 mGy (30-day)

   Thyroid (7-day) – 40 mGy

   Maximum gamma dose rate – 900 μSv/h

   Case 4:

   Whole body exposure (external) – 150 mGy (7-day), 250 mGy (30-day)

   Whole body exposure (internal) – 85 mGy (7-day), 130 mGy (30-day)

   Thyroid (7-day) – 75 mGy

   Maximum gamma dose rate – 1500 μSv/h

   Case 5:

   Whole body exposure (external) – 9 mGy (7-day), 15 mGy (30-day)

   Whole body exposure (internal) – 4 mGy (7-day), 7 mGy (30-day)

   Thyroid (7-day) – 25 mGy

   Maximum gamma dose rate – 300 μSv/h

Suggested Answers:

Case 1:

No urgent protective actions are appropriate since the acute and longer term doses are well below the recommended action levels for both deterministic effects and increased risk of stochastic effects. Information on the longer term exposure, specifically the annual dose and the dose to fetus are lacking. It seems unlikely that the action levels for these potential concerns would be reached due to the low 30-day values.

This scenario would be either an Alert or a Facility Emergency depending upon the consequences to the on-site population. No medical consequences to the off-site population would be expected.

Case 2:

These exposure levels do not approach levels that cause deterministic effects and are below the level of increased risk from stochastic effects. However the analysis predicts exceeding OIL2 and OIL3 which would require consideration for relocation and food restrictions to an area 10 times the distance at which OIL3 is exceeded. Relocation may be unnecessary since the 30-day exposures are well below the annual criteria for relocation; environmental monitoring should be used to establish the need for relocation. Restriction of food, milk and water is appropriate since the analysis results do not consider exposure from contamination of these necessary foodstuffs. Analysis of the local produce, milk and water and comparison to OIL5 or OIL6 would be used to determine if restrictions are appropriate. Iodine thyroid blocking would not be recommended at these exposure levels. As in Case 1, longer term exposures should be evaluated.

Because of the OIL2 actions, this scenario would be a Site Area Emergency. If no protective actions were taken, ingestion of contaminated foodstuffs may increase the risk of stochastic effects. This would likely not be detected unless the internal exposure to iodine was above 50 mSv where an increase in thyroid cancers, most likely to young children could be detectable.

Case 3:

This scenario should be classified as a General Emergency, due to the potential threat to pregnant women. The 30-day internal dose exceeds the 100 m Gy threshold for potential severe deterministic effects to a fetus. For this situation relocation and medical counselling would be appropriate protective actions. Additionally, OIL2 and OIL3 are clearly exceeded and the margin to exceed OIL1 is too small to ignore given the potential uncertainties in the analysis. Environmental measurements would determine the need for evacuation; however, this scenario is one which should be considered as necessitating such an action and the appropriate plans developed by the authorities who would implement such an action. Food restrictions should be recommended, and the use of iodine thyroid blocking if the scenario includes a release of I-131 and replacement foodstuffs are not immediately available. Field or laboratory analysis of locally grown produce, milk and water would be performed to determine which foodstuffs were safe to use.

The potential medical consequences with no protective actions implemented would be an increased occurrence of birth defects due to exposure to the fetus. Depending on the internal iodine dose, thyroid cancer rate in young children could show an increase. Medical screening would be necessary if no protective actions reduce the exposure to the public.

Case 4:

This scenario clearly creates a General Emergency due to the threat to pregnant women as in Case 3, and the 30-day external dose that potentially exceeds the criteria for deterministic effects from high Z nuclides, although this would have to be more closely evaluated to determine which nuclides are present in the release. Evacuation would be appropriate since OIL1 is exceeded. Environmental monitoring would confirm if evacuation was indicated. Evacuees should be screened for contamination and decontaminated as necessary. Restriction of foodstuffs would be recommended pending analysis to compare measurement results to OIL5 or OIL6. Medical screening should be recommended and may indicate the need for long-term medical follow-up of affected individuals. Iodine thyroid blocking would be recommended if replacement foodstuffs were not immediately available and analysis of local foodstuffs determines the food should not be used.

This scenario poses a potential increase in stochastic effects in the off-site population if no protective actions are implemented and a potential for severe deterministic effects on foetuses.

Case 5:

OIL2 is exceeded indicating the potential need for relocation and restriction of foodstuffs based on results from environmental monitoring. Recall that these values do not include the potential exposure from contaminated foodstuffs. A Site Area Emergency would be an appropriate classification for this scenario since no criteria for severe deterministic effects is reached.

The potential for an increase in stochastic effects is present, most likely an increase in thyroid cancers among young children, if the thyroid dose from contaminated foodstuffs is found to exceed 50 mSv. No deterministic effects are expected.

2. What are the likely physiological effects of these external whole body RBE-weighted doses to an individual?

1.2 Gy

120 mGy

12 mGy

Answers:

1.2 Gy – This is above the threshold for severe deterministic effects and all members of the exposed population would exhibit symptoms of ARS. Deaths, even without supportive treatment, would not be expected. Pregnant women would have an increased incidence of children born with birth defects.

120 mGy – No severe deterministic effects are expected to the general population, but stochastic effects would be expected, perhaps at a rate that would not be detected unless the exposed population was very large. Children born of pregnant women exposed to this level may have an increased occurrence of birth defects.

12 mGy – No deterministic effects are expected. An increase in stochastic effects is unlikely.

3. Which emergency classes are appropriate for emergencies that have no radiological threat to an individual beyond the site boundary?

Answer:

An Alert causes an uncertain risk to people at the facility, or to the public. However, this emergency class is not expected to cause a radiological threat off-site. A Facility Emergency is also not expected to create a radiological threat off-site

4. **Which emergency classes are appropriate for emergencies that pose a radiological threat beyond the site boundary and, for a Threat Category II research reactor facility what is the affected zone?**

Answer:

A Site Area Emergency creates a radiological threat to facility personnel and to the public near the site. A General Emergency threatens severe deterministic effects from radiation for the public beyond the site boundary. For a research reactor the threat includes the UPZ and would be evaluated by environmental monitoring.

5. What steps are necessary to determine the Threat Category of a research reactor facility?

Answer:

The facility must evaluate potential reactor accidents, even those of low probability, and determine the radiation exposure to individuals both on-site and off-site. If there is a risk of stochastic effects to the off-site population, then the facility is in Threat Category II. It would be expected that the PAZ is within the site boundary. The difference between the two zones is the urgency of implementing urgent protective actions. If the time to perform and evaluate environmental monitoring and then implement urgent protective actions cannot be rapid enough to avoid severe deterministic effects within the exposed population, then the area where this can occur is the PAZ.

6. As a minimum, what external agencies should a research reactor facility obtain support agreements with and do these agreements need to be written?

Answer:

The most likely necessary off-site support would be firefighting, medical aid and security support from a local police department. The medical support must include an ambulance service if not associated with the hospital planned for treatment of contaminated patients. These departments should receive some basic training in radiation protection, depending upon the assumed emergencies, and a review of the necessary supplies. For example, the medical treatment facility may require supplies for limiting the spread of contamination to the medical staff and the facility. Responsibilities for radiation measuring instrumentation should be included in the agreement.

The agreements must be written and clearly detail the specific responsibilities of both the research reactor facility and the off-site organization. Periodic review of these agreements is necessary to ensure they are still recognized by the off-site organization.

7. Should environmental monitoring extend beyond the UPZ if an OIL is exceeded within the UPZ?

Answer:

If OIL3 is exceeded, EPR-RESEARCH REACTOR recommends environmental monitoring to evaluate for contaminated foodstuffs in an area at least 10 times the distance from the reactor that the OIL was found to be exceeded.

8. A nuclear power plant has three barriers to fission product exposure, fuel clad, primary piping system and containment? For a research reactor what are the similar barriers? What are the qualitative differences, relative to releasing fission products, to the barriers that exist at a research reactor?

Answer:

Research reactor fuel uses fuel element cladding just like a nuclear power plant. This is the first fission product barrier in both types of facilities. Protection of this barrier is the main purpose of reactor emergency operating procedures and usually can be guaranteed at a research reactor if the core remains covered with water. At a research reactor, the second barrier is the reactor pool itself. Although some fission products from failed fuel cladding will escape from the pool, the fraction of the most dangerous fission products is small. Again, keeping the core covered with water is the best strategy, even if forced circulation is required to prevent damage to the fuel clad. The building that contains the reactor is the equivalent to the containment required at nuclear power plants. Few small research reactors have a containment structure, however, a building, sometimes referred to as confinement, will contain many of the fission products that escape from the pool.

9. An Emergency worker has volunteered to enter an area with an estimated gamma radiation field of 4 Sv/hr. If the actions are not taken, an off-site population could receive radiation doses that would cause severe deterministic effects. What would be the calculated stay time for this intervention (stay time is the calculated amount of time the individual would be in a radiation field in order to not exceed a planned dose)? What other advance preparations for this intervention would you take based on the guidance in EPR-RESEARCH REACTOR?

Answer:

The recommended guidance value for an intervention that prevents severe deterministic effects is 500 mSv. Thus the maximum stay time would be (0.5 / 4.0) × 60 minutes = 7.5 minutes. However, some dose will be accumulated in travel to and from the location where the task is to be performed. Depending upon the transit time and estimate of the radiation fields on the transit path, the 7.5 minutes would be reduced. For example, if it was expected that 50 mSv would be accumulated during transit to and from the location, the stay time would be reduced by 45 seconds. The calculation is:

$$\text{Stay time} = ((0.50 - 0.05) / 4.0) \times 60 \text{ minutes} = 6.75 \text{ minutes}$$

A turnback dose rate should be assigned, especially when the radiation levels are only estimates, and the combination of stay time and turnback dose rate should be set to avoid exceeding the 500 mSv exposure criteria. For example, assuming the same 50 mSv for transit time and a turn back dose rate of 6 Sv/hr, the stay time would be reduced to 4.5 minutes. This calculation is:

$$\text{Stay time} = ((0.50 - 0.05) / 6.0) \times 60 \text{ minutes} = 4.5 \text{ minutes}$$

If the task can't be completed within the calculated stay time, it may be possible to separate the task into smaller tasks and use more than one Emergency Worker to complete each part of the task.

Each Emergency Worker should be briefed on the details of the expected task, including response to some likely problems that could be encountered. The briefing must include a discussion of the risks associated with the expected exposure. In this case, a potential for an increased risk of stochastic effects is the consequence of the anticipated exposure and exposures much above the planned value carry a risk of severe deterministic effects.

Instrumentation to measure up to the turnback dose rate must be provided, and, if available, a self-reading dosimeter to allow the Emergency Worker to recognize when the 500 mSv value is being accumulated. If the self-reading dosimeter is equipped with an alarm, the alarm should be set at a value that provides a audible alarm at a value such that exit from the area will not result in inadvertently exceeding the planned dose.

Protective equipment should be established based on the potential for high levels of contamination or airborne activity. This would include an area out of the radiation field where the potentially contaminated protective clothing would be removed.

Similar precautions should be taken for intervention to avert a large collective dose with the only change being the reduced criteria of 100 mSv for the dose during the intervention. Maximum stay time would be (0.1 / 4.0) × 60 minutes = 1.5 minutes.

10. Explain and discuss the acronym CLAIM.

Answer:

The acronym stands for Classify, Life saving, Assess and protect, Inform, Manage. These are the steps that the emergency response actions are expected to follow. Classify refers to classification of the emergency, a step that defines the severity in terms of the consequences and the affected population. Life saving is a step to assure that actions to save lives, which includes accounting for all affected individuals and obtaining necessary medical assistance. Assessing and protecting is the step of determining the radiological consequences, either based on facility conditions or on environmental monitoring, and then implementing the appropriate protective actions to minimize the consequences. Inform is the actions to notify organizations responsible and able to assist in the response. The actions to inform include information provided to the public, either directly or through the media. Manage is the overall actions that maintain control of the response by coordination actions with all responding organizations, monitoring and evaluation additional information as it becomes available and follow-up of recommended protective actions to verify proper implementation and effectiveness.

11. **Explain the difference between reactor emergency operating procedures and facility emergency response procedures.**

Answer:

Reactor emergency operating procedures are usually step-by-step specific actions taken by the reactor operators to mitigate a reactor emergency. They involve operating reactor controls and operating specific equipment, for example, pumps, or valves. The actions are designed to put the reactor and reactor systems in a safe, stable condition. The facility emergency response procedures are designed to mitigate the radiological consequence of the emergency by protecting both on-site and off-site personnel from any radiation that may be a consequence of the reactor emergency. Reactor operations personnel perform the emergency operating procedures, and are most likely the first ones available to initiate the emergency response procedures. The continuation of emergency response procedures is transferred to an Emergency Response Team once that group assembles.

12. What is the purpose of the emergency classification table?

Answer:

A well designed emergency classification table assists the emergency response process by providing guidance to quickly determine the severity of the emergency and which groups of people may be at risk from any radiological threats created by the event. This enables the responding organizations to more quickly prepare for protective actions should they be appropriate. Classification is expected within 15 minutes of recognition of an emergency and is likely to be assigned by the reactor operating staff. The severity levels are defined based on reactor instrumentation and conditions of reactor systems and equipment so the information is readily available to the reactor operators. By clearly setting conditions for each type and severity level of emergency, a trained operator can quickly assign a classification which then initiates more specific emergency response actions, such as urgent protective actions appropriate to that level of severity.

13. Suppose a certain reactor emergency necessitates evacuation of a large number of individuals. What other protective actions should be taken regarding the evacuees and the area that was evacuated?

Answer:

The evacuees should be screened for contamination, warned against inadvertent ingestion of external contamination and decontaminated as necessary. Evacuees should wash hands and face as soon as possible to reduce the potential for inadvertent ingestion if prompt access to decontamination facilities is not available. A subsequent shower and change of clothes would reduce the levels of contamination.

The evacuees should be registered for follow-up medical evaluation. The recorded information for each person should include the contamination levels and location found by monitoring and the decontamination actions taken or recommended.

The affected area should be isolated to prevent access until contamination levels can be assessed, and mitigated. If contamination cannot be reduced, the area may remain isolated until radiation levels have declined to acceptable values.

14. Explain the difference between PAZ, UPZ and LPZ. Where are these zones for your research reactor?

Answer:

PAZ stands for precautionary action zone. It is the area closest to the reactor and, thus, the area of greatest risk from radiation consequences of a reactor emergency. The next furthest region is the urgent protective action planning zone, or UPZ. For Threat Category III research reactors both of these zones are within the boundaries of the reactor site. Only the PAZ is within the site boundaries for a Threat Category II research reactor. The LPZ is off-site for a Threat Category II research reactor and may be off-site for a Threat Category III research reactor.

Because the PAZ is expected to present the most severe threat, urgent protective actions are taken immediately, based on the emergency class. This prompt response is appropriate because of the potential for severe deterministic effects to individuals within the PAZ if implementation of urgent protective actions is delayed by waiting to gather environmental monitoring information. Environmental monitoring is still conducted; however, the results are used to determine if the urgent protective actions are necessary, not to decide to promptly implement them.

In contrast, urgent protective actions in the UPZ are based on environmental monitoring results. It may be appropriate to recommend sheltering to the individuals in the UPZ while waiting to obtain and evaluate the environmental monitoring results. Sheltering provides some reduction in radiation exposure, and can help prepare the UPZ population for more intrusive protective actions if appropriate.

A third zone should be determined by the facility threat analysis. This is the area furthest from the reactor facility known as the longer term protective action zone, or LPZ. Environmental monitoring in this area will determine if protective actions such as relocation, resettlement, restriction of foodstuffs, or medical evaluation are appropriate.

15. **Why does the guidance propose a difference in the emergency response team for a Threat Category II research reactor relative to a Threat Category III research reactor??**

Answer:

Radiological consequences for emergencies at Threat Category III research reactors are not expected to create threats to the off-site population. The emergency response team has fewer interactions with the off-site authorities and can combine some roles that are assigned to separate positions in the Threat Category II emergency response team. For example, the role of Protective Action Manager on the Threat Category II team is tasked to determine and recommend urgent protective actions for on-site and off-site populations. The Threat Category III team only need consider urgent protective actions for individuals at the reactor site.

Of course each research reactor facility should establish an emergency response team that fits their planning and response needs and establishing the Threat Category II team at a Threat Category III research reactor is a decision of the reactor operating organization.

Another reason for the difference is the recognition that many small research reactors, such as those in Threat Category III, may not have the staff to fill all the positions in the recommended Threat Category II response team.

16. Explain the Concept of Operations.

Answer:

A Concept of Operations (Con-ops) is both part of the emergency plan and is also part of the planning process. It should be established as a written document. A research reactor may have more than one Con-ops. For example radiation emergencies could generate two, one for Alert and Facility Emergency and a second for Site Area Emergency and General Emergency. A Con-ops could also be generated for emergencies that involve security forces. It all depends on the scope established for the particular site and the potential emergencies.

The Con-ops:

- is a simple overview of how the ideal response will proceed
- describes the basic responsibilities of the major responders

It is used:

- to assure all parities understand and agree to roles
- as a basis for development of detailed plans
- must be completed and agreed to before planning begins

17. This course presented a concept of four different emergency response groups. Explain who these are and their roles in an emergency response involving radiation.

Answer:

The major parties in a response (responders) are:

The *operating Organization* can be the staff at the facility. They are responsible for:(1) the immediate actions to mitigate the emergency;(2) protecting people on-site; (3) notifying off-site officials and providing them with recommendations on protective actions and technical assistance, and (4) providing initial radiological monitoring.

Emergency *services:* The local off-site response organizations that provide emergency services and which can typically respond anywhere. These include police, fire and rescue brigades, ambulance services, medical treatment facilities and possibly hazardous materials control teams.

Local *officials:* the government and support agencies responsible for providing immediate support to the operator and prompt protection of the public in the vicinity of the research reactor.

National *and regional (province or State) officials:* the governmental agencies responsible for planning and response on the national (or regional and State) level. These agencies are typically responsible for tasks that do not need to be implemented urgently to be effective. This includes: (1) longer-term protective actions, and (2) support of local officials in the event their capabilities are exceeded. This group includes the nuclear regulating agency and may assist with technical guidance if requested by the operating organization or the local officials.