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ON-SITE EMERGENCY PLANNING AND RESPONSE APPROACH FOR NUCLEAR POWER PLANTS

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NÜKLEER SANTRALLER İÇİN SAHA İÇİ ACİL DURUM PLANLAMA VE MÜDAHALE YAKLAŞIMI

Abstract

The on-site emergency response strategy for nuclear power plants which identifies the basic principles of the protective and other response actions should be constituted in the scope of the on-site emergency plan. First of all, the details related to the on-site emergency management organization which will be formed during an emergency should be explained and the responsibilities related to the emergency response should be delegated in the emergency plan.

In this study, Turkey's National Radiation Emergency Plan, other national regulations, the documents and approach of the International Atomic Energy Agency about the topic and the regulations and technical documents of other reference countries such as USA, Finland, Russian Federation and Japan were examined. Emergency classification and the operational criteria to be used during this classification; arrangements for alarms, notification and communications; radiological monitoring to be implemented on-site and in the region close to the site; emergency centers and points to be used during emergency response are other topics which will be covered together with the main topics stated above during the explanation of the main topics that should be present in the on-site emergency plan.

Özet

Nükleer santral kaynaklı acil durumlarda saha içinde uygulanması gereken müdahalenin esaslarını belirleyen müdahale yaklaşımı saha içi acil durum planı kapsamında oluşturulmalıdır. Saha içi acil durum planında öncelikli olarak acil durum sırasında saha içinde oluşturulacak acil durum yönetim organizasyonuna ilişkin detaylar açıklanmalı ve saha içi acil durum müdahalesine ilişkin sorumluluklar belirlenmelidir.

Bu çalışma kapsamında, Ulusal Radyasyon Acil Durum Planı başta olmak üzere ulusal mevzuat ve düzenleyici dokümanlar, Uluslararası Atom Enerjisi Ajansının konuya ilişkin yaklaşımı ve dokümanları, Amerika Birleşik Devletleri, Finlandiya, Rusya Federasyonu ve Japonya gibi örnek ülkelerin konu ile ilgili düzenleyici ve teknik dokümanları incelenmiştir. Saha içi acil durum planında yer alması gereken ana konu başlıkları açıklanırken yukarıda belirtilen ana hususlara ek olarak, acil durumun sınıflandırılması ve bu sınıflandırma yapılırken kullanılacak operasyonel kriterlerin tanımlanması; alarmlar, bildirimler ve haberleşmeye ilişkin düzenlemeler; tesiste, saha içinde ve sahaya yakın bölgelerde gerçekleştirilecek olan radyolojik

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izleme çalışmaları; acil durum müdahalesi sırasında kullanılacak merkez ve noktalar gibi konuların üzerinde durulacaktır.

Keywords: Nuclear power plant, on-site emergency plan, emergency management organization, emergency response, emergency action levels.

Anahtar Kelimeler: Nükleer santral, saha içi acil durum planı, acil durum yönetim organizasyonu, acil durum müdahale, acil durum eylem seviyeleri.

1. Introduction

A nuclear or radiological emergency can be defined as a possible hazard or an event that could cause people and workers to be exposed to radiation above the normal levels as a result of an existing exceptional event. Events such as the spread of radioactive materials, the destruction of the seal of radioactive sources and the emergence of radioactive sources from regulatory control during the events such as stealing or disappearing are included in the definition of nuclear or radiological emergency (Nordic Flag Book, 2014, s. 2).

Radioactive materials released from the nuclear power plant to the environment during nuclear power plant emergency situations (gaseous radioactive materials releases to the atmosphere) can cause biological effects on people living in the region of 3-5 km radius within a few hours from the release, if necessary protective actions are not conducted properly. The source of high exposure doses are external radiation from the airborne radioactive materials deposited on the ground and internal radiation from the radioactive materials taken into the body by inhalation. The most effective way to prevent high radiation doses during an emergency situation is to initiate protective action actions when the seriousness of the conditions in the nuclear power plant is determined and as a result of these conditions the possibility of radioactive substance release in significant quantities from the plant to the environment is aroused, and apply these actions before the airborne radioactive substances reach to the area. At this stage, the implementation of radiological monitoring studies, the preparation of their results and the expectation of evaluation should not delay the implementation of urgent protective actions.

The main danger for the people living further away from the nuclear power plant site (5-30 km) is the increased incidence of cancer cases due to the radiation dose to be taken as a result of inhalation of airborne radioactive materials. The most effective way to prevent this increase is again to implement the urgent protective actions in accordance with the above approach and to use the results of radiological monitoring studies in later phases of emergency situations during decisions regarding the implementation of protective actions. In this context, the general responsibilities of the operator (on-site emergency response organization) are listed below (IAEA, 2015, s. 32-36):

- Identification and classification of emergency situations;
- Implementing the necessary actions to mitigate the emergency;
- Protection of people on the site;
- Declaration of the emergency class and urgent notification to the off-site emergency response organization;
- Providing technical assistance to the off-site emergency response organization and give recommendations on protective actions and other intervention activities;
- Establishing uninterrupted communication with off-site emergency response organization;

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- Supporting the off-site emergency response organization for alerting and informing the public;
- Making radiological monitoring near the site in the early phase of the emergency and giving technical advice to the radiological measurement teams of the off-site emergency response organization.

Nuclear power plant operators are obliged to make the necessary planning during emergency preparation in order to fulfill all the responsibilities listed above. The basis of all of these preparations and the implementation of the responsibilities should be present in the on-site emergency plan. As a result of the planning studies that will determine the principles of preparation and intervention regarding the emergency situations, it is aimed to provide effective and timely implementation of emergency protective actions and other response activities on the site.

In this study, the relevant regulatory and other documents and the approach of Turkey, International Atomic Energy Agency (IAEA) and selected countries on the on-site emergency planning and response strategy are examined and technical information about these topics were compiled. Within the examined documents, Turkey's National Radiation Emergency Response Plan (URAP) is prepared for the determination of the basis for planning to be done at the national level and the provincial level and of the principles for the execution of the intervention and international relations which will be held during radiation emergencies (nuclear power plant related emergency situations is also included in this definition) that may occur domestically or abroad. The duties and responsibilities of the parties which are involved in the preparation and response for the radiation emergencies, time objectives and necessary technical guidelines for the implementation of the intervention are provided in the plan. The IAEA's top-level document on radiation emergencies is the GSR Part 7 which was published in 2015 and superseded the GS-R-2 "Preparedness and Response for a Nuclear or Radiological Emergency". This document describes the general, functional and infrastructural requirements for the arrangements to be made in the context of radiation emergency preparedness and response, and the general radiological criteria to be used for emergency preparedness and intervention. The GSG-2 "Criteria for Use in Preparedness and Response for a Nuclear or Radiological Emergency" and the GS-G-2.1 "Arrangements for Preparations for a Nuclear or Radiological Emergency" documents in the IAEA's Safety Standards Series, are other basic documents detailing the requirements described in the GS-R-2 document and containing recommendations and guidance on the implementation of this document's requirements. Detailed technical information on all important issues covered in the preparedness and response for radiation emergencies is presented in the technical documents in the Emergency Preparedness and Response (EPR) series of IAEA. Details of the operational criteria to be used during the operator's emergency classifications can be found in the UAEA's TECDOC-955 "Generic Assessment Procedures for Determining Protective Actions During a Reactor Accident" document (these criteria are also included in the GSG-2 document of the IAEA).

USA's NUREG 0654 "Criteria for Preparation and Evaluation of Radiation Emergency Response Plans and Preparedness in Support of Nuclear Power Plants" document contains the criteria for preparing and evaluating both on-site and off-site plans for radiation emergencies that may occur in nuclear power plants. The Russian Federation's NP-015-12 "Standard Content of the Plan of Personnel Protection Measures in Case of Accident at Nuclear Power Plant" document addresses only the on-site emergency planning, response organization and response strategy. Finland's YVL C.5 "Emergency Arrangements of a Nuclear Power Plant" document is a comprehensive resource explaining all the fundamental issues related to radiation

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emergencies and focusing heavily on the site area. Act on Special Measures Concerning Nuclear Emergency Preparedness of Japan, dated 17/12/1999 and number 156, and The Nuclear Emergency Response Guideline which was prepared by Nuclear Regulatory Authority (NRA) after the Fukushima Daiichi accident, provides guidance on emergency plans, the responsibilities of operators in nuclear emergencies, on-site and off-site emergency response organizations, the responsibilities of the off-site emergency response organization, the operational criteria to be used in the emergency classification and intervention, and the remedial work to be carried out after the emergency situation. The Nordic Guidelines and Recommendations, the Nordic Flag Book (NFB) "Early and Intermediate Phases of a Nuclear or Radiological Emergency" document is an emergency plan which provides information on preventive actions and other response activities that are being conducted by Scandinavian countries in early and later stages of nuclear or radiological emergencies.

In this study, it is aimed to explain the topics such as on-site emergency response organization, classification of emergencies, communication during emergency situations, radiological monitoring in the case of emergency, protective actions and other response activities to be applied during protection of emergency workers and others on the site comparatively by taking into account the approaches of selected countries and IAEA.

2. On-Site Emergency Plan

When examining country approaches to the content of the on-site emergency plan, it has been found that there is a common approach to this topic, which is generally addressed in a similar way. The on-site emergency plan to be prepared by the nuclear power plant operator should generally include at least the following topics (STUK, 2014, s. 4):

- Classification of the emergency and the identification of the underlying events and plant parameters when this classification is made
- Formation of on-site emergency response organization and determination of responsibilities
- Principles of response activities to be carried out on-site and preparations for response activities
- Arrangements for alarms, notifications and communication
- Emergency management and realization of the situation assessment
- Emergency worker’s safety and protection from radiation
- Radiological monitoring to be carried out in the facility, on-site and near the site during emergency situations
- Information to be provided for off-site emergency response organization to inform the public about the emergency situation
- Centers and points to be used during emergency response, equipment and other additional units
- Termination of the emergency and remedial actions
- Implementation instructions of the emergency response organization

Emergency planning should take into account that all units on-site may be affected in an emergency at the same time. When planning, it is important to consider that an emergency can spread over a long period of time and that major release of radioactive material may occur as a result of the emergency. It is also assessed that accident scenarios should be updated in accordance with the modifications made in the in the plant during operation period.

In the on-site emergency plan, organizations that are expected to assist the on-site response, even though they are involved in the off-site emergency response organization, such

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as regulatory body or search-and-rescue teams, should be identified in addition to the on-site emergency response organization (STUK, 2016, s. 3).

Radiological conditions in critical areas of the plant and the internal and the external radiation dose exposed by personnel in these areas should be assessed during the general emergency situation (in the case of facility and site emergencies there may be radiological conditions that may affect the workers also) within the scope of radiation protection of emergency workers which is explained in the "Protective Actions and Other Response Activities to be Implemented during Radiation Protection of Emergency Workers and Other People On-Site" section of this paper, in detail. The number of employees to be evacuated during an emergency must be determined for all shifts. Routes and infrastructure to be used for evacuation must be established (such as the condition of the roads, the number of vehicles to be used). Analysis performed for the estimation of the evacuation time should be presented. Preparations for the establishment of adequate capacities for personal protective equipment and radiation monitoring devices to be used by the workers on the premises should be explained. Arrangements should also be made for the sheltering of non-evacuated employees and availability of iodine tablets in case of emergency.

Establishing the infrastructure for alarms, notifications and communication is crucial for timely initiation of on-site and off-site response during an emergency. All the systems (software and hardware) and communication centers to be used in this context should be included in the on-site emergency plan (Russian Federation, 1998, s. 10). Personnel (in key positions) to be alerted by the warning system in the event of an emergency should be identified at the planning stage and schemes (Russian Federation, 2012, s. 40-41) on how this alert should be carried out should be prepared. It is necessary to establish the necessary infrastructure for the activities such as warning of the units in the emergency response organization and the centers and points to be used in the scope of the emergency response, transfer of the information about the emergency situation to these units and giving instructions. In order to ensure uninterrupted communication with the off-site emergency response organization through the site, information about the on-site and off-site systems should be provided.

The details of the emergency management organization to be established on-site in case of the emergency should be explained. In particular, information such as who will be the emergency manager, who will be in charge until the emergency manager arrives, who will be responsible for communicating the decisions that are taken by the emergency manager, and who will be responsible for ensuring their implementation should be given. The main activities to be carried out by the emergency response manager in support of the on-site emergency response organization and the timing objectives for these activities should be determined. It should be taken into account that the emergency response organization is ready to full capacity when the timing objectives for the actions to be implemented during the emergency are determined.

Information on the preparation of the centers and points on-site and near the site to be used during the emergency response should be given in the on-site emergency plan. In addition, the settlement, structure, equipment and preparation timing objectives of the units to be served related to the monitoring and evaluation of the emergency situation, within the scope of the response actions to be implemented on-site, and the documents regarding management schemes of these units, should be provided within the plan.

3. On-Site Emergency Response Approach

The emergency response approach is a brief description of the response expected to be implemented during an emergency. The essential requirements for the on-site emergency response approach are explained in the IAEA's documents and in the regulatory and technical

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documents of the related example countries. In this section, firstly the approaches of the example countries related to the main topics of the on-site emergency response which are described in the regulatory documents of these countries were compared and summarized in Table 1.

Table 1. The comparison and summary of the information related to the main topics of the on-site emergency response which are given in the regulatory documents of the example countries

Main Topic	Whether the Main Topic is Addressed in the Document					Explanation Related to the Approaches Described in the Documents
	Turkey URAP	USA NUREG 0654	Russian F. NP-015-12	Finland YVL C.5 NFB	Japan Act and related guideline	
On-Site Emergency Response Organization	Partially	Yes	Yes	Yes	Partially	NUREG 0654, NP-015-12 and YVL C.5 documents have more detailed provisions about the on-site emergency response organization than URAP and Japan's nuclear emergency law. In these documents, while defining the on-site emergency response organization, a special emphasis was placed on the determination of the on-site emergency response manager and the responsibilities of this person, and different approaches to this issue were also established. The NP-015-12 document states that for all emergency classes, the activities that must be carried out by the nuclear plant shift supervisor (According to NP-015-12, director of the nuclear power plant will be the emergency response manager, shift supervisor is the primary responsible for communicating and implementing the director's decisions) and timetable for these activities should be presented in a detailed table and it is also stated that emergency planning should be done within this scope. Fire, chemical accidents, external effects caused by natural disasters should also be covered in this table. In this section, it is stated that the activities to be carried out by the nuclear power plant's director for all emergency classes and other incidents, the information that is essential for these activities, the criteria to be used for taking decisions about them and the timing of these should be presented in a table and the emergency plans should be done within this scope. In addition, urgent protective actions to be taken in order to protect nuclear power plant employees in case of emergency are given in the main headings and a table to be presented in the emergency plans regarding the timing of key actions to be implemented

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						during the response is also presented in the NP-015-12. In NUREG 0654, a detailed categorization of the activities to be carried out during the emergency situation according to the emergency class has not been realized. Similar to NP-015-12 document, in YVL C.5 on-site emergency response manager charge is defined and the actions that the emergency response manager with support from the response organization, are also listed without specifying timing targets. URAP and Japan's Nuclear Emergency Law leave the on-site emergency response manager charge to the emergency response organization. A diagram describing the outline of the response organization that should be established on-site is given in URAP and the timing objectives for the critical functions and tasks in the response are presented in tabular form (TAEK, 2015, s.30). In Japan's nuclear emergency law, the responsibilities of the on-site emergency response manager and the activities to be applied during the on-site emergency response are outlined.
Detection and Classification of Emergency and Emergency Action Levels	Yes	Yes	Partially	Partially	Yes	NUREG 0654, YVL C.5 documents, and Japan's Nuclear Emergency Guide classify the nuclear power plant emergencies into three as General Emergency, Site Emergency and Warning Status. In addition to the classes listed above, the Facility Emergency is also defined in the classification made at URAP. In the NP-015-12 document, the emergency classes were designated as "Emergency Preparedness" and "Emergency Environment" as opposed to the URAP and IAEA approach. The use of operational criteria during the emergency classification were not included in the YVL C.5 document. The NP-015-12 document refers to other regulatory documents, without giving details for determination of the operational criteria for classifying the emergency situation. URAP, NUREG 0654, and Japan's Nuclear Emergency Guide state that Emergency Action Levels (EAL) should be used during emergency classification. This guide also describes sample EAL for emergency classes (NRA, 2012, s.58).
Communication to be Carried out during	Yes	Yes	Yes	Yes	Yes	The communication to be carried out during the emergency and its instructions have been dealt in detail in both NP-015-12 and

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Emergency Situations						NUREG 0654 documents. In NP-015-12 document, sample schemes for all the units to be notified during the emergency and the communication arrangements to be implemented were established and it was stated that the on-site emergency plans should have the diagrams based on these schemes. NUREG 0654 document, states that the provisions for the content of the emergency messages to be sent to the notification points or points off-site during the early and progressive phases of emergency should be prepared during the emergency preparation phase and also provides information on the contents of these messages. YVL C.5 document states that the on-site emergency response organization should notify regulatory body and the off-site emergency management center about the declaration of emergency and emergency class. It is stated that the communication instructions to be used during an emergency should be set within the mutual agreement of on-site and off-site response organizations. It is stated in URAP that this notification must be made by the on-site emergency response organization to the notification point at the off-site emergency management center, and that the notification to the regulatory body will be made by the off-site emergency management center. In Japan's Nuclear Emergency Law, notification and communication methods between on-site and off-site emergency response centers and their managers are defined in detail after the emergency class has been identified by the operator. The contents of the messages to be sent during these notifications and the provisions about informing the public are outlined.
Radiological Monitoring to be Carried out during Emergency Situations	Yes	Yes	Partially	Yes	Yes	It has been observed that the radiological monitoring activities to be carried out on-site during the emergency situation are handled at a certain scale in all the documents examined in this study. The operational criteria (Operational Intervention Levels) to be compared with on-site and off-site radiological monitoring results when decisions are taken on preventive actions and other activities to be applied are explained in detail in URAP, Japan's Nuclear Emergency Guideline and NFB documents.

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						The NP-015-12 document contains some basic provisions regarding the radiological monitoring to be carried out on-site. In the NUREG 0654 and YVL C.5 documents, there are detailed provisions in this regard for both on-site and off-site.
Protective Actions and Other Response Activities to be Implemented during Radiation Protection of Emergency Workers and Other People On-Site	Yes	Partially	Partially	Yes	No	In URAP "Guidance values for the restriction of the radiation doses of emergency workers" is given but it was found that no more detail about the actions to be implemented in this context are stated. This guideline has been found to be consistent with the values and the relevant provisions of YVL C.5 and NFB documents. NUREG 0654, NP-015-12 documents do not contain guidance values for limiting radiation doses. Emergency protective actions, especially concerning evacuation procedures and personal radiological monitoring, have been emphasized in these documents, as well as information on the methods and equipment to be used for radiation protection of personnel, to be given in emergency plans. Unlike NUREG 0654 in the document NP-015-12, it is stated that information about chemical substances in nuclear power plants, damages they may cause to the environment during emergency situations and details about the measures to be taken in this situation should also be included in the emergency plans.

The main headings (topics) of the actions and activities to be carried out within the scope of a general emergency situation originating from the nuclear power plant and some details deemed important for these headings were explained in the following sub-sections.

3.1 On-Site Emergency Response Organization

In accordance with the general approach established in the documents of the example countries, the emergency response organization to be established from the nuclear plant staff should be identified in the plan for all shifts and the links to the duties and responsibilities of that organization to normal operation should be described. An example of the overall structure of an on-site emergency response organization that can be established is shown in Figure 1.

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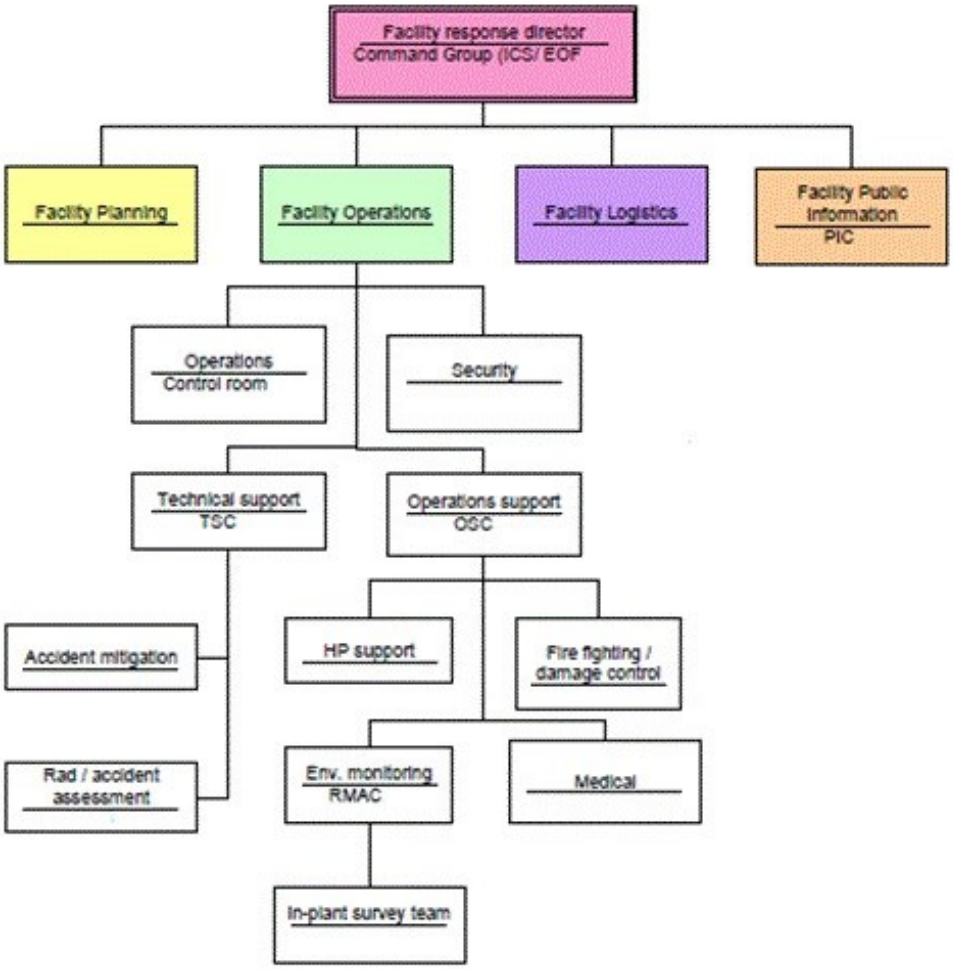

Figure 1. General Structure of On-Site Emergency Response Organization for Nuclear Power Plants (IAEA, 2003, s.223)

A person who has the authority and responsibilities necessary to give instructions on the actions to be taken during an emergency, without delay and on a unilateral basis, including information on the application of urgent protective actions to be carried out off-site and the delivery of recommendations to off-site officials, who is always available on-site or who is able to access the facility quickly, must be designated as the emergency response manager and must be specified in the emergency plan. The order of taking over the task for the emergency response manager position must also be specified in the plan and the special conditions for the assignment of this position to senior facility employees must be defined. The functional responsibilities of the emergency response manager should be determined in the on-site emergency plan and it should be indicated that which of these responsibilities cannot be transferred to other units or persons in the response organization.

The positions or titles of the people who will work in the functional areas within the scope of the emergency response and the basic tasks to be carried out in these areas must be defined in the plan. Responsibilities of the personnel who are or are not present on the site during an emergency must be specified for all shifts (NUREG 0654 recommended a minimum number of 11 personnel to be in shifts during an emergency). The basic tasks to be performed by the relevant personnel in an emergency must also be given in a table. Following the declaration of an emergency, the shift capacities should be brought to a state where response

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procedures can be carried out as soon as possible (YVL C.5 and NUREG 0654 indicated that 30 minutes should be sufficient for this operation) and preparations for this should be included in the plan.

3.2 Detection and Classification of Emergency and Emergency Action Levels

According to the IAEA's approach, the reactor parameters such as temperature, pressure, flow rate, specific events related to the plant safety, radioactive material releases, radiological measurement results, or other parameters related to extraordinary conditions based on different observable indications in the plant, operational criteria (Emergency Action Levels), as determined during the licensing or preparation phase, should be used for rapid and accurate identification and classification of the emergency situation. The main purpose of the emergency classification system established by using EAL is to create a reference approach that can be used for all light water reactor designs. This system should take into consideration the features of the existing design when adapting to a particular design or construction.

The classification system is based on the possibility of causing a major release from the primary reactor building or reactor vessel or a damage to the reactor core or critical safety systems in order to detect high radiation doses on-site. Emergency classes are associated with increased risk of damage to the reactor core or increased probability of high radiation doses occurring off-site. The use of such a classification system will ensure that appropriate conditions are established and sufficient time is available for the on-site emergency response organization to be able to mitigate the situation and for the off-site emergency response organization to implement effective protective actions. EAL are predetermined variables that can be measured or threshold values for each observable case which were predetermined for each emergency class during the emergency preparedness phase. EAL can be categorized into two categories as display-based and event-based. Display-based EAL are the values read from certain measuring devices (e.g. pressure value of the reactor cooling system is above a certain value) or other observable or measurable thresholds (e.g. a failure of the emergency power supply, which can be understood by monitoring a certain parameter). Event-based EAL are more subjective criteria that the operator (control room operators) need to evaluate. An example of this kind of criterion is the occurrence of an inland fire where very important reactor safety systems are located. The use of display-based EAL in all possible situations is necessary, as the use of such critiques will allow classification to be done in less time and with fewer errors (IAEA, 2011, s.53-59).

3.3 Communication to be Carried out during Emergency Situations

Providing uninterrupted communication between the centers and points on-site and off-site during the emergency is an important consideration in emergency planning and preparation. All institutions and organizations involved in the emergency response organization should establish primary and backup communication lines to be used during emergencies and care should be taken to ensure that these lines are compatible with each other.

Communication plans to be established within the on-site and off-site emergency plans should identify the communication channels on both sides, together with their titles and alternatives. The following points should be taken into account, when establishing on-site communication plans:

- Establishment of a communication system consisting of at least one telephone line and alternative, which can be active 24 hours a day, providing notification to the off-site emergency response organization and initiating response actions
- Continuous communication with off-site notification point

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- Establishment of communication with regulatory body
- Ensuring continuous communication between centers and points to be used during emergency response
- Providing communication with the institutions and organizations involved in the national and local emergency response organizations when necessary and being able to activate emergency workers of these institutions by notifying them

On-site and off-site emergency response organizations should have instructions consistent with the emergency classification system and the response organization, established on a common understanding of the notifications to be made during an emergency, and include them in relevant plans. Such instructions should also include methods of verifying mutual messages (such as making the necessary confirmation by calling the notifier after the notification point has received the message) without going into too much detail. The contents of the first emergency messages to be sent to the notification point off-site must be established at the preparedness stage. These messages should include information on the class of the emergency, whether a release is likely to occur, the possible areas affected by the accident, and whether the urgent protective actions need to be implemented.

Preparations should be made during the planning phase, for the messages that will be sent off-site during the following phases of the emergency and these messages should include the following information:

- The facility on which the accident has taken place, the name, title and telephone number of the person making the notification
- Date and time of the accident
- Emergency class
- Characteristics of the release that has been occurred or likely to be occur (These should include the properties such as liquid, gas, surface spill, duration/period. In this context, the chemical and physical properties of radionuclides in the releases that has been occurred or likely to be occur during the emergency must also be taken into account, including the relative concentrations / concentrations of radionuclides, inert gases, iodine and other particulates.)
- Meteorological data (wind speed, direction, stability class, amount of precipitation, etc.)
- Current or estimated radiation dose rates at site boundaries
- Estimated radiation dose rates for the points at certain distances to facility (these distances are specified as 2, 5, 10 miles in NUREG 0654)
- Estimates of surface contamination in facility, on-site and off-site
- Information on response actions performed on-site
- Recommended protective actions and other response activities off-site
- Information on the support requested from the off-site emergency response organization
- Information on the development of the emergency which is prepared in accordance with the site conditions (including worsening of the situation or the emergency ending scenarios as a result of successful mitigation actions)

It should also be taken into account by the on-site emergency response manager that during the communication to be carried out during an emergency, on-site emergency response manager may give recommendations for actions to be taken to protect the public by the off-site response organization, and may require technical assistance from off-site emergency response organization.

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Within the scope of requesting technical support from off-site, important parameters of the installation (safety parameters) will be transferred to the regulatory body, off-site emergency management center and technical support resources outside the facility (such as supplier of nuclear installation). In case of emergency, the parameters to be transferred from the site must include at least the following headings (U.S. NRC, 1980, s.52-55):

- Significant reactor core parameters and primary and secondary cycle parameters
- Back-up water sources and emergency cooling system parameters
- Residual heat cooling system parameters
- Key containment parameters
- The most important electrical system parameters
- Information on the radiation situation in the facility and on-site
- Information on the radiation situation near the site
- Meteorological data

3.4 Radiological Monitoring to be Carried out during Emergency Situations

According to the documents examined in the study, the necessary preparations must be made by the on-site emergency response organization to determine the amount of releases and the composition of radionuclides that occur or are likely to occur during an emergency. For this purpose, radiological monitoring programs to be carried out in the facility, on-site and near the site should be established in order to be able to detect exceptional releases that can occur during an emergency. When these programs are being conducted, local conditions must be considered and plans should explain the degree of preparation of the personnel, the timing of the measurements to be performed, the amount and types of equipment to be used in the measurements, and the personal protective equipment to be used and reporting of the results of the measurements. Procedures should also be set up for sampling operations.

The teams which will perform radiological monitoring in the facility, on-site and near the site should have an infrastructure capable of measuring dose rates and collecting air samples, and to determine the concentration of the important radionuclides in the area where they are measured and communicate the results of the measurements to the on-site emergency response organization when needed. Particularly off-site measurement teams should have vehicles with features that they can use during measurements and channels that can communicate with the on-site emergency response organization at any time. Routes and areas to be measured by off-site monitoring teams must also be planned in advance.

International generic criteria has been set for the response actions such as evacuation, sheltering, relocation and food restrictions that should be implemented during emergencies related to the nuclear power plants (Table 2). However, the generic criteria cannot be used operationally because they are not directly measurable quantities on-site or off-site during the emergency situations.

Table 2. Generic Criteria Used for As a Basis for the Response Actions (IAEA, 2017, s. 25)

Actions	Generic Criteria
Take response actions under any circumstance to avoid or minimize severe deterministic effects	GC(Acute,$AD_{skin\text{-}ext}$,10 h) = 10 Gy RBE weighted absorbed dose to 100 cm^2 of the skin dermis of the representative person from acute external exposure in the first 10 hours
	GC(Urgent,E,7 d) = 0.1 Sv Total effective dose to the representative person in the first 7 days
	GC(Urgent,H_{fetus},7 d) = 0.1 Sv

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Take urgent response actions to reduce the risk of stochastic effects	Total equivalent dose to the fetus in the first 7 days
	GC(Urgent,$h_{thyroid,thy\text{-}burden}$) = 0.1 Sv Committed equivalent dose to the thyroid from radioiodine in the thyroid (thyroid burden)
Take early response actions to reduce the risk of stochastic effects	GC(Early,E,1 a) = 0.1 Sv Total effective dose to the representative person in the first year
	GC(Early,H_{fetus},9 mo) = 0.1 Sv Total equivalent dose to the fetus in the full period of in utero development
Take response actions to reduce the risk of stochastic effects due to the ingestion of food, milk or drinking water	GC(Ingestion,e_{ing},1 a) = 0.01 Sv Committed effective dose to the representative person from ingestion of food, milk and drinking water during the first year
	GC(Ingestion,$h_{fetus,ing}$,9 mo) = 0.01 Sv Committed equivalent dose to the fetus from ingestion of food, milk and drinking water during the full period of in utero development

Operational criteria (Operational Intervention Levels) that are based on the generic criteria should be developed for the use of the results of the radiological monitoring studies carried out during the emergency (Table 3). Operational Intervention Levels (OIL) should be used in order to make decisions on the implementation of response actions and other response activities for the protection of the public, the employees and the environment.

Table 3. Operational Intervention Levels Used for the Emergencies Related to the Nuclear Power Plants (IAEA, 2017, s. 7)

OIL	OIL Value	Radiological Monitoring Type
OIL1γ	1000 μSv/h	Ground Monitoring Ambient dose equivalent rate at 1 m above ground level
OIL2γ	100 μSv/h (for the first 10 days after reactor shutdown)	
	25 μSv/h (later than 10 days after reactor shutdown or for spent fuel)	
OIL3γ	1 μSv/h	
OIL4γ	1 μSv/h	Skin Monitoring Ambient dose equivalent rate at 10 cm from the bare skin of the hand and face
OIL4β	1000 cps	Skin Monitoring Beta count rate at 2 cm from the bare skin of the hand and face (The use of OIL4γ is preferable over OIL4β)
OIL7	1000 Bq/kg of I-131 and 200 Bq/kg of Cs-137	Monitoring of Food, Milk and Drinking Water Samples Activity concentration of I-131 and Cs-137 in food, milk and drinking water samples
OIL8γ	0.5 μSv/h	Thyroid Monitoring

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		Ambient dose equivalent rate in front of the thyroid in contact with the skin

Radiological measurements to be performed during an emergency in a nuclear power plant can be grouped under three main headings:

- personal radiological monitoring (γ and β dose rate measurements from the skin, γ dose rate measurements from thyroid, whole body count);
- measurements to be performed on-site and in the emergency planning zones (monitoring of the radiation dose which can be incurred from the radioactive materials present in the air by γ dose rate measurements, monitoring of ground contamination by γ dose rate measurements)
- activity concentration measurements of the marker radionuclides in the food, milk and drinking water samples (Gross α and β measurements, γ spectroscopy).

Results of the radiological monitoring activities to be obtained during the early phases of the emergency situation will be confusing and probably inconsistent due to the following reasons:

- radionuclides that are released into the environment have complex and variable accumulation distributions in the area as a result of natural processes due to meteorological and geological conditions of the region
- in the event of an emergency, the measurements cannot be carried out fully in accordance with the instructions
- the content of radionuclide mixtures that are released from the plant will vary due to the changes in the plant conditions during emergency

As a result these reasons, the decision takers should be very careful and should take the characteristics of the measurements, the natural and social environment of the area and the representativeness of the measurements into account, while taking decisions about the protective actions in the early phases of the emergency.

3.5 Protective Actions and Other Response Activities to be Implemented during Radiation Protection of Emergency Workers and Other People On-Site

Main topics of the preparations to be made in order to protect those on-site from radiation in the framework of emergency response are:

- preparation of warning systems for personnel warning,
- formation of on-site gathering points,
- preparations for evacuation,
- distribution preparation for personal protective equipment, radiation measurement devices and iodine tablets,
- preparation for contamination measurements and decontamination procedures.

Emergency workers are those who have special duties to perform during an emergency and are likely to be exposed to radiation when performing these tasks. Emergency workers may be personnel employed by the licensee or may be persons such as police officers, firefighters, medical personnel, drivers of evacuation vehicles and other employees involved in the off-site emergency response organization (IAEA, 2006, s.80).

National standards for the management, control and registration of radiation doses to be incurred by emergency workers should be established taking into account international recommendations. These standards should include operational criteria (personal equivalent

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dose) that can be measured directly during the implementation of these tasks for emergency workers with different duties. Radiation doses that can be incurred due to external radiation during emergency situations can be continuously measured. The operational criteria to be established for emergency workers should basically be based on external irradiation (measured by active or passive dosimeters). Radiation doses that can be caused by inhalation or radioactive substances that accumulate on the skin are considered to be reduced by the use of protective equipment and iodine tablets. Any information on radiation levels on-site should be used when decisions are made regarding the radiation protection of emergency workers (IAEA, 2007, s.97-98).

Life-saving activities that may require incurring doses close to or above threshold radiation doses that may result in severe deterministic effects are only applicable if the benefit to other individuals is greater than their own health risk and the emergency workers understand and accepts health risks. Tasks that might exhibit radiation doses of 50 mSv or more should be performed on a voluntarily basis. Emergency workers should be trained about these tasks, supplied with all kinds of protective equipment and informed in detail about the health effects related to the radiation doses they might be incurred. Relevant planning should be done during the preparation stage by taking into account that emergency workers will act on the voluntary basis during an emergency.

Conformity with the evacuation actions to be carried out off-site and evacuations to be carried out on-site within the scope of protective actions and other response activities to be applied for the protection of people on-site should be considered from the planning stage. These evacuations should be implemented in such a way that they do not interfere with each other. Contamination control should be performed by radiological measurements on clothing and skin before people are evacuated from the site. Decontamination activities should be carried out.

4. Conclusions

In this study, it was aimed to explain the importance of on-site planning for emergencies arising from nuclear power plants by taking into account the objectives of the on-site emergency response, lessons learned from past nuclear power plant emergency situations and evaluations on the infrastructure to be prepared for emergency preparedness and response. These explanations were generally made by examining the regulatory and technical documents of Turkey, IAEA and example countries such as USA, Finland, Russian Federation, Japan and stating the different approaches given in these documents in a comparative way.

During the compilation of technical information on the topic, the main objectives of the actions and activities to be carried out by the on-site and off-site emergency response organizations were determined. In this context, the mentioned ones within the site during the emergency situations arising from the nuclear power plant are to classify the emergency situation, to notify the authorities off-site, to implement preventive actions and other response activities, to perform radiological monitoring and sampling studies in areas close to the site and to carry out mitigation studies to reduce the damage. Within the scope of the study, it was stated that the on-site emergency plans should include the structure of emergency response organizations and the distribution of duties and responsibilities, which can fulfill the intervention objectives listed above. The importance of the emergency response manager in the examined documents and the criteria for selection and duties of this person were listed in detail at different levels and contents.

When examining lessons learned from past nuclear power plant emergencies, it was seen that during Chernobyl and Three Mile Island accidents, the field emergency response organizations were not able to quickly understand the seriousness of the situation and to take

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urgent measures quickly. In both cases the necessary planning and preparation for emergencies that are unlikely to occur was not been made in advance. Similar to these two emergencies, it was observed that no preparations involving appropriate planning were made during the emergency situation arising from the Fukushima Nuclear Power Plant. The failures during these emergency situations were mainly due to the lack of implementation guidelines based on pre-determined criteria (EAL) in the provision of emergency classifications and on-site training programs within the scope of low-probability serious accidents. It was observed that in the related sections of the documents examined during the study, the emergency preparedness should be taken into consideration in all situations that may be experienced in the nuclear power plant, and that there was a common approach to the use of operational criteria during the emergency situation but the details about this issue may vary. Another fundamental problem encountered in this context was that top managers in the on-site and off-site emergency response organizations generally do not participate in training and exercises due to their workload and therefore should not know what to do under stressful conditions in case of emergency. The following approaches in the given countries were adopted; the trainings and the implementation instructions should be based on the consideration of the serious accident conditions that may occur in the nuclear power plants, and the strict participation of senior managers in trainings and exercises should be realized.

As a result of the examinations made in the sections of the documents related to the infrastructure to be used in the emergency intervention, it was determined that the equipment and systems used in normal operating conditions and the centers and points may not always be used during emergency situations. Another frequent problem was that the communication instruments of the personnel involved in the emergency response organization might be incompliant with each other and this might cause disruption in communication during emergency conditions. Furthermore, radiological monitoring devices used during normal operation were shown to be unavailable during emergencies due to inadequate measurement capacities. It was determined that systems, equipment, centers and points should have features that can work under all kinds of adverse conditions, and that standardization should be provided in devices used for radiological monitoring and communication when preparations are made in these fields. Past experiences showed that the outdated communication lists, the application instructions and other documentation including the contents of messages to be sent off-site disrupt the emergency response and these documents should be updated periodically. When all these criteria were taken into consideration, communication and radiological monitoring studies to be carried out during the emergency situation were very important for the effectiveness of the emergency response.

In Turkey, IAEA and the example countries' related regulatory and technical documents, on-site (especially in the work spaces) radiological monitoring studies, the determination of spent time in the personnel's work space and information to be given related to the reduction of exposure was emphasized and criteria related to these issues were set. It was also stated in these documents that, plans should be made for the preparation of emergency workers and equipment decontamination instructions, access control and communication with radiological monitoring teams on-site and near the site.

In this study, topics considered to be important when dealing with on-site emergency plans that should be prepared for nuclear power plants and response approach related to the emergency situations were explained comparatively by examining the Turkey, IAEA and the example countries' regulatory and technical documents. During the presentation of the information on the topic, it was tried to explain the issues related to the criteria to be used in

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the review and assessment of the on-site emergency plans during the licensing process of the nuclear power plants. As a result of the comparison made during the study, it was found that the basic approaches for on-site planning and response are common but there are various approaches especially to the on-site response organization.

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