INTERNATIONAL NUCLEAR SAFETY JOURNAL
vol.4 issue 1, 2015, pp.18-27

ISSN 2285 – 8717
ISSN–L 2248 – 8717
http://www.insj.info

A Model for the Monitoring Organization for Forest Ecosystems of Japan Contaminated with ^{137}Cs and ^{134}Cs Resulting the Fukushima Daiichi NPP Accident

N.E.Zarubina[1], D.O.Vishnevskiy[2], O.L.Zarubin[1]
[1] Institute for Nuclear Research of NAS of Ukraine, Kiev, Ukraine
[2] State Specialized Enterprise "Chornobyl Spetzcombinat", Chornobyl, Ukraine
Corresponding author: nataliia.zarubina@gmail.com

Received: *5 February 2015*; accepted: *19 March 2015*

Abstract
Anthropogenic accidents, which result in high-scaled radionuclides released into environment, show a similar mechanism in the contaminated territories is created. Therefore, the analysis of separate cases, despite their uniqueness, provides considerably high value. Such analysis allows the determination of the most and least effective solutions. Radioecological monitoring has become the main subject or our study, being an essential managerial instrument under the high-scaled radionuclide contamination of environment. The main characteristics and the development stages of the monitoring organization for surface ecosystems within the Chernobyl NPP accident zone have been considered. Basing on the analysis results, an organizational model for the radioecological monitoring of forest ecosystems within the Fukushima Daiichi NPP accident zone has been proposed. The monitoring includes two levels for the observation network – basic and special, which produce information on the contamination parameters and the radioecological processes development, correspondingly.

Keywords
monitoring, forest ecosystems, accident, radioecology

1. Introduction

The terms "accident" and "catastrophe" are usually used to name huge anthropogenic accidents.

The term "accident" is used to describe the event itself, but the term "catastrophe" defines a large-scale consequences of the event. Prior experience shows that accidental releases of radioactive substances, which happen during the exploitation of nuclear power reactors and in radiochemical industries (6- and 7-level accidents according to the International Nuclear Event Scale (INES), lead to considerable environment contamination, which consequences that could be described as a catastrophe. Therefore, that type of accidents has a great importance for the theory and practice with concerns to the ecological safety.

Despite the small number of accidents (ChNPP, 1986; PO "Mayak", 1957; Fukushima Daiichi, 2011), there are several key stages describing an accident progression that could be distinguished:

1. Physical barriers destruction as a result of the accidental process occurring inside the facility;
2. Transformation of radioactive substances participating in the accidental process together with the construction elements;
3. Release of the transformed radioactive substances into atmosphere;
4. Radioactive substances fallout from the atmosphere (dry deposition or washout), and the formation of radionuclides concentration fields within territories.

Radioactive fallouts distribution is non-uniform. Nuclear weapons testing experience shows that the fallouts could be divided into two categories – local, which precipitate during the first two days, and global, which continue precipitation for years. The local fallout consists of big radioactive particles, but the global fallouts are gases and highly dispersed particles. The local radioactive fallout comprises around 50% of all radionuclides released after a surface nuclear explosion. Big radioactive particles are formed the fireball touches the soil surface. These fallouts form the highest radionuclide concentration fields, constitute the highest biological danger, and they are considered as one of the main adverse factors [1].

In the case of some radiation accident, the process of the radioactive substance fallout from the atmosphere possesses the same character. Initial radioactive substances, the facility construction materials, and other elements incorporate into the accidental process and transformation into radioactive fallouts possessing a broad nuclide composition and dispersity. Low-dispersed particles precipitate at the territory close to the contamination source and form the highest radioactive substances concentration field. There is a range of important consequences from the fact. Firstly, the most serious radiation safety actions are undertaken at the territory up to and including population evacuation. Secondly, urgent emergency and rescue actions have to be performed because the high-level ionizing radiation conditions. Thirdly, a complex radiation situation at the territories persists even after the radionuclide release source localization. For the territories are assigned a special legal status (*e.g.*, “radioactively dangerous territories”), and corresponding governmental management is applied to them.

The territory, where the radioactive substances precipitated, could be considered from the point of practical radioecology as an open areal contamination source. Many factors influence the radionuclide migration within landscape, thus complicating its prognosis. The information on such system state could be obtained through regular observations only. Radiation-ecological monitoring performs the information providing function using the observation technique.

Radiation-ecological monitoring is a serie of observations specifically organized in the physical space and time to study the radiation state of a certain environment component. The information obtained during the monitoring program performance is designated for the current state estimation, and for the response actions prognosis. The components could be separate objects (*e.g.*, radioactive waste storage facility, a water pond, and “hot points”) and whole natural clusters (surface and underground water, landscapes, surface atmospheric layer and other) [2].

Forest ecosystem monitoring is an obligatory radioecological monitoring subsystem in case of forests existence in the monitored region. Forest ecosystems serve as a barrier for radionuclide spreading route: isotopes are excluded from the biological substance circulation for a long time after they be trapped into branches and trunk tissue. Forest vegetation reduces the surface water flow and prevents dust formation. However, forest could be a source of radionuclide release into environment by liberates the accumulated radionuclides. Specifically, radionuclides are released onto atmosphere during forest fires and massive blossoming. Forest fires could cause radionuclide shock release into rivers in the same conditions for mountain landscape [3].

The accident at Fukushima Daiichi NPP has shown that the work experience obtained during the localization of other radiation accidents is in demand. It is especially important for managerial decisions – the decision-making authorities must perform in time- and information-deficient conditions. In this article, the experience on the organization of radiation-ecological monitoring of forests at the ChNPP exclusion zone territory has been discussed. An organizational scheme for such monitoring at the territories contaminated after the ‘Fukushima-Daiichi’ NPP accident has been proposed.

2. Radioecological monitoring of forests within accident zone – Chernobyl catastrophe experience

Chernobyl NPP accident resulted in the most wide release of anthropogenic radionuclides into the environment. The whole activity of the radionuclides released from the damaged reactor is about 50 million Ci. All landscape components were contaminated because deposition from the atmosphere, surface and underground water, surface layer of the atmosphere, ground ecosystems, technogenic objects. Total territory area considered by law as radioactively contaminated is about 50,000 km^2. The most part of radionuclides fall out on the territory of the exclusion zone (further – EZ). Its territory is 2,600 km^2. Total forest area at the contaminated territories is equal to 9,500 km^2, from equivalent to EZ limits – 2,100 km^2 [4].

Two components were used for the development of monitoring systems at the territories suffered from the ChNPP accident. The first component – techniques, approaches, and organization structures for environment contamination surveillance existent in the USSR at the time of the accident. The second component - techniques, approaches, and radioecological monitoring surveillance network developed after the accident. Let's look at them in details.

The first component. The term 'environmental monitoring' was introduced in 1972 at the First International Environment Protection Conference in Stockholm and was defined as "a system for regular and continuous spatial and temporal surveillance of the environment state and warning about developing critical situations hazardous and dangerous for human beings and other live organisms".

At the first half of the 70s of the 20^{th} century, an environment monitoring concept developed by academician Yu.A. Israel was accepted in the USSR. This concept emphasized the observation function with no interference: "…monitoring includes observation, evaluation, and prognosis for the environment state and does not involve environment quality and human activity control". This ensured the independence of monitoring system methodological from control tasks and a certain excessiveness of obtained information. At the same time, this approach also provided high quality of information, its reliability and independence from separate control subjects. The State Committee for Hydrometeorology and Environment Surveillance controlled environment monitoring programs in the USSR.

Environmental geophysical approach was employed as the fundamental for the Soviet monitoring concept. The program for contaminating substances background monitoring at biosphere reservations could be an example for the monitoring program development basing on such approach. According to the program, concentration of a limited set of contaminating substances in atmosphere, snow, soil, biota, surface and underground water, bottom deposits and suspensions are measured regularly.

In addition to the determination of the character of contaminating substances distribution in environment, the monitoring system estimated ecosystem dynamics at the conditions of combined contaminators influence. This task became urgent in 70s, when multiple cases of vegetation degradation started to be observed (including forests) under the influence of industrial emission. Techniques for the determination of stability limits for ecosystems, mechanisms for their rehabilitation after catastrophic influence, and interaction effects of negative factors combination were being developed and studied during that period. Bioindication is the main (basic) approach for the solution of this task. A wide parameter spectrum at all biological object organization levels – from biochemical and genetic to ecosystem levels – are employed [5].

In addition to the national monitoring system, environmental determination of radioactive substances was performed at territories close to NPPs. Radioactive substance content in the surface air, surface and underground water, soil and biological objects (including forests) was monitored. This work was performed by a special NPP department – a laboratory for external dosimetry.

The second component. As it was said above, ecology monitoring programs initially were developed for the observation of environment state at national and global scales. Ecosystem state monitoring at the zones with intensive anthropogenic influence is performed for relatively small number of natural objects, mainly for research purposes. Before the ChNPP accident, nobody has experienced with a situation of massive supply of long-lived anthropogenic radionuclides into environment. Because of that a necessity for the performance of a special regional radioecological monitoring has appeared.

In general, there was no task on the monitoring performance as a complex of regular environment state observations at the accident zone during the initial, "sharp", period of the accident. At this stage, upper management felt acute deficit in information about the scale and character of environment radioactive contamination. Thus, all environment monitoring resources – personnel, equipment, techniques – were aimed at this task solution. There was no regular surveillance network per se. Surveillance program tried to include the largest number of environmental objects to construct a reliable event picture. This period could be named an information saturation stage.

Also, a complex program for radioecological scientific research aimed at the estimation and prognosis for accident consequences influence on the environmental objects was started. These activities might estimate ecosystem degradation risks and possible ways for their transformation under the ionizing irradiation influence. The role of various type landscapes in the radioecological situation formation in the nearest future was studied separately. Here the research was concentrated on the elucidation of the mechanisms of radiation impact on live organisms and the processes of radionuclide migration within landscapes.

In a certain sense, scientific organizations possessed their own surveillance system – station, testing areas, surveillance points. However, these objects were not always consistent with the regular monitoring network requirements.
It could be said in the conclusion that there was no environment (including forest) monitoring as an integrated system during the initial period of the ChNPP accident. There were important reasons for such situation. Firstly, control organs received environment radiation state information quite promptly because of concentrated resources from scientific and specialized organizations. Secondly, neither surveillance network could provide urgent information on wide-spectrum requests from the control organs. Thirdly, while estimating the radioecological situation, the priority was given to the anthropogenic contamination sources – object 'Sheletr', ChNPP near zone, radioactive waste storage points. Personnel and inhabitants locations were also a priority. Therefore, during the first five years after the accident, systems were developed for regular observation of media critically important for the radiation condition formation: surface air, surface and underground water. Fourthly, the question on the long-term existence of the exclusion zone was not raised during the first three-four years. The zone gradual return into economic use was supposed.

Radioecological monitoring of exclusion zone forests was not performed till 1996. Forestry renewal in the exclusion zone and understanding of the necessity to control the forest at this territory became a reason for the monitoring start. Initially, the radioecological monitoring of the exclusion zone forests was a sub-system for the integrated forest monitoring covering the sanitary and ecology forest situation surveillance. The radioecological monitoring provided the following information: quantitative dependencies in the system 'soil contamination density – radionuclide content' in each forest-growth condition type (FCT), radionuclide distribution in soils for different FCT, transfer coefficients range. Surveillance network with monitoring plots located at 16 km, 8 km, and 4 km grids was employed.

The surveillance network included two levels:
1) ***extensive*** – aimed at the collection of a statistical information array;
2) ***intensive*** – where special research aimed at the determination of cause-effect relationships for changes detected at the first level. First-level surveillance network points are located in a grid, but the second-level network points – within typical and 'critical' landscapes [6].

3. Natural and radioecological conditions for the Fukushima Daiichi NPP accident region

Fukushima Daiichi NPP is located at the eastern cost (Pacific Ocean) of the Honshu island. Evacuation zone, which was formed as a result of the accident, represents a semicircle with 20-km radius. Such geometrical form of the evacuation zone is not connected with radioactive deposition peculiarities, but a result of administrative decisions aimed at the optimal employment of available resources and the minimization of risks for population exposure to radiation. Therefore, the change of the zone limits is possible in both directions in future.

Climate. This region climate belongs to tropical monsoon. Total solar irradiation equals 120 kcal/cm^2 per year. Annual radiation balance exceeds 60 kcal/cm^2. Average temperature in January is 4-8^{0}C. Average temperature in July-August is 26-27^{0}C. Heat supply is considerable: active temperatures sum is 4500-5300^{0}C. Annual precipitates amount to 2200-2500 mm, exceeding 4000 mm at some locations.

The climate is constantly damp – humidity factor is higher than 1 during the whole year. Summer contemporizes with the wet season. There are two precipitation maximums – in June (so called plum rains) and in September. In October, precipitations begin to decline.

Precipitation abundance causes intensive flow off, which annual amount exceeds 500 mm. Prolonged summer floods take place in accordance with the year precipitation distribution. The run-off coefficient is 0.5-0.6; actual evaporation is around 800 mm. Water flows erosive activity is strongly expressed.

Vegetation cover corresponds to the east-Asian subtropical zone is represented by a variety of species composition. The zonal vegetation type is evergreen forests of complex composition. The characteristic representatives are Lauraceae, Theaceae and other. Oak is represented with several species. The undergrowth includes rhododendrons. There are many lianas and epiphytes. Vegetation grows all the year round. During winter, forests save the green aspect, but some bushes shed their leaves, and grass canopy dries.

Abundance of invertebrates fauna is caused by ecological ties with forest vegetation (phyliophagous forms, carpenter moths). There are many termites in the soil, which eat organic tree waste, especially wood. Thus, detritus ecosystem chain is characterized by high exchange rate.

Covered with forests territories occupy about 10-15% of the plain. Forest-covered territories prevail in mountains. By territory, artificial forest plantations of Japanese cedar (*Cryptomeria japonica*) dominate, which are used for wood production. Phytomass supply in the forest is 240-480 t/ha, from which 7-10 t/ha belong to green assimilating organs. Annual production is 12-20 t/ha. Forest phytomass accumulates up to 400 kg/ha of nitrogen and 1,000 – 1,500 t/ha of ash elements. Biological cycle occurs intensively. Organic substance mineralizes and decomposes during the whole year, and not more than 1.5-2% of humus is accumulated in soil. Soils are represented by yellow soil [7].

Relief at the evacuation zone region id represented with coastal plains with lowlands transient to mountains. The mountains extend along the meridian direction in parallel ridges, partitioned by transversal valleys, and composed by secondary and tertiary limestone, sandstone, and peach stone. Mountain maximum height is 500-700 m. The plain – mountain ratio within the evacuation zone relief is approximately equal.

It should be pointed out that the plain component of the relief is highly utilized. It characterized by a high settlement density, a developed transport network, and considerable agricultural grounds. The main crop plant is rice. During summer period (April-October), rice crops are harvested twice. Te fields are covered with water all this time. Forest are mainly artificial. Hydrological network is represented mainly with rivers (the main flow direction is 'west-east') and artificial reservoirs.

Radioactive contamination. The isotopes ^{134}Cs, ^{137}Cs, and ^{131}I were released into environment as a result of the accident. The presence of trans-uranium elements was detected in some soil samples. ^{137}Cs will be the dose-forming radionuclide in a long-term perspective. This isotope amount released into environment equals 540-541 Ci (estimated by the Institute for Nuclear Energy Safe Development Problems of RAS).

The character of radioactive precipitates fall-out during the accident at the Fukushima-Daiichi NPP resulted in the appearance of a territory with the high contamination level ($\geq$ $^{134,\ 137}$Cs 1000 kBq/ m^2, maximum values – 3000-4000 kBq/ m^2), which outspreads to the north-west from the NPP. Its area is 428 km^2 [8]. The most part of radionulides leaked into environment is within the area. From a certain point, the territory is an analogue of "radioactively dangerous grounds" formed after the accident at ChNPP. In a long-term perspective, a special control regime will be being active at the territory, and radioecological monitoring will be being performed to support the regime.

4. Monitoring tasks for forest ecosystems within the Fukushima Daiichi NPP accident region

Taking into account our Chernobyl experience, we have developed a preliminary list of tasks to be performed by the monitoring:

- obtaining of full, detailed, and statistically reliable information about radioactive contamination levels at forest territories;
- the determination of radioactive contamination dynamics at the forest territories;
- the study of radionuclide redistribution in different soil types and landscapes;
- the study of the intensity of radioactive elements migration into wood species, bushes, grass, fungi, moss, lichen, and in

the system 'soil-forest biota component' (plant species, fungi, animals0;

- the study of radionuclide migration in the system 'soil – fodder plant – wild animals';
- the study of radionuclide migration along food chains from forest to human beings.

5. The estimation of key parameters during monitoring performance

The following parameters are determined during radioecological monitoring performance:

- Surface contamination density – it is soil specific activity, expressed in Bq/m^2 or Ci/m^2 (km^2 is used for the characterization of large territories). This parameter is the main one for the characterization of a radiation state as a whole. The surface contamination density is used as a basic value for the calculation of external and internal irradiation doses, radionuclide accumulation levels in vegetation, as a criterion for the determination of radiation protection activities.
- Radionuclide vertical migration in soil. The parameter is obtained using the estimation of soil layers contamination in a 50-cm deep pithole. Long-term observations allow estimating the factors and velocity of radionuclide vertical migration. One-time inspections provide information about radionuclide stock distribution in soil.
- Radionuclide content in landscape components. The group 'landscape components' includes vegetation (tree stand with the division into separate composing part, surface herbaceous cover, moss, fungi) and vegetation waste, which forms forest ground litter. Radionuclide content in these components allows to estimate its stock within the ecosystem outside soil, determine the most active radionuclide accumulators, and develop a ranked row for the radionuclide content in the landscape components. Separately, components possessing economic value in forestry could be analyzed: wood, medical herbs, mushrooms, plant raw material.
- Transition coefficient. It is a relation of radionuclide specific activity in a landscape component to the radionuclide activity on a soil surface area unit (surface contamination density). This parameter allows to estimate the accumulation process intensity for the landscape components and obtain basic information for the development of a model for isotope migration within an ecosystem. Other coefficients could be used – accumulation, proportionality – which are needed for the solution of more specific research tasks.
- Ionization exposure rate. It is a universal express-parameter of a radiation situation. Measurements are performed at each sampling point in two positions: on the soil surface and at one meter height.

Radioecological monitoring goes beyond the parameters of environment radioactive contamination. Its results interpretation (determination of factors and causes for the radiation parameters dynamics), model development, and prognosis require the employment of data for the non-radiation monitoring of environment. We propose the following set of parameters for the non-radiation monitoring:

- Forest vegetation parameters. Key characteristics of the forest cover are estimated according to the criteria approved in the national forestry system. International forest state monitoring system could also be used, e.g., ICP Forest, which was employed at the ChNPP accident region.
- Mycocenological research. It is performed in order to obtain information about species composition, quantity, and macromycetes phenology, which are employed in the monitoring.
- Meteorological observations. Temperature and precipitates directly influence on the velocity and character of substance cycling processes within an ecosystem. The necessary meteorological data could be obtained from a weather station, if it is located in the monitoring performance region. If there is no station, a meteorological post should be organized, which observation program needs to include the following elements: air temperature in the surface layer, air relative humidity, atmospheric precipitates, soil profile humidity, soil thermal flow, soil profile temperature.
- Observations of soil cover state. The main factors determining radionuclide mobility in soil are the soil physical-chemical properties. Therefore, regular observations of the following parameters should be performed: humus content and composition, pH and mobile compounds, exchange cations composition.

6. Monitoring time frames

Monitoring performance duration depends on three groups of factors – radioecological, managerial, and social. However, the main question could be formulated as follows: for how long will control organs need information on territory radiation conditions and on the character of radioecological processes taking place there? All the three factor groups should be studied to answer the question.

Radioecological factor group may provide a prognosis for situation development and determine the time moment, when the monitoring performance necessity falls away. We can roughly calculate right now the time period after which the territory would be clean from the ^{137}Cs radionuclide. It is ten radionuclide's half-lives – 30.17 years. We may consider this period as the most possible for the conditions at the accident zone of Fukushima-1 NPP.

Radiation situation changes not only during the process of physical radionuclide decay. Radionuclide migration and redistribution within landscape also play an important role. They result in radionuclide quantity or concentration decrease in certain landscape components and elements. At the late period of ChNPP accident (in 1995-2000), these processes were in focus of researchers and considered as an alternative to area deactivation active techniques. Landscape typification was performed for the ChNPP exclusion zone basing on two groups of factors: "openness-closeness" for the substance flow and "fast-slow" for the substance flow velocity. "Open" landscapes with active substance flow possessed the most ability for self-cleaning.

However, contaminating substances redistribution processes within a landscape could be considered as a variant of a game with null sum: contaminator quantity decrease in one system element leads to the increase in other elements. The appearance of "clean" landscape elements is compensated with appearance of areas with high concentration of contaminating substances – "hot" spots. Radioecological research at the Totskiy testing area (USSR) could be mentioned as an example, where scientists identified considerable excess of radionuclide concentration in river valley soil 40 years after nuclear testing performance. Dissemination is one more result of the radionuclide redistribution. Specific concentration decreases, but the level of background contamination increases. For example, extreme values of atmosphere surface layer radiation contamination at the ChNPP exclusion zone till 1992 had been determined by meteorological factors – dust storms, hurricanes, and high wind speeds. The correlation between these events could not be identified after 6-7 years after the accident. The reason was that open soil areas were covered with vegetation during the period as a result of the vegetation cover natural recovery. Dust elevation decreased dramatically, and air contamination fluctuations leveled [9].

Starting 2000, spring radionuclide concentration maximum in air started to be detected throughout the whole exclusion zone territory. Pollen became the reason for that phenomenon as a result of its massive release into atmosphere during flower blossoming. Increase of area covered with vegetation resulted in the change of the mechanism for the radionuclide release into air. Annual spring peak substituted random air contamination splashes connected with loal soil deflation conditions. Air contamination during the peak is considerably lower than during dust storms, however it registered throughout the whole territory of the ChNPP exclusion zone.

A very similar situation was observed with the ChNPP exclusion zone while performing water protection actions, which might prevent radionuclide introduction from overflow land into Prypiat river. Almost 100 of different purpose engineering constructions were developed – dams, stoppings, traps. The project performance actually considerably decreases radionuclide flow from overflow land into the river and made impossible their "burst" release during floods. At the same time, inundable reservoirs damming resulted in the underground water level increase and the promotion of ^{90}Sr migration from the surface soil layers and temporary radioactive waste storages into the underground water. Currently, the main source of the Prypiat river contamination with ^{90}Sr is the underground water. There is no solution for the problem for the time being [2].

Thus, dynamic processes for radionuclide redistribution within the landscape may take place and result in its separate elements "self-cleaning". Chernobyl experience shows that the situation becomes more complex in time after massive environment contamination – radionuclides incorporate step-by-step into geochemical and biogeochemical exchange processes after the accident outburst. At this stage, radioactive contamination could hardly be controlled, and additional problems with the contamination detection and monitoring appear.

The managerial (control) factor plays the leading role in the monitoring organization. First of all, the radioecological monitoring is performed at the territories which possess a special status connected with the radiation factor. Control organs establish criteria basing on which the territories attain the status. In Ukraine, the criteria are the surface contamination density and human effective equivalent exposure dose. There are two categories of land, which possess the special status connected with the radioactive factor: “radioactively dangerous lands” and “radioactively contaminated lands”. The surface contamination density for the radioactively dangerous lands must be: for $^{n}Cs \geq 15$ Ci/km^2, $^{n}Sr \geq 3$ Ci/km^2, ^{n}Pu 0,005 – 0,01 Ci/km^2; human effective equivalent exposure dose must be $\geq$ 5 mSv/h. The surface contamination density for the radioactively contaminated lands must be: for $^{n}Cs \leq 1$ Ci/km^2, $^{n}Sr \leq 0.02$ Ci/km^2, $^{n}Pu \leq$ 0,005 Ci/km^2; human effective equivalent exposure dose must be ≤ 5 mSv/h.

Authorities at these territories should take into account the radiation factor, thus, control organs need information on the radioactive contamination of environment, agricultural lands, etc. This information could be obtained employing the radiation surveillance and monitoring, which scale, character, and tasks are established by the control organs as the main users for the produced information.

Radiation parameters change in time, first of all, because of the radionuclide natural decay. For example, at the territory of Ukraine, the area of land where ^{137}Cs contamination exceeds 10 kBq/m^2 decreased by two times during 25 years after the accident at the Chernobyl NPP. Correspondingly, the boundaries of the territories exposed to contamination as a result of the ChNPP accident also changed. Several administrative units were excluded from the “radioactively contaminated lands” list [10]. Radiation monitoring and control were decreased or suspended at these territories.

A group of social factors points at another user for the information on environment radiation state – the society. As it has been pointed out earlier, a territory may lose the special status, which was connected with the radioactive contamination, and it may be considered safe for living and economic activity. However, the reputation of a “dangerous” and “contaminated” area may be kept in social perception for a long time. People need confidence in that the acquired safety state is constant, and there is no tendency for its worsening. In this case, the monitoring information serves for the social tension decrease. This is also important for the territory social-economic development, when investors need the most full information concerning risks.

One can say as a conclusion that the term for the monitoring performance should be determined for each case separately basing on the situation at a certain territory. At the same time, not only the character of radiation contamination should be considered but the peculiarities of the information users – control organs and society – as well.

Finishing the discussion, we can look at the experience obtained during other large radiation accidents: at the ChNPP in 1986 and PO “Mayak” in 1957, where the radiation-ecological monitoring has been being performed since the accidents for 28 and 57 years correspondingly.

7. Spatial organization for the surveillance network

The size and peculiarities of a surveillance network depends on territory size, its shape (relief), and landscape structure as well as on control tasks.

According to the nature of obtained information, the network is split into two levels – basic and special. The basic level includes all territory under surveillance. It is a set of sampling points located in the nodes of a square 8-km increment grid (Fig.1). Soil samples and vegetation cover indicating components are sampled there. The basic surveillance network data are employed for the development of a general contamination picture.

The special monitoring network level includes plots where processes are monitored which have been determined by monitoring tasks, such as migration and radionuclide accumulation by vegetation cover components. Also,

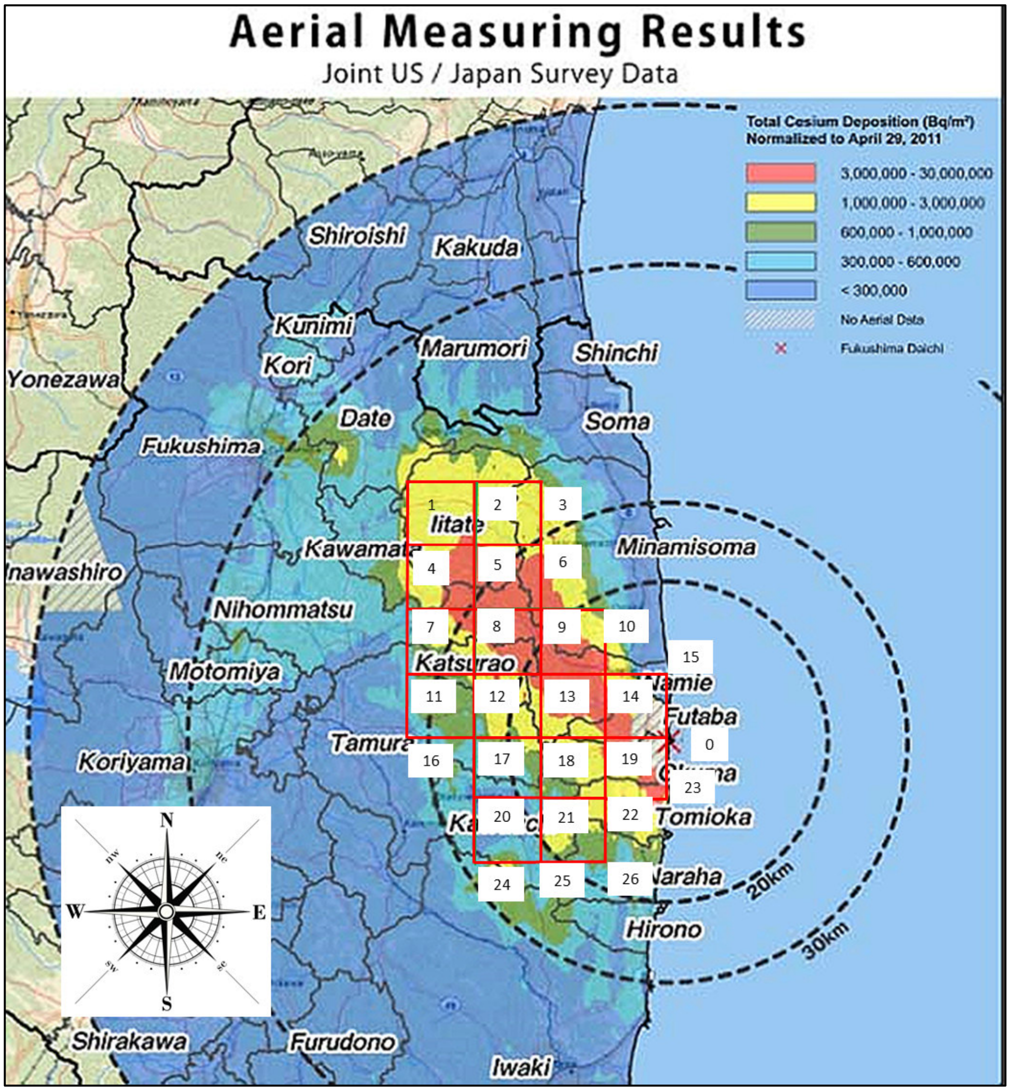

Figure 1. Proposed main control stations of the basic radionuclide monitoring level at the region of Fukushima NPP (the employed map*: http://www.kananet.com/health/6disast.htm*).

Table 1. Main characteristics of testing areas of the special monitoring network.

Resting area, No	***Relief level***			***Forest type***		
				Deciduous broadleaf forest	***Evergreen needleleaf forest***	
				Soil type		
	Watershed	***Slope***	***Base***	***Brown forest soils***	***Black soils***	***Immature soils***
1	+	-	-	+	-	-
2	-	+	-	+	-	-
3	-	-	+	+	-	-
4	+	-	-	-	+	-
5	-	+	-	-	+	-
6	-	-	+	-	+	-
7	+	-	-	-	-	+
8	-	+	-	-	-	+
9	-	-	+	-	-	+

additional ecological information collection is performed at the plots. The plots should represent main landscape conditions of the monitored region, therefore, their number is not strictly determined. There are three landscape characteristic axes which could be used for the plot establishment. These are (1) soil cover character: three soil types dominate here - brown forest soils, black soils, immature soils; (2) forest type: deciduous broadleaf forest, evergreen needleleaf forest; and (3) landscape level: watershed, slope, base. It is known that brown forest soils and the deciduous broadleaf forest are located at the northern part of the territory, and black soils, immature soils and the evergreen needleleaf forest are at the eastern part of the territory. A combination of these characteristics allows to propose nine testing area types for the special monitoring network (Table 1).

Basic level allows fast obtaining of unequivocal information concerning the forest radioactive condition. The information provided by the special level needs a more prolonged treatment period.

8. Conclusion

Decision-making process at emergency situation conditions possesses two important properties – time and information deficit. After the finish of the accident acute phase, time deficit is gone, but the information deficit is still in place. The understanding of the radioecological situation at the territories with high contamination levels is the main “puzzle” to solve during control processes. Monitoring, as the main means for the task solution, is effectively employed at anthropogenic catastrophe and ecological disaster zones. However, the choice of an effective solution at emergency situation conditions is not evident. Therefore, the management experience obtained during the liquidation of other catastrophes should be used. Choosing models which led to positive results in the past, it helps to save time and other resources.

The forest ecosystem monitoring organization model proposed by our team is based on the strategy employed at the ChNPP exclusion zone. This monitoring organization variant is not a final one and should be considered as a model, which would be adapted to local conditions. The final choice of a monitoring organization scheme depends on how forest is considered within the territory management system: as an ecosystem within a natural reserve; as a landscape part performing a barrier function; or as an industrial unit.

References

1. Israel, Yu.A. Radioactive fallout after nuclear explosions and accidents. St-Pb.: Progress-pogoda, 1996. 355 p.
2. Kireev, S.I., Vishnevsky, D.O., Obrizan, S.M., Khaliava, V.G. Current trends in information support for the control of objects with high risk of emergency situation. (on the example of the ChNPP exclusion zone) // Bulletin for the ecological state of the exclusion zone and the zone of unconditional (compulsory) evacuation. - 2006, №2. - P. 32-37.
3. Obrizan, S.M., Godun, B.A., Kireev, S.I. The influence of dangerous natural phenomena and processes at the exclusion zone on the radioactive contamination of environment. // Twenty Years of Chernobyl Catastrophe. The View into Future; International Conference. April 24-26, 2006. Kiev, Ukraine. Proceedings (365 p.). P. 54-56.
4. Chernobyl exclusion zone atlas. — Kiev: Kartographiya, 1996. — 26 p.
5. Israel, Yu.A. Ecology and environment state control. – M.: Gidrometeoizdat, 1984. – 559 p.
6. Savich Yu.M., Zibtsev S.V. Results of ChNPP exclusion zone forests monitoring during 1995-1997 years // Scientific bulletin of the National agrarian university. – 1998. – Issue. 8. – P. 80–85.
7. Isachenko, A.G., Shliapnikov A.A. Landscapes. – M.: Mysl, 1989. – 504 p.
8. Hashimoto S, Ugawa S, Nanko K, Shichi K. The total amounts of radioactively contaminated materials in forests in Fukushima, Japan Scientific Reports, 2, doi:10.1038/srep00416 Article number: 416.
9. Godun B.O., Derevets, V.V., Kireev, S.I. *et al*. The influence of certain meteorological conditions on the radioactive contamination of exclusion zone atmosphere surface layer. // Bulletin for the ecological state of the exclusion zone and the unconditional (compulsory) evacuation zone. – Chornobylinterinform, 2003. - №22. – P.7-12.
10. 25 years from Chernobyl catastrophe. Safety of the Future: Nationa report of Ukraine.– K.: «KIM», 2011. — 355 p.