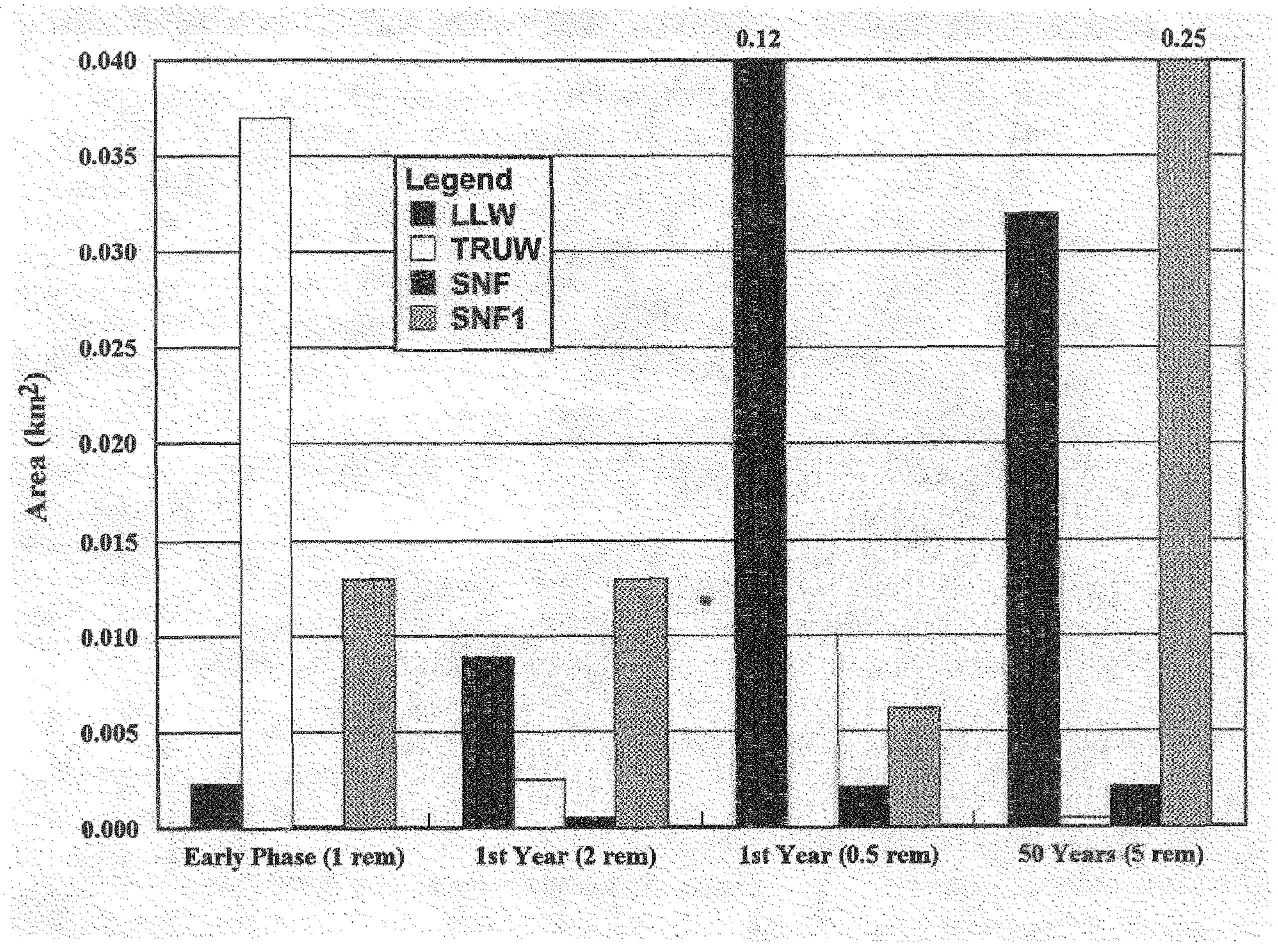

Figure 2. Amount of area affected by early-phase and intermediate-phase PAG values

Using Chernobyl Experience to Develop Methods and Procedures of Post Accident Radiomonitoring

V. Poyarkov

European Centre of Technogenic Safety, Kiev, Ukraine

INTRODUCTION

The Three Mile Island, Goiania and Chernobyl accidents have resulted in the re-examination of many emergency planning principles and practices.

A nuclear, or radiation emergency response planning is based on expected avertible doses for short (4 hours, 2 days, 1 week) and long (50 or 70 years) periods of time. Therefore, in emergency planning one has to differentiate the following three periods in evaluating accident exposure: the acute (at and 4-6 hours after a radioactive discharge), the short-term (duration of the acute period plus 48 hours) and the long-term (50-70 years).

The primary task of radiation protection in the acute period is to forecast the area distribution of radionuclide contamination in order to prevent deterministic effects as the effective doses can exceed 1Sv from the moment of release to the following 4-6 hours. The principal protective measures are evacuation, sheltering, and iodine prophylactics. The acute period evaluation is based on the state of the reactor core and that of the area of 3-5 km around the NPP.

The main task of the short-time period evaluation is to forecast territories, where doses could exceed 1 Sv in the following month. The forecast is made on the basis of accident radiomonitoring with a due account of protective measures undertaken.

The long-term evaluation is designed to forecast territories where doses for 50-70 years can exceed permissible levels. The forecast is made on the basis of comprehensive radiomonitoring, soil characteristics, and expected soil-plant transfer coefficients, as well as the economic possibilities to carry out the corresponding countermeasures and the analysis of socio-psychological situation.

To develop a comprehensive integrated system for emergency response, it is necessary to elaborate on the methods and procedures for post-accident radiomonitoring, which would provide countries with uniform techniques and procedures for accident radiation measurement and appropriate dose assessment, and could be integrated as a part of the decision support system.

International study and analysis of consequences of the Chernobyl accident set up a unique basis for using the Chernobyl experience in the areas of environmental radiomonitoring techniques, dose assessment, and decision making. The contaminated area is the largest out-door laboratory for testing developed methods and procedures.

The two stages in emergency response require techniques and procedures for accident radiation measurement and appropriate dose assessment, i.e. the short-term and the long-term periods of assessment. The main components of exposure, which need to be assessed during the short-term period are external and internal exposures from the released radioactive cloud, external exposure from the radioactive fallout, and internal exposure from the contaminated food and water.

DISCUSSION

In an emergency situation the contamination can cover large areas and have unpredictable spot structure due to meteorological conditions and other factors. Since for most nuclear accident scenarios the highest part of the dose is external exposure, the first priority is to have a measurement of the external dose. In this case, the first step of the monitoring should be to use integrated methods, like aerial monitoring, which have high productivity and provide opportunity to have a generic structure of contamination on the large area during a short time. But this survey does not have a sufficient accuracy for ambient dose assessment and requires knowledge of the ground dose rate measurement. This measurement details the contamination structure but does not provide information on composition of the fallouts for evaluation of the avertible dose. Unfortunately, the radionuclides composition in the release and fallout can significantly vary depending on the processes in the reactor core and the mechanism of precipitation. The in-situ gamma-spectrometry is commonly used for measurement of the radionuclides composition. It provides information about radionuclides mixture integrated for an area of about 30-50 sq.m The main problems of the accident in-situ gamma-spectrometry are high dose and complicated spectrum. Currently existing devices and techniques are completely acceptable in real reactor accident situations.

The information about radionuclides composition can be made more precise by soil sampling. The local soil contamination varies significantly (up to 3-5 times within a few sq.meters) due to a complex mechanism of deposition. Fig. 1 presents an example of frequency distribution (FD) of the activity soil samples collected within 5 m radius. This FD in theory follows a log normal distribution. The geometric mean of activities of as minimum as 10 samples collected within a few square meters should be used as an estimator of the real density of the contamination.[1]

For internal exposure assessment, samples of air, water, vegetables, milk, and other ingestion stuff are collected. The main goal of such activity is to assess collective and individual doses for the public. Thus, the air samples should be collected in the settlements near the accident source immediately after the early warning signal about the accident occurs.

The water, vegetables, milk, and other ingestion stuff samples should be collected at the same time as the soil samples. The activity of these samples also can vary significantly, and for assessment of the real contamination one should use a geometric mean of activities on a minimum of 5 samples. It is also necessary to take into account that for the emergency personal collection of the samples is the most difficult and expensive step of the monitoring. Thus, you should have a guarantee that collected amounts of samples are sufficient for real radiological assessment.

The Chernobyl experience has demonstrated that in case of a nuclear reactor accident only two radionuclides ^{137}Cs and ^{90}Sr have the highest contribution to the long-term exposure. These radionuclides have half-lives (~ 30 years) close to the human life, high ratio in the reactor core inventory and release, as well as similar chemical characteristics to elements as potassium (for Cs) and calcium (for Sr) with such importance for human beings.

More than 99% of the Chernobyl accident collective effective dose (CED) is due to ^{137}Cs (90-95%) and ^{90}Sr (0.5±4%). The internal exposure produced about 70% of the total CED. The main part of this dose (90-95%) was produced by ^{137}Cs. The food stuff contributed the most (97-98%) to the internal dose. In Ukraine 70-90% of the 137Cs intake is due to milk. The contamination of milk depends on radionuclide migration within a chain soil-plant-milk.[2]

One of the main parameters used for radiological status forecast is the root-layer clearance half-time. The ^{137}Cs effective clearance half-time for the 0-10 cm soil layer, taking into account radioactive decay, typically varies from 10 to 25 years. The soil layer clearance was slower in the upper layer (24-27 years for the 0-5 cm layer) than in the deeper layer (10-17 years). Typically, the processes of soil clearance of ^{90}Sr are up to 3 times faster than those of ^{137}Cs. The clearance half-time for ^{90}Sr is typically 7 to 12 years. Three years after the accident, a stabilisation of the transfer factor between soil and plant has been observed. The variability in observed soil-plant transfer is due to the varying chemical and physical properties of different soil types.

The level of contamination of agricultural products depends on several factors, including the level of soil contamination, the soil properties, and the biological characteristics of the plants. The transfer coefficients of radionuclides into the plants growing on soddy-podzolic loamy soils are 1-3 times lower than the same coefficients for soddy-podzolic sandstone soils. Thus the treatment of soddy-podzolic soils through the complex use of organic fertilizers, liming and high doses of potassium and phosphorus fertilizers, makes it possible to reduce the ^{137}Cs contamination of agricultural crops by up to 4 times when accompanied by water regime improvement, i.e. increased irrigation and drainage by up to 10 times.[3]

CONCLUSION

As a result, for the long-term period of the radiological assessment of the consequences of an accident, the type of the soil of the contaminated area should be measured and the transfer coefficient, be evaluated. Everybody hopes that we will never have to face another nuclear accident, but the emergency response plans should be prepared, and all the details of the monitoring and modeling procedures be taken into account and tested in a real contaminated area.

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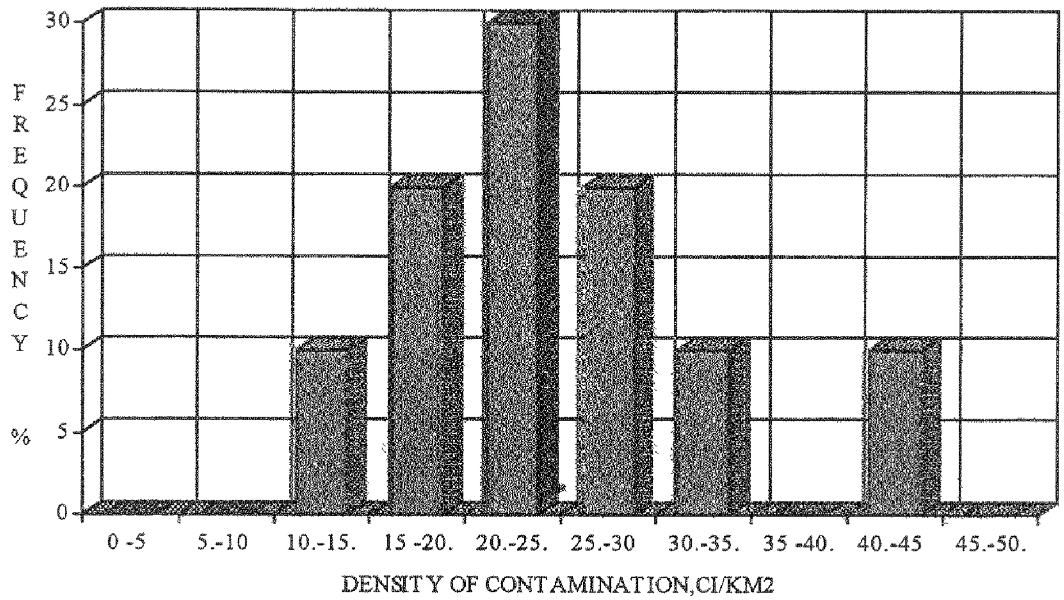

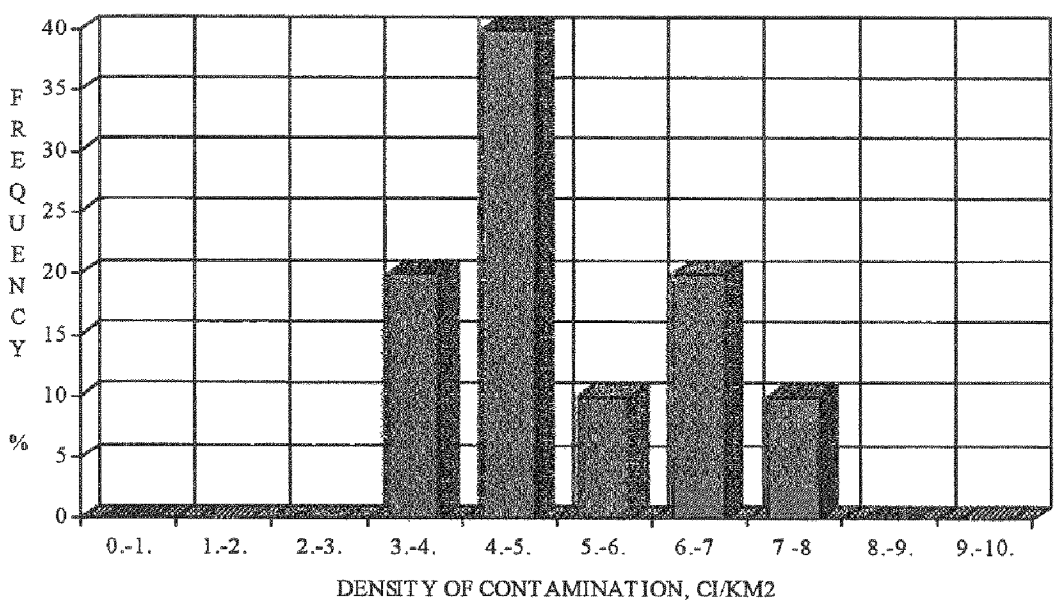

Figure 1. Frequency distribution of the soil sample activities collected within 5m radius

Session E, Track 2:
Public Health Issues II
Thyroid Disorder as a Result of Chernobyl and Other Health Issues

Thursday, September 10, 1998
2:15 p.m. - 4:40 p.m.

Chair: Andrea Pepper, State of Illinois, Department of Nuclear Safety

A Model Explaining Thyroid Cancer Induction from Chernobyl Radioactivity

E.M.Parshkov, A.F.Tsyb, V.A.Sokolov, I.V.Chebotareva

Medical Radiological Research Center of Russian
Academy of Medical Sciences, Obninsk, Russia

INTRODUCTION

The high level of the incidence of thyroid diseases in children and adolescents born from 1968 to 1986 is the most especially dramatic health consequence of the Chernobyl nuclear catastrophe[1,4]. The number of thyroid cancers in the radioactively contaminated territories of the Russian Federation, as well as in Belarus and Ukraine, has significantly exceeded the preliminary prognostic estimates made by national and international experts.

At present, in the most heavily contaminated territories of the Russian Federation (the Bryansk, Kaluga, Orel, and Tula regions), more than 250 cases of thyroid cancer in children and adolescents have been registered. The ages of these patients, at the time of the accident, ranged from newborn to 18 years. Based upon known ratios between Cesium-137 (^{137}Cs) and Iodine-131 (^{131}I) in fallout, no apparent correlation exists between the incidence of thyroid cancer and the mean levels of radioactive contamination of ^{131}I and ^{137}Cs in the contaminated areas.

Based upon ten years experience with this problem, we propose a process model for the development of thyroid pathology in the post-Chernobyl period.

DISCUSSION

In spite of numerous publications on the thyroid problem, many questions remain because of the lack of factual material, or because of the absence of adequate explanations for the occurrence and mechanism of causation for such an increased incidence. At this writing, the following questions remain unresolved:

1. The role of short-lived radioisotopes of iodine in the radiation exposure of the thyroid;
2. The interdependencies among the exchange of stable and radioactive iodine, the physiological state of the thyroid itself, and differences of exposure dynamics as a dependency on the maturity or physiological condition of the individual (i.e., in utero, neonate, prepubertal and postpubertal, pregnant and lactating, menopausal, etc.);
3. The dynamics and relationships between the intake and delivery of the internally absorbed dose;
4. The epidemiology of thyroid disease for patients living in areas with iodine deficiency;

5. The difference in disease latency periods in children affected by uptakes of radio-iodine into the thyroid and then afterwards either remaining in radioactively contaminated zones or living in clean territories of Russia following evacuation;
6. The role of isotopic transport factors in active radionuclide transfer in the first hours and days after the accident and its contribution to thyroid exposure doses;
7. The effect provided by life-style differences between urban and rural populations in the affected territories; and,
8. Reactions of immune, endocrine and other systemic responses due to chronic exposures from low dose rates of external and internal irradiation.

As can be seen, the assessment of the aftermath of thyroid radiation exposure after the Chernobyl accident reveals a very complex medical problem. After extensive study of post-Chernobyl thyroid pathology, we believe that we have developed a model describing the mechanism of induction of radiogenic thyroid cancer. This process model consists of the following features:

1. In Russia, a definite dependence between the cancer incidence and the proximity of children living near major roads and railways was discovered[5]. This fact is inconsistent with the commonly held assumption that all exposure resulted from an airborne plume of activity from the damaged reactor. We conclude that in the first hours and days after the accident, trains and automobiles served as passive transport pathways for significant quantities of short-lived iodine radionuclides. These radionuclides were inhaled and ingested by children living near transportation arteries. These intakes resulted in significant doses to the thyroid of these children.

2. The highest frequency of the thyroid cancer is registered in children who were between 0 - 4 years of age at the moment of the accident. This is of great significance for several reasons. First, thyroid gland function in infants and young children differs markedly from that in adults. In young children, one notes higher proliferation of thyreocites and elements of stroma, a non-competent immune system, etc. Second, in children under one year of age, the frequency of breathing is 2-2,5 times greater than in adults, and this, in turn, could enhance the intensity of radionuclide inhalation. Third, the mass of the thyroid, at these ages, is much smaller than that of an adult. Thus, it can be demonstrated that in terms of specific dose (i.e., mSv/gram), the exposure levels to the thyroid of small children results in a dose nearly 8 times that received by an adult for a similar intake of activity. Because of this higher specific dose, the effectiveness of the radiation is higher, and cancer incidence is more prevalent. These factors all combine to effectively concentrate the effect of iodine intake in very young children and multiply the potential damage of the resulting thyroid dose.

3. It has been established that among all thyroid cancers, the papillary morphological form comprises more than 95%. Because of the high incidence of this specific type, it can be safely assumed that this form is radiogenic in nature. It was also shown that this papillary

form of cancer results in early metastasis into the lymph collector in the neck, and owing to this, the radiation induced cancer is considered to be the most aggressive type. It is our view that children are particularly susceptible to this form of cancer. During the first 4 years of life, there is an intense development of the follicular apparatus of the thyroid gland, accompanied with formation of the stroma, basal membranes, and capsula of the gland. This developmental physiology opens the possibility for tumor growth in the form of endofit and subsequent transformation into papillary cancer. The existence of a rich network of lymphatic capillaries facilitates the fast transfer of cancer cells into neighboring lymph nodes and the subsequent development of early metastasis there. As a result, in young children (0-3 year old), the papillary form of cancer will be induced with early metastasis into lymph nodes. The absence of formed capsula in the thyroid gland permits the easy exit of a tumor outside the gland. With the maturing of the organism and the completion of the thyroid gland formation, the one should anticipate a decreasing of the papillary form of the disease, and an increase of follicular form.

4. We believe that hypothyrosis is the trigger in development of pathology. We are of the opinion that the development of thyroid cancer in children after the Chernobyl accident takes place against the background of *non*-oncological thyroid pathology – diffuse goiter, hypothyrosis, autoimmune thyroiditis. We initially adopted this position with great caution, but are finding it to be true with growing reliability. We theorize that a chronic deficiency of thyroid hormones induces a diffusion of local hyperplasia of thyroid tissue. Thyroglobulins are synthesized in excess, but are non-realized. These compounds enter into thyroid tissue and blood, which, in turn, stimulates the production of antibodies. As a consequence, autoimmune thyroiditis occurs. The elevated level of TSH, in this case, might stimulate the accelerated growth of malignant tumors. This mechanism may have particular importance and prevalence in iodine endemic zones.

The above mentioned items are of importance not only to children affected by the Chernobyl accident, but also to other cohorts of the affected population, particularly personnel involved in the recovery of the Chernobyl plant ("liquidators"), pregnant women, and lactating women.

It is still too early to make final conclusions related to the nature of incidence, development, treatment, rehabilitation and prophylaxis of thyroid pathology in the after-Chernobyl period. Long-term, cross-disciplinary efforts for the continued collection and analysis of data are still vitally needed

CONCLUSION

The primary health effect of the Chernobyl disaster was the increased incidence of childhood thyroid cancer After ten years of study of the problem, a process model is proposed that explains the main contributors to the onset of this disease. The clustering of cases around transportation arteries suggests that significant levels of radioactive contamination were carried in by motorized vehicles leaving the Chernobyl region immediately after the accident. The effect of this contamination on children was heightened due to the developmental stages of the thyroid in these children, which increased susceptibility to the induction of cancer from radiation exposure. In addition, the cancer appears to develop from a background of non-oncological disease, and a pathway for this induction was proposed.

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