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The Organization of the Internal Irradiation Monitoring System in Conditions of Nonstandard Radionuclide Intakes

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Abstract. Scientific knowledge presently available in the area of monitoring the internal radiation due to nonstandard radionuclide intakes gives no way of identifying the location and nature of intakes in a reasonably accurate and expeditious manner. Both theoretical models and practical methods of personnel internal radiation screening exhibit the lack of research. To this end, the present paper deals with the experience gained by the SGChE in the monitoring of the nonstandard radionuclide penetration into internals and tissues of the personnel. It provides recommendations for the organization and implementation of such monitoring procedures, and describes the practical method for the vulnerary intake containment.

1. Introduction.

Joint-Stock Company “Siberian Group of Chemical Enterprises” (SGChE) incorporates four plants for nuclear materials handling: Isotope Separation Plant, Sublimate Plant, Radiochemical Plant and Chemical and Metallurgical Plant. SGChE plants integrate high radiation and nuclear hazard industries and facilities, engaged in the development, production, operation, storage, transportation, utilization of nuclear materials and goods. The Company is integrated into “TVEL” Fuel Company of “Rosatom” State Corporation.

The process technology employed at the SGChE as one of “Rosatom” State Corporation nuclear fuel cycle and weapons-related enterprises involves external and internal irradiation of personnel. Internal irradiation results from the penetration of radionuclides into the worker body. Radioactive substances have the capability to accumulate and travel in human tissues, and, as this takes place, they can reach the health-hazardous levels. There are different paths of radionuclide penetration into the human body to include: ingestion, inhalation, or intakes through intact or damaged skin. The path by which radioactive substances penetrate into the body significantly dictates the behavior and course of radiologic pathology.

The most detailed description in research works [1, 2] dedicated to the issue of human internal exposure is given to the chronic inhalation intake of radionuclides. However, instances of the acute radionuclides intake crop up frequently in the manufacturing environment. The “acute intake” is hereinafter considered to mean a vulnerary or critical single-time radionuclides intake by the worker body. By the example of the analysis done on of the SGChE plutonium production workers examined at the Biophysical Lab No. 81 of the State Center for Sanitation and Epidemiological Supervision,



research work [3] shows that acute intakes of actinides entail larger radiation exposure of individual workers. It primarily pertains to plutonium and americium intakes through the damaged skin.

2. Problem Definition

The initial stages of the nuclear industry development showed poor radiation safety culture both inside and outside of the RF. There occurred a large number of occupational injuries involving radionuclides intake. Research [4] reports on 1,250 incidents of radionuclides intake through the damaged skin registered in respect of the Windscale personnel during the period 1979 to 1989. Research work [5] cites data on 137 wounds potentially contaminated with transuranic elements at the Los-Alamos National Laboratory over the period 1960 to 1972. More than 80% cases describe wounds localized in the area of hands or fingers. These data correlate well with the observations taken at the JSC “SGChE” Chemical and Metallurgical Plant site.

Over the period of the JSC “SGChE” Chemical and Metallurgical Plant plutonium facilities operation, the total amount of recorded skin injuries ran to about 200, of which 100 involved radionuclide contamination (the graph in Picture 1 shows the yearly distribution of radionuclides intakes as a result of skin injuries). Like those at similar plutonium production facilities, most of injuries were accounted for stabs and cuts of hands primarily attributed to imperfections in process equipment used in the plutonium production.

Due to the implementation of the action plan meant to prevent abnormal intakes, the number of nonstandard radionuclide penetration events for the JSC “SGChE” workers has been considerably reduced since 2000.

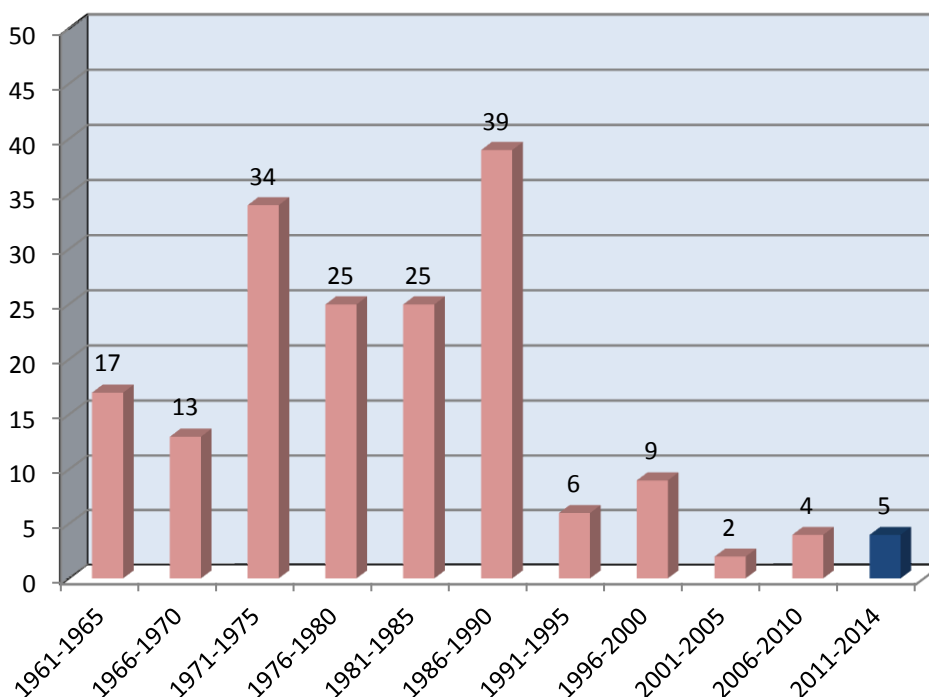


Figure 1. Incidents of Nonstandard Radionuclide Intakes by the JSC “SGChE” Employees during 1961 to 2014

For the time being, however, the issue of improvements in the internal irradiation monitoring system for acute intakes continues to be relevant for the nuclear industry. The reason is that the existing working environment does not make it practicable to completely rule out such intakes.

There are frequent occasions when the vulnerary intake either goes unnoticed or is deliberately kept back by the worker until it shows up in the course of examination by the spectrometer of human irradiation (SHI) or at the biophysical laboratory. In such events, because of long time between the intake and the adoption of measures to minimize health hazards, the worker receives a considerable radiation burden.

Accordingly, it is of current concern nowadays to explore the issue of improvements in the acute intake detection and containment methods.

3. Empirical Research

During 2013 to 2014, the JSC “SGChE” carried out empirical research into the enhancement of methods used to detect and localize acute intakes of radioactive substances in the worker body.

The group under study included 115 workers of critical trades (molders, equipment operators) engaged in the operations at the JSC “SGChE” Chemical and Metallurgical Plant. The periodicity of the SHI examination for the said group was scaled down from annual to quarterly.

The research used the “Lung SHI” detection units. Advantages offered by such detection units as affected spot location finders include the maximum detection area and the minimum time needed to conduct one examination. As part of the measurement, two detectors were fixed at the chest level, and the other two were attached to the examinee’s hands.

The potential acute inhalation intake was detected with the aid of measurement procedure “²⁴¹Am Detection in Lungs” [6]. The ²⁴¹Am presence in hands of the worker was determined qualitatively through the comparison of the measured spectra and the background. In the event of increased readings, measures were taken to exclude any surface contamination (by means of measuring the density of the α -emitting flux using the DKS-96 radiation-measuring dosimeter). If no surface contamination was identified, ²⁴¹Am and ²³⁹Pu intakes were assessed quantitatively using the “Wound SHI” detection unit. The final stage was to find the exact location of the vulnerary intake with the aid of the lead collimator installed onto the “Wound SHI” detection unit.

To speed up the detection of radionuclides present in other parts of the body in the event of abnormal intake, it was suggested to use hand-operated dose-metering gamma-monitor IR-560. The IR-560 enables the qualitative analysis of the worker skin for presence/absence of radionuclides.

The drawback to the appliance of the IR-560 is that it can be used only in the low-background camera, the lower limit of detection being not less than 500 Bq, by an experimental estimate; in addition, radionuclides location error will amount to a minimum of 10 cm (experimental evaluation).

Once the location of radionuclides has been roughly determined, the “Wound SHI” detection unit [7] was used to obtain more precise location data. In this event the localization is confined to the area of the “Wound SHI” detector measuring window that is 40 mm in diameter.

After that, the lead collimator is mounted onto the measuring window of the “Wound SHI” detection unit. The collimator represents a lead plate, 3 to 4 mm in thickness, fitted with an opening, the opening diameter varying in the range from 100 mm to 3mm depending on the expected area of the radionuclides location. The lead collimator is mounted in such a way that the measuring window of the “Wound SHI” detection unit is limited to the diameter of the collimator opening. The above measures make it possible to localize radionuclides to an accuracy of 1-2 mm followed by the applicable actions to confine/resect soft tissues in the affected area.

4. Conclusion

Owing to the enhanced radiation monitoring procedures, in 2013 the relevant JSC “SGChE” experts detected two cases of the abnormal radionuclide intake (local contamination of tissues in the knee-cap and forefinger areas) by workers engaged in the JSC “SGChE” plutonium production operations.

In 2014, the systematic quarterly examination of the SGChE Chemical and Metallurgical Plant critical group resulted in the detection of one case of vulnerary ^{241}Am and ^{239}Pu penetration into the examinee's body.

The use of the contaminated tissue confinement method developed at the JSC "SGChE" permitted taking expeditious and comprehensive measures to confine contamination and resect the affected skin that enabled a significant decrease in the radiation exposure of workers.

The described method for the vulnerary intake confinement makes it possible to considerably expedite the localization of radionuclides in the skin. The work done demonstrated the following advantages:

- Possibility of scheduled "critical group" examinations for the presence of radionuclides in soft tissues of hands;
- Detection of unrecorded vulnerary or abnormal radionuclide intakes that is of particular importance in case that the worker is unaware of the radionuclide penetration in his/her body;
- Reduced examination interval that expedites responsiveness to unrecorded vulnerary or acute inhalation intakes, and hence considerably reduces the radiation burden of the worker; and
- Localization of radionuclides with an accuracy of 1-2 mm with a view to taking further measures to resect soft issues in the affected region.

Based on the research findings, the JSC "SGChE" has been conducting scheduled health surveys of workers engaged in critical occupations at the Chemical and Metallurgical Plant since 2014.

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