Disposal of Disused Sealed Sources and Approach for Safety Assessment of Near Surface Disposal Facilities (National Practice of Ukraine)

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1 Radwaste Sources and Management

At present a significant amount of radioactive wastes are accumulated in Ukraine. The main sources of wastes are 13 units of nuclear power plants under operation at 4 NPP sites (operational wastes and spent sealed sources), uranium-mining industry, area of Chernobyl exclusion zone contaminated as a result of ChNPP accident. Besides there are over 8000 small users of sources of ionising radiation in different fields of scientific, medical, industrial applications (including radioisotope devices, gamma defectoscopy and therapeutic gamma units, radioisotope thermoelectric generators etc.).

Currently post accidental Chernobyl waste is disposed of into near surface repository “Buriakovka” located in the exclusion zone, waste from NPPs operation are accumulated in the temporary repositories at NPP sites. Disused sources, arising under NPPs operation, are also collected by NPP operators and are stored in repositories for solid radwaste at NPP sites. Such practice has been authorised by Ukrainian Regulatory Body.

As regards to small users, spent sources may be stored temporarily by the users only for one month at the place of generation. A return of spent sealed sources to the suppliers is not possible because the most of suppliers are in Russia. So, small producers collect disused sources and deliver them to the regional specialized utilities of “RADON” state corporation (hereinafter referred to as RADON) for treatment and disposal (Fig.1).

There are 6 special regional RADON utilities situated close to big industrial cities (Kiev, Donetsk, L’vov, Odessa, Dnepropetrovsk and Kharkow). RADON is responsible for collection, transportation, treatment, storage/disposal of all non-NPP radwaste from adjacent areas. Collection and transportation of spent sources are realised with own transport means of RADON enterprises.

Up to now the management of spent sources is carried out basing on the technology that have been implemented in the early sixties. In accordance with this scheme accepted sources are disposed of either in the near surface concrete vaults or in borehole facilities of typical design (Fig.2). Radioisotope devices and gamma units are placed into near surface vaults and sealed sources in capsules into borehole repositories respectively. Isotope content of radwaste in the repositories is multifarious including Co-60, Cs-137, Sr-90, Ir-192, Tl-204, Po-210, Ra-226, Pu-239, Am-241, H-3, Cf-252. The characteristics of a range of sealed sources are tabulated in Appendix 1. Figure 3 demonstrates the data on spent sealed sources disposed of at Kharkow Radon facility to illustrate typical nomenclature and quantities.

It should be mentioned that according to Ukrainian regulations the spent sources are allowed to be disposed of in containers in near surface repositories for solid radwaste only in specific cases by compliance with Regulatory Body. But actual practice of near surface repository operation at RADON facilities does not comply with this requirement, and almost a half of solid radwaste buried in RADON vault type repositories are spent ionizing sources in packages (mainly Co-60, H-3 targets, Am-smoke detectors etc.). It’s connected with the fact that most of low level activity sources (for instance Am-smoke detectors) are transferred to RADON together with devices and installations. Moreover, last few years a lot of industrial enterprises were decommissioned. Another enterprises refuse to apply the ionizing radiation sources for monitoring of technological processes, and gamma sources in the shielding containers don’t depleted their life time, are transferred to RADON as solid waste. For these reasons at present the repositories for solid radwaste are filled to extent of 80-90% or filled fully at some of the RADON utilities.

Design of borehole repositories is typical for such type of disposal facilities (Fig.2) and operated directly from the surface.

Unconditioned spent sealed sources are unloaded from the transport containers in a hot cell and send down freely through hopper to the steel reservoir (with a diameter 400mm and height of 1500mm) that is placed in concrete module at the 5 metres depth and surrounded by backfill material. Isotope content is multifarious but total activity is mainly defined by Co^{60}, Cs^{137} and Ra^{226}. It should be mentioned that majority of spent sources were disposed of nearly thirty yeas ago, without any segregation or their sorting out according to sources characteristics (such as activity, radionuclides half-life, construction of sources, physical and chemical form, etc). During loading of these repositories spent sources are accumulated at the bottom of reservoir causing the increasing of radiation and temperature effects on the constructive materials. Besides there is some risk of mechanical damage of capsules during sources unloading because some of sources were unloaded in heavy steel container KI-400 (for loading of SISs of total activity 15 TBq) and the others have been disposed of without additional packaging (in capsules).

The borehole repositories were designed for long-term storage of ionising sources under dry conditions. However as investigations have shown there is some amount of water inside the borehole repositories. Under water presence inside the repository these effects lead to corrosion of steel and protective capsule of sources.

Another feature of existing practice for disused sources management at the RADON facilities is loss of reliable information on characteristics of industrial sources of ionizing radiation by users. In these cases user of source transfer disused source to RADON without exact data sheet only with approximate description of source characteristics.

In some cases disused sources may be reused by other user or may be reprocessed as raw materials. But there is no adequate instrumentation at RADON facilities for devices dismantling or gamma sources blocks discharging.

Last years the issue of safe disposal of radioactive waste including disused sealed sources became more pressing for Ukraine because some of the RADON repositories for solid waste are in emergency condition. At Kiev and Kharkow Radon disposal facilities resulting from the engineering structure failures a tritium has been leaching into the environment and contamination beyond the repositories exceeds the acceptable level for drinking water. Decision was made to relocate waste from Kiev Radon emergency repositories.

Thus, past practice of disused sources management become out of date and does not comply with safety criteria for waste disposal provide the adequate safety level, safety of old RADON repositories needs to be reassessed to make decision relating future development.

In 1996 National programme for radwaste management was adopted. This Programme prescribes a new scheme for radwaste management (Figure 4) according to which spent sources management shall be realized: at the places of waste generation, at RADON facilities and finally at the centralized facility for long-term storage and waste disposal ("Vector" Complex in Chernobyl exclusion zone). At that it is supposed that Radon facilities will be modified to centres for temporal long-term waste storage in containers. For this purpose for every Radon utilities a project of the transformation to the temporary storage technology will be developed after analysis of storage condition, waste inventory and safety assessment. On the basis of safety assessment a decision will be made concerning the necessity of retrieval and relocation for specific waste types. After safety reassessment of old repositories the major task will be to retrieve waste, to sort waste in accordance with their properties and than pass them to "Vector" repositories . It is supposed that high level and long-lived sources extracted from vaults and borehole repositories will be stored up to decision making in relation to geological disposal.

At the moment the practice of temporal storage is implemented at some of RADON facilities. The possible option for transformation of RADON facility into temporal storage was proposed and implemented at Kharkow Radon facility (Fig.5). At this facility the complex for spent sources temporal storage (Fig.6) which includes the unloading of spent sources into new designed containers KNT-180 (Fig.7) and further storage till relocation into centralise disposal facility was commissioned. In this option the attention is paid to spent sources identification, sorting and selective accumulation, sources extraction from blocks of industrial gamma installations or devices. The proposed technology for SIS management will minimise the disposed radioactive waste volume, provide safe management of

SIS at RADON facilities and under transportation, also further long-term storage at centralised Vector complex.

2 Available and planned repositories for disposal of disused sources

Retrieved waste from Kiev's RADON facility is planned to be disposed in new trenches of Buriakovka facility until VECTOR Treatment and Disposal Facility (Vector Complex) will be commissioned. Extracted high level sources in containers will be stored at the same facility. The design of "Buriakovka" repository capacity extension and disposal facility reconstruction is under development. Reassessment of waste acceptance criteria needs to be performed in particular to address the issue of spent sources disposal which to be extracted from RADON facilities.

Vector Complex will be built in the site which is located within the exclusion zone 10Km SW of the Chernobyl NPP. In Vector Complex two types of disposal facilities are designed to be in operation:

1) Near surface repositories for short lived LLRW and ILRW disposal in reinforced concrete containers. Repositories will be provided with multi layer waterproofing barriers – concrete slab on layer composed of mixture of sand and clay. Every layer of radwaste is supposed to be filled with 1cm clay layer following disposal;

2) Repositories for disposal of bulky radioactive waste without cans into concrete vaults.

3 Approach for Safety Assessment of Near Surface Repositories in Ukraine

Safety of radwaste disposal including disused sources is achieved through compliance with requirements set out in the following national documents for radwaste management:

1. **Laws of Ukraine:**
   - "On Radwaste Management";
   - "On environment protection";
   - "On human protection from radiation impact"
2. **Norms and rules:**

- Radiation Protection Standards (NRBU-97) and Addendum "Radiation protection against sources of potential exposure" (NRBU-97/D-2000);
- Radwaste disposal in near-surface repositories. General Requirements for radiation Safety - RD 306_ 604.95;
- Environmental Impact Assessment. Requirements for report at design and construction of facilities, buildings and constructions. State constructions norms of Ukraine -A.2.2.-1-95;
- NP 306.3.02/3.038-2000. Requirements as to format and content of safety analysis report for near surface radioactive waste storage facilities;

Safety criteria for waste disposal in near surface repositories are established in Radiation Protection Standards (NRBU-97) and Addendum “Radiation protection against sources of potential exposure” (NRBU-97/D-2000). This document states that the same level of protection must be guaranteed for future generations as it is acceptable today and establishes the following authorised dose limits due to near surface vault or borehole disposal facilities:

1. Operational period:

- for occupational exposure of workers 20mSv per year averaged over five years but not greater than 50mSv in any single year;
- to the members of the critical group 1mSv in a year, and 40 μSv\y from the repository (which is considered as a single sources of exposure).

2. Long-term post closure period

Exposure due to natural processes (normal exposure) and disruptive events in the future (potential exposure) shall be considered. All the critical events are divided by the probability of occurrence. The events with probability higher than 10^{-2} per year are considered as gradual and lead to the “normal” exposure (e.g. migration of radionuclides to the environment due to degradation of the disposal system). Should this probability is less (random events due human actions and other disruptive events) - exposure is considered as potential.

For gradual events - effective doses to members of the critical group shall not exceed 40 μSv\y and 10 μSv\y during the period of institutional control over the site and following this period respectively;

Potential exposure shall not exceed 1mSv\y after a period of 300 years. The potential dose higher than 1mSv\y but less than 50mSV\y are considered acceptable in compliance with Regulatory body. Under decision making in relation of acceptable disposal option, annual collective effective dose is assessed as well (dose limit 1man·Sv) .

As it follows from above presented in connection with construction of new near surface repositories and modernisation of old facilities a safety assessment becomes urgent task to be implemented in the nearest future. It shall be mentioned that old repositories of RADON facilities were designed and constructed without comprehensive assessment whether the site together with repository engineering barriers would provide safety in future.

The necessity of safety assessment performance for near surface disposal facilities is established by Law of Ukraine «On Radioactive Waste Management» (edited in 1995), which emphasises that a repository design shall include safety assessment results as for operating phase and for long term post closure period (clause 23). This Law also declares that only solid or solidified short-lived radwastes can be disposed of in near surface repositories. Short-lived wastes are determined as waste that could be released from the institutional control in 300 years following waste disposal. Concentrations of long-lived nuclides in waste must be restricted and proved basing on safety assessment results. This requirement shall be met under determining the option for safe disposal of disused sources.

Law of Ukraine «On the authorisation activity in the field of the use of atomic energy» (2000 y) prescribes the licensing of activities on radwaste storage or disposal at all stages of a repository life cycle including design, construction, operation and repository closure (clauses 7,8). In accordance with this Law the licence is granted basing on the results of comprehensive disposal facility safety assessment (clauses 12). The results of safety substantiation are proved by appropriate documentation. The Law also establishes that the order and conditions to grant a license, as well as list of needed documents, application forms and content of documents should be determined by Regulatory Body. State Nuclear Regulatory Committee of Ukraine developed the guidance "Provisions on list and requirements related to format and content of the documents submitted by operator of near surface disposal facility in the frame of licensing for the stages of repository life cycle" (2000 y). This guidance prescribes the necessity of safety assessment report submission to the NRC in the frame of licensing process at the design, construction, operation and closure stages of the disposal facility lifetime. Report content shall be in compliance with the regulation in force "Requirements as to format and content of safety analysis report for near surface radioactive waste storage facilities " (2000 y).

The document "Requirements as to format and content of safety analysis report for near surface radioactive waste storage facilities" states that the purpose of the safety analysis report is to describe the fundamental assumptions upon which the design of repository is based. SA shall demonstrate that the disposal facility can be operated and closed safely, i.e. in compliance with the safety criteria for the protection of workers and of members of the public.

In Safety Assessment Report of a repository it should be given the basic design criteria; site characteristics and details of facility structures important for safety (engineered barriers); a general description of the disposal facility operation, predicted repository impacts upon workers and the members of the public. In safety assessment a consideration must be given to radwaste acceptance criteria (radwaste origin; physical state, heat release, radionuclides inventory and limit activity, requirements for packages etc.); scenario analysis and their consequences as for operational stage and post-closure period for normal and accidental radionuclides releases. The maximum activity and inventory in each package and for repository as a whole accepted by specific facility can differ depending on repository design and site characteristics. The radwaste acceptance criteria for specific repository are developed by disposal facility operator and than must be justified by appropriate safety assessment analysis to ensure the meeting of the radiation protection criteria for operational and post-closure period. Basing on the obtained information the conclusion is made on acceptability of a selected disposal option.

At the moment in Ukrainian normative base there is no guidance in force on safety analysis performance. These issues are partly addressed in the Addendum to Radiation Protection Standards (NRBU-97) "Radiation protection against sources of potential exposure" (NRBU-97/D-2000). Five mandatory scenarios responding to main pathways of doses formation are also established. These scenarios shall be considered under carrying out of safety analysis, the calculated doses for each of scenario are compared with permissible limits established in the document. Such comparison is the basis for the decision-making concerning acceptability of specific waste disposal in a specific disposal option. The basic scheme for safety assessment procedure under decision making on acceptability of near surface disposal for specific wastes is also proposed (Fig.8). The principal issue is that radiation safety shall be guaranteed as for normal, gradual conditions and for potential exposure as well. The next aspects are supposed to be considered step by step during safety substantiation.

1. Safety assessment objectives

An essential first step of safety assessment is the explicit determination of specific purpose of the assessment (e.g. acceptability of specific near surface disposal option for specific waste disposal).

2. Disposal system description

The description of near surface disposal system should include information on radioactive waste characteristics, repository design features, site characteristics.

The data should be sufficient to distinguish the pathways of radionuclides transfer and the conceptual model of disposal system development.

3. Scenarios development and analysis

The fundamental system features which define the most essential pathways of radionuclides release and their significance for system safety should be determined.

The factors, events and processes which may initiate or increase the release of radionuclides from the facility should be determined. The gradual processes (waste form degradation, corrosion process etc. – normal evolution scenario of a repository) as well as disruptive events causing the abrupt changes of disposal condition (earthquake, flooding, human intrusion etc.) should be considered and likelihood of occurrence shall be analysed.

4. Scenarios consequences analysis

The calculation of doses as a result of radionuclide releases is performed for gradual and random events.

5. System performance evaluation

Comparison of calculation results with safety criteria should be done.

The next 5 pathways of exposure are necessarily considered under potential effective dose evaluation for in 300 years after closure of a repository (end of the active institutional control):

- radionuclides ingestion with drinking water;
- radionuclides ingestion with food;
- inhalation dose;
- external exposure;
- dust intake.

As regarding modelling, today there is no methodological guidance in Ukrainian normative base which contains verified method and unified procedure for near surface and borehole repositories safety evaluation. It is a reason of difficulties arising under safety assessment performed by Licensee, under expert review of assessment results and decision making by Regulatory Body on acceptability of safety level.

The guidance on safety assessment methodology application basing on ISAM methodology is under development. The guidance shall permit to harmonise national requirements with IAEA documents and unify approaches for safety assessment.

The guidance has to include procedure of near surface repository safety assessment with reference to specific stage of its lifetime, list of parameters needed for repository safety substantiation and methods of their determination. The guidance shall unify approaches to safety assessment and clarify all safety assessment issues to provide a reliability of safety assessment results to be obtained.

The final result of work is expected to be the technical document that will include both the guidance on application of near surface disposal safety assessment methodology and the demonstration of developed guidance application for the case of module repository being constructed within exclusive zone.

REFERENCES

1. Law of Ukraine «On the authorisation activity in the field of the use of atomic energy»
2. Law of Ukraine «On radioactive waste management"
3. Law of Ukraine «On the use of of atomic energy and radiation safety»
4. NP 306.5.04/2.060-2002. Conditions and safety requirements (licensing conditions) related to the activity on radioactive waste treatment, storage and disposal
5. NP 306.2.02/3.037-2000. Provisions on list and requirements related to format and content of the documents submitted by operator of near surface disposal facility in the frame of licensing for the stages of repository life cycle.
6. NP 306.3.02/3.038-2000. Requirements as to format and content of safety analysis report for near surface radioactive waste storage facilities
7. NP 306.5.02/3.017-99. Requirements as to quality assurance program for each stages of nuclear facilities
8. Radiation Protection Standards (NRBU-97) and Addendum "Radiation protection against sources of potential exposure" (NRBU-97/D-2000);
10. Rules for safe keeping of nuclear materials, radioactive wastes, and other sources of ionising radiation (order of Ministry of environmental protection №241 from 14.12.2000).

APPEDIX 1. Inventory of ionising radiation sources

Table 1 – Sources of ionising radiation of industrial application

Application	Main radionuclide	Half-life	Activity of sources (Bq)
Industrial radiography	^{60}Co ^{137}Cs ^{192}Ir ^{75}Se	5,3 y 30 y 74,0 days 119,8 days	$1{,}53x10^{12}$ $7{,}4x10^{11}$ $8{,}65x10^{10}$-$8{,}65x10^{12}$
Well logging	^{238}Pu ^{238}Pu-Be ^{137}Cs ^{252}Cf	87,74 y 30 y 2,63 y	$(6{,}3\text{-}37)10^{8}$ $(2{,}1\text{-}5.1)10^{9}$, $(5\text{-}500)10^{5}$ neutron/c $6{,}2x10^{8}$ 10^{6} neutron/c
Moisture gauges	^{238}Pu-Be	$2{,}4x10^{4}$ y	$1{,}2x10^{9}$
Densimeters	^{137}Cs	30 y	$1{,}2x10^{6}$
Level gauges	^{137}Cs ^{60}Co	30 y 5,3 y	$1x10^{8}$ – $5{,}0x10^{10}$ $1x10^{8}$ – $1{,}4x10^{10}$
Thickness gauges	^{85}Kr ^{90}Sr	10,8 y 29,1 y	$0{,}1x10^{9}$-$5{,}0x10^{10}$ $0{,}1x10^{9}$-$4{,}0x10^{10}$
Devices for technological processes control	^{147}Pm ^{85}Kr ^{90}Sr ^{137}Cs ^{60}Co ^{238}Pu ^{241}Am ^{63}Ni ^{55}Fe	2,63 y 10,8 y 29,12 y 30 y 5,3 y 87,7 y 433 y 96 y 2,7 y	$5x10^{7}$-$2{,}7x10^{9}$ $18x10^{7}$-$3{,}0x10^{8}$ $92{,}5x10^{7}$-$16{,}1x10^{8}$ $1x10^{8}$-$2{,}7x10^{10}$ $2{,}9x10^{9}$- $6{,}5x10^{11}$ $1{,}85x10^{7}$-$5{,}0x10^{10}$ $4{,}01x10^{6}$-$1{,}0x10^{9}$ $2{,}5x10^{8}$-$1{,}1x10^{10}$ $5{,}5x10^{4}$- $3{,}5x10^{9}$
Electron-capture detectors	^{63}Ni	96 y	$2{,}0x10^{8}$-$5{,}0x10^{8}$
	^{60}Co ^{137}Cs	5,3 y 30 y	$1{,}9x10^{13}$-$2{,}96x10^{16}$ $1{,}0x10^{12}$Бк
Calibration	^{60}Co ^{137}Cs	5,3 y 30 y	$2{,}0x10^{4}$-$1{,}0x10^{19}$ $2{,}0x10^{4}$-$1{,}0x10^{12}$
Smoke detectors	^{241}Am ^{239}Pu	433 y $2{,}4x10^{4}$ y	 $18{,}5x10^{5}$

Table 2 - Sealed ionising radiation sources for medicine application

Radionuclide	Half-life	Activity
^{60}Co	5,3 y	Up to 300 TBq
^{137}Cs	30,0 y	Up to 44 GBq
^{192}Ir	74,0 y	51 GBq
^{22}Cf	2,6 y	41 GBq
^{90}Sr	29,1 y	110 GBq
^{204}Tl	3,8 y	1,2 GBq
^{147}Pm	2,6 y	65 MBq

Table 3 - Sealed ionising radiation sources for scientific application

Application	Radionuclides	Half-life
Calibration facilities	varying	varying
Electron-capture detectors	^{63}Ni	96,0 y
Gamma-ray sources	^{60}Co ^{137}Cs	5,3 y 30,0 y
Tritium targets	^{3}H	12,3 y

Fig.8 – General scheme for safety assessment performance (NRBU-97/D-2000)