

MANAGEMENT OF SPENT SEALED SOURCES: BELARUS EXPERIENCE

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ABSTRACT

Today is clear that there are four main tasks to be solved to ensure that disused and spent radioactive sources (SRS) are managed properly and that the number of orphaned sources is reduced to a minimum. They are following:

- to establish an effective system for control, accounting and supervision of all radioactive sources (RS), both in use and disused;
- to take adequate measures to ensure security of RS, both in use and disused, prompt reporting and recording of missing sources;
- to establish proper regulation for management of disused and spent sources (re-use, storage, disposal);
- to implement adequate safety procedures for storage/disposal of spent sources

This paper outlines the experience of Belarus in solution of the above-mentioned tasks with a special emphasis on problems related to spent sources utilisation. We hope the subject may be of interest to other countries, which are upgrading their regulatory infrastructure and may have the similar problems.

INTRODUCTION

Belarus has been using sealed radiation sources for many decades in various sectors of national economy, research and medicine. Till 1991 this activity was controlled within the regulatory framework laid down by the Ministry of Health Care of the former Soviet Union. After break-up of the USSR it became clear that the existing regulatory system did not meet sound safety requirements and a new system for control of use of RS should be created. In this context, late in 1991 Gostekhnadzor of Belarus was transformed into the State Committee for Supervision of Industrial and Nuclear Safety (Promatomnadzor). The Committee incorporated the Interregional Nuclear and Radiation Safety Inspectorate, which was later supplemented by the Department for Nuclear and Radiation Safety Regulation. By special decree of the Government, the Promatomnadzor was designated a national Regulatory Authority in nuclear and radiation safety. A number of special regulations have been developed by now to provide the Promatomnadzor with a legal instrument to exercise control and supervision in the field of RS management. The following regulations of this group are reasonable to be mentioned:

- "On licensing by the Promatomnadzor of activities conducted by economic subjects" (approved by the order of Chairman of the Promatomnadzor as of 25.05.1999 pursuant to Government resolution No. 393 as of 23.03.1999).

- «On the unified state system of registration and control of ionising radiation sources” (approved by Chairman of the Promatomnadzor pursuant to Government resolution No 1537 as of 04.10.1999);
- “On procedure of issuing authorisations for the movement (import, export, transit) of ionising radiation sources, nuclear substances and materials as well as devices, installations and parts comprising such substances, across the customs border of the Republic of Belarus” (approved by the order of the Minister for Emergencies No 81 as of 01.12.1999 pursuant to Government resolution No 218 as of 18.03.1997);
- “On procedure of preparation, keeping and use of radiation-hygienic passports” (approved by Government resolution No 391 as of 22.03.99);

In line with provisions of the regulations Promatomnadzor, which is currently under auspices of the Ministry of Emergencies has responsibility for developing the legislative, regulatory and technical framework related to RS applications. It exercises assessment and verification of RS safety, issues licenses and conducts inspection of all activities involving RS in use, those disused and spent ones.

Along with establishing adequate regulatory regime serious steps have been taken to set a legal procedure for prolongation of RS working lives and implementation of modern safety technologies for SRS storage/disposal. Hereafter main results of the actions taken are reported.

A STATE SYSTEM FOR CONTROL, ACCOUNTING AND SUPERVISION OF RADIOACTIVE SOURCES

The system created by Promatomnadzor on base of above stated regulations works effectively to ensure proper regulatory control of new coming sources and to prevent all registered RS from becoming orphan sources. The system consists of the following main components.

1. Authorisation regime for all kinds of work with RS including RS applications in medicine and research;
2. Issuing authorisations for receiving (delivering) RS including their remove from one institution to another one;
3. Authorisation regime for the movement (import, export, transit) of RS as well as devices, installations and parts comprising RS, across the customs border of the Republic of Belarus;
4. Inventory of RS on two levels: local level, where the responsibility lies with a source user, and state level, which is implemented by the Promatomnadzor. Registration of all sources in the Promatomnadzor, including those for calibration and sources for medical applications;
5. Inspection regime to check up observance of radiation safety requirements and license conditions at user's premises;
6. Instituting administrative and criminal proceedings for offenses related with safety and security of sources.

Inventory on the state level is one of the most important components of the system. Regrettably it is based on reliable information only for RS entering country over the past 8 years.

The inventory list of RS entered users premises before 1992 was created in 1992-1996. Main database was formed based on records provided by the Ministry of Health Care, which were not regular and completed. In order to check and to supplement these records the Promatomnadzor distributed a special circular prescribing that every organisation in the territory of the republic should register all RS it used or stored. At the same time the Interregional Nuclear and Radiation Safety Inspectorate conducted very detailed investigations of premises that belonged or could belong to potential users. This contributed very much to the information about so called historic sources. In case the owner of premises had no certificate (passport) for RS revealed in his facilities, he was prescribed to apply to a special certification division for making this document. The division was set up at the Nuclear Power Engineering Institute due to the initiative of Promatomnadzor. It has got a license for certification activity from the Promatomnadzor.

Today the total number of officially registered shielded sealed radiation sources, located in the users premises is about 6500. This includes:

- 694 sources in industrial radiography with main isotope Ir^{192} , in some devices Co^{60} or Se^{172}
- 4534 sources in gauges, moisture detectors and other devices used in industry with isotopes: $\text{Am}^{241}/\text{Be}$, Co^{60} , Cf^{252} , Cs^{137} , Kr^{85} , Sr^{90} , Po^{210}
- 1332 sources in research and educational applications with isotopes: Co^{60} , Cf^{252} , Cs^{137} , H^3 , Ni^{63}
- Sources in 49 medical radiotherapy units with isotope Co^{60} in the teletherapy units and Co^{60} , Ir^{192} , Cs^{137} , Sr^{90} , Pd^{103} , I^{125} , I^{131} used for brachytherapy
- Sources in 15 gamma-irradiators with radioisotopes Co^{60} and Cs^{137}

The number of smoke detectors containing mainly Pu^{239} is more than 45,000

The only in the country central disposal facility Ekores maintains its own computerised database for accounting spent RS, disposed of at the facility. The database is based on the records, which were kept by the Ekores staff in special notebooks from the beginning of the facility operation. The database includes over 200 000 spent RS, which are described according to following characteristics:

- date of receive
- owner, last user of the source
- radionuclides
- original activity/date
- disposal/storage location

Regrettably relatively completed RS inventory available now both for the users premises and for the Ekores facility does not give the possibility of assess of quantity of "lost" sources by making balance between RS under regulatory control and those whenever delivered to the country. Despite of the fact that almost all former RS suppliers are available, they are not in position to give the data required for the balance making. Very approximate assessments show that number of lost RS in the country is about 15% of the total number of sources.

State inspectors of the Promatomnadzor and the Ministry of Health Care conduct inspections of enterprises and facilities. Complex inspections are conducted with participation of

inspectors of both regulatory bodies and specialists of other control agencies like the Ministry of Internal Affairs, The Ministry of Environmental Protection and Natural Resources, etc.

When visiting a facility inspector checks up observance of normative and technical requirements as well as fulfilment of license requirements. Based on the results of the inspection a prescriptive instruction is issued, a copy of which is given to the user. Such instruction is obliging and must be fulfilled within a specified time. Inspector may propose that persons responsible for violating radiation safety regulations should be made answerable under administrative (fine, discharge from office) or criminal liability. In case of serious violations that may constitute threat of damage to human health and life or environment, the license may be withdrawn and/or the work suspended. For instance, in 1999 the Promatomnadzor's inspectors issued prescriptions for suspension of work at 305 facilities.

MEASURES TO ENSURE SECURITY OF RADIATION SOURCES

In accordance with provisions of the Law "On Radiation Safety of Population" an owner of RS shall take all necessary measures to guarantee their security. The above mentioned Government resolution No 1537 of 04.10.1999 establishes that the Ministry of Internal Affairs jointly with the Promatomnadzor shall exercise control over establishing appropriate measures and conditions for the security of radiation sources and radioactive materials.

The Promatomnadzor provides bodies of the Ministry of Internal Affairs with all information concerning places of RS location. The bodies provide security service and access control of the places by means of periodical inspections of RS users premises.

A loss of RS is considered as a radiation accident. The Promatomnadzor, the Ministry of Internal Affairs, the Ministry of Health Care are immediately informed of any such case or case of unauthorised RS use. Following such cases a special commission is established. Headed as a rule by an official from the Promatomnadzor, the commission makes a narrow inquiry into the facts and compiles an act of investigation. Based on the act, measures are taken to address the case and to prevent it from recurring. Depending on situation the Prosecutor's Office is approached to commence prosecution.

The Criminal Code of Belarus contains the following articles:

Article 322. Illicit procurement, storage, use, sale or destruction of radioactive materials.

Article 323. Theft of radioactive materials.

Article 324. Threat of dangerous use of radioactive materials.

Article 325. Violation of regulations for safe management of radioactive materials.

Offenses under these articles shall be punished with three to fifteen years of imprisonment.

NATIONAL PROVISIONS FOR THE MANAGEMENT OF DISUSED AND SPENT RADIOACTIVE SOURCES

The existing regulations prohibit the use of sealed sources if their hermeticity is broken or if their service life is expired. The service life is normally specified in a source passport and, according to the rules, can be extended by decision taken by special commission on the basis of the results of certification tests. The latter procedure is very frequently used nowadays, because users have no funds to purchase new sources.

Radioactive sources not suitable for further use are regarded as radioactive waste. Regulations require that the time of interim storage of such sources at a facility shall not be longer than six months. During this time the source must be decommissioned and transferred to the specialized facility 'Ekores' for centralized storage or disposal. Regrettably, in some cases the Promatomnadzor has to authorize deviation from this rule and permit prolonged storage of spent radiation sources at user's locations. This is basically the case for two types of sources:

1- Co^{60} and Cs^{137} sources installed in obsolete gamma-installations. Retrieval of such sources from the installations entails considerable expenses, which the country's budget cannot at present afford.

2 – high-power gamma-sources used in irradiation equipment and in gamma-therapy.

The existing Radon-type borehole repositories are considered as not safe enough for disposal of such sources. Moreover, the capacity of these repositories has been practically exhausted. In the former USSR, standard procedure required the return of such kind spent sources back to suppliers in exchange for new devices. In 1992, such practice was stopped because of the Russia's legislation. The attempts to renew the procedure have not been successful.

It seems it would have been in line with recent trends in international legislative development to have a document that spells out the supplier's responsibility in the exporting country to ensure that the user in the country of import may have option of returning back RS after they have been withdrawn from service.

To ensure centralized storage of powerful spent sealed sources the Promatomnadzor has initiated Project on Ekores facility reconstruction. It includes creating new specialized near-surface repositories for spent RS. In parallel there are making attempts to renew the procedure of the return of disused sources to Russian manufactures.

It should be noted however that at present there no real opportunities for the bulk disposal of all spent RSs with expired service lives because the majority of industrial and research companies are not ready to apply such measures.

EXERCISE OF CONTROL OVER ORPHAN SOURCES

The existing regulatory system works effectively to prevent both new-coming and registered sources from becoming «orphaned» ones but it can not set an effective barrier against abnormal events connected with finding orphan sources or with burglary of registered RS. In the last 9 years about 20 incidents of such kind occurred in Belarus. Luckily they did not have hard consequences but from the point of view of the radiation risk they were the most serious ones.

Regrettably Belarus has no regulations that are specially focused at this issue. In case the orphan source comes to light one of the following bodies is usually informed: the Ministry of Internal Affairs, the Ministry of Emergencies, the State Security Committee, the Promatomnadzor, the Republican Center of Hygiene and Epidemiology or the Radioactive Waste Disposal Facility "Ekores". Depending on situation the representatives of these agencies take a joint decision on measures to be taken for liquidation of radioecological consequences of the incident.

As a rule it is the specialists of the Ekores Facility who execute all the procedure on removal of orphan source to their facility. Then measures are taken by the Ministry of Internal Affairs to commence a prosecution in accordance with the existing legislation.

In 1998 the Ministry of Finances and the Ministry of Emergencies approved special *Procedure for financing activities related to utilization and disposal of radioactive and other hazardous materials whose owner is unknown*. According to it resources needed to pay for utilization of found orphaned sources are defined by Regional Commissions for Emergencies on the basis of calculations made by the enterprise that conducts the utilization. The activity related to the liquidation of the incident is financed from the existing funds for Nature Protection or covered at the expense of Regional Funds for Natural Disasters, Accidents and Catastrophes

In this section, we regard it appropriate to stress the importance of dissemination of knowledge of radiation sources not only among personnel but also among all strata of the public. Every citizen should know about potential consequences resulting from contact with a source and where one should address to in case of such contact.

The Promatomnadzor maintains cooperation with republican, regional and district newspapers which publish materials, articles and interviews devoted to important issues of security and safety of sources 'Direct lines' and press conferences of the Committee's leadership are arranged to ensure provision of real-time information of the public.

A monthly scientific-technical journal called 'Industrial Safety' has been published by the Promatomnadzor since March 1998. The journal is also addressed to members of the general public who, somehow or other, may find themselves in an area affected by radiation source.

STORAGE AND DISPOSAL OF SPENT SEALED RADIOACTIVE SOURCES AT THE EKORES DISPOSAL FACILITY

Staff of the Radioactive Waste Disposal Facility «Ekores» executes all the work on collection, transport and utilization of spent RS. The facility started in 1964 is intended for all radioactive waste from nuclear applications in industry, medicine and research. It is a typical RADON-type facility, located in the neighborhood of Minsk [1]. The first "history" repository comprised two concrete line trenches, up to 4 meters deep. All spent RS entered the facility until 1977 were buried in these trenches, which afterward were closed.

Since 1977 there exist two options for spent RS disposal. Those in protective containers with upper wall unloading are disposed of in the existing vaults for low and intermediate level waste together with their biological shielding.

RS from containers with bottom unloading are disposed of in bore-hole repositories or so-called "wells". The construction of "wells" was carried out in accordance with the standard project TP-416-9-1 "Disposal radioactive waste facility" developed by Moscow Project Institute (GSPI) for Radon-type facilities of the former USSR in 1970. This is (Fig1, a) a stainless steel cylindrical vessel (5) with diameter 400 mm and height 1500-mm, which is placed at 6 m depth in a steel-enforced concrete well (3). The thickness of vessel walls is 5 mm. The stainless steel loading channel (2) of the repository has a S-shape form and diameter 108 mm. At the upper part of repository there is a carbon steel conical socket (1), which provides safe discharging of transport containers. A carbon steel lid closes this socket. The

concrete wall of the well is surrounded by sand, which fills the initial construction hole as a sealed material. The wells were designed for disposal of sources with the total radioactivity corresponding to a radium equivalent of 20 000 g-eqv. The maximum dose rate on the surface of repository near the loading channel is designed less than 8 mSv/h. Design maximum allowable temperature in the reservoir is 230 °C.

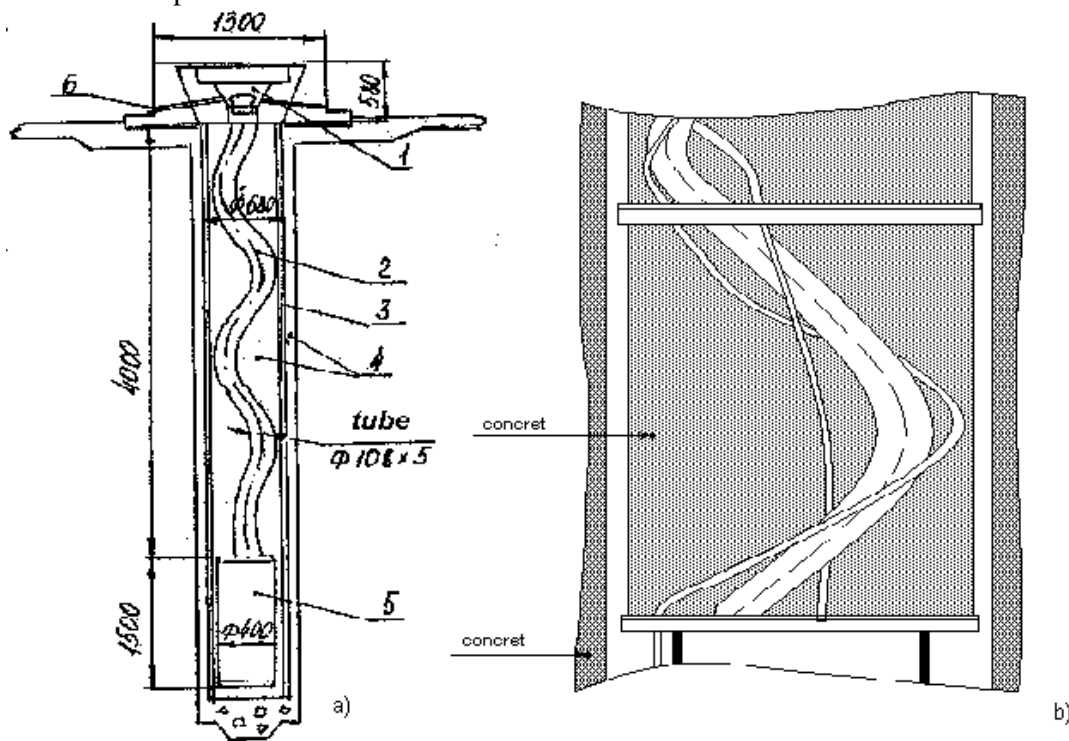


Fig 1. Construction of bore hole repositories
a) existing well b) section of a modernized well

By now 10 935 of spent RS, including those most powerful have been buried in the Ekores wells. Most of them are represented by short-lived radionuclides, however there are long - lived sources, also those including Ra^{226} . Data on each well for main radionuclides are given in the table I.

Table I. Spent sealed radioactive sources disposed of in the wells of the Ekores facility.

	Number of sources		Radioactivity			
	Total	Ra^{226}	Total TBq	Ra^{226} GBq	Cs^{137} TBq	Co^{60} TBq
Well No 1	3578	3	?	5,0	10,5	34,7
Well No 2	93	2	1,7	3,7	-	-
Well No 3	7198	547	820,9	40,1	41,8	2796,3
Well No 4	66	-	0,2	-	0,003	570,4

The well No1 is currently closed. This is due to its blockage a number of years ago when a cassette with sources overlapped the loading channel in its middle. Since then the well has not been in use. The upper part of the loading channel was filled up with iron pellets to provide additional protection from gamma radiation.

The well No 2 is under operation since 1982. It is used for disposal of neutron sources, which include Cf/Be, Pu/Be and Po/Be sources

The wells No 3 and No 4 are under operation since beginning of nineteen's. They are used for disposal of gamma-sources.

Currently the activity of the sources in the well No 3 is higher than that allowable according to design documents. In April of 2000 the Ekores staff during the examinee of the facility determined an intensive emanation of Rn^{222} from the well.

Since that time Promatomnadzor has prohibited the disposal of the spent RS in the wells. The expert team mission under the IAEA Technical Co-operation Project BYE/004/02 was carried out to assist in the assessment of the existing situation, in particular to evaluate safety of wells, containing long-lived and radon-emitting sources. A detailed investigation made by the expert team confirmed the early assumption that intensive Rn emanation had been brought out by Ra sources with failed integrity. Analysis of recording data and of original documentation has shown that it could be capsules made of brass foil containing radium bromide ($RaBr_2$). The integrity of capsules may be destroyed by corrosion resulting from wet media and powerful radiation fields inside of wells.

Measurements of contamination of the well No 3 loading channel indicated that some of sources in the well were partly unsealed. This was confirmed by the fact that the samples of dust from the underground vessel contain Cs^{137} (0,379 Bq/cm²) and Ra^{226} (0,12 Bq/cm²).

Measurements of air samples indicated Rn^{222} contamination not only in the well No 3. Enhanced concentrations of Rn^{222} were found also in the well No 4 despite of absence of Ra^{226} sources in this well accordingly to the computer database. There was oral information that some radium ampoules could be possible disposed of in the well No 4 in 80-s. Video pictures taken by the IAEA mission team showed some broken ampoules, which could be radium sources, perhaps confirming this conclusion.

The examination of the wells included water presence and temperature measurements in the underground reservoirs. The trace amount of water was observed only in the well No 3, which is a problematic one. Namely in this repository the temperature is enhanced, that can course convection of air in a loading channel and slow condensation of water on cold walls.

There are some reasons to suppose that the situation will be aggravating. Investigations of the same type repositories under operation in Russian Federation [2] showed dose rates in the underground reservoirs up to 20 mrem/h, temperatures higher than 80° C and concentrations of radiolytic hydrogen 3,5%. Due to non-uniform allocation of sources in the underground vessel the radiation fields are extremely high even for total radioactivity of sources below repository design limit. The contamination of water in repositories was determined to be up to 10 MBq/l. Small amounts of water were accumulated due to condensation of water vapors on cold walls of loading channel. Though this is a slow process, during many years of operation in dump conditions, when there is a flow of a hot air from the radiogenically heated zone,

some portion of water is accumulated in the underground reservoir. Radiolysis of water and air causes accumulation of hydrogen, ozone and nitrogen oxides and results in producing a nitric acid. These processes significantly accelerate corrosion of source shielding cases. In accordance with the conclusion of Russian specialists on status of Radon type "wells" *free disposal of sealed RS in such type bore-hole repositories has an insufficient level of safety.*

The geological and hydro-geological conditions at the Ekores site are of great interest in this connection. They are available from the "Technical report on engineer geological investigations", reg. No 46877, prepared by the State Enterprise "GEOSERVICE" and show that the geological formation at the Ekores site is of a very high water permeability. The water filtration rate can be as high as 10 m/day. The first aquifer can be rapidly contaminated in case of well failure.

In view of the above stated information Belarus experts study the possibility of allocating sources in the wells into a matrix material, which must protect source shielding from corrosion during storage time.

The IAEA mission team recommended to apply the technology of embedding RS into a metal matrix "in situ" developed and put into operation by Russian Association "RADON" in the mid of 80-s [3].

Taking into account the situation, this technology presents many advantages:

- First, it provides embedding of sources into a metal matrix directly in the underground reservoir that makes the task of conditioning much more feasible.
- Second, the mobile units used for conditioning RS "in situ" are under operation in Russian Federation and they can be available in Belarus without great problems.
- Third, a complete safety assessment report on use of the above mentioned Russian technology, prepared by three leading Russian institutes (SIA Radon, VNNNM and the Institute of Biophysics of RAC) [4] clearly showed high degree of safe isolation of RS from the environment.
- Fourth, according to proposed technological scheme the metal matrix (block) can be retrieved from underground repository after an identified period of time. This is important because the disposal facility Ekores is regarded today as «interim for 20 years» according to the approved conception of its reconstruction [5].

There are a number of organisational and financial issues, which should be settled before a final decision on implementation of the technology in Belarus can be taken. Nevertheless we expect that the work will start not later than the next summer.

It is also supposed that the technology should be spread on the new generation borehole repositories, which are being under construction at the Ekores site.

MODERNISED BORE HOLE REPOSITORIES FOR INTERIM STORAGE OF SPENT RS

According to the above mentioned reconstruction conception, all spent sources entering the Ekores facility must be stored within specialised retrievable RS storage. The storage procedures used in the former USSR and those recommended by the IAEA have been considered by the experts team when working on design for new storage repositories.

The experts did not find a real possibility for bulk conditioning of spent RS into cement matrix as it was recommended by the IAEA guiding documents owing to a great quantity of sources having a high level of activity. It was concluded that the above described technology developed by the Russian Association «Radon» was preferable, especially in view of the fact that it had been approved for conditioning sources in the existing wells. The borehole repository design has been modernised in order to provide the possibility of retrieval of the underground reservoir with SRS.

A loading channel of the modernised well is made dismountable and consists of three sections of the same type, as shown in Fig.1, b. The bottom and top parts of the sections are so designed as to ensure their butt-joint connection in operation and disconnection in case retrieval is required. The weight of each section is about 3 ton, the weight of reservoir fully filled, in a form of an entire metal block, is 2.2 ton. So, standard crane mechanism could be used for reservoir retrieval.

Each section contains parts of the loading and auxiliary channels. One of the auxiliary channels ends near the bottom of the receiving reservoir, and the other – near its cover. The loading channel is used for loading sources into the underground reservoir and pouring molten metal. The loading channel is also used for pumping out water (if necessary) and drying up the well. The auxiliary channels are used for making check measurements and, if necessary, for cooling of the receiving reservoir.

The modernised borehole repositories and Russian technology for RS conditioning (low melting metallic matrices) are intended for storage of RS with less than ~30 years half-lives, including mainly Co-60, Cs-137 and Sr-90/Y-90.

Sources with very long half-lives, much greater than 30 years, are planned to be stored in 'wells' of other type, represented in Fig.2. These RS include mainly 'smoke detector'-type sources, containing Pu-239 and Am-241, which can be handled without beta/gamma shielding.

Walls of the wells are made of a cast iron tube, which is housed into reinforced concrete tube of 732 mm external diameter. The gap between the tubes is filled with cement-sand mortar. Drainage is ensured by means of sand-gravel package 1300 mm thick surrounding the concrete tube. Four identical receptacles of 350 mm height made of stainless steel are used to receive sources. New receptacles are inserted in the well by using a special device, as the previous ones have been filled. Each receptacle is closed with a top cover having grooves helping positioning of receptacle inside the well.

Pending construction of new facilities currently sources of this type are temporarily stored in a simple metal vessel suitable for storage.

The both types of modernized borehole repositories described in this section are under construction and are expected to be completed by July of 2001. To put them in operation the disposal facility "Ekores" should organise an expert assessment of the wells safety and to obtain a license from the Promatomnadzor for activity on SRS storage in the new wells.

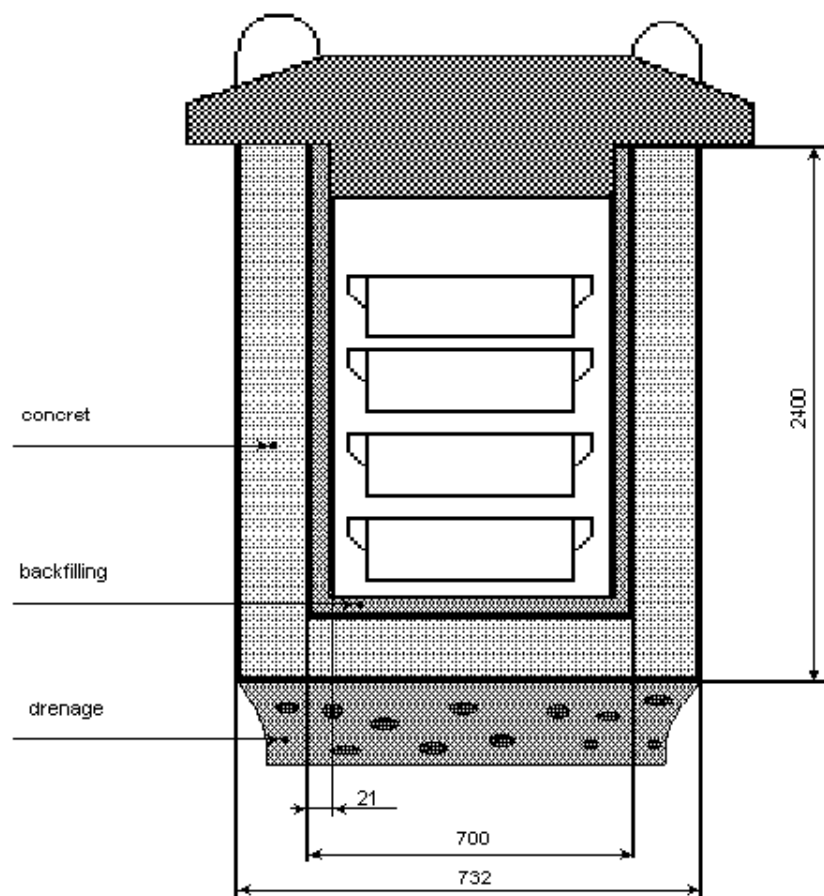


Fig 2. A bore-hole repository for α - sources

CONCLUSION

A sound regulatory regime established in Belarus in recent years provides for effective measures aimed to minimise the arising of orphaned sources from current RS applications. However, there is still a considerable scope for improvement of the existing management scheme for disused and spent radioactive sources.

Belarus, like most of the other NIS's, is not in a position to ensure sound management of spent high-level sources and is looking forward to some real steps in international legislation aimed to spell out responsibilities of suppliers in case of transboundary supply of RS.

The technology for interim storage of sources immobilised in metal matrix has been approved by the team of Belarussian and international experts. To implement the technology, modernised borehole repositories have been developed and are constructed at the Ekores facility.

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