UNDERGROUND RADIOACTIVE WASTE DISPOSAL CONCEPT

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ABSTRACT

The paper presents some solutions for radioactive waste disposal. An underground disposal of radioactive waste is proposed in deep boreholes of greater diameter, fitted with containers. In northern part of Croatia, the geological data are available on numerous boreholes. The boreholes were drilled during investigations and prospecting of petroleum and gas fields. The available data may prove useful in defining safe deep layers suitable for waste repositories. The paper describes a Russian disposal design, execution and verification procedure. The aim of the paper is to discuss some earlier proposed solutions, and present a solution that has not yet been considered - lowering of containers with high level radioactive waste (HLW) to at least 500 m under the ground surface.

1 INTRODUCTION

One of characteristics of the modern civilisation is an ever-increasing quantity of process waste. Enormous efforts to introduce new technologies, recycling, and partial incineration have not reduced generation of enormous quantities of hazardous waste that demands long-term and adequately safe disposal.

Safe disposal of low- and intermediate-level radioactive waste (LL&ILW) generated by nuclear technologies used in power industry (and other industries, medicine and scientific research centres) poses an international problem. Different countries have developed their solutions to the problem. The radioactive waste repository within the Krško Nuclear Power Plant fence is presently used as an interim storage [1,2].

The chemical waste is also dangerous. These include, for example:
- heavy metals (mercury, cadmium, lead)
- inorganic poisons (arsenic, phosphate)
- organic poisons (pesticides, insecticides, waste from pharmaceutical and chemical industry, phenols, waste from textile industry and leather-works etc.)

To prevent its impact on the environment and its propagation, the hazardous waste (radioactive and non-radioactive) must be confined with a multiple barrier system:
- the waste must be conditioned (packed in impermeable containers),
- the waste containers have to be of material not reacting either with waste or with the environment,
- the engineered barrier has to be of durable resistant materials,
• the geological barrier has to prevent dispersion of dangerous substances into the environment and penetration of the groundwater into a repository and vice versa, i.e. leakage of radionuclides into the groundwater.

The repository and its surroundings are considered as a whole, and its safety depends on efficiency of natural and engineered barriers that prevent leakage of radioactive matter into the environment.

2 SHALLOW LAND AND UNDERGROUND REPOSITORIES

There is a difference between low- and intermediate-level radioactive waste repositories and those for the high-level radioactive waste.

Two options are available for the radioactive waste disposal: shallow land [3] and underground repositories [4].

The first option is setting up of a shallow land disposal for low- and intermediate-level radioactive waste (like for example, in Spain [5], France [6] and Great Britain [7]).

The disposal area is carefully prepared, isolated and provided with a controllable drainage system. The voluminous waste has to be compacted, closed in metal barrels assembled in concrete containers. The arranged containers are finally covered with a layer of impermeable soil.

The second possibility is to arrange the underground repository (like, for example, in Germany [8] and Finland [9]). The repositories are placed in deep impermeable rock layers. The system of tunnels and rooms is functionally arranged, with separate waste and staff passages. Once the rooms are filled up with barrels and containers, they are sealed.

The whole underground system has to be drained and leaching controlled.

The high-level radioactive waste repositories demand much more attention. This kind of waste is stored only in deep geological formations. The waste is always conditioned in metal containers with thick walls.

Different approaches are used for the HLW disposal: in Switzerland, the metal containers are designed to be placed in the middle of a filled up tunnel [10]; in Belgium, the containers are designed to be placed in boreholes excavated laterally from a main tunnel [11].

Such repositories should be built in tectonically undisturbed areas, in impermeable formations or between geological barriers, and on a safe distance from the groundwater impact.

The arrangement of the waste handling facilities and final waste conditioning is almost the same for both alternatives (shallow land disposal and underground repositories).

3 DEEP-WELL LIQUID WASTE DISPOSAL

An interesting concept of liquid waste disposal was developed in Russia over 40 years ago [12]. A specific geologic medium was used for deep-well injection of waste (Fig. 1). Russian scientists and geologists proposed using deep permeable formations for radioactive and toxic waste disposal.

Based on the requirements for the radioactive waste disposal, the following principles were adopted for deep-well injection:

• Deep-well liquid wastes disposal is allowed only under geological conditions favourable for the purpose.

• Injection zone used for disposal is separated from shallow groundwater by low permeability formations underlying the region likely to be impacted by subsurface disposal.

• Velocity of groundwater migration in the injection zone beds is small.
• During and subsequent to injection, the wastes are contained within the established boundaries of the geological medium
• Specially constructed wells are used for waste injection
• Wastes are chemically modified prior to injection to ensure compatibility with the geological medium
• The chemical and physical state of the geological medium and injected waste is monitored through complex observations in compliance with the regulations
• Utilisation of the geological medium for the other purposes in the area of disposal facilities is restricted.

**Figure 1:** The sitting of rock formation for the injection of the liquid radioactive waste

To fulfil the last requirement, it is necessary to consider possible future activities in the area and to take measures to control such activities. Such measures should prevent any access to disposed radioactive waste.

The primary safety criterion for the deep-well waste disposal is minimisation of the extent to which the waste migrates inside the formation. The waste migration should conform to the predictions made in a feasibility study prepared beforehand. To be sure that this criterion is met, the condition of both geological medium and the waste should be monitored. The monitoring data have to be compared with the prediction data. From this comparison, conclusions regarding the safety of the process are drawn as the bases for recommendations on the injection conditions optimisation. Such criteria, conditions and requirements are necessary and specific for the each radioactive waste deep-well injection process stage.

The first stage includes a study of geological structure, the parameters of the potential injection zones, and the upper impermeable layers. The work performed during this stage includes the drilling of well, geophysical exploration and the exploration of rock samples. The wastes and their interaction with the rock and water formations should also be analysed.
These data are used as the criteria for predicting the waste behaviour in the geochemical medium and possible consequences of the waste disposal. The waste disposal safety depends on the reliability of collected data.

In testing stage one injection well and a number of observation wells are installed in the area proposed for the radioactive waste injection. The wastes containing nitrates and radionuclides are injected. The propagation of the waste is controlled in the observation wells. The passage of the waste front through the wells is indicated by the gamma-logging data. The test confirms the geological conditions established by earlier investigation, and critical parameters relating to radionuclides. As a result of the initial testing phase, pilot facilities for waste disposal are designed, constructed and put into operation. During the process of waste injection, certain parameters are monitored, including hydrodynamic, hydrochemical, and geophysical.

The next stage in the feasibility study preparation and the injection facilities design includes calculation of the distribution of wastes in a specific geological medium and estimation of volume of injection zone. The injection rock is used only for waste disposal; its use for other purposes is not allowed. Both the feasibility study and the design of injection facilities include an analysis of possible accidents, their cause and consequence.

The deep-well injection of liquid radioactive wastes has been used in practice in Siberia (Tomsk and Krasnoyarsk) and in Central Russia (Dimitrovgrad). The reservoirs near Tomsk and Krasnoyarsk consist of clean sandstone, those near Dimitrovgrad consist of limestone. High retention of radionuclides was determined in these rocks. About thirty million cubic meters of various wastes have been injected in Tomsk. All waste was specially treated before injection. The monitoring system included a large number of observation wells (near hundred Fig. 2).

![Figure 2: Distribution of wells at Tomsk](image)

Problems connected with the operation of deep-well injection do not cause emergencies. Such problems are usually caused by bad physical condition of old wells, originally drilled for exploration of petroleum and gas, and later used for injection. Other problems include presence of gas in the injection zone generated by the activity of denitrifying bacteria during testing. Furthermore, there is a problem of high migration rate of wastes in individual layers under high injection pressures. None of these problems threatens the environment outside the plant area.
Experience collected from deep-well injection of radioactive wastes is of considerable value and has served as a basis for the development of disposal facilities for non-radioactive toxic and industrial wastes in different regions of Russia.

The first disposal practice of this kind was that from the thirties of the last century in the USA. The use of boreholes is in the USA strictly regulated (1995), so five classes of boreholes applicable for waste storage are differentiated:

I. grouting of municipal and industrial waste below the deepest water-bearing strata
II. grouting connected with petroleum exploitation
III. injections for soluble minerals extraction
IV. grouting of dangerous and radioactive waste over a water-bearing strata (not allowed), and other boreholes for liquid impression.

4. DEEP BOREHOLE CONTAINER DISPOSAL

The northern part of Croatia belongs to the geological area of the Pannonian Basin. It has been systematically investigated, so the data are available on some 4500 boreholes. Some of them are located in the active petroleum and gas fields, and many in the so-called sterile fields. The geological picture of this area is very clear, so the existing data should only be looked at from a different point of view to find the area with convenient properties.

The petroleum and gas deposits in the Pannonian Basin are in the most part in Tertiary sandstone and limestone layers, at the depth of 1000 to 2500 meters. These layers are predominantly covered or underlied with impermeable layers of marl and clay. Studying of the available data and finding the deep layers satisfying the most stringent criteria and the layers where the HLW conditioned in containers could be stored directly in the boreholes should be no problem.

The normal boreholes (to 6000 m or deeper) start with large borehole diameter, up to 20" (about 50 cm), and this diameter is worked up to 1000 to 1500 m in depth. Technically, drilling of even larger diameters and reaching of the greater depths should be no problem, but special drilling rigs would be necessary. So, a borehole with diameter that enables lowering of special barrels (containers) with solid waste to the depth of a thousand meters can be executed. The space between the barrel and the borehole casing, and the space between the barrels can be filled up with impermeable material, such as clay or bitumen. For any borehole, the geological conditions determine the total depth and the convenient length to be filled with waste. The rest of the hole, approximately 300 or 500 meters to the surface, has to be filled with concrete or clay.

The deep impermeable layers contain petroleum conserved under the pressure of hundreds bars for millions of years, from Tertiary to the present day. There is no better argument that a well-chosen and technically correctly designed deep underground repository satisfies the most stringent safety criteria. Thus, based on the experience of other countries, and the fact that the deep boreholes suitable for the purpose are available, we would propose that this radioactive waste disposal method be taken for further geological, technical and economic consideration.
The Fig. 3 illustrates functioning of such a disposal facility that could be implemented in stages.

**Figure 3**: Solid waste disposal in deep borehole

**CONCLUSION**

The deep impermeable layers contain petroleum conserved under the pressure of hundreds bars for millions of years. This is a good argument to choose boreholes for waste disposal.

For the radioactive and other dangerous waste, we would propose filling of the deep boreholes with containers. One borehole 50 cm in diameter and 1000 m deep, half-filled, can be a safe repository for approximately 100 m³ of solid radioactive waste. Since the quantity of such waste in Croatia is not large, a small number of boreholes could satisfy all the needs for radioactive waste disposal. This is not the cheapest solution, but it can satisfy the most stringent safety requirements. However, our intent has not been to give a cost estimate of such a project.

Siting of repositories for the radioactive waste is faced with yet another problem confirmed by numerous polls of public opinion – not in my back yard, the NIMBY syndrome. This is an additional reason for serious consideration of the waste disposal approach proposed in this paper.

**REFERENCES**