# CHEMICAL RISKS FROM NUCLEAR WASTE REPOSITORIES

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## ABSTRACT

Recent studies on chemical risks from nuclear waste repositories are reviewed. The radiation risk is according to the studies of primary concern but there exists also a small risk from genotoxic, chemical substances, which could reach the biosphere. The possible chemotoxic effects should thus be studied as a part of the risk assessment of a final repository for nuclear waste.

## INTRODUCTION

Ionizing radiation and many chemical substances give rise to so- called genotoxic effects, so named because the initial event leading to the disease is a damage to the gene material, DNA. These effects which comprise cancer and hereditary diseases have certain characteristics which make them a special problem in the context of health protection: The effects appear already at very low doses, most probably without any threshold and the risk is increasing proportionally to the dose. Since the frequency of the diseases but not their severity is affected by the dose, these effects are considered to be a stochastic phenomena. This property differs from toxic effects in a classical sense which do not appear until above a critical threshold dose or threshold concentration. What is known about the carcinogenic effects of radiation and chemicals is reviewed in (1).

Apart from their potential radiotoxicity the elements introduced in waste repositories may thus exhibit a certain chemical toxicity. These radioactive or stable elements originate in reactor operations and in irradiated fuels or in reprocessing operations. Chemical wastes are also generated during the decommissioning of nuclear facilities. They are also found in the container assembly and possibly in the engineered barriers of the repository.

While, in a short term, the radiological toxicity of these materials is of primary concern, the potential chemical toxicity should not be overlooked. In the longer time frame, as radioactive decay depletes the radionuclides, the chemical toxicity potential may even become the dominant issue. The risk of any genotoxic material reaching the biosphere from the repository and the synergistic effects of chemicals and radionuclides should thus be factored into the safety analysis. Depending on various factors (e.g. solubility, volatility, particle size, decomposition rate), the relative chemical toxicity may either increase or decrease with time. Some of the chemicals, however, will remain as they are, while some of the organic material will decompose with time. The methodical tools applied in nuclear waste disposal safety assessment for the radiological harm is also suitable for the chemical component.

### Safety Analysis of a Swedish Repository for Reactor Waste

In connection with the safety assessment of the Swedish SFR-1 underground rock repository at Forsmark for low-level and intermediate level nuclear waste, studies on the chemical risks from the repository were presented (2,3). It was concluded that the small leakage from the repository should not give any significant chemical harm to man and environment. This conclusion was also accepted by the National Franchise Board for Environment Protection.

### Environmental Effects of Swiss Nuclear Waste Repositories

The Swiss national cooperative for the storage of radioactive waste (Nagra) has made a detailed survey of potential chemical risks of planned repositories in Switzerland (4).

According to the protection objectives for the Project Warranty as formulated by the Swiss federal authorities, a radioactive waste repository should not exhibit any adverse effects on man and environment also from a chemotoxic point of view.

The Swiss Federal Office for Environmental Protection made available a list of relevant ecotoxic materials and other substances which could present a problem due to their chemical and toxic properties. The inventory of ecotoxic and other potentially harmful substances in the type B (low and intermediate level waste) and type C (high-level waste) repositories has shown that these materials occur mainly in the type B repository and the heavy metals Ni, Cd, Cu, and Cr can be taken as representative.

Due to the possible implications for human health, Cd was selected for further investigation by Nagra, mainly because of the interest attracted by this metal in ecological discussions. Under the assumption that Cd originally emplaced in metal form later oxidizes and migrates as a bivalent cation with groundwater from the repository zone into the biosphere, the maximum expected Cd concentration in the biosphere can be determined. The methods and parameters used for the transport calculation were similar to those used for radioactive materials in Project Warranty.

The maximum allowable concentrations are laid down for Cd and other chemotoxic materials in the environment in Switzerland. However, in order to assess the values calculated, reference can be made to the standard values for heavy metal content in agriculturally viable soils as well as to natural concentrations. For Cd the calculated content in the ground is around an order of magnitude lower than the corresponding standard value for agriculturally exploited ground, while the soluble proportion is around a factor of 30 lower than the relevant standard value.

Based on the conservative calculation of material transport in the geo- and biosphere and on the evaluation of the results outlined above, Nagra has concluded that leakage of Cd present in the repository causes no significant increase in environmental Cd concentrations. The ecotoxic risk potential of Cd from the type B repository was therefore regarded as insignificant. This conclusion holds as well for a type C repository, because its content of Cd is low and the migration paths to the biosphere are large.

Simple comparative calculations in the report of Nagra show that the ecotoxic conditions for the other heavy metals (Ni, Cu, and Cr) are basically the same as those for Cd. The result of the Nagra study has been accepted by the Swiss Federal Office for Environmental Protection to be in line with the protection principles of Project Warranty.

## CHEMICAL RISKS FROM NUCLEAR WASTE IN CANADA

The Atomic Energy of Canada Limited (AECL) has in 1987 issued a report concerning an assessment of the long-term impact of chemically toxic contaminants from the disposal of nuclear fuel waste (6). The report presents a study on the potential for impact on man of chemically toxic contaminants associated with the Canadian concept for the disposal of nuclear fuel waste. The elements of concern are determined through a series of screening criteria such as elemental abundances and solubilities. A systems variability analysis approach is then used to predict the possible concentrations of these elements in the biosphere. These concentrations were compared with environmental guidelines such as permissible levels in drinking water. Conclusions were finally made regarding the potential for the chemically toxic contaminants to have an impact on man.

According to the AECL study there are over 50 elements associated with nuclear fuel waste disposal to be taken into consideration for an assessment of the chemical toxicity impact. For the purposes of the study, these elements were assumed to occur in one or more of the six representative waste forms, where the "waste form" refers to any potential source of toxic elements. The six waste forms considered are: used fuel, sodium borosilicate glass, a hypothetical composite container, a lead-antimony infilling material, a zinc infilling material and Zircaloy.

A consideration of criteria such as solubility limits and natural abundances has resulted in the elimination of most elements from further detailed consideration. The 12 remaining elements for which a more detailed assessment was carried through were B, Br, Cd, Cr, Cs, Mo, Ni, Pb, Sb, Sm, Tc, and Zn.

This assessment was carried out using a modified version of the stochastic systems assessment code, SYVAC 2, originally developed to evaluate the radiological impacts of underground disposal of nuclear wastes. In SYVAC 2 a set of equations describes the transport of chemical elements from the repository through the bedrock to the biosphere. Some parameters in these equations cannot be measured precisely, but upper and lower limits can be given from them. This uncertainty about parameter values, and consequently about the results of the calculation, is handled by repeated calculations. In each calculation different parameter values are selected in a random way, but so that each parameter is within its uncertainty range.

In all 1000 calculations were made in the AECL study for each waste form. Each calculation gave the concentrations of each of the elements in respectively the soil, lake and well compartments of the biosphere. These concentrations differed from one calculation to another since the parameters had been changed, but the results from the 1000 calculations gave a range of predicted concentrations for each element and the probability that the concentrations exceed acceptable levels in the biosphere. Maximum estimated concentrations were then compared with acceptable levels of concentration in the biosphere, and the results statistically interpreted.

In general, the results suggest that there exists a low probability that nuclear fuel waste disposal could give rise to chemically harmfull impacts. For the soil compartment, only Cr,Mo and Pb occasionally exceeded their acceptable levels, with a maximum occurrence of 17 out of 1000 simulations for Mo which owes to the composite container. For the lake compartment, the same three elements were the only ones to exceed their acceptable levels, with a maximum occurrence of 8 out of 1000 simulations for Cr (from the composite container). For the well compartment B, Br, Cr, Mo and Tc occasionally exceeded their acceptable levels, with a maximum occurrence of 83 out of 1000 simulations for B (from the sodium borosilicate glass).

As a measure of the potential risks, Goodwin et al. have compared the ratios of the calculated mean concentrations with the corresponding acceptable levels. Using this criterion, only the well compartment has ratios exceeding unity for Cr (from the composite container), Mo(from the composite container and from the sodium borosilicate glass) and B (from the sodium borosilicate glass).

There are four major factors that affect these results. The first three, the elemental inventories, release rates and toxicities, mostly affect the magnitudes of the estimated impacts. The fourth factor, the elemental mobility in the geosphere, mostly affects the frequencies with which estimated impacts occur. All four factors contribute to the potential hazards from chemical toxicity, although one or more factors may be dominant.

Based on these results, it was concluded by the authors that there is a low probability of realizing significant chemical impacts from the disposal of nuclear fuel wastes in Canada. If desired, these impacts can be readily reduced or even eliminated.

Nevertheless, the major recommendation of the AECL study is that the assessment of potential chemical impacts should be part of the formal concept safety assessment, and that these studies should be repeated using the updated models and data. It is also suggested that, for future assessment studies, the evaluation of chemical toxicity effects be based on a better quantified measure of impact and risk, possibly through detailed evaluations of the toxicologies of the selected elements.

## DISCUSSION

A comparison of chemical and radiological hazards presents difficulties from the differences in the types of harm and the problems in qualifying the extent of harm. High acute doses of radiation or high acute intakes of chemical poisons can produce deleterious effects. For these cases the risk for lethality can be used to compare chemical and radiological toxicities.

Such comparisons are a of very limited value in the study of nuclear waste repositories since large single intakes of contaminants are very unlikely. A much more likely situation is the intake of very small quantities of contaminants involving either radiological or chemical risk or both types of risks. These risks appear already at very low doses, most probably without any threshold.

For assessing the risks of chemicals the approach is similar to that used with radiation in those cases where human data are available, but the data are rarely as complete as with radiation (1). Furthermore, estimation of the dose is usually more difficult with chemicals because of the lack of good data.Chemicals thus vary widely in their capacity to cause cancer. The amount of data on individual chemicals is far smaller than the amount of data on radiation. Chemicals also often undergo metabolism to yield carcinogenic derivatives. Thus the risk assessment of chemicals generally involve greater uncertainties than the risk assessment of radiation.

An evaluation of the chemical risks from nuclear repositories is given in (6). It is concluded that repositories for low-level and medium-level nuclear waste represent a much lower chemical risk than normal repositories for hazardous waste represent. For high-level nuclear waste it is concluded in (6) that the chemical risk is secondary to the radiation risks.

## CONCLUSION

Neither the studies of the SFR-repository in Sweden (2,3) nor the detailed studies carried out in Switzerland (4) and in Canada (5) indicate a significant chemical risk for man and environment from repositories for nuclear waste.

However, it is recommended that the possible chemical impact on man and environment is evaluated as a part of the formal concept safety assessment of nuclear waste repositories .

## REFERENCES

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