IN-SITU SOLIDIFICATION TECHNIQUE FOR WASTE DISPOSAL IN UNDERGROUND CAVERNS

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ABSTRACT

The paper gives a comprehensive review about a recently terminated project on an alternative waste management concept which is in development in the FRG since 1976.This concept was primarily developed for the disposal of radioactive low-and intermediate level wastes but it is generally applicable for liquid and special forms of solid wastes (grains,powders,slurry).The main features of the in-situ concept are: 1) containerless disposal technique of fluid waste-binder mixtures,2) direct disposal from above ground into underground caverns at 1000 m depth and 3) in-situ solidification at the final disposal position.

Solution mining technique is favored for the allocation of the underground caverns.All important items of the concept are now demonstrated up to an industrial relevant scale,above all: processing of primary waste solutions using granulation technique and the vertical transport of concrete enriched with granules through pipelines of 1000 m length.

INTRODUCTION

Allocation of disposal sites for radioactive and toxic wastes is presently running in administrative and technical difficulties above all in densely populated countries. Near-surface repositories will find less acceptance due to potential ground ater contamination and repositories in the deep geological underground are expensive and the retrievability is limited. According to a governmental decision only the geologic repository option is followed in the FRG with respect to radioactive wastes and considerable experience was already gained in the field of waste disposal using drums and containers in a mined underground repository located in the ASSE-saltmine in Lower Saxony.

In the mid seventies a nuclear back-end center was designed in the FRG which was characterized by a concentration of all nuclear installations with respect to fuel fabrication, spent fuel management, waste conditioning and waste disposal. This center was to be located above geologic formations which may be used as host rock for the repository.

Consequently waste management could be based on new concepts as no transport of waste containers on public ways, i.e. railway and roads, had to be carried out. The idea was born to apply a containerless waste disposal technique using viscid waste binder mixtures which solidify at the final position in the repository thus saving efforts for waste packaging and shielding.

R + D-efforts started in 1976 resulting two years later in the definition of the reference concept. The components were tested with inactive halfscale equipment in the next three years and fullscale demonstration plants but still inactive were erected and operated in the next seven years.

The paper gives a comprehensive overview about the recently terminated project on the in-situ solidification technique which was primarily developed for radioactive LLW and MLW but it is generally applicable for liquid and special forms of solid wastes (grains, powder, slurry).

Though the German nuclear back-end center was not realized as designed in the above mentioned way, the in-situ concept was developed as alternative to the drum disposal technique and considerable benefit with respect to health and safety, reliability and last not least economics could be evaluated.

The reprocessing plant in the FRG is now located in Wackersdorf/Bavaria which results in considerable transportation efforts for the allocation of waste containers in the repository at Lower Saxony. Consequently the in-situ technique had to be adjusted to the new situation and the waste transportation problem had to be solved with adequate containers.

On the other hand this circumstance opened the possibility to manage also wastes from nuclear power plants and R + D establishments, which were at first eliminated.

IN-SITU SOLIDIFICATION CONCEPT

The main process steps of the in-situ solidification concept are summarized as follows and illustrated in Fig. 1.

1) Prefabrication of granules at the waste producer's site from MLW/LLW (concentrates and slurries) and cement. The granules (grain size: 0.3-5 mm) are kept in an interim storage facility for a setting time of approx. 48 h. Some solid waste e.g. ion exchange resin, ash, may be used directly as granules without any prefabrication step.
2) Transportation of the granules in special shielded containers from the waste producer's site to the final repository.
3) Unloading of granules at the final repository site and mixing of the granules (50%) with cement grout (50%), using tritiated waste water from the reprocessing plant, if the occasion arises.
4) Vertical transport by gravity of the viscid grout from above ground into a salt cavern of 75.000 m3 located at 900-1000 m depth through a relatively thin pipeline (API 2 7/8"), which limits the flow speed to reduce erosion damage.
5) In-situ solidification of the concrete-like waste form in layers, each of which represents one filling campaign. The open cavern space is finally completely back-filled with a large monolith consisting of granules embedded in solidified grout.

The underground cavern system is illustrated in Fig. 2, which shows three caverns in different states, i.e.,

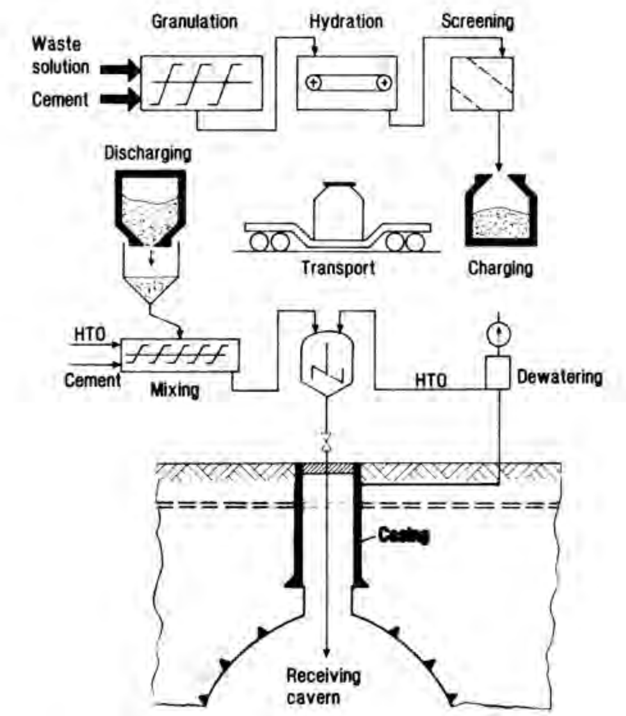

Fig. 1. Schema of the In-Situ Solidification Technique.

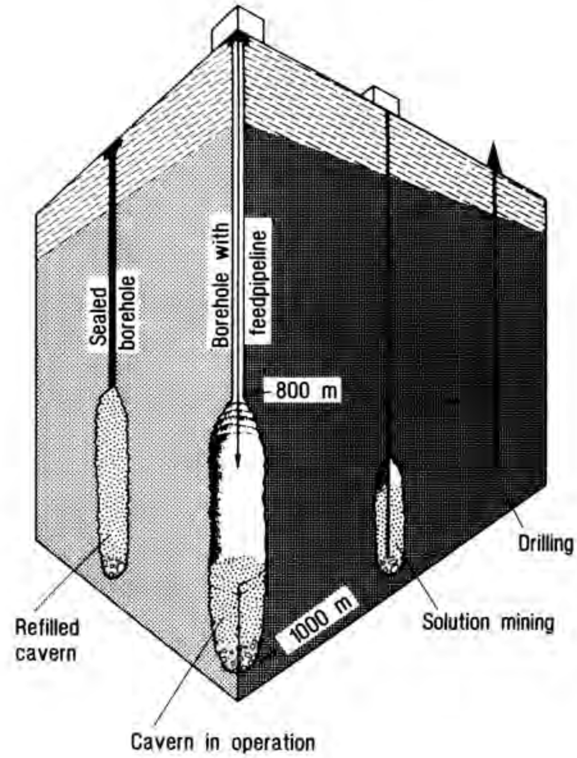

Fig. 2. In-Situ Cavern System.

construction, operation and the final refilled and sealed position.

Due to the fact that the receiving cavern does not need any manual operations contamination of the cavern atmosphere can be tolerated to a high extent and the special layout of the ventilation system effects a setting of the reference waste form in a quasi closed system.

An important feature of the in-situ solidification concept is the possibility of filling solution-mined caverns via bore holes which offers advantages with respect to operational safety, health and safety and economic benefit.

The paper reviews mainly recent results obtained during the operation of an industrial demonstration plant for the granulation of simulated liquid waste concentrates and describes the production facility for the reference mixture at the ASSE salt mine with the successive transport through the vertical pipeline into the salt cavern.

GRANULATION OF SIMULATED RADIOACTIVE WASTE CONCENTRATES

The in-situ solidification concept applies granules as primary matrix material for liquid radioactive waste concentrates to be disposed of.

The granulation technique which was developed by F.J. GATTYS Company up to an industrial scaled demonstration plant applies a ploughshare mixer as granules generator. This is a batchwise operating unit with a production rate of 0.55 Mg granules per charge which amounts in a 3-shift day to 9 Mg/d. (2)

The different operational steps of the granulation process are as follows:

- charging the mixer with dry components (cement, bentonite)
- injection of liquid concentrates
- agitation by permanent rotation of the ploughshares in combination with a rotating cutter which keeps the grain size below 5 mm
- discharging the "green granules"

The whole process as described above takes 45 minutes and is controlling the capacity of the whole plant.The complete hydration of the "green granules" takes place in succeeding hydration units at elevated temperatures and air humidity. The mean residence time till the granules have got enough stability for further handling procedures like sieving and loading in adequate transport containers comes to 32 h.The demonstration plant has produced already 1300 t of granules of the following specifications:

Composition:	80 wt% cement
	5 wt% bentonite
	15 wt% waste concentrate
product density:	2.6 Mg/m^3
bulk density:	1.56 Mg/m^3
pore volume:	15 vol.%
grain spectrum:	0,3 - 5,0 mm
impact strength:	1 cm^2/J

TRANSPORT OF GRANULES

A special container design was necessary for the transportation of loose goods in form of radioactive granules. The filling and discharging-procedure had to be carried out dust free and without major contamination.

The Type-B reference container as designed by TRANSNUCLEAR Company is represented by a massive cylindrical bottle-like cast body of nodular cast iron (GGG 40.3) equipped with a flap valve at the stainless steel lid.The main characteristics are as follows:

capacity	5 m^3
maximum pay load	7,5 Mg granules
gross weight	31,5 Mg
diameter	2,28 m
height	3,63 m

Two containers can be transported in vertical position by one railroad car with six axles.The filling procedure is performed in vertical position below the silo whereas the container has to be inverted for the discharging of granules.With the help of a mock-up the filling and discharging procedure has been tested and there was only minimum amounts of contamination by dust evolution.

VERTICAL PIPELINE TRANSPORT OF WASTE-BINDER GROUT IN UNDERGROUND CAVERNS

The vertical transport of the concrete-like reference product as specified in the following Table

granules:	45-47 wt%
grout:	53-55 wt%
water/cement:	0,57
density:	2 Mg m^{-3}

was subject of major efforts i.e.

1) Construction of an above ground demonstration plant for mixing and dosing reference product in a technical scale (design capacity 10 m3 h-1); see also Ref.(3).
2) Installation of a vertical pipeline (API 2 7/8 ") of 960 m length in shaft IV of the ASSE-saltmine through which the prototype cavern of 10000 m3 capacity could be fed with the reference product.
3) Operation of 5 filling campaigns feeding altogether more than 1000 Mg inactive reference product onto the cavern floor, where setting took place. The maximum operation time of one filling campaign was 36 hours.
4) The cavern atmosphere was equipped with remote instrumentation to measure air temperature and humidity as well as the product level and product surface temperature profiles.

The positive results of the filling campaigns proved the feasibility of the concept in an industrial relevant scale. A lot of labscale and halfscale experiments had to be carried out to arrive at the present state. Two different systems for the vertical grout transport were tested in an underground facility with a 100 m vertical pipeline and the necessary mixing station i.e.

1) gravity driven vertical grout transport and
2) use of a slurry pump to maintain the vertical grout flow.

Both systems proved to be technical feasible and the decision to use the gravity driven system for the final large scale experiment was based on the judgement that it can be adopted better for radioactive operation than a system which has to apply contaminated slurry pumps.

A detailed presentation of the above mentioned activities is given in poster session XXI/23; see (4).

SOLUTION MINED CAVERNS AS WASTE DISPOSAL FOR MLW AND LLW

As an alternative to the conventional technique for the allocation of mined caverns in a saltformation investigations have been made by the Gesellschaft für Strahlen- und Umweltforschung and Kavernen Bau- und Betriebsgesellschaft to apply solution mined caverns as waste repository.

There is great potential that the in-situ solidification concept may apply this well established technique due to the following reasons:

Only viscid waste slurries without containers will be disposed using pipelines which may well be installed in relatively small boreholes as applied at the solution mining technique.

The open underground space can be completely refilled in one decade by a monolith with mechanical properties similar to those of the surrounding rock formation.

There will be complete isolation and independent operation from the "mined" repository during the construction- and operational phase of the solution mined cavern.

As there are no underground manual operations contamination of the cavern atmosphere is acceptable and elevated ambient temperatures can be tolerated which means that deeper levels in the geologic formation can be made accessible. Those are normally excluded for miners unless extended cooling requirements are fulfilled.

A detailed safety and feasibility analysis has been elaborated about three caverns of 75000 m^3 each, which are connected with one single filling station above ground via three separate boreholes which show a deviation of 128 m from the vertical line and a maximum inclination of 21 (see Fig. 3). The well casing scheme shows four casing pipes starting with 30 " and ending with the last pipe diameter of 11 3/4 ". The space between casing and boreholes as well as outer casing is refilled with cement slurry in order to prevent any water intrusion in the cavern through the borehole. Before the leaching operation starts, a tightness check of the well casing is performed by applying a test-pressure (80% of fracture-pressure) along the whole borehole.

The safety analysis arrives to the conclusion that the allocation of three leached caverns which are filled from one filling station above ground is technically feasible without additional R + D and guarantees at minimum the same operational safety than a mined repository. See also (5).

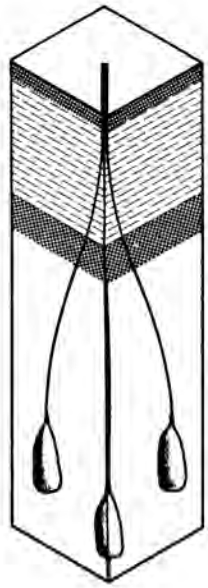

Fig. 3. Construction of Three Leached Caverns Via Boreholes.

CONCLUSIONS

1)The in-situ solidification technique has been demonstrated successfully up to an inactive industrial scale.

2)The technique has the potential to manage LLW and ILW in the form of inorganic solutions, grains, powder and slurry.

3)Waste solutions need a granulation step prior to disposing as viscid hydraulic concrete through a vertical pipeline

4)Solution mined caverns as repository have the best properties for the application of the technique with respect to operational safety and economic benefit.

5)100% of the available underground cavern space can be refilled with hydraulic waste product and without ballast represented by package and shielding material. After decomissioning the refilled cavern system can be considered as stable as the original geological formation.

6)The complete refilling of open underground space prevents access of ground-water after decomissioning thus mobilization of waste components can be eliminated.

7)The in-situ concept is also feasible for hazardous chemical waste if specifications as mentioned in 2) are met. Adequate investigations are under way.

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