Waste Characterization and Conditioning

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Abstract:

The Backfilling Ordinance regulates the legal criteria concerning waste and the requirements of environmental protection as to the recycling of wastes as backfilling material. Salt mines with an admitted long-term safety proof meet the safety requirements of underground depots in Germany. Backfilling has been approved by the European Court as a form of recycling on condition that by means of a necessary measure natural resources are being substituted by industrial wastes and resources are protected. The original qualities of wastes are used directly or for producing backfilling materials following special mix designs. For the backfilling procedure numerous technical possibilities can be applied. An essential pre-condition for admission of waste for backfilling is the preparation of an expert opinion checking the suitability as backfilling material.

1 Introduction

Certain types of hazardous wastes must be disposed in underground disposals that are classified as class IV according Landfill Ordinance of 27th April 2009 (DepV), /Dep 09/ and exclude the wastes permanently from the biosphere. The different types of waste are packaged in permitted containers, drums or big bags and transported into separated disposal chambers. In Germany these special chambers are exclusively erected in evaporate and safely isolated from the other parts of the mine. The disposal of the containers with the waste is carried out very carefully like in a storehouse. Position and time of the disposal are documented by a special waste register to ensure the retrievability of the wastes. For safety reasons only waste types with similar chemical and physical properties are disposed in the same chamber.

In contrast backfilling means the back stowing of mines for safety reasons, mine cavities that have emerged from the exploitation of natural resources by mining. The material properties of the mineral industrial wastes and the resulting backfilling materials are used to minimise convergence, avoid the danger of latent sink holes or seismic events and for technical measures in the mine. Backfilling so meets the target priority of waste recycling over waste disposal of the Closed Substance Cycle and Waste Management Act (KrW-/AbfG), /KrW 94/. Backfilling has been approved by the European Court as a form of recycling on condition that by means of a necessary measure natural resources (e.g. sand, gravel, soil) are being substituted by industrial wastes and resources are protected (assigned backfilling).

It is possible to use mineral industrial wastes with adequate geomechanical properties and low content of toxic substances without further treatment as backfilling material. Furthermore wastes are applied for the production of adequate backfilling mixtures according established and admitted mix designs by using their specific material properties (e.g. binding agent, filling material, mixing liquid). The backfilling materials must be completely enclosed in the host rock after the end of mine operation and sealing the shafts. Thus its long-term elimination from the biosphere is guaranteed.

This paper gives attention to the legal regulation of backfilling in Germany, characterizes the applied backfilling technologies and gives an overview about the procedure and the testing methods for the proof of suitability of inorganic industrial wastes as backfilling material.

2 Ordinance on Underground Waste Stowage (Backfilling Ordinance)

The Backfilling Ordinance (VersatzV), /Ver 02/ regulates the recycling of wastes in companies that are controlled by the mining authorities. It implements the claims of KrW-/AbfG for high-quality recycling by priority of metal reclaiming (§ 3) and for harmless utilization (§ 4) by definition of material requirements for the waste.

According to § 1 the VersatzV is valid for:

- Waste producers and owners of wastes,
- Managers of mines that are controlled by the mining authorities and
- Operators of facilities producing backfilling materials.

Wastes reaching the metal content value listed in the following table 1 may neither be utilized to produce stowage materials nor for direct use as stowage materials if it is technically possible and economically viable to reclaim these materials from the waste, and insofar as this is feasible while observing the permissibility requirements of such recycling.

Table 1: Limit value concentrations (g/kg) for metals in wastes according VersatzV

Iron	≥ 500
Chromium	≥ 150
Zink, lead	≥ 100
Nickel	≥ 25
Tin	≥ 15
Copper	≥ 10

In the Backfilling Ordinance limiting values of harmful substances within waste (appendix 2, table 1) and of the leaching behaviour (appendix 2, table 2) have been determined with respect to environmental protection.

According to § 4 para. 3 these limiting values are not valid for salt mines which have completely enclosed the harmful substances of waste within the mine thus permanently closing them from the biosphere by means of a long-term safety proof. Contact of wastes with aquiferous layers on the surface resulting in mobilizing the harmful substances in wastes can definitely be excluded. This way salt mines meet the safety requirements of underground depots in Germany. Only the correlation values for the parameters TOC (organic carbon) and glowing loss of the organic substances mentioned according appendix 2, table 1a have to be applied to guarantee the inorganic character of the wastes.

The limiting values for the content of harmful substances (applied to dry matter) and for the eluate mean a serious restriction for backfilling in different geological formations, like ore and coal. Because the harmful substances of the backfilling materials can get in contact with groundwater of deeper horizons or surface waters in these host rocks, the limitation was strongly necessary for the protection of the biosphere. The exceeding of the limiting values is permitted only in the following cases:

- the respective contents do not exceed the contents of the absorbing rock (geogenous basic content) or
- for carbon and secondary rock:
  a) for wastes only from coal firing (coal- or lignite-fired power stations)
  b) no higher noxious impurities than provided for under a) in the case of co-incineration of other materials

According to VersatzV rock salt or potash mines were selected for backfilling because they offer a total enclosure and permanent isolation of the waste materials from the biosphere after the end of operation and sealing the facility.

3 Backfilling Technologies

Different backfilling methods are use in Germany, the following figure 1 gives a schematic overview of the actually practiced technologies. Pneumatic stowing has become less important during the last 10 years and is therefore not illustrated in the flow chart.

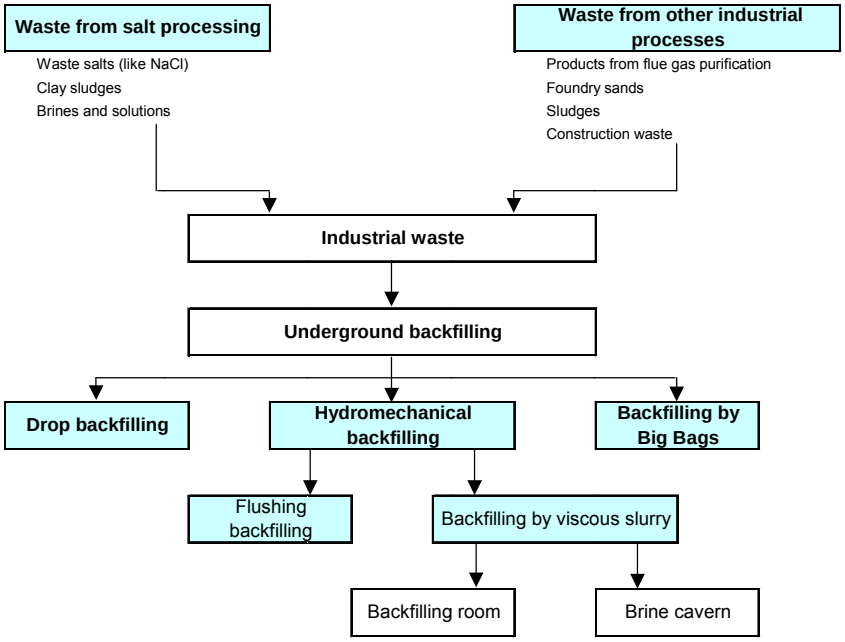

Figure 1: Backfilling technologies

Drop Backfilling

Mainly wastes that can be backfilled without further treatment (because of low content of hazardous substances and adequate geomechanical properties) are recycled in drop backfilling (e.g. contaminated soil, construction waste, furnace lining and slags). They are transported in containers down the shaft. Special vehicles take over the underground transport. The backfill materials are dumped into the backfilling chambers. If necessary, the bulk goods are sprinkled with water or saline solutions on the surface to make them dustproof.

Figure 2: Backfilling of a mining site with bulk goods

Backfilling by Bag Bags

Backfilling can be done also with industrial wastes already packaged by the producer or packaged by the operator of the backfilling mine on-site. This technology is especially used for foundry sands, boiler slags, industrial salts and waste blasting material with low content of hazardous substances and sufficient compression behaviour. Furthermore backfilling by big bags is suited for products of mixing plants or cemented mixed products. The big bags are transported into the underground via the shaft, and there lorries and big vehicles transport them into the backfilling rooms. Forklift-trucks install the big bags into the backfilling chambers in layers. Alternating storage with covering salt is applied to reduce the pores.

Figure 3: Backfilling of a mining site with big bags

Hydromechanical Backfilling

Finely grained and grained wastes such as dusts, ashes, products of chemical flue gas treatment from waste incineration, foundry sands, boiler slags and sludge are usually processed into a flowable (flushing backfilling) or pumpable (backfilling by viscous slurry) backfilling material mix with adding a concentrated salt solution. The applied transporting solution must be chemical inactive against the host rock.

In the process of ***flushing backfilling*** the backfilling suspension is produced on the surface according to various mix designs with a procedure of referring to material groups. The mixture with a considerable excess of mixing liquid remains in a reaction drum to reduce exothermal effects and a possibly existing gas formation potential. After a residence time of 2 to 4 h on average the backfilling suspension is transported into the backfilling rooms by means of a piping system thus using the geodesic difference in height. The salt solution applied in this procedure serves as a transporting medium for solid particles and reactant for the setting behaviour. The excess transporting solution drains the backfilling material by means of a dam construction respectively a barrier system, and under surveillance it is collected in a brine-collecting basin at a deeper point of

the mine. Subsequently it is transported back into the process on the surface (circulation of the transporting solution). Figure 4 shows the flow chart of a flushing backfilling plant.

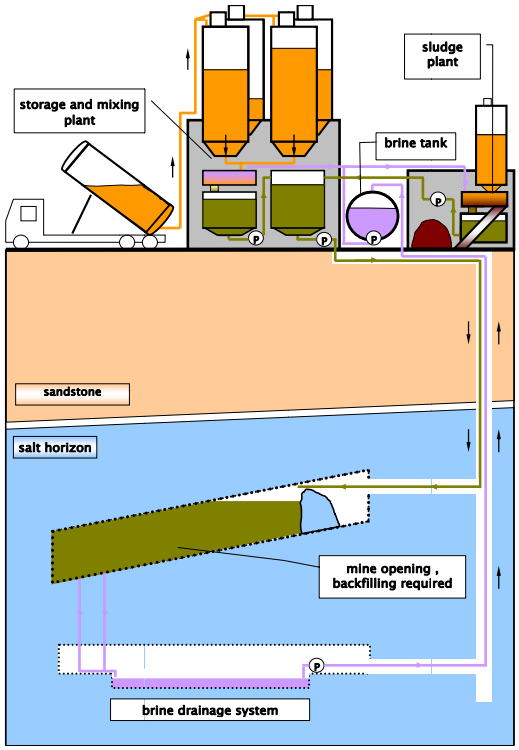

Figure 4: Flow chart of a flushing backfilling plant

By means of flushing backfilling a nearly complete backfilling (> 90 Vol-%) of the mining sites can be achieved.

Backfilling by viscous slurry shows the following important differences in comparison with the technology of flushing backfilling:

- No or only low excess of mixing liquid required
- No brine drainage system necessary, small amounts of excess transporting solution are removed by weathering or admitted by excavation disturbed zone
- High saturation of the pore liquid ⇒ can be used also for sensitive host rocks
- Higher viscosity requires the installation of high performance pumps (e.g. plunger pumps)
- Mixing process can be carried out on surface or in the underground

The application of backfilling by viscous slurry for stabilization of brine filled caverns combined with the use of the discharged brine as mixing liquid is a comparatively new technology.

Hydromechanical backfilling is, in comparison with drop backfilling and backfilling by big bags, a cost-saving technology and achieves a high stowing degree with good contact to the host rock.

The geomechanical properties of the backfilling material can be adjusted to some degree by selection of the adequate backfilling technology, the use of appropriate waste materials and the additional application of binders (e.g. cement, MgO).

4 General Requirements for Backfilling

The recycling of wastes as backfilling material or as component of backfilling mixtures in salt mines with accepted long-term safety proof depends on strict criteria which mainly concern aspects of safety and the requirements of work protection as well as health protection. The essential requirements for the backfilling materials are summarized in the Technical Rules to be applied to industrial wastes for backfilling by the Federal States Committee for Mining /TR 06/.

Wastes or mixtures that (if applied under underground conditions) are

- spontaneously flammable,
- extremely flammable, highly inflammable or flammable,
- explosive (or tend to be explosive),
- oxidizing or
- infectious

are excluded from underground backfilling. Nuclear wastes are equally excluded.

5 Work and Health Protection

The Ordinance on Hazardous Substances (GefStoffV), /Gef 04/ is valid for the handling of wastes on surface. The requirements of work and health protection in the mine are determined in the Health Protection Ordinance for Mining (GesBergV), /Ges 91/. According to § 4 para. 1 GesBergV it is forbidden to let people deal with materials and mixtures that are to be classified and marked as

- carcinogenic,
- mutagenic,
- toxic for reproduction or
- very toxic and toxic.

With respect to backfilling these criteria are only valid for the completed backfilling material. Wastes that show one or more of these characteristics can be processed as a component of the backfilling mixture if it meets the requirements of GesBergV. Recycling of highly odorous backfilling materials is not permitted either.

6 Verification of the Suitability for Backfilling in Laboratory Scale

Before the operator of a salt mine can apply for admission for the application of a special industrial waste as backfilling material, it has to be examined as to its characteristics relevant to backfilling

by an expert opinion regarding its suitability. This expert opinion also verifies the suitability of the examined waste as component of a mix design.

The following basic investigations are carried out in an expert opinion:

Phase 1: Examination of the waste properties

- Preparation of a chemical declaration analysis according to fixed standards taking into consideration the origin of the harmful substances
- Determination of essential physical parameters (humidity, densities, grain size distribution)
- Investigation of hazardous waste properties (e.g. flammability)
- Investigation of the gas forming behaviour (gas forming potential in highly acid and alkaline solutions, gas emission in contact with water and saline brines)
- Examination of the waste as to its characteristics as a binder in contact with brines
- Evaluating the waste according to legal instructions concerning waste management (VersatzV), industrial hygiene and chemicals (GefStoffV, GesBergV)

Phase 2: Evaluation of the waste as a component of a mix design

- Preparation of exemplary mix designs with the waste in laboratory scale, testing of the processing properties
- Examination of qualifying for backfilling under aspects of building physics (density, strength)
- Determination of the properties regarding mining safety (tolerance of backfilling materials among one another, hydrogen formation, behaviour against host rock)
- Evaluation of aspects of work protection of the backfilling mixtures

Figure 5: Determination of the flow extent of a viscous slurry mixture

Figure 6: Test sample of a hardened backfilling product

Expert opinions about the suitability for backfilling certify that the wastes examined show the same characteristics as building material as the natural resources they substitute and they also confirm

that there are no dangers arising from the harmful substances in the waste, when backfilling materials are produced and processed.

7 Summary

By applying mineral industrial wastes as backfilling measures in salt mines ordered by the Mines Inspectorates a kind of waste disposal has been created that provides a highly environmentally-friendly form of recycling industrial wastes by encapsulating them in a depth of a few hundred meters. As to environmental standards these backfilling mines meet the requirements of underground deposits in Germany. Such a high amount of environmental protection cannot be guaranteed by disposing of the wastes in other rock formations or by the deposition of wastes with or without pre-treatment (e.g. immobilization) on landfills on the surface.

The Backfilling Ordinance regulates the legal criteria concerning waste and the requirements of environmental protection as to the recycling of wastes as backfilling material.

Backfilling has been approved by the European Court as a form of recycling on condition that by means of a necessary measure natural resources are being substituted by industrial wastes and resources are protected (assigned backfilling).

The original qualities of wastes are used directly or for producing backfilling materials following special mix designs. For the backfilling procedure numerous technical possibilities can be applied.

An essential pre-condition for approving wastes for recycling or producing backfilling material is the analysis of their characteristics as to their relevance for recycling. That is usually carried out by means of an expert opinion checking the suitability for backfilling. If waste shows dangerous properties that do not allow its application for backfilling it is excluded from recycling. All approved wastes are regularly checked as to their quality.

Waste producers will be guaranteed maximum safety by German salt mines with assigned backfilling over a period of several years.

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