20th WORLD MINING CONGRESS & EXPO2005
7 – 11 NOVEMBER 2005, TEHRAN, IRAN
"Mining and Sustainable Development"

Substantial Aspects of the Recycling of Industrial Wastes as Backfilling Material in Salt Mines

Heiner Marx*
K-UTEC GmbH Germany
Heiner.Marx@kutec.de

Dittmar Lack
K-UTEC GmbH Germany
Dittmar.Lack@kutec.de

Wolfgang Krauke
K-UTEC GmbH Germany
Wolfgang.Krauke@kutec.de

ABSTRACT

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). At the example of the Sondershausen mine the numerous technical possibilities of applying wastes as backfill materials are demonstrated. The original qualities of wastes are used for producing backfill materials following special mix designs. An essential pre-condition for approving wastes for recycling or producing backfill material is the analysis of their characteristics as to their relevance for recycling.

Key words: Backfilling mine, industrial waste, waste management, suitability, salt solution, hydraulic backfilling, Big Bag-backfilling, drop backfilling, convergence, subsidence, long-term safety

INTRODUCTION

Backfilling means the back stowing of mines for safety reasons, mine cavities that have emerged from the exploitation of natural resources by mining. For a long time mining wastes (e.g. residues) as well as (to an increasing extent) appropriate industrial wastes have been used for backfilling.

Applying industrial wastes for backfilling is a special form of recycling waste which according to current knowledge base is being applied in Germany only. By passing the backfilling ordinance on 30th October 2002 standardized requirements were introduced in Germany. The backfilling ordinance determines certain requirements for waste management as well as the requirements of environmental protection with recycling wastes for backfilling. This was confirmed by the sentence of the European Court of 27th February 2002. The European Court states in its sentence that it is usually considered to be a recycling measure if natural resources are substituted by recycling waste.

Recycling wastes for backfilling in German mines as well as waste management have achieved a great importance in Germany and in some neighbouring countries within the past few years. This has resulted in an excellent opportunity for mines to protect resources and to reduce expenses and at the same time to fulfill the backfilling measures of completely or partially substituting natural resources (e.g. gravel, sand, binders) as required by the mines inspectorates. For waste management backfilling means an environmentally-friendly measure of recycling wastes as building material that are not allowed to be dumped on the surface (or only after an appropriate pre-treatment, e.g. immobilization) because of their content of harmful substances and their consistency (e.g. flue gas dusts, sludges, disposal brines).

THE BACKFILLING ORDINANCE „VERSATZ -V"

The backfilling ordinance regulates the recycling of wastes in companies that are controlled by the mining authorities.

According to § 1 VersatzV that is valid for:

- Waste producers and waste proprietors
- Managers of mines that are controlled by the mining authorities
- Producers of backfill material

In the backfilling ordinance the limiting values of harmful substances within waste and of the leaching behaviour have been determined with respect to environmental protection. According to § 4 Par. 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 check. Contact of wastes with aquiferous layers on the surface resulting in mobilising the harmful substances in wastes can definitely be excluded. This way salt mines meet the safety requirements of underground depots in Germany.
On principle the assignment values for the parameters TOC (organic carbon) and glowing loss of the organic components mentioned in table 1a of enclosure 2 are to be applied. In § 3 of the backfilling ordinance the predominance of utilizing wastes as secondary material for metal recovery is regulated. Recycling as backfill material is forbidden if the metal content (mentioned in enclosure 1) is surpassed, and if it is technically feasible as well as economical to permit the recovery of these metals applying the appropriate procedure.

BACKFILLING AS UNDERGROUND DANGER PREVENTION IN MINING

There are extensive mine cavities in Germany from the still active salt mining industry but also as a residue of the recovery of mineral salts which was closed down meanwhile. These mine cavities can endanger the infrastructure on the surface. This convergence leads to a subsidence along with a subsidence trough on the surface. There are some mining areas where subsidences of several meters are predicted if there is no backfilling. These subsidences may lead to damages in the infrastructure and at buildings but they may also lead to changes of the fluid lines of rivers.
Another danger is to be found in the latent risk of rock fall in those mines in which carnallite is mined as mineral containing potassium. Safety pillars breaking down can lead to a collapse of the whole mining site with effects similar to those of an earthquake.
A backfilling ordinance is passed by the mining authorities to prevent resp. to reduce dangers from mining for the mines concerned or for parts of these mines. The manager of the mine is responsible for the application of the ordinance.
According to § 4 Par. 3 of the backfilling ordinance it is principally taken into consideration to utilize industrial wastes but of course meeting its requirements.

RECYCLING OF WASTES IN SALT MINES SONDERSHAUSEN

One of the most important backfill mines is the mine in Sondershausen/Thuringia.

Figure 1. Backfilling plant in Sondershausen

Since 1996 backfill materials on the basis of industrial be backfilled. This has been done by the managers of the mine, the GSES mbH (a waste management company) in order to follow the duty of backfilling assigned by the Thuringian Mines Inspectorate. The GSES mbH provides all necessary mining and environmental permissions for the reception, the storage and the recycling of wastes on the surface, and, what is more, it applies the most commonly used technologies for both producing and backfilling of the materials as well as the common safety equipment of a backfill mine. Therefore the Sondershausen mine is highly suitable to present the essential aspects of backfilling.

BACKFILLING METHODS

Because of its active operating phase the mine Sondershausen has considerable experience concerning the backfilling of production waste. Whereas mining wastes were exclusively backfilled by hydraulic backfilling, today the following backfilling methods are applied:

- Hydraulic backfilling
- Big Bag-backfilling
- Drop backfilling (backfilling with bulk goods)

Because of its extraordinary effectiveness hydraulic backfilling is the dominant method of backfilling in the Sondershausen mine. Big bag-backfilling and drop backfilling just complement hydraulic backfilling.
The backfilling methods applied can be characterized as follows:

Hydraulic backfilling

Finely grained and grained wastes such as dusts, ashes, sands and sludges are usually processed into a flowable backfilling material mix with adding a concentrated salt solution. These backfilling material

mixtures are produced on the surface for days and according to various mix designs with a procedure of referring to material groups. The backfilling material mixtures are transported into the recoveries to be backfilled. The mixture remains in a reaction drum to reduce exothermal effects and a possibly existing gas production potential. After a residence time of 3 to 4 h on average the backfilling material mixtures are transported into the recoveries to be backfilled 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 reactants of the setting behaviour. The excess transporting solution drains the backfilling material by means of a dam construction resp. 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). The $MgCl_2$-content of the transporting solution applied in the Sondershausen mine has to amount to ≥ 240 g/l to prevent of partial dissolution of the safety pillars in the mine.
By means of hydraulic backfilling a nearly complete backfilling (> 90 Vol. %) of the mining sites is possible (figure 2 and 3).

Figure 2. Mining site backfilled by hydraulic backfilling - end of pipe –

Figure 3. Mining site backfilled by hydraulic backfilling - completed mine cavity -

In the figure 8 is shown the scheme of hydraulic backfilling in a salt mine

Big bag-backfilling

In the Sondershausen mine mainly wastes already packaged by the producer are recycled by means of big bag-backfilling (e.g. salts, mix products or backfill products). The big bags are transported into the underground via the shaft, and there lorries and big vehicles transport them into the backfilling chambers. Forklift-trucks install the big bags into the backfilling chambers in layers. Alternating storage with covering salts is applied to reduce the pores.

Figure 4. Backfilling of a mining site with big bags

Drop backfilling

Mainly wastes that can be backfilled without further treatment are recycled in drop backfilling (e.g. contaminated soil, construction waste, furnace waste). 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 5. Backfilling of a mining site with bulk goods

VERIFICATION OF THE SUITABILITY FOR BACKFILLING

Before waste is certified for recycling in the Sondershausen mine it is examined as to its characteristics relevant to backfilling by an expert opinion about its suitability for mining. If the single materials are positively evaluated a high number of wastes will be classified into one of the existing mix designs for backfilling that are applied by the GSES mbH to produce mixtures for hydraulic backfilling. The expert opinion mentioned above also verifies the suitability of the examined waste as component of a mix design.
The following basic investigations are conducted in an expert opinion about the suitability for mining:

- conducting a declaration analysis according to fixed standards taking into consideration the origin of the harmful substances
- stating essential physical parameters (humidity, density, grain size distribution)
- examining the waste as to its characteristics as a binder in contact with brines
- investigating the gas forming behaviour (tracing the gas forming potential in highly acid and alkaline solutions)
- evaluating the waste according to legal instructions concerning waste and chemicals
- evaluating the waste as a component of a mix design (verification of its suitability as a building material, evaluation of aspects of safety in mining and work protection

Expert opinions about the suitability for mining 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, the wastes contain, when backfill materials are produced and processed.
In addition the GSES mbH has to present to the Thuringian Mine Inspectorates a statement about hygienic in mining made by the Institute of Hygiene of the Ruhr Area (requirement according to special operation plan for backfilling). The Staatliches Umweltamt Sondershausen (Sondershausen environmental office) has a say in permitting waste to be recycled in the Sondershausen mine.

IDENTITY CHECKS

The GSES mbH checks the recycled wastes themselves. That is why a sample is taken from every delivery, which is organoleptically controlled and then recorded. Every six months an external certificated laboratory conducts an analytic control of the wastes according to parameters determined by the mines inspectorate. The results of the analyses are examined by expert opinions as to the identity of the waste, as to the wastes and the backfill mixtures meeting the requirements of the GesBergV and as to their qualities as building material. If a significant potential of forming hydrogen is to be found, random samples are taken for comparable measurements in external laboratories especially equipped for backfilling. In addition random samples are taken by the Thuringian Mines Inspectorate and the Sondershausen environmental office to check the identity of the wastes.

SURVEILLANCE OF THE BACKFILLING QUALITY

The solidity values of the inserted backfill are tested by regular measurements of the compression strength as dynamic modulus of deformation (E_{vd}). In the Sondershausen mine final values of a solidity of $E_{vd} \geq 40$ MN/m² have to be achieved for the backfilling methods applied. The quality of backfilling is further evaluated by drop-penetration tests and measurements of the shearing strength.

Figure 6. Measurements of the shearing strength and drop-penetration tests in hardened hydraulic backfilling

The solidity measurements are part of a documentation programme confirming the high quality of the backfill inserted in Sondershausen. They are conducted and evaluated by external experts.

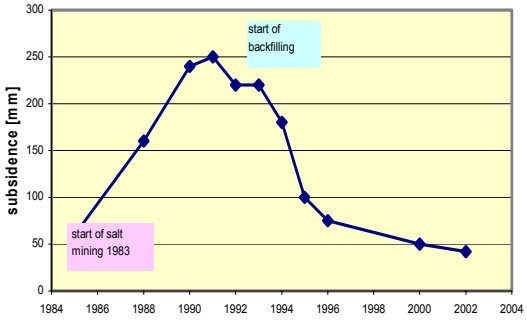

Figure 7. Development of subsidence on surface in Sondershausen, enlarged view in figure 9.

The effectiveness of the inserted backfill is regularly measured as to the stability of the safety pillars and by observing the development of subsidences on the surface.

CONCLUSIONS

By applying 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 backfill mines meet the requirements of underground landfills 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 backfill ordinance, passed in October 2002 regulates the legal criteria concerning waste and the requirements of environmental protection as to the recycling of wastes as backfill 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).

At the example of the Sondershausen mine the numerous technical possibilities of applying wastes as backfill materials have been demonstrated. The original qualities of wastes are used for producing backfill materials following special mix designs. Wastes from flue gas cleaning of waste incineration plants are of particular importance as because of their characteristic salt components they can be integrated extremely well into the mineralogical profile of salt mines. Another advantage is the function as a binder, if mixing waters containing salt are used.

An essential pre-condition for approving wastes for recycling or producing backfill material is the analysis of their characteristics as to their relevance for recycling. That is usually conducted by means of an expert opinion checking the suitability for mining. If waste contains dangerous properties that do not allow its application for backfill mining 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 decades.

REFERENCES

Behnsen, H., 2001, Abfallverwertung und -beseitigung im Kali- und Steinsalzbergbau: Schriftenreihe der GDMB (Association for Mining, Metallurgy, Raw material's and Environmental technology), Vol.88, 53-66

Krauke, W., technische Anforderungen an Spülversatzrezepturen mit Abfällen: Freiberger Forschungshefte A 855 Bergbau und Geotechnik, 69-81

Lack, D., 2001, Stowing of excavations in salt deposits by using waste material that has not arisen from mining: 11th EURO-ARAB conference for the environment, Rostock, Germany, 157-165

Pfeifer, P., Kohlhase, L., Tischbein, U., 2001, Verbringung von Abfällen mineralischen Ursprungs mittels Spülversatztechnologie als Pflichtversatz-aufgabe in der Nachbetriebsphase im Bergwerk Bleicherode: Freiberger Forschungshefte A 855 Bergbau und Geotechnik, 93-113

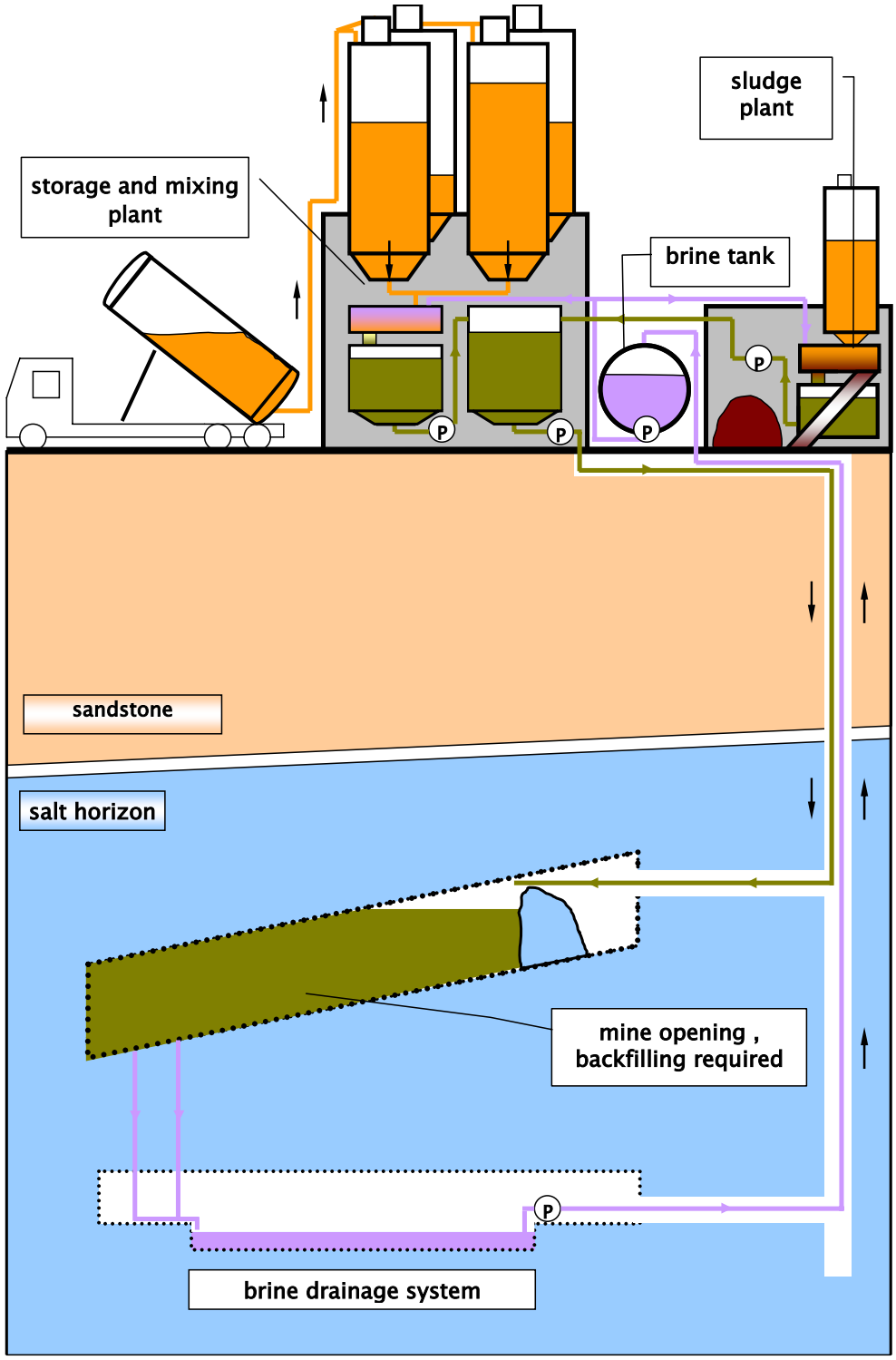

Figure 8. Scheme of the hydraulic backfilling with an excess of the additional solution in a salt mine

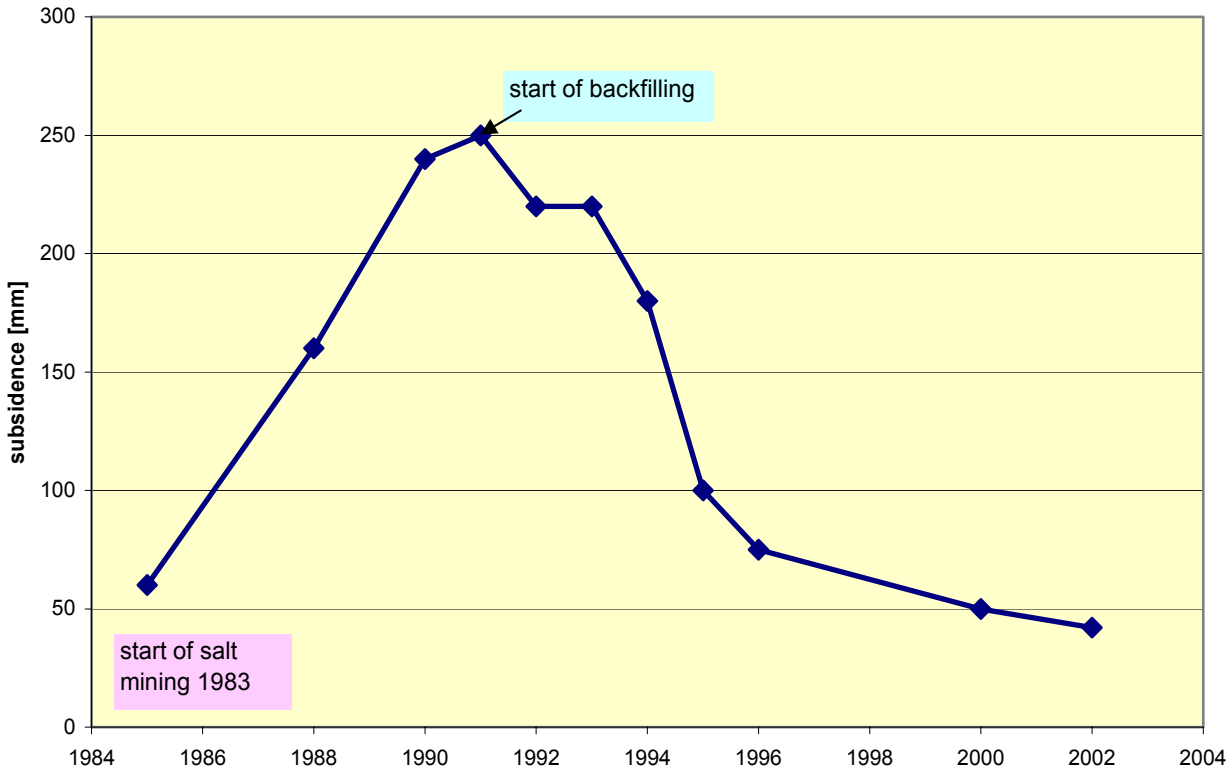

Figure 9. Development of subsidence on surface in Sondershausen