Backfilling waste material composites environmental impact assessment

by J. Kortnik*

Synopsis

Mining has always been, and still is, an activity which is vital for the development of mankind. This is because a predominant proportion of industrial products and energy is produced from raw materials that are excavated using mining methods. The need for environmental protection and the close proximity of urban settlements and mines in Slovenia have necessitated ever stricter requirements for the excavation of raw materials and the introduction of more environmentally-friendly mining methods. This is achieved by implementing a closed eco-technological cycle of raw material excavation within the scope of mining methods.

In surface mines, this means prompt reclamation of the degraded surfaces, and in underground mines the use of methods with minimized impact on the surface and on underground water. In underground mines, mining methods with backfilling installed according to the multi-barrier disposal system are the only ones that allow the possibility of implementing a closed eco-technological cycle of excavating raw materials. Various industrial waste materials are also included in the backfilling material in order to improve its strength properties.

Backfilling consisting of several different waste materials is produced in the form of a composite. Before backfilling consisting of waste material composites can even begin to be used in mines, an environmental impact assessment of its suitability for mines needs to be made. In order to make such an assessment, a pressure leaching cell and an open diffusion cell were made, i.e. a pressure leachate test and a sorption test were developed. The two cells and the developed tests will enable the study of the influence of backfilling on the environment if installed in an underground mine.

The pressure leachate test performed with the use of the pressure leaching cell simulates leaching from a consolidated backfill during the seeping of underground water into the backfilling material under pressure. The sorption test performed in an open diffusion cell simulates the flow of eluate leached from the backfilling material through the rock/geotechnical barrier. The two tests were developed in such a manner that they are performed either in succession immediately after one another, but they can also be performed separately at a certain time interval. The paper presents an assessment of the suitability of backfilling made of different waste material composites.

Keywords: environmental impact assessment, multi-barrier disposal system, waste material composites, pressure leachate test, sorption test, pressure leaching cell, open diffusion cell, eco-technological cycle, mining methods with backfilling.

Introduction

The demand for various types of industrial products and energy is increasing along with the world's population and economic growth. In spite of the increasingly important role of recycling in providing the industry with raw materials, we are still predominantly bound to ores obtained through mining as the source of these raw materials. Due to a constant increase in the demand for various minerals, new ore deposits are sought which would enable the use of mass mining techniques, while in already known deposits highly productive mining methods (MMs) have been introduced in order to reduce mining costs. In deposits in which the quantity and quality of the ores allow inexpensive mining, environmental impact is usually great due to intensive mining. This has caused ever louder demands for introducing environmentally friendly mining technologies[6]. For deposits which do not enable inexpensive mining and in areas where mines are being closed, appropriate rehabilitation work is required prior to final mine closure in order to ameliorate the impact of mining on the environment over the long term.

The mining of ores always has some impact on the environment, which means that technological procedures for mining and mineral processing must include as many elements of environmental protection[6] as possible. Surface mining must be combined with simultaneous rehabilitation of the degraded surface, and the effect of underground mining on the surface and release of harmful substances into the environment must also be minimized. This can be achieved through the use of mining methods with backfilling and the introduction

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of a closed ecological-technological mining method, i.e. by returning waste into the excavated spaces. Furthermore, various types of waste materials produced during ore mining and processing and certain secondary waste materials from the industry can be used to produce waste material composites (WMC)[4,5] for backfilling. Composites for backfilling must consist of those types of waste materials which have no detrimental effect on the environment, which must be proven using verified procedures and methods. This approach enables reuse of materials which would otherwise be deposited at specially built surface deposits. Mining methods with backfilling (MMBs) are therefore more environmentally friendly and show increasing promise for the future.

Backfill suitability assessment (BSA)

A backfill suitability assessment (BSA) of waste materials for use in mines consists of the following partial assessments:

- assessment of the suitability of waste materials (AWM)
- assessment of the suitability of WMC as backfilling materials (AC)
- assessment of the rock as a geological/technical barrier after backfill installation in the mine (AR)
- assessment of the geotechnical properties of installed backfill (AG).

The AWM serves as the basis for the preparation of the catalogue of backfilling materials[8]. It comprises the codes, names and descriptions of waste materials and their properties; description of previous or additionally required processing of waste materials or justification for the omission of prior processing; and findings concerning dangerous properties of waste materials. The AWM is based on analysis of the situation concerning waste materials and on chemical analyses. It comprises sampling and leaching of waste materials and measurement of waste and leachate parameters as part of the chemical analysis.

The AC is based on testing of the composite in the pressure leaching test (PLT)[8] using the pressure leaching cell (PLC) and on the chemical analysis of eluate parameters. The PLT also enables the determination of certain geotechnical parameters of an already installed backfill.

The AR, i.e. assessment of rock as a technological/ technical barrier after backfill installation in the mine is based on the sorption test (ST)[8] in an open diffusion cell (ODC)[2] and on the chemical analysis of leachate parameters. The ODC also enables the determination of some geotechnical parameters of backfill. The AC and AR assessments can be performed simultaneously after backfill installation.

The AG is based on the determination of geotechnical parameters of the backfill.

The use of WMC backfills in mines is not permissible if:

- individual assessments show that its use would be inadvisable
- interactions with the previously installed backfill would increase the risk of environmental pollution
- the AG of the backfill and conditions for backfill installation do not guarantee the required stability of the stopes
- a BSA has not been made.

Pressure Leaching Test (PLT)

The Slovenian Regulations on Waste Deposition[7] prescribe only the DIN 38414/4 for the leaching of granulated, solidified, pasty or sludgy waste. In practice, however, tests ÖNORM and stand leaching test (SIT) and also the total leachable amount test (TLAT) are used to test for leaching of solid and monolithic waste. Since the conditions in which leaching takes place in backfills installed in mines differ from those simulated in the above-mentioned tests, the pressure leaching test (PLT) was developed. This test simulates the conditions of leaching into the old part of the stopes of an installed backfill and belongs to the group of dynamic leaching tests[1].

The following two types of test cells were developed and produced for the PLT:

- Pressure leaching cell (PLC)
- Open diffusion cell (ODC).

When the PLT is performed, the two cells are connected in succession, but they can also be used separately.

The use of a PLC enabled us to establish similar conditions to those which are present during and after consolidation of a backfill installed in the old part of the stopes, and simulates leaching after the penetration of groundwater into the old part which is consolidated with a backfill. The PLC was developed to study the leaching of partially bound granulated and solidly bound or monolithic samples. During measurement of the leaching parameters, PLCs can also be used to measure the initial hydraulic gradient, the coefficient of permeability, and the porosity of backfill samples.

The use of multicompartmental systems of backfill installation into MMBs requires an additional study of the rock as a geological and technical barrier. In order to be able to study the influence of rock as a geological and technical barrier on the eluate, an ODC was produced according to the description of Hume[2].

The measurement of sorption, the coefficient of diffusion and distribution coefficients for heavy metals and other impurities during the flow of eluate through rock is used to determine the mobility of individual substances and study the isolating properties of geological and technical barriers. In ODCs, diffusion takes place in the form of a uniform infinite flow.

Comparison of the results of various leaching tests

In order to be able to check the results of the PLT, a comparison was made with some of the most widely used static leaching tests:

- Stand leaching test (SLT)
- Total leachable amount test (TLAT)
- DIN 38414/4 test (DIN).

Comparisons of the obtained results of content analyses for eluates from different leaching tests have shown only partial deviations from the permissible values. Among all tests, TLAT results deviate the most and exceed some permissible limits, which are not exceeded in other tests, and vice versa. In the PLT, element contents of eluate samples are usually higher than those in other leaching tests, but this is not a rule. In separately taken PLT eluates, one usually

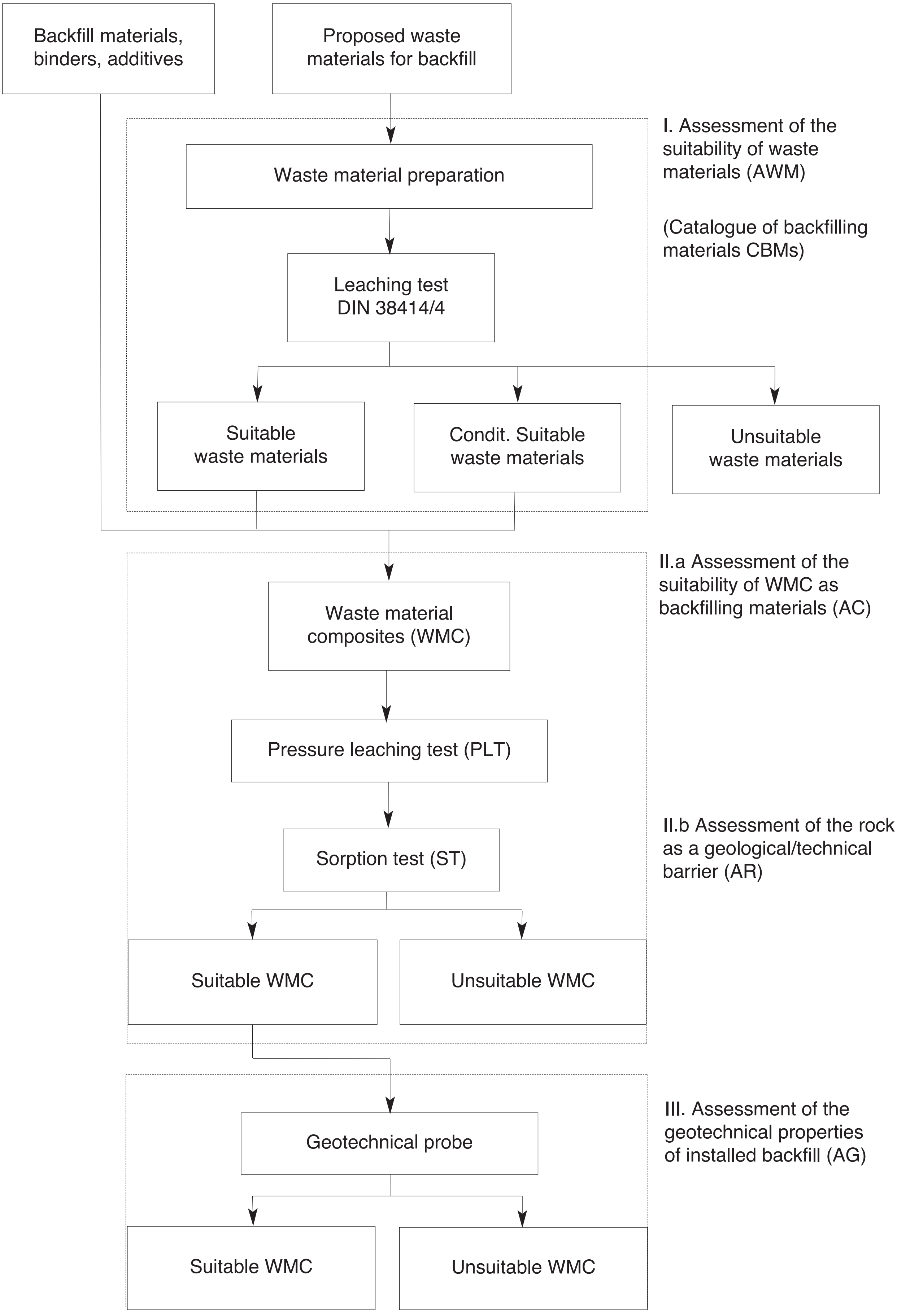
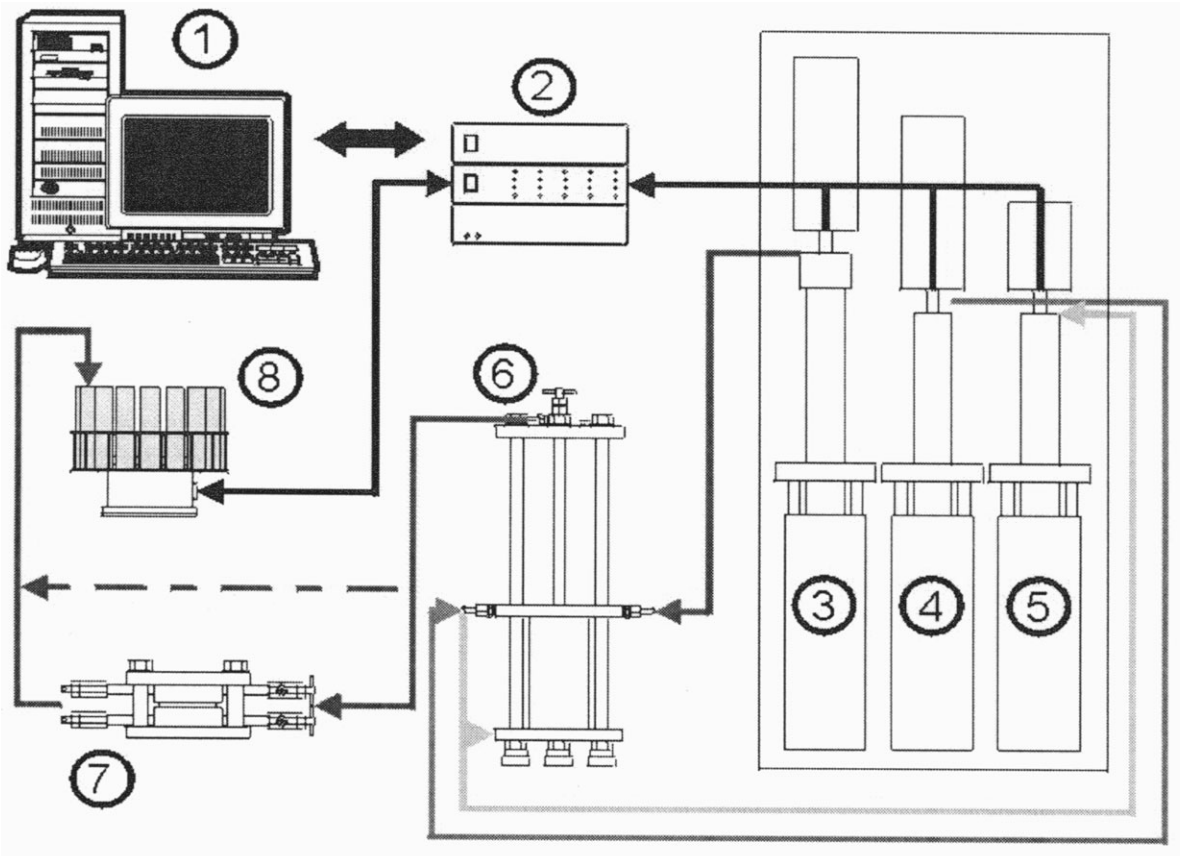


Figure 1—Schematic representation of the proposed BSA procedure



1 Equipment for data capture, imaging and processing
2 Electronic measurement system
3–5 Drive unit
3 Water injection into the sample
4 Horizontal pressure on the sample
5 Axial pressure on the sample
6 Pressure leaching cell
7 Open diffusional cell
8 Automatic scale for separate eluate sampling

Figure 2—Schematic representation of PLT equipment

Table I

Possible applications of the PLT

Areas of application	Main objectives	Determination of individual parameters
Assessment of environmental impact	Determination of the leaching time of solid bound backfill installed into the old part of the stopes	Leaching as a function of time and the L/S ratio
		Effects of the pH, redact potential, DOC, etc. on the degree of leaching
	Determination of the total amount of contaminants which can (potentially) be leached from all of the backfilling material	
Verification of measurement results		Total amount of contaminants present in the eluate in extreme conditions
	Verification of compliance of the eluate with the regulations in force and other special requirements	
Catalogue of backfilling materials	Classification of the types of waste into groups with respect to leaching properties	Compliance of the contaminants with the prescribed maximum concentrations

encounters exceeded permissible limits also for those elements which ordinarily do not present a potential risk for exceeding the waste and water pollution limits for the total amount of the eluate sample.

Conclusions and plans for the future

Before backfilling consisting of waste material composites can even begin to be used in mines, an assessment of its

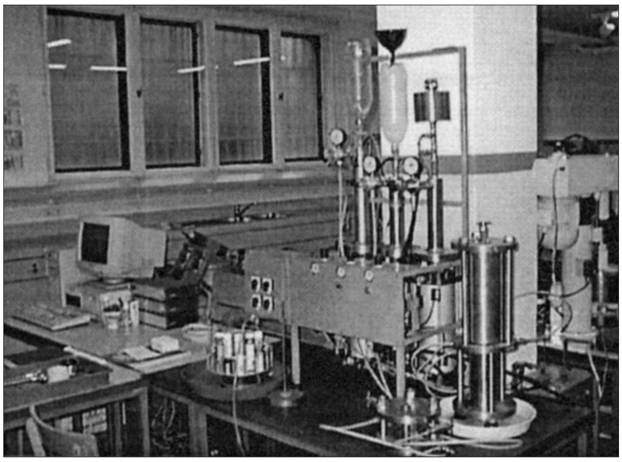


Figure 3—PLT equipment

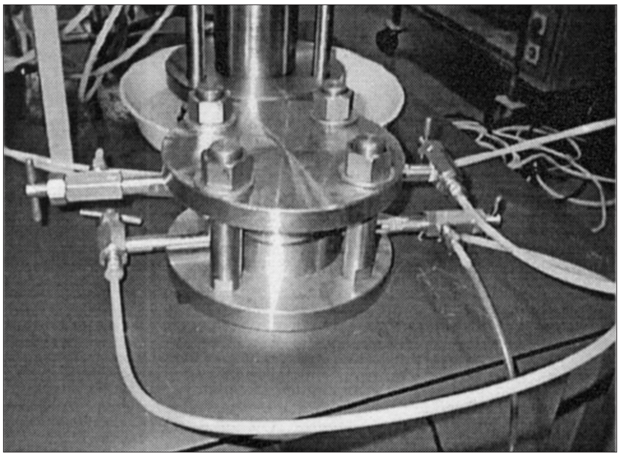


Figure 4—Open diffusion cell (ODC)

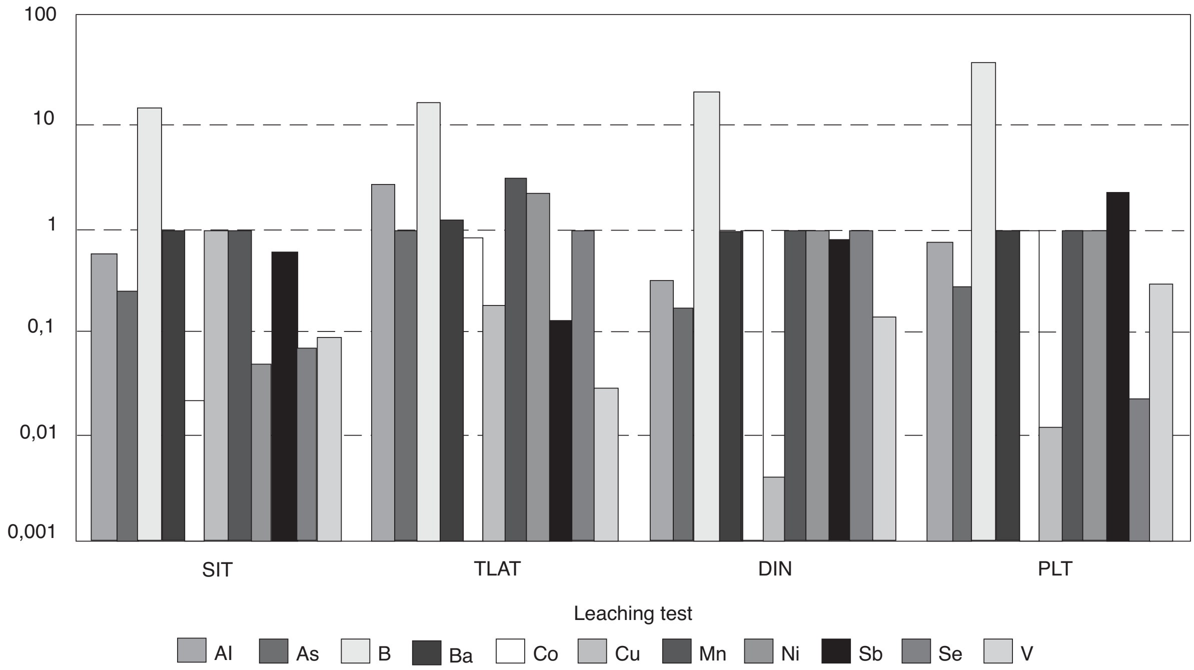


Figure 5—Comparison of the results of different leaching tets

suitability for mines needs to be made. In order to make such an assessment, a pressure leaching cell and an open diffusion cell were made, i.e. a pressure leachate test and a sorption test were developed. The two cells and the developed tests will enable the study of the influence of backfilling on the environment if installed in an underground mine. The pressure leachate test performed with the use of the pressure leaching cell simulates leaching from a consolidated backfill during the seeping of underground water into the backfilling material under pressure. The sorption test performed in an open diffusion cell simulates the flow of eluate leached from the backfilling material through the rock/geotechnical barrier. The two tests were developed in such a manner that they are performed either in succession immediately after one another, but they can also be performed separately at a certain time interval.

Leaching of a WMC backfill installed in a mine takes place under special conditions, which also need to be taken into account when leaching is simulated in a laboratory. These primarily include consolidation of the backfill after installation, various leaching scenarios after penetration of groundwater into a consolidated backfill, and the influence of rock as a geological and technical barrier on the eluate parameters. The leaching tests (DIN, SLT, TLAT), which have been used so far for BSA, simulate various leaching scenarios, but do not include backfill consolidation and penetration of groundwater into the backfill.

The Slovenian Regulations on Waste Deposition[7] prescribe the use of a DIN 38414/4 test for leaching of waste materials (with the use of demineralized water under predefined conditions). The DIN test simulates the processes which take place in the backfill due to specific physical properties of the backfilling material and dissolving and changing of the chemical structure of various heterogeneous substances in contact with the eluent, but does not simulate the conditions established after backfill installation and consolidation in a mine. For this reason, the PLT was developed for the assessment of WMC backfills and it simulates leaching of a consolidated backfill after the penetration of groundwater into it.

The developed pressure leaching and open diffusion cells, the pressure leachate and sorption tests, and the proposed assessment of the suitability of backfilling for use in mines must all be integral parts of planning for the use of backfilling in mines, and can also be applied to waste deposition at underground deposit sites. They can also be used for planning surface waste deposit sites and temporary waste deposit sites, as well as other waste management procedures and studies of environmental impact under various conditions of waste deposition.

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BATEMAN Pneumo-Drier installed at Anglo Platinum mine*

The BATEMAN Pneumo-Drier installed recently at an Anglo Platinum mine near Rustenburg is the first full-scale plant to be used in the platinum industry to simultaneously convey and dry particulate solids. With a total conveying capacity of 96 t/h it is, to date, the largest Pneumo-Drier system to be supplied by BATEMAN.

The order for the system was placed by Hatch Africa Project Managers following a successful pilot-plant at another site. The system comprises two separate trains, each feeding 48 t/h of material to the converter-slag and the furnace-matte plants. Each train contains two parallel Bateman Pneumo-Driers with a capacity of 24 t/h. With parallel units, production losses will be minimized if either one fails. Approximately 4 MW of installed power is used to reduce the moisture content of the 96 t/h feed of platinum matte and slag from 15% to zero.

The BATEMAN Pneumo-Drier dries a wet particulate solid while conveying it along a pneumatic-conveying system driven by air heated up to 350°C, depending upon the properties of the solid. The material is enclosed from the time of entry until rapid delivery, with few handling stages, enhancing product security and preventing contamination of either the product or the surrounds.

A Roots-type positive-displacement blower with variable-speed drive propels the conveying/drying air into the inline heater (electrical or heat exchanger) and to the feeding tee. A small amount of blower discharge air is bled off to the feeder sub-system, to protect the rubber pinch valves and compensators from over heating, and then re-enters the system via the feeding tee. This arrangement provides the necessary airlock between system overpressure and ambient conditions. A vibrating-tube feeder then batch-feeds the material through the feeding tee into the conveyor pipe where it is dried while being transported to the knockout bin, where it cools as it free-falls in a large volume of low-velocity secondary (ambient) air. The latter is extracted from the bin into either a dust-filtration system or wet/dry-scrubber system, while the dry material is conveyed pneumatically to the storage silos.

Used predominantly in the diamond industry to handle kimberlite (diamondiferous ore), alluvial diamond ore and marine silica, the BATEMAN Pneumo-Drier has also successfully conveyed and dried other materials such as coal, foundry sands, salt and crushed rubber.

In many instances it has replaced traditional rotary, infrared and fluidized-bed driers because of its capital, operating cost and downtime advantages. It is simple, robust and compact, requiring less headroom than conventional drying systems. The flexibility of the pipe routing allows for easy retrofitting into the existing establishments. Continuous on-line temperature monitoring and accurate product dosage maintain system efficiency.

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