

## INDUSTRIAL WASTES AND ECONOMICS OF THEIR UTILIZATION

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The contribution deals with the utilization of industrial wastes, especially from mining and metallurgical enterprises. The wastes are being processed into the form of hydraulic non-washable stowing which can be deposited in the closed underground mines. The economic aspects of this activity which compete with depositing of non-processed industrial wastes on surface stockyards are considered here.

**Key words:** *industrial wastes, hydraulic stowing, underground coal mines, economic result*

**Industrijski otpad i ekonomija njegovog iskorištavanja.** Ovaj rad je doprinos problematici iskorištavanja industrijskih otpada, naročito iz rudnika i metalurških poduzeća. Otpadi se obrađuju hidraulički u oblik neisperivih naslaga koje se mogu odlagati u zatvorene podzemne rudnike. Ovdje se razmatraju ekonomski aspekti ove aktivnosti koja konkurira odlaganju neprerađenih industrijskih otpada na površinskim dijelovima odlagališta.

**Ključne riječi:** *industrijski otpadi, slaganje hidraulikom, podzemni rudnici ugljena, ekonomski učinak*

### INTRODUCTION

The economic development after 1989 in existing Czech Republic as well as Slovak Republic was characterized by (1) reduction of demanding processes as to the material and power connected with closing of production capacities (2) more proper application of economic and ecological criteria in decision making processes.

The operations were left closed. However, after years of their activity, a huge quantity of industrial wastes, especially in the areas where the mining, metallurgical and chemical industry developed in the past. From the total quantity of waste which was produced in the Czech Republic 60 % of industrial wastes and 96 % of communal wastes are deposited on surface stockyards [3, 4].

The stockyards hold the land, deface the landscape and their stability makes problems, e.g. in case of floods or landslides. The ecological and safety risks, however, are connected also with the closed enterprises, especially the underground coal mines. The mining liquidated capacities jeopardize the environment, property and safety of persons by outflow of mineralized waters, outlet of mine gases, destruction of rock massif, surface subsidence.

The problems connected with industrial wastes as well as closed underground mines can be solved today, and it had

already occurred in the past - this is a question of stowing of underground spaces with hydraulic non-washable stowing produced of „classical“ materials as e.g. flotation waste rocks and power plants or heating plants ashes.

In last years, also other industrial wastes have been used for this purposes - e.g. sludge from the blast-furnace gases washing in metallurgical plants, dust from filters from foundries.

### UTILIZATION OF INDUSTRIAL WASTES

Utilization of „classical“ industrial wastes from coal preparation or utilization was possible because the mixtures created in such a way did not worsened the ecological parameters of mine environment, especially they did not increase the content of harmful substances in mine water. That is why it is necessary to emphasize that this is not a question of depositing of non-processed wastes in the underground. The depositing of non-processed industrial wastes especially the wastes of dangerous character in underground mines with the possibility of flooding with mine waters would be the worse variant than their depositing on surface.

The recent research works proceeded in the way of treatment - solidification - of industrial wastes with further components so that the resulting mixture would meet the ecological criteria, especially the class of extractability. The hydraulic stowing created in such a way represents the specific type of concrete mixture composed of clastic material, binder and water.

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As classic materials the following ones were used: blast-furnace and steel-making slag, dust removal products and sludge, the foundry ashes used, ash from coal combustion, dust removal products and sludge from stone and aggregates processing, other mineral sludge from metallurgical processes, wastes from waste water treatment plants, contaminated soils.

Among the binders the following ones can be included: dust from cement production, dry ashes from classical and fluid beds, power-gypsum, lime sludge from the acetylene production etc.

The research works in the sphere of creation of stowing mixtures did not remain on laboratory level but thanks to the firm GEMEC s.r.o. they got the realization form. In the year 1993 the firm took over the Jan Šverma Mine for liquidation in East Bohemia and this liquidation was carried out with the help of a new method - filling in of free mine spaces with hydraulic non-washable stowing produced on the basis of industrial wastes. The mine workings were filled in in separated sections in such a way so that the remaining part could serve further for transport of outfit dismantled, ventilation and check activity. The experience showed that it came to significant reduction in mine gases exhalations, to lower contamination of mine waters flowing through the areas with significant content of sulfates and iron, the landslides were limited significantly.

Because of the fact that the mentioned firm is the business subject, the condition for industrial wastes utilization for stowing of underground mines is the economic advantage of these activities.

## ECONOMICS OF INDUSTRIAL WASTES UTILIZATION

Laboratory research as well as practical experience of preceding years, in a substance, have solved the problems of industrial wastes processing and depositing of hydraulic stowing mixtures created in such a way into the closed underground mines. To a certain extent, also the legislative questions are solved so the practical realization of these activities depends on economic effectiveness of their carrying out. In considering of economic effectiveness, it is possible to base on two model situations:

1. The processor of industrial wastes (business subject) produces the stowing mixtures from industrial wastes taken off, whereas the originator of these wastes pays for their taking off to the business subject. The economic effect follows from difference of revenues for the industrial wastes taken off and costs for their processing, transport and depositing in the underground including - in most cases - settlement of continuing costs connected with the underground mine operation. It can be presupposed theoretically that these continuing costs can be settled by the mine operator in connection with

mining phasing out and course of liquidation works in the underground. Because of the fact that the industrial wastes processing is competition activity compared with the wastes depositing on surface stockyards in the non-processed state the price paid to the industrial wastes processor must be lower than the price for waste depositing on surface stockyard.

2. Processor of industrial wastes (usually the mine operator) makes use of its own industrial wastes (the wastes from the coal preparation, as a rule) so payments are made for industrial wastes taking off. The difference between the costs saving which the mine operator need not expend and costs for processing, transport and depositing of industrial wastes processed can be considered as economic effect. The costs saving is connected with mine damages, reclamation and restoration of the space being mined what is the consequence of non-carrying out of stowing of underground mine spaces.

The following structures of stowing mixtures were taken into account for concrete calculations of economic results of industrial wastes processing and depositing of mixtures arisen in the underground:

- mixtures arisen from foreign wastes: (i) ash, sludge from gases washing (ii), ash, sludge from the waste water treatment plants (iii) ash, foundry sand, sludge from gases washing (iv) binder purchased, power-gypsum with the content of heavy metals, foundry sand,
- mixture arisen from the own wastes: flotation waste rocks.

As the basic variables for simulation calculations of the following ones were considered: continuing costs of a mine being liquidated (i.e. costs of necessary operation of equipment in a mine and on surface of locality being closed and costs for activities connected with management of a mine being liquidated), capacity of stowing (i.e. volume of mixtures stowed per day) and variable costs for creation, transport and stowing of unit of stowing mixture. These basic values corresponded with indicators currently achieved in purchase of industrial wastes, their processing and stowing in the underground of mines.

The results of the first step of simulation calculations showed:

- in making use of the own industrial wastes no means for covering of variable costs are created so the economic result of this activity would be negative,
- in processing of foreign industrial wastes the positive economic results are achieved only under the situation when the continuing costs of a mine being liquidated are settled by its operator and not the industrial wastes processor.

That is why it was found out, in further step of simulation, what the values of prices for industrial wastes tak-

ing off, continuing costs of a mine being liquidated and capacity of stowing would have to be such ones that these variables taken separately would lead to positive economic result. But the calculation showed that none of parameters considered separately provided satisfying values, getting near to reality.

That is why, it was found out, in a further step of simulation calculations what combination of values of basic variables, which differ from the basic values will, ensure positive economic result. The mixture being created from ash and sludge from waste water treatments plants seemed to be promising. Where, compared with the basic parameters, the single variables were as follows:

- price from take off by 10 % higher,
- continuing costs by 27 % lower,
- capacity of stowing by 21 % higher.

The positive economic result can be got by acceptable deflection from basic values of input parameters which were considered as achievable in practice.

So the calculations showed that reaching of positive economic result, under situation when the processor of industrial wastes must settle the continuing costs of a mine being liquidated, is connected with processing of „more expensive“ industrial wastes. In conditions of the Czech Republic this is a question of wastes for take off of which the wastes originator pays more than 55 USD per ton.

The research works in last years were focused especially on extension of industrial wastes kinds utilizable for creation of hydraulic stowing mixtures for stowing of underground spaces. The parameters of the mixtures being created and prices for taking off of single industrial wastes, however, influence the economic results of industrial wastes utilization process. Given methodology of economic evaluation should be used as the last step of laboratory research determining the recipes of mixtures produced from industrial wastes for usage as stowing material in underground mines liquidated. The goal of economic evaluation is the proving of economic feasibility of procedures being proposed.

It is also important, for practical realization, to compete with depositing of non-processed wastes on surface stockyards, so:

- to set the prices of industrial wastes taking off from their originator under the level of prices required by the firms depositing the non-processed wastes on surface stockyards,
- to ensure contractually the deliveries of relevant industrial wastes in longer time horizon. It seems to be

absurd, on the first sight, to aim at obtaining a sufficient quantity of waste, however, in this situation the industrial waste ceases to fulfill the role of unnecessary thing and becomes the important secondary raw material.

## CONCLUSION

The results of laboratory researches as well as practical experience showed that processing of large-volume industrial wastes into the form of hydraulic stowing mixtures and their utilization in underground spaces of underground mines being liquidated is the way of solution of two groups of problems:

- ecological and safety ones connected with the existence of left underground spaces,
- ecological problems connected with industrial wastes.

The existing legislation of the Czech Republic makes the mining companies responsible for mines with the mining finished only in short time period after the locality closing. If the situation occurs that the mine operator becomes responsible for mining locality without time limitation, it can be presupposed that the stowing of underground spaces will become an integral part of the deposit exploitation technology. Its economic evaluation then should be an integral part of these activities management process.

Application of these procedures is not limited only on underground coal mines, because also the ores mining industry meets the similar problems, and the stowing mixtures can be utilized also in reclamation of open pit mines with the mining activity finished.

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