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EVALUATION OF DIFFERENT CONCEPTS FOR UNDERGROUND DISPOSAL OF CHEMICAL- TOXIC WASTE

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ABSTRACT: The lecture "Evaluation of different concepts for underground disposal of chemical-toxic waste" tackles the difficulty with evaluating waste management plants. With use of the system analytic approach AKUT, developed at the Institute of Mining Engineering I of the Aachen University of Technology, it is possible to subject waste management plants to a holistic evaluation In this process, the evaluation is exerted via value analysis.

1. INTRODUCTION

A well-ordered waste disposal is of existential relevance to an industrial nation with a high population density, such as Germany. Even in the case of an optimum exploitation of all possibilities for waste avoidance and (re-)utihsation, the large body of waste to be disposed cannot be entirely reduced. At present, technical concepts in

- surface and
- underground

waste disposal are pursued

The option of surface waste disposal is limited by a reduced space capacity of surface waste disposal plants, increased public sensitivity in recent years and consequent difficulties in approval procedures For this reason the possibility of underground waste disposal is becoming a more and more important and attractive alternative to surface waste disposal

The term "underground waste disposal" means in our case both, the (re-)utılisation, i e the waste is used as stowing and the removal of waste For this, widely different methods and procedures are used Waste disposal plants are planned and executed individually, since they consistently have to fulfill the needs of specific conditions. That is why the evaluation of such plants which is essential for the selection of an optimal concept requires a systematic appioach

So far, this could only be realized in an incomplete way because of overlapping statements and varying definitions This is the reason why the Institute of Mining Engineenng I at Aachen University of Technology was asked to carry out not only a systematic comparison of underground waste disposal concepts for chemical-toxic waste, but also an evaluation of those concepts This project is now realized within the frame of the support program "research and development for the waste management of hazardous waste in deep geologic formations" of the Federal Ministry for Education, Science, Research and Technology (BMBF) The recently established research group AKUT (which stands for underground waste disposal concepts) took into consideration both, already realized concepts as well as generally conceivable concepts, based on domestic and foreign information.

In order to work on such complex constructions comprehensively, methods and procedures of system science would provide a solution

2 SYSTEMATIZATION

Basing upon a system scientific point of view, interdependences and effects within the construction of underground waste disposal plants can be discerned and displayed With this, it is possible to perform a holıstıcal evaluation

The system analyuc view offers a generally valid presentation of disposal plants as it is displayed in Figure 1 (Walther, 1994)

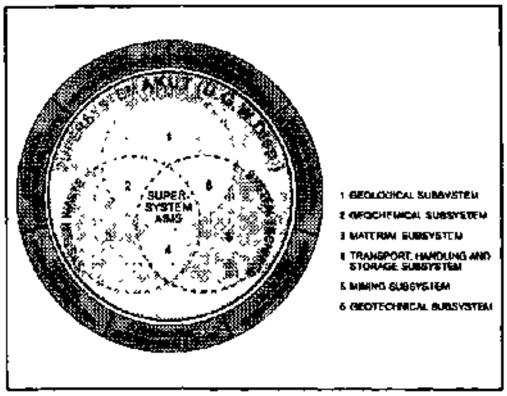

Figure 1 Supersystem AKUT

In consequence of the hierarchical order, the overriding supersystem AKUT encloses three minor systems i e. waste, rock, and technics

Supersystem goals are allocated to the supersystem AKUT Principal goals are the protection of humans, protection of the environment, protection of mineral deposits, and the economising of profit contribution. In this respect, each of the three systems is not capable of achieving the supersystem goals on its own. Only with the knowledge of the mterdependency of particular systems, assertions concerning the completion of those goals can be made

The overlap of systems leads to the formation of six subsystems, combining requirements which have on the completion of the supersystem goals influence (concerning safety, economical or technical aspects) In particular, these subsystems are the geological subsystem, the geochemical subsystem, the material subsystem, the geotechnical subsystem, the mining subsystem as well as the transport, handling and storage (i h s) subsystem (Figure 1)

Geological subsystem. The geological subsystem consists, for instance, of requirements ıelated to the fields petrography, stratigraphy, tectonics, hydro-geology and geodynamics These CHII be planar extensions of barriers, sufficiently light permeability of the overlying rock, and sufficient thickness of layers in which the waste has to be disposed.

<u>Geochemical subsystem.</u> The nature of waste also exerts its influence on the geochemical subsystem. It is, for instance, claimed that the waste should behave together with the rocks in a way that no damage to the biosphere has to be taken into account.

<u>Material subsystem</u> The material subsystem subsumes the knowledge about the requirements which the property of the waste to be stored has to fulfill in order to suit an underground disposal for instance the wastes should be incombustible and consistent with each other.

<u>Transport handling and storage subsystem.</u>The transport, handling and storage system allows the interaction between waste and technics, such as considering the possibilities of storage and transport technics for different types of waste Requirements defined from this point of view are, for instance, that no influence on the environment may originate from the transportation device itself or from the material to be conveyed.

<u>Mining subsystem.</u> The mining subsystem contains entire measures towards production, preservation and discarding of single disposal opening or opening systems. Further measures are the operational functions, such as ventilation and drainage. Requirements of this subsystem are, for instance, the technique for producing apt openings as well as linking of these openings to a supply and disposal * structure.

<u>Geotechnical subsystem</u> The geotechnical sub-system represents the interaction between rock and techniques, as can be examplanly discerned from the stress distribution m rocks in connection with different underground cavity shapes Within this subsystem, the requirements are defined from a biotechnical point of view, such as the position of different disposal openings in relation to each other

A waste disposal system is, on the exterior, connected to its surrounding (in the following to be coined as surrounding system) and is being influenced by it Belonging to the surrounding system are the political surrounding system (e g the determination of disposal paths), the economic surrounding system (c g. the amount of waste), the political economic surrounding system (eg the levy of lees loi special waste), the legislative surrounding.

system (e g legal regulations concerning waste), the geographic surrounding system (e g transport paths, topography), the technical surrounding (e g the state of technology) and the sociological surrounding (e g acceptance among the public)

This generally valid approach enables an evaluation in safety, economical and technical respect As an example for the evaluation, the following mining subsystem in relation to the supersystem goal "protection of the biosphere" is presented

3 DELIMITATION OF THE MINING SUBSYSTEM

All procedures that are neither directly influenced by the waste system nor by the rock system are part of the mining subsystem

These are (figure 2)
- number of accesses from the surface
- shaft lining
- number of accesses to the different disposal openings
- horizontal barriers

vertical barriers

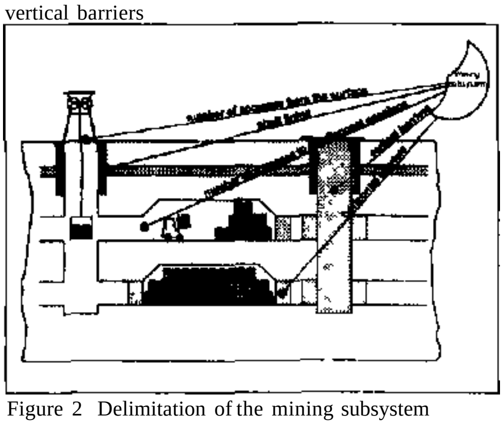

Figure 2 Delimitation of the mining subsystem

After defining the system limits a suitable évaluation method have to be chosen

4 ME fHOD AND PROCEDURE 01 EVALUATION

Various demands have to be fulfilcd tor an evaluation procedure of Ihe mining subsystem Some of the most import anl characteristic winch such an evaluation procedure should provide ate mentioned as follows

- a system of goals or values has to be determined
- the scale of utility of the goals has to be ordinal
- the utilities of the goal enterions have to be independent from each other
- the total utility of each alternative to be evaluated has to be calculable by addition of its partial utilities
- the total of all partial utilities has to be equal to the total utility of each alternative

Amongst other evaluation methods scoring models combine those characteristics in one evaluation method They have been employed for the evaluation of the mining subsystem

In general the scoring procedure works as follows (Weber et ai, 1995)
1 definition and structuring of the goal system (goal catalogue and goal structure)
2 goal weighting
3 score placing for the existing distinct alternatives
4 combination of scores and weightings
5 determination of the partial utility value
6 sensitivity analysis

These steps for an evaluation with the sconng model will be described by the following

Definition and structuring of the goal system At the outset of the evaluation of alternatives, tne drawing-up of the goal system relevant to the decision problem was entirely completed The goal system has to contain all goals contributing to the fulfilment of Ihe major goJ (protection of the biosphere) The only restrictions of the goal system were made exclusively by previously determined system limits o) each specific subsystem Hrst goals found were at first written down in unananged order and less specifically Ihe ascertainment of relevant goals was exerted with the help of literature on the subject, expert conversation and discussions wilhin the working group AKUI In the next step, possible oveilaps of particular goals were eliminated and the cleaied-up goals weie summed up in a catalogue This goal catalogue, which contains iclevant goals for the fulfilment of the major goal, however, registers these goals m a merely unananged and very global way In a second step the goal structure was developed (I iguie Ï)

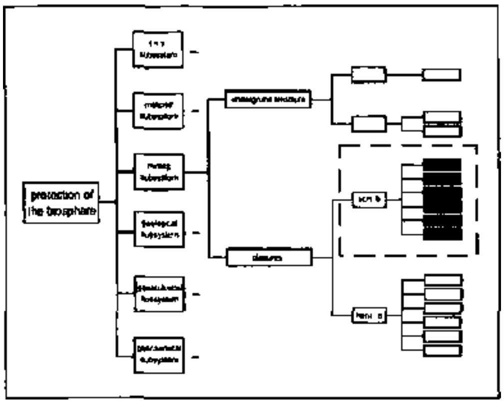

Figure 3 Goal structure

For this, the goals enclosed in the goal catalogue were sorted according to their character of fulfilment A differentiation was drawn between "must"- and "can"-goals, which were separated from each other "Must"-goals were not taken up in the goal structure but viewed in isolation They are used as knock-out cntena m the run-up, in order to rule out unreahsable alternatives at an early stage and to optimise the expenditure of work

In complex systems, such as each of the subsystems, the objective generally includes several "can"-goals When there were several competing goals it was necessary to organize them hierarchically This was performed by means of developing the aforementioned goal structure For this, it was at first scrutinised whether the prerequisites for the definition of a goal structure, namely the completeness of goals and their independence from each other are fulfilled

After scrutinising, the vertical division into diverse goal levels of decreasing complexity was performed Then, the horizontal division into different goal areas was made The procedure consisted of searching for suitable generic terms and closing of existing gaps

The supersystem goal "protection of the biosphere" constitutes the first goal level It has to be fulfilled by relevant properties of the following six subsystems as mentioned before

- geological subsystem
- geocheinical subsystem
- material subsystem
- transport, handling <tnd storage subsystem (l b s)
- mining subsystem
- geotechnical subsystem

This is the second goal level

The examined mining subsystem has to meet the requirements of

- the underground structure and of
- the closures

This is the third goal level
As an example, I would like to define the subsystems for the closures
Under the term "closures" fall

- vertical barners
- horizontal barners

that were assigned to the 4th goal level

The vertical barners again, on the fifth goal level, are viewed upon under the following goal-cntena (Figure 4)

- permeability of the barrier
  cntenon coefficient of permeability (m/s)
- resistance to honzontal stress
  cntenon set safety factor
- adaption to rock movement
  cntenon E-modul (N/mm^2)
- resistance to vertical stress
  criterion set safety factor
- temperature resistance to temperature of virgin rock
  cntenon set safety factor
- corrosion resistance to the surroundings
  cntenon set safety factor

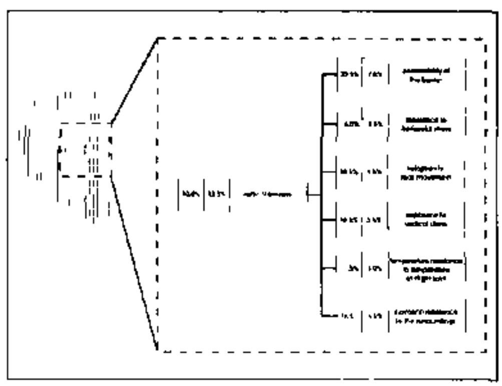

figure 4 Goal structure of the subsystem mining

From this structure we are now able to subject each underground waste disposal concept to an evaluation by means of the enterions of the 5th goal level

<u>Goal weighting.</u> After defining the goal catalogue and creating a goal structure in the next step, the weighting of goals was executed For the goal weighting of the subsystem, methods of the absolute weighting were utilised

For this a scale was fixed, reaching from "extremely important" up to "unimportant" and scores from 5 to 1 for the goals of all levels were given.

In the second step, the importance of single goals in one level was assessed. Then the relative weight of the goals was calculated To achieve this, first the absolute weights of all compared goals of one level were summed up and then the absolute weight of each goal was divided by this sum. The result Is the relative weight of each single goal

<u>Score placing for the existing distinct alternatives.</u> The following procedure step, the score placing, has to discern in how far the alternatives are capable of fulfiling specific partial goals of the lowest, i.e the 5th, level. The premise exists that all evaluations have to be subjected to corresponding evaluation procedures. Because of that an evaluation scale is usually utilised in order to enable the comparison of <u>individual degrees of goal fulfilment.</u>

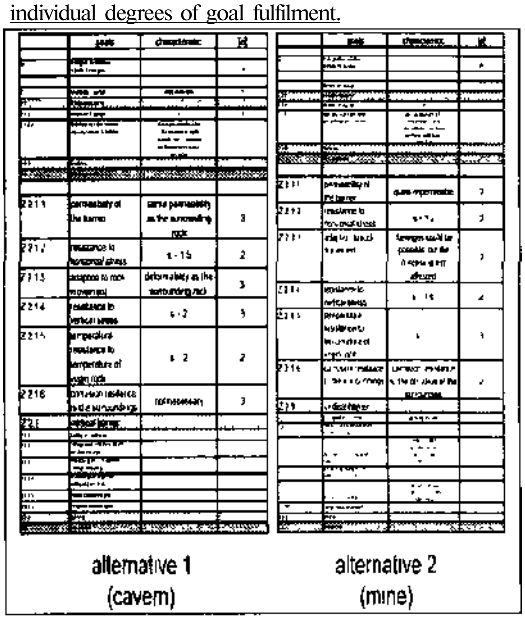

Figure 5 Formalized data of the alternatives

Thus the research group AKUT set a three-part scale for the "can"-goals, from "very good fulfilment (3 points)" to "poor fulfilment (1 point)" (Figure5).

In the following figure, two alternatives, representing two different waste disposal concepts, are shown Alternative 1 represents the concept of underground waste disposal in a salt cavern, alternative 2 represents a concept for underground waste disposal m a salt mine (figure 6)

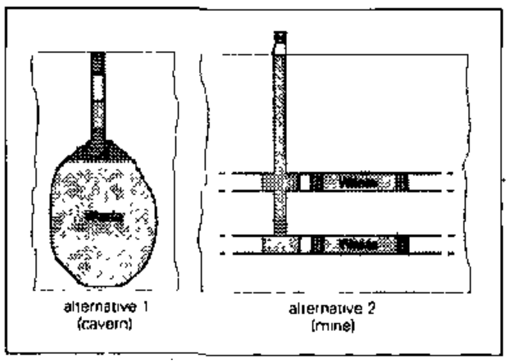

Figure 6 Waste disposal concepts

The data of existing enterprises are formalized and made anonymous.

Combination of scores and weightings and determination of the partial utility value The sum of all multiplicative lmkings of goal scores together with the weights of the respective goals, results in the total utility value To each alternative a total utility value is assigned, which displays how well it fulfils the goal system (Figure 7) This finally allows a ranking of the alternatives Automatically selecting the alternative with the highest lotal utility is not to be recommended due to the existing problem of subjectivity in assessmeni

To do justice to the judgement scope within the goal weighting and to make statements about the stability of the order rank determined, sensitivity analyses should be performed

Alternative			1 (cavern)		2 (mine)	
	[illegible]		fulfilled		fulfilled	
		[g]	[e]	[g·e]	[e]	[g·e]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	[illegible]					
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	[illegible]					
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2 2 1 1	permeability of the filter	0 076	3	0 228	2	0 150
2 2 1 2	resistance to horizontal stress	0 055	2	0 110	2	0 110
2 2 1 3	adaption to rock [illegible]	0 055	3	0 165	2	0 110
2 2 1 4	resistance to vertical stress	0 055	3	0 165	[illegible]	0 150
2 2 1 5	temperature resistance to temperature of virgin rock	0 040	2	0 080	3	0 120
2 2 1 6	corrosion resistance to the surroundings	0 055	3	0 165	2	0 110
2 2 2	[illegible]					
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	[illegible]	[illegible]		[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	[illegible]					
	total utility value of the mining subsystem			2,92		1,97

[e] - score
[g] weighting
[g·e] - combination of score and weighting

Figure 7 Détermination of the utility values

<u>Sensitivity analysis</u> The sensitivity analysis performed verifies the stability of the systems For the examined subsystem, the method of "cntjcal goal weights" was selected

5 SUMMARY

After establishing the total utility value for both alternatives and performing the sensitivity analysis which verified the stability of the systems, one is now enabled to form a definite preference

In this example case, alternative 1, the concept of waste disposal m a salt cavern, should clearly be prefered to alternative 2, the concept of waste disposal in a salt mine, because of safety aspects in the mining subsystem According to different concepts, specific strengths and fraılıtıes can be located

The fact that there exist no horizontal barriers in the waste disposal concept in a salt cavern clearly demonstrates its concept-specific strength That means, caverns developed from the surface do not require any additional barriers exepl shaft burners Another couLcpt-specifit siu-uyih is the ııımbeı of surface accesses Salt taverns managt willi only onu access of which cross section is only a tıauınn (it the. area of usual shaft sections, whereas disposal mines almost always need at least two accesses from the surface

The remaining preferences can be considered as specific to the particular location of each of the two alternatives

The example presented demonstrates how the evaluation of one subsystem under the existing conditions leads to the decision that the concept cavern should be prefered to the concept mine

Concluding, the methodical approach developed by our institute to compare different concepts for underground waste disposal of hazardous waste and related to the supersystem goal "protection of the biosphere", forms the basis to evaluate such concepts entirely

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