Strategies at the disposal and utilization of solid wastes

Stratégies pour l'emmagasinage et l'utilisation des déchets solides

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During the last eight years, several official investigations have been carried out in Sweden concerning solid waste problems. The paper reports the author's suggestions on ingredients of a general "waste treatment strategy" based on the results of the Swedish projects. The suggested strategy at disposal comprises a physio-chemical classification of the waste, principles at siting and design of waste deposits. Finally, the disposal strategy should hold specifications on the monitoring and maintenance of the deposits. At utilization the suggested strategy stresses the importance of not only that technical properties are surveyed but also the environmental properties. The paper also discusses principles when using waste as structural fills, land reclamation, sealing and coverage and erosion control material. The strategy at utilization should also consider the long term stability and the fate of reused waste.

1. BACKGROUND

Like in most other countries, the production of solid wastes has increased rapidly in Sweden the last decades. A future increase in waste production is foreseen in Sweden, especially after the national decision to close down nuclear reactors. The nuclear energy production has to be replaced by solid fuel combustion generating a lot of solid residues.

During the last eight years there has been several official projects with the objective to find solutions to the solid waste problems. One of the general and rather selfevident conclusions has been that higher (and necessary) ambitions in the abatement of air pollution create increasing problems at the solid waste treatment. With the improvement of techniques to reduce airborne emissions, not only the amount of residues increases but also the number, the properties and the hazardness of the new products. Due to the variety of wastes, it has been difficult to establish a general strategy for the disposal and the utilization of waste in the projects. However, based on the results of the Swedish projects a general strategy now can be formed. The present paper reports the authors suggestions on what should be incorporated in a general "waste treatment strategy". Some of the suggestions may be of common interest.

2. GEOTECHNICAL CONTROL OF WASTE

2.1 Waste products - their physio-chemical properties and classification

In order to be able to plan the options of utilization and disposal of waste, respectively, a general classification scheme should be used for the waste. This scheme should be based on the following parameters:

- Amount of waste generated (waste flow rate).
- Toxicity of waste or leachate properties.
- Total strength of waste source, relating to heavy metals, organic substances, etc.
- Technical properties like compressive strength, permeability, hardening, shrinkage, frost susceptibility etc.
- Sensibility to unfavourable synergistic processes if blended with other waste types.
- Physical and chemical long term stability (durability).
- Possibility to modify the leachate properties of the waste.

The existing regulations in different countries are most often based on the two first mentioned of the above points. The toxicity of the waste is often determined according to a special, specified extraction procedure or leaching test. The procedure to perform these tests is decisive and should be subject to international standardization. Different waste types require different types of tests. It is also important to incorporate waste production rate, physiochemical properties and other relevant factors in the classification.

2.2 Siting of waste deposits

There are two principally contrary disposal options which should be carefully examined: wet disposal and dry disposal. The "wet" disposal alternative comprises disposal in or close to the recipient, even sea dumping. It also includes disposal under the ground water table. The "dry" disposal alternative only includes siting on land, above the ground water table and in the areas where precipitation infiltrates the ground (infiltration or inflow areas). Siting on exfiltration or outflow areas should be classified as wet disposal since at least a part of the waste will be flooded.

There are pros and cons with both the "wet" and the "dry" disposal option, In wet disposal, the advantage of a rapid and extensive dissolution is derived. On the other hand, no attenuation due to sorption in the ground, beside the precipitation and sorption in the sediments, is effective. In dry disposal the leachate production is possible to regulate to a lower level than in a wet deposit, and the attenuation processes in the ground can be used. It is evident that the siting of waste deposits is in principle an important question which does not only involve leaching and pollutant transport but also the sensitivity of different receiver systems to increased levels of contamination and the policy of protecting specific areas from pollution, such as wildlife habitat and fresh water resources. It also involves the question of reserving possibilities for future generations to get rid of their waste. For all these reasons it is not possible to put one of the basic disposal principles above the other. They both must be used depending on the individual conditions at the site.

The recommendations which could be made concern the large scale land use planning and the surveys prior to localizing a specific waste deposit.

2.3 Design and construction of waste deposits

Disposal in water areas (wet deposits) should be restricted to waste with low solubility and low consumption of oxygene. If the waste is filled in a liquid state (like in a hydraulic filling) some sort of dam construction is required to contain it, unless a natural (or manmade) depression is used.

Dams should be designed stable enough to withstand the active load of the contained waste as well as erosion and seismic activities as long as there is no internal strength in the waste. A manmade dam is not stable enough in the long term run to withstand such forces without continuous inspection and maintenance. Therefore liquid waste should be stabilized before disposal or contained in a natural depression only.

The diffusion barrier concept is used in the disposal of waste generating acid drainage if oxidized (e.g. sulphidic mine tailings) or radioactive waste to prevent radon esmissions (e.g. uranium mill tailings). If a stable water table is used as a diffusion barrier above the deposited waste, then only depressions under a natural water level should be chosen. A permanent dam structure with a permeability low enough to guarantee a water table above the contained waste cannot be constructed to fulfill this requirement for a long time period (thousands of years). This solution should therefore be avoided.

Three principal cases are important to consider when disposing waste on land. Disposal of waste that decomposes or comprimates causing severe settlements in the waste pile. These settlements result in difficulties to creat efficient surface sealing layers. Disposal of solid, inert waste products like ashes and slags seldom suffers from settlements if localized to stable areas with no slides and compaction of the basement. Disposal of hazardous waste is an intricate affair, especially if the waste is in a sludge form.

Dry disposal on land should consider the following:

1. No part of the deposit should be localized under the highest groundwater table. If this cannot be accomplished, a bottom drainage layer should be constructed to hinder the groundwater to leach the waste. The drainage layer may possibly consist of waste with favourable leaching characteristics, like bottom ash from coal combustion.
2. Diverting ditches should be constructed around the deposit to prevent surface water to flood into the waste.
3. A bottom sealing layer is only necessary if there is a need to collect the surface run off from the waste during the filling operation. This water can be either reinfiltrated into the waste or discharged after proper treatment.
4. The purpose of the ultimate cover layer is to:

- protect the waste from spreading by man or animals
- protect the waste from erosion
- reduce the leachate percolation rate through the waste
- reduce the gas diffusion rate to the atmosphere, methane, radon etc or in some cases the diffusion rate of oxygen from the atmosphere to the waste
- form a suitable basement for a proper vegetation culture making it possible to fit the waste deposit in the landscape.

These different purposes define the specification on the materials and the construction of the coverage. In most cases a multilayer system including a sealing layer is preferable. In many countries synthetic liners are preferred, due to their favourable technical properties, especially when used in the coverage. However, the long time durability should be questioned and alternatives should therefore be considered until their properties in the long term run are specified.

In most climates the hydraulic conductivity of the sealing layer must be less than 10^{-8} m/s to have any reducing effect on the net percolation rate through the sealing layer. This is accomplished by most clayey soils if compacted in a proper way and close to the optimum water content for compaction. Also sandy soils blended with bentonite can be used as well as cement or limestabilized pozzolanic ashes. The durability of these materials has not been studied in detail, especially not in relation to root penetration. However, material analogs suggest them to be rather stable if covered by a sufficiently thick protective layer. The dimension and choice of material of the protective layer should consider local factors like natural vegetation, land use, rain intensities, snow melting and frost action. A sloping drainage layer on top of the sealing layer will enhance the sealing effect but may be uneconomical. It is often cheaper to make the sealing layer correspondingly tighter.

The sloping of the waste deposit should not be too steep to avoid erosion and stability problems. It should neither be too flat, as this means that a large leachate producing area is formed and that surface run off is reduced. To build a high deposit is in principle favourable as it results in a small bottom area discharging leachate.

2.4 Monitoring and maintenance of waste deposits

The ultimate control of waste deposits also comprises to check the function of the deposit. If the deposit works according to the design, it will in most cases take a long time before even the smallest influence is experienced in the surrounding environment. The monitoring points and technique should be chosen to reveal if the system works unsufficiently. It is therefore necessary to perform a special hydrogeological field survey which shows the groundwater and surface water streams from the deposit area. Some of this information, perhaps all, are covered by the siting operations. Monitoring can be done by taking water samples from different strategic points and depths from both surface water and groundwater. Analyzation of both organic and inorganic components, salts and trace elements, is essential. The analysis program may consist of two levels, one simple which is used regularly and one which is used only when contamination is suspected or with long time intervals. If the background level is small and a low contamination level will be covered, clean field and laboratory procedures are called for, including uncoloured polyethylene (polypropylene) tubes, etc.

In the long term perspective, the function of the deposit should be independent on maintenance. However, it is favourable if surface structures like ditches, vegetation and erosion protectives are controlled and maintained. This is especially important if leachate water treatment is applied in the early stage of the life time of the deposit. When water treatment has terminated, drainage layers should be plugged and all tubes inactivated.

Collection of leachate in a special "drainage between double liner system" is sometimes used as a system to control the effectiveness of a bottom sealing system, especially in hazardous waste deposit. This should only be used under the following conditions:

1. The surface sealing layer is at least as efficient as the bottom sealing system. Otherwise a ground and groundwater pollution problem is turned into a surface (water) (and possibly also a groundwater pollution problem).
2. Plastic liner systems are used only in the short time perspective. With this bottom drainage system all leachates will be collected. This is positive only during the collection/treatmant stage. When no longer pumped and treated it is disadvantageous since it effectively collects leachate and discharges it uncontrolled.
3. Monitoring through tubes etc in the bottom draingage system only is doubtful. If there is a failure in the system due to glogging, tube breakes etc, the lack of warnings then creates a false picture of security.

3 GEOTECHNICAL UTILIZATION OR REUSE OF WASTE

3.1 Technical and environmental properties of waste to be utilized

Utilization of waste is beneficial to society provided that:

- o It reduces the need for deposit space.
- o It conserves energy or natural resources.
- o It has no significant impact on the environment when used or ultimately disposed off.

General investigations related to these questions are recommended for different types of waste. These waste types, which are assessed to be feasable to use, are recommended to be subjects of technical development. It is important that the conformity to national standards are determined at an early stage. It may be necessary to modify the standards which usually take a lot of time. It is also important that not only the technical properties are surveyed but also the environmental properties. One way of evaluating the environmental feasability is to carry out environmental scenarios, modelling the leachate production and attenuation in the environment. In this way the load on different units may be calculated, expressed as both background concentration increase and annual, total amounts (kg) or specific amounts (kg/m^2). As long as the concentration increases in surface waters are less than 100%, the ecological effects probably can be ignored. If they are more, they have to be assessed individually by ecological experts. The total or specific load can be compared to other, natural or artificial, pollution sources like atmospheric deposition, leaching of natural soils, discharge from sewage water plants and deicing salts on roads.

3.2 Structural fills of waste products

Only homogeneous waste products are recommended as filling material in load bearing structures, such as blast furnace slags, bottom and fly ashes from coal combustion and separated slags from municipal incinerators. Some of these wastes are possible to stabilize in order to increase their strength by additives like lime or cement. Systematic testing of such stabilization of ashes and slags are highly recommended since it also reduces the permeability of the waste and hence reduces the leachate production.

The environmental load of the structural fills is governed by the leaching properties of the filling material, the permeability of the waste and the attenuation conditions in the vicinity. It has been found for coal ashes that the leaching properties are only marginally affected by stabilizing agents such as lime and cement. Therefore the only positive environmental effects of the stabilization is the increase in strength and decrease in permeability. The reduction of leachate production corresponds to a factor of 2-100 and is therefore significant.

From an environmental point of view there are some principally different cases:

- o Fills above the groundwater table with only the percolation of infiltrating rainwater leaching the waste.
- o Fills under the groundwater table with the additional percolation of groundwater.
- o Fills which are covered by a mere sealant structure like a building reducing the rainwater percolation close to zero.

Environmental assessments, based on comparisons with the background levels, will give different results in urban areas than in rural areas. For instance, in urban areas the background level is generally much higher for heavy metals and comparisons can be made with the storm water quality, etc.

3.3 Land reclamation operations with waste products

The potential environmental impact of reclaimed land is basicly the same as for waste deposits. Therefore it is recommended that land reclamation objects are treated equally to waste deposits when waste is used as a filling material, cf chapter 2.4.

3.4 Sealing and coverage operations with waste products

In some cases it may be advantageous to cover a special waste with another waste with special properties. The objective may be to adjust the pH or oxygen concentration of the percolating water or, simply, to reduce the rate of leachate percolation or to construct a barrier against gas transport. These possibilities are not very well developed technically and, with the exception from the leachate production, we know very little of their full scale efficiency. Furthermore the knowledge of what synergistic effects may arise from the layerwise blending of waste is very small. This is an important issue if both metalrich waste and organic wastes are involved.

3.5 Erosion control measures

Cementstabilized fly ash from coal firing is a raw material especially favourable when manufacturing blocks on site with moderately high specifications on strength. Such blocks can be used as erosion protection on sea shores and in harbours. The leachate production rate is small and the dissolution in the sea is enormous. As shown by a full scale project (Artificial Reef Project) outside New York, no effects have been experienced in 5 years on the adoption of the reef to the natural habitat.

3.6 Long term stability considerations - the fate of reused waste

If the long term perspective is an important question when considering the environmental potential impact of a waste deposit, it is equally important to assess what happens to the reused waste with time. Will it desintegrate or change its leaching properties with time? What is the fate of e.g. a road embankment fill of a residual product? Will it be disposed off in a regular deposit or reused in a similar position? In any case, what will the future environmental implications be when a lot of waste is generated, recycled, deposited or reused? Will forgotten, reused waste units constitute a future unknown threat to health and environment? This is an interesting issue that should be emphasized in national investigations.