UTILIZATION OF SECONDARY CONSTRUCTION MATERIALS IN A LANDFILL COVER SYSTEM

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SUMMARY: Many landfills in Sweden as well as in Europe are subject to closure in the near future. Roughly 2,000 hectares of landfill area in Sweden have to be covered, equivalent to almost one hundred million tonnes of construction material. In addition to material costs in the order of tens of billions Euro, this also puts a strain on the environment through the exploitation of virgin materials. The deadline for this adoption to the EU Landfill directive is due in 2008 but it is already apparent that many landfills will not meet the deadline. Many landfill operators are considering alternative cover designs in order to reduce resource spending. However, there is a fair amount of uncertainty with regard to functional and environmental consequences of using alternative materials, both from the side of the companies and the authorities. It is necessary to characterise these materials in terms of chemical and physical properties. For example, the leaching of the materials is of great interest in order to estimate the requirements and design of future leachate treatment.

1. INTRODUCTION

In recent years a significant increase in waste generation could be seen from households, construction, waste treatment, and industries. Statistics for many kinds of wastes show an increase of more than 15 % per year. Consequently, existing landfill volume will soon be used up and new sites are required. However, the landfilling of burnable waste was prohibited in 2002, and organic material from 2005. Much effort is put into recycling and this has resulted in a decrease of landfilled waste by 11 % in 2002.

Nowadays, at most major sites, landfilling itself is only a minor activity. At Tveta Återvinning (Recycling) Site, about 50 km south of Stockholm, more than 200,000 tonnes of waste were received in 2004 but only less than 10,000 tonnes were deposited. This is the result of intense efforts to recycle waste, commenced in early 1990 and escalated about six years ago.

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Figure 1. Aerial photo of the Tveta Landfill Site with slope to be covered, leachate pond, purification plant and wetlands. In the foreground the forest for the irrigation system

For testing the recycling of materials by using them in a cover construction, the first Swedish full scale application of alternative landfill cover materials is built at a test area at the Tveta landfill. Four hectares are to be covered using alternative materials such as ashes, bed sand, sludge and compost.

The landfill operator Telge Återvinning AB has designed the area for studies in cooperation with the division of Waste Science & Technology at LTU (e.g. Arvidsson, 2001; Tham et al. 2003). The construction will be completed in 2005.

Figure 1 shows the Tveta Landfill site with the Eastern slope to be covered, the leachate pond, the purification plant for metal reduction, and the wetlands for nitrogen treatment. The forest for the irrigation of leachate after treatment is to be seen in the foreground.

The decrease of landfilled wastes and development of new cover systems will decrease the amount of leachate to treat to a small fraction of the present amount, but at the same time new kinds of polluted waters are emerging from different working areas, parking lots, and the upper layers of the covers. The diversity of waters calls for a diverse treatment, and in consequence a flexible water emission management needs to be developed.

2. USE OF SECONDARY WASTE MATERIALS

In the past, more than one hundred different types of waste materials from households, construction companies and heavy industries have been deposited at the Tveta landfill. Today, the chemical and physical properties of almost every incoming material are identified, in order to find a potential area for recycling.

About half of the landfill area at the Tveta Site will be closed, due to the recycling of waste material. Several categories of materials have been considered for utilisation in final covers, e g:

- Ashes, both fly ashes and bottom ashes
- Vitreous slag from steel industry

- Compost material after anaerobic and aerobic treatment
- Foundry sand from truck industry
- Municipal sewage sludge
- Concrete
- Glass

The materials considered at this stage are all classified as non-hazardous waste. However, future research will also include hazardous waste, in cases where the utilization would prove to be safe.

3. CONSTRUCTION OF A LANDFILL COVER SYSTEM

A final cover construction is a system of components that all contribute to achieving the desired function. The legal requirement in Sweden is directed towards the maximum amount of leachate generated: < 5 and < 50 l $(m^2*a)^{-1}$ for landfill class 1 and 2, respectively (SFS 2001:512). The functions of the single layers within the cover are described in Figure 2. The figure also gives examples of possible alternative construction materials and for the impact on the water balance of the different layers.
The field test at the Tveta landfill includes a number of alternative cover constructions where primarily the materials for the barrier layer are varied. The design and layout has been described at the last Sardinia symposium (Tham et al., 2003). By now, four test areas have been covered and equipped with instrumentation. The construction activities will be finished by the end of 2005. Figure 3 shows the installation of lysimeters for leachate collection below the liner in area 1.

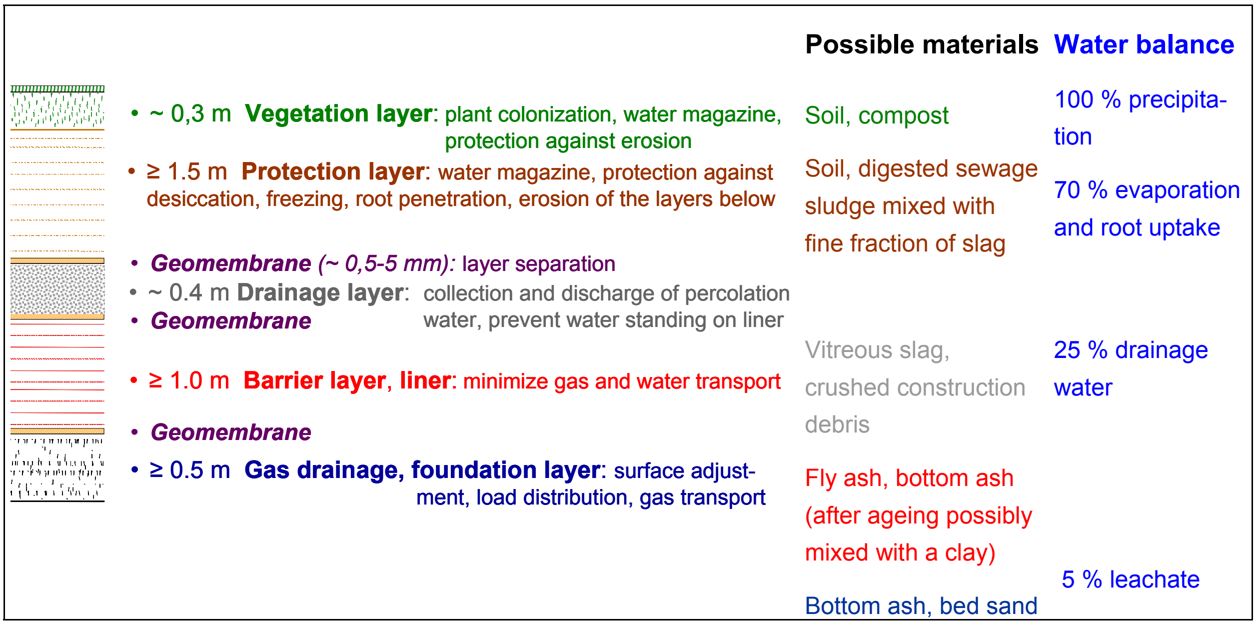

Figure 2 Layers and their function in a cover construction with a mineral liner; examples for possible alternative materials and water balance for the different layers.

Figure 3 Lysimeter boxes with hoses and protection hoses installed below the liner of fly ash.

The lysimeters are filled with vitreous slag as drainage material. In the background the construction of the liner – fly ash in this area – can be seen. First results of the field test are presented at this years´ Sardinia; see Travar et al. (2005).

4. INVESTIGATIONS IN LABORATORY AND FIELD SCALE

4.1 Theory and method

The evaluation of the function and long-term durability of the cover construction has to be made in both laboratory and full scale. Legislation prescribes only elementary analysis and short-time leaching tests for material characterization (NFS 2004:10). Simple leaching tests can indicate if the material contains substances that leach under the chemical conditions of the used test. They are not pH- or redox controlled and hence do not reveal information about the interaction of the tested materials with other materials. The short time of the test prevents the observation of processes governed by biological reactions in the sample. Though some of the tests are performed at high L/S[1] ratios the significance for the long-term behaviour is reduced to the leaching of e.g. salts and other components that do not change their behaviour over time and/or depending on the environment (Andreas, 2000).

In order to make more realistic predictions a combination of different assays must be used (Kylefors et al. 2003). Also, predictive models must be validated through field observations. Many detail issues are to be studied in the over all evaluation of the landfill cover such as:

- How do the different parts of the structure affect the water balance?
- How are landfill gas emissions affected by and interacting with the liner?
- How is the construction affected by landfill settlements?
- What reactions take place as water percolates through the different layers?
- How should the water above the liner be treated and for how long?
- What are the impacts of external and landfill internal processes on the liner?

[1] L/S ratio – liquid to solid ratio

With regard to construction issues, also mixing procedures and different standard contractor equipment (compacting technique, lay-out procedures etc) are tested. The field tests are the predominant part, including monitoring and sampling from the existing experimental area (water quantity and quality, gas quality, temperature, settlements; see Tham et al. 2003 and Travar et al. 2005). The laboratory tests include material characterization (elemental analysise, leaching tests) and tests for the evaluation of the long-term behaviour using physical models (e.g. 80-liter-vessels). By providing optimum conditions and increased L/S ratios, leaching and partly also degradation and ageing can be accelerated in laboratory scale. By means of this, predictions for the future development of both function and emissions can be made.

4.2 Results and discussion

4.2.1 Compaction properties and hydraulic conductivity

Prior to the field test all materials were tested in laboratory. Proctor density (compaction properties) and hydraulic conductivity of the ashes and different mixtures (with other ashes or clay minerals) to be used in the liner were tested. Measurements were performed directly after the admixture of water and some time afterwards (6 and 24 hours) in order to test how the properties will change under practical construction conditions where the material for a whole working day probably will be prepared at once e.g. in the morning. The proctor densities were in the range of 1.2 to 1.5 t/m^3 TS and the hydraulic conductivity between $8.0 \cdot 10^{-9}$ and $1.3 \cdot 10^{-10}$ m/s, depending on the mixture but with only marginal differences due to the time of compacting after adding water.

According to Swedish legislation, the permeability for a cover system in a landfill for non hazardous waste must not exceed 50 litres per square meter and year. As described above, the cover system consists of a number of different layers that all contribute to achieve the desired function. As can be seen in Figure 2, the largest reduction of potential leachate formation occurs in the layers above the liner, depending on design aspects like the relative permeability of the different layers, their slope and the pipe and trench system design. The covers used are designed to allow a percent or less of the yearly precipitation to form leachate.

4.2.2 Leaching properties

One step leaching tests have been used as a first, simple method, of indicating potential emissions from the used secondary materials. Both single materials and different combinations of the materials were tested according to the conditions as they will appear in a landfill cover. Examples of some results are given in Table 1.

The leaching properties of bed sand from a fluid bed incineration were tested in a physical model (100 l scale) together with a covering sludge mixture in order to simulate conditions in the drainage layer below the protection layer.

The bed sand contains antimony in high concentrations. Leaching the material in a simple leaching test under oxidizing conditions leads to a high mobilization, exceeding the limit values. However, the environment in a full scale cover will very likely be more reducing and hence inhibit mobilization of antimony. In our case the potential antimony emissions lead to the exclusion of this material from the layers above the liner.

Another result from the same test was the observation of the development of the nitrogen concentrations in the percolate. Initially very high, a wash-out could be seen after some time (L/S ~ 0.9) but after that the concentrations remained high, around 600 mg/l at L/S 1.25. This shows that sludge addition in the cover layer must be moderate and balanced by the up-take in vegetation.

Table 1. Results of leaching tests at L/S 10 conducted with individual materials and material mixtures (examples).

		Fly ash	Bottom ash	Fly+bottom ash	Sludge+ash	Compost
pH		12.6	10.7	12.3	9.9	7.4
EC	mS/cm	11.8	3.8	18.9	6.7	4.4
Chloride	mg/l	1 338	736	4 606	3 460	570
NH_4-N	mg/l		0.4	2.3	183	151
N_{to}	mg/l		3.1	3.3	282	271
Sulphate	mg/l	555	663	437		
COD	mg/l	<15	21		2 222	1 857
DOC	mg/l			4.2	578	540
Ca	mg/l	1 370	332	2 350	0.3	69
Fe	mg/l	<0.004	<0.003	<0.004	0.1	4.2
K	mg/l	271	166	758	1 437	94.4
Mg	mg/l	<0.09	4	<0.5	4	23
Na	mg/l	122	177	679	184	412
S	mg/l	185	186	146		
Al	mg/l	8.1	4 966	7	116	293
As	μ/l	4	4	<16	36	215
Ba	μ/l	586	220	851	68	98
Cd	μ/l	0.2	0.27	0.20	0.6	7.7
Co	μ/l	<0.05	0.7	<0.05	47	13
Cr	μ/l	274	29	14	13	47
Cu	μ/l	3.1	16	23	17 533	4 093
Hg	μ/l	<5	<0.02	<0.02		
Mn	μ/l	0.7	3.1	0.4	6	166
Ni	μ/l	6.6	1.1	<0.5	462	130
Pb	μ/l	1 010	10	2 830	14	236
Sb	μ/l	26		0.20		
Zn	μ/l	66	8	399	92	1 127

4.2.3 Characterization of aged ashes in an ash fill

In 2002 four holes were drilled in the old ash landfill at Tveta which is about 20 years old. Samples were taken every metre and analysed on e.g. water content, organic and inorganic content, leaching properties, carbonation potential and thermal analysis. The ash landfill consists of mixed ash: fly ash and bottom ash. The results from this investigation show that the ash landfill does not hold any water and that there is no percolating water. This indicates that the ash is stabilized soon after deposition and that only surface leaching takes place. Recent studies indicate that the ash landfill is forming a monolith and that silicates in the ash are transforming into clay-like mineral.

An interesting question now – not at least for the authorities – is whether it is better to deposit or to reuse suitable materials. From an economical perspective, it is clearly advantageous to utilise the materials.

The cost of covering a landfill with the system discussed above is in the range of € 40-45 per square metres excluding material costs (i.e. only the handling and construction). Recycling waste materials and using them as secondary construction materials leads to a substantial pay-back in terms of gate fee and taxes (as an incentive to use secondary materials). This will lower the cost by € 10-30. The use of virgin materials has a purchase price for gravel, sand, and clay in the order € 40-60 per square meter. This means that the total cost for the cover using secondary construction materials would be in the range of € 100 per square meter cheaper than using virgin materials.

5. THE ENVIRONMENTAL IMPACT OF USING SECONDARY MATERIALS

For decades, different wastes have been combined in landfills. The resulting leachate requires treatment due to high concentration of organic substances, nitrogen and metals. As it is not clear to what extent hazardous waste has been included, it is difficult to find a recipient for treated leachate.

The aim at the Tveta Site is to source-separate different waters not only from external sources but also from the internal work at the site. Waters from different surfaces used for sorting industrial waste, fragmentation of burnable waste for incineration, parking areas, drainage water etc. will be treated individually. Water with high nitrogen content will be stored during winter and used for the irrigation of forests, water with a variety of pollutants will have to pass through the entire leachate treatment sequence of metal separation, wetlands and irrigation of forest.

6. SUMMARY AND CONCLUSIONS

Research work on secondary construction materials is in its initial phase. Leaching tests are used to characterize the used materials and physical models are a first step to predict the expected emissions from covered landfills.

Much research is still required in order to show the impact of secondary materials in the long term. The study of ashes from incineration has provided many important results which need to be followed up.

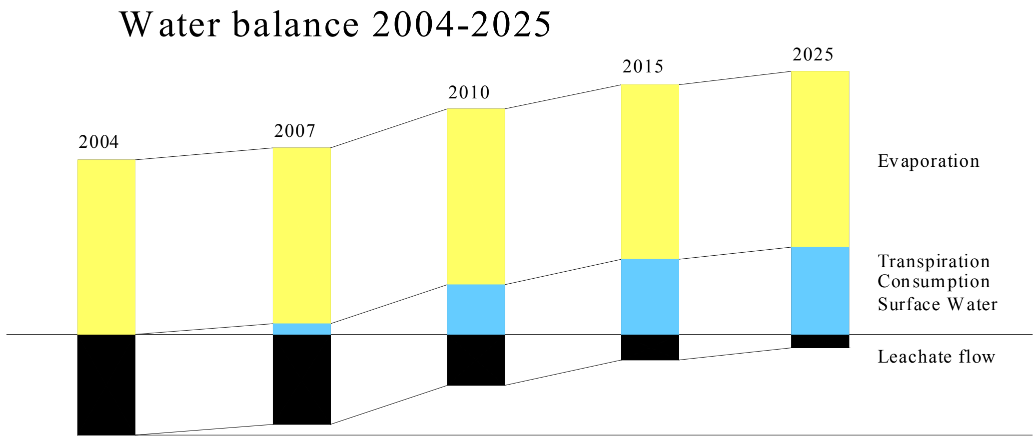

Figure 4 Water balance estimate over 20 years. The leachate is reduced and replaced by less polluted waters.

Although further studies are required to verify the long-term impact of using secondary construction materials, it is evident that ashes, both fly ash and bottom ash, can be used. Other secondary materials can also be used, although some might not be uniform enough to provide long-term stability. The available results show that:

- no groundwater table exists in the ash landfill indicating that the ash deposit forms a monolithic structure.
- fly-ash contains abundant alumino-silicate glass which is predisposed to form clay minerals during weathering. This is an important factor as regards to long term stability.
- the cover construction fulfils regulations with regard to the permitted leachate generation.
- the water above the liner has too high but declining concentrations of Nitrogen, Mg, Mn, Fe, Zn, Co, Ni and Pb. The design of upper levels in the cover need to be optimised and with the present design treatment of the water is needed over some years.

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REFERENCES

Andreas, L. (2000) Langzeitemissionsverhalten von Deponien für Siedlungsabfälle in den neuen Bundesländern (Long-term emission behaviour of MSW landfills in the new federal states of Germany). Beiträge zur Abfallwirtschaft 14, *Forum für Abfallwirtschaft und Altlasten e.V.* Eigenverlag, Dresden, Tyskland.

Arvidsson, K. (2001) Utveckling av tätskikt för sluttäckning vid Tveta Avfallsanläggning. Development of liners for final cover at the Tveta waste management facility. MSc Thesis 2001:194 CIV. *Luleå Tekniska Universitet*, Luleå Sweden

Bidlingmaier, W., Voigt, J. (2001) Alternative sealing systems. Sardinia 2001 8^{th} International Waste Management and Landfill Symposium, Sardinia, Italy vol.:3, p. 303-316,

EU (1999) Council Directive 1999/31/EC of 26 April 1999 on the Landfill of Waste, The Council of The European Union, Brussels, Belgium.

Kylefors, K.; Andreas, L.; Lagerkvist, A. (2003) A comparison of small-scale, pilot-scale and large-scale tests for predicting leaching behaviour of landfilled wastes. Waste Management, Vol. 23, No 1, 45-59.

NFS Handbok 2004:10 Naturvårdsverkets föreskrifter om deponering, kriterier och förfaranden för mottagning av avfall vid anläggningar för deponering av avfall. Naturvårdsverket, Stockholm. ISSN 1403-8234.

Renman, G.; Tham, G. (2005). New trends in waste management for optimising landfill leachate treatment – A case study. *6^{th} Int. Conference Environmental Engineering, Vilnius.*

SFS 2001:512 Förordning om deponering av avfall. Ordinance on the landfilling of waste, Published: 2001-06-07.

Tham, G., Andreas, L., Lagerkvist, A. (2003) Use of ashes in landfill covers. Sardinia 2003, 9^{th} International Waste Management and Landfill Symposium, Sardinia, Italy.

Travar, I.; Tham, G.; Lagerkvist, A.; Andreas, L. (2005) Results of field experiments with secondary construction materials in a landfill cover. 10th International Waste Management and Landfill Symposium, Sardinia, Italy, 2005.

Zevenbergen, C.; Bradley, J.P.; van Reeuwijk, L.P.; Shyam, A.K. (1999) Clay formation during weathering of alkaline coal fly ash. Int. Ash Utilization Symposium, University of Kentucky.