ANTHROPOGENIC AND NATURAL ANALOGUES FOR THE DEVELOPMENT OVER TIME OF MIXTURES OF WOOD-BASED ASH AND ACTIVATED SEWAGE SLUDGE

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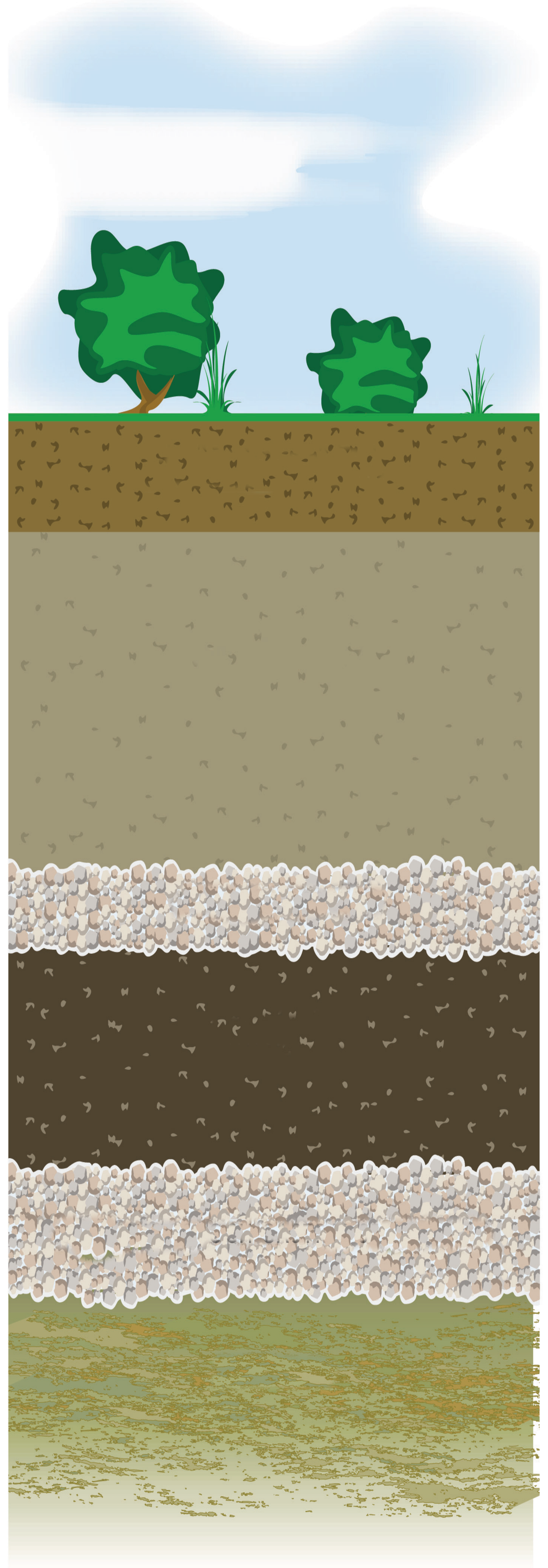
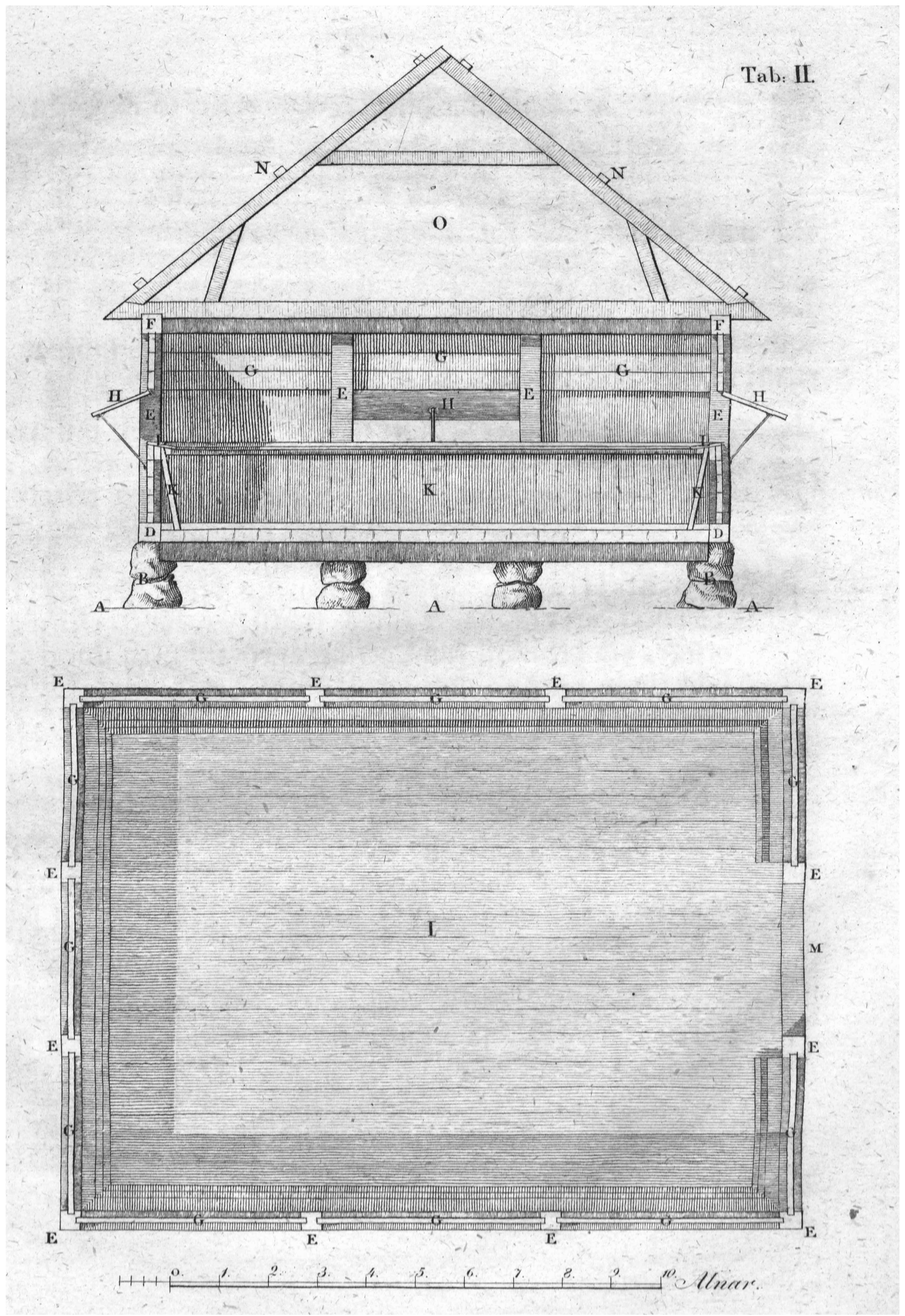


Figure 1. The generic design for covers at the Landfill Site at the Tveta Recycling Plant.

The total thickness of a cover is 3,5 – 4 m.

The fuel giving rise to the ash was a mixture of wood, plastic and corrugated fibreboard but also peat and wood chips.

- ***The vegetation layer*** comprises mainly compost. Typical thickness ≥ 0,3 m.
- ***The protection layer*** comprises activated sewage sludge mixed with fine slag fraction of ash. Typical thickness ≥ 1,5 m.
- ***The drainage layer*** comprises slag (bottom ash). Typical thickness ≥ 0,3 m.
- ***The impervious liner*** comprises compacted ash, typically with a high content of reactive fly ash. Typical thickness ≥ 1,0 m.
- ***The gas transport layer*** comprises bed sand. Typical thickness ≥ 0,3 m.
- ***The waste*** comprising mainly domestic waste.



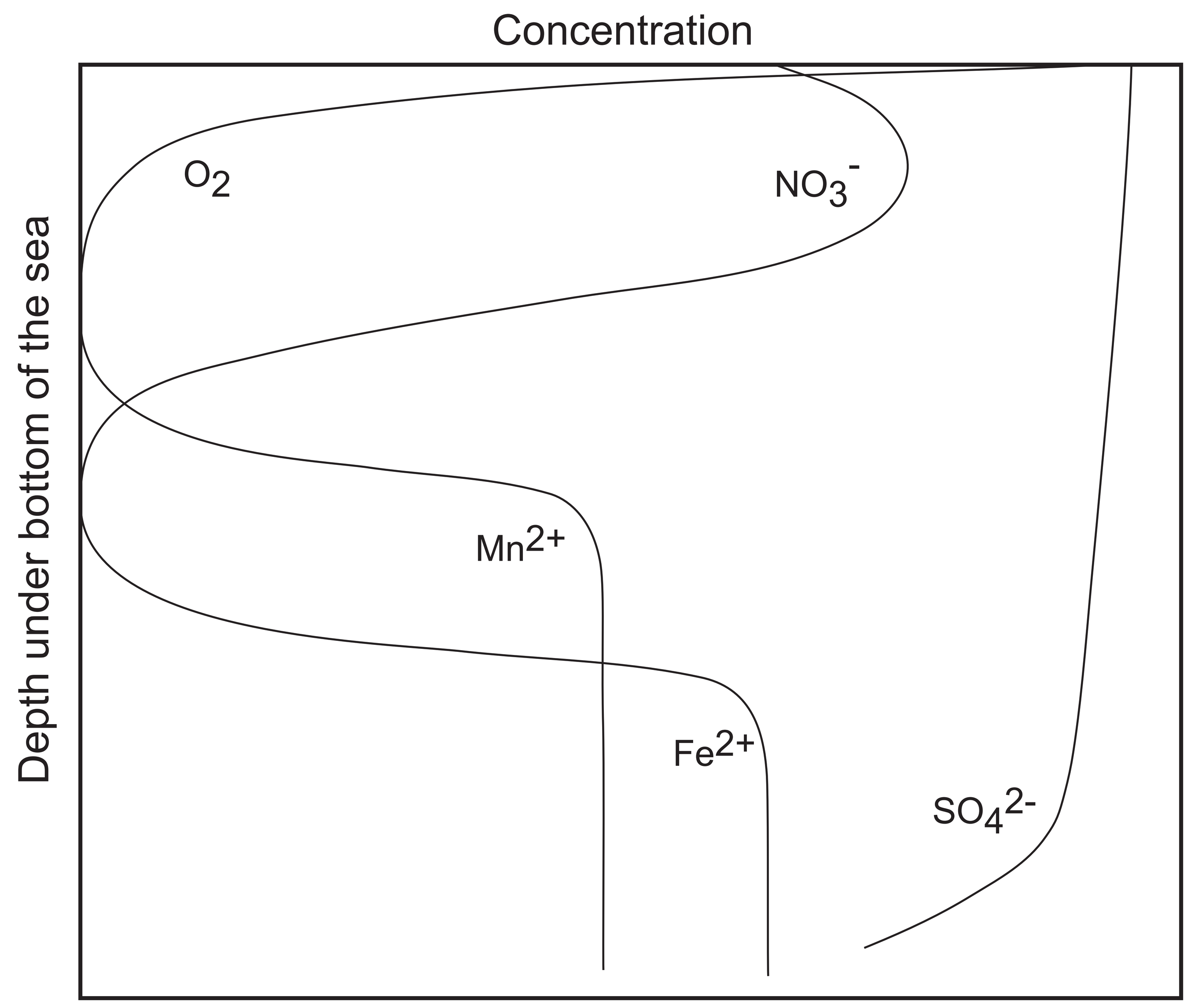


Figure 3, above. Oxidation of sea sediments. The bacteria usually prefer free oxygen as the oxidant, but nitrate and other reducible species can also be used. Nitrate formed in the decomposition can diffuse considerably deeper into the seabed than oxygen. In the absence of oxygen, manganese may be reduced, and at lower redox potential also iron. At the lowest redox potentials, sulphate can become reduced in which case sulphur or hydrogen sulphide is formed.

Figure 2, left. A saltpetre barn according to Edman 1813. The barn was filled to a height of around one metre with a mixture of faeces, ash, mortar and organic structure material. Urine was recurrently poured over the bed. In this way, organic nitrogen was added at the same time as the bed was kept constantly wet. The bed was turned a few times every summer season. After five years or somewhat less, the process was completed. At this stage, the material might contain on the order of 6 kilograms saltpetre per cubic meter.

The saltpetre was beneficiated by fractional recrystalization in which it was utilised that the desired product, potassium nitrate, had certain solubilities in water at low and at high temperature.

The challenge to cover landfills. Many landfills in Sweden are subject to closure within the next ten years. It is estimated that the total area to be covered amounts to some 20 square kilometres and that the total volume of material may exceed 50 million tonnes. Suitable virgin materials such as clays, moraine e t c are scarce due to the recurrent glaciations, and are also largely to be conserved. Instead, recycling is encouraged in our Environmental Code.

The pure ash seal. In concordance and compliance – as well as with the full approval of the Swedish Environmental Court - the Tveta Recycling Plant south of Stockholm is utilizing various residues such as ash and activated sewage sludge for the purpose of covering an old landfill. The design is shown in Figure 1.

The perhaps most crucial issue in this regard has been to show that a seal made of ash is sufficiently impervious to water in order to meet the Swedish implementation of the European Union Landfill Directive. Another task has been to determine the health and environment related properties of the ash. It was concluded that it is possible to obtain a liner built of ash within the cover such that it complies with the Swedish criteria for imperviousness. The prerequisites include an initially high pH and adjustment of the moisture together with mixing to obtain a suitable grain size distribution.

The requirements on long-term performance. The Swedish Environmental Protection Agency has stated that a landfill for non-hazardous waste must maintain its intended function for several hundred years, and a landfill for hazardous waste for thousands of years. Consequently, the ageing of ash and possible long term behaviour has been studied with positive results. The conclusions are supported by comparisons with natural analogues such as volcanic ash in Roman cements in old constructions.

The seal comprising ash and activated sewage sludge. Liner seals using a homogenous mixture of ash and activated sewage sludge have also been subject to extensive investigations for landfill covering purposes in Sweden. A total of sixteen unique reports are referenced in the Proceeding to this conference. It was claimed in this work that oxygen from the air cannot be more accessible to the activated sludge in the seal than what corresponds to the solubility in water in combination with the percolation. At an oxygen saturation degree of 10 %, only 0,1 grams organic material (figured as carbon) can become decomposed per square metre and year. This is compared with the seal, which has a thickness of 0,5 metres and contains 30 kg organic material (figured as carbon) per square metre. It has also been maintained that the high salinity and the high alkalinity prohibit or at least substantially impede decomposition.

Does a seal with pure ash correspond to Best Available Technology? The purpose of the present work is to investigate whether the Tveta Recycling Plant approach actually complies with the requirements in the Swedish Environmental Code on use of best available technology (BAT).

Studies of natural and anthropogenic analogues. It was soon found that the crucial question is whether a homogenous mixture of ash and activated sewage sludge might have a more positive prognosis regarding the long term functioning as compared to a seal made of only ash. Therefore, anthropogenic and natural analogues have been studied in order to find a basis for the assessment and comparison. (Comparison has also been made with methods in which virgin materials are utilized but those results are not presented here).

Anthropogenic analogue. Decomposition of organic matter in soil is almost always biological in nature and takes place in such a manner that a metabolite from one organism is the nutrient of another. The rate is strongly dependent on the chemical composition. It has been assessed that about two thirds of fresh dead matter becomes decomposed within one season, while the average age of humus in soil may vary between 250 and 1 900 years.

Waste consisting of faeces, ash and food residues has been generated by civilisations for millennia. Thus, historical landfills and latrine pits (which contained ash as well) constitute an anthropogenic analogue, where historical sources have be consulted for details. There is actually a considerable literature on the topic since such deposits were excavated for saltpetre which is the major ingredient in gunpowder. Saltpetre was found even in deposits of substantial dimensions (metres) provided that the age was up to a century or two. Later, various constructions – with and without roofing – were introduced in order to improve the efficiency of the process. It was found that ash was a necessary ingredient both as a pH buffer for the nitrification and as a potassium source for the saltpetre itself. An example of the alternative with roofing is shown in Figure 2.

Natural analogue. Similarly, various residues - including organic matter - sediment onto the bottom of the sea, and this constitutes a natural analogue, at least for the case of not very high pH-values. The fate of organic matter in sea sediments is of great importance in geochemistry and geology, and the topic has been studied extensively. Excellent compilations of current knowledge are available on the oxidation of sea sediments, and they report that the influence of oxygen in the sea water extends far below the narrow depletion zone near the surface of the sediment. Details are provided in Figure 3.

Conclusions. The conclusions with regard to the ashes available to the Tveta Recycling Plant are as follows.

The significance of the alkalinity of the ash. A large number of tests have shown that aged but not carbonated ash generally has pH-values in their pore waters below 10. Thus, the pH conditions are insufficient to ensure any long-term durability.

The significance of the salt content. Although salt may impede microbial activity, it cannot be concluded that salt in ash is sufficient to inhibit it. Moreover, modern ash, including the one at the Tveta Recycling Plant, contains substantial amounts of sulphate from the flue gas cleaning. This sulphate offers a high redox buffer capacity although the rate of reaction may be moderate and the incubation time perhaps relatively long,

The significance of the imperviousness of the seal. It has been put forward that a seal consisting of a mixture of ash and activated sewage sludge is so impervious, the penetration of water so slow, and the content of oxygen in the water so low that the oxidation of the sludge is insignificant (cf above). This mechanism is, however, not identical with the ones found and observed in seabed sediments, and may not be in full concordance with the historical data on decomposition of organic material in mixtures with ash. No definite conclusions are therefore drawn on this issue.

The significance and consequences for the Tveta Recycling Plant. For the ash currently available, it appears daunting to attempt to accumulate sufficient evidence to prove the long-term feasibility of mixtures of ash and activated sewage sludge in a seal.

The reader is referred to the main document for further detail and relevant references.