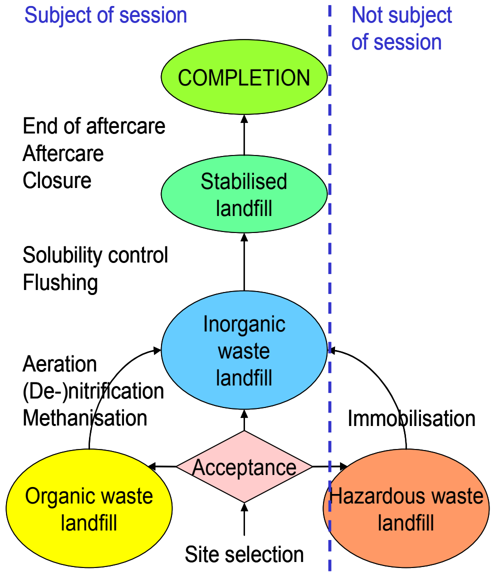
ICLRS4 Session report
Theme: Integrated discussion on landfill stabilisation and sustainable landfill

Introduction and chair: Heijo Scharff
Bioreactor technology, landfill stability, landfill processes and process modelling are relevant aspects for landfill stabilisation and sustainable landfill. These aspects should be brought together in order to answer the major question of stabilization and appropriate end-points for landfill. The intention of this session was to "bring all the pieces of the puzzle" together. The idea was proposed that several types of waste can be processed in different landfill concepts. But in the end the goal is the same: to achieve completion. Or in other words to obtain a stabilised landfill that after a limited period of post-closure care can be considered a safe element in the landscape requiring only minimal maintenance depending on its future destination. The session is part of the work carried out by the IWWG Sustainable Landfill Task Group. In order to focus the discussion immobilisation of hazardous waste is not subject of the session at hand. Also methane emissions were excluded from the discussion. This belongs to the activities of the CLEAR group.



Bioreactors: Debbie Reinhart
It is well documented that bioreactors can accelerate degradation. Anaerobic bioreactors can also sequester carbon and thus play a role in reducing carbon dioxide emissions to the atmosphere. Bioreactors have great potential of which the maximum is not reached yet, e.g. with respect to nitrogen degradation. Economical benefits can be found in volume reduction within a shorter time frame. Aspects requiring more attention are:

- moisture and air distribution
- the inhomogeneous matrix: how many untreated pockets are acceptable?;
- the long-term release of specific components in the leachate;
- long term performance of leachate collection system, cap, and liner
- difficulty in collecting gaseous emissions early in the landfill life (in terms of capping) and;
- monitoring of processes and waste stability.

Aerobic (post)treatment: Rainer Stegmann
In-situ aeration receives more and more attention. It can intensify biological processes due to the high potential of aerobic degradation. The aim of aeration is to release a landfill from aftercare in a shorter period of time. Aeration improves the leachate quality. It has the potential to perform nitrogen removal by nitrification / denitrification. All these aspects help to obtain a sustainable landfill. In order to limit the energy demand, aeration can be performed actively with low pressure aeration (a system is comprised of gas wells, pumping station and off gas treatment) or passively with the semi-aerobic Japanese approach (Fukuoka system). The processes are understood better and better. More work needs to be done on:

- effective temperature control (in both aerobic and semi-aerobic conditions);
- prevention of adverse effect (e.g. heavy metals) on leachate quality;
- nitrification at higher temperatures, and;
- when can we stop aeration (required reduction of waste, gas and leachate properties).

Modelling & hydrology: Richard Beaven
The movement and distribution of liquid has great impact on the degradation and consequently on gas production and settlement. The key challenges are moisture distribution and flushing. More knowledge on moisture distribution can be obtained by research and related geophysical modelling. This will ultimately result in improved design and construction of landfill infrastructure. Flushing is currently mainly considered by means of simple complete mixing models. In the future dual porosity models will (have to) be used. More knowledge about (the development of) structure characteristics of the waste is required. To that end both gas tracer and water tracer experiments need to be developed. With that knowledge appropriate flushing strategies (e.g. fill & draw, on-off) can be designed. Attenuation within the landfill requires hydraulic equilibrium. In order to obtain that, appropriate and effective engineering controls are required (the right type of waste in the right concept with the right structural characteristics).

Leaching, completion, predictions: Hans van der Sloot
Characterisation tests are the tools to assess leaching criteria and to gain knowledge on processes that determine the leaching behaviour of materials. There are three types of tests: pH-dependence test,

percolation and tank test. A lot of work is going on to harmonise these tests. They are not only applicable in waste, but also in contaminated soil, secondary materials, construction materials, various industrial products. In addition to leaching characteristics also aspects like dissolved organic matter, redox potential, acid and base neutralisation capacity and ferrous and aluminium oxides are of great importance. Knowledge of these properties in addition to leaching characteristics enables understanding and explanation of differences between field, lysimeter and laboratory results. Moreover, these parameters are needed to assess the long-term behaviour of landfills by geochemical modelling. Data can be transformed to a uniform format and presentation, this enables comparison of data from different studies. One single database enables establishment of consistency and validation of process knowledge that is essential for modelling the long-term environmental impact of landfills.

Stability: Morton Barlaz
A landfill is "functionally stable" when the waste mass, post-closure, does not pose a threat to human health and the environment. This condition must be assessed in consideration of leachate quality and quantity; gas composition and production; cover, side-slope and liner design; site geology and hydrogeology; climate; potential receiving bodies, ecosystems and human exposure; and other factors deemed relevant on a site-specific basis". SWANA Stability Subcommittee: "Functional stability should be assessed in the context of a proposed end use and a proposed level of post-closure care, which may vary from no care, to some level of ongoing maintenance or monitoring that is designed to assure that no factors change that could increase potential threats to human health and the environment".

Summary of the discussion:
The audience was invited to put itself in the position of a regulator and try to define what it would require before considering to release a landfill operator from its aftercare obligations. If we can determine what is required for completion, we might also be able to define what we need in the process to achieve completion.

It was put forward that zero emissions are an illusion. Regulators will have to accept that there will always be some emission. Regulators intend to avoid risks. The most important thing is to convince them that the risk of a landfill is minimised. It was felt that we have to widen our knowledge of waste and waste processes in order to achieve sustainable landfills. To that extent compiling and integrating data is of utmost importance. Regulators need to be convinced with data on the current condition. The leachate quality and quantity from a perspective of human health and the protection of the environment need to represent acceptable level of emission. But also 'evidence' has to be presented that this situation is not going to change in the future, e.g. by any catastrophic events.

This implies that some kind of risk assessment is necessary. Risk assessments can however be influenced. Many believe that risk assessments do not yet provide a robust tool. It is therefore unavoidable to rely on monitoring values for waste, gas and water (table values). This does however provide another problem. Based on table values it can be determined that the waste mass has stabilised. That does however not yet take the environment of the waste mass into account. The residual emission of the stabilised waste mass may be acceptable in one environment, but possibly not in the next. An extreme example is arid regions with minimal precipitation. Another example is the appropriateness of limiting chloride and sulphate emissions near the sea.

An important aspect is where the responsibility of the operator ends and the responsibility of society starts. It is society that produces the waste and wants it to be disposed. It would therefore be fair if society accepts some risk and thus takes some of the responsibility. It was also recognized that waste management companies are paid to accept the waste and therefore have a responsibility for its safe disposal. Society also takes responsibility in another way. That is by accepting directives that reduce harmful substances in products and consequently in waste.

There seems to be a contradiction between all the things we still need to learn and convincing the regulators. We have to realise that the first cars were far from perfect. They were nevertheless produced and used. They were improved and perfected based on the experience that usage provided. It was recommended to start working on the development of a completion framework and demonstrate it to the world with concrete case studies.

Conclusion
It was recommended to convince regulators by 1) compiling and integrating data, 2) disseminating the acquired knowledge, e.g. by organising workshops and 3) developing and discussing a completion framework and making it concrete with landfill case studies. These recommendations will be considered for inclusion in the IWWG Sustainable Landfill Task Group action plan.