Waste degradation and leachate and gas production

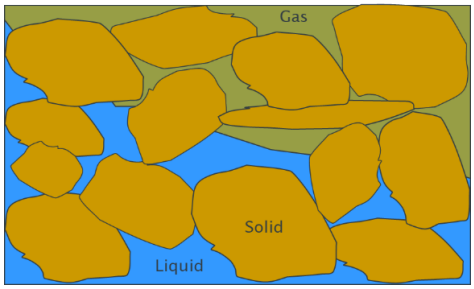
Summary: A fraction of the waste materials deposited in a landfill degrade or decompose as the result of chemical reactions. The solid phase of the compounds first dissolve into the liquid phase and then break down into simpler compounds which include acids and gases. The chemical reactions take place at rates that are influenced by populations of bacteria.

Four main bacteria types are involved in the degradation process – fermentative, acetogenic, methanogenic, and sulphate reducing bacteria. The bacteria consume and break down the dissolved organic matter. The bacteria emit acids and alcohols which are consumed and broken down by the acetogenic and methanogenic bacteria populations. All bacteria types emit dissolved gases which become part of the gas phase when they come out of solution. They also emit the gas hydrogen sulphide that is responsible for the bad egg smell that is associated with landfills.

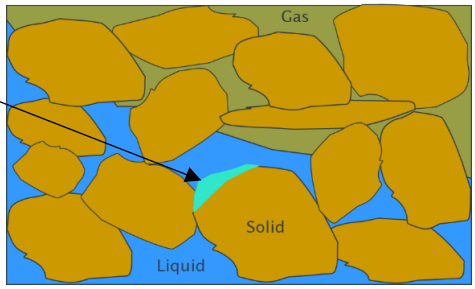
Waste degradation

A fraction of the waste materials deposited in a landfill are not stable. They degrade or decompose. Water needs to be present, because degradation /decomposition is the result of chemical reactions that can only take place in water.

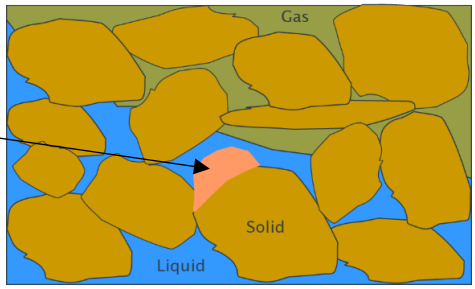
Landfilled waste takes the form of an assembly of porous material that contains an unsaturated mixture of liquid and gas within its pore space.



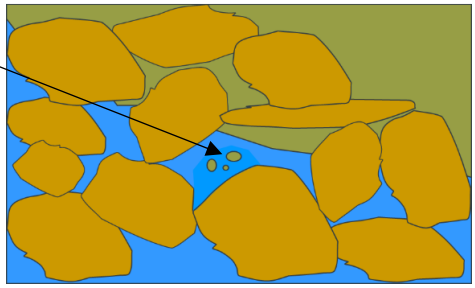
The solid phase compounds first dissolve into the water.



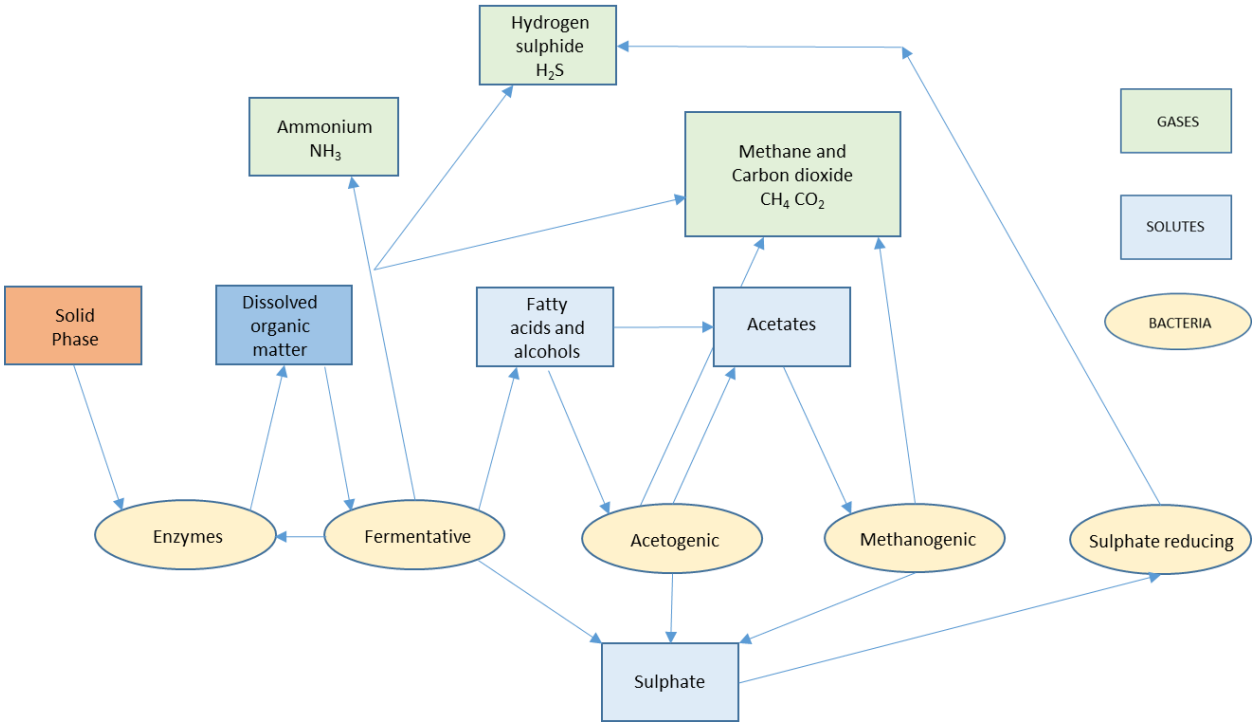
The dissolved waste compounds then react and the complex dissolved waste compounds are broken down into simpler compounds which include acids and gases.



As the concentration of the dissolved gases increases some of the gas comes out of solution and joins the gas phase in the pore spaces of the solid waste material.



The chemical reactions take place at rates that are influenced by the bacteria populations that are present. The reactions lead to a reduction in the solid phase which induces settlement of the waste material.



The processes involved in waste degradation are very complex and the literature on the subject contains a large number of versions of a block flow diagram of waste decomposition that attempt to describe what is happening. The diagram above is a simple version derived from one published by (Christensen and Kjeldsen 1989).

The diagram shows how four of the main bacteria types are involved in the degradation process – fermentative bacteria, acetogenic, methanogenic, and sulphate reducing. The fermentative bacteria consume and break down the dissolved organic matter, whilst producing enzymes that assist with the dissolution of the waste solid phase into the liquid phase. The fermentative bacteria emit acids and alcohols which are consumed and broken down by the acetogenic and methanogenic bacteria populations. All three bacteria types emit dissolved gases which eventually find their way into the gas phase when they come out of solution. They also emit sulphate which joins the sulphate dissolved from otherwise inert sources such as demolition waste. This is consumed by sulphate reducing bacteria which emit the gas hydrogen sulphide that is responsible for the bad egg smell that is associated with landfills.

<u>Leachate and gas production</u>

To understand how leachate and gas are produced we have to understand the chemistry involved. This means we need to be able to convert the description of the waste in terms of the more familiar characteristics of Food, Green waste, and so on, to a description in terms of chemical compounds (Protein, Fat, Carbohydrate and Glucose).

The link to *chemical compounds* lists the chemical compounds found in a landfill as the result of waste decomposition.

The link to *Chemical degradation stoichiometric equations* lists the pathways of the chemical degradation reactions that take place. These pathways are expressed in the form of stoichiometric equations.

The stoichiometric equations can be used to estimate the quantities of leachate and gas consumed or produced as the waste degradation reactions proceed. A small amount of water, equivalent to 9% of the mass of the degradable waste fraction is consumed in the reactions. About 3% of the gas mass formed is accounted for by ammonium, hydrogen sulphide and trace gases. The remaining 97% consists of methane and carbon dioxide. The CH4:CO2 ratio is around 30:70 by weight or 50:50 by volume.

The stoichiometric equations also describe the interaction between the dissolved waste compounds and the bacteria that are present. The bacteria only consume some of the waste that they break down. In fact they break down about 10 times the amount they consume. This phenomenon is known as a catalytic process which enhances the degradation reaction rates considerably and determines the rate at which the leachate and gases are produced.

The growth of the bacteria populations and therefore the rate of the reactions can be inhibited by the acidity (pH) of the leachate. The pH is determined by the state of the chemical equilibrium of the leachate. Rates of reaction are also influenced by temperature which is determined by heat generation as the result of the reactions themselves. *Both chemical equilibrium and heat generation and transfer are discussed in other Notes which may be downloaded from the LDAT Help documentation.*

Reference

Christensen, T. H. and P. Kjeldsen (1989). Basic biochemical processes in landfills. Sanitary Landfilling: Process, Technology and Environmental Impact (Eds T. H. Christensen, R. Cossu, & R. Stegmann), Academic Press, London, UK.