decomposition

The following is a very basic description of the composting process in the compost toilet. You don't have to worry too much, as nature takes care of it – it works. It is the same process that happens in the wild all the time (thank God – otherwise we'd be wading through fallen leaves, dead animals and poo all the time). Nature has had millions of years of practice, and will do the job perfectly.
Decomposition is what happens to organic material on the path to becoming inorganic, or mineral. Everything that was once alive is organic. All our food was once alive, and therefore all our waste is organic.

The work is carried out by micro-organisms, mainly bacteria and fungi. In a compost toilet, or in a compost heap, bacteria tends to work on the fresher material near the surface, and fungi breaks down the older material in the middle of the heap. In our design, it is mainly fungi that do the work, as the heap doesn't get too hot. You may have noticed your compost heap (especially if you have just added a lot of grass cuttings) can get very hot. This is the action of bacteria. But your compost toilet pile won't get this hot; it will usually operate between 15-30°C, at which temperatures the decomposition will mainly be carried out by fungi and moulds, although there will be some bacterial activity.

In organic matter, molecules contain long chains of carbon atoms. When organic matter decomposes, the bonds in these chains break, and energy is released which the micro-organisms use. Oxygen is used in breaking these bonds, and is converted to water. Chains become smaller and smaller each time they break down, until they won't break down, or decompose any more. The material can then be considered inorganic, or mineral.

The process is the same as in a compost heap, but in a compost toilet, although there may not be enough material to generate much heat, due to the time involved between use and emptying, organic material will all break down to compost. It would probably be more accurate to call this a mouldering process rather than a composting process. However, it produces compost, and the phrase 'mouldering toilet' is if anything, probably less attractive to most people than compost toilet.

95% of all living tissue is made up of 4 main elements:

- oxygen (O): 62% (mainly in the form of water)
- carbon (C): 20%
- hydrogen (H): 10%
- nitrogen (N): 3%

Fats contain mainly carbon and hydrogen.
Carbohydrates contain mainly carbon, hydrogen and oxygen.
Proteins contain mainly carbon, hydrogen, oxygen and nitrogen.

Other important elements present in organic matter that contribute to the formation of nutrients on decomposition are:

- phosphorus (P)
- sulphur (S)

aerobic decomposition

Aerobic decomposition occurs when organic matter decomposes in the presence of oxygen. This is the type of decomposition we're after in the compost toilet.

Aerobic decomposition is around 20 times faster than anaerobic decomposition.

Elements combine with oxygen to produce odourless, harmless, and/or useful (to plants) end-products:

- oxygen - oxygen O_2
- carbon - carbon dioxide CO_2
- hydrogen - water H_2O
- nitrogen - nitrates NO_3
- phosphorus - phosphates PO_4^{3-}
- sulphur - sulphates SO_4^{2-}

Oxygen and hydrogen have many ways of escaping, in combination with other elements.

Carbon is converted to carbon dioxide and leaves as a gas.

Nitrogen, found mainly in proteins, is very important in that it forms nitrates which are the most important nutrients for plants, and paradoxically, cause the most problems in watercourses via algal blooms.

It eventually ends up either as nitrogen gas, or as part of the proteins of living tissue again after it is taken up as nitrates by plant roots.

Here is a brief outline of the path it takes:
Firstly, it is excreted from the body as urea (lots of different versions of the chemical formula of urea: $CO(NH_2)_2$; $(NH_2)2CO$; CH_4N_2O; CON_2H_4 – the figures all add up to the same combination of elements though), which then degrades to ammonia (NH_3). Ammonia then uses oxygen (quite a lot – around 5mg of oxygen per 1mg of ammonia) to create nitrites (NO_2), in combination with a type of bacteria called nitrosomonas. Then the same process produces nitrates (NO_3), with another type of bacteria called nitrobacter. These processes also require carbon, and don't work too well in the cold (less than 5°C).

Then, either:

1. the nitrates are taken up by plant roots, or
2. micro-organisms use some oxygen from nitrates (especially in the absence of free oxygen) to decompose more organic matter, leaving nitrites (NO_2), nitric oxide (NO), nitrous oxide (N_2O), or (by far the most abundantly) nitrogen gas

Phosphorus combines with oxygen via the action of micro-organisms to produce phosphates. These are very useful to plants, but are the main cause of eutrophication (algal blooms) if they get into watercourses.

Sulphur is present in small quantities in all organic matter. As organic matter decomposes, it combines with oxygen to produce first sulphites ($SO3^{2-}$), which then combine with more oxygen to become sulphates ($SO4^{2-}$). If the decomposition is aerobic, they cause no problems.

anaerobic decomposition

Anaerobic decomposition occurs when organic matter decomposes in the absence of oxygen.

Elements then combine with hydrogen to produce end-products which can be smelly, potentially explosive and not so useful to plants:

- oxygen - water H_2O
- carbon - methane CH_4
- hydrogen - hydrogen H_2
- nitrogen - ammonia NH_3
- phosphorus - phosphane PH_3
- sulphur - hydrogen sulphide H_2S

This is the type of decomposition that occurs when the micro-organisms can’t get any oxygen, i.e. if the heap is waterlogged. We certainly don’t want this kind of decomposition in the toilet – ammonia and hydrogen sulphide (the rotten eggs smell of stink bombs) stink to high heaven, and methane and hydrogen are explosive! As for phosphane, it will only be present in small amounts, which is good, as chemical industry health and safety data indicates that it is both explosive, and may cause asphyxiation in enclosed, poorly ventilated areas.

So we absolutely have to ensure that oxygen is present in the heap, and the most important factor in achieving this is to ensure that there is a permanent drain at the lowest point of the chamber, and to check that it never gets blocked.

You shouldn’t wee in the compost toilet if you can possibly help it (and let's face it, you often can't); small amounts are OK, but don’t use it just for a wee. As well as making the heap waterlogged,

urine breaks down to ammonia, which gives off a foul smell, and actually kills useful micro-organisms.

Another reason that the heap should be kept aerobic is that certain microbes that feed on bacteria need oxygen to survive. If the heap starts to turn anaerobic, these microbes will begin to die off, and allow bacteria numbers to spiral out of control; their dead bodies will clog any air gaps that might be left, and contribute to the general slimy, smelly nature of an anaerobic pile. Yuk.