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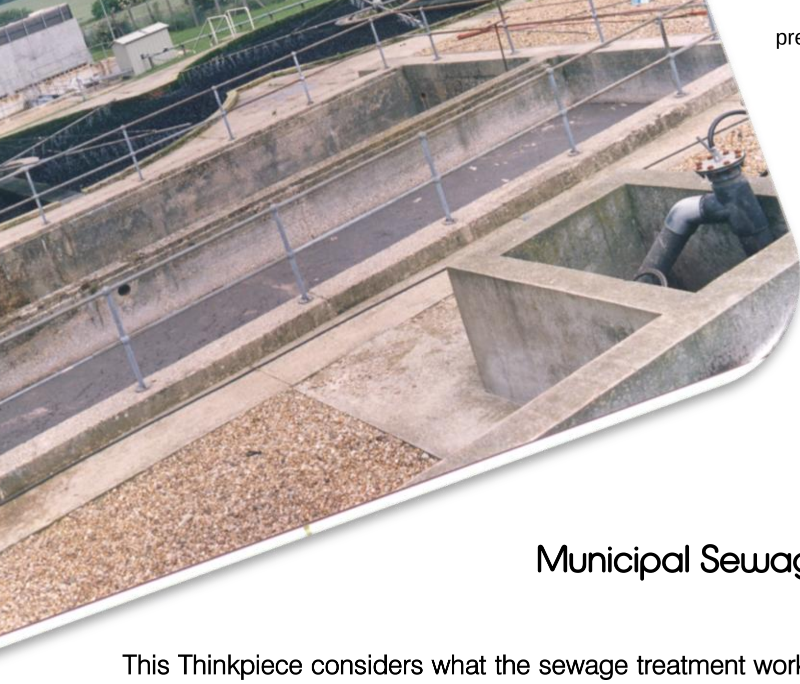

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# Municipal Sewage Treatment in 2050

**This Thinkpiece considers what the sewage treatment works of 2050 might look like. Factors that will influence the choice of flowsheet, such as sewerage infrastructure, carbon accounting and water use, are considered. Management of the sewage treatment flowsheet itself is predicted to be a major innovation, together with the use of novel unit operations.**

## 1 Introduction

Pick up a textbook from the start of the 20th Century and those familiar with today's sewage works will not have difficulty recognising the flowsheet of the 1900's (1). The sewage treatment flowsheet has remained largely unaltered for almost a century.

At its core, sewage treatment relies upon sedimentation and aerobic biological processes. The great innovation of the late 19th Century was the trickling filter, harnessing biology to allow polluting organic matter to be removed. The development of the activated sludge process – in 1913, a long time ago - allowed for greater control and in modified formats becomes capable of nutrient removal i.e. nitrogen and phosphorus (2).

So why might a new flowsheet be needed, and what will a sewage works look like in 2050 ? It is worth quoting the Kershaw (1) from almost a century ago, "There is no 'best method of sewage disposal' which can be universally adopted regardless of local conditions". This will remain true; but the nature of the sewage to be treated in 2050 will have changed.

## 2 Sewerage

In 2050, there will still be an extensive sewerage network. Dry composting and urine separating toilets will be more readily available but their acceptability to society will remain limited, particularly so in urban areas. Life cycle analysis, public acceptability and public health studies will have shown that continuing to use water borne sanitation remains the accepted and most universally applied system.

Currently, the total waste sector is reckoned to be responsible for 3 % of total global greenhouse gas (ghg) emissions (3). Between now and 2050, the big reductions in ghg emissions are likely to come from other sectors, such as primary energy production and transport. In 2050 this means that the carbon footprint of sewerage networks and treatment plants will be a higher proportion of the overall carbon footprint, and so be subject to greater scrutiny. Alterations will be avoided whenever possible to reduce increases in embedded carbon (4).

Planning permission, with greater stakeholder engagement embedded through EU legislation, means that relocation of existing wastewater and waste disposal sites will remain very difficult and often uneconomic. Therefore best use will be made of existing sites and their infrastructure.

## 3 Sewage Flows and Loads

In 2050, influent flows and loads to municipal sewage treatment works will have changed – but not dramatically. There will be some attenuation of stormflows through the application of techniques such as Sustainable Urban Drainage Systems (SUDS). However, the cost of retrofitting sewer networks – in money and carbon footprint terms as noted above – means that extensive separation of foul and storm waters will not have taken place.

There will be a much reduced contribution from trade effluents as industry moves to more efficient water use and better in-process water recycling. Changed formulation of detergents, cleaning and personal care products will mean that non-biodegradable – 'hard' - chemical oxygen demand (COD) and nutrient concentrations will have been reduced. Therefore sewage constituents will be more biodegradable.

Domestic water consumption will have fallen, reaching today's upper target of 120 l per head per day (5), but not beyond because of people's lifestyles. Therefore typical sewage strength will have increased. There will be more widespread use of collected rainwater for toilet flushing, presenting the regulators and water utilities with an interesting problem on how to charge for sewerage decoupled from potable consumption.

So the sewage of 2050 will remain variable in terms of flow and quality but will be stronger and more biodegradable.

## 4 Flowsheet Management

At all medium and large treatment works, smarter use of flow balancing and internal recycles will be the norm. Rather than designing all parts of the works to treat 3 dry weather flows, whatever the flowrate, this will allow crucial unit operations to be operated at near-steady hydraulic loads close to their optimal design.

On-line sensors will also allow the strength of sewage, in terms of key components such as suspended solids and biochemical oxygen demand (BOD), to be monitored and therefore adjusted by adding different streams to be blended to maintain constant loading. These sensors will not be 'fit and forget'. However, many will not only be self-cleaning but self-calibrating. Managers of treatment plants will recognise that care and maintenance of sensor systems will be crucial to better treatment.

Overall, control of sewage treatment works will look more like that of chemical process plant than sewage works of today. Techniques that have been commonplace in the manufacturing sector, such as the use of statistical process control, implementation of continuous improvement ('Kaizen') and application of 'six sigma' will be widespread. Good quality data from the sensor systems mentioned above will be critical in applying these techniques that will allow plants to be operated in optimal modes, thereby reducing overall life cycle costs of operation and minimizing the carbon footprint.

The practice of composting green wastes will have been restricted; the realisation that this fastracks carbon dioxide back to the atmosphere will have been realised. At suitable sites, modified anaerobic digesters will receive a mixture of organic municipal waste with primary sludge to generate methane.

## 5 The New Flowsheets

As noted above, in 2050 there will be a range of flowsheets applied to sewage treatment depending upon the local circumstances, as there always has been.

There will, however, have been a revolution in the core unit operations used in municipal sewage treatment works. A major development will have been the application of anaerobic processes to mainstream flows. Ambient temperature anaerobic treatment of sewage will be possible by fortification of the influent waste stream, either from sludges generated on-site or other imported organic wastes as noted above. These processes produce biogas to recover energy but the major benefit will be reduced aeration costs (Cartmell, pers. comm.).

Where aerobic processes are used, they will be operated to maximise biomass production. This leads to a reduction in carbon dioxide emissions – at a maximum, 5 times less oxygen is required to treat organic carbon when compared to a zero biomass yield aerobic process (6). Aeration costs will be reduced further by using bubbleless gas mass transfer bioreactors; this technology removes the need to dissolve oxygen in water, the rate limiting step of oxygenation (7). Aeration needs will be further reduced through greater understanding of the underlying microbial processes and better process control. For example, nitrification will be stopped at nitrite prior to denitrification and anammox-type processes, oxidation of ammonia by nitrite, will be more widely used.

More works will be covered to prevent odour dispersion to local communities. This will offer the opportunity of removing pollutants via the off-gases. For example, low energy total nitrogen removal could be achieved by inhibiting nitrification to form nitrous oxide gas, reducing aeration requirements compared to converting ammonia to nitrite or nitrate, which can be removed while off-gas odours are treated.

At some works, primary sedimentation will have been replaced by continuously moving fabric belt filters. These ensure that suspended solids removal is more efficient, leaving an almost solids free effluent – which might be called 'filtered sewage' rather than 'settled sewage' – for onwards treatment. Mechanical removal of the solids – 'primary filtered sludge' – from the filters ensures that the solids dry weight composition is high, eliminating the need for one or more solids thickening and dewatering stages prior to further sludge treatment.

The overarching principle of waste minimisation – deal with waste at the source rather than mix and dilute – will be applied to sludge treatment and handling. Sludges will be treated as a fuel rather than a waste (8). The drive will be to remove water in order to recover energy from sludges. Sludge dewatering technology will have benefitted from concerted research investment so that economic physico-chemical unit operations are available.

Almost complete removal of solids, either as described above or using membrane bioreactors, will allow adsorption processes to be applied for residual nutrient removal. For example, ammonia and phosphate selective ion exchange processes will recover these materials for further industrial uses, including fertilizer. Alongside biogas and biomass production, some sewage works will be considered as chemical production plants.

## 6 Final Effluent Uses

By 2050, consenting will have changed also. An environmental risk-based approach will see sewage works operators changing discharge quality depending on the receiving waters capacity for self-cleaning without adverse environmental impact.

Rather than undertaking expensive nutrient removal, final effluents will be reused in agriculture where local conditions permit. Secondary effluents will be delivered to farm storage reservoirs or direct to fields and glasshouses for crop production. Better quality effluents will be reused locally for non-potable applications such as toilet flushing and irrigation of sports fields.

Thus in 2050, smarter use will be made of final effluents, as cleaner water will remain the most valuable product resulting from sewage treatment.

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