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Sewage: some problems and solutions

A. T. Willimas
Centre for Environmental Science and Technology, School of Applied Sciences, University of Glamorgan, Pontypridd, Wales, UK
E-mail: AWILLIAM@Glamorgan.AC.UK

Abstract

Sewage sources are varied and sewage may be discharged from long sea outfalls, sewage treatment plants, combined sewer overflows (CSO's), fly tipping, shipping, etc. The question of malfunctioning and badly designed CSO's is probably the biggest sewage problem for the 21st Century. Removal of the dissolved/suspended pollutants allowing discharge of substantially clear water from sewage treatment plants (preliminary, primary, secondary and tertiary treatments) into the sea or rivers, is the usual solution, but incineration - which has long lead in times, and recycling are among factors to be considered. Sewage works were designed as plants for the removal of solids and organic matter from sewage and *never* to remove pathogenic bacteria. EC legislation will mean that sewage discharges from these sources will have minimal effect on the environment in the future, but concentrated sewage sludge disposal is a problem as are the questions of viruses and bacteria in our waters as a result of sewage discharge. Sewage cake produce derived from these works, can be spread on agricultural/forest land, tips, pumped to sea, dumped at sea by boat or incinerated. Some 40,000ha of derelict land is reclaimed per year in the UK. Currently some 5% of sludge is used on such land but the potential exists for up to 20%. A large problem is matching continuous sludge production to irregular availability of restoration sites. In the UK, 25mt of domestic and industrial waste are disposed of in landfills; 15% of sludge production is disposed of by this method. Forestry is expanding in the UK at some 30,000ha per annum and 1% of the sludge output is applied to forest soil. This could increase to 12%. The USA uses

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composting techniques to ease the landfill problem but in the UK uncertainty exists as to how the sludge regulations apply. Options for resource recovery include low temperature pyrolosis to produce fuel oil, protein and fat extraction, animal feed, building materials, but the constraints are that it is too costly and therefore uneconomic. The future outlook will probably be a more widespread use in land reclamation and forestry.

1. Introduction

With increasingly bureaucratic European legislation, sewage derived from sewage treatment plants will have to conform to acceptable standards. Sewage can be a health problem, is aesthetically unsightly (Fig. 1), can cause a loss of water resources in river catchments and has the potential to inject metallic and other persistent pollutants into a food production environment. Nearly 80% of the metals ends up in sewage sludge.

Fig. 1. The 'Christmas Tree' effect of sewage material (and plastics) along the river Ogmore, South Wales.

Purification of sewage to produce a final effluent suitable for discharge will concentrate any pollutants and the big problem in treatment works is sludge removal. Volume reduction is achieved thorough dewatering, heating, digestion by storing for some 8 weeks at *circa* 30 degrees C. Water is then removed by drying, filtering, vacuum filtration and cake produced. It should be noted that treatment plants were never designed as plants for the removal of pathogenic bacteria - they were built for the removal of solids and organic matter from sewage. Sand filters are good for bacterial removal but for a completely sterile environment chemical dosing is needed e.g. chlorine.

The main future European problem appears to be the question of Combined Sewer Overflows (CSO's) which discharge untreated sewage into rivers and coastal waters usually during storm periods. They act as safety valves which operate at six times Dry Weather Flow, but many leak, and exact numbers are not known. Large numbers were built in the Victorian era and the capital investment needed is probably of a magnitude much greater than for conventional field work.

Some 13.5 million menstruating women in the UK use more than 3 billion tampons, towels and panty liners per year. Two billion Sanpro items are flushed each year into the sewage system and these together with condoms, toilet paper and faecies, constitute an aesthetic and hygienic hazard to our waters as large quantities of the above can be found at 'black spot' beaches [1] and there is currently a £2bn clean up of UK beaches [2].

2. Sewage Disposal

In essence, disposal can be carried out by Long Sea Outfalls, Sewage Treatment Plants, CSO's, Ships, Incineration. Over 300 million gallons of essentially untreated sewage per day is discharged into British coastal waters from the above. This has to be reduced to a basic minimum level.

A. Long Sea Outfalls.

This is the simplest disposal method. Objections include, the risk of infections whilst bathing, the aesthetics of raw sewage, general pollution of tidal waters, heavy metal injection. In the UK these are being phased out. Current outfalls will be utilised to shed excess urban run off water rather than run off water plus sewage. In the Mediterranean, sea outfalls exist in many areas as it is nutritionally poor and can take huge amounts of sewage inputs. The siting of such outfalls causes problems, i.e. near beaches etc. Raw sewage can contain 10 million pathogenic bacteria per 100ml.>5000 times higher than EC Mandatory levels. Clear, sunny water can mean that large amounts of bacteria last for only a very limited time but virus survival times can be months.

B. Incineration

In the Netherlands, a 1km deep pipe has been inserted into the ground which incinerates some 22,000 tonnes of sewage waste per year at a temperature of

280 degrees C. The initial cost was $20 million and building bricks are produced from the ash - 100 tonnes of ash produces 4 tonnes of bricks. Incineration is costly and is utilised usually with clinical wastes rather than sewage. It is worth noting that in Germany, each hospital bed fills an 18kg bin / year. This amount is generated per week in the UK! This is due to inefficient segregation of the 155,000 tonnes produced annually. Even with planning permission, these sites need long lead in times, and political considerations weigh heavily in the planning process. Landfill sites have limited availability so incineration is a future option but will be limited by the high cost factor

C. Sewage Treatment Plants

The aim of these plants is to turn sewage into a clean state so as to comply with legal standards. Essentially, they remove solids and organic matter and effluent levels are set in the UK by the Environment Agency taking into account the ability of the receiving waters to accept pollutants. Water Companies in the UK have been underfunded for years but recent privatisation means that they can approach the open market for money, so that better companies can invest for the future e.g. at Cog in Wales, UK, a £60 million investment is some 3 years ahead of planning.

In essence, in treatment plants, the dissolved/suspended pollutants are removed allowing the discharge of substantially clear water. The usual treatment is:

- Preliminary - which removes inorganic material e.g. grit, dissolved matter and suspended gross solids.
- Primary - which after tank storage achieves a 70% reduction in suspended matter and 40% removal of organic matter.
  - (a) Aerobic biological tanks (Fig. 2). This removes dissolved pollutants using bacteria, especially zoogloea, protozoa, worms etc. i.e. it is a 'food chain'.
  - (b) Percolating filters covering well graded media and travelling sprinkler arms.
  - (c) Activated sludge which has oxygen introduced via diffused air systems plus mechanical aeration.
  - (d) Pasveer Oxidation Ditch which acts as small scale activated sludge tanks.
- Secondary. The above has a high proportion of solids which must be removed before effluent discharge, and this is done under quiet conditions
- Tertiary treatment is undertaken when a higher than usual standard of effluent is needed. e.g. Ultra-violet, micro-strainers (stainless steel drums with small orifaces), sand filters, back upward flow through gravels which helps flocculation, etc.

The above treatment produces a final effluent suitable for discharge, but also concentrates the pollutants.

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C,H,O,N,S, P — Increased micro-organisms

\+ — \+

Micro-organisms → → → Energy

\+ — \+

Oxygen — Carbon dioxide, water, sulphur, etc.

Fig. 2. The basic biochemical equation in aerobic biological treatment.

D. Combined Sewer Overflows.

The impact of these 'on receiving water quality has been more extensively studied than any other type of impact' [3, p5]. It is a very common in periods of heavy rainfall, to find within urban drainage systems, storm sewage, discharging into the nearest watercourse. These operate at 6 times the dry weather flow but they suffer a large problem in that many are simply holes on river banks and monitoring to obtain reliable data needs much careful thought [3]. Increased urbanisation means increased flows into the drainage system and consequently more frequent and longer CSO discharges. For large scale successful operation, a power source and consistent maintenance is needed. Estimates for the number of CSO's in Wales are 3,000, but the actual number is probably much higher. Field work evidence on the river Cynon which drains into the Taff in South Wales, UK, has shown that over this 20km stretch of river, there exists an extra 2 CSO's per km that are not officially recorded [5]. The river Taff, typically carries sewage related debris from this source, as 23% of its load (Fig. 3). This could have interesting repercussions with respect to the Cardiff Bay Barrage currently due for completion in 1998. Breakdown of sewage constituents found in the river Taff, is given in Fig 4.

The bulk of sewage related debris found on the coastline of the UK, comes from this source and on average 11 sanitary items can be found per km of coastline. For large CSO's, hydrodynamic separators can remove large amounts of the first flush plus removal of solids [6].

E. Shipping.

Sewage disposal by sea dumping at special offshore sites from ships in the UK is due to cease in 1998 in accordance with the North Sea Declaration. Currently only three areas operate such disposal schemes (The Firth of Forth, Thames and Plymouth), so problems will soon end in the UK.

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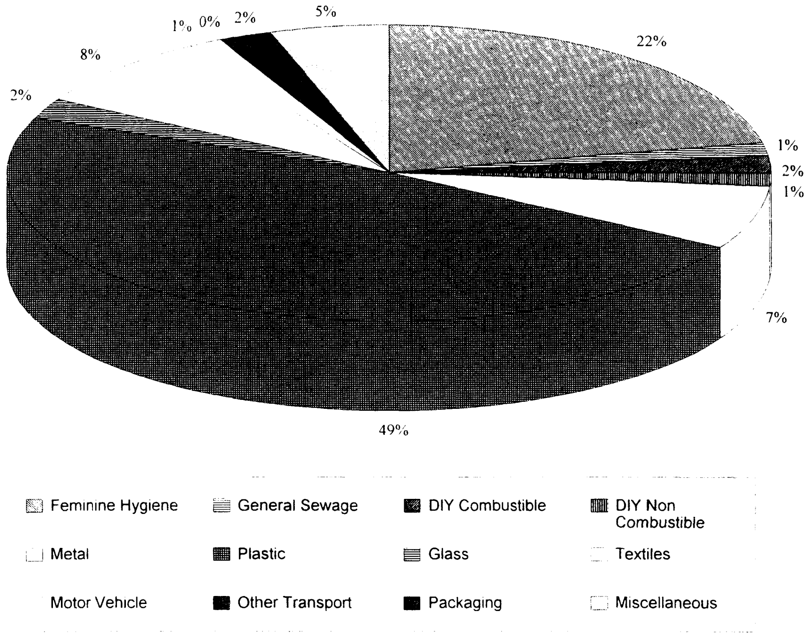

Figure 3 Litter Composition in the river Taff, South Wales, UK.

3. Sludge Disposal/Recycling

Once sewage has been purified to produce a final effluent suitable for discharge, the pollutants, inorganics, etc. will have been concentrated. The BIG problem is recycling the sludge and disposal [7]. Volume reductions are needed e.g. by dewatering (sometimes with chemicals), heating, digestion by storing for several weeks at 27-30 degrees C. Water can be removed via drying beds - especially in rural works, vacuum filtration and sewage cake produced by centrifugation is becoming popular.

The question of volume production is economic. At Cog in South Wales, UK, 6,000 tonnes of dry solids equates to 6,000 trucks; 25% sewage cake means 1,200. Drying the cake necessitates high operating and capital costs. Digested cake has an economic cost of £20 million against £5 million for raw sewage and some 30 Mt is produced per year in the UK. [8].

A. Land reclamation.

There appears to be little appreciation of its value and some 40,000ha of derelict land occurs in the UK. The use of sewage sludge plus soil forming minerals can eliminate the need for expensive top soil cover. Currently the usage is some 5% but there is potential for >20% to be utilised. Public apprehension of the potential environmental problems is evident - heavy metals, odour, etc. but these can be controlled. The big problem is of matching continuous sludge production to the irregular, limited availability of restoration sites.

B. Forestry.
This is a long term crop and UK forests are expanding at some 30,000ha per annum (plus a 120,000ha target for 'set asides'). Some 1% of dry cake is applied, which could be increased to >12%. Assuming transport distances of 16 and 32km respectively, some 6,000-12,000ha of current forests could be available for sludge disposal by this means. Approximately 100 tonnes can be applied to 1ha of clearfill. Concerns exist about the build up of heavy metals especially on nutrient recycling, costs, the appropriate operational practises and protection of the catchment areas.

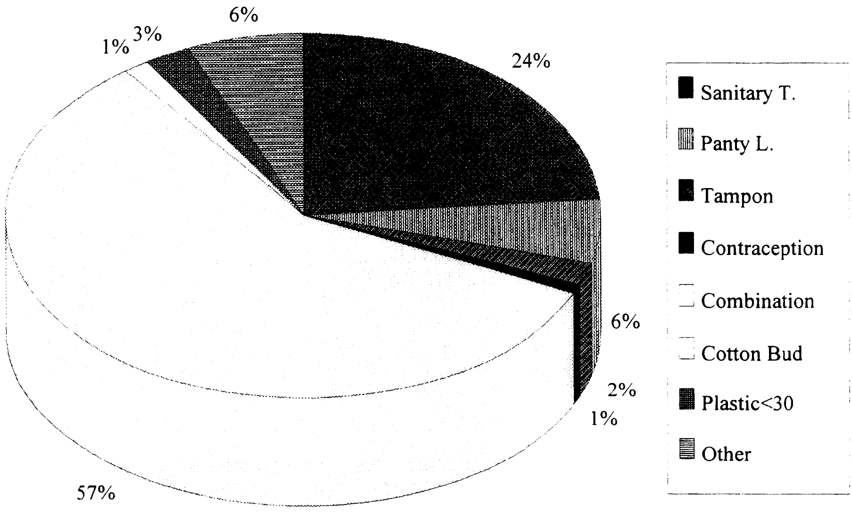

Figure 4. River Taff Sewage Litter Composition: Percentage Volumes

C. Landfill.
Over 25 million tonnes of domestic and industrial wastes are disposed of by this method. Some 15% of the current sludge production is utilised here. Sludge handling methods, settlement rates, leachate production, emissions and cost all exist as problems. The landfill tax of £7 a tonne that was introduced in UK in 1996 could have an appreciable effect on this method of disposal as it could result in higher incidences of fly tipping.

D. Compost and Soil Products,
These are extensively used in the USA to ease pressure on landfills and need large surface areas. Aerobic treatment facilitated by mixing sludge with a bulking agent is very common e.g. straw. The end result is dry and friable. Sludge can be mixed with low grade soils for land restoration, road side verges and general use. This is frequently carried out in the Netherlands. Perceived problems are in relation to heavy metals, pathogens, costs, uncertainty as to how the sludge regulations apply and a need to develop a code of practice.

E. Agriculture
A Code of Practice applies which complements statutory regulations enforcing Directive 86/278/EEC. As sludge comprises significant proportions of N,P and organic matter, sludge application when crops can utilise it makes economic sense. Application is dependent upon treatment processes i.e. high/low releases of nitrogen etc. Careful control is needed because of potential pathogenic bacteria, viruses, protozoa and other parasites which can create health hazards. Monitoring occurs at least once every 6 months and each time significant changes in sewage quality occurs at treatment plants (e.g. levels of zinc, copper, nickel, cadmium, selenium, arsenic, pH, etc.). Sampling is taken to a 25cm depth. All should take into consideration the initial concentrations of potentially toxic elements. For grasslands, no grazing or harvesting takes place within 3 weeks of application; for cereals, fruits, vegetables, none is to be applied within 10 months before planting. Untreated sludge is not used in orchards or glasshouse/plastic structure agriculture.

F. Resource recovery.
Options here include:
- low temperature pyrolosis to produce fuel oil.
- The extraction of proteins, fats, vitamins, metals, etc.
- Use as an animal feed, building materials (bricks and fibre board).Some constraints are that it is very costly, there is a lack of technical development and a residue disposal problem. Most products are currently uneconomic.

4. Some Recommendations

- Ban placement of untreated sewage sludge on land. Inject it.
- Accept Codes of Practice.
- More research is needed. For example, into the utilisation of biogas, but the cut off point of a population of some 30,000 people is still inefficient. Sewage should not only be looked at as one litter component and a more holistic approach is needed. Principal Component Analysis of the river

Taff (Fig. 5), has showed 3 prime litter sources - Factors 1 (household); 2 (Industrial/commercial) and 3 (Sewage). *ALL* should be tackled.

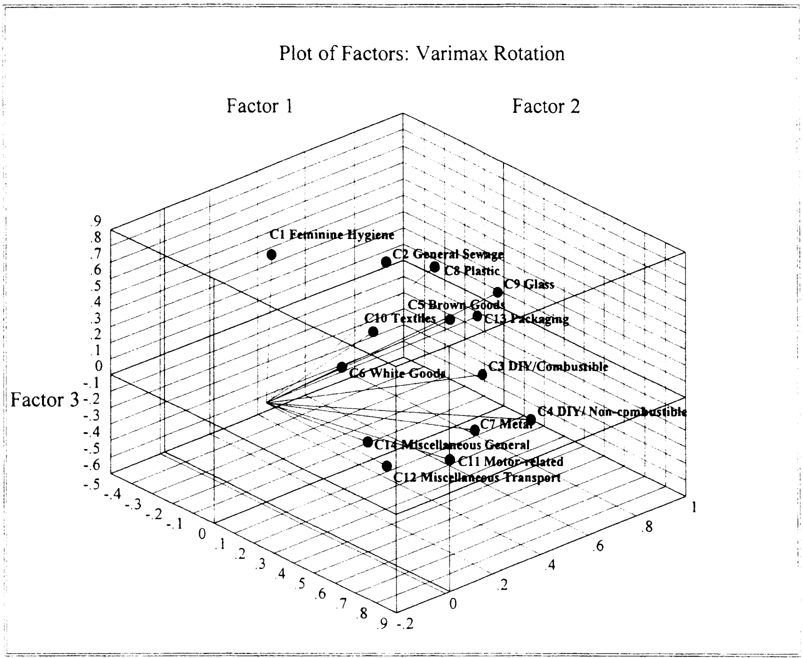

Figure 5. Principal Component Analysis for the river Taff, UK Litter Groups.

- Improve the economics of items such as the flushing bioreactor.
- More promotion by local authorities of the problems of remediated sites.
- Reduce the bureaucracy e.g. that associated with BS 7750 and the Eco Management and Audit Scheme.
- Pay close attention to the minimum standards associated with the Urban Waste Water Directive.
- Review the EC Bathing Waters Directive (EC 76/160) with the aim of giving it tighter status e.g. investigate the role of bacterophages.
- Aim for a behavioural change. For example the ‘bag it and bin it’ campaign for feminine hygiene in the UK has reduced the amounts of sanitary protection items going into the sewarage system from 70% in 1990 to 50% in 1995.
- Pick appropriate engineering solutions, for example, odour. Pumping is a key element in the generation of hydrogen sulphide. Controls can be via air, oxygen, calcium nitrate, ferric sulphate injection, etc.
- Education of the public, There is an old political adage that ‘*there are no votes in sewage*’. Sewage systems are essential but most people do not

want to know about them. The sensitivity of locals must be taken into account. In the SW region of the UK a £900 million project covering 32 schemes impinges upon 81 different bathing locations! [4].

- Research into future treatment by UV light. A Received Dose Radiation (RDR) of 30mW per square cm. can achieve a kill at one plant and not another due to dissolved constituents opaque to UV. It is expensive.
- Upgrade the sewer network - tremendously expensive.

5. Conclusions

1. Greater quantities of sludge could be incinerated, landfilled
2. Incineration has a long lead in time whilst land fill is limited by site.
3. A static use in agriculture will mean a more widespread use in land reclamation and forestry.
4. Outlets will emphasise operation flexibility and cost effectiveness to achieve the best practical environmental option - especially recycling, a policy favoured by the US Environmental Protection Agency.
5. The question of efficiency in CSO's should be addressed.

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