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CHAPTER 1

INTRODUCTION

Increasing environmental awareness has forced operators of wastewater treatment plants to review their options for the disposal of wastewater sludges. Environmental impact and cost considerations feature strongly on the list of criteria used to evaluate routes for the disposal of wastewater sludges. Ultimate disposal also depends to a large extent on the characteristics of the processed sludge.

Johannesburg currently treats approximately 600 Mℓ wastewater daily in its four treatment plants. Direct application of sewage sludge to land which is the current disposal route for most of the sludge generated in these plants, is becoming increasingly unacceptable due to environmental considerations. Conversion to a suitable product, i.e. compost has already been successfully carried out at the Johannesburg Northern Works.

During this research project aspects of this route were further investigated, in particular the effect of legislation on the feasibility of this option. International experience was also reviewed in respect of the agricultural uses of sewage sludge.

In addition a wide range of other options were evaluated in a desk study. Minimisation of the amount of sludge produced in the process could make a significant contribution to solving the disposal problem.

1.1 AGRICULTURAL USE OF SEWAGE SLUDGE

International Experience

Use of human wastes as a resource in agriculture has a long history. Nightsoil has been applied to fields since ancient times, and as cities throughout Europe and North America installed water-borne sewerage systems in the nineteenth century, many of them established "sewage farms", adopting crop irrigation as their preferred means of wastewater disposal. Some even argued that an improved food supply could be one of the major benefits of sanitation. The practice became less popular as concern mounted at its potential for disease transmission, and it disappeared in many countries soon after the 1914-18 war, as the development of modern wastewater treatment processes in the early years of the century made it possible to discharge effluent to surface waters without causing appreciable pollution. (Anon, 1990).

In a 1987 survey of the disposal of sewage sludge in the United Kingdom, it was found that utilisation on agricultural land is the most economic option for inland treatment plants and that this route accounts for 40% of the $1,2 \times 10^6$t DS sludge disposed of annually. (Davis, 1987).

Guidelines for the safe use of the sludge taking into account pathogens and heavy metals are applied. Utilisation of sludge on agricultural land is widely practised in Europe. (See Figure 1.1).

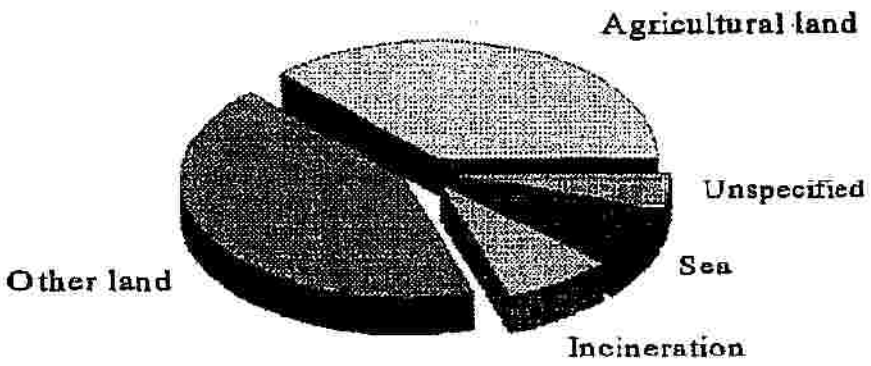

Figure 1.1 : Disposal of sludge in Europe.

Other land uses include landscaping and land reclamation and landfill disposal. Farmers in the UK receive the sludge free on a voluntary basis and only sometimes bear the cost of spreading the material. (Davis, 1987).

Another survey carried out in the European Community in 1987, estimated annual sludge production at 6 million tonnes DS, of which 30% is used in agriculture. (Scheltinga, 1987).

Co-operation in the field of scientific and technical research has been actively promoted by the members of the European Community. Five working parties were set up to consider various aspects of sludge disposal. These were :

- Improvements in the conventional methods of processing (i.e. stabilisation, dewatering, composting) with the objective of reducing costs.
- Methods of odour control and odour evaluation with particular concern for standardisation of olfactometric methods.
- Improvements in anaerobic processes for production of biogas from sludges and manures.
- Development of methods for processing sludges to improve their value, i.e. use as animal feed, as fuels and as chemical feedstock.
- Studies of processes to eliminate heavy metals at their source.
- Improvements in spreading equipment (e.g. injection devices) with the objective of optimising land use.

However, it was not found possible to consider either of the two last topics in the Working Party's activities. Even with just these restricted terms of reference, it was still necessary to narrow down the objectives to a few priority tasks for the period 1984-1985.

More than 706 000 t sludge is sold or given away annually in the United States. Concentrations of 22 pollutants are limited. (Anon, 1989).

In Iowa, sludge is transported to the farmer via injector trucks which inject liquid sludge into the soil. Before a farmer takes part in the programme a careful evaluation of his site is made. Sites with soils with a pH less than 6.5, sandy or sandy loamy soils or sites having a greater than 12 percent slope are ruled out. Locations with a high water table, poor drainage, waterways or areas for runoff are also ruled out. Loading rates are worked out to conform to federal and state requirements. (Haney and Becker, 1987).

In Hong Kong sewage sludge is used for landscaping and topsoil where health risks are minimal. (Wu, 1987).

A review of agricultural application of sewage sludge in the UK concluded the following in 1989 : (Davis, 1989)

1. Agricultural utilisation of sewage sludge is a well-established disposal option in the UK which has developed over the last thirty years.
2. There have been voluntary guidelines to regulate agricultural utilisation for about twenty years, but statutory requirements will be introduced in June 1989 by the implementation of an EC Directive.
3. The water industry uses agriculture to receive 40% of its annual sludge production, but requires only 1-2% of farmland in England and Wales for this purpose.
4. Farmers take sludge on a voluntary basis, therefore sludge producers must offer them a professional service maximizing the benefits of sludge for the farmer and avoiding environmental problems.
5. Research into the effects of contaminants, pathogen destruction and operational aspects has a continuing role in supporting regulations and the professional service and allaying unnecessary public anxiety about sludge utilisation.
6. Apart from agricultural utilisation there is also scope to recycle more sludge to forest land and to land for reclamation.

Experience indicated that two main sources of chemical contamination caused difficulties in the application of sewage sludge to land.

Metal Contamination

Research carried out in France, where metal levels in control plants and plants grown on soils improved with different types of organic waste including sewage sludge, indicated that no significant differences in metal levels occurred. The experiments were carried out over a period of six years and at the end the concentrations of Cadmium and Copper were higher than in the initial values in soils even in the controls. The differences in metal concentration observed with different treatments indicates that the organic wastes themselves play a role in the geochemical metal cycle. (Berthet et al., 1989).

According to EPA guidelines allowable metal concentrations are a function of soil cation exchange capacity. Suggested values are shown in Table 1.1.

Table 1.1 : Suggested limits of metal addition to agricultural crop land (kg ha^{-1}) (U.S. Environmental Protection Agency, 1983).

Metal	Soil cation exchange capacity (meq/100g)		
	5	5-15	15
Pb	560	1 120	2 240
Zn	280	560	1 120
Cu	140	280	560
Ni	140	280	560
Cd	5	10	20

If sludge application ceases after these limits are reached no detrimental effects on plant growth should be observed. (Mininni and Santori, 1987).

In considering the effect of heavy metal contamination of soils, the solubility of the metals is an important consideration. A German study concluded that the solubility of Zinc, Nickel and Cadmium in sludges and soils increases considerably with a decline in pH values. If sludge is to be used as a soil conditioner, Cadmium contents of between 1-1,5 mg/kg should not be exceeded in the interests of longterm soil protection. (Herms, 1987).

Organic Contamination

The polynuclear aromatic hydrocarbon (PAH) levels in soils subjected to 25 separate sludge applications over 23 years were found to be significantly higher than control areas. However these high values were the same as normally observed in urban soils. The sludge application had in fact raised the levels to the same level as in urban soils. This increase resulted from a total application of 44 kg PAH/ha over the 23 years. (Wild et al., 1990).

The presence and behaviour of organic contaminants in the soil depends on substance specific characteristics and a number of soil parameters. The regulation and control mechanisms of the soil are normally sufficient to fix this foreign matter and soil/plant transfer remains relatively low (less than 0,1). Plant animal transfer on the other hand amounts to about 5,0 as a result of the intake of soil or sludge during grazing. (Markard, 1988).

In 1991, a report on a situational analysis of sludge disposal stated that until that date no representative test results on the organo-pollutant load of sewage sludges was available. (Feigner et al., 1991).

However the availability of analytical technology which permits detection of organic contaminants in the parts per million or billion range has allowed the sludge ordinance to stipulate recurrent testing for organically persistent pollutants of sewage sludges used in agriculture. (Bergs, 1991).

In Germany inhibitory measures or restrictions on certain organics have resulted in measurable reduction of the input of these substances to the environment. Even in this technologically advanced country the great number and diversity of substances creates problems in monitoring. (Leschber, 1991).

The pollutant load in sludges in Germany today is considerably lower than limits established or being discussed and the sludge is therefore suitable for use in agriculture.

A long term utilisation concept for sewage sludges in agriculture should be accompanied by strategies which allow swift transition to another option. The use of sludge in agriculture is based on private law agreements and cannot be made mandatory. (Zillich, 1990).

Studies in the USA have shown that the half life of PCB's in the environment is dependent on the structure of the compounds. (Berthouex and Gan, 1991).

As a result of the increased agricultural use of sewage sludge, many countries are in the process of promulgating regulations to manage this practice.

The proposed regulations for disposal of sewage sludge as envisaged by the EPA have released a storm of criticism. One of the main concerns is that the regulations contain maximum application rates for land application of sludge containing certain elements, which make land application on a large scale impractical and therefore appear to be in conflict with the EPA's promotion of beneficial use of sludge. (Anon, 1989).

The limits proposed for the UK compared to those specified by the EEC are given in Tables 1.2 and 1.3. (Ramsay, 1988).

Table 1.2 : Permissible concentrations of heavy metals in sludge amended soils (mg/kg dry matter).

	EEC Values	Probable UK Limits
Zinc	150 - 300	300
Copper	50 - 140	135
Nickel	30 - 75	75
Cadmium	1 - 3	3
Lead	50 - 300	300
Chromium	awaited	600

Table 1.3 : Permissible annual average rate of addition of heavy metals sludge applications (kg/ha/a).

	EEC Values	Probable UK Limits
Zinc	30	15
Copper	12	7,5
Nickel	3	3
Cadmium	0,15	0,15
Lead	15	15
Chromium	awaited	40

This model comprises the following requirements :

- The use of sewage sludges must be organised by a person or organisation which farmers regard as "one of them".

- The control of the sludge quality must always be ensured.

- Considerable financial benefits should arise to all interested parties (farmers, sewage treatment plants, enterprises). (Rudolph et al., 1989).

The European Community has established objectives for waste management which are important in the context of sewage sludge disposal these are : (Truesdale, 1989)

- to reduce the quality of non-recoverable waste and ultimately abolish it;

- to recover, recycle and re-use waste for raw materials and energy;

- to manage non-recoverable waste properly and dispose of it in a harmless manner.

Despite the impending restrictions, a survey in the European Community indicates a saving in mineral fertilizers of 295 million DM, (R 600 million) by the use of sewage sludge. This economic advantage covers the cost of transport over 8 km and that of spreading liquid sludge.

South African Situation

Data obtained from Smith and Vasiloudis (1989) and processed by Ekama in 1992, revealed that approximately 47% of sewage sludge was being disposed of to sacrificial land. (See Figure 1.2).

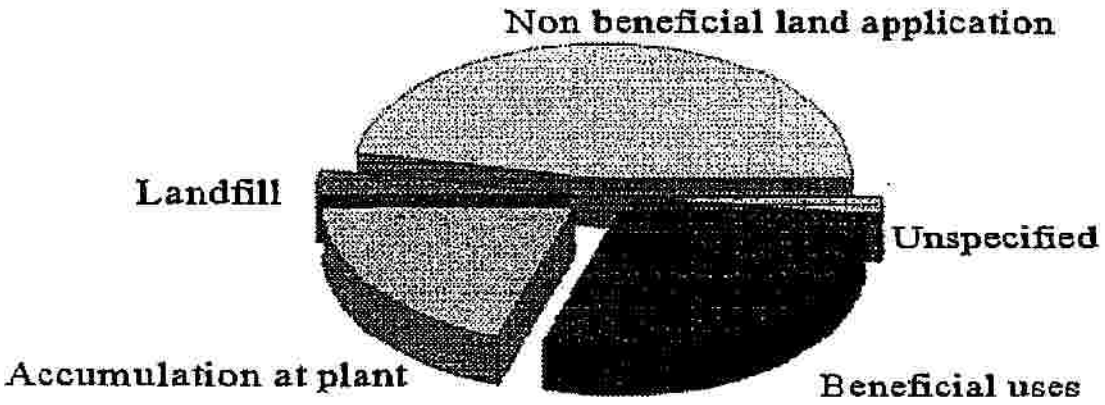

Figure 1.2 : Disposal of sludge in South Africa.

Of the 27% being disposed of in a beneficial manner half was to municipal parks and gardens. (See Figure 1.3).

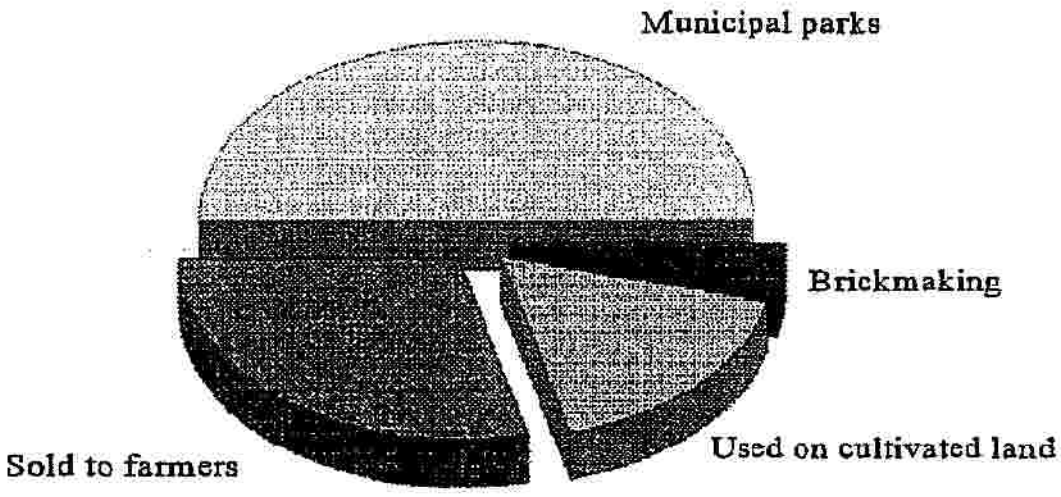

Figure 1.3 : Beneficial use of sludge in South Africa.

1.2 DISPOSAL OPTIONS FOR SEWAGE SLUDGE IN JOHANNESBURG

Composting had already been shown to be a satisfactory option at the Northern Works and was pursued at this plant. It is estimated that 300 t/d of sewage sludge will be generated by wastewater treatment in the Southern Drainage Basin by the year 2014. In order to safely dispose of this amount of sludge a sludge handling strategy had to be developed. The strategy selected had to comply with the following criteria :

- Environmentally acceptable;
- Cost effective;
- Minimum risk;
- Operationally feasible; and
- Politically acceptable.

A project team was formed comprising the two consulting firms who were involved with the extensions to the Olifantsvlei and Bushkoppie plants and Council officials from the Wastewater and Scientific Services Departments. All available options for sludge conditioning and disposal were evaluated. The options considered and the final selection are summarized below.

In view of the sensitivity of sewage sludge disposal in the eyes of the public and the Government authorities it was considered essential to investigate every possible means by which the sludge could be disposed of. Unfortunately there is no single means of sludge disposal that could be acceptably applied, instead there are various steps through which the sludge must proceed in order to be in a suitable condition for the numerous final disposal techniques available. With this in mind, the treatment options were investigated in five categories, namely pre-treatment, conditioning, thickening, dewatering and final disposal.

Pre-treatment

The purpose of pre-treatment is to reduce the volume and mass of sludge and to alter its properties to suit downstream processes, usually in terms of the stability and odour potential of the sludge. Two processes were investigated in this section.

Anaerobic Digestion

The sludge undergoes bacteriological digestion under anaerobic conditions at mesophyllic temperatures (20-40°C). The volatile components of the sludge are reduced in mass and reductions of 30 percent in overall mass were allowed for raw sludge and 15 percent for WAS. Biogas (a mixture of methane and carbon dioxide) is produced as a by-product, at a rate of $1 m^3/kg$ VSS removed.

Dual Digestion

Both aerobic and anaerobic bacteriological digestion take place. This option was not considered in great detail due to the difficulties associated with dewatering the sludge produced by this process, the fact that pure oxygen is required in the aerobic phase, and patent restrictions on the process.