4. PROPERTIES OF WASTES RELEVANT TO AGRICULTURAL BENEFIT AND ENVIRONMENTAL IMPACT

This Section draws on the detailed information from each Member State (Appendices) to present a summary guide to each of the main categories of waste and includes suggestions for pretreatment and good practice for use on the land. Not all categories of waste could be included because of different classification schemes between Member States and a lack of information for some wastes. Also, sewage sludge and compost are outside the remit of this study.

4.1 Farm Animal wastes

4.1.1 Typical composition

The fertiliser value of manures and slurries is highly variable from farm to farm and is dependent on factors such as type of livestock (species, breed and age), diet, type of production, housing system and waste handling system. The dry matter content and nutrient content can also vary considerably from one batch to another. It is thus difficult to come up with a single value on quality of animal manure and slurry. For example feeding standards for N content in practice differ from recommendations and vary between countries, and especially with grazing animals, diet composition is less under control than for other livestock categories such as pigs and poultry. Moreover, N content of grass varies greatly. In addition, nitrogen losses from animal excreta vary according to the housing and storage systems.

Typical ranges for nutrient content of farmyard manures and slurries in Europe are given below in Table 4.1 (Hall 1999). A recent EC study has established criteria for the assessment of nitrogen content of animal manure, the results for each animal category are reported in Table 4.2 and compared to previous values submitted by Eurostat. Based on the information collected during this survey, information on other parameters for each category of livestock is presented in the Table 4.3– to 4.7.

Table 4.1 Typical nutrient content of farm yard manure in Europe (Hall 1999)

	DM (%)	Nitrogen (kg N t^{-1})	Phosphorus (kg P_2O_5 t^{-1})	Potassium (kg K_2O t^{-1})
FYM				
Cattle	20-50	4-9	1-8	4-12
Pigs	25	5-6	1-6	4
Sheep	35-44	10-14	2-3	1-10
Slurry				
Cattle	1-18	2-18	1-12	2-15
Pigs	1-18	2-16	1-12	2-9
Sheep	25-46	14-17	4-21	3-15

FYM – Farm yard manure

Table 4.2 Comparison of EUROSTAT data on N in manure for livestock in EC Member States (EC 1999)

	N content (kg N animal^{-1} year^{-1})	
Livestock type	**EUROSTAT**	**EC 1999**
Cattle		
Dairy cows	68 – 133	60 – 147
Other cows	51 – 101	44 – 115
0 – 1 year	15 – 40	18 – 40
1 – 2 year	37 – 85	31 – 74
> 2year	40 – 85	35 – 81
Pig		
Sows with piglets till 25 kg	12 – 33	21 – 32
Slaughter pigs (25 – 100 kg)	3.4 – 12.8	7.5 – 13.1
Poultry		
Laying hens	0.45 – 0.90	0.35 – 0.82
Broilers, 1.8 kg	0.06 – 0.64	0.23 – 0.52
Ducks, 3.3 kg	0.24 – 2.07	0.41 – 0.97
Turkeys, 13 kg	0.24 – 2.07	0.90 – 1.68
Sheep		
Ewes with lamb till 40 kg	9 – 23	13 – 26
Goat		
Females with kids till 7 kg	10 –20	13 – 21
Rabbit		
Females with kittens	0.21 – 7.60	3.9 – 6.9
Horses	40 – 120	35 - 90

Limitations of the data

There is a vast amount of information on nutrient content of farm wastes. There is more limited information on their metal content and no information on their organic content. The information on the quality of the waste was mainly provided from Denmark, France, Germany and United Kingdom. When information on a particular parameter was only available from one country, the figure was reported as a mean value.

Table 4.3 Typical composition of cattle manure

ELEMENTS	Min	Max	Mean
Dry solids (%)	20	50	
C/N ratio			
pH			7.3
Agricultural value (kg t^{-1}) (fresh weight)			
Organic matter	130	150	
N-TK	4	9	
N-NH_4	1.5	3.1	
P_2O_5	1	8	
K_2O	2.5	12	
CaO	1.8	4.2	
MgO	0.5	1.5	
SO_3			
Na_2O			1.3
Oligo elements (mg kg^{-1} DS)			
Iron- Fe			
Manganese- Mn			
Molybdenum- Mo			
Boron-B			
Cobalt- Co			0.7
Heavy metals (mg kg^{-1} DS)			
Cadmium - Cd	0.1	0.4	
Chromium -Cr	0.4	2.6	
Copper - Cu	15	75	
Mercury - Hg			
Nickel - Ni	1	14	
Lead - Pb	1.4	4.3	
Zinc - Zn	63	175	
Selenium - Se			
Organic compounds (mg kg^{-1} DS)			
PAH			
Sum of 7 PCB			

Table 4.4 Typical composition of cattle slurry

ELEMENTS	Min	Max	Mean
Dry solids (%)	1	18	
C/N ratio			
pH			
Agricultural value (kg t^{-1}) fresh weight basis			
Organic matter	10	107	
N-TK	2	18	
N-NH_4	0.6	2.2	
P_2O_5	1	12	
K_2O	2	15	
CaO	0.3	4.5	
MgO	0.3	1.5	
SO_3			
Na_2O			0.8
Oligo elements (mg kg^{-1} DS)			
Iron- Fe			4000
Manganese- Mn			400
Molybdenum- Mo			
Boron-B			
Cobalt- Co			1.9
Heavy metals (mg kg^{-1} DS)			
Cadmium - Cd	0.2	0.6	
Chromium -Cr	2.6	15	
Copper - Cu	31	70	
Mercury - Hg			0.17
Nickel - Ni	3.3	14	
Lead - Pb	4.3	5.8	
Zinc - Zn	132	750	
Selenium - Se			0.2
Organic compounds (mg kg^{-1} DS)			
PAH			
Sum of 7 PCB			

Table 4.5 Typical composition of pig manure

ELEMENTS	Min	Max	Mean
Dry solids (%)			25
C/N ratio			
pH			
Agricultural value (kg t^{-1}) fresh weight basis			
Organic matter			160
N-TK	5	7	
$N\text{-}NH_4$	0.7	2.5	
P_2O_5	1	7.6	
K_2O			4
CaO			6
MgO			2.5
SO_3			
Na_2O			
Oligo elements (mg kg^{-1} DS)			
Iron- Fe			
Manganese- Mn			
Molybdenum- Mo			
Boron-B			
Cobalt- Co			
Heavy metals (mg kg^{-1} DS)			
Cadmium - Cd			0.7
Chromium -Cr			1.9
Copper - Cu			346
Mercury - Hg			
Nickel - Ni			5
Lead - Pb			2.8
Zinc - Zn			387
Selenium - Se			
Organic compounds (mg/kg^{-1} DS)			
PAH			
Sum of 7 PCB			

Table 4.6 Typical composition of pig slurry

ELEMENTS	Min	Max	Mean
Dry solids (%)	1	18	
C/N ratio			
pH			
Agricultural value (kg t^{-1}) fresh weight basis			
Organic matter	34	70	
N-TK	2	16	
N-NH_4	2.1	3.6	
P_2O_5	1	12	
K_2O	2	9	
CaO	1.4	6.7	
MgO	0.5	1.8	
SO_3			
Na_2O	0.8	0.9	
Oligo elements (mg kg^{-1} DS)			
Iron- Fe			
Manganese- Mn			
Molybdenum- Mo			
Boron-B			
Cobalt- Co			
Heavy metals (mg kg^{-1} DS)			
Cadmium – Cd	0.2	0.5	
Chromium -Cr	2.4	18	
Copper - Cu	180	574	
Mercury - Hg			0.05
Nickel - Ni	3.2	17	
Lead - Pb	<1	12	
Zinc - Zn	403	919	
Selenium - Se			0.6
Organic compounds (mg kg^{-1} DS)			
PAH			
Sum of 7 PCB			

Table 4.7 Typical composition of poultry manure

ELEMENTS	Min	Max	Mean
Dry solids (%)	30	60	
C/N ratio			
pH			
Agricultural value (kg t^{-1}) fresh weight basis			
Organic matter			
N-TK	14	29	
$N\text{-}NH_4$	5.3	6.1	
P_2O_5	12.4	25	
K_2O	8.4	21	
CaO	14.5	40.5	
MgO	1.2	4.2	
SO_3			
Na_2O			9.2
Oligo elements (mg kg^{-1} DS)			
Iron- Fe			1500
Manganese- Mn			600
Molybdenum- Mo			
Boron-B			
Cobalt- Co			0.5
Heavy metals (mg kg^{-1} DS)			
Cadmium - Cd	0.38	0.8	
Chromium -Cr	4.1	24	
Copper - Cu	59	100	
Mercury - Hg			
Nickel - Ni	4.9	17	
Lead - Pb	2.2	4	
Zinc - Zn	403	556	
Selenium - Se			0.6
Organic compounds (mg kg^{-1} DS)			
PAH			
Sum of 7 PCB			

4.1.2 Background

Animal manures and slurries have been used for centuries to fertilise the land. The major plant nutrients are imported to livestock in animal feed but animals utilised only a small proportion of these nutrients and the rest is excreted. If livestock manure is not recycled to land, the farmer is not recovering the full value of the imported feed and unless these wastes are managed efficiently as a fertiliser, pollution occurs.

In the last 50 years, intensive livestock production has increased significantly across Europe to produce a cheap and balanced supply of food. This has resulted in large increases in the quantities of farm yard manure and slurry produced and their inadequate management. The intensive livestock units have separated themselves from the land where the food source is produced and where the manure and slurries can be returned to. Especially in areas where there has been insufficient land area, the nutrient pollution from agriculture due to inadequate disposal of manure and slurry has progressively degraded the quality of water resources as well as soil acidification and ecosystem degradation.

Animal densities vary however widely across Europe with generally low densities in the Southern European countries and much higher densities in the North. For pigs, for example, the density in Northern Europe is about ten times greater than that in the southern countries. Nevertheless, even in countries with lower animal densities, localised diffuse pollution of rivers also happens.

4.1.3 Key properties

The agronomic value of livestock manures depends on their nutrient, organic matter and trace element content. The water content of slurry and dirty water may also be of value for irrigation. For example, slurry is very rich in ammoniacal nitrogen which can be rapidly assimilated by plants while solid manure has a slower release of nutrient and has beneficial effect on the soil structure.

4.1.4 Potential impact on water quality

Animal wastes are responsible for a large number of diffuse pollution of both surface and groundwaters. Following manure application to land, ammonium-N (plus uric acid N for poultry manure) will be converted to nitrate-N which is susceptible to leaching.

Most animal excreta such as slurries have a high biochemical oxygen demand (BOD) ranging from 10,000 to 30,000 mg l^{-1} which if entering a watercourse after application to land can deplete the available oxygen content in water and result in ammonia levels which are toxic to many aquatic animals. High BOD waste added to wet soils can give rise to anaerobic conditions in soil due to soil oxygen depletion and result in poor plant growth. Manures and slurries also contain suspended solids which can increase turbidity in water and smother benthic fauna and flora.

4.1.5 Potential impact on soil quality

Manures and slurries can contain high levels of potential toxic elements (PTEs), particularly zinc and copper due to the use of mineral supplements and veterinary products. This is more problematic for pig slurry which can contain up to 600 mg/kg ds of copper and up to 900 mg/kg ds of zinc, compared to the current EC recommended limit value for sewage sludge used in agriculture of 2500 mg kg ds for zinc and 1000 mg kg ds for copper.

4.1.6 Odour nuisance and potential impacts on air quality

Pig and poultry farms produce the most complaints about odour. The storage on farms of such wastes can also cause problems if the wastes turn anaerobic and give rise to strong odour when the crust is broken.

The sources of ammonia from livestock production are from animal housing, waste handling, storage and landspreading. It has been reported that more than half of the emissions arose from spreading slurry on land. Soil incorporation can be very effective in reducing odour but it must be done rapidly, i.e. within hours or via injection if a significant reduction in losses is to be achieved. The dry matter content has a large influence on ammonia losses from surface application of slurries and other liquid manures.

The emissions from landspreading of the two greenhouse gases nitrous oxide (N_2O) and methane (CH_4) are relatively small compared with emissions from manure stores, fertilised land, housing and outdoor livestock.

4.1.7 Potential impacts on animal and human health

Animal manures contain pathogenic elements in variable quantities depending on the animal health. Manures are applied without treatment and restrictions on the application to land of agricultural wastes are less stringent than other wastes. They potentially represent a greater risk because of the large volumes compared with other wastes for possible contamination of meat, dairy products, vegetables and water resources. In many cases, manures and slurries are applied on the same farm that they originated from. While this practice does not reduce the risk to humans or wild animals, the resident animal population is likely to become re-infected.

There have been reports on cases of drinking water supplies contaminated by cattle slurry resulting in outbreaks of disease in people.

4.1.8 Potential impacts on plant health

The risks associated with the application of agricultural and horticultural wastes are not well documented. Farm slurry is not perceived to be a risk to plant health because it usually takes place on the farm of origin. It is possible that potato cyst nematode may pass through the animal gut if it is present in feed and thus be present in slurry.

4.1.9 Variability

The nutrient content of manures is highly variable from farm to farm and is dependent on factors such as type of livestock (species, breed and age), diet, type of production and waste handling system. The dry matter content and nutrient content can also vary considerably from one batch to another.

4.1.10 Treatment

Most farm animal wastes are not treated. There are, however, examples of treatments applied to farm wastes such as anaerobic digestion at the farm level or in centralised treatment centres. Unfortunately there are no successful large scale processing plants in operation. Liquid animal waste could be added to the sewage and treated in a wastewater treatment works.

There has been success in reducing nutrient release in manures through feed improvement. The other way of controlling the input of nutrient, is by taking into account more accurately the amount added to the soil by manure application together with the other fertilisers and the set up a clear objective at the farm level.

4.1.11 Application/storage

The application of livestock manure varies widely between European countries from > 200 kg N ha^{-1} and > 100 kg P ha^{-1} in the Netherlands to < 40 kg N ha^{-1} and < 20 kg P ha^{-1} in Southern Europe (Hall 1999).

Poultry manure may contain up to 30 kg of N per tonne and thus should be spread at a rate of less than 8.5 tonnes per ha to comply with an N limit of 250 kg N per ha.

4.2 Blood and gut contents from abattoirs

4.2.1 Quality data

A summary of the quality data from the European reports is displayed in Tables 4.8 – 4.10 below:

Limitations of the data

Comparable quality data for these wastes were only available from the UK, France and Belgium. There is also some quality data for abattoir waste in the German country report (Appendix F), this was not included as different waste categories were used.

Table 4.8 Abattoir waste – blood

ELEMENTS	Min	Max	Mean
Dry solids (%)	0	38	11
C/N ratio			
pH	5.3	10.3	6.6
BOD (mg l^{-1})	88	122 000	33 100
Agricultural value (% DM)			
Organic matter			
N-TK	0.6	34.5	12
$N-NH_4$	0	7.3	1.5
Mg	0	0.3	0.03
P_2O_5	0	10.8	1.2
K_2O	0	5.8	0.9
Heavy metals (mg kg^{-1} DS)			
Cadmium – Cd	<0.25	<0.7	<0.25
Chromium –Cr	<0.1	3.2	0.3
Copper – Cu	0.3	34	3.2
Mercury – Hg	<0.01	10	<0.01
Nickel – Ni	<1.0	5.7	0.4
Lead – Pb	<0.1	10	0.3
Zinc – Zn	0.1	87	13
Organic compounds (mg kg^{-1} DS)			
PAHs			
Sum of 7 PCB			

Table 4.9 Abattoir waste – stomach contents

ELEMENTS	Min	Max	Mean
Dry solids (%)	2.4	21	
C/N ratio	16.6	27	22
pH	5.2	9.7	
BOD (mg l^{-1})	6000	41 000	18 000
Agricultural value (% DS)			
Organic matter	88	93	90
N-TK	0.2	26	
$N-NH_4$	0	0.6	
CaO	0.8	1.8	1.3
MgO	0.1	0.2	0.15
P_2O_5	0.0	3.4	
K_2O	0	1	
Heavy metals (mg kg^{-1} DS)			
Cadmium – Cd	<0.25	0.5	
Chromium –Cr	<1	14	
Copper – Cu	0.8	51	
Mercury - Hg	<0.01	0.1	
Nickel - Ni	<1	12	
Lead - Pb	<0.1	54	
Zinc - Zn	2.4	122	
Organic compounds (mg kg^{-1} DS)			
Fluoranthene	<0.1	<0.5	
Benzo (b) fluoranthene	<0.1	0.4	
Benzo (a) pyrene	<0.1	0.6	
Sum of 7 PCB	<0.0007	0.2	

Table 4.10 Abattoir waste – sludge

ELEMENTS	Min	Max	Mean
Dry solids (%)	8	25	16
C/N ratio	6	24	13
pH	6	13	
BOD (mg l^{-1})			
Agricultural value (% DS)			
Organic matter	60	88	77
N-TK	1.9	80	22
$N-NH_4$	0.1	0.2	0.1
CaO	3.5	44	17
MgO	0	4	1
P_2O_5	1.7	36	11
K_2O	0.8	4.4	1.3
Heavy metals (mg kg^{-1} DS)			
Cadmium – Cd	0.1	1	
Chromium –Cr	5	71	
Copper – Cu	5	210	
Mercury - Hg	0.03	1.2	
Nickel - Ni	7.7	36	
Lead - Pb	10	54	
Zinc - Zn	133	1099	
Organic compounds (mg kg^{-1} DS)			
Fluoranthene	<0.1	<0.5	
Benzo (b) fluoranthene	<0.1	0.4	
Benzo (a) pyrene	<0.1	0.6	
Sum of 7 PCB	<0.0007	0.2	

4.2.2 Background

Wastes from abattoirs include blood, gut contents, wash waters and sludge from dissolved air flotation treatment where this process has been used to separate solids from liquid waste materials of the abattoir. Some wastes such as hoof parts and bone meal are recycled in other industries (e.g. fertiliser and glue). Landspreading of abattoir wastes is probably the best practicable environmental option for small-scale abattoirs but it is likely to be much less appropriate for modern large-scale abattoir operations.

Landspreading of blood and gut contents from abattoirs is liable to cause public nuisance due to odours and environmental concerns. If spread on the soil surface it is unsightly and there is potential for disease transmission. The material should be dealt with as for untreated sewage sludge and applied to the land by subsurface soil injection or else incorporated as soon as possible after spreading on the surface of the arable land. The land-use restrictions as for untreated sewage sludge should apply. The rate of application of the waste should be in accordance with crop requirements for nutrients.

4.2.3 Key Properties

Waste blood is produced in large quantities from abattoirs and has various uses including landspreading. Its high fertiliser value has been known for a long time, and it is one of the more traditional materials spread on land. Its nitrogen content is extremely high and its levels of potassium and phosphorus make it a good source of plant nutrients. Nutrients are also found to be more available than those found in other organic wastes.

Waste stomach contents consist predominantly of partially digested feed or vegetable matter. As with the blood waste, stomach contents usually contain high levels of nitrogen, potassium and phosphorus. These nutrients are generally in well balanced proportions with an N:P:K ratio of around 5:1:1. Moderately high ammonium nitrogen content is an added benefit.

As with many other food processing industries, large volumes of wash waters are produced, and the term is often used to describe a wide range of low solid waste materials. This category can contain dung and urine from animal holding areas and washings from distribution vehicles. As for the other abattoir wastes, the wash waters contain a mixture of nitrogen, potassium and phosphorus but at lower concentrations.

4.2.4 Potential Problems

From the data above, it is seen that abattoir wastes contain high levels of nitrogen, potassium and phosphorus. If applied in excess to plant requirements, these elements can cause potential water pollution problems, and may also pose a danger to plant health.

These wastes also have a tendency to have a high BOD which makes the waste readily degradable by soil micro-organisms ; this can rapidly result in anaerobic soil conditions if over applied.

In general, slaughterhouse wastes are a recognised source of environmental contamination by *Salmonella* and other zoonotic pathogens (Wray and Sojka 1977, Edel *et al.* 1978) *Cryptosporidium* may occur in gut contents although not necessarily in infective form. Veterinary ante-mortem inspection at slaughterhouses ensures that no animal suffering from notifiable disease or any other disease likely to affect the fitness of meat is slaughtered for human consumption. However, slaughtered animals may be symptomless carriers of pathogenic bacteria and therefore slaughterhouse wastes should be used with caution and with restrictions on land for rearing livestock or grazing after application.

Strict statutory procedures are now enforced at abattoirs and renderers with the intention of removing, for separate disposal, components of cattle carcasses which might contain BSE.

Abattoir wastes normally have an offensive odour and may, therefore cause public nuisance unless appropriate precautions are taken. To minimise odour nuisance, the wastes should be applied by subsurface injection into grassland or immediately incorporated into arable land. Public nuisance can be reduced by avoidance of spreading in fields close to and upwind of housing. Storage for long periods will encourage odours to develop and so should be avoided where possible.

Different types of abattoir wastes will contain different types and percentages of fat, but chicken processing plants are potential sources of high fat materials. Deleterious effects on crop growth from additions of animal fat are usually observed at relatively low fat percentages compared to wastes containing other fats and oils. Wastes containing animal fats should be incorporated into the soil.

4.2.5 Variability

Abattoir waste can vary considerably depending on the number and type of animals processed and operating system employed. All wastes should be evaluated for major nutrients, pH and solids and BOD before land application. Blood should also be analysed for electrical conductivity and sodium.

4.2.6 Treatment

Landspreading of abattoir waste is liable to cause public nuisance through odour and environmental concerns, and has potential for disease transmission. It would, therefore, be beneficial to treat the waste before by a stabilisation process before land application.

Currently, it appears that there are few waste treatment plants installed at abattoirs across Europe. These are more popular in Scandanavia, with some having aerobic or anaerobic digestion facilities that also produce biogas. Abattoirs in some countries are connected to the community waste water system.

4.2.7 Application

As has been discussed in earlier sections in this chapter, abattoir wastes have potential to cause public nuisance and environmental harm. It is therefore imperative that land application is handled with great care.

The rate of application of the waste should be based on the level of plant nutrients present and a waste management plan should be prepared for the site receiving the waste. Other properties of the waste such as BOD, electrical conductivity and fat content should also be considered when deciding application rate.

As a general rule all abattoir wastes should be injected into the soil to reduce odour and avoid any potential pathogen transmission, and should not be surface spread on pasture land or forage crops. If these materials are surface spread on arable land, they should be incorporated immediately by ploughing. Injection into grassland should be followed by a minimum interval of three weeks before grass is used for grazing or conservation.

Storage time should be kept to a minimum to avoid further development of odours.

4.3 Waste from food and drinks preparation

Examples of the average composition of food and drink industry wastes: Food and drink industry effluent, food and drink industry sludge, and earth-laden suspensions from sugar processing industry

Table 4.11 Average composition of effluent from the food and drink industry

ELEMENTS	Min	Max	Mean
Dry solids (%)			
C/N ratio			
pH	3.7	7.8	5.6
Suspended materials (mg l^{-1})	53	19 730	2 952
COD	434	23 000	9 822
Agricultural value (mg l^{-1})			
Organic matter			
N-TK	2.2	815	243
$N-NH_4$	0.1	463	72
$N-NO_3$	0.02	55	5.5
P_20_5	1.2	519	122
K_20	16	2 582	657
MgO	2.2	173	54
CaO	27	2 170	504
Cl	25	11 634	991
Na_2O	17	10 193	968
Heavy metals (µg l^{-1} DS)			
Cadmium - Cd			1.9
Chromium - Cr			46
Copper - Cu	10	257	117
Mercury - Hg			6.6
Nickel - Ni			53
Lead - Pb	33	100	83
Zinc - Zn	200	989	2 347

Table 4.12 Average composition of food and drink industry sludge

ELEMENTS	Min	Max	Mean
Dry solids (%)	1.3	91	12
C/N ratio	3.6	43	7
pH	2.3	13	7
Agricultural value (% DS)			
Organic matter	25	93	58
N-TK	0.7	12	3.5
N-NH4	0.03	4	0.5
P_2O_5	0.1	16	2.4
K_2O	0.1	16	1.4
CaO	1.3	56	10
MgO	0.04	4	0.6
SO_3	0.4	1.6	1.5
Na_2O	0.4	1.9	1
Oligo elements (mg/kg^{-1} DS)			
Iron- Fe	780	1305	1 042
Manganese- Mn	20	45	32
Molybdenum- Mo	7,9	23	15
Boron-B	11	42	23
Cobalt- Co	0.1	0.8	0.4
Heavy metals (mg/kg^{-1} DS)			
Cadmium - Cd	0.01	10	0.8
Chromium -Cr	0.05	240	28
Copper - Cu	0.10	379	57
Mercury - Hg	<0.01	8	0.2
Nickel - Ni	0.10	154	14
Lead - Pb	0.10	250	10
Zinc - Zn	0.10	1 815	199
Selenium - Se	0.35	6	3.7
Organic compounds (mg kg^{-1} DS)			
Fluoranthene	0.01	0.3	0.2
Benzo (b) fluoranthene	0.01	0.05	0.04
Benzo (a) pyrene	0.01	0.06	0.04
Sum of 7 PCB	0.02	0.21	0.07

Table 4.13 Average composition of earth laden suspensions in sugar beet processing industry

ELEMENTS	Min	Max	Mean
Dry solids (%)			
C/N ratio			
pH			6.7
Suspended materials (mg l^{-1})			215 650
COD			10 922
Agricultural value (mg l^{-1})			
Organic matter			
N-TK			446
$N\text{-}NH_4$			18
$N\text{-}NO_3$			0.1
P_20_5			235
K_20			495
MgO			305
CaO			990
Cl			187
Na_2O			67
Heavy metals (µg l^{-1} DS)			
Cadmium - Cd			
Chromium - Cr			
Copper - Cu			
Mercury - Hg			
Nickel - Ni			
Lead - Pb			
Zinc - Zn			
Selenium - Se			

Limitations of the data

The information on the quality of the waste from the food and drink processing industries as reported above mainly come from Denmark, France, Germany and the United Kingdom.

4.3.1 Background

A large proportion of waste from the food and drink processing industries is re-used in animal feed (vegetable residue, oil production residue) and in the production of organic fertilisers.

The food processing industry is a major water consumer, producing large volumes of wastewater that is generally not dangerous but is heavily loaded with organic matter. A significant proportion of the water consumed is used for washing purposes. To provide a general idea, the dairy industry consumes 2 to 6 m^3 of water per tonne of milk entering the plant, the preserves industry 10 to 50 m^3 of water per tonne of primary material and breweries 4 to 15 m^3 of water per tonne of beer produced.

The effluent produced on food industry sites is either spread directly on agricultural land or treated in an on-site or local mixed (domestic/industrial) wastewater treatment plant. Both the latter cases lead to the production of sludge. Handling the effluent in a wastewater treatment plant on site requires the installation of buildings and equipment designed to accommodate the maximum daily volumes and characteristics of the effluent since the level of its production and its quality vary throughout the year.

A company's choice between installing an effluent treatment plant on site and spreading the effluent directly is not solely dictated by economic factors but also by the local agricultural situation. Local agriculture may permit the direct spreading of effluent or not, depending on the acceptability of the environmental conditions, the hydrogeological and pedological potential of the agricultural sites, the presence of irrigatable crops, etc.

4.3.2 Key properties

Food processing industry effluent is quite variable in composition, depending on the type of industry involved and the period of the year for seasonal industries. The effluent is, however, heavily loaded with potassium. Elements beneficial to plant growth are in solution in the liquid phase and so are rapidly available to plants. Very few trace organic compounds or heavy metals are found in typical effluent from this industry.

The sludge produced by the effluent treatment plants contains high levels of organic matter and nitrogen and has a low C/N ratio. The sludge ferments very easily since the organic matter it contains breaks down very rapidly. For this reason the sludge requires to be stabilised.

A large proportion of the effluent or sludge produced by the food and drink processing industry tends to be produced in varying volumes throughout the year, this is dependent on crop harvesting times. The quality of the effluent can also vary quite significantly, especially if production involves a series of successive operations, as in the preserves industry, which works with a variety of different vegetables. Dairy industry sludge, although produced all year round, tends to decrease in volume during the winter months.

Dairies

Dairies use large amounts of water, mainly for cleaning. Many dairies have built their own effluent treatment plants and produce large amounts of sludge, which contain high levels of N, P, K and organic matter.

Preserves producers

The effluent from the preserves producing industries contains high levels of organic matter, potassium, chloride and sodium as a result of washing, peeling and blanching the vegetables and washing the equipment and the production areas.

Breweries and distilleries

The effluent from the brewing and distilling industry is generally treated in an effluent treatment plant and is also sometimes anaerobically digested. This is to reduce the amount of sludge being produced and to generate energy that is used to heat the bioreactor. The reduction of COD and BOD can be as high as 90%.

Brewery residues contain grain husks and yeast settled out or separated out during the malting and brewing processes. Such waste is mainly reused as animal feed or reprocessed for use in food or nutrient materials.

Distillery effluent contains little suspended material and is rich in potassium, sodium and sulphur.

Sugar producers

Effluent from the sugar-producing industry contains high levels of suspended materials, comprising soil particles and other organic residues. It is rich in potassium, nitrogen, chloride and sodium. Sludges produced by the industry consist mainly of waste lime and pulp residues.

Soft drinks waste

In the soft drinks industry, most of the water supplied does not end up in the product itself but is used for rinsing containers, equipment, floor washing, etc. The waste produced by soft drinks manufacturers is therefore low in solids concentrations but may have a high sugar content.

4.3.3 Potential problems

Food and drink processing industry effluent is frequently heavily loaded with chloride and sodium stemming from the cleaning agents used. If it is spread in too large a quantity these components can damage the soil fertility and the crop yields. If applied to soils under the wrong conditions salts can lead to soil structural damage, reduce the availability of soil water for plant uptake (induce artificial drought conditions) and can be toxic to plant growth.

Waste may also constitute a vector for the potential transfer of plant pathogenic organisms, particularly potato nematode cysts. These organisms constitute a major pest for potato crops, are endemic in Europe and could be introduced in the effluent discharged from vegetable processing factories. Water and soil sediment from potato starch and sugar factories may carry cysts and spread the pests if discharged onto agricultural land. Beet necrotic yellow vein virus (BNYVV) is a causal agent of rhyizomania in sugar beet and could also potentially occur in the sludge receiving discharges from infected crops.

Spreading effluent directly is not a system capable of much development. Effectively, it requires the establishment of a highly local network linking the company to the agricultural areas around the production site where spreading can take place. Once this network is established, the area for spreading can alter very little.

4.3.4 Variability

Seasonal food processing industries produce effluent whose volume and quality vary considerably according to the period of the year. The levels of effluent produced by the dairy industry undergoes strong fluctuations both on a seasonal basis, depending on the volume of milk arriving, and a daily basis (washing periods).

4.3.5 Treatment

Dewatering of food and drink processing industry waste

No system of dewatering is used when spreading the effluent directly.

At companies equipped with effluent treatment plants, sludge is dewatered quite poorly because of its high organic matter content and its lack of structuring elements. Dewatering can be effected using drip tables, centrifuges, band filters or filter presses.

Stabilisation of food and drink processing industry waste

Food processing industry sludge is extremely odorous since it is very rich in poorly stabilised organic matter (with a low C/N ratio). It can therefore frequently cause an olfactory nuisance during storage and spreading. Those nuisances can be reduced through stabilisation such as significant liming. Direct spreading is the solution that restricts problems with odour to the maximum since it only requires a very limited storage capacity. Liming or ramp irrigation techniques can also help to reduce the olfactory nuisance during spreading.

Composting food processing industry sludge is also a possibility. This enables the organic matter to be stabilised and the olfactory nuisance to be reduced. The compost produced has an agronomic value higher than that of the original sludge.

Anaerobic digestion is also a very effective method for transforming the organic matter into methane, a gas with a high calorific value that can be used by the company. This is a process frequently used by the food processing industry and significantly reduces the organic content of the effluent, whilst producing a minimum of sludge. Digestion is highly suitable for the treatment of food processing industry effluent whose production levels and content fluctuate widely over the year.

4.3.6 Application/storage

Storage of food and drink processing industry waste

Environmental factors prohibiting the spreading of liquid waste for a few months of the year compel the industry to build more storage capacity. The storage of food and drink processing industry effluent or sludge may create an olfactory nuisance around the storage site because of the potentially high levels of poorly stabilised organic matter in the effluent or sludge. The effluent, when fresh has a moderate, sweet/sour odour, but can give rise to odour problems during decomposition.

The volume of effluent to be stored can vary quite significantly if the factory operates in seasonal stages, as is the case with sugar producers, distilleries and preserves manufacturers. Part of the effluent needs to be stored so that it can be spread during the most favourable period for the crops. In the case of direct spreading, temporary storage in a lagoon on the production site is desirable. In the case of sludge storage systems, sludge is usually stored in sealed silos, on covered, sealed concrete platforms; this depends on the dry solids content.

Agricultural spreading of food and drink processing industry waste

Spreading effluent directly requires the installation of a pumping station, temporary storage facilities and an underground irrigation network from the industrial site to the spreading sites. Sprayers enable the crops to be irrigated with fertiliser or spreading when no crops are being grown, a continuous practice throughout the year depending on the period when the effluent is produced.

The limiting factor determining the dosage comprises either the hydrous conditions (the quantity of water being contributed to the site) or the fertilising elements being contributed, taking into account the amount of fertilising elements contained in the effluent and the amounts removed by the crops.

The limiting factor for fertiliser irrigation or for spreading effluent or sludge is generally the nitrogen level for the dairy industry, and frequently the potassium level for the other industries. When the element representing the limiting factor presents little risk of being carried away through leaching, the dosage can be calculated to satisfy the requirements for 2 or 3 years.

The dosages of effluent spread vary from 500 to 1500 m^3 ha^{-1} $year^{-1}$ for the dairy and preserves industries and from 300 to 1500 m^3 ha^{-1} $year^{-1}$ for the sugar-producing industry. The dosages of sludge spread are of the order of 35 to 60 m^3 for liquid sludge, 25 tonnes for viscid sludge and 20 tonnes for solid sludge.

4.4 Pulp And Paper Industry Sludge

The average composition of pulp and paper industry sludge is shown in Table 4.14 below.

Table 4.14 Average composition of mixed pulp and paper industry sludge

ELEMENTS	Min	Max	Mean
Dry solids (%)	2	65	32
C/N ratio	12	200	78
pH	4	9	7
Agricultural value (% DS)			
Organic matter	19	90	64
N-TK	0.4	5	1.3
N NH4	0	0.3	0.02
CaO	0.5	20	12
MgO	0.02	6	1
P_2O_5	0.2	8	0.7
K_2O	0.06	0.8	0.2
SO_3			1.3
Heavy metals (mg kg^{-1} DS)			
Cadmium - Cd	0	4	1
Chromium -Cr	< 1	44	34
Copper - Cu	2	349	61
Mercury - Hg	< 0.01	1.4	0.2
Nickel - Ni	< 1	32	12
Lead - Pb	< 1	83	13
Zinc - Zn	1,3	330	135
Arsenic - As			<8
Organic compounds (mg kg^{-1} DS)			
Fluoranthene	0.01	<0.1	<0.05
Benzo (b) fluoranthene	<0.005	0.04	<0.02
Benzo (a) pyrene	<0.005	0.03	<0.02
Sum of 7 PCB	0.002	<1	<0.5

Limitations of the data

The information on the quality of pulp and paper sludge reported above mainly comes from France, Benelux, England and Finland.

4.4.2 Background

The production process used in papermaking depends on the stock used to generate the fibre. The wastewater generated and therefore the characteristics of the sludge produced are dependent on the production processes used.

When virgin wood fibre is used to produce paper, the pulp creates liquid effluent and the sludge mainly contains lignin and cellulose. When waste paper is used in the process, de-inking and bleaching is required and the waste paper will contain colours and chemical and bleaching residues, which will be present in the de-inking sludge. The process of reusing fibre from recycled paper produces larger amounts of sludge (1 tonne of sludge for every tonne of paper produced). De-inking sludge will also contain high levels of carbon, calcium carbonate and, generally, aluminium silicate.

Within the paper industry, the most economic choice for sludge disposal can determine the process used. For example, in France, paper recycling is currently favoured because the method of disposing of the sludge produced costs less than in other countries. The process of re-using fibre from recycled paper produces a large amount of sludge. In the Netherlands, sludge disposal systems cost significantly more than in France because of the high environmental constraints. A process producing less sludge is therefore favoured, i.e. using virgin pulp.

Application of the European IPPC directive will enable the best production processes for paper, board and pulp in terms of the environment to be determined as well as the best techniques for handling the waste. The paper industry is a sector of prime importance for this directive and it will therefore endeavour to have its preferred method, i.e. spreading, accepted as the best system for handling its sludge.

4.4.3 Key properties

Sludge produced by paper industry and recycled to agriculture does not generally come from the same source and is often a mixture of primary, biological and possibly de-inking sludge.

Paper sludge contains very high levels of dry solids because it is rich in fibres and therefore dehydrates quite easily. All pulp and paper sludge comprises a mixture of cellulose fibre (40 to 60% of dry solids), printing inks and mineral components (40 to 60% dry solids: kaolin, talc, and calcium carbonate). Paper sludge is largely carbon (around 30 % C in ds) and mineral matter (clay and calcium carbonate (5 to 25 % in ds)) with a high C/N ratio (50-200). It has low levels of fertilising elements and a low metal content.

In the case of de-inking sludge, the metal content of the ink has been significantly decreased over the past 15 years and nowadays contains fewer heavy metals, in order to comply with the food regulations. De-inking sludge therefore also contains few heavy metals. Depending on the nature of the de-inking process, the sludge contains $CaCO_3$, which can be up to one fifth as effective as ground limestone.

Due to the high concentration of organic carbon in the sludge, application contributes significantly to the organic matter content of the soil, this stimulates soil microbial activity and thus increases breaking down soil OM. As the sludge contains little nitrogen, soil nitrogen is accumulated by microbes for use in growth and reproduction, thus binding N into the OM. The leaching of nitrates over the winter months will therefore be reduced. Mineralisation of the organic compounds then accelerates by virtue of the development of a larger microbial sphere of activity, and N is released at a slow rate into the soil pool.

The high levels of $CaCO_3$ in paper industry sludge afford it the characteristics of a calcic amendment, enabling the addition of lime to be avoided for acidic soils.

4.4.4 Potential problems

The high C/N ratio of paper sludge can cause immobilisation of soil N when it is incorporated into the soil and hence crop nitrogen deficiency. The losses in yield can be minimised in the first year by applying a dressing of N fertiliser above the normal N requirement of the crop. There is little or no immobilisation of N in the second year after application. This has to be apply appropriately to avoid N leaching.

The potential for other contaminants arising in waste paper sludge depends on the nature of the manufacturing process and the raw matter used. De-inking sludge contains the ink and colour residues deriving from the metal constituents. In the case of newsprint, which is the most common source of recycled waste paper, the sludge can contain on average 150mg zinc/kg of dry solids.

4.4.5 Variability

The composition of the sludge being spread depends on the origins of the mixed sludge (primary, biological and de-inking sludge) and the papermaking process used (heavy metal content of the primary materials, processes used: pulp bleaching method and type of de-inking process, etc.). No seasonal variations are recorded on the same site in terms of the composition of the paper industry waste.

4.4.6 Treatment

Physical behaviour of pulp and paper waste:

Paper industry waste, whether of primary, biological or de-inking origin, is of the viscid to solid type. The dry solids content can vary from 20 to 60% depending on the level of dewatering. It stacks well and is easy to utilize.

Compost from this sludge is, a dry product containing more than 50% dry solids.

Dewatering of pulp and paper waste

Dewatering enables the volume of sludge to be reduced. Dehydration can be effected by a variety of processes, some of which can be used in complementary fashion: centrifuge, band filter, filter press, screw press. De-inking or mixed sludge tends to be drier than primary and biological sludge. Sludge containing a high level of lignin is easier to dehydrate than other types of sludge.

Stabilisation of pulp and paper waste

Paper industry sludge contains high levels of mineral material and low levels of changeable organic matter because of its very high C/N ratio. More often than not, there is no provision for stabilising the organic matter at the production sites. Paper industry sludge, therefore, constitutes little of an olfactory nuisance.

Additional stabilisation of paper industry sludge is conceivable using composting and can result in a further reduction in the volume, facilitating storage, but the low levels of organic matter and the high C/N ratio hinder composting such sludge. Furthermore, the compost produced from paper industry sludge is not of any higher benefit than the uncomposted sludge, although it can eliminated some problems with smells during storage and reduce the visual impact of paper industry sludge when it is spread.

Composting of this sludge is therefore practised using a good structuring medium, enabling the mixture to be correctly aerated, and a nitrogen-rich component (animal farming effluent or domestic waste) to compensate for the low level of nitrogen in the sludge. If its physical behaviour so permits, paper industry sludge can therefore serve as an ancillary product for composting with other waste that is rich in nitrogen.

4.4.7 Application/storage

Storage of pulp and paper waste

Storage capacity at a site must be sufficient to enable the paper industry to store the sludge during periods when it cannot be spread on land. This means that, for most mills, there needs to be sufficient storage capacity to cover about six months of sludge production.

Storage can take place at the production site on suitably designed, large, waterproofed concrete platforms, or on composting platforms when the sludge is to be transformed into compost. Storage on part of the area to be spread may be permitted, depending on the local regulations, but this must only be a temporary measure because of the visual and olfactory nuisance caused.

Agricultural spreading of pulp and paper sludge

The rate of application of paper mill sludge on agricultural land can vary from 15 to 30 t/ha. Given its low fertilising elements content, the rate-determing factors are the $CaCO_3$ content or the level of nitrogen deficiency that would result from spreading sludge with a very high C/N ratio. In practice, the heavy metal content never represents a limiting factor.

4.5 Tannery sludge

Typical analysis data for tannery waste from plans not using chromium is shown below in Table 4.15 below.

Table 4.15 Tannery sludge

ELEMENTS	Min	Max	Mean
Dry solids (%)	4	13	7
C/N ratio			
pH	6.7	7.2	6.9
Agricultural value (% DS)			
Organic matter	48	69	54
N-TK	3	6	5
$N\text{-}NH_4$			
P_2O_5	0.4	0.9	0.6
K_2O	0.1	0.9	0.6
CaO	13	21	16
MgO	0.3	0.5	0.4
SO_3			
Heavy metals (mg kg^{-1} DS)			
Cadmium - Cd	0.15	0.7	0.17
Chromium -Cr	92	162	128
Copper - Cu	8	13	10
Mercury - Hg	0.03	0.04	0.03
Nickel - Ni	1.1	2	1.5
Lead - Pb	2	5	4
Zinc - Zn	20	31	27
Arsenic - As			
Organic compounds (mg kg^{-1} DS)			
PAH			
Sum of 7 PCB			

Limitations of data

The information on quality of wastes from leather and tannery industries reported above are coming mainly from Belgium, France and UK.

4.5.2 Background

The raw material is mammalian skin, which is derived principally from animals which are butchered for the food industry.

The tannery operations consist of transforming the raw hide, a highly putrescible material, into leather, a stable product which can be conserved indefinitely and which has a significant commercial value. These operations follow a sequence of organised chemical reactions (using reactive products) and mechanical processes using specialised machinery. Among these, tanning is the fundamental stage that confers to leather its stability and essential characteristics.

The leather manufacturing activity generates liquid and solid wastes. The solid wastes from tanneries consist of hairs, which can be composted if they are pre-degraded in the preparation of hides. The second waste comes from the tanning operation in itself, which is the most important step in the production of leather and is carried out in an aqueous environment with water in rotating drums. During this operation, collagen, the principal protein of the skin, will fix the tanning agents to their reactive sites, thus stopping the putrefaction phenomenon.

In order to be transformed into a commercial product, leather needs to be dried with colouring agents, then fat liquored with the natural or synthetic fats in order to render the product flexible.

The products that are capable of being fixed to skin are many and varied but they can be classified into three groups:

- Mineral tannins (mostly chromium). Quick, simple and very cost effective, that means 70% of used tannins. But the chromium has a very high impact on the environment.

- Vegetable type tannins (mimosa, chestnut, quebracho). 20% of used tannins. Liquid sludge from vegetable tannins has no impact on the environment.

- Other organic tannins (formaldehyde, synthetic tannins, fish oil,…)

4.5.3 Key properties

Wastewater from degreasing and tanning operations are rich in soluble proteins that can be treated by various aerobic biological treatment technologies. Purified sludge from tanneries and tanning plants are rich in nitrogen-bearing material (total nitrogen 2 to 5% of the dry solids) and are therefore likely to be of interest to farmers as a high nitrogen fertiliser.

Other waste from the tanning process, like hairs, can be composted.

4.5.4 Potential problems

Only sludge from tannery industry using vegetable tannins can be recycled to land. The spreading of tannery sludge coming from a process using mineral tannins is often blocked because of its heavy metal content. The chromium is particularly toxic for the environment and the regulations set strict tolerance levels both in sludge and in the soil.

The low C/N ratio of liquid sludge from the tannery industry provides quantities of nitrogen with a high availability. So it’s strongly recommended apply a green manure just after the spreading to capture the nitrogen.

The required storage capacity for waste can be high, this takes up space on the industrial site, can incur extra costs and can produce odour nuisances around storage area because of fermentable matter into the sludge (proteins).

4.5.5 Variability

Sludges from tanneries can vary considerably according to the processing chemicals used. Each waste should be evaluated for major nutrients, pH and solids, BOD, Electrical conductivity and sodium and potentially toxic elements, before a land application program is initiated.

4.5.6 Treatment

To reduce the storage space required and transportation costs, most tannery sludges are dewatered. Composting of dewatered sludge can further reduce storage, odour problems and improve the C/N ratio.

Agricultural fertiliser can be produced from tannery sludges by adding lime to the wastewater to make it alkaline, then adding ferrous or aluminium sulfate to coagulate it. The mixture is dewatered, leaving a sludge containing about 20% dry matter. The sludge can be fermented and composted before the application to cropland.

Successful experiments in France have been conducted on purified sludge mixed with untanned waste into a ratio of 82%:18%. 450 m^3/week of biogas, containing 74% methane to feed a digester, have been obtained with mixtures of 45-50 g l^{-1} of dry solids. This represents three-quarters of the organic load in the waste being eliminated in the form of energy.

Recycling to energy in in-house incineration is selected wherever technically and economically feasible. However, such methods of recycling require control of the chromium levels in the sludge to enable the ash to be landfilled.

4.5.7 Application/storage

In order to attract the farmer on the basis of nitrogen fertilisation, the spreading quantity used is quite high (50-80 m3/ha). Tannery sludge can be applied for cereal production followed by sugar beet. Therefore, spreading should be carried out just after the crop harvesting times in the summer, thus avoiding problems of run-off and soil compaction.

To respect this spreading period and give a higher flexibility to the producer, the liquid waste would be stored in a water-tight settling sump.

After the spreading it is good practise to sow a cash crop (green cover), a short time after the harvest, to reduce the risk of nitrate leaching. A direct injection application is recommended to reduce gaseous emissions and odours.

4.6 Textile waste

There are two examples of textile waste which are spread on land in the EU; textile processing sludge and wool scourers waste. Typical quality data for these wastes are shown in Tables 4.16 and 4.17 below.

Table 4.16 Textile processing sludge

ELEMENTS	Min	Max	Mean
Dry solids (%)	0.7	44	10
C/N ratio	7	12.5	8
pH	5	13	7
Agricultural value (% DS)			
Organic matter	16	91	73
N-TK	2.7	17	3.1
$N-NH_4$	0.06	16	0.5
P_2O_5	1.1	5.4	1.5
K_2O	0.2	1.8	0.8
CaO	0.7	43	7
MgO	0.3	2.4	0.3
Na_2O			3.6
Oligo elements and sulphur (mg kg^{-1} DS)			
Sulphur - SO3	0.1	2.4	1.6
Heavy metals (mg kg^{-1} DS)			
Cadmium - Cd	0.15	1.2	0.5
Chromium -Cr	<1	430	40
Copper - Cu	0.5	892	131
Mercury - Hg	<0.01	3.1	0.4
Nickel - Ni	<1	31	8
Lead - Pb	<1	22	7
Selenium - Se	1.8	5.4	4.6
Zinc - Zn	1.4	1249	188
Organic compounds (mg kg^{-1} DS)			
Fluoranthene			0.06
Benzo (b) fluoranthene			0.05
Benzo (a) pyrene			0.02
Sum of 7 PCB			0.01

Table 4.17 Wool scourers waste

ELEMENTS	Min	Max	Mean
Dry solids (% RP)	7.7	73	55
C/N ratio	36	41	38
pH	2.8	8.4	6.8
Agricultural value (% DS)			
Organic matter	61	61	61
N-TK	0.2	1.4	0.3
P_2O_5	0.2	0.9	0.3
K_2O	0.06	7.8	4
CaO	0.8	0.8	0.8
MgO	0.02	0.3	0.3
Na_2O	3.1	3.9	3.5
Heavy metals (mg kg^{-1} DS)			
Cadmium - Cd	<0.25	0.7	0.5
Chromium -Cr	1.5	20	14
Copper - Cu	1.7	26	13
Mercury - Hg	<0.01	0.1	0.06
Nickel - Ni	0.5	9	7
Lead - Pb	1.3	11	7
Zinc - Zn	12	95	62
Selenium - Se			8
Organic compounds (mg kg^{-1} DS)			
Fluoranthene	< 0.01	0.04	
Benzo (b) fluoranthene	< 0.01	< 0.01	
Benzo (a) pyrene	< 0.01	0.01	
Sum of 7 PCB	< 0.05	< 0.05	

Limitations of the data

The information regarding the quality of textile waste reported above mainly comes from France, Italy and the United Kingdom.

4.6.2 Background

Textile industries use large volumes of water because textile products have to undergo a number of successive treatments: for example, pre-washing, bleaching, pre-treatment, dying, soaping, washing, initial dressing, second dressing, washing, rinsing, etc. Water consumption is rarely less than 100 m^3 per tonne of treated product and can exceed 300 m^3 per tonne for the wool industry.

The quality of the effluent produced by the textile processing industry depends on the type of fibres, the dyeing and printing processes and the products being used. The effluent is highly coloured and has a COD that is difficult to break down both chemically and biologically.

Some textile units have installed on-site effluent treatment plants. These generally use traditional biological processing procedures, possibly preceded by physical-chemical pre-treatment.

4.6.3 Key properties

Sludge is produced from the treatment of textile industry effluent. The sludge's characteristics depend on the type of treatment applied to the liquid waste, physical-chemical (coagulation-flocculation) or/and biological and the quality of the original effluent. It would appear that traditional biological treatments have proved quite effective as regards effluent from dyeing processes. The collection water contains small amounts of degradation products resulting from the breaking down of bleaching agents and dyestuffs.

Textile waste contains little organic matter and very few elements beneficial to plant growth. The nitrogen content is average and the waste contains only low levels of phosphorus and potassium. The waste has a low C:N ratio, therefore the organic matter breaks down rapidly. Such waste has therefore only a low agronomic value that can be augmented by liming or composting with an additional carbonaceous structuring medium.

Waste from the wool industry has a clearly greater agronomic value (potassium, magnesium) but contains significant fatty matter in the concentrates from washing the wool, which are not recyclable as they stand. The dust from the wool constitutes dry waste with a C/N ratio of around 6. It is rich in potassium and nitrogen.

Wool-washing/wool-combing industry by-products characteristically contain few heavy metals.

Wool processing by-products can also contain organic compounds from treating fleeces with pesticides. When the wool is washed, these are transferred to the washing water and end up in the sludge. Degraded versions of these pesticides can therefore be found in the sludge. Pesticides are used to treat sheep such as sheep dip or to treat the wool. If the wool is exported from countries outside the Union with different pesticide authorisation, some unauthorised products can be found in the sludge.

4.6.4 Potential problems

Textile processing industry sludge is of low agronomic value and can contain higher levels of heavy metals than other industrial sludge being recycled to agriculture. Levels of chromium are generally higher than those found in domestic sewage sludge. This is due to the use of metalliferous dyestuffs, however, levels still remain below the limits established for agricultural recycling. Other dyestuffs, that do not contain heavy metals, can be substituted to produce these shades.

Furthermore, the methods used for bleaching the fabric during the finishing process can lead to concentrations of organo-halogenated compounds in the sludge. Oxidisation techniques (ozonation, UV radiation) are currently being experimented with to destroy some of the AOX present in the sludge.

The concentrates from washing the wool contain high levels of fatty matter and cannot be recycled to agriculture as they stand. They must be mixed with bark to make them pelletisable and so that they no longer cling to the handling equipment. An potassium based organic medium can be created by this type of mixture. This breaks down slowly within the soil by utilisation of soil nitrogen (C/N = 30) and is slightly basic. This material is rich in potassium, magnesium and sodium.

The wool dust produced by wool combing operations can present problems with self-propagation when recycled to agriculture. The dust may, in fact, contain plant seeds that then colonise the area being spread.

4.6.5 Variability

Textile industry waste varies in composition depending on the treatment process (biological, physical-chemical or both), the dyestuffs, the detergents, the dampening and bleaching agents and the auxiliary products being used.

4.6.6 Treatment

Textile waste dehydration

Small textile production units will favour liquid sludge involving lesser investment in dewatering equipment (drip tables), whereas larger sites will install band filters or a centrifuge to reduce the quantities of sludge to be stored. The investment in dewatering equipment is often insufficient to obtain correctly dewatered sludge. There are very few filter presses to be found in the textile industry.

Filter pressing can dewater most of the sludge produced by biological treatments relatively easily. The problem of sludge dewatering has restricted the use of physical-chemical waste water treatment methods, however effective, since such treatment produce a colloidal sludge that is particularly difficult to dewater.

Textile waste stabilisation

In order to stabilise and reduce the olfactory nuisance created during its storage and when it is spread, sludge containing organic matter requires stabilisation treatment, involving the addition of lime. The addition of lime increases the sludge's agronomic value.

Stabilisation by composting such sludge can also present a solution to stabilising the organic matter and produces compost with a significantly higher agronomic value than the original sludge.

4.6.7 Application/storage

Physical behaviour of textile waste

Textile industry waste comprises either textile processing industry sludge or wool industry waste. Sludge from process industry may be either in liquid or viscid form, depending on the level of dewatering. Wool waste is either in the form of very fatty, viscid sludge (concentrates from washing the wool), which cannot be recycled directly to agriculture, since it is very glutinous, or in the form of dry waste (wool dust).

Storage of textile waste

Textile processing industry sludge does not stack very well since it contains no fibres and is not always sufficiently dewatered. Liquid sludge is stored in sealed silos and viscid sludge on sealed concrete platforms, which may be covered. Waste from the wool industry is stored on covered platforms.

Agricultural spreading of textile waste

The nitrogen content of the sludge is the limiting factor for its use in agriculture. The normal rates of spreading are 40 to 60 m^3 for liquid sludge and 20 to 30 tonnes for viscid sludge.

The limiting factor for the spreading of potassium based organic amendments is the potassium content. Normal rates are 10 to 15 tonnes per hectare.

For wool dust, the normal rate is around 10 tonnes per hectare.

4.6.8 Conclusion

Currently in most regions, agricultural spreading is favoured over landfill or incineration, except in certain factories producing large amounts of waste, where incinerators may be profitable. To increase savings, some factories are attempting to reduce their water consumption. Many work with a recirculating system, recovering and purifying the water as it leaves the process.

To improve the quality of the sludge, attempts are now being made to replace the chemical products, such as chromium and copper salts. Those removed are considered to be the most polluting, difficult to eliminate, or of a toxic nature in the outflow from biological purification plants. They are replaced with products with a lower environmental impact on the water quality, or that are more readily biodegradable.

The European IPPC directive of 1997 requires the textile industry to select the least polluting processes in terms of the environment. Each sector must adopt these before 2007. The choice from the various processes available is made according to effectiveness, profitability and the level of risk of environmental pollution produced, the aim being to produce less waste and a better quality of waste.

4.7 Decarbonation Sludge

Quality data for decarbonation sludge is shown in Table 4.18 below.

Table 4.18 Quality data for decarbonabiton sludge

ELEMENTS	Min	Max	Mean
Dry solids (%)	55	70	61
C/N ratio			
pH	8.3	10.5	8.9
Agricultural value (% DS)			
Organic matter	0	6	1.2
N-TK	0	0.7	0.2
$N\text{-}NH_4$			
P_2O_5	0.01	1.6	0.5
K_2O	0	0.6	0.1
CaO	29	54	42
MgO	0.5	1.4	1
Na_2O			
Oligo elements and sulphur (mg kg^{-1} DS)			
Sulphur - SO_3			
Heavy metals (mg kg^{-1} DS)			
Cadmium - Cd	0.07	0.9	0.2
Chromium -Cr	0.7	26	11
Copper - Cu	0.6	20	9
Mercury - Hg	0.01	0.16	0.06
Nickel - Ni	0.8	32	10
Lead - Pb	0.8	36	16
Selenium - Se			
Zinc - Zn	9	110	51
Organic compounds (ppm = mg/kg DS)			
PAH			
Sum of 7 PCB			

Limitations of data

The information on quality of wastes from decarbonation sludge from reported above are mainly come from Belgium.

4.7.1 Background

In many power stations, boilers using hot water need a conditioning system to treat cubic meters of water coming from river, ground water or spring.

The soluble residues (calcium and magnesium bicarbonates) present in water make it hard, which affects the metal pipes and the boiler durability.

To reduce or remove hardness in water, a process of chemical precipitation is used: "lime softening". The precipitation causes soluble salts to become insoluble salts, so they can be removed by sequential sedimentation. The process is called lime softening, as lime is predominately used, it maintains the pH value in the ideal range for the precipitation of decarbonation sludge. There are different processes to precipitate soluble salts from water.

The waste from this treatment process is therefore sludge primarily composed of calcium carbonate ($CaC0_3$). A dewatering system is required to dry the sludge.

4.7.2 Key properties

The only significant elements contained in the by-product are calcium and magnesium. The agronomic value of the by-product is based on the quantity of calcium and magnesium in the by-product and the benefit of calcium to the soil and plants used in agricultural crop production.

In the soil the pH is a very important factor for optimal plant development and general agricultural crop production. Soil pH is influenced by many factors including soil type, soil structure, rainfall and agricultural production system. The pH of the soil will naturally tend to fall due to rainfall and the removal of elements by crop production and harvesting. Therefore there is an essential requirement to keep the pH of soils as it will naturally tend to decrease.

The pH level of the soil can only be increased by the addition of basic elements such as calcium and magnesium. This is obtained by the regular application of basic elements to the soil as liming materials.

There are two important factors in evaluating a lime product:

1. The Total Neutralising Value (T.N.V.)

The total neutralising value of a lime product is determined by comparing the neutralising value of the product to the total neutralising value of pure calcium carbonate $CaCO_3$. The neutralising value of pure calcium carbonate is assigned the value of 100.

In the analysis carried out, the total neutralising value of the decarbonation sludge cakes at 60% dry matter content was 30% T.N.V. The ground limestone ($CaC0_3$) is the commonest form of lime sold and is T.N.V. is 90% The spreading rate is approximately 10 tonnes per hectare of decarbonation sludge (3000 T.N.V.) per 3 years.

2. The fineness

There is a standard of fineness for licensed ground limestone products ($CaC0_3$) to guarantee the good efficacy of the T.N.V.

The standard for licensed ground limestone products is a Total Neutralising Value of greater than 90% and a fineness of 100 % through a 35 mm sieve and 35 % through a 0.15 mm sieve.

The fineness of the product and the uniformity of the fineness of the product has a direct impact on the ability to spread the product evenly over the ground and guarantee his solubility. A finer material will react more quickly with the soil than a product, which has large clumps or particle sizes.

4.7.3 Potential problems

The process used to precipitate soluble salts influences the size of carbonate particles and the reactivity of this lime with the soil. In some installations, the precipitation is realised on a sandy substrata and gives small granulates of carbonate which have no reactivity (very low) with the soil.

The origin of water used in the boiler has an influence on the sludge quality, so water pumped from canal or river in industrial zone has sometime problems with hydrocarbons and heavy metal residues (see the dredged silt). If the origin is a ground water there is generally no problem.

The dry matter is highly influenced by the dewatering process. A mechanical dewatering system like a belt press produces calcium cake at approximately 55-60 % dry solids content with a good stability on land. However with other systems, a less dry matter content (15-20%) can produce problems for the storage.

Lime application normally takes place after soil analysis and it is possible to adjust the spreading rate according to the lime application rate recommendations. The recycling of a lime product has an agronomic benefit in regions with acid or neutral soil. Responses to lime on higher pH soil would give diminishing returns.

4.7.4 Variability

The process and the hardness of water are stable, but the quality of the dewatering operation can influence the dry matter and in the same time the neutralisation capacity. (fresh weight).

4.7.5 Treatment

Dewatering treatment is required to facilitate transportation and spreading of the waste.

4.7.6 Application/storage

The spreading rate depends on the dry matter and the neutralisation capacity (from 8 to 25 t ha^{-1}).

Storage is better facilitated when sludge is dewatered to approximately 55-60% dry solids content.

4.8 Sludge from the production of drinking water

ELEMENTS	Alum sludge	Ferric sludge
DS (%)	0.1 - 30	0.1 – 30
C/N ratio		
pH	5.5 – 7.5	7.3 – 9.3
Agricultural value (% DS)		
Organic matter	<15%	
N	0.7	0.4
P_20_5	0.8	0.8
K_20	Negligible	
Ca0	+	+
S	+	+
Heavy metals (% DS)		
Aluminium - Al	20	5
Iron - Fe	3	10
Heavy metals	+	+
Pathogens		
Pathogens	+	+

Limitations of the data

The data are 'typical' values for the coagulant sludges only.

4.8.2 Background

Waterworks sludge is the residue arising from the treatment of raw water to produce drinking water. The sludge is composed of the impurities removed and precipitated from the water together with the residues of any treatment chemical used.

Waterworks sludge can be broadly classified either as coagulant, natural, groundwater or softening sludge. The most common process for surface water treatment is chemical coagulation and rapid gravity filtration which produces aluminium or ferric sludge according to whether Al or Fe salts were used as the coagulant chemical.

4.8.3 Key properties

The application of waterworks sludge to agricultural or other land is potentially a major disposal route which has not been fully exploited because the product has no obvious attributes which could be associated with agricultural benefit or ecological improvement. There may be benefit in some circumstances from its content of sulphur, trace elements and small amount of organic matter. Benefits resulting from the application to land of coagulant sludges are not easily demonstrated. Benefit can be more easily demonstrated for softening sludges produced as a result of the softening of hard waters. Softening sludges contain valuable amounts of calcium and can be used for liming of agricultural land. Natural sludge, or slow sand sludge, results from the washing of slow sand filters and may contain enough organic matter, with organically bound plant nutrients, to be of agricultural value.

4.8.4 Potential problems

There are some concerns about potential adverse effects on plant growth, concentrations of heavy metals and aluminium, and possible contamination of surface or groundwaters. The accumulation of aluminium or iron due to extended applications of sludge would not be expected to cause problems in most circumstances especially if the soil pH value is kept above 6.0. Nevertheless, it is understood that agricultural advisors in Scotland have concerns that aluminium-rich waterworks sludge applied to acid soils could have a deleterious effect on the growth of barley in particular if the soil pH falls below pH 5.5. Build up of iron in the topsoil of pasture land following surface applications of iron-rich waterworks sludge could have a deleterious effect on the copper metabolism of grazing animals, especially sheep. It is reported that aluminium and iron hydroxides in coagulant sludges can adsorb soluble phosphorus and reduce its availability to plants, adversely affecting growth. However, co-application with sewage sludge or the addition of supplemental phosphorus to the soil would eliminate or reduce this effect, if necessary. It is possible that waterworks sludges contain pathogens, such as *Cryptosporidium*, removed from the raw water at the waterworks.

4.8.5 Variability

Quality will vary according to the type of waterworks sludge and the particular waterworks producing it. Low grade coagulant chemicals may be contaminated with heavy metals. While the treatment process at the waterworks remains constant, including the source of coagulant chemicals, then the quality of the waterworks sludge produced would be expected to remain comparatively constant.

4.8.6 Treatment

Coagulant sludges are likely to be supplied as a cake of about 25-40% dry solids. Alternatively these sludge may be supplied as a slurry of about 10%ds.

A practical option for disposal may be for the waterworks to divert its sludge to the foul sewer as a licensed discharge in which case it will become an integral part of the sewage sludge after treatment at the sewage works, and can be applied to land under the ‘sludge recycling to land’ Directive 86/278/EEC.

4.8.7 Application/storage

Waterworks sludge of the coagulant type is likely to have no more than a ‘neutral ‘ effect on the land as opposed to bringing positive agricultural benefit. Soil pH should be kept at 6.0 or above and rate of application limited to about 10 tonne ds ha^{-1} yr^{-1} . Other products, such as softening sludge, may have a useful content of lime and organic matter which can form the basis for calculating a suitable rate of application to the land.

The application of waterworks sludge to forest lands has been investigated in several countries. In one US study, liquid alum sludge was applied to deciduous and coniferous forested land. One year after the initial application, it was concluded that the alum sludge had no adverse effects on tree growth or nutrient uptake in the short term. However, because of the slow growth rate of trees, measurements would need to continue for many years before conclusions regarding long-term effects could be drawn.

Land reclamation could also be a significant disposal route for waterworks sludge, subject to acceptance by the relevant regulatory authorities. Potential benefits of using waterworks sludge include its reported pH buffering capacity, soil conditioning properties and capacity to adsorb heavy metals.

4.9 Dredgings from Waterways

Typical quality of dredgings from waterways is shown in Table 4.19.

Table 4.19 Dredgings from waterways

ELEMENTS	Min	Max	Mean
Dry solids (%)	8	63	23
C/N ratio			
pH	5.4	7.6	6.7
Agricultural value (% DS)			
Organic matter	6	44	25
N-TK	Variable		
$N-NH_4$			
P_2O_5	0.4	5.6	1.1
K_2O	Likely to be		
CaO	Variable		
MgO			
Na_2O			
Heavy metals (mg kg^{-1} DS)			
Cadmium - Cd	0	21	2.2
Chromium -Cr	25	4010	160
Copper - Cu	26	1360	137
Mercury - Hg	0.1	1570	83
Nickel - Ni	34	204	79
Lead - Pb	22	8300	410
Zinc - Zn	154	6700	960
Selenium - Se			
Sulphides	0	6330	1810
Cyanides	0	2.6	0.6
Organic compounds (mg kg^{-1} DS)			
PAH	0	203	16
Sum of 7 PCB			
Phenols	2.1	292	23.4

Limitations of the data

The data are taken from samples of dredgings collected along 100km length of canal in the UK. The data illustrate that dredgings from the same waterway can be very variable according to sampling location and that dredgings can be heavily contaminated with both inorganic and organic micro-pollutants.

4.9.1 Background

Sediment has to be dredged periodically from the beds of canals, rivers and estuaries to maintain navigability and water quality. Sediments may have built up over many years and in some cases the canals pass through industrial areas. Most contaminants typical of industrial activities can be found in these sediments. The dredgings are usually deposited into an area near to the waterway and left to dewater, after which the solids, if suitable, can be used as soil making material on surrounding land. Sediments which are unsuitable for landspreading owing to contamination would be disposed of to landfill. Modern restrictions on discharges of contaminants to waterways should ensure that sediment quality is usually compatible with landspreading in future.

4.9.2 Key properties

Dredgings can supply phosphate-rich soil building material in the form of minerals and organic matter including some bound nitrogen. Sandy material, low in organic matter and fine particulates, has potential value for land levelling purposes.

4.9.3 Potential problems

Many inland waterways, canals in particular, run through urban and industrial areas and sediments may have become polluted with various contaminants following industrial and other discharges to the waterway made before these were adequately regulated. The Table above indicates the levels of some contaminants that may be found in dredgings. Tributyltin residues may be present in dredgings from boating centres. The mud of dredgings, which contains a high proportion of silts and clays, is highly adsorptive of bacteria and viruses as well as chemical contaminants. Therefore pathogens may be present on a local basis in dredgings downstream of discharges from sewage works, storm sewage overflows, farms and certain industrial premises such as compounders of organic fertilisers, abattoirs and tanneries. Dredgings rich in fine particulates may cause drainage problems after application and would be best incorporated into a coarse textured, sandy soil. Salinity must be considered in the case of estuarine dredgings. Dredgings are likely to contain items of undegraded plastic litter and scrap metal which are unsightly, potentially hazardous to farm animals and can impede cultivation of the soil.

4.9.4 Variability

As the table above exemplifies, dredgings are likely to vary in quality even along the same stretch of waterway. This is likely to be linked to the passage of the waterway through urban and industrial areas so dredgings from stretches through rural catchments should be more consistent in quality and largely free of contaminants.

4.9.5 Treatment

Dredgings are likely to be anaerobic and smelly when first recovered and will probably needed to be stacked and periodically turned (aerated) before landspreading. Such a period of weathering and exposure to rainfall will remove the salinity from estuarine dredgings. Screening may be necessary if the dredgings contain plastic and scrap metal litter items.

4.9.6 Application/storage

Bankside storage is the usual practice. In view of their composition, it is suggested that dredgings are applied to the land in accordance with the 'sewage sludge recycling' Directive 86/278/EEC. Higher applications of clean, sandy dredgings may be justified for soil building or land levelling operations.

4.10 Waste lime from cement manufacture or gas processing

4.10.1 Quality Data

Some data from operational analysis of waste lime from cement manufacture or gas processing is shown below in Table 4.20.

Table 4.20 Waste Lime

ELEMENTS	Min	Max	Mean
Dry solids (%)	2.9	100	
C/N ratio			
pH	6.5	12.5	
BOD (mg l^{-1})	95	2000	1224
Agricultural value (% DM)			
Organic matter			
N-TK	0	0.7	
N- NH_4	0	0.4	0.06
P_2O_5	0	0.4	0.3
K_2O	0	4.7	0.7
Mg	0	5	1
Na_2O			
Heavy metals (mg kg^{-1} DS)			
Cadmium – Cd	0.1	8	
Chromium –Cr	0.5	31	
Copper – Cu	0.3	46	
Mercury – Hg	0	3.5	
Nickel – Ni	0.1	35	
Lead – Pb	0	1000	
Zinc – Zn	0.2	153	
Organic compounds (mg kg^{-1} DS)			
PAH			
Sum of 7 PCB			

Limitations of the data

Data was only available from the UK and Belgium.

4.10.2 Background

The two biggest producers of waste lime are cement manufacture and gas processing, although the salt industry produces significant quantities of waste lime and gypsum. These wastes, by virtue of their chemical nature and origin are inherently pathogen-free. Lime and lime sludges have pH values of 10-12+ and are therefore self-disinfecting, as long as this high pH value is maintained.

The waste material from cement manufacture consists of cement kiln dust, which is a mixture of calcium carbonate and calcium oxide. Waste lime is produced from the production of acetylene gas.

4.10.3 Key properties

The benefit of cement kiln dust is derived from its liming value. Neutralising Values can vary depending on the moisture content of the material, but are usually in the range 20-40%. Some wastes may also contain moderate amounts of potash, but as the material is traditionally applied to the land at low rates the benefit from potash is negligible.

Lime waste from gas processing consists of a large percentage of calcium hydroxide and therefore also has a high neutralising value. Other nutrients, and indeed contaminants, may be present in varying amounts, and these may have an agronomic effect, but this depends to a large degree on the nature of the production process. Trials have shown that this material can compare favourably with calcium carbonate (Munoz *et al.* 1994).

4.10.4 Potential problems

Cement kiln dusts usually contain residues from the combustion of materials used to generate the high temperature requirements of the process. Some manufacturers have recently started using waste organic solvents as sources of fuel for these processes and therefore organic residues may occur in kiln dusts. Over-liming should be avoided as trace element deficiencies can be induced when soils are limed above their optimum for specific crops.

The production of acetylene gas involves reaction of calcium carbide with water, producing lime as a by-product. Other constituents are also produced, e.g. thiourea, for which the consequences of land application may be uncertain. Properly qualified advice should be taken before land application is undertaken.

4.10.5 Variability

Quality of the wastes from these processes will depend upon the actual systems and methods of production used. It is important that products for landspreading should be accompanied by a full analysis of potentially toxic elements including Cu, Ni, Zn, Cd, Cr, Hg, Pb, B, As, Se, Mo and Fe. Assurance should be given by the waste producer, based on analysis, that the product is free from organic contaminants.

4.10.6 Treatment

The nature of these wastes is such that further treatment would be unlikely to improve the quality of the waste for landspreading purposes.

4.10.7 Application / Storage

The rate of application of these wastes should be based on the neutralising value of the waste and the lime requirement of the receiving soil. The pH of the soil should be determined prior to landspreading, because the agricultural benefit will not be achieved if the land has no lime requirements. All wastes should be evaluated for potentially toxic elements and organic contaminants prior to landspreading.

The wastes are inherently stable so storage in dry conditions should not affect their suitability for landspreading.

4.11 Waste Gypsum

Table 4.21 Waste gypsum

ELEMENTS	Min	Max	Mean
Dry solids (%)	8.7	78	48
C/N ratio			
pH	5.5	12.4	9.4
BOD (mg l^{-1})			
Agricultural value (% DM)			
Organic matter			
N-TK	0	28	2.3
$N\text{-}NH_4$			
P_2O_5	0	2.2	0.4
K_2O	0	2.0	0.4
CaO		High	
SO_3		High	
Heavy metals (mg kg^{-1} DS)			
Cadmium – Cd	0.1	5.0	1.4
Chromium –Cr	1.6	51	466
Copper – Cu	1.2	32	12
Mercury – Hg			
Nickel – Ni	1.0	144	33
Lead – Pb	1.3	53	404
Zinc – Zn	2.4	1075	124
Organic compounds (mg kg^{-1} DS)			
PAH			
Sum of 7 PCB			

Limitations of the data

Analytical data from 4 – 12 samples from UK. As with much analysis of this kind the mean concentrations of trace metals reported are skewed to high values and concentrations likely to be encountered are probably medians and nearer to the minimum values in the Table above.

4.11.1 Background

Mined gypsum is a widely occurring mineral that has been used for many years in agriculture as a soil conditioner for clay and saline soils and as a source of the plant nutrients, calcium and sulphur.

Industrial gypsum is derived as a by-product from the manufacture of phosphoric acid (phosphogypsum), from the capture of sulphur dioxide in the flue gases of fossil-fuel powered generators (flue gas desulphurisation gypsum), from the neutralisation of sulphuric acid in many chemical processing industries (waste acid neutralisation gypsum) and from salt extraction.

Gypsum is a mineral (hydrated calcium sulphate), used for preparing plaster and plaster-based building materials. As in the production of lime, heat is used in preparing plaster, which disinfects the product.

4.11.2 Key properties

Acid neutralisation gypsum

Large volumes of waste sulphuric acid are produced from a wide range of industrial processes. The acid is used as an extractant for a variety of chemical compounds, but especially for the extraction of mineral ores. Consequently, the acid contains many different contaminants derived from the primary raw materials. The contaminants can be carried over in the neutralisation process and incorporated into the gypsum produced.

The use of gypsum as a soil conditioner is well known. One application is on saline sodic soils, especially those affected by flooding from sea water, where the gypsum is used to restore soil structure. Use of gypsum is also beneficial in less extreme cases, where poorly structured clays can be improved in the long term by additions of gypsum at rates in excess of 5 t ha^{-1}. There is little, if any, structural benefit from adding gypsum to very light soils such as sands and loamy sands.

Gypsum also contains very large quantities of sulphur, which can in theory be as high as 20% depending on the purity of the product. With the reduction in atmospheric depositions of sulphur in acid rain, many agricultural soils are becoming sulphur deficient and sulphur-containing fertilisers are increasingly being used. In recent years, applications of gypsum have sometimes produced unexpected improvements in crop yields which may have resulted from correction of sulphur deficiency not previously diagnosed. The presence of other plant nutrients depends on the process from which the material is derived, but such gypsum wastes can contain quantities of phosphate which also have an agronomic value.

Flue Gas Desulphurisation gypsum

The soil conditioning benefits gained from FGD gypsum are identical to other sources of high purity gypsum, but gypsum from this source will not usually contain other beneficial nutrients.

4.11.3 Potential problems

Due to the wide range of different industries, it is not possible to give a detailed description of potential contaminants that may occur in gypsum. However, contamination from metals is very common, as the strong acids used in the mineral based industries will lead to the extraction of metals. Properly qualified advice should be sought before these materials are considered as suitable for landspreading.

FGD gypsum is produced primarily to remove sulphur dioxide in flue gases. It will, therefore, absorb other contaminants in the flue gases. The nature of the contaminants will depend on the fuel used in the combustion process. The majority of FGD gypsum is produced from coal-fired power stations and, therefore contains a range of metals as well as combustion products. Gypsum derived from the burning of other materials may contain complex organic compounds.

4.11.4 Variability

The analytical programme should take account of the likelihood that the gypsum will be variable in quality between works and with time from a single works until proven otherwise.

4.11.5 Treatment

Gypsum should be dried so that it can be applied in a farm limespreader, or should be suitable for wet application from a slurry spreader.

4.11.6 Application/storage

Details of the relevant production process related information are necessary before considering landspreading this material. The waste should be analysed for content of calcium, sulphur and PTEs. If these results are satisfactory, applications as a soil conditioner can be made to heavy land at a range of 5-20 tonne ha $^{-1}$, or to sulphur deficient land in accordance with crop requirements for this nutrient. Excessive additions of sulphur to grassland can induce copper deficiency in livestock.

4.12 Slag from the Steel Industry

Quality of slag from the steel industry is shown in Table 4.22, below.

Table 4.22 Slag from the steel industry

ELEMENTS	Min	Max	Mean
Dry solids (%)	Supplied as a dry material		
C/N ratio			
pH	High pH material effective for liming		
BOD (mg l^{-1})			
Agricultural value (% DM)			
Organic matter	None		
N-TK	None		
$N\text{-}NH_4$			
P_2O_5	10	22	
K_2O	Negligible		
CaO	35	42	
MgO	+		
SO_3	+		
Heavy metals (mg kg^{-1} DS)			
Cadmium – Cd			
Chromium –Cr			
Copper – Cu	+		
Mercury – Hg			
Nickel – Ni			
Lead – Pb			
Zinc – Zn	+		
Boron – B	+		
Molybdenum – Mo	+		
Cobalt – Co	+		
Organic compounds (mg kg^{-1} DS)			
PAH			
Sum of 7 PCB			

Limitations of the data

Generalised analysis

4.12.1 Background

This material is a by-product of steel making and is used on land principally as a source of phosphorus. The value of slags for crops depends on the solubility quality of the phosphate present which varies according to source and is tested by measuring the solubility of P in citric acid. Basic slags are also effective liming materials having a high content of calcium and some magnesium. Other elements of potential agricultural benefit that slags contain are sulphur, boron, cobalt, copper, molybdenum and zinc.

4.12.2 Key properties

Source of phosphate and lime with trace elements.

4.12.3 Potential problems

Basic slags need to be checked for content of potentially toxic elements (PTEs) which may be excessive

4.12.4 Variability

Likely to be variable between steel works in terms of total content of nutrients, extractability of P and content of PTEs. Elemental content of slag from a particular works may be consistent over time whilst the works is using the same furnace feedstock but this would need to be checked.

4.12.5 Treatment

Basic slag should be supplied in suitable physical form for use in a conventional farm limespreader or fertiliser application equipment.

4.12.6 Application/storage

Suitable for dry storage in bags. Basic slag should be applied to the land in accordance with crop requirements for P, and the neutralising value of the slag must be considered in relation to the lime requirement of the soil.

4.13 Waste wood, bark and other plant materials

The typical quality of waste wood, bark and other plant materials is displayed in Table 4.23.

Table 4.23 Waste wood, bark and other plant materials

ELEMENTS	Min	Max	Mean
Dry solids (%)	1	55	32
C/N ratio			
pH	4.1	8.4	5.8
BOD (mg l^{-1})			
Agricultural value (% DM)			
Organic matter			
N-TK			
$N\text{-}NH_4$	<1	10	4
P_2O_5	<0.1	0.5	0.2
K_2O	<0.1	1.5	0.6
CaO			1
Na_2O			
Heavy metals (mg kg^{-1} DS)			
Cadmium – Cd			
Chromium –Cr			
Copper – Cu			
Mercury – Hg			
Nickel – Ni			
Lead – Pb			
Zinc – Zn			
Organic compounds (mg kg^{-1} DS)			
PAH			
Sum of 7 PCB			
Pathogens			

Limitations of the data

The analytical information is from the UK only.

4.13.2 Background

This category refers to plant materials recycled in the normal management of land and would be expected to come from the following sources:

- Municipal parks and gardens – usually such waste would be recycled at the site of origin;
- Green waste which is often composted;
- Waste from processing of vegetables other than residues classed as food waste;
- Woody wastes e.g. sawdust and shavings from timber yards, materials from chipboard and other timber product processing, reclaimed timber from buildings, pallets and packing crates.

4.13.3 Key properties

The long-term benefits from adding waste wood, bark or other plant material to agricultural land result from the high organic matter content of the wastes which gives them value as soil conditioners. Some products, such as chipped wood or bark, can be used for immediate benefit as a mulch to discourage weed growth and conserve moisture.

4.13.4 Potential problems

These waste materials are potentially benign. Exceptions would be material containing old fencing / waste wood which may have been treated with preservative chemicals such as pentachlorophenol, lindane or copper chrome arsenate. Timber yard by-products may also contain persistent preservative chemicals. If their presence is possible, a precautionary analysis should be undertaken unless the waste producer can give an assurance that the waste is free of preservatives.

The nature and origin of waste plant matter needs to be considered in case diseased material is present that could act as a source of infection for succeeding crops e.g. haulms of potatoes infected with the potato blight fungus *Phytophthora infestans.* Rotten wood may harbour the honey fungus, *Armilleria*, which can destroy trees and shrubs.

Application to land of wood products with a high C/N ratio can temporarily remove plant-available nitrogen from the soil. Additional inorganic nitrogen should be applied to the soil to compensate for this and avoid crop yield and quality loss.

4.13.5 Variability

Chemical variability of plant nutrient content is probably of little consequence in the use of these materials which are essentially soil conditioners. See Treatment.

4.13.6 Treatment

Physical quality may need to be improved by screening and shredding. Many of these materials are suitable for composting.

4.13.7 Application/storage

If these materials are to be used as soil conditioners then a rate of application to the land of about 20 tonne ha^{-1} yr^{-1} would be suitable and is not critical; more or less could be applied according to local circumstances. A mulch of bark or wood chips would be applied over the soil to a depth of about 3 – 8cm according to the size of the chips. Site or field storage without containment should be feasible except perhaps in the case of putrescible vegetable waste, which should be stabilised by turning occasionally until it no longer smells (a simple form of composting).

4.14 Waste from chemical and pharmaceutical manufacture

4.14.1 Quality Data

Data from operational analysis of waste from pharmaceutical manufacture is shown below in Table 4.24. This represents sludge from biological synthesis of pharmaceutical. Quality data for various wastes from the chemical industry is displayed in Tables 4.25 – 4.27 below. It covers a wide range of industries such as ammonia production, ammonium sulphate production and gelatine production.

Table 4.24 Pharmaceutical waste

ELEMENTS	Min	Max	Mean
Dry solids (%)	0.9	52	9
C/N ratio			
pH	3.7	10.5	
BOD (mg l^{-1})	400	88 800	17 000
Agricultural value (% DM)			
N-TK	0	17	5
$N\text{-}NH_4$	0	17	1.7
P_2O_5	0	2.9	0.8
K_2O	0	1.7	0.3
Mg	0	1.6	0.1
Heavy metals (mg kg^{-1} DS)			
Cadmium – Cd	<0.25	<0.25	<0.25
Chromium –Cr	<1.0	<1.0	<1.0
Copper – Cu	0.0	13	3.5
Mercury – Hg	<0.01	<0.01	<0.01
Nickel – Ni	<1.0	3.4	0.5
Lead – Pb	<1.0	<1.0	<1.0
Zinc – Zn	0.5	19.5	6.3

Table 4.25 Waste ammonia

ELEMENTS	Min	Max	Mean
Dry solids (%)	0	38	8
C/N ratio			
pH	1.5	12.2	8.6
BOD (mg l^{-1})	11	28 000	7200
Agricultural value (% DM)			
N-TK	1	79	31
$N-NH_4$	0	57	27
P_2O_5	0	47	5
K_2O	0	0.9	0.1
Mg	0	0.2	0.05
Heavy metals (mg kg^{-1} DS)			
Cadmium – Cd	<0.25	1	0.2
Chromium –Cr	<1.0	25	3
Copper – Cu	<1.0	18	4
Mercury – Hg	<0.01	<0.01	<0.01
Nickel – Ni	<1.0	1.7	0.3
Lead – Pb	<1.0	19	2
Zinc – Zn	<1.0	18	5

Table 4.26 Waste ammonium sulphate

ELEMENTS	Min	Max	Mean
Dry solids (%)	2.3	50	
C/N ratio			
pH	4.3	9	
BOD (mg l^{-1})	5	33 000	11 000
Agricultural value (% DM)			
N-TK	2	33	17
N-NH_4	0.5	30	14
P_2O_5	0.0	0.03	0.01
K_2O	0.0	0.2	0.03
Mg	0.0	0.09	0.03
Heavy metals (mg kg^{-1} DS)			
Cadmium – Cd	<0.25	<0.25	<0.25
Chromium –Cr	<1.0	<1.0	<1.0
Copper – Cu	<1.0	2.2	0.6
Mercury – Hg	<0.01	0.6	0.1
Nickel – Ni	<1.0	1.0	<1.0
Lead – Pb	<1.0	<1.0	<1.0
Zinc – Zn	<1.0	2.8	0.9

Table 4.27 Waste from gelatine production

ELEMENTS	Min	Max	Mean
Dry solids (%)	22	69	44
C/N ratio			
pH	7.2	12.6	11.8
Agricultural value (% DM)			
N-TK	7.4	75	28
P_2O_5	10	66	27
K_2O	0.2	14.5	2
MgO	1.3	20	6.5
Heavy metals (mg kg^{-1} DS)			
Cadmium – Cd	0.7	2.5	1.3
Chromium –Cr	6	37	14
Copper – Cu	4	45	17
Mercury – Hg	0	10	1.3
Nickel – Ni	1	39	14
Lead – Pb	2	22	12
Zinc – Zn	92	1178	411

Limitations of the data

Quality data was only available from the UK and Belgium. Data is limited due to the relatively small amounts of these wastes being spread on land and the general lack of data from the industry.

4.14.2 Background

Organic wastes produced in the pharmaceutical industry are mainly biomass (cells from the fermentation process), synthesis residues, alcohol and organic solvents from the cleaning processes, product residues and dust from reprocessing. Pharmaceuticals are produced using synthesis or fermentation. Waste products from synthesis are typically synthesis residues and solvents. Waste products from fermentation are typically biomass and fermentation liquid. Of these wastes the fermentation residues are most likely to be landspread. The biomass in these residues breaks down in the soil providing nutrients for plant growth.

A large amount of waste is produced by the chemical industry, some of this may be beneficial to crop growth and used for landspreading, particularly waste ammonia, ammonium sulphate and wastes from the manufacture of fertilisers. These vary considerably in quantity and quality and should be considered for landspreading on an individual basis. It should be remembered, however, some countries do not allow wastes of this origin to be spread on land, this is most likely due to their variable nature making blanket authorisation virtually impossible.

4.14.3 Key properties

Analyses have shown that some of these wastes contain nutrients beneficial to plant growth. In Denmark, pharmaceutical and fertiliser wastes make the largest contribution of nutrients of all industrial wastes, contributing to 62% of the total P and 23% of the total N applied to land from industrial waste.

Chemical wastes such as ammonium and ammonium sulphate have obvious benefits of high nitrogen content.

4.14.4 Potential problems

These wastes are highly variable according to their origin and therefore properly qualified advice should always be sought when considering land application of these wastes (see section 1.1.5).

Particular care has to be taken where biomass originates from antibiotic production: Most of the antibiotics are removed in the extraction process, however, it is very difficult to remove the last trace of product. Antibiotics remaining in the waste may adversely affect the soil microbiological population, but this is likely to be a short term effect. Exposure of soil-micro-organisms to antibiotics could result in dissemination of resistance to antibiotics through natural populations. Some research is needed to resolve this question.

Care should be taken when applying wastes with very high nitrogen content. These should be applied at very low rates and strictly in accordance with crop requirements. Surface applications should be avoided to prevent damage to crops by scorching.

4.14.5 Variability

The quality of these wastes will vary considerably according to the product produced and the processes and raw materials used. Before considering the landspreading of such a material, properly qualified advice must be taken as to its safety and any environmental risk associated with the process. A thorough evaluation should be made of the wastes, to include, the quantity of antibiotic and cells/colonies remaining in the waste; the major plant nutrients in the waste and other contaminants; and the effect that residual antibiotic or cells/colonies may have on the soil microbiological population.

4.14.6 Treatment

The need for treatment will depend on the nature and origin of the waste. Treatment may involve stabilisation via digestion or composting or addition of lime, or a controlled pasteurisation process. Level of treatment will also depend upon economies of scale involved and local regulation.

4.14.7 Application / Storage

Wastes from these industries should not be spread without a detailed evaluation of the waste and use of properly qualified advice. Application rate should be based on crop nutrient requirement and concentrations of potentially toxic elements.

Where wastes contain high concentrations of ammonia, care should be taken to avoid direct contact with leaves so as to avoid scorching. Applications can lead to a reduction in soil pH value.

5. LEGISLATION AND OTHER CONTROLS, ENVIRONMENTAL AND ECONOMIC FACTORS

5.1 Legislation

The Waste Framework Directive (75/442/EEC as amended 91/156/EEC)) sets out the principles of the necessary controls where waste materials are to be recycled to the land but there is a case for introducing more specific controls to ensure a high level of environmental protection. The principles are that Member states shall take the necessary measures to ensure that waste is recovered or disposed of without endangering human health and without using processes or methods which could harm the environment, and in particular:

- without risk to water, air, soil and plants and animals;
- without causing a nuisance through noise or odours; and
- without adversely affecting the countryside or places of special interest.

Member States shall also take the necessary measures to prohibit the abandonment, dumping or uncontrolled disposal waste.

Annex IIB of Directive 75/442/EEC lists the operations which may lead to recovery, including R10 – spreading on land resulting in benefit to agriculture or ecological improvement, including composting and other biological transformation processes, except in the case of waste excluded under Article 2 (1) (b) (iii). The latter includes animal carcasses and the following agricultural material: faecal matter and other natural, non-dangerous substances used in farming.

These principles could be adjusted and expanded to provide a higher level of environmental protection where wastes are recycled to land but without introducing excessive restrictions which lead to more disposal of waste and less waste recovery by landspreading.

Competent authorities in several Member States (Denmark, France, Germany, UK – see Appendices) have already taken initiatives to develop effective regulation by building on the

Waste Framework Directive. As regards reporting, there is an onus on Member states under Article 5 of Directive 91/692/EEC, on standardising and rationalising reports on the implementation of certain Directives relating to the environment, to supply information to the Commission about implementation of the Waste Framework Directive. There is a need for this information to obtain firm data about the extent of landspreading of wastes in the EU.

More specific controls for landspreading of wastes could be compiled from the European Waste Catalogue (classification) and from Directives 86/278/EEC on landspreading of sewage sludge and 91/676/EEC on protection of waters against pollution caused by nitrates from agricultural sources. These two Directives, and extended guidance for their implementation which is available in most Member States, contain much of relevance to the landspreading of wastes.

Also relevant is the EC initiative on biodegradable waste, now at the discussion stage, which is intended to help meet the targets of the Landfill Directive 1999/31/EC to progressively reduce the quantities of biodegradable waste disposed of to landfill. The Working Document (2^{nd} draft) on the Biological Treatment of Biowaste has the following objectives:

- To promote the biological treatment of biowaste by harmonising the national measures concerning its management in order to prevent or reduce any negative impact thereof on the environment, thus providing a high level of environmental protection.

- To protect the soil and ensure that the use of treated and untreated biowaste results in benefit to agriculture or ecological improvement.

- To ensure that human as well as animal and plant health is not affected by the use of treated or untreated biowaste.

- To ensure the functioning of the internal market and to avoid obstacles to trade and distortion and restriction of competition within the Community.

The current exclusion from Regulation of farm animal waste should be reconsidered bearing in mind the large quantity recycled to land in the EU and its polluting potential (nutrients, pathogens and chemicals).

For some industrial waste producers Directive 96/61/EC concerning integrated pollution prevention and control (IPPC) will be of relevance.

5.2 Environmental factors

The key tenet in support of landspreading of wastes is that it recycles nutrients and organic matter to the land which would otherwise be lost in disposal to landfill or thermal destruction. In landfill, organic waste is potentially polluting because it causes leachate production and release of the greenhouse gas, methane. A residual ash or char is left behind from most thermal processes which still needs to be disposed of and carbon dioxide is lost to the atmosphere. There is potential for energy recovery from thermal processes and landfill (through methane collection). Provided that benefit to agriculture (or ecological improvement) can be demonstrated, landspreading of wastes is considered preferable to thermal destruction or landfilling in the ranking of options in the Waste Framework Directive. The Directive on the landfill of waste 1999/31/EC details requirements for Member States to set up a national strategy for the implementation of the reduction of biodegradable waste going to landfills and, together with the landfill tax in some Member States, this will encourage the recycling of more waste to land.

Therefore, the potential advantages of landspreading for the environment include:

- Recovery of waste which might otherwise be dumped or destroyed;

- Replacement of chemical fertilisers – a potentially more sustainable approach than reliance on continuous supplies of nitrogenous fertiliser from energy-intensive processes, and phosphate fertiliser and peat soil conditioners from finite sources; and

- Improvement of soil structure.

Potential disadvantages of landspreading include:

- Hazard to human and animal health due to pathogens;
- soil contamination from potentially toxic and persistent elements or organic compounds, and associated implications including long-term effects on soil fertility.
- pollution of water (surface and groundwater);
- nuisance (odour, visual);
- damage to soil structure from spreading operations.

Other environmental effects to be considered and compared between the waste management options would include:

- Acid gas emissions, comprising the oxides of sulphur and nitrogen ($N0_2$ and N0);
- greenhouse gas emissions – carbon dioxide, methane, nitrous oxide ($N_2 0$) and the oxides of sulphur;
- net primary energy consumption – fuel, other energy associated with treatment, storage and transport assets, net electricity consumption, the value of waste used on the land in (partially) substituting for fertilisers, any waste heat recovered.

Waste producers using the landspreading outlet must recognise that it is waste recovery not waste disposal. They should be prepared to improve the management of wastes for landspreading by investment as appropriate in storage at the point of production, dewatering and other treatment, monitoring and analysis, and field trials to quantify the agricultural benefit of their wastes.

Provided its potential disadvantages can be suitably controlled, landspreading should compare favourably with the other waste management options. Such a comparison would be complicated by the variability of activities but could be demonstrated by environmental impact assessment or life cycle analysis of operations selected as being either generally representative, or evaluation of options for the major wastes – farm animal waste, paper waste, and food waste.

5.3 Economic factors

Two of the benefits of landspreading of waste are that it is often an economic route for the waste producer compared with the other options available and for the farmer it usually represents a free or competitively-priced source of nutrients and/or soil conditioner. Obviously many factors will influence the economics of particular operations, but a broad estimate is made as follows for the cost of disposal of 1 tonne of waste or $1m^3$ of effluent using data from France.

Landspreading = 15 - 25 Euro for solid waste, or 1 – 4 Euro for effluent

Landfill = 25 - 55 Euro including a landfill tax of 9 Euro

Incineration = 45 - 90 Euro

See also Appendix E, Fance, Table E2 and text.

The many factors which will influence the comparative cost of landspreading include:

- Distance from site of production to the farm. A round trip of no more than 20 km is preferred. Suitable land for the waste may not be available locally and it cannot be assumed that all farmers will be prepared to use waste on their land.
- Cost of finding suitable land and negotiation/contact with farmers.
- Cost of pretreatment of the waste. Often, the extent of pretreatment is minimal and a commitment by the producer to ensure that the waste is consistent, for instance in such a basic parameter as dry solids content, would demonstrate some movement from disposal to recycling and would encourage farmers to take the material.
- Cost savings on transport and field spreading from minimisation treatment of the waste (thickening, dewatering, drying) which reduces the bulk volume for disposal.
- Recovery of value from the waste. If the producer pretreats the waste so that it is consistent and defines broadly the agronomic value (for instance, content of crop-available nutrients) of the treated material then the farmer is able to realise some value in terms of savings on fertiliser expenditure and may be prepared to pay for the waste product. The balance of economics here lies between the cost of pretreatment and testing compared with the charge recovered for the product. Another less quantifiable but important consideration is that the treated and tested product is likely to have improved acceptability and sustainability for landspreading.
- Cost of storage of the waste. There may be periods of the year, possibly up to 6 months or more when land is not available for landspreading due to unsuitable soil conditions (too wet, frozen) or presence of a standing crop.
- Cost of compliance with regulations (licensing, testing, monitoring, record-keeping, administration).
- Emergence of economically viable alternative options (e.g. in energy recovery technology).

5.4 Social factors

The development of landspreading depends partly on public acceptance of the concept and of landspreading operations at the local level. Acceptance of the concept requires a public relations exercise to inform and educate about the need for recycling of wastes to land as opposed to dumping in landfill or incineration. This can be achieved through the media and by exhibitions and ‘open days’ at operational sites. The promotion must be supported by demonstration that all environmental aspects of landspreading are understood and controlled so that the practice is safe and of environmental and agricultural benefit.

Landspreading depends on the willingness of farmers to accept waste for recycling on their land and this willingness may be influenced by various outside influences. An important factor is the attitude of the buyers of farm produce to the fact that waste has been recycled on the land. Any suggestion of a public acceptance problem with food made from crops grown on waste-treated land might cause the buyer to compel the farmer to stop the practice.

Public acceptance at the local level is important. Neighbourhood concerns can be triggered by odour, visual and traffic nuisance all of which must be avoided both at the plants where the waste is produced and treated, and at the farms where it is spread. This will require making sure the waste is treated as far as possible to remove odour, planning lorry routes to the farm to avoid nuisance, and ploughing in waste soon after spreading on the land or else applying the waste by subsurface soil injection.

6. RECOMMENDATIONS FOR CONTROLS AT COMMUNITY LEVEL

These recommendations set out an outline scheme for cost-effective controls on landspreading intended to provide across the EU a ‘level playing field’ for stakeholders, reliable information for regulators and a high level of environmental protection where landspreading of wastes is practised. The recommendations include a strong element of self regulation; the waste producer or their agent has to provide most of the information required in the proposed scheme.

6.1 Definitions

The terms *benefit to agriculture* and *ecological improvement* from the Waste Framework Directive must be fulfilled if a waste is to be permitted for spreading on the land and they need further definition to clarify what has to be achieved. For example, definitions suggested in the UK (Environment Agency UK 1998) are as follows:

Agricultural benefit will be achieved when the application of a waste to land improves soil conditions for crop growth whilst ensuring the protection of environmental quality in the broadest sense as required by Article 4 of the Waste Framework Directive 75/442/EEC.

The benefits can be measured in terms of:

- Crop yield and quality. The most important indicator of agricultural benefit to which the other benefits each make some contribution;
- Soil chemical properties. Benefits that the waste will bring to the soil in terms of addition of plant nutrients in particular, and improvements in soil pH value;
- Soil physical properties. Addition of organic matter; improvements in water holding capacity, porosity, stability, tilth, workability and soil structure, and reduced potential for soil erosion. Addition of chemicals such as gypsum can also improve the workability of salty and heavy clay soils;
- Soil biological properties. Addition of organic matter improves water retention and aeration, conditions for root growth and populations of worms and micro-organisms, and provides a buffer against leaching of nitrogen and phosphorus.
- Soil water content. Application of watery wastes can bring benefit when there is a soil moisture deficit limiting crop growth;
- Land levelling. May bring agricultural benefit in some situations.

Conversely, properties of wastes that can be non-beneficial include: excessive application of nutrients or nutrient imbalance, nutrient immobilisation, content of potentially toxic contaminants, excessive acidity or alkalinity, sodium content and conductivity, smell, visual appearance including colour and litter content, pathogens (human, animal and plant), texture and handleability, high carbon/nitrogen ratio and high BOD – biological oxygen demand.

Ecological improvement will be achieved by the maintenance of habitats and their biodiversity where these would otherwise deteriorate, the provision of new habitats for wildlife and the development or restoration of existing habitats to give greater biodiversity and sustainability.

Usually, the case for landspreading a waste will be determined by demonstrating benefit to agriculture. The ecological improvement criterion is likely to be confined to situations where it is proposed to use wastes in land reclamation or similar operations.

The *categories of wastes* likely to be suitable for landspreading: The survey shows that there is some confusion about definitions of the wastes suitable for landspreading. Suitable wastes need to be identified, defined and if appropriate grouped into broad categories to make for a workable classification for use across the EU. Only this way will it be possible to control landspreading effectively since the classification is fundamental to collect coherent information and make sensible comparisons. The new EC list of wastes to be published in the Official Journal of the EC and which will take effect on 1st January 2002 may help clarify the position by providing a starting point in terms of a list of named wastes. A separate list of wastes suitable for landspreading could be selected from the EC list and further classified and grouped as appropriate. Inclusion on the EC list ‘does not mean that the material is a waste in all circumstances’. This is relevant to the question of ‘by-products’ which also needs to be resolved in deriving a workable classification of wastes for landspreading. For example, the food and drink sector generates large quantities of materials it considers to be not wastes but by-products, most of which are recycled into the process, used in secondary processes or supplied to farmers for use as animal feed or for landspreading. There are similar examples from other sectors of industry which supply ‘by-products’ for landspreading. As ‘by-products’ these materials are currently outside the controls on landspreading of wastes in agriculture which may be convenient for the producer but is not necessarily compatible with ensuring a high level of environmental protection where these materials are used in agriculture for landspreading. The German experience on classification of wastes for landspreading (Appendix) will be of assistance in developing a scheme for the EU as a whole. This process has already begun with the useful waste and waste treatment definitions in The EC Working Document (2nd draft) on the Biological Treatment of Biowaste.

In developing a practical scheme for operational purposes, a further banding of materials into broad groups maybe helpful. All materials would be subject to overall generic controls and there would be further specific controls for each group according to their properties. The main groups might be:

Class 1 Farm residues recycled on the farm of production e.g. manure from animals grazing *in situ.*

Class 2 Benign wastes containing negligible levels of contaminants e.g. green waste, biological sludge from food waste treatment.

Class 3 Wastes which may contain contaminants (pathogens, heavy metals and other potentially toxic elements, organic contaminants) e.g. Dredgings from waterways, tannery waste, paper waste.

6.2 Registering a waste for landspreading

The competent authority in each Member State would use the scheme above to classify particular wastes proposed for landspreading on receipt of a standard submission from the waste producer or their agent. Progressively detailed information would be required according to the class of waste along the following lines:

Class 1 Source of waste (address of place of production or treatment centre, and quantity of waste arising tonne/annum)

Extent of treatment e.g. storage for 3 months at ambient temperature.

Class 2 As for Class 1 plus

Basis for benefit to agriculture e.g. content of nitrogen.

Content of plant nutrients and lime (nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, trace elements), organic matter, dry solids. pH value

Evidence that the waste contains only negligible concentrations of contaminants

Class 3. As for Class 1 plus

Basis for benefit to agriculture

Content of plant nutrients etc. as for Class 2

Content of contaminants (pathogens – most probable numbers; concentrations of heavy metals, other potentially toxic elements and organic contaminants)

Evidence that the waste is free of contaminants other than those specified

All analytical data presented in the submission would be obtained on the basis of specified sampling and other procedures so as to provide results statistically representative of the waste for landspreading. As regards the *Class 3* wastes the quality rules in Directive 86/278/EEC (landspreading of sewage sludge) could provide the basis for deciding on acceptability for landspreading.

If the competent authority is satisfied with the information received it can use the classification scheme to designate the waste into its specific and generic class were it to be used for landspreading. Alternatively, the competent authority might ask for further information before making its decision or might designate the waste as unsuitable for landspreading. In the latter case, the competent authority would indicate the basis for its decision so that the producer could take necessary actions such as pretreatment or clean-up to improve the quality of the waste and reapply for landspreading designation. The designation of the waste (suitable or unsuitable for landspreading) would hold for a specified period or until such time as changes occur to the quality of the waste which could affect its designation according to the classification above. The competent authority would keep a register of wastes it had designated.

6.3 Permit for a landspreading operation

How the landspreading operation is managed on the farm is very important if benefit to agriculture is to be achieved and environmental problems are to be avoided.

Once the waste has been designated as suitable for landspreading, the waste producer or their agent can apply to the competent authority for a permit for a proposed landspreading operation.

In the UK landspreading of a list of 'exempted' wastes is authorised under the Waste Management Licensing Regulations 1994. The regulating authority in the UK is the Environment Agency which must be notified in advance of any proposed landspreading activity. Similar arrangements apply in Denmark for instance. The waste producer or contractor has to notify the regulatory authority of an intended landspreading operation including details of the quantity and quality of the waste and the location of the spreading site. The minimum prenotification period is not usually specified and often not enough notice is given to the regulatory authority to check up the details supplied and properly appraise the operation before it takes place. A prenotification period of a minimum of two weeks is suggested.

A permitting system may be preferable to ensure a high level of environmental protection. There is no reason why the permit should be confined to a single operation. It might cover several wastes and farms and a number or spreading operations provided that the competent authority is satisfied that the following criteria are met:

- The waste(s) have been designated as suitable for landspreading
- Article 4 of the Waste Framework Directive
- 91/676/ EEC (nitrates)
- 86/278/EEC for *Class 3* wastes
- The operation will be compatible with the farm waste/fertiliser plan
- The activity will be undertaken by competent operator(s)
- A site risk assessment has been carried out by properly qualified personnel and necessary precautions to ensure a high level of environmental protection will be acted upon
- A record of each spreading operation will be kept (type of waste, quantity of waste applied, location of farm and field, date of spreading) including the results of monitoring and analysis, and supplied to the competent authority

It will be easier to demonstrate compliance with these criteria for a benign waste than a *Class 3* waste. The competent authority would keep a register of permits issued and the record of each landspreading operation.

The competent authority would make the necessary site visits and spotchecks to confirm that landspreading operations were in compliance with the permit conditions and the records would indicate where any pollution incident could be linked with a landspreading operation.

A further consideration which might streamline the registering of wastes and permitting of landspreading operations would be to issue landspreading licences to operators. A licensed operator would be familiar with the control requirements for landspreading and their administration and would be known to the competent authority, all of which should streamline the authorisation process. In order to obtain a licence, an operator would make a submission including the capabilities of personnel, track record in landspreading of wastes including any pollution offences, access to properly qualified advice, transport and spreading equipment available, environmental policy, quality assurance procedures and liability insurance. The competent authority would either issue a landspreading licence for a designated period or indicate why it could not do so. The competent authority would keep a register of operators licenced for landspreading.

6.4 Database of information

As a result of this proposed scheme, the competent regulatory authority in each Member State could build up from its regional offices a national database comprising the registers of designated wastes and landspreading permits from which all relevant information about landspreading of wastes could be derived. Summary data could be reported to the Commission as required to present a synopsis of landspreading of wastes across the EU.

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