Good practice in QUALITY MANAGEMENT of AD residues from biogas production

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Task 24
Energy from Biological Conversion of Organic Waste

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GOOD PRACTICE IN QUALITY MANAGEMENT OF AD RESIDUES

GENERAL CONSIDERATIONS

The modern society generates great amounts of wastes that represent a tremendous threat to the environment and human and animal health. To prevent and control this, a range of different waste treatment and disposal methods is used. The choice of method must always be based on maximum safety, minimum environmental impact and as far as possible, recyclable end products.

One of the main trends of today's waste management policies is to reduce the stream of organic waste going to landfills and to recycle the organic matter and the plant nutrients back to the soil. The way of achieving this is through the biological treatment of organic waste - anaerobic digestion (AD) and composting.

The residues from anaerobic digestion of organic waste, also called digestate, have a considerable market potential. Nevertheless, applicable standards for these products do not exist. The recycling of AD-residues is generally poorly regulated in most countries. At the level of the European Commission a draft working document was elaborated at the beginning of 2001. The working document is intended as a basis for preliminary discussion, regarding the biological treatment of waste and the criteria for the future regulation of this area. The main objectives of this initiative are [21]:

- To promote the biological treatment of organic waste by harmonising the national measures concerning its management in order to prevent or reduce any negative impact thereof on the environment.
- To protect soil and ensure that the use of treated and untreated organic waste results in benefit to agriculture or ecological improvement.
- To ensure that the human as well as animal and plant health is not affected by the use of treated or untreated organic waste.
- To ensure the functioning of the internal market and to avoid obstacles to trade and distortion and restrictions of competition.

In order for the recycling of AD residues to reach the objectives listed above, comprehensive quality management measures must be implemented as an integrate part of any organic waste management system. This report outlines the existing good practice concerning the quality management of the recycling of AD residues. Its structure follows the three main links of the AD system: the biomass feedstocks, the AD process and the AD residues (digestate) and their recycling as soil fertiliser. At each of the three links, the relevant aspects of quality management - chemical, biological, and physical – are highlighted and discussed.

1. ANAEROBIC DIGESTION

The renewed interest in AD technologies is explained by its potential of stabilising the organic matter, reducing odours and pathogens, controlling physical and chemical contaminants, and providing recyclable end products biogas and digestate.

1.1 ANAEROBIC DIGESTION (AD) – THE MICROBIOLOGICAL PROCESS

Anaerobic digestion is indigenous to natural anaerobic ecosystems and represents the microbiological conversion of organic matter to methane in the absence of oxygen. It takes place in a variety of natural anaerobic environments such as the marine and fresh water sediment, paddy fields, water logged soils and in the region of volcanic hot springs and deep sea hydro thermal vents, the stomach of ruminants as well as in sewage sludge. The digested organic matter resulting from the anaerobic digestion process is usually called digestate

Figure 1 shows the main theoretical stages and the intermediary products of the anaerobic digestion. In practice, these stages coexist within the process and each stage is characterised by the main activity of a certain group of bacteria. During the AD process, the bacteria decompose the organic matter in order to produce the energy necessary to their metabolism, of which methane is a by-product.

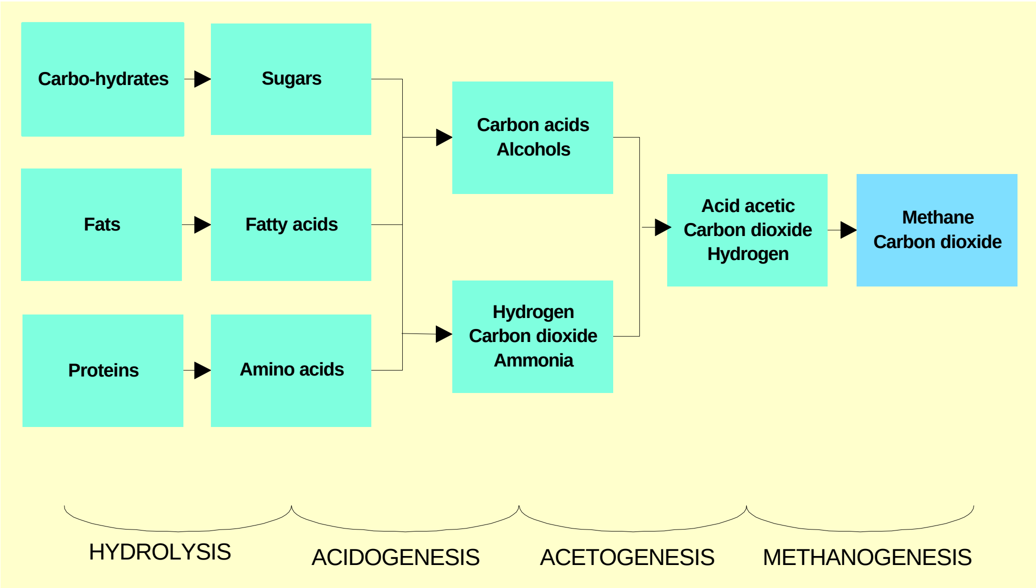


Figure 1. Schematic diagram showing the main theoretical stages of the anaerobic digestion process.

AD also known as the biogas process has been widely utilised by the modern society for stabilising primary and secondary sludges in municipal wastewater treatment plants. The biogas process has also been applied as an alternative method for the treatment of animal manure, organic waste from households, urban areas and industries, often associated with energy recovery and the recycling of the nutrients from digested biomass to the agricultural sector.

The biogas resulted from anaerobic digestion is a renewable and CO_2 neutral fuel used to produce electricity and heat. It consists of methane (CH_4) and carbon dioxide (CO_2), as well as minor quantities (less than 1% of total gas volume) of nitrogen, hydrogen, ammonia and hydrogen sulphide.

The digested biomass, also called digestate, is usually a low dry matter product, rich in plant nutrients. Digestate can be recycled as a high quality organic soil fertiliser, if the content of heavy metals and organic pollutants makes it suitable for this.

1.2 ANAEROBIC DIGESTION (AD) – THE TECHNOLOGIC PROCESS

A relative large number of AD-technologies are applied today around the world, each of them with its advantages and limitations.

A classification of the basic technologies can be made according to the dry matter content of the substrate, which divide the AD processes in wet (max. 10-15% DM) and dry (max 20-40 %DM). The process can be single-step or multi-step, continuous or batch or it can be a combination of these.

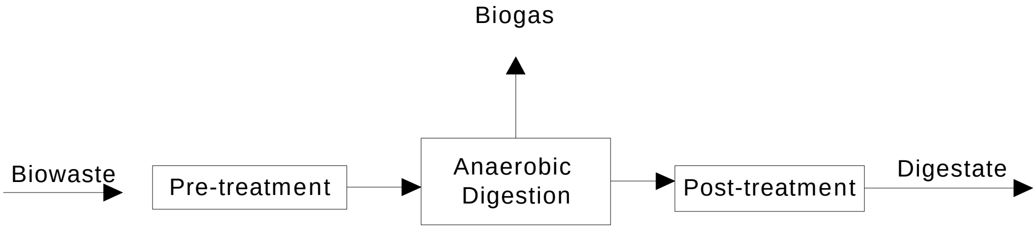


Fig 2. Schematic representation of the single-step process. Source: Wellinger, A. (1999).

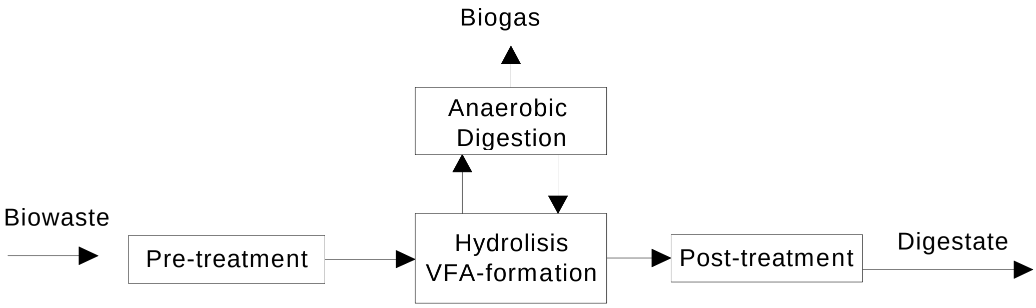


Fig 3. Schematic representation of the multi-step process. Source: Wellinger, A. (1999).

Figures 2 and 3 show the schematic representation of the single step and respectively the multi-step process. The pre-treatment usually consists of a bacterial hydrolysis (aerobic or/and anaerobic) or a chemical hydrolysis. The post treatment can be nitrogen removal sand removal, precipitation of heavy metals or separation into a liquid and a solid fraction (fibre separation). The solid fraction can either be composted, if its content of heavy metals and organic pollutants is within the legal limits, or it can be incinerated or landfilled. The liquid fraction is usually utilised as fertiliser in agriculture or treated in a wastewater treatment plant.

1.3 THE APPLICATIONS OF THE AD PROCESS IN THE SOCIETY

Figure 4 shows a schematic representation of a sustainable AD cycle in the modern society. The biogas process is today utilised in four main sectors of manure and organic waste treatment:

Manure stabilisation

Anaerobic digestion of animal manure, in order to produce energy and to improve the fertiliser quality of manure. It is perhaps the most common utilisation of AD-technologies. There are several million low technology installations in Asia providing biogas for cooking and lighting and more than eight hundred manure based plants in Europe and North America.

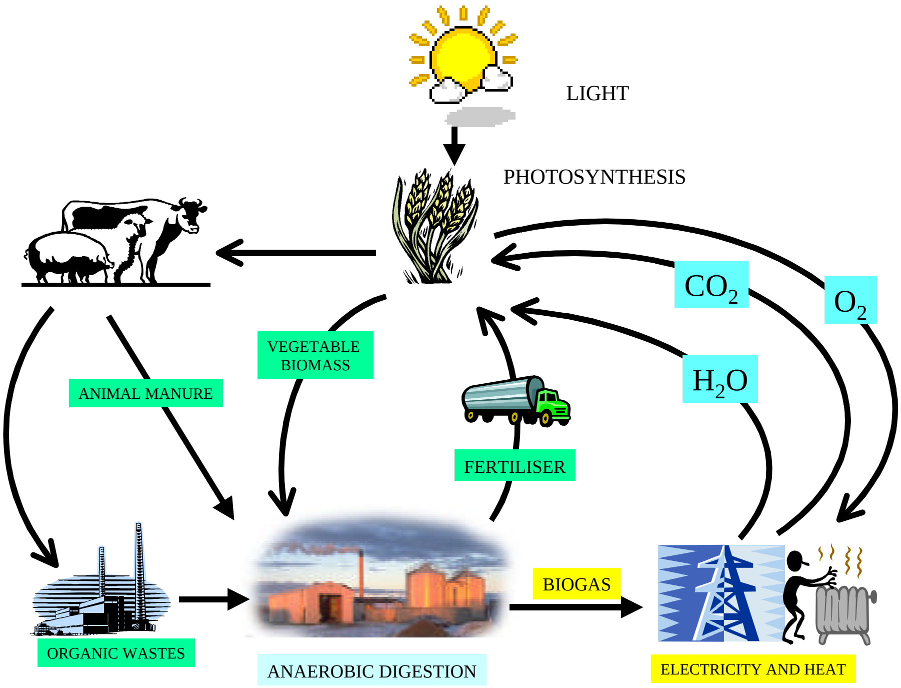


Figure 4. Schematic representation of the sustainable cycle of anaerobic co-digestion of animal manure and organic wastes.

Due to the environmental and veterinary benefits related anaerobic digestion, it is largely applied in countries

With intensive animal production and high manure density per hectare, controlled by strict rules concerning handling, storage, distribution and application of manure. There are two main concepts of manure based biogas production: the large scale, co-digestion plant and the small farm scale biogas plant.

Sludge volume reduction and stabilisation

Treatment of primary and secondary sludge resulted from the aerobic treatment of municipal wastewater. The system is widely utilised in thousands of installations in the industrialised world in connection with the advanced treatment systems of municipal wastewater. The anaerobic digestion process is used to stabilise and reduce the final amount of sludge. The digestate is used as fertiliser on agricultural land, dried and incinerated or landfilled. The biogas produced is used to partly cover the energy needs of the wastewater plant.

Industrial waste water treatment

Treatment of the industrial waste water from food-processing, agro-industries etc. More than 1300 AD plants are pre-treating organic loaded industrial waste waters from beverages, food, meat, pulp and paper, milk industries etc. before final disposal. The biogas is normally used to generate process energy. The environmental benefits and the high costs of alternative disposal will increase the application of this process in the future.

Organic waste treatment

Treatment of source separated organic fraction of solid household waste is one of the areas with a large biomass potential all over the world. Around 120 plants operate today with a total capacity of almost five million tonnes. The aim of this application is to reduce the flow of organic waste to other treatment systems e.g. landfill or incineration and to recycle the nutrients to the agricultural sector. Some AD treatment of organic household waste takes place at the manure based co-digestion plants. AD treatment of household waste is a technology that still needs to be improved and developed.

1.4 ENVIRONMENTAL ASPECTS OF ANAEROBIC DIGESTION

A study that compares the environmental impact, the economic and energetic aspects of different technologies for the treatment of biogenic waste: anaerobic digestion, tunnel composting, combinations of anaerobic digestion and composting as well as incineration in an incineration plant was carried out by W. Edelmann and K. Schleiss (“Ökologischer, ökonomischer und energetischer Vergleich von Vergärung Kompostierung und Verbrennung fester biogener Abfallstoffe ,1999) The conclusion of the study “strongly recommends to treat biogenic wastes with biotechnology in the future. Within biotechnology as much material as possible should take the anaerobic way”.

Anaerobic digestion of organic waste and manure provides direct and indirect environmental benefits:

- increased recycling and resources saving
- sanitation of wastes and manure and breaking the chain of pathogen transmission
- energy savings through production of a renewable energy source - the biogas
- utilisation of digestate as fertiliser and the fibre fraction as soil improver leads to energy savings from the production of mineral fertilisers and to saving rare sources of organic matter (e.g. peat).
- less greenhouse gas emission by displacement of fossil fuels by the CO_2 neutral biogas
- less air pollution by emissions of methane and ammonia and less leakage of nutrient salts to ground and surface water.

Anaerobic digestion has a limited impact on the environment, which is related to the biogas production itself:

- risk of odours, solved by burning odorous components in the exhaustion air or other odour treatment techniques
- risk of explosion, solved by utilisation of explosion-proof equipment.

2. QUALITY MANAGEMENT OF THE RECYCLING OF AD – RESIDUES

The main issues related to quality management of AD residues are

- the control of chemical pollutants (organic and inorganic),
- breaking the chain of diseases transmission by inactivation of pathogens and other biological hazards,
- the removal of physical impurities and the recycling of the nutrients and
- the organic matter by optimal utilisation of digestate as soil fertiliser /soil conditioner.

The quality requirements are different according to the end use of digestate:

Recycling /as fertiliser

- domestic use
- professional food production use
- professional non-food production use

Incineration

- recommended only if the quality of digestate is not suitable for recycling
- implies recycling or disposal of slag and emission control

Landfilling

- allowed only when recycling or incineration are not considered a suitable option
- current environmental regulations in EU limit the landfilling of organic wastes, due to its environmental impact and lack of sustainability

Recycling of AD-residues, by utilisation as fertiliser in agriculture, is by far considered the only sustainable utilisation of digestate.

Recycling requires a corresponding quality of digestate, to ensure application on farm land without hazard for humans, animals or the environment.

In all cases, there are three main steps of the quality management of AD residues:

A. Feedstock quality management
B. Management of AD process /Pasteurisation
C. Digestate quality management

Each step is concerned with three key aspects: chemical, biological and physical. Figure 5 illustrates the three main steps of the quality management of digestate.

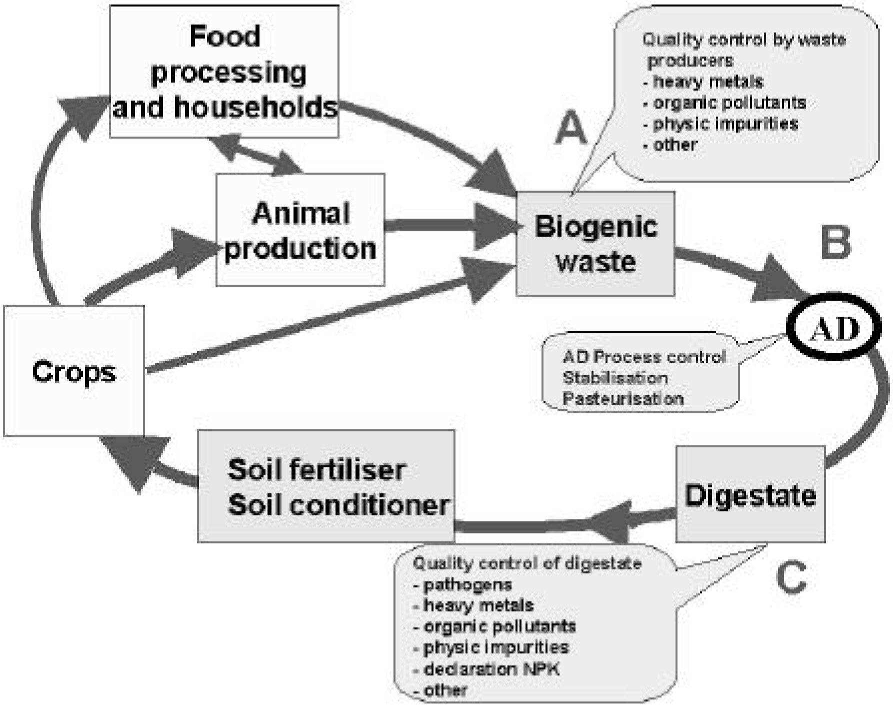


Figure 5. Schematic representation of the closed cycle of anaerobic digestion of biogenic waste and the three main steps (A, B and C) of the quality management of digestate.

2.1 THE MAIN ASPECTS OF QUALITY MANAGEMENT OF AD RESIDUES

Chemical aspects

The chemical aspects of quality management of digestate are related to the presence of:

- Heavy metals and other inorganic contaminants
- Persistent organic contaminants
- Macro elements (NPK)

Heavy metals in digestate usually come from anthropogenic sources. Domestic wastewater effluent contains metals from metabolic wastes, corrosion of water pipes, and consumer products. Industrial effluents and waste sludges may substantially contribute to metal loading.

Agricultural wastes can contain persistent organic contaminants as pesticide residues, antibiotics and other medicaments. Industrial organic waste, sewage sludge and household waste can contain aromatic, aliphatic and halogenated hydrocarbons, organo-chlorine pesticides, PCBs, PAHs etc.

The content and accessibility for the plants of macro-elements must be precisely defined, in order to prevent pollution from overloading of nutrients, when recycling these elements back to the soil by applying digestate as fertiliser in much the same way as with chemical fertilisers.

Biological aspects

According to their origin, organic wastes can contain hazardous matters, which can result in new routes of pathogen and disease transmission between animals, humans and the environment. The quality control of these types of biomass is therefore essential in relation with the biological treatment. The main problems are related to:

- Pathogens
- Seeds and Propagules
- Transmissible Spongiform Encephalopathy (TSE)

Physical impurities

The presence of impurities in digestate can cause a negative public perception of the AD technology, aesthetic damage to the environment, increase the operational costs and affect operational stability of the plant, wear and damage the plant components etc. The most frequent physical impurities are:

- Plastic and rubber
- Metal
- Glass and ceramic
- Sand and Stones
- Cellulosic materials (wood, paper etc)
- Other

2.2 THE MAIN STEPS OF THE QUALITY MANAGEMENT OF DIGESTATE

A. FEEDSTOCK QUALITY MANAGEMENT

Quality control of the feedstock is the most important way of ensuring a quality end product, suitable for a safe recycling for humans, animals and the environment.

The need of quality control differs according to the type of feedstocks and the kind of hazards that are involved.

Before being supplied to an AD plant, each load of biogenic waste must be analysed and characterised concerning:

- Origin (the name and address of the company producing the waste), which process the waste originates from, based on which raw materials or processed materials, amounts available and the security of supply.
- In case of household waste, the area of collection, if source separated or not and the collection recipients (plastic bags, paper bags, bins, other).
- Chemical declaration of the content of macro and micro elements, heavy metals, persistent organic compounds, pH, dry matter etc.
- Description (colour, texture, smell etc.).
- Health hazards related to handling the product or to the utilisation as soil fertiliser /soil conditioner.

The most common categories of AD feedstock are:

- Vegetable waste
- Animal manure and slurry
- Digestible organic wastes from food industries
  - wastes of vegetable origin
  - wastes of animal origin*
- Organic fraction of household waste/ food remains
  - wastes of vegetable origin
  - wastes of animal origin*
- Sewage sludge

*** Observation:**

Organic wastes and household wastes of animal origin require extraordinary attention regarding the utilisation as substrate for anaerobic digestion, with reference to the utilisation of digestate as fertiliser or as soil conditioner. The existing EU decision 2000/766 of 4 December 2000 stipulates a range of precautions against the spreading of transmissible spongiforme encephalopathy and introduced a temporary ban on foddering with processed animal protein. In extension to this was supplying of animal protein to biogas plants also banned.

Table 1 shows a classification of the organic wastes suitable for anaerobic digestion.

The animal manure and slurries and the vegetable wastes can be contaminated with crop and animal diseases (table 2). The organic wastes from food industries, the household waste and the sewage sludge can contain chemical, biological and physical contaminants. The quality control of these types of biomass is therefore essential in relation with the biological treatment.

Management of heavy metals / inorganic contaminants

Description of contaminants

Heavy metals are elements having atomic weights between 63 and 200 Living organisms require trace amounts of some heavy metals, including cobalt, copper, iron, manganese, molybdenum, vanadium, strontium, and zinc. Excessive levels of essential metals, however, can be detrimental to the organisms.

The heavy metals of particular concern for the application of waste products and digestate as soil fertilisers are: cadmium (Cd), chromium (Cr), mercury (Hg), lead (Pb), copper (Cu), nickel (Ni), zinc (Zn). The presence of heavy metals in digestate usually occurs from anthropogenic sources. Domestic wastewater effluent contains metals from metabolic wastes, corrosion of water pipes, and consumer products. Industrial effluents and waste sludges may substantially contribute to metal loading. Currently, anthropogenic inputs of metals exceed natural inputs. Excess metal levels in soils, surface and ground water may pose a health risk to humans and to the environment.

Table 1. Biowastes suitable for biological treatment

Waste Code	Waste description	
02 00 00[1]	Waste from agriculture, horticulture, aquaculture, forestry, hunting and fishing, food preparation and processing	Waste from agriculture, horticulture, aquaculture, forestry, hunting and fishing Waste from the preparation and processing of meat, fish and other foods of animal origin Wastes from the fruit, vegetables, cereals, edible oils, cocoa, tea and tobacco preparation and processing: conserve production; yeast and yeast extract production, molasses preparation and fermentation Wastes from sugar processing Wastes from the dairy products industry Wastes from the baking and confectionery industry Wastes from the production of alcoholic and non-alcoholic beverages (except coffee, tea and cocoa)
03 00 00	Wastes form wood processing and the production of panels and furniture, pulp, paper and cardboard	Wastes from wood processing and the production of panels and furniture Wastes from pulp, paper and cardboard production and processing
04 00 00	Waste from the leather, fur and textile industries	Wastes from the leather and fur industry Wastes from the textile industry
15 00 00	Waste packing; absorbents, wiping cloths, filter materials and protective clothing not otherwise specified	Packaging (including separately collected municipal packaging waste)
19 00 00	Waste from waste management facilities, off-site waste water treatment plants and the preparation of water intended for human consumption and water for industrial use	Wastes from anaerobic treatment of waste Wastes from waste water treatment plants not otherwise specified Wastes from the preparation of water intended for human consumption or water for industrial use
20 00 00	Municipal wastes (household waste and similar commercial, industrial and institutional wastes) including separately collected fractions	Separately collected fractions (except 15 01) Garden and park wastes (including cemetery waste) Other municipal wastes

Source: [21]

1) The 6-digit code refers to the correspondent entry in the European waste catalogue (EWC) adopted with European Commissions Decision.

Description of hazards

- direct toxicity
- indirect toxicity
- eco-toxicity/environmental accumulation

Factors

- concentration
- biological availability
- species differences

Table 2. The characteristics of some digestible feedstock types

Type of feedstock	Organic content	C:N ratio	DM %	VS % of DM	Biogas yield $m^3 * kg^{-1}$ VS	Unwanted physical impurities	Other unwanted matters
Pig slurry	Carbohydrates, proteins, lipids	3-10	3-8	70-80	0.25-0.50	Wood shavings, bristles, water, sand, cords, straw	Antibiotics, disinfectants
Cattle slurry	Carbohydrates, proteins, lipids	6-20	5-12	80	0.20-0.30	Bristles, soil, water, straw, wood	Antibiotics, disinfectants, NH_4^+
Poultry slurry	Carbohydrates, proteins, lipids	3-10	10-30	80	0.35-0.60	grit, sand, feathers	Antibiotics, Disinfectants, NH_4^+,
Stomach/intestine content	Carbohydrates, proteins, lipids	3-5	15	80	0.40-0.68	Animal tissues	Antibiotics, disinfectants
Whey	75-80% lactose 20-25% protein	n.a.	8-12	90	0.35-0.80	Transportation impurities	
Concentrated whey	75-80% lactose 20-25% protein	n.a.	20-25	90	0.80-0.95	Transportation impurities	
Flotation sludge	65-70% proteins 30-35%lipids					Animal tissues	Heavy metals, disinfectants, organic pollutants
Ferment. slops	Carbohydrates	4-10	1-5	80-95	0.35-0.78	Undegradable fruit remains	
Straw	Carbohydrates, lipids	80-100	70-90	80-90	0.15-0.35	Sand, grit	
Garden wastes		100-150	60-70	90	0.20-0.50	Soil, cellulosic components	Pesticides
Grass		12-25	20-25	90	0.55	Grit	Pesticides
Grass silage		10-25	15-25	90	0.56	Grit	
Fruit wastes		35	15-20	75	0.25-0.50		
Fish oil	30-50% lipids	n.a.					
Soya oil/margarine	90% vegetable oil	n.a.					
Alcohol	40% alcohol	n.a.					
Food remains			10	80	0.50-0.60	Bones, plastic	Disinfectants
Organic household waste						Plastic, metal, stones, wood, glass	Heavy metals, organic pollutants
Sewage sludge							Heavy metals, organic pollutants

Source: [3], [17], [18].

Health effects

Ingestion of metals such as lead (Pb), cadmium (Cd), mercury (Hg), arsenic (As), barium (Ba), and chromium (Cr), may pose great risks to human health. Trace metals such as lead and cadmium will interfere with essential
nutrients of similar appearance, such as calcium (Ca2+) and zinc (Zn2+)

Environmental effects

Soil and aquatic organisms may be adversely affected by heavy metals in the environment. Slightly elevated metal levels in natural waters for example may cause the following sub-lethal effects in aquatic organisms such as: histological or morphological change in tissues, suppression of growth and development, changes in circulation, enzyme activity and blood chemistry, change in behaviour and reproduction etc.

Fertiliser effects

Utilisation of digestate as fertiliser may transport dissolved heavy metals to agricultural fields. Although most heavy metals do not pose a threat to humans through crop consumption, cadmium may be incorporated into plant tissue. Accumulation usually occurs in plant roots, but may also occur throughout the plant.

Examples of management of heavy metals in feedstock

1. Two–stage process
2. Acid hydrolysis /precipitation

Limit values /existing regulations

- directive 86/278/EEC, Danish SO/49/20 .01. 2000, Swedish, others.

Table 3. Example of concentration limits of heavy metals in sewage sludge (mg/kg DM) for application on farmland in different European countries.

Country/Region	Cd	Pb	Hg	Ni	Zn	Cu	Cr
EU, recommendation	20	750	16	300	2500	1000	1000
EU, maximum	40	1200	25	400	4000	1750	1500
Austria	4	500	4	100	1000	400	150
Belgium	6	300	5	50	900	375	250
Denmark	0.8	120	0.8	30	4000	1000	100
Finland	1,5	100	1	100	150	600	300
France	20	800	10	200	3000	1000	3000
Germany	10	900	8	200	2500	800	900
Ireland	20	750	16	300	2500	1000	1000
Italy	20	750	10	300	2500	1000	-
Luxembourg- rec.	20	750	16	300	2500	1000	1000
Luxembourg- max.	40	1200	25	400	4000	1750	1750
Norway	4	100	5	80	1500	1000	125
Spain (pH< 7)	20	750	16	300	2500	1000	1000
Spain (pH> 7)	40	1200	25	400	4000	1750	1200
Sweden	2	100	2.5	50	800	600	100
Switzerland	5	500	5	80	2000	600	500
The Netherlands	1,25	100	0,75	30	300	75	75
United Kingdom	-	1200	-	-	-	-	-

Source: [10], [17]

Management of persistent organic contaminants (organic xenobiotic substances)

Description of main contaminants

PAH - Polycyclic aromatic hydrocarbons.
Mainly found in smoke from incineration and the exhaust fumes from vehicles. They deposits on roofs and road surfaces, from where they are flushed into the sewage sludge systems by rainwater.

DEPH - Di (2-ethylhexyl) phthalate.
The compounds are primarily used as plastic softeners, especially of PVC (e.g. tarpaulins, toys, cars and vinyl flooring). By washing, the substance ends up in the sewage system.

LAS - Linear alkylbenzene sulphonates.
Primarily used as surfactants in detergents and cleaning agents.

NP and NPE - Nonylphenol and nonylphenolethoxylates with 1-2 etoxy groups.
Typically used as surfactants in detergents, cleaning agents, cosmetic products and vehicle care products. They find their way into the sewage system via wastewater from laundries and vehicle workshops and from cosmetics in household waste and sewage.

Description of hazards

The hazard for humans, animals and the environment is linked to their volatility, mobility/water solubility, persistence/low biodegradability and bioavailability that can cause dispersion of volatile compounds to the atmosphere, bioaccumulation and/or induced toxicity in plants.
The presence in digestate of persistent organic compounds of xenobiotic origin represent a hazard to humans, environment and plants due to their toxicity or other environmental adverse effect as well as their effect on ozone layer depletion.
Numerous xenobiotic organic compounds are known to have oestrogenic effect on vertebrates (xenoestrogens) or to be endocrine disruptors. These compounds are considered to be responsible for decline in human male reproductive health and for a number of forms of cancer in humans.

Sources of contamination

AD residues, composted materials and waste derived products can contain persistent organic contaminants according to the origin of their base ingredients. Agricultural wastes can contain pesticide rests, antibiotics and other medicaments. Industrial organic waste, sewage sludge and household waste can contain aromatic, aliphatic and halogenated hydrocarbons, organo-chlorine pesticides, PCBs, PAHs etc.

Limit values/existing regulations

- 80/778/EEC (water quality for human consumption)
- Danish so 49/20.01.2000-02-29, The Netherlands, Germany, others

Table 4. Example of limit values for persistent organic pollutants in Denmark from July 2000. (mg/kg dry matter)

LAS	1300
PAH’s	3
NPE	30*
DEPH	50

* the limit value for NPE will be reduced to max. 10 mg/kg dry matter from July 2002
Source: Danish Ministry of Environment and Energy

Examples of management of persistent organic pollutants in feedstock

The problem related to the control and management of the organic contaminants in digestate is that it is difficult to perform a screening of such a broad spectrum of contaminants at a reasonable cost. The most common and economically feasible way to deal with the problem reefers to :

- Feedstock quality control
- The effect of AD on reduction of organic contaminants through out the digestion process
- Continued aerobic-anaerobic treatment

The aerobic treatment /composting has a positive effect on reduction of the main persistent organic pollutants. The method is largely utilised today in composting systems and in some cases in association with AD, usually as a post- treatment step.

Latest studies proved that the AD in itself has a certain effect on reduction of these pollutants. The laboratory trials on the four groups of organic contaminants listed before show that a certain reduction of some of the persistent organic contaminants can occur during the anaerobic digestion [16]. Some conditions must be fulfilled:

- A relevant micro flora (bacteria populations) must be present in the reactor
- The reactor should offer optimal life conditions for the relevant micro flora
- The persistent organic pollutants must be accessible to bacteria.
- An adaptation period for the bacteria is required as well as a rather constant supply of the organic matters to be converted.

The reduction of LAS and NPE seems to be more effective than the reduction of DEHP and PAH's. The issue still requires further research based on full-scale trials.

Management of physical impurities

Description of contaminants

The most common physical impurities are:
- plastic and rubber
- glass
- metal
- stones
- sand
- larger particle size of digestible materials (roots, wood, bark etc.)
- other

The biodegradable, natural materials (wood, straw, roots, wood, bark etc) are not considered an aesthetic hazard [6], while plastic (PVC and other plastics), glass and metal etc are aesthetically unacceptable and can cause pollution and trauma to the environment.

Description of hazard

Physical impurities are considered all the non-digestible materials and the digestible and low–digestible materials, due to their particle size. Physical impurities are likely to be present in all kinds of biomass feedstock, but most frequently in household wastes, food waste, garden waste, straw, solid manure and other solid types or waste.

The presence of physical impurities in the supplied biomass can cause fouling, obstruction and heavy wear of the plant components, disturb the operational stability and cause economic losses. Their presence in digestate can cause aesthetic damage, pollution and trauma to the environment. The regulation and management of physical impurities increases the public acceptance of the digestate as fertiliser.

Examples of management of physical impurities in feedstock

The control and management of physical impurities is mainly a matter of ensuring a high feedstock quality. This can be done either by source sorting or by on site separation (mechanically, magnetically, other). As a supplementary safety measure, physical barriers like sieves, stone traps or protection grilles can be installed in the pre-storage tanks, at the AD plants.

The feedstock can be collected through public or private systems of collection.
The separation of the digestible fraction can be done already in the collection phase or it can be done later, using the known waste separation technologies.

Source sorting

The separate collection and source sorting has the highest priority as the method that gives the best waste quality and the most economical way of ensuring a good quality of the digestible biomass. Separate collection excludes contamination from other materials. To be effective, it must be an integrated part of any waste management system.

Advantages of source sorting/separation:

- Decreases the quantity of waste for biological treatment and thus reduces the capital and operating costs for facilities
- Contribute to the recycling of wastes and consequently savings of raw materials and of energy
- Improves the quality of biological waste treatment
- Reduces the wear on biological treatment equipment
- Eliminates the costs of time, energy and materials consumption linked with separation and purification operations

Comments:

- Difficult to find and implement a simple and well functioning system of separate collection
- Quality of sorting is often poor (plastic and other non-digestible items can be present). It is therefor important to choose the appropriate collection system.

Separate collection in recyclable paper bags must be considered a better alternative to the collection in plastic bags. The method ensures better waste quality, prevents the need of on site separation step, for the removal of the rests of plastic bags and avoids lost of biodegradable matter that is removed together with the plastic impurities.

On site separation

The extent of the on site separation depends of the waste collection method (separate or bulk) and the purity and type of the collected waste. On site separation does not provide the same waste quality as the source sorted separate collection and can be more costly. It usually is part of a pre-treatment process. The most frequent steps of on site separation / pre treatment [19] are:

Waste reception:	Dumping in an intake bunker, silo, on the floor. Visual inspection, manual separation.
Shredding /bag opening:	Low speed multi-screw shredder, hammer mill
Screening:	Drum screen with 3-8mm hole diameter
Screening oversize:	Manual sorting on a conveyer belt
Wet separation:	A hydro-pulper where non-biodegradable materials are taken out of the suspension due to their different densities. The light fraction (plastics, textiles, cork, wood, leather etc.) floats on the surface of the suspension while the heavy fraction (metal, glass, stones etc.) is removed by a lock system at the bottom of the pulper.
Magnetic ferrous:	Electro-magnetic separator/magnetic drum that separates scrap iron materials.
Conveying:	Vibrating conveyers, front-end loader, open belt conveyers, screw conveyers.

Sand removal

The presence of sand in the biomass flow is not wanted, as it heavily loads the stirring systems, the pumps and the heat exchangers, causing fouling, obstructions and heavy wear. When accumulated inside the tanks and digesters, the sand reduces the active volume of these.

The general practice in order to avoid sand problems in an AD plant refers to:

- Regularly emptying of pre-storage and storage tanks
- Establishing of a sufficiently large pre-storage capacity
- Adequate stirring strategy
- Adequate placement of the pumping pipe stubs in order to avoid sand circulation
- Avoiding highly sand containing biomass feedstock
- Utilisation of specially developed methods of sand evacuation from the digesters
- Building reactor tanks with conic bottom

B. AD-PROCESS MANAGEMENT

Process parameters related to digestate quality

The process control ensures a stabilised end product and an effective reduction of pathogens by sanitation. An effective digestion can also contribute, to some extent, to the conversion of some persistent organic pollutants.

The most important process parameters related to the quality of digestate are the temperature and the minimum guaranteed retention time (MGRT).

Digestion temperature

The temperature inside the digester can be 40-55^{0}C (thermophilic digestion), 30-40 ^{0}C (mesophilic digestion, or under 30^{0}C (psychrophilic digestion). Depending on the kind of biomass to be digested, the suitable combination of process temperature and the hydraulic retention time (HRT) ensures a stabilised digestate.

Definitions:

Hydraulic retention time (HRT)
The retention time of the fluid biomass feedstock inside the digester. Important in correlation with the digestion temperature , in order to ensure a full digestion/stabilisation of the substrate. Measured in days.

Minimum guaranteed retention time (MGRT)
The minimum time interval for which any potion of the feedstock will be inside a continuous digester. Usual units hours (digester volume divided by feed flow rate).

The heating of biomass (fresh feedstock or digestate) to a certain level of temperature and maintaining this temperature during a certain amount of time provides effective pathogen reduction for most of the pathogens present in digestible wastes.

Pasteurisation usually occurs at 70^{0} C for one hour, ensuring effective pathogen reduction in biomass feedstock like sewage sludge, household waste etc.
Depending on the types of biomass to be sanitised, in some countries (like Denmark) a combined action of digestion temperatures and a minimum guaranteed retention time is allowed, in order to obtain the equivalent effective pathogen reduction during the digestion process.

Management of pathogen contamination /Pasteurisation and controlled sanitation

Description of contaminants

- bacteria,
- viruses,
- intestinal parasites
- other

Description of hazard

The modern technologies of manure and biogenic waste treatment may result in new routes of pathogen and disease transmission between animals, humans and the environment:

- humans: infectious diseases, mucous membrane irritation, bronchitis, asthma and allergy.
- domestic animals and wild fauna: zoonoses and other diseases spreading.

The risks mentioned before have made that many countries enforced legislation regarding pathogen control. Denmark has been a pioneer country in this area, with regulations since 1989. Countries like Austria, Germany, Sweden etc. used the Danish experience to create their own regulations. The main target is to effectively reduce the pathogens in digested biomass and generally in all kinds of waste products utilised for agricultural purposes.

Limit values/Existing regulations

Dir.91/118/EEC, 79/869/EEC. The sanitary aspects are regulated differently in different countries. Table 5 shows an example of sanitary restrictions on application of organic waste products in Denmark.

Table 5. Example of sanitary restrictions on application of organic waste products in Denmark. ("+" *means* "permitted")

Treatment Waste	Untreated	Stabilised	Controlled composting	Controlled pathogen reduction
A. Sludge from vegetable production	+	+	+	+
B. Sludge etc. from fish farming	Not for gardening	+	+	+
C. Sludge etc. from animal production	Not for agricultural purposes	Incorporated latest 12 hours after application. Not for gardening.[1)]	+	+
D. Source separated waste	Not for agricultural purposes	Not for edible crops. Incorporated latest 12 hours after application	[2)]	+
E. Sewage sludge	Not for agricultural purposes	Not for edible crops or gardening. Incorporated latest 12 hours after application.	Not for edible crops or gardening.	+

[1)] The restriction is not applicable to AD stabilisation
[2)] Application and incorporation before sowing
Source: Danish Ministry of Energy and Environment

The main steps in effective control of pathogens and other infectious matters via anaerobic digestion

- **Livestock health control**. No animal manure and slurries will be supplied from any livestock with health problems (zoonoses, TEC etc).
- **Feedstock control.** Hazardous biomass types are to be excluded from anaerobic digestion and canalised towards suitable, safe disposal methods.

- **Pasteurisation.** Usually at 70^{0}C, for one hour.
- **Controlled sanitation.** In Denmark, a combination of temperature and MGRT is applied for certain biomass types, that gives a pathogen reduction equivalent to pasteurisation.
- **Control of pathogen reduction efficiency** in digestate. There are many methods. One of the most used methods is the log10 of FS, based on the measurement of the Faecal Streptococci in digestate [4].

Pasteurisation is the basic method of pathogen reduction. It can be post-sanitation if is done after the digestion process or it can be pre-sanitation, if the fresh feedstock types are pasteurised before the anaerobic digestion. In both cases it normally takes place at 70^{0}C for one hour.

Depending on the types of wastes mixed and co-digested, combinations of temperatures and minimum guaranteed retention times (MGRT) are also allowed in countries like Denmark. The regulation for the use of waste products and sludge on agricultural land formulated by the Danish Ministry of Environment and Energy is based on the results of comprehensive research projects concerning the presence and the reduction of pathogens in organic wastes, manure and digestate. Table 6 shows the allowed combination of temperatures and MGRT, according to Danish law.

Table 6. Controlled sanitation equivalent to 70^{0}C for 1 hour as required in the notification no. 823 of the Danish Ministry of Energy and Environment.

Temperature	Retention time (MGRT) in a thermophilic digestion tank [a)]	Retention time(MGRT) by treatment in a separate sanitation tank [b)]	
		before or after digestion in a thermophilic reactor - tank [c)]	before or after digestion in a mesophilic reactor - tank [d)]
52,0°C	10 hours		
53,5°C	8 hours		
55,0°C	6 hours	5,5 hours	7,5 hours
60,0°C		2,5 hours	3,5 hours

Source: [9]

The treatment should be carried out in a digestion tank, at thermophilic temperature, or in a sanitisation tank combined with digestion in a thermophilic or a mesophilic tank. The specific temperature / MGRT combinations should be respected.

a) Thermophilic digestion is in this case at 52^0 C. The hydraulic retention time (HRT) in the digester must be at least 7 days
b) Digestion may take place either before or after pasteurisation
c) Se pct. a)
d) The mesophilic digestion temperature must be from 20^0 C to 52^0 C. The hydraulic retention time must be at least 14 days.

The effect of anaerobic digestion on pathogen reduction compared to untreated slurry is shown in table 7. The most common pathogens are destroyed by the thermophilic process temperatures during one hour of GRT.

Table 7. Comparison between the decimation time (T-90) of some pathogenic bacteria through the biogas system and the untreated slurry system.

Bacteria	Biogas system		Untreated slurry system	
	53^0C hours	35^0C days	$18\text{-}21^0C$ weeks	$6\text{-}15^0C$ weeks
Salmonella typhi murium	0.7	2.4	2.0	5.9
Salmonella dublin	0.6	2.1	-	-
E.coli	0.4	1.8	2.0	8.8
Staphylococcus aureus	0.5	0.9	0.9	7.1
Mycobacterium paratuberculosis	0.7	6.0	-	-
Coliform bacteria	-	3.1	2.1	9.3
Group of D-Streptococci	-	7.1	5.7	21.4
Streptococcus faecalis	1.0	2.0	-	-

Source: [4]

Inactivation of seeds and propagules via anaerobic digestion

Hazard description

- decreased product value of crops and products
- unwanted weeds spreading
- aesthetic damage for products
- extended need for herbicides

Existing regulations

- CEN /TC 237 Wg2 [6]

C. DIGESTATE QUALITY MANAGEMENT

Sampling, analysing and product declaration

In order to utilise digestate as a valuable organic fertiliser in agriculture and forestry it must have a defined composition.

Average samples of all loads of digestate must be analysed for heavy metals and persistent organic contaminants and ensured that these contaminants are not exceeding the detection limits prescribed by the environmental law (See chapter 3, Grindsted case story).

To be safely applied as fertiliser or soil conditioner, the digestate must be free of pathogens, prion-transmitted disease (TSE) and physical impurities. It must have a declared content of macro and microelements, dry matter and pH.

Nutrient Management

Environmental aspects related to nutrient management in recycling of AD residues

One of the concerns regarding recycling of digestate is the load of nutrients on farmland. Nitrate leaching, over loading of phosphorus can be caused by inappropriate handling, storage and application of digestate as fertiliser. The nitrate-directive (91/676/EEC nitrate) regulates the input of nitrate on farmland, aiming to protect the ground and surface water environment from nitrate pollution, allowing a maximum of 170 kg N/ha/year. The nutrient loading on farmland is regulated in different countries in order to avoid water pollution from the intensive animal production (table 8).

Table 8. Example of national regulations of the nutrient loading on farmland

	Maximum nutrient load	Required storage capacity	Compulsory season for spreading
Austria	100 kg N/ha/year	6 months	28/2-25/10
Denmark	until 2003 230-210 kg N/ha/year(cattle) 140-170 kg N/ha/year (pig) from 2003 170 kg N/ha /year (cattle) 140 kg N/ha/year (pig)	9 months	1/2-harvest
Italy	170-500 kg N/ha /year	90-180 days	1/2- 1/12
Sweden	Based on livestock units	6-10 months	1/2- 1/12
UK	250-500 kg N/ha/year	4 months	-

Source: [17]

There is a considerable potential of ammonia emissions from handling, storing and spreading of digestate. This is more likely to happen when co-digesting organic wastes and animal manure from areas with high manure density. The good agricultural practice for digestate application reduces considerably the environmental risks associated with this.

The application of digestate as fertiliser must be done on the basis of a fertiliser plan. The fertiliser plan must be elaborated for each agricultural field, based on the type of crop, the planned yield level, the anticipated utilisation percentage of nutrients in digestate, the type of soil (texture, structure, quality, pH), the existing reserve of macro and micro nutrients, the pre-crop, the irrigation conditions and depending of the geographic area. The experience in Denmark shows that from both an environmental and an economical point of view, an optimum application of digestate as fertiliser means to fulfil the phosphorus requirements of the crops and to supplement further more with mineral fertiliser in order to meet the nitrogen requirements.

3. CONCLUSION

General measures for safe recycling and quality digestate

- Source sorting and separate collection of digestible wastes, preferably in biodegradable recipients.
- Selection / excluding from AD of the unsuitable waste types / loads, based on the complete declaration of each load: origin, content of heavy metals and persistent organic compounds, pathogen contamination, other potential hazards etc.
- Periodical sampling and analysing of the biomass feedstock.
- Extensive pre-treatment/on site separation (especially for unsorted waste).
- Process control (temperature, retention time etc.) to obtain a stabilised end product.
- Pasteurisation or equivalent controlled sanitation for effective pathogen reduction.
- Periodical sampling, analysing and declaration of digestate.
- Including digestate in the fertiliser plan of the farm and using a “good agricultural practice” for application of digestate on farmland.

4. CASE STORIES

4.1 GUIDELINES FOR OPTIMUM USE OF DIGESTATE

Example from Ribe Co-digestion Plant, in Denmark [12].

The guidelines are based on several years field trials and experience achieved by advising the many farmers, who used digested slurry from Ribe Biogas Plant in Denmark [12].

- As a principal rule, digestate should only be applied at the start of the growing season, in March and April, and later on, only in vegetative growing crops.

- By the establishment of spring-sown crops, the digestate must be incorporated into the soil immediately after it has been applied. The time from application to incorporation must be as short as possible, to minimise ammonia volatilisation. The best thing to do is to simultaneously spread and incorporate the digestate.

- In over wintering crops, the crop must be started with one third of the total N-requirement in mineral fertiliser. The best utilisation of the digestate in over wintering crops is achieved in the period mid spring to early summer, when the crops are in vigorous vegetative growth. To make the digestate infiltrate quickly into the soil, dragging hose-equipment must be used. The most suitable crops for digestate utilisation are: Winter wheat, winter barley, winter rye and winter rape. Digestate can supply 50-70% of their N-requirement.

- The risks of ammonia volatilisation from digestate is rather high and can be reduced by using the right equipment - dragging hoses - and by taking the weather into consideration. During storage, handling and spreading it is important to take the ammonia volatilisation into consideration.

In figure 6 is shown a model calculation of the NH_3- and NH_4^+-concentration in Europe. The dark areas on the maps show high ammonia concentrations and are correlated with the areas with high animal production. Besides the environmental pollution, losses of nitrogen due to ammonia volatilisation are also an economic loss for the farmers.

The potential loss of ammonia from digestate during storage, under different conditions is shown in figure 7. In case of covered tank (not shown on the figure), the loss of ammonia is practically zero.

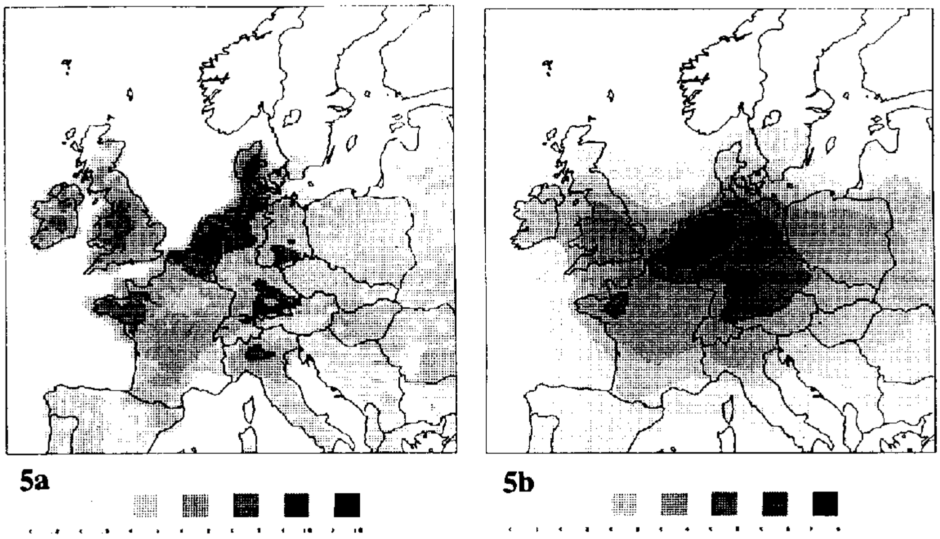


Figure 6. The calculated geographic distribution of the NH_3- and NH_4+-concentration in Europe (ug/m³). Source: [12]

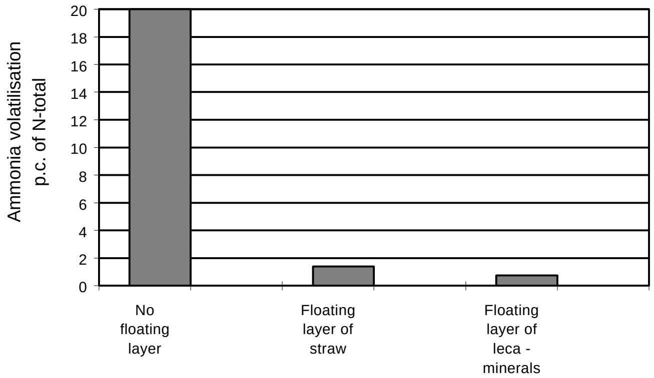


Figure 7. Ammonia volatilisation from storage tanks.
Source: [12].

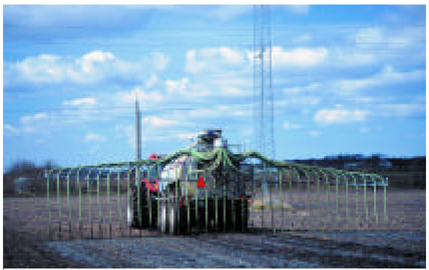


Figure 8. Dragging hoses for the application of digestate
Source : BioPress

To minimise the ammonia volatilisation, during the storage and spreading of digestate, some general guidelines should be followed:

- Always have a covered or a floating layer on the storage tank.
- Avoid stirring by always pumping from the bottom of the tank.
- The digestate should only be stirred just before application.
- Place storage tank where they are sheltered from wind and.
- Incorporate the digestate in the topsoil immediately after application.
- Use dragging hoses when digestate is applied in growing crops (fig 8).
- Apply digestate only under optimum weather conditions: cool, humid and no wind.
- There is a possibility to add acid to the digestate when it is applied. This decreases the pH-value and thereby ammonia's liability to volatilise.

Discussion

After at Ribe Biogas Plant has been in use for a decade, it proves that co-digesting animal manure and suitable organic wastes in a biogas plant can help solving some major environmental problems of the local animal farming and of the waste management sector in the area:

- Energy is produced from resources that have not been utilised until now (animal manure and suitable organic wastes).
- Manure loading per hectare decreased and a higher nutrient efficiency is achieved.
- Storage capacity for nine month was established.
- The animal farming sector got better environmental image.
- New jobs were created in the area.

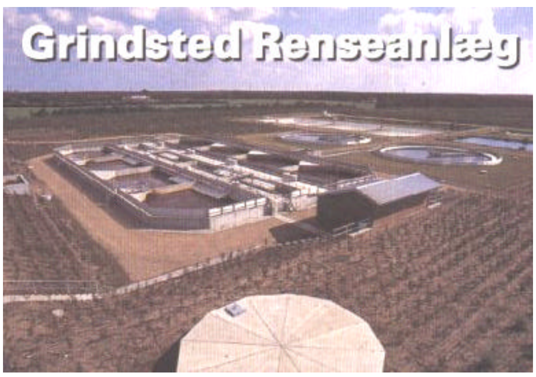
The digestate is a well declared and homogenous liquid organic fertiliser and can become the dominating type of organic fertiliser in the future. Preventing the ammonia volatilisation will be the next task of the environmental protection law, as digestate contains approximately 15% more ammonium-N than ordinary cattle slurry. The problem is rather critical, but covered storage tanks and good application practice can solve the problem.

Application of digestate has changed the farmers' behaviour drastically. Nearly all digestate and manure is spread during the springtime, when the utilisation percentage of nutrients is very high. This resulted in a considerable reduction of the consumption of mineral fertilisers, without reducing yields. On the contrary, since 1980 the consumption of nitrogen from mineral fertilisers has dropped by 21%, while grain yield per ha increased by 63% [5].

4.2 DIGESTATE, FROM WASTE TO FERTILISER

Case story from Grindsted wastewater treatment /AD plant in Denmark

By Bjarne Bro, process engineer
Grindsted Municipality, Denmark



The citizens of Grindsted Municipality in Denmark are very good at source separating their household waste. This is the main reason why the local wastewater treatment and AD plant (fig. 9) can produce a good quality digestate, that is used as fertiliser on the agricultural fields, plantations and forests.

Figure 9. Grindsted wastewater treatment plant
Source: Grindsted Municipality

The AD plant is integrated into the sewage treatment plant. The plant receives and treats sewage sludge, active sludge, industrial waste and daily food waste from private households. The biomass mixture, based on dry matter is on yearly base 45% sewage sludge, 20 % organic industrial waste and 35 % household waste/food waste.

Sewage sludge

The supplied sewage sludge originates from the wastewater treatment plants inside the borders of Grindsted Municipality, and is a mixture of primary and active sludge.

Food waste

The food waste is mainly kitchen waste, organic fraction of source separated household waste from 6200 out of the 7100 households in Grindsted Municipality. The main part of waste originates from one family houses and only a minor part from blocks of flats.

Figure 10. Grindsted AD plant: Delivery of household waste pre-sorted in paper bags.

The food waste is collected in the kitchen, in dustbins with a paper bag inset (fig 10). A dust car collects the waste each 14 days. The retention time in the dustbins is between 1 and 14 days. In this period moisture evaporates from the refuse and the dry matter content increases to around 40 %. No diapers, plastic packing and aluminium wrapping are allowed. The sorting work is controlled by the dustman. A warning and a penalty system, managed by the administration keeps missorting to a minimum so the waste treatment plant can run with a minimum of maintenance and operation stoppages.

Industrial waste

Industrial waste feedstocks originate from the food industry in the neighbourhood and are waste from production of food additives and from manufacturing of vegetable products such as chopped salads and potatoes based products. Most of the waste consists of peel, cover leaves and spoilt production. Figure 11 shows the simplified flow diagram of the wastewater treatment plant, including the AD plant.

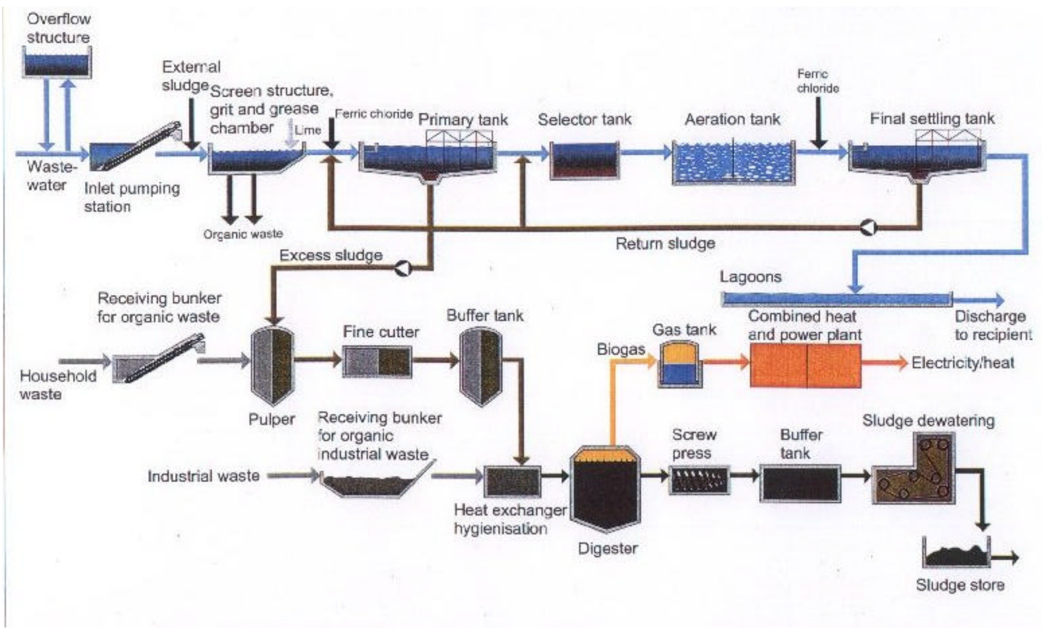


Figure 11. Grindsted wastewater treatment plant: simplified process diagram
Source: Grindsted Municipality

The biomass is delivered in two separate tanks. The daily food waste from households is solid and source sorted in paper bags and is delivered in a silo while all the other are the fluids and are delivered in an underground tank.

The food waste is shredded to an appropriate size and mixed in a pulper with active sludge and sewage sludge. This mixture is further minced in a macerator and mixed with the industrial sludge in the buffer tank.

The biomass is pasteurised at 70 °C for one hour. The digestion is mesophilic, at 38 °C. The substance is de-watered in a band strainer. The reject is passed to the sewage plant and the sludge is pumped to a storage facility with capacity for one year's production.

The produced biogas is used to generate electricity that is sold to the grid.

Main biomass data

Sludge:	28000 tons; 2,5 % DM
Industrial Refuse:	2900 tons, 10 % DM
Food refuse:	1200 tons, 50 % DM
Average Dry Matter:	4,3 %
Sludge output:	2500 tons, 23 % DM
Total reject:	47 tons
Magnet separator:	4 tons
Pulper:	17 tons
Sieve:	26 tons

Quality management of digestate at Grindsted Waste Water Treatment Plant (WWTP).

The plant co-digests WW-sludge and biological sludge from Grindsted WWTP and from three small WWTP inside Grindsted Municipality, organic industrial waste and kitchen waste from 6200 households. The biomass is mixed, pasteurised at 70 °C for one hour, and co-digested at mesophilic temperature, cooled, de-watered, stored for a year and brought on farmland as fertilizer. The plant is owned and operated by Grindsted Municipality, which is to be considered as the sludge producer (SP).

According to the Danish legislation, the sludge producer has to document all the inlet and outlet sludge streams to the local authorities, to the sludge users, to the county and to the government. This documentation is based on a control program based on the analysis of the content of nutrients, heavy metals and xenobiotic substances as well in the inlet and the outlet streams of each single charge as principle.

The digested sludge has a dry matter content of 23 %, no odour, is pasteurised and its level of heavy metals and organic pollutants is within the limits permitted and is allowed to be used without any hygienic restrictions.

The quality of the digested biomass is ensured via a quality management system (QMS) introduced by the producer. It includes a line of management and control steps in all the sludge and waste streams, starting with the control of household sorting and separate collection to the chemical analysis of the final product.

The Danish legislation requires that no inlet concentration of heavy metal and persistent xenobiotic organic should be higher than the permissible limits for the outlets. Both feedstocks and end products are controlled, as the contaminants can only be eliminated by tracing contamination to individual waste sources.

Source sorting

This only concerns organic household waste. Each household has to sort and collect separate its own daily waste in two bins. One for food waste and one for the rest. The sorting must be done according to a sorting list made by the SP. The dustmen make the first visual control. If physical contaminants such as plastic, bottles, batteries etc are visible, the dustbin will not be emptied and a standard note is handed over to the respective household explaining the problem and the consequences if the sorting is not better next time. SP measures the sorting quality two times a year. The current results show about 99 % purity of the source separated household waste.

Food waste contracts

The industrial waste, supplied by food industries, is controlled in conformity with a contractual agreement between those industries and the SP. In the contract each type of industrial organic waste is described with name, address of the producing industry, statement of origin in the industrial process, based on listing the raw materials and auxiliary materials and its chemical composition, as seen in the table 9 and 10.

Table 9. Sampling in inlets

Type of waste	Supplier	Action	Frequency	Type
Sludge	WWTP Grindsted	SP	1/y	Spot test
	WWTP Sdr. Omme	SP	1/y	Spot test
	WWTP Krogager	SP	1/y	Spot test
Foodwaste	Households	SP	2/y	Spot test
Industrial Waste	Private companies (2)	Supplier	4/y	Spot test

Table 10. Analysing of samples in inlet/Analysed parameters

Nutrients and micro-nutrients	Heavy metals	Xenobiotics
Nitrogen	Mercury	PAH[1]
Phosphorus	Lead	DEHP[2]
Potassium	Nickel	LAS[3]
Sulphur	Cadmium	NPE[4]
Magnesium	Copper	
Barium	Chrome	
	Zinc	

1) Polycyclic aromatic hydrocarbons. Found in smoke from incineration and the exhaust fumes from vehicles (see page 12 in this report).

2) Di (2-ethylhexyl) phthalate. Used as plastic softeners in PVC (see page 13 in this report).

3) Linear alkylbenzene sulphonates. Used as surfactants in detergents and cleaning agents (see page 13 in this report).

4) Nonylphenol and nonylphenolethoxylates with 1-2 etoxy groups. Used as surfactants in detergents, cleaning and vehicle care products, cosmetics (see page 13 in this report).

For some types waste from the food industry there is a reduced control program if the waste originates from a production with inherently very low concentrations of heavy metals.

Process control

The hygienic control is documented in the computerised control system. It monitors and records parameters of temperature and retention time in the pasteurisation tank.

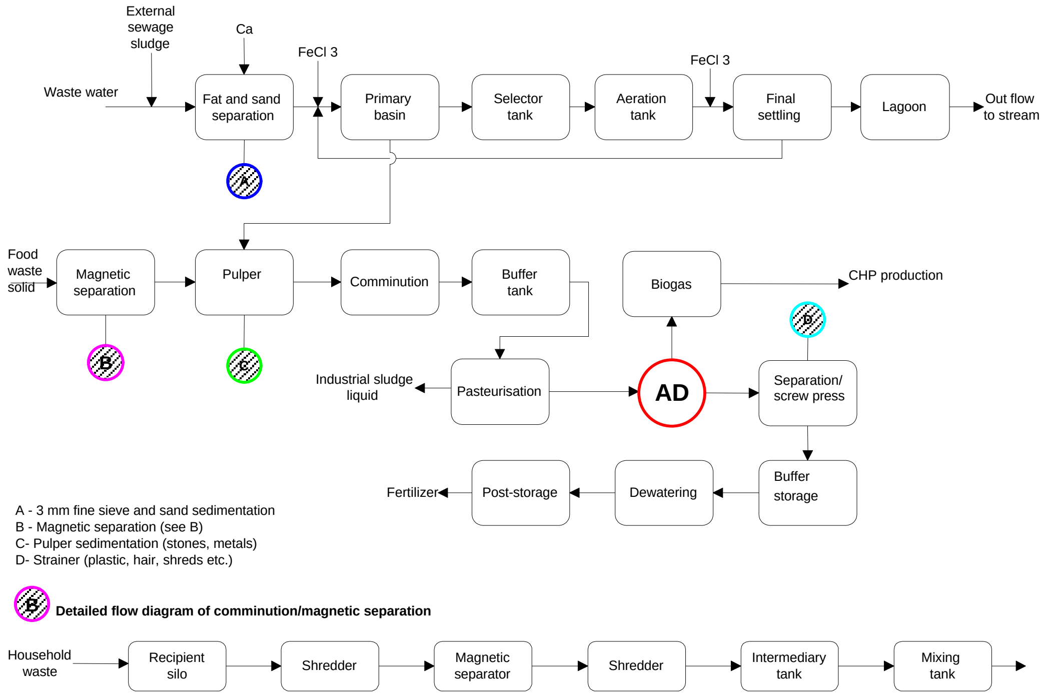


Figure 12. Grindsted wastewater treatment plant: biomass flow diagram and the main separation steps (A, B, C and D).
Source: Bioenergy Department, SDU

Data from over a year after the sludge is processed can be printed for each batch (15 m^3). This is followed up with microbiological tests for salmonella and faecal streptococci once a year.

Analysing of samples in outlet

The analysed parameters in table 11 are in relation to the dry matter content.

Table 11. Analysing of samples in outlet/Analysed parameters

Nutrients and micro-nutrients	Heavy metals	Xenobiotic
Nitrogen	Mercury	PAH
Phosphorus	Lead	DEHP
Potassium	Nickel	LAS
Sulphur	Cadmium	NPE
Magnesium	Copper	
Barium	Chrome	
	Zinc	

Monthly samples are collected in a sequence of four. One sample a week is taken in digestate after de-watering. The samples are stored in a freezer, thawed, mixed and a final sample is taken for analysis. A neutral accredited laboratory, according to Danish law makes the sampling and analysing. Copy of the analysing reports are controlled by the Danish Plant Directorate, which makes sure that no biomass that exceeds the required detection limits for heavy metals or xenobiotic compounds are used as fertiliser in agriculture or forestry. In addition to that, the SP provides a monthly sample for the determination of the macro-elements N, P and K in digestate.

Product declaration

Before the digestate is delivered to the farmers, the SP provides a report containing a full product declaration, based on all analysis through the year. The report contains information concerning the origin of the waste, the treatment, the amount, the analyses report numbers as well as the restrictions of use.

Agricultural practice for the application of digestate from Grindsted Biogas Plant as fertiliser.

The farmers who use the digestate as fertiliser must respect the application regulations required by Danish agricultural laws, that prescribes, as an average for 3 years:

Table 12. Regulation of application of digestate according to Danish law.

Nutrient	Max. limits (kg/Ha/year)
Nitrogen	170
Phosphorus	30
Dry matter	7 tons/Ha/year

The utilisation of nitrogen shall be at least 30 % the first year and 10 % the next year. To ensure a high utilisation rate of nutrients it is important that the application of digestate is done properly and succeeded by harrowing or ploughing, for sanitary concerns.

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TASK 24 ENERGY FROM BIOLOGICAL CONVERSION OF ORGANIC WASTE

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