Solid Waste: Assessment, Monitoring and Remediation
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III.2
Agricultural wastes

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III.2.1. Introduction

During the twentieth century agricultural production became more and more industrialized and the traditional production systems were gradually replaced by systems where mechanization, use of mineral fertilizers, pesticides, herbicides, concentrates, etc. led to intensification and concentration of agricultural production and not only increased the volume of the production but also changed the composition and the quality of the agricultural output.

Most agricultural wastes are valuable resources that should be recycled, used for industrial purposes and for energy recovery. If unsuitably handled and managed, agricultural wastes become an environmental problem and a hazard for human and animal health. The example of animal manure and how the perception of the value of animal manure changed during the last century, from a valuable natural fertilizer to a problematic excessive waste, as a consequence of intensive, industrialized agricultural practice, is a typical example (Wadman et al., 1987).

The management of agricultural wastes is considered today an important target in the global waste management strategy. Since 1990s the public has become increasingly concerned about the environmental impact of agricultural practices. As a result, the environmental and human and animal health consequences of today's agricultural practices are recognized, evaluated, and reflected into an increasingly restrictive legislative framework.

III.2.2. Agricultural wastes categories

A possible classification of the most common categories of agricultural wastes is shown in Figure III.2.1.

III.2.3. Main issues related to agricultural wastes and their utilization

Any kind of waste can become a hazard factor for humans, animals, and vegetation if its concentration in the environment is excessive. Water quality is affected if manure runs into

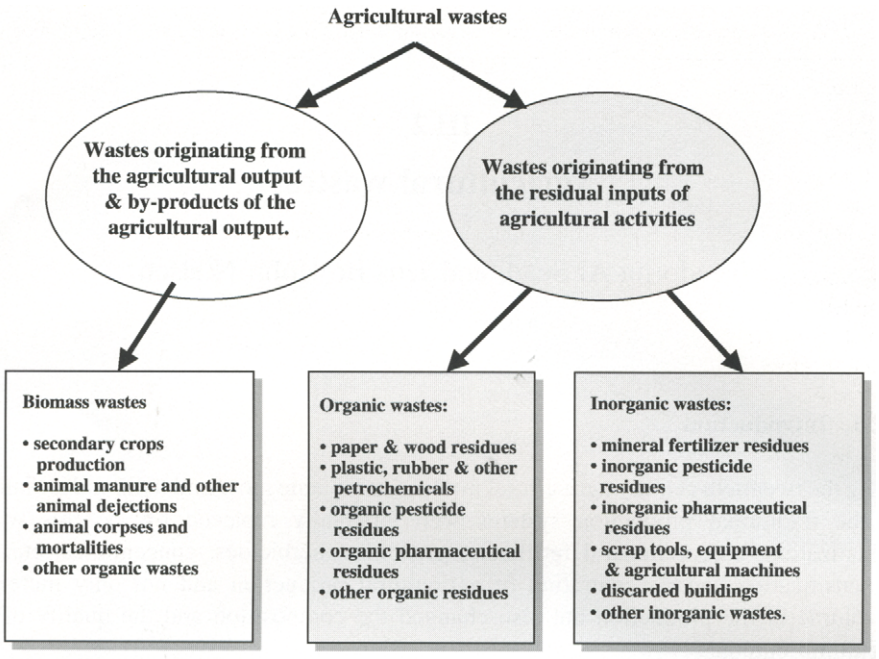

Figure III.2.1. Agricultural wastes.

water streams as a result of inappropriate and excessive land application, spillage, overflow, or deliberate dumping. The nutrients and the organic matter contained in manure can pollute the ground water by leaching or by runoff when manure is applied at rates that exceed crop fertilizer requirements. In such cases, arrangements should be made to move excess manure to other cropland, or to use it for other purposes (Bauder and Vogel, 1989–1990).

Agricultural practices can be an important source of groundwater pollution. The most frequently occurring groundwater contaminants are shown in Tables III.2.1 and III.2.2. Nitrates are one of the groundwater contaminants of concern in drinking water. High concentration in groundwater can cause methemaglobinaemia (blue baby syndrome). Sources of nitrates can be mineral fertilizers and animal manure that leach from grasslands and arable crops, liquids that percolate into the groundwater in areas with high concentration of animal manure, septic systems that are too close together or too close to the wells (Bauder and Vogel, 1989–1990).

Wastes of agricultural origin can be contaminated with crop and animal disease-causing organisms and chemicals, and with chemical and physical contaminants. Some of the main issues related to optimum utilization of agricultural wastes refer therefore to the control of chemical pollutants (organic and inorganic), breaking the chain of diseases transmission by inactivation of pathogens and other biological hazards and the removal of physical impurities. The quality control of these types of agricultural wastes, supported by regulations, is therefore essential in relation to their safe utilization and recycling for both the environment and human and animal health.

Table III.2.1. Sources of groundwater contamination (after Bauder and Vogel, 1989–1990).

Industrial operations
Mining
Drilling
Construction
Forestry
Disposal of industrial waste into landfills, pits, lagoons and deep injections wells
Agricultural
Pesticides
Mineral fertilizers
Animal manure
Soil erosion
Irrigation practices
Feed lots
Municipal
Landfills
Sewage treatment plants
Urban runoff
Underground storage tanks
Households
Improper disposal and use of cleaners, solvents, automobile products, septic tanks

Residual wastes originating from inputs of agricultural activities such as pesticides, fertilizers, or pharmaceutical residues are considered hazardous wastes, and their disposal and management must be done in accordance with the legal prescriptions.

III.2.3.1. Inorganic contaminants/heavy metals

The presence of heavy metals in agricultural wastes is of great concern due to their poisoning effect on humans and animals. Table III.2.3 shows an example of heavy metals content in animal manure.

The presence of heavy metals in manure and agricultural wastes occurs from natural and anthropogenic sources (metabolic wastes, corrosion of water pipes, consumer

Table III.2.2. Frequently occurring groundwater contaminants (after Bauder and Vogel, 1989–1990).

Organic hazards	Inorganic hazards	Microbial hazards
Pesticides (insecticides, herbicides, fungicides)	Heavy metals (Pb, Cu, Hg, Ba)	Coliform bacteria
Gasoline, petroleum derivatives and additives	Nitrate	Viruses
Chemicals in paints and solvents	Sulfate	
	Sodium	

Table III.2.3. Heavy metals in animal manure (after Danish Ministry of Agriculture and Fisheries, 1996).

Kind of manure	Number of samples	Dry matter (%)	Dry matter (mg/kg)				
			Pb	Cd	Ni	Cr	Co
Solid manure							
Cattle	9	19	0.50	0.07	1.04	0.42	0.13
Pigs	3	23	0.74	0.06	1.29	1.56	0.29
Poultry	5	44	0.96	0.37	5.46	1.82	0.23
Slurry							
Cattle	47	6.3	0.27	0.04	0.52	0.20	0.12
Pigs	31	3.8	0.13	0.02	0.55	0.41	0.05

products, etc.). Surface water can also be a source of contamination with heavy metals. Anthropogenic inputs of some metals in surface water systems may locally exceed natural inputs (Connell and Miller, 1984). Industrial effluents and waste sludge may substantially contribute to metal loading.

Excess metal levels in soils, surface and ground water may pose a health risk to humans and to the environment. 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 behavior and reproduction, etc. (Connell and Miller, 1984; Manahan, 2002). The presence of heavy metals in agricultural wastes used as fertilizer may transport dissolved heavy metals to agricultural fields. Although most heavy metals do not pose a threat to humans through crop consumption, some of them (e.g. cadmium) may be incorporated into plant tissue. Accumulation usually occurs in plant roots, but may also occur throughout the plant.

III.2.3.2. Persistent organic contaminants

Waste-derived products can contain persistent organic contaminants according to the origin of their base ingredients. Agricultural wastes can contain persistent organic contaminants such as pesticide residues, antibiotics, and other medicaments. Organic wastes from agro-industries and household wastes can contain aromatic, aliphatic, and halogenated hydrocarbons, organo-chlorine pesticides, polychlorinated biphenyls (PCBs), PAHs, etc.

The persistent organic compounds of xenobiotic origin represent a hazard to humans, flora, and fauna due to their toxicity and environmental adverse effect (e.g. ozone layer depletion). 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 (Al Seadi, 2001).

Numerous xenobiotic organic compounds are known to have estrogenic effect on vertebrates (xenoestrogens) or to be endocrine disruptors (Manahan, 2002). These compounds are considered to be responsible for decline in human male reproductive health and for a number of forms of cancer in humans (Danish Environmental Protection Agency, 1995). Chemicals reported to be estrogenic include, but are not limited to: organo-chlorine pesticides, PCBs, dioxins and furans, alkyl phenol polyethoxylates, phytoestrogens, etc. (Manahan, 2002).

In many countries there are regulations about the permitted limit values of persistent organic pollutants in different products, such as the Danish statutory order 49/20.01.2000-02-29 (Danish Ministry of Environment and Energy, 2000), similar regulations in the Netherlands, Germany and other countries, or the European Community Directives 80/778/EEC (EEC, 1980) and 98/83/EC (EC, 1998) concerning water quality for human consumption. Table III.2.4 presents an example from the Danish legislation concerning the limit values for persistent organic compounds in organic wastes utilized as fertilizers.

- *PAH: Polycyclic aromatic hydrocarbons.* Mainly found in smoke from incineration and the exhaust fumes from vehicles. They deposit on roofs and road surfaces, from where they are flushed into the sewage sludge systems by rainwater.
- *DEPH: Di(2-ethylhexyl)phthalate.* The compound is primarily used as a plastic softener, especially of PVC (e.g. for tarpaulins, toys, cars, and vinyl flooring). By washing, the substance ends up in the sewage system.
- *LAS: Linear alkylbenzene sulfonates.* Primarily used as surfactants in detergents and cleaning agents.
- *NP and NPE: Nonylphenol and nonylphenolethoxylates with 1–2 ethoxy 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.

The problem related to the control and management of the organic contaminants is that it is difficult to perform a screening of such a broad spectrum of contaminants at a reasonable cost. The most feasible way to deal with the problem refers to waste quality control.

The aerobic treatment/composting has a positive effect on reduction of the main persistent organic pollutants. The method is largely utilized today in composting systems

Table III.2.4. Example of limit values for persistent organic pollutants in Denmark from July 2000 (*Source*: Danish Ministry of Environment and Energy, 2000).

Persistent organic pollutant	Maximum limit values (mg/kg dry matter)
LAS	1300
PAHs	3
NPE	30[a]
DEPH	50

[a]The limit value for NPE is reduced to maximum 10 mg/kg dry matter from July 2002.

Table III.2.5. Animal by-products categories and conditions for anaerobic digestion treatment (after Sander Nielsen, 2003).

Category 1	Category 2	Category 3
All parts of animals that may contain TSE prions	Fallen stock, by-products not suitable for human consumption and all animal materials collected when treating wastewater from slaughterhouses	Parts of slaughtered animals and fish, suitable for human consumption
	Manure and digestive tract content	The same categories, unfit for human consumption, but posing no risk for animals and humans Food and catering waste
Must always be destructed by incineration	May be digested in biogas plants after pressure sterilization at 133°C for 20 min at 3 bar	May be digested in biogas plants after pasteurization at 70°C for 60 min
	Manure and digestive tract content may be digested without pre-treatment	Maximum particle size 12 mm

and in some cases in association with anaerobic digestion (AD), usually as a post-treatment step.

Recent studies proved that AD has a certain effect on reduction of these pollutants. The laboratory trials on the four main groups of organic contaminants (see Table III.2.5) show that a reduction of persistent organic contaminants occurs during anaerobic digestion. The reduction of LAS and NPE seems to be more effective than the reduction of DEHP and PAHs (Manahan, 2002). The issue still requires further research based on full-scale trials.

III.2.3.3. Pathogen contamination

Safe utilizations of animal manure and other agricultural wastes must not result in new routes of pathogen and disease transmission between animals, humans, and the environment. The main contaminants can be bacteria, viruses, intestinal parasites, and more recently TSE prions.

For many years it had been widely accepted and considered economically profitable to use animal by-products from slaughterhouses and fallen stock as feed. The acknowledgment that transmissible spongiform encephalopaties (TSE) may be spread by food and feed brought animal by-products to the attention of the European Commission. The attempts made over the years to guarantee food safety were this time concretized into an important decision to ban the use of animal by-products as feed. A comprehensive and strict veterinary regulation (EC) 1774/2002 came in force in May 2003 and is still in a state of continuing amendments. The Regulation 1774 categorizes animal by-products and defines obligatory processing methods and acceptable final use of the by-products, stipulating very detailed health rules concerning collection, processing, and final disposal

or use of animal by-products with the aim of preventing not only TSE but also other agents that may cause diseases in humans or animals.

According to the regulation 1774, animal by-products belong to three categories (Table III.2.5). Category 1 contains materials with the highest risk for public health, animals, or the environment and must always be disposed by incineration or in special cases buried in special landfills after pressure sterilization. Category 2 materials include animal by-products that do not fit into category 1 or category 3 as well as manure and digestive tract content. These materials may, e.g. be supplied for digestion in biogas plants after pre-treatment by pressure sterilization at 133°C at 3 bar for 20 min (manure and digestive tract content is exempted from pre-treatment). Finally, those animal by-products that would be fit for human consumption but, for commercial reasons, are not intended for human consumption, represent category 3 materials (Kirchmayr et al., 2003). Category 3 materials may be used in biogas plants after pasteurization at 70°C for 60 min. The use of category 3 materials for feed production is banned for the time being.

The EC Regulation 1774 will have a major impact on the future role of biological treatment processes for animal by-products and other wastes of biological origin (Braun and Kirchmayr, 2003).

Anaerobic digestion has a pathogen reduction effect due to the combination of temperature and retention time. The effect of anaerobic digestion on pathogen reduction in digested animal slurry compared to untreated animal slurry is shown in Table III.2.6. The most common pathogens are destroyed by thermophilic, at process temperatures around 53°C, during 1 h of guaranteed retention time.

A veterinary safe utilization of agricultural wastes implies some basic principles:

- *Livestock health control*: No utilization of animal manure and slurries from any livestock with health problems (zoonoses, transmissible spongiform encephalpathy (TSE), transmissible spongiform, etc);
- *Waste selection*: Hazardous waste types must be excluded from any utilization and canalized towards suitable, safe disposal methods (e.g. incineration);

Table III.2.6. Comparison between the decimation time (T-90) of some pathogenic bacteria through the biogas system and the untreated slurry system (after Al Seadi, 2001).

Bacteria	Anaerobic digestion		Untreated slurry system	
	Thermophilic (53°C) hours	Mesophilic (35°C) days	18–21°C weeks	6–15°C weeks
Salmonella typhimurium	0.7	2.4	2.0	5.9
Salmonella dublin	0.6	2.1	–	–
Escherichia coli	0.4	1.8	2.0	8.8
Staphilococcus 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-streptococi	–	7.1	5.7	21.4
Streptococcus faecalis	1.0	2.0	–	–

- *Pre-treatment*: Before utilization certain waste categories require controlled sanitation through thermal treatment (e.g. pasteurization at 70°C for 1 h, pressure sterilization, etc.);
- *Follow-up and regular control of pathogen reduction efficiency.*

III.2.3.4. Comments

The increased agricultural output, generated by the intensive, industrialized agriculture caused also an increasing of the amount of agricultural residues, wastes, and by-products. Valuable resources, when suitably managed and utilized, these wastes and by-products can be a threat to human and animal health and to food safety and create serious environmental pollution problems.

The mechanization of agriculture, the use of mineral fertilizers, pesticides, pharmaceuticals, etc. have simultaneously caused a change in the composition, the quality and the properties of the traditional wastes (e.g. animal manure) and has generated new kinds of wastes from the agricultural sector (pesticides residuals, pharmaceutical residuals, heavy metals, etc.).

Changing the perception of agricultural wastes from environmental problems to valuable resources is a matter of finding and implementing sustainable solutions for their safe collection, recovery, recycling, and utilization for agricultural, industry, or energy purposes.

References

Al Seadi, T., 2001. Good Practice in Quality Management of AD Residues from Biogas Production. Report made for International Energy Agency, Task 24 – Energy from Biological Conversion of Organic Waste, AEA Technology Environment, Oxfordshire, UK, p. 3.

Bauder, J.B., Vogel, M.P., 1989–1990. Groundwater Contaminants – Likely Sources and Hazardous Levels. Article No. 6 in a series of articles on Groundwater, 1989–1990 Series, in cooperation with Montana Farm Bureau, Montana State University, PUB 1, MO.

Birkmose, T., 1999. How is regulation protecting water quality in Denmark. In: KTBL – Kuratorium für Technik und Bauwesen in der Landwirtschaft e. V. (Ed.), Proceedings of the International Congress Regulation of Animal Production in Europe, Wiesbaden, Germany, 1999, pp. 154–158, Darmstadt, Germany.

Braun, R., Kirchmayr, R., 2003. Implementation Stages of Directive EC 1774/2002 on Animal By-products. Proceeding at the European Biogas Workshop "The future of Biogas in Europe II", SDU-Esbjerg, Denmark, pp. 30–43.

Connell, D.W., Miller, G.J., 1984. Chemistry and Ecotoxicology of Pollution, Wiley, New York.

Danish Environmental Protection Agency, 1995. Male reproductive health and environmental chemicals with estrogenic effects. In Environmental Project No. 290, Copenhagen, pp. 49–54.

Danish Ministry of Agriculture and Fisheries, 1996. Animal manure – a source of nutrients. In SP Report No. 11, Copenhagen, pp. 38–39.

Danish Ministry of Environment and Energy, 2000. Statutory Order No. 49 of January 20, 2000 on Application of Waste Products for Agricultural Purposes, Copenhagen.

EC: Council Directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption.

EEC: Council Directive 80/778/EEC of 15 July 1980 relating to the quality of water intended for human consumption.

Kirchmayr, R., Scherzer, R., Baggesen, D., Braun, R., Wellinger, A. 2003. Animal by-products and anaerobic digestion. International Energy Agency, Task 37-Energy from biogas and landfill gas. September 2003.

Manahan, S.E., 2002. Toxicological Chemistry and Biochemistry, 3rd edn, Lewis Publishers, Boca Raton, FL, p. 504.

Mogensens, S., Angelidaki, R., Ahring, B., 1999. Biogasanlæg nedbryder de miljøfremmede stoffer. Dansk BioEnergi, BioPress, pp. 6–7.

Sander Nielsen, B., 2003. The new EU regulation on animal by-products not intended for human consumption – purpose and implementation in Denmark. Proceeding at the European Biogas Workshop "The future of Biogas in Europe II", SDU-Esbjerg, Denmark, pp. 20–23.

Wadman, W.P., Sluijsmans, C.M.J., de la Lande Cremer, L.C.N., 1987. Value of animal manure: changes in perception. Animal Manure on Grassland and Fodder Crops. Fertilizer or Waste? International Symposium, Martinus Nijhoff Publishers, The Netherlands, pp. 2–13.