Ecosystem Health and Sustainable Agriculture

Sustainable Agriculture

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Recycling of Nutrients

Sewage Sludge Management in Relation to EU-requirements

Summary

When Latvia implemented the EU directive on sewage sludge (Directive 86/278/EEC) it was done in a very complicated way. In practice, it meant that several permits were needed for sludge use in agriculture and for forest plantation purposes. Apart from being a costly process, it was very bureaucratic, time-consuming and an obstacle for sludge use. This was obvious to wastewater treatment plant operators, farmers, administrators and others. When planning for this project (year 2002) a revision of the EU sludge directive was under way, although the timetable was unclear. Drafts were available making it possible to see which directions the proposed new sludge directive would take. Apart from tightening limit values, the hygiene question would most probably be regulated in one way or the other in a new directive. The project ‘Sewage sludge management in Latvia in relation to EU-requirements’ was performed between the years 2004 and 2005. The project has given the following outputs:

• Suggestion for revised Latvian legislation on the use of sludge. A number of discussions took place with the Environmental Ministry to improve and simplify the legislation in order to promote the use of sludge. Suggestions for changes were made and a completely new regulation for sludge was elaborated and enforced in 2006.

• National recommendations for different treatments and outlets for sludge suitable for Latvia. Fourteen information leaflets were produced and distributed on recommendations related to different sludge outlets and treatment methods.

• Overview of sludge hygienisation methods for different sizes of wastewater treatment plants – technically and economically. The knowledge about hygiene questions related to sewage sludge management was weak in Latvia. A baseline study of prevalence of microorganisms in sludge was performed with a total of 40 samples analysed (untreated, digested, composted and long-term stored sludge). The results from the study are in line with similar studies in other countries: mesophilic digestion is not enough for proper hygienisation; long-term storage is difficult to control, thus long-term stored sludge has to be managed and used with caution; composting can be an efficient treatment method if managed properly.
• **Knowledge among key-actors in Latvia about sludge management.** Eleven demonstrations and seminars were held all over the country. Establishment of practical demonstrations allowed sludge management processes to be experienced under Latvian conditions. This clearly showed opportunities and possible drawbacks with different methods, which are described in the recommendation and outlet leaflets.

• **A Latvian internet website, devoted to sludge production issues and utilisation possibilities.** The target of the website was to propose technical solutions and suitable information for sludge.

**Background and Use of Sewage Sludge in Latvia**

There are more than 1,000 biological wastewater treatment plants in Latvia producing wastewater sludge. Accounting for the amount of produced wastewater sludge started in late 1990s, as part of the water consumption and wastewater treatment report. Starting from 2001, the Latvian environment agency started to enter these data into a separate database about sludge. Since there is no specific method for accounting for the amount of sludge, each analyst decides on the method independently and hence the results are very different and could quite often be questioned. Only some of the wastewater treatment plants of the municipal sector are reporting about sludge management; on average only about 30% of treatment plants. The largest producer of sludge is Riga city, which produces about 30% of all sludge in Latvia. Riga is also the only place in Latvia where the amount of sludge is weighed and hence not calculated.

Information published by the Latvian Environmental Agency shows that in 2003, about 223 million m$^3$ of wastewater were produced in Latvia, including 136 million m$^3$ that were treated in wastewater treatment plants. In total, 1,421 sewage treatment plants operated in Latvia at that time, including 964 biological treatment plants. On average for 2003, treatment of 1 m$^3$ of wastewater in a treatment plant produced about 100-120 g of dry sludge. Calculated per person equivalent (p.e.) this means about 80 g of dry sludge per day, which is about the same as in Sweden.

In 2004 the production of sewage sludge increased to 36,000 tonnes (d.m.) from 29,000 tonnes d.m. in 2003, including 5,800 tons of digested sludge from Riga. About 12,000 tonnes (d.m.) of the sewage sludge produced in 2004 were utilised in agriculture, as compost material or in other ways. About 11,000 tonnes (d.m.) were stored in temporary storage. The production and utilisation of sludge during recent years are shown in Figure 20.1.

Most of the sludge is produced in treatment plants producing between 1,000 and 5,000 tonnes per year (Table 20.1). In second place are plants producing between 5,000 and 10,000 tonnes per year. Smaller treatment plants also have the most serious problems with sludge management. Very few investments in sludge treatment and utilisation have been made. Some of these treatment plants do not even have temporary storage facilities for sludge, in spite of this being required by legislation.

There are differences in sludge properties between different wastewater treatment facilities. For example, smaller facilities with a treatment capacity of about 2,500 p.e. and an annual sludge production of about 100 tons d.m. (296 facilities reported in 2004) produce about 4% of the total amount of sludge (Table 20.1). This sludge usually has a low dry matter content, is not treated and is non-polluted. The second group of treatment plants (up to 25,000 p.e. and annual sludge production between 100-1,000 tonnes d.m.) represents centres of districts. The sludge from these
Table 20.1. Production of sludge (size classes) in Latvia, 2004.

<table>
<thead>
<tr>
<th>Sludge production capacity</th>
<th>Number of plants</th>
<th>Total amount of sludge produced, tonne d.m.</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 100 tonnes per year</td>
<td>299</td>
<td>2,625</td>
</tr>
<tr>
<td>100 - 1,000 tonnes per year</td>
<td>26</td>
<td>10,030</td>
</tr>
<tr>
<td>1,000 - 5,000 tonnes per year</td>
<td>6</td>
<td>12,532</td>
</tr>
<tr>
<td>5,000 - 10,000 tonnes per year</td>
<td>2</td>
<td>10,977</td>
</tr>
<tr>
<td>Total</td>
<td>333</td>
<td>36,164</td>
</tr>
</tbody>
</table>

Plants is often not treated and could be dewatered or a liquid sludge with low concentrations of pollutants.

There were only 8 wastewater treatment plants producing more than 1,000 tons d.m. of sludge in 2004 (accounting for about 2/3 of the sludge produced in Latvia). The sludge from this group of treatment plants is usually dewatered, using filter presses or centrifuges (Riga city). These treatment plants also treat industrial wastewater, thus the sludge can have higher amounts of heavy metals and other pollutants compared with other sludges in Latvia. The most common sludge treatment method for this group of plants is long-term storage.

Two outlets of sludge are commonly used in Latvia – agriculture and composting with further utilisation in agriculture or for greening (Figure 20.2). About 22% of the sludge was utilised in agriculture and about 9% was composted, as an average for the period between 2001-2004. About 6% of the sludge was utilised in other ways (i.e. in forestry, land reclamation, greening). Data collected in the Environmental Agency show a slight increase in agricultural use of sludge. Most of the sewage sludge in Latvia (63% from the period 2001-2004) is stored at temporary storage sites, usually close to the treatment plants. Each year the amount of stored sludge increases by 10,000-20,000 tonnes (d.m.), corresponding to about 60,000-120,000 m³ sludge (wet volume). According to Latvian legislation, storage of sludge can continue without any time limit. Thus, there is no incentive for treatment plants to change the situation if they have enough storage capacity.

The information about sludge production and utilisation is not correct from all treatment plants, as essential equipment for measurement is lacking. Sludge has a high concentration of plant nutrients (nitrogen, phosphorus, calcium, microelements and organic substances) and the interest in returning these nutrients to biological cycles and thus replacing mineral fertilisers is increasing in Latvia.

The Latvian sludge outlet (Figure 20.2) can be compared with the Swedish (Figure 20.3). The major difference between sludge management in Latvia and Sweden is that storage of sludge is less common in Sweden than in Latvia. Another difference is that sludge use for soil production and for coverage of landfills is an increasing outlet in Sweden and still very small in Latvia (compost will probably be used for these purposes in Latvia).

Recommendations for Different Sludge Outlets and Treatment Methods, Including Economical and Organisational Aspects
The recommendations relating to different sludge outlets and treatment methods are found in the information leaflets produced within the project. However, the leaflets are in Latvian.

There have been several studies in the EU about sludge management practices in so-called ‘new’ and ‘old’ European countries, including cost estimation and feasibility studies. Within the scope of the project these results were summarised to give some advice about the theoretical costs of sludge management and practically implementable technologies, taking into account Latvian conditions. The EU report ‘Disposal and recycling routes for sewage sludge, Part 4 - Economic report’ (2002) was used as the main information source for the calculations.
At the end of this section, a comparison is also made with estimations for Swedish conditions (from the VA-Forsk report ‘Regional or Local Sludge Handling in Thirteen Municipalities in South Western Sweden – Technologies, Environmental Impact and Costs 2005’ – in Swedish).

Costs of different methods of sludge treatment and utilisation consist of direct and indirect outcomes and incomes. Costs of sludge management consist of investments and maintenance costs. Maintenance costs consists of salaries, different resources, other applicable costs of different stages of technology, transportation, spreading, depositing and other costs.

The average costs of different wastewater treatment and utilisation in ‘old’ European countries are shown in Table 20.2. The average cost for utilisation of non-treated sludge is 160-210 EUR/tonnes d.m. Utilisation of dewatered sludge in agriculture or forestry, incineration with household waste or reclamation of degraded areas costs about 210-300 EUR/tonnes d.m., but utilisation of composted sludge for the same purposes, including composting, costs about 300-330 EUR/tonne d.m. This calculation does not include potential incomes. The depreciation period for the investment part is assumed to be 10 years.

Sludge management costs vary significantly among different counties, with the difference between minimum and maximum being at least 25%, but landfilling costs differ by up to 80%. When ‘new’ countries are taken into account the variation will increase further. For instance, in Latvia it is very common for wastewater treatment companies to not include sludge management in their cost calculations. This means that these companies are not assumed to spend money on sludge treatment and utilisation.

During recent years composting technologies and production of different soil materials have been growing very rapidly in European countries. The common trend is for landfilling and agricultural use of sludge to radically decrease, and for production of soil material to increase by the same level. Compost is sold both as a commercial product (sometimes also mixed with other materials to make a soil product) or is freely distributed to farmers or landfills as soil amendment and covering material. Usually all costs for production of the compost and mixing with other material to a soil product are covered by the wastewater treatment plant.

One of the most significant sludge management costs is transportation, which in most cases comprises at least 30% of total sludge management costs. It is therefore very important to reduce transportation distances in all management steps, but especially in early steps where sludge contains a lot of water.

The estimated costs in Sweden (Table 20.3) are generally lower than the costs for other European countries given in the EU report. The reasons for this are not clear. However, a feasibility study for a given treatment plant has to be carried out when deciding possible outlets or treatments. Such a study will give more correct figures and will also take into account the actual conditions for a plant, including transport distance, energy price, labour costs, etc.
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Table 20.2. Costs of different treatment and utilisation methods.

<table>
<thead>
<tr>
<th>Outlet</th>
<th>Costs, EUR/tonnes d.m.</th>
<th>Remarks and descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw sludge in agriculture</td>
<td>160</td>
<td>It is forbidden to use raw sludge in agriculture in Latvia</td>
</tr>
<tr>
<td>Partly dewatered sludge to agriculture, (15-25% of d.m.)</td>
<td>160</td>
<td>This is the most common way of sludge utilisation</td>
</tr>
<tr>
<td>Dry sludge to agriculture</td>
<td>210</td>
<td>No drying equipment available in Latvia</td>
</tr>
<tr>
<td>Forestry</td>
<td>240</td>
<td>Utilisation of raw or partly dewatered sludge in forest cultivation</td>
</tr>
<tr>
<td>Composting</td>
<td>310</td>
<td>Composting with further utilisation of compost in agriculture and for greening</td>
</tr>
<tr>
<td>Incineration</td>
<td>315</td>
<td>Sludge drying and incineration</td>
</tr>
<tr>
<td>Combined incineration</td>
<td>250</td>
<td>Incineration of dewatered or dry sludge with organic waste or biomass fuel, for instance, using fluidised bed technology</td>
</tr>
<tr>
<td>Gasification</td>
<td>-</td>
<td>This method is not commonly used, so it’s hard to predict costs when it comes conventional. Now it seems that costs of gasification can be at the same level as for incineration</td>
</tr>
<tr>
<td>Glasification or incineration at very high temperature</td>
<td>-</td>
<td>This method is not used in EC-countries and is applicable for polluted sludge, where there is a high risk of heavy metal leaching</td>
</tr>
<tr>
<td>Wet oxidation</td>
<td>-</td>
<td>This is an experimental method not used in conventional practice and it causes several other problems, for instance utilisation of nitrogen-rich by-products from the treatment process</td>
</tr>
<tr>
<td>Reclamation of landfills and degraded areas</td>
<td>255</td>
<td>Utilisation of sludge for landfill covers is becoming more and more common in European countries. It is recommended to use composted sludge, thus costs for composting should be added</td>
</tr>
<tr>
<td>Landfill</td>
<td>255</td>
<td>Landfill of sludge is decreasing due to restrictions on landfilling of organic waste in EC. It is also restricted in Latvia</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Outlet</th>
<th>Cost, EUR/d.m.</th>
<th>Remarks and descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>100</td>
<td>Very dependent on transport distance</td>
</tr>
<tr>
<td>Landfill</td>
<td>215</td>
<td>Tax not included</td>
</tr>
<tr>
<td>Soil production</td>
<td>200</td>
<td>Sludge mixed with sand and other structural materials</td>
</tr>
<tr>
<td>Drying and incineration</td>
<td>240</td>
<td>Small unit for 1,000 d.m. sludge/year</td>
</tr>
</tbody>
</table>

Utilisation of sludge and compost in agriculture, energy crops and for greening replaces mineral fertilisers, which is especially important in case of phosphorus, as this is a limited resource.

**Sludge Management Feasibility Study in a Latvian City**

Within the scope of the project a separate feasibility study was carried out for reconstruction of a wastewater treatment plant and the sludge treatment system in one of the Latvian district centres, Valka city.

The sewerage system in the city has 4,000 customers in the household sector. Water production is 333,000 m³ per year. Electricity consumption for water production and distribution is 0.24 MWh/year (0.71 kWh/m³). The sewerage system manages 447,000 m³ of wastewater per year, including about 200,000 m³ of stormwater. Electricity consumption is 1.17 MWh/year (2.61 kWh/m³), including the wastewater treatment plant (0.5 MWh/year). Wastewater sludge comes from: primary settlers (10-20 tonnes/year) and secondary settlers (70-100 tonnes/year).

A nearby district heating facility produces about 170-200 tons of wood ash per year, which could be used together with the sludge. Sludge from primary settlers is landfilled, but sludge from secondary settlers is dewa-
tered in filtration fields and then composted together with organic wastes from parks and gardens.

Sewage sludge properties:
- After treatment in filtration beds:
  - dry matter: 10-15%,
  - organic substances: 57%,
  - N: 3%,
  - P – 0.8%,
  - heavy metals (mg/kg): Cd 1.36; Cr 27; Cu 144; Hg 3.5; Ni 13; Pb 57; Zn 1 090.
- After composting:
  - concentration of heavy metals increases by 10-40%,
  - N decreases, P increases.

Sludge confirmed to quality class II by Latvian legislation.

Annual production costs and tariff in sewerage sector in 2004:
- electricity Ls 23,325,
- salaries Ls 19,489,
- other costs Ls 17,488,
- sewerage tariff to households Ls 0.30 per 1 m³.

It is planned to reconstruct the existing wastewater treatment plant by installing new grids, sand catcher, new aeration tank with anaerobic, anox, aerobic zones (Celpox technology, developed in Sweden) and secondary settlers. Biological N and P removal will occur. A separate pumping station will be installed to pump filtrate from filtration beds to the wastewater treatment plant. Sludge treatment will start with thickening in a settling tank and dewatering in a centrifuge.

Reconstruction costs:
- pre-treatment plant Ls 70,000,
- biological treatment step Ls 250,000,
- pump stationing and pipeline Ls 20,000,
- dewatering equipment Ls 220,000.

Three methods are proposed for sludge treatment and utilisation (Table 20.4):
- raw sludge with reed beds or filtration beds – no need for dewatering, small energy consumption, insignificant maintenance costs,
- dewatering and treatment with lime – larger dry mass outcome, hygienic effect, simple technology,
- dewatering and composting – sanitising effect, wider utilisation possibilities, simple technology.

Proposal for utilisation of treated sludge:
- agriculture – stable market, simple agricultural machinery,
- gardening (city parks) – small transportation distance, smaller costs for soil material for greening,
- plantation of forests and willow plantations – smaller hygienic risks,
- reclamation of landfills – stable market in near future, less quality requirements and control.

Cost comparison of different treatment methods and outlets:
- agriculture – Ls 100-120 /tonnes,
- gardening – Ls 150-180 /tonnes,
- plantation of forests and willow plantations – Ls 80-100 /tonnes,
- reclamation of landfills – Ls 150-170 /tonnes.

It was decided that composting could be the best alternative to treat sludge, despite reed beds seeming to be more feasible. Reed bed technology is not approved in Latvia and it is hard to predict whether this method would be considered sufficient and approved by funding sources financing reconstruction of wastewater treatment plants.

Further calculations were made for the compost utilisation.

Total sludge management costs:
- Utilisation of composted sludge in:
  - agriculture – Ls 280-300 /tonnes,
  - gardening – Ls 320-350 /tonnes,
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- plantation of forests and willow plantations – Ls 250-290 /tonnes,
- reclamation of landfills – Ls 320-350 /tonnes.

Average sludge treatment and utilisation costs will reach about Ls 25,000 per year and per 2,000 p.e. Reconstruction of the wastewater treatment plant and introduction of sludge treatment will also influence production costs according to Table 20.5.

Most of the additional costs for sludge management come from the dewatering system and not from the composting part of the reconstruction.

It is recommended to compost dewatered sludge directly after dewatering. The amount of compostable material was calculated to about 400 m$^3$ of sludge + 300 m$^3$ of wood ash and incineration residues + 300 m$^3$ of sawdust = 1,000 m$^3$ per year. The predicted amount of compost is 400-600 m$^3$ per year (200-300 tonnes). Potential income from selling compost or replacing it with peat and soil substrates in city parks and gardens is about Ls 1,200-1,800 per year. An additional cost reduction (Ls 800-1,000 per year) comes from ash management, since the ash no longer has to be landfilled.

**Overview of Suitable Sludge Hygienisation Methods and a Hygienic Investigation of Sludge**

Use of sewage sludge in agriculture or on other land may be a resource-efficient method for returning plant nutrients to soils. It is important that it is not seen as a way to get rid of sludge, but rather used in a careful way, applying to guidelines for contaminants and according to ‘best practice’. Regarding pathogens, the view should be to break the possible chain of environmental transmission and not to introduce new routes for disease transmission in the society. Since pathogens will be present in wastewater, they will also occur in the sludge, often in higher concentrations since they may be particle-bound and accumulate in the sludge. In Latvia the only pathogen that has been analysed for, and found, in sludge is *Salmonella*, but other pathogens have been detected in e.g. Swedish studies. For further information on the presence of pathogens, statistics on enteric infections in Latvia could be scrutinised.

Evaluating whether there is a risk regarding sludge use has proven difficult. The NRC (National Research Council, USA, 2002) evaluated 23 studies of exposure to wastewater and sludge and concluded that there is no evidence to say that there is a risk, but on the other hand, there is no evidence to say that there is not a risk. The NRC suggested that further epidemiological studies and sophisticated risk assessments are necessary. How risks related to sludge are conceived is often discussed in a subjective manner, but in recent years hygiene risks have been acknowledged within Europe, including Sweden, and proposals for stricter regulations have been put forward within the EU and in Sweden. These proposals include demands on treatment in combination with restrictions on use and quality controls to various extents.

Treatment before use is considered the most efficient barrier towards disease transmission. By applying different treatment methods it is possible to inactivate (kill) the majority of pathogens present. These treatments need to be defined according to available experience on their efficiency, but the need for further evaluations has also been acknowledged and research is ongoing. Only relying on microbial analysis in order to state whether a treatment is acceptably efficient is not sufficient, since with current knowledge it is still uncertain how different indicators that are more easily analysed correspond to the behaviour of true pathogens. In most circumstances it is not possible to analyse for a range of relevant pathogens to get a proper picture of the quality of the sludge. Along with microbial analyses, there are always crucial parts regarding sampling procedures and choice of methods, and these are issues that need to be dealt with in Latvia as well, if regulations including quality control are to be introduced. In the drafts from the EU for a new sludge regulation, the organisms to analyse for and the severity of the reductions and limits required have been debated. In the Swedish proposal for new regulations some quality parameters are included, mainly to indicate possible regrowth, whereas requirements for reductions are not included. A demand on absence of *Salmonella* has been

<table>
<thead>
<tr>
<th>Sludge Management</th>
<th>Today</th>
<th>After reconstruction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without sludge management</td>
<td>Ls 69,000</td>
<td>Ls 77,000 (0.45/m$^3$)</td>
</tr>
<tr>
<td>With sludge management</td>
<td>Ls 86,000</td>
<td>Ls 86,000 (0.51/m$^3$)</td>
</tr>
</tbody>
</table>
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included since it is a zoonotic disease and considered to be of great health significance.

In the evaluation of Latvian biological treatment plants (BTPs) for sludge, efforts have been devoted to analysing indicator bacteria. As mentioned, how the results relate to inactivation of actual pathogens, especially those from other groups of microorganisms, e.g. viruses and protozoa, is still unclear. According to published literature it is difficult to find correlations between indicator bacteria and pathogens.

Even if uncertainties are connected to the indicator bacteria in how they represent pathogens, they are not considered to belong to the most persistent organisms. Therefore a significant reduction is expected in sludge treatment. The results from sludge sampling and analysis during this project in Latvia indicate that mesophilic treatment is not efficient, in accordance with other studies. Storage may be the only viable treatment before a plant has the possibility to invest in more a efficient treatment process, and a 12-month period is one of the methods included in both Latvian and Swedish (proposed) regulations. Even if inactivation occurs over time, it is important to remember that storage is an uncertain process, with the outcome being dependent on climate and season, which have little possibility of being controlled. This sludge should therefore be handled with care, and perhaps be subjected to further restrictions than sludge treated by other processes. Composting can be an efficient treatment, mainly due to the achievement of high temperatures, but it needs to be well managed. Results from the present study were variable and similar results have been seen in e.g. Nordic studies of composting of organic waste, where numbers of indicator bacteria increased during subsequent handling of the product.

Comparisons to suggested guideline values are at this stage not so relevant, but can of course be made. The reduction during 12 months of storage corresponded to demands for conventional treatment, but increasing numbers were also reported. Composting could have resulted in >2 log_{10}-reduction but since starting concentrations are not specifically available, it is not possible to define actual reductions. The guideline value for *E. coli* of 500-1,000 cfu/g DM was reached for some of the storage and composting processes (1/3, respectively), but not after mesophilic digestion. Clostridia are considered too persistent to be valuable as an indicator, and these results should therefore not be in focus. *Salmonella* was not detected in 50 g of sludge after storage, which is in compliance with proposed legislation.

Introduction of various treatment methods defined during the project is considered valuable in order to decrease the risks of disease transmission. Whether these treatments are to be divided into different classes depending on their efficiency and the possibility to control the material could be further discussed. As well as having proper parameters to monitor (e.g. temperature), it is necessary to oversee the full management of the treatment plants. For example, it was mentioned (during seminars in Latvia) that the same transport vehicle was used for untreated sludge and treated sludge, which could then be reinfected. Storage of sludge as a treatment method and after another treatment process should also be conducted as safe as possible so that exposure to humans and animals is limited. With different classes it is possible for the treatment plants to adapt to their own specific conditions.

With careful management of sludge, acceptance for sludge use could hopefully be obtained from all parties involved in Latvia. The views on sludge use differ between European countries, depending e.g. on how risks are perceived and the availability of other fertiliser products. In Sweden, the debate has in periods been intense, and due to ‘unknown risks’ and the food industry’s concerns regarding consumer acceptance, other types of use than in agriculture are common, e.g. in land construction and for covering landfills. However, any application of sludge in the environment could lead to spread of pathogens. Partly removing the route of transmission to edible crops by not allowing sludge on vegetables (within a 10-month period), as now decided in Latvia, is considered a proper barrier and risk management measure.

**Conclusions from the Project**

In Latvia the need for careful management of sludge has been acknowledged and regulations that aim at reducing the risks of disease transmission are being adopted. A zero risk is not possible to achieve but the combination of
rules for defined treatments and restrictions for use will together function as barriers and reduce the risks to what can be considered an acceptable level.

Three different biological treatment processes, partly differing from the new legislation, were evaluated regarding the reduction of indicator bacteria and *Salmonella*. Specific conclusions from these analyses and general statements based also on existing knowledge include:

- The quality indicators *E. coli* and Enterococci should be re-evaluated since it is unclear how well they represent pathogens.
- These indicator bacteria should not be used as the only means of controlling a sludge treatment process.
- Clostridia may not be a suitable indicator for determining sludge quality since the clostridia spores that are analysed are very persistent, and a reduction during treatment cannot always be expected.
- *Salmonella* was present occasionally both before and after treatment, as previously recorded in other studies.
- Aiming at absence of *Salmonella* is relevant, since it has implications for risks both to animals and humans and to the management of the treatment plant.
- Mesophilic digestion only reduces microorganisms slightly and is not considered a treatment that gives a safe fertiliser product.
- Mesophilic digestion is preferably used in combination with a treatment process that is specifically aimed at reducing pathogens.
- Storage of sludge gives varying results in reduction of indicator organisms and pathogens.
- Storage of sludge is a treatment method that is not possible to control and sludge that has only been treated by means of storage needs to be handled and used with caution.
- To further reduce hygiene risks from sludge, more efficient treatment methods than mesophilic digestion and long-term storage need to be applied.
- Composting can be an efficient treatment method but it is important to manage the process and ensure that basically all material is subjected to thermophilic temperatures.
- The Latvian regulations for sludge need to be further evaluated, not only in relation to process parameters but also to the overall management of the treatment plants.
- To evaluate the efficiency of various treatment methods, it would be valuable also to include groups of microorganisms other than bacteria.
- The introduction of improved treatment of sludge will be costly, but other benefits such as more use of sludge/higher acceptance and further reduction of organic contaminants may be achieved.
References


Chapter 18


Chapter 19


NTP 17-99. The norms of technological projects of the systems for manure removal and preparation to utilization.


Chapter 20


Chapter 21

