Farm Standards for Manure Storages

Farm Standards are recommendations for design and construction of agricultural buildings based on EU requirements, findings from research and farming experience. Farm standards are developed on housing systems for cattle, pigs, poultry, sheep and horses and storage facilities for feed and manure.
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When referring to the handbook the following literature reference must be stated:
Preface

This handbook gives an extensive presentation of recommendations for dimensioning, construction and operation of storage facilities for livestock manure. In the handbook the newest findings from international recommendations are combined with legal requirements as well as experience from practical farming. All presented recommendations will therefore fulfil the EU requirements on hygiene and environmental issues.

EU and the Polish Ministry of Agriculture and Rural Development within a Phare Twinning Project Farm Standards have funded elaboration of the handbook. The elaboration has taken place in close co-operation between Polish Experts from Institute of Building, Mechanisation and Electrification, (IBMER) and Danish Experts from The Danish Agricultural Advisory Service, National Centre, (DAAS).

Many experts have contributed to the elaboration and finalising of this book: Polish and Danish experts, editors, administrative staff, interpreters and translators. It is not possible to mention all the names, but without their help the preparation of this publication would be impossible. However, special thanks go to Joanna Krahelska, who translated all materials. Her input significantly helped with the elaboration of this publication.

The materials were elaborated during 2003 and finalised by the end of the year. We realise that over the years to come, both Polish and EU legislation is bound to grow and change. Hence the user of the handbook has to be aware of later changes in the legislation. Due to climate differences inside Poland, requirements as to the construction of the storage facilities vary between different regions. The handbook can therefore be used as an inspiration and guide in the planning phase. Farmers planning individual constructions have to consult the relevant advisers and experts in order to check that the regional requirements are fulfilled.

The objective of the Farm Standards project is to elaborate recommendations for housing systems for cattle, pigs, poultry, sheep and horses as well as storage facilities for fodder and manure. The proposed recommendations fulfil all EU requirements and also make it possible for the farmers to run an efficient and profitable production. The other materials developed within the project will be published during the spring of 2004.

Questions to the handbook and suggestions of improvement for the next edition can be directed at the authors.

The handbook may be quoted with indication of sources.

June 2004

Henry Joergensen
Pre Accession Adviser
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1. **General Introduction**

The purpose of this handbook is to provide advisors dealing with design of manure storage facilities as well as applications for permits with an overview of relevant subjects in the process of designing, constructing and the daily use and maintenance of the facilities.

The handbook has been written by a working group consisting of both Polish and Danish Experts within research, education and advisory service.

EU legislation, international research and experiences are the basis for the contents of the handbook.

The handbook can be used by different persons for different purposes. Some examples are given in the following.

Equipment and technical aid developers within livestock production can find information on basic requirements for individual functions. Moreover, they can find professionally supported arguments in a future marketing of new solution methods within the field.

Politicians and interest group may use the handbook as reference in dealing with environmental protection issues at national and international levels.

Advisers can use the handbook in the process of planning as a work of reference to inspire and document in connection with elaboration of decision bases for livestock producers who consider and plan for new storage facilities for livestock production.

Livestock producers can clarify and support their requirements and on the basis of this control the function in established as well as planned production systems (functional study in connection with quality management).

Lecturers and students may use the handbook as reference in connection with lectures at schools as well as universities in general.

For a good understanding of the terms used in this handbook, please consult the following definitions:

Animal excrements – all excrements excreted by farm animals, or a mixture of litter/bedding materials with excrements excreted by the animals, also in a processed form (Council Directive 91/676/EEC of 12 December 1991);

Manure (natural fertilisers) – animal excrements: farmyard manure, urine/liquid manure, and slurry designed for agricultural use (Journal of Laws No. 89, item 991. Law of 26 July 2000 on fertilising and fertilisers);

Farmyard manure – solid and liquid animal excrements mixed with litter/bedding materials (as e.g. straw) and used as an organic fertiliser (Technika w chowie zwierzat. Terminologia. IBMER, Warsaw 1979);
Urine/liquid manure – effluents from animal housing where the animals are kept on litter, used as an organic fertiliser (see above);

Slurry – a mixture of animal excrements, feed rests and technical water from animal housing leaks from the water supply system included (see above);

Dung hill – an outdoor structure related to a specific animal housing in terms of technology and function, and designed for storage of farm manure. The dung hill includes: a concrete dung storage area sloping towards a collecting pit, and a liquid manure tank for gravitational draining of the liquid parts of dung through the collecting pit (see above).

It has to be stressed that animal excrements are not agricultural waste; instead, they are valuable natural fertilisers used not only to fertilise plants but also to shape the structure of the soil. However, their improper use may result in contamination of the ground water with nitrates, and of the air through ammonia emission.

**Structure and contents of the handbook**

The handbook comprises 8 chapters. Each chapter includes descriptions and recommendations on storage facilities for solid and liquid manure as well as treatment plants for livestock manure. The recommendations cover conditions of direct relevance to the dimensioning and construction of storage facilities of directly applicable value.

The first chapter is a general introduction to the handbook. Chapter two describes the relevant EU directives concerning environmental protection. Chapter three describes how the capacities of storage facilities are calculated. Chapter four describes the design, construction and operation of storage facilities for solid manure. Chapter five describes the design, construction and operation of storage facilities for liquid manure, e.g. urine and slurry. Chapter six describes the technical equipment used for transportation of the manure from the livestock buildings.

Chapter seven describes treatment plants for livestock manure, including biogas plants and composting plants. The final chapter eight consists of examples on the construction of storage facilities for livestock manure, both solid and liquid.
2. Rules and regulations

This chapter describes the rules and regulations concerning environmental protection, location of storage facilities for manure, and safety requirements.

2.1. Environmental protection

EU legislation


Council Directive 91/676/EEC of 12 December 1991 provides that member states should establish a code or codes of good agricultural practice, to be implemented by farmers on voluntary basis. The codes of good agricultural practice should contain provisions covering, among different subjects, the storage of livestock manure and application of fertilisers on farmland, including in particular:

- A requirement as to the adequate capacity and construction of storage facilities for animal excrements, and as to actions aimed at prevention of water pollution through drainage and leakage of liquids containing animal excrements and effluents from stored plant materials, as e.g. roughage;

- A requirement as to the capacity of storage facilities for animal excrements, which should be bigger than the capacity required for the longest storage period when field application of the stored material is prohibited in danger zones. The exception is a situation when it can be demonstrated to the competent authority that all animal excrements in excess of the actual storage capacity will be removed in a manner involving no harm to the environment.


- 40,000 places for poultry
- 2,000 places for finishers (over 30 kg), or
- 750 places for sows
**Best Available Techniques**
Council Directive 96/61/EEC of 24 September 1996 concerning integrated pollution prevention and control does not point out any specific techniques or technologies to prevent or reduce emissions. On the other hand, the directive requires that all appropriate preventive measures should be taken against pollution, in particular through application of the Best Available Techniques (BAT). The Best Available Techniques should be used for housing systems, storages for manure, on-farm manure processing, and application of manure on arable land.

In general, BAT on manure storages are as follows:

- To design storage facilities for pig manure with sufficient capacity until further processing or land application can be carried out. The required capacity depends on the climate and the periods in which application to land is not possible.

- To install a concrete floor, with a collection system and a tank for run-off liquid, in storages for solid manure that are located at the same place on a permanent basis.

- To locate any newly built manure storage areas where they are least likely to cause annoyance to sensitive neighbours, taking into account the distance to the neighbours and the prevailing wind direction.

BAT on the storage of slurry in a concrete or steel tank comprise all of the following:

- A stable tank able to withstand likely mechanical, thermal and chemical impact.
- The base and walls of the tank impermeable and protected against corrosion.
- The storage emptied regularly for inspection and maintenance operations.
- Double valves on any valved outlet from the storage facility.

A slurry lagoon is as viable as the slurry tank if it has an impermeable base and walls combined with a leakage detection system and provisions for a cover.

It is BAT to cover the slurry tanks using one of the following options:

- A rigid lid, roof or tent structure
- A floating cover such as chopped straw, natural crust, canvas, foil, peat, light expanded clay aggregate (LECA) or expanded polystyrene (ESP)

In general, on-farm processing of manure is BAT under certain conditions only (conditional BAT). The criteria for on-farm manure processing that determine whether a technique is BAT are related to conditions such as availability of land, local nutrient excess or demand, marketing possibilities for green energy, local regulations, and the presence of abatement techniques.

Even though the directive only refers to large holdings for pigs and poultry, it is recommended that the BAT techniques should also be used on holdings with cattle, horses and sheep. When deciding which systems and techniques might be considered BAT, it is most important to focus on the proportions between the size of the holding, the risk of pollution and the extra costs for the farmer.
**Polish legislation**

Polish law (Ordinance of the Council of Ministers of 24 September 2002, Journal of Laws No. 179 item 1490) mentions among the installations that may significantly affect the environment, and thus require the environmental impact report, installations related to animal production with over 240 big animal units of 500 kg live weight (DJP); the coefficients for calculating DJP for animals of different species have been provided in an Annex to the Ordinance.

In some cases, the environmental report is required for holdings with over 50 DJP. The Ordinance contains details of individual elements of the report as well as the following criteria for qualifying an installation as one with potential significant impact on the environment (§ 4):

1. **Type and characteristics of the installation, including:**
   - Scale and area of the installation and proportions of the two values
   - Interrelations between the installation concerned and other installations, especially as regards superimposed environmental impact,
   - The use of natural resources,
   - Emissions and other noxious characteristics,
   - The risk of serious breakdowns by substances and technologies used;

2. **Location of the installation from the viewpoint of potential dangers to the environment, with special consideration to the existing land development, the environment’s ability to clean itself and renewal ability of the natural resources, nature and landscape values, as well as the local land development plans for:**
   - Water and marsh areas as well as other areas with shallow-running underground waters
   - Coastal areas
   - Mountain or forest areas
   - Nature preserves, including protection zones of water intakes and protection areas of inland water reservoirs
   - Areas under special protection due to incidence of plant and animal species and their habitats, and of protected natural habitats
   - Areas where the environment quality standards have been exceeded
   - Human residential areas
   - Areas with historical, cultural or archaeological landscapes;

3. **Type and scale of possible impact resulting from:**
   - The scope of impact – geographical area and the size of the population that might possibly be affected
   - The installation’s impact on individual elements of nature extending to a neighbouring country or countries
   - Size and complexity of the impact, with due consideration to the burden caused by the existing technical infrastructure
   - Probability, duration, frequency and reversibility of the environmental impact.

Polish provisions quote the size limits of ventures that may significantly affect the environment and require the environmental impact report; the values are shown in big animal units (DJP), and the relevant coefficients for calculation of DJP for different species and types of animals are defined in Table 3.6, in section 3.2.
**Emission limits**

In Polish law, the limit values of emission have been specified in Ordinance of Minister of Environment Protection, Natural Resources and Forestry concerning the protection of air against pollution (Journal of Laws No. 15 item 92 of 12 February 1990). The permissible concentrations of air pollutants have been specified in Annex 1 to the Ordinance:

<table>
<thead>
<tr>
<th>Type of pollutants</th>
<th>Permissible concentrations in µg/m³ during the period of</th>
<th>Yearly average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30 minutes</td>
<td>24 hours</td>
</tr>
<tr>
<td>Ammonia emission</td>
<td>400</td>
<td>200</td>
</tr>
<tr>
<td>Ammonia emission in areas under special protection</td>
<td>100</td>
<td>50</td>
</tr>
<tr>
<td>Nitrates emission</td>
<td>200</td>
<td>100</td>
</tr>
<tr>
<td>Nitrates emission in areas under special protection</td>
<td>50</td>
<td>30</td>
</tr>
<tr>
<td>Nitrogen dioxide emission</td>
<td>500</td>
<td>150</td>
</tr>
<tr>
<td>Nitrogen dioxide emission in areas under special protection</td>
<td>150</td>
<td>50</td>
</tr>
<tr>
<td>Hydrogen sulfide emission</td>
<td>30</td>
<td>5</td>
</tr>
<tr>
<td>Hydrogen sulfide emission in areas under special protection</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Hanging dust emission:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hanging dust emission in areas under special protection</td>
<td>1) 120</td>
<td>50</td>
</tr>
<tr>
<td>Hanging dust emission in areas under special protection</td>
<td>1) 60</td>
<td>40</td>
</tr>
</tbody>
</table>

1) There are no limits defined for the period of 30 minutes.

Besides, the Ordinance of Minister of Environment Protection, Natural Resources and Forestry of 5 November 1991 concerning classification of waters and the requirements to be met by sewage discharged into waters or soil (Journal of Laws No. 116 item 503) provides (§14) that starting from 1 January 2000, in sewage discharged into flowing inland waters and sea waters to the amount exceeding 2000 m³/d, the overall phosphorus content may not exceed 1.5 mg/l, and the value of Biological Oxygen Demand [Biologiczne Zapotrzebowanie Tlenu (BZT₃)] must be 15 mg/l. Detailed admissible values of the indices of inland surface water pollution are contained in Annex 1 to the Ordinance.
2.2. Location of manure storages

The location of manure storages is restricted in order to prevent pollution of ground and surface waters. Also the risk of pollution of feed storages and nuisance to the neighbours is taken into consideration. The minimum distances between a manure storage facility and other facilities are shown in figures 2.1, 2.2, and 2.3.

Figure 2.1. Minimum distance between dunghills and other facilities at the farm.

Figure 2.2. Minimum distance between closed slurry tank and other facilities at the farm.
2.3. Safety requirements

Manure storage causes a number of risks concerning safety when handling the manure. Handling of solid manure involves loaders and other technical equipment that can cause severe injuries if not operated appropriately. Liquid manure (primarily slurry) produces toxic gases during the storage period. The gases can be lethal and safety precautions must be taken.

Safety requirements: Solid manure

- The operation of the equipment should follow the manufacturer's instructions.
- No entry into the manure conveyor outlet operation zone.
- No entry onto the dunghill while it is being filled/emptied.
- Safety boards stating the equipment’s operating conditions, i.e. the permissible load or range of operation.
- Safety boards should be placed in visible spots, where they will not get damaged or dirty with manure or dust.
- While the machinery or equipment is in operation, do not touch working elements or electrical installations and wires with your hands.
- Each load-handling device should be equipped with a reliable brake to immobilise the lifted load, as well as separate protection devices preventing accidental lowering of the load.
- No entry under the loader outrigger or into its zone of operation.
- The equipment and machinery e.g. the grab loader or tractor-mounted bulldozer should work on a stable basis.
- Each time prior to starting the work check the technical condition of the equipment.
- Repairs should be made on immobilised equipment only (with disconnected drive).
- Substantial repairs should be contracted to a specialised repair shop.
- Dunghill walls over 1 m high should prevent people from entering the dunghill.
Safety requirements: Slurry
Toxic gases released from liquid manure kill many farmers and animals. The problem is very often that the staffs are not aware of the potential danger when entering a slurry system or when toxic gases have been released from the slurry. It is important to construct systems for handling and storing liquid manure in a way that does not require the staff to enter tanks for operation and inspections.

General remarks
- Facilities for handling of animal manure should be constructed of suitable materials and dimensioned so that there is no risk of work accidents.
- The regulations concerning buildings should be fulfilled.
- The environmental rules concerning animal manure should be observed.

Livestock building, channels, collecting pit and machinery
It is important that the buildings and the manure system are constructed so there are no risks for people or animals working or staying in the buildings.

Recommendations based on Danish experiences:
- Liquid manure may not be stored in livestock buildings or other buildings. The exception is slurry stored in channels up to 1.2 m deep.
- Slurry channels, manure ditches and pump pits should be so constructed as to prevent gases released from the slurry from entering the livestock building or other buildings.
- Pump pits connected to the livestock buildings by pipes should be so constructed as to ensure that toxic gases are released from the slurry effectively before it is used for flushing the channels.
- Flushing pipes must be connected to the slurry channel at a maximum distance of 0.2 m from the bottom.
- There should be a water seal on all pipes and channels leading from the livestock building to the collecting pit. The water seal should be efficient no matter what the level of slurry in the channels.
- If a pump is placed directly in closed connection with the pipeline the water seal can be left out.
- Pipes and mechanical systems to bring the slurry to the collecting pit should be constructed so as not to hinder the agitating and pumping.
- Mechanical systems to bring the slurry to the collecting pit should have a water seal or valve between the livestock building and the collecting pit and an effective airing of the channel.
- In livestock buildings equipped with low-pressure ventilation the airing system should be mechanical, starting at the same time as the pump, or the low-pressure ventilation should be stopped.
- If channels or pipes lead from more livestock buildings to one and the same pit, there should be a water seal at each livestock building.
Openings for inspection and other purposes
Most of the fatal accidents have occurred when people entered a slurry tank or a pit to repair the pump or remove a blockage in the system. When the slurry then started to flow again, poisonous gases were released and the person collapsed. Often another person entered the pit in order to help and also collapsed. Therefore it is necessary to prepare a rescue operation so that only one person should be lifted up. This means that such person should wear a safety belt with a strong line already when entering the tank. There should always be an extra person present who knows exactly what to do in an emergency.

- All closed tanks that people can enter should be ventilated effectively. Effective airing normally requires a fan and two separate openings.
- Openings in closed tanks that people can enter should be so constructed that the rescue team can pull an unconscious person up and out through the opening.

Slurry pumps and propellers
- Slurry pumps, propellers, valves and gates should be used without running the risk of the user being exposed to dangerous amounts of gas.
- Start and stop switches should be placed at least 1.5 m away from openings of the pumping pit.
- Slurry pumps and agitators should be so installed that they can be lifted and taken out of the tank for repair and maintenance.

Shielding of slurry tanks
- A 1.8 m high fence or a lid should bar access to slurry tanks so that animals, children and other unauthorized persons can be kept away from dangerous areas.
- A tank wall and cover can provide sufficient protection against falling into the tank.
- The fence should be made of imperishable material and have a mesh of maximum 40 x 40 mm.
- The top of the wall should be less than 50 mm wide or it should have an inclined top.
- Gates in the fence should require a key or special tool to be opened.
- Work platforms should be secured by railing at foot, knee and hand levels.
- The platform should be constructed so as to prevent children from entering it.
- The lid over a tank should either be strong to resist normal traffic or it should be fenced. If the lid is open a warning sign should be put up.
- A cover over a tank at ground level, which cannot resist heavy traffic, should be fenced so that tractors and cars cannot drive onto the cover.
- A hatch cover should close manholes and openings for inspection. The cover should require a key or special tool for opening.
- Service ramps and access area for the servicing of open tanks for slurry should be secured with a guard-rail minimum 1.1 m high with a cross-bar placed in the middle of its height and 0.15 m over a ramp.
Figure 2.4. Pipes that connect livestock buildings and collecting pits must be constructed with water seals to prevent toxic gasses from entering the livestock buildings.

All types of slurry storages must bear the following safety boards:

- A safety board at all manholes, warning against dangerous gases
- A safety board informing about first aid in case of an accident.
- A safety board near pumping places, informing about fire danger.
- Tankers must have safety boards warning about toxic and flammable gases.
- The safety boards must be placed on the front-end of the tanker or at a ladder where it will not get dirty.
- The safety boards must be clear and made of weather resistant material.

Figure 2.5. Safety board warning about toxic gases.
**Instructions**
The manufacturer of the storage and technical equipment for manure handling must provide an instruction manual, which, as a minimum should inform about the following items:

- The required warning signs.
- Agitating and flushing in the livestock buildings may only take place when emptying the slurry channels.
- Emptying, agitating and flushing must be carried out without release of dangerous amounts of toxic gases in the livestock buildings.
- Flushing may only be done with water or with slurry from which the gas has been released by sufficient agitating in the collecting pit. It is recommended to delay the flushing until the most of the liquid part of the slurry has been removed out of the livestock building.
- When agitating the slurry and flushing the channels in the livestock building the level of slurry should not go higher than 0.5 m below slatted floor level.
- If work has to be carried out in the slurry tank, collecting pit or channels, the staff must wear safety belts with a lifeline attached. At least one rescue person should wait at the opening with a ready-to-use tackle strong enough to haul the worker up to a safe area.
- Or: “If the job is to remove a blockage, the staff must wear breathing masks.”
- When entering a slurry tank or slurry channels the staff must wear breathing masks. Otherwise, all the following requirements must be met:
  - The tank must be emptied thoroughly before it can be entered.
  - Any gate or valve must be secured against opening.
  - The tank must be efficiently ventilated.
  - The concentration of H₂S may not exceed 10 ppm or 15 mg/m³.

In livestock buildings with slurry systems clear signs/boards must be put up with information about operation and maintenance of the system. The signs must also inform about all the safety procedures and where the safety equipment is stored. The signs should be kept up to date.

The manager should instruct the staff about the correct use of the slurry plant and about all the risks involved.
3. Capacity of manure storages

3.1. Introduction

The calculation of the necessary capacity of manure storages is based on the excretion of faeces and urine from the animals, the amount of bedding, spillage of drinking water, and the use of cleaning water. Also rainwater is calculated.

This chapter gives specific figures on excreted manure from different categories of animals in different housing systems. The amount of spilled drinking water and cleaning water is also estimated.

The handbook only mentions standard figures. The actual amounts of urine or slurry from two herds that seem to be identical on the face of it can vary greatly. Differences of up to 25 per cent are not uncommon. The differences may be caused by many factors, the most common of which are as follows:

- Yields and efficiency of the animals.
- Amount and type of bedding.
- Spillage of drinking water depending on type of drinkers
- Water used for cleaning and sprinkling
- Differences in diet that may cause a higher consumption of drinking water and thus also higher urine production.

The variations are shown in Tables 3.1, 3.2, 3.3, 3.4 and 3.5

3.2. Manure production

Table 3.1. Manure production from different cattle housing systems.

<table>
<thead>
<tr>
<th>Type of animal</th>
<th>Housing system</th>
<th>Litter [kg/animal/day]</th>
<th>Type of manure</th>
<th>Manure production including litter [kg/animal/day]</th>
<th>Storage capacity [m³/animal/month]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loosehousing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calves</td>
<td>Deep litter, group pens</td>
<td>1 – 2</td>
<td>Farmyard manure</td>
<td>6 – 10</td>
<td>0.25 - 0.40</td>
</tr>
<tr>
<td></td>
<td>Slatted floor, group keeping</td>
<td>-</td>
<td>Slurry</td>
<td>7 – 12</td>
<td>0.25 - 0.45</td>
</tr>
</tbody>
</table>

To be continued...
<table>
<thead>
<tr>
<th>Type of Animal</th>
<th>Housing System</th>
<th>Litter [kg/animal/day]</th>
<th>Type of Manure</th>
<th>Manure Production Including Litter [kg/animal/day]</th>
<th>Storage Capacity [m³/animal/month]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Heifers</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Deep litter</td>
<td>3 – 5</td>
<td>Farmyard manure</td>
<td>20 – 25</td>
<td>0.75 - 0.95</td>
</tr>
<tr>
<td></td>
<td>Deep litter in resting area, solid concrete floor in dunging area</td>
<td>2 – 4</td>
<td>Farmyard manure</td>
<td>20 - 26</td>
<td>0.70 - 0.90</td>
</tr>
<tr>
<td></td>
<td>Cubicles with litter, solid concrete floor in dunging area</td>
<td>2 – 3</td>
<td>Farmyard manure</td>
<td>18 - 26</td>
<td>0.65 - 0.95</td>
</tr>
<tr>
<td><strong>Young bulls</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Deep litter</td>
<td>3</td>
<td>Farmyard manure</td>
<td>28 – 38</td>
<td>1.10 - 1.4</td>
</tr>
<tr>
<td></td>
<td>Deep litter in resting area, solid concrete floor in dunging area</td>
<td>2 – 3</td>
<td>Farmyard manure</td>
<td>28 - 40</td>
<td>1.0 – 1.3</td>
</tr>
<tr>
<td></td>
<td>Slatted floor</td>
<td>-</td>
<td>Slurry</td>
<td>30 – 40</td>
<td>0.9 – 1.3</td>
</tr>
<tr>
<td></td>
<td>Deep litter in resting area, self-cleaning floor with 8% slope</td>
<td>2 – 3</td>
<td>Farmyard manure</td>
<td>28 – 38</td>
<td>1.05 – 1.4</td>
</tr>
<tr>
<td><strong>Dairy cows</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Deep litter in resting area, solid concrete floor in dunging area</td>
<td>4-5</td>
<td>Farmyard manure</td>
<td>40 – 50</td>
<td>1.4 – 1.8</td>
</tr>
<tr>
<td></td>
<td>Deep litter in resting area, slatted floor in dunging area</td>
<td>3-5</td>
<td>Farmyard manure + slurry</td>
<td>30-35</td>
<td>1.1-1.3</td>
</tr>
<tr>
<td></td>
<td>Deep litter in resting area, self-cleaning base</td>
<td>4-6</td>
<td>Farmyard manure</td>
<td>45-50</td>
<td>1.6-1.9</td>
</tr>
<tr>
<td></td>
<td>Cubicles with litter, solid concrete floor in dunging area</td>
<td>2 – 3</td>
<td>Farmyard manure</td>
<td>45 – 50</td>
<td>1.6 – 1.9</td>
</tr>
<tr>
<td></td>
<td>Cubicles without litter, slatted floor in dunging area</td>
<td>-</td>
<td>Slurry</td>
<td>40 – 52</td>
<td>1.20 - 1.60</td>
</tr>
<tr>
<td><strong>TIED-UP HOUSING</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Calves</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Deep litter (group keeping)</td>
<td>1 – 2</td>
<td>Farmyard manure</td>
<td>6 – 10</td>
<td>0.25 - 0.40</td>
</tr>
<tr>
<td></td>
<td>Slatted floor, group keeping</td>
<td>-</td>
<td>Slurry</td>
<td>7 – 12</td>
<td>0.25 - 0.45</td>
</tr>
</tbody>
</table>

*To be continued...*
<table>
<thead>
<tr>
<th>Type of animal</th>
<th>Housing system</th>
<th>Litter [kg/animal/ day]</th>
<th>Type of manure</th>
<th>Manure production including litter [kg/animal/day]</th>
<th>Storage capacity¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young bulls</td>
<td>Stalls with litter, shallow channel behind stalls</td>
<td>1 – 2</td>
<td>Farmyard manure</td>
<td>28 – 35</td>
<td>1.0 – 1.3</td>
</tr>
<tr>
<td></td>
<td>Stalls without litter, channel covered with grating</td>
<td>-</td>
<td>Slurry</td>
<td>30 – 40</td>
<td>0.9–1.2</td>
</tr>
<tr>
<td>Heifers</td>
<td>Stalls with litter, shallow channel behind stalls</td>
<td>1 – 2.5</td>
<td>Farmyard manure</td>
<td>18 – 23</td>
<td>0.8 – 1.0</td>
</tr>
<tr>
<td></td>
<td>Stalls without litter, channel covered with grating</td>
<td>-</td>
<td>Slurry</td>
<td>20 – 27</td>
<td>0.6-0.8</td>
</tr>
<tr>
<td>Dairy cows</td>
<td>Stalls with litter, shallow channel behind stalls</td>
<td>2 – 3.5</td>
<td>Farmyard manure</td>
<td>45 – 55</td>
<td>1.5 – 1.9</td>
</tr>
<tr>
<td></td>
<td>Stalls without litter, continuous self-flush, channel covered with grating</td>
<td>-</td>
<td>Slurry</td>
<td>40 – 45</td>
<td>1.2 - 1.5</td>
</tr>
</tbody>
</table>

¹ Capacity of the liquid fraction included.

**Table 3.2. Manure production from different pig housing systems.**

<table>
<thead>
<tr>
<th>Type of animal</th>
<th>Housing system</th>
<th>Litter [kg/animal/ day]</th>
<th>Type of manure</th>
<th>Manure production including litter [kg/animal/day]</th>
<th>Storage capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boars</td>
<td>Solid floor with litter</td>
<td>3 – 4</td>
<td>Farmyard manure</td>
<td>12 – 16</td>
<td>0.5 – 0.7</td>
</tr>
<tr>
<td>Pregnant sows</td>
<td>Deep litter</td>
<td>2 – 3</td>
<td>Farmyard manure 10 – 140.45</td>
<td>0.6</td>
<td>0.45 – 0.65</td>
</tr>
<tr>
<td></td>
<td>Deep litter in resting area, solid floor in dunging area</td>
<td>0.8 – 1.2</td>
<td>Farmyard manure</td>
<td>12 - 17</td>
<td>0.45 – 0.65</td>
</tr>
<tr>
<td></td>
<td>Solid floor in resting area, slatted floor in dunging area</td>
<td>0.1 – 0.25</td>
<td>Slurry</td>
<td>10 – 15</td>
<td>0.3 – 0.45</td>
</tr>
</tbody>
</table>

To be continued...
<table>
<thead>
<tr>
<th>Type of animal</th>
<th>Housing system</th>
<th>Litter [kg/animal/day]</th>
<th>Type of manure</th>
<th>Manure production [kg/animal/day]</th>
<th>Storage capacity [m³/animal/month]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lactating sows</td>
<td>Solid floor in resting and dunging area</td>
<td>4 – 5</td>
<td>Farmyard manure</td>
<td>14 – 16</td>
<td>0.6 – 0.7</td>
</tr>
<tr>
<td></td>
<td>Partly or fully slatted floor</td>
<td>0.05 – 0.1</td>
<td>Slurry</td>
<td>15 – 20</td>
<td>0.45 – 0.6</td>
</tr>
<tr>
<td>Weaners</td>
<td>Deep litter</td>
<td>0.5 – 1</td>
<td>Farmyard manure</td>
<td>2 – 3</td>
<td>0.15 – 0.2</td>
</tr>
<tr>
<td></td>
<td>Resting area with litter, solid floor in dunging area</td>
<td>0.15 – 0.3</td>
<td>Farmyard manure</td>
<td>1.5 – 2.5</td>
<td>0.1 – 0.15</td>
</tr>
<tr>
<td></td>
<td>Partly slatted floor</td>
<td>0.05 – 0.1</td>
<td>Slurry</td>
<td>1 – 2</td>
<td>0.09 – 0.1</td>
</tr>
<tr>
<td>Finishers</td>
<td>Deep litter</td>
<td>1 – 3</td>
<td>Farmyard manure</td>
<td>4 – 7</td>
<td>0.25 – 0.35</td>
</tr>
<tr>
<td></td>
<td>Resting area with litter, solid floor in dunging area</td>
<td>0.3 – 0.5</td>
<td>Farmyard manure</td>
<td>3 – 5</td>
<td>0.2 – 0.4</td>
</tr>
<tr>
<td></td>
<td>Partly slatted floor</td>
<td>0.05 – 0.1</td>
<td>Slurry</td>
<td>5 – 8</td>
<td>0.15 – 0.25</td>
</tr>
</tbody>
</table>

Table 3.3. Manure production from different poultry housing systems.

<table>
<thead>
<tr>
<th>Type of animal</th>
<th>Housing system [kg/animal/day]</th>
<th>Litter</th>
<th>Type of manure</th>
<th>Volume of droppings (without litter) [m³/1,000 birds]</th>
<th>Storage capacity [m³/1,000 birds/months]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broilers</td>
<td>Floor 0.80</td>
<td>Farmyard manure</td>
<td>3.0</td>
<td>3.8</td>
<td></td>
</tr>
<tr>
<td>Pullets reared for layers</td>
<td>Floor 0.120</td>
<td>Farmyard manure</td>
<td>4.7</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td>Layers</td>
<td>Cages 0.220</td>
<td>Droppings</td>
<td>8.2</td>
<td>8.2</td>
<td></td>
</tr>
<tr>
<td>Adult ducks</td>
<td>Floor 0.500</td>
<td>Droppings</td>
<td>20.6</td>
<td>22.0</td>
<td></td>
</tr>
<tr>
<td>Broiler ducks (end of fattening)</td>
<td>Mesh 0.500</td>
<td>Droppings</td>
<td>18.7</td>
<td>18.7</td>
<td></td>
</tr>
<tr>
<td>Broiler ducks (end of fattening)</td>
<td>Floor 0.500</td>
<td>Farmyard manure</td>
<td>18.7</td>
<td>20.0</td>
<td></td>
</tr>
<tr>
<td>Adult turkeys</td>
<td>Floor 0.430</td>
<td>Farmyard manure</td>
<td>16.0</td>
<td>18.0</td>
<td></td>
</tr>
<tr>
<td>Slaughter turkeys</td>
<td>Floor 0.350</td>
<td>Farmyard manure</td>
<td>13.0</td>
<td>14.8</td>
<td></td>
</tr>
<tr>
<td>Adult geese</td>
<td>Floor 0.960</td>
<td>Farmyard manure</td>
<td>36.0</td>
<td>41.0</td>
<td></td>
</tr>
<tr>
<td>Broiler geese (end of fattening)</td>
<td>Mesh 0.900</td>
<td>Droppings</td>
<td>33.0</td>
<td>33.0</td>
<td></td>
</tr>
<tr>
<td>Broiler geese (end of fattening)</td>
<td>Floor 0.900</td>
<td>Farmyard manure</td>
<td>33.0</td>
<td>36.0</td>
<td></td>
</tr>
</tbody>
</table>

2 The saumed litter is straw
### Table 3.4. Manure production from different horse housing systems.

<table>
<thead>
<tr>
<th>Type of animal</th>
<th>Housing system</th>
<th>Excrements + litter [kg/animal/day]</th>
<th>Type of manure</th>
<th>Manure production including litter [kg/animal/day]</th>
<th>Storage capacity [m³/animal/month]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colt aged over 1 year (400 kg)</td>
<td>Litter</td>
<td>17 + 5 kg litter</td>
<td>Farmyard manure</td>
<td>22</td>
<td>1.0</td>
</tr>
<tr>
<td>Mare, stallion, gelded male (600 kg)</td>
<td>Litter</td>
<td>25 (+ 5 kg litter)</td>
<td>Farmyard manure</td>
<td>30</td>
<td>1.38</td>
</tr>
</tbody>
</table>

### Table 3.5. Manure production from different sheep housing systems.

<table>
<thead>
<tr>
<th>Type of animal</th>
<th>Housing system</th>
<th>Litter [kg/animal/day]</th>
<th>Type of manure</th>
<th>Manure production including litter [kg/animal/day]</th>
<th>Storage capacity [m³/animal/month]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lamb aged 3.5 months</td>
<td>Litter</td>
<td>0.3</td>
<td>Farmyard manure</td>
<td>1.5</td>
<td>0.050</td>
</tr>
<tr>
<td>Lamb ewe aged 12 months</td>
<td>Litter</td>
<td>0.4</td>
<td>Farmyard manure</td>
<td>2.5</td>
<td>0.083</td>
</tr>
<tr>
<td>Mother ewe, ram and wether aged 12 months</td>
<td>Litter</td>
<td>0.5</td>
<td>Farmyard manure</td>
<td>2.8</td>
<td>0.093</td>
</tr>
<tr>
<td>Ram and wether</td>
<td>Litter</td>
<td>0.4</td>
<td>Farmyard manure</td>
<td>4</td>
<td>0.133</td>
</tr>
</tbody>
</table>

**Conversion to Big animal units**

Conversion of the number of animals into big animal units (DJP) determines the necessary storage capacity for manure. Ordinance of the Council of Ministers of 14 May 2002 on the detailed scope and directions of activity as well as procedures of the Agency for Restructuring and Modernisation of Agriculture in the area of managing resources from EU funds (published on 9 July 2002, Journal of Laws No 102, item. 928) gives the coefficients to be used for conversion of animals into big animal units (Table 3.6).
Table 3.6. Coefficients used for conversion of animals into big animal units.

<table>
<thead>
<tr>
<th>Type of animals</th>
<th>Average Body Weight, kg</th>
<th>Conversion Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CATTLE</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cows</td>
<td>500</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>600</td>
<td>1.20</td>
</tr>
<tr>
<td>Pregnant heifer</td>
<td>450</td>
<td>0.90</td>
</tr>
<tr>
<td>Heifer aged 12 to 18 months</td>
<td>350</td>
<td>0.70</td>
</tr>
<tr>
<td>Heifer aged 6 to 12 months</td>
<td>250</td>
<td>0.50</td>
</tr>
<tr>
<td>Calf aged 6 months</td>
<td>100</td>
<td>0.20</td>
</tr>
<tr>
<td>Young bull aged 12 months</td>
<td>375</td>
<td>0.80</td>
</tr>
<tr>
<td>Adult bull</td>
<td>900</td>
<td>1.80</td>
</tr>
<tr>
<td><strong>PIGS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sow</td>
<td>175</td>
<td>0.35</td>
</tr>
<tr>
<td>Adult boar</td>
<td>200</td>
<td>0.40</td>
</tr>
<tr>
<td>Piglet aged up to 8 weeks</td>
<td>10</td>
<td>0.02</td>
</tr>
<tr>
<td>Weaner aged 2 to 4 months</td>
<td>35</td>
<td>0.07</td>
</tr>
<tr>
<td>Finisher</td>
<td>70</td>
<td>0.14</td>
</tr>
<tr>
<td><strong>HORSES</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stallion</td>
<td>600</td>
<td>1.20</td>
</tr>
<tr>
<td>Mare and gelded horse</td>
<td>600</td>
<td>1.20</td>
</tr>
<tr>
<td>Colt aged over two years</td>
<td>500</td>
<td>1.00</td>
</tr>
<tr>
<td>Colt aged over 1 year</td>
<td>400</td>
<td>0.80</td>
</tr>
<tr>
<td>Foal aged 6 to 12 months</td>
<td>300</td>
<td>0.60</td>
</tr>
<tr>
<td>Foal aged up to 6 months</td>
<td>150</td>
<td>0.30</td>
</tr>
<tr>
<td><strong>SHEEP</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mother ewe, ram and wether aged 12 months</td>
<td>60</td>
<td>0.12</td>
</tr>
<tr>
<td>Lamb aged 3.5 months</td>
<td>25</td>
<td>0.05</td>
</tr>
<tr>
<td>Lamb ewe aged 12 months</td>
<td>50</td>
<td>0.10</td>
</tr>
<tr>
<td>Ram and wether</td>
<td>100</td>
<td>0.20</td>
</tr>
<tr>
<td><strong>POULTRY</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adult laying hen</td>
<td>1.8</td>
<td>0.0036</td>
</tr>
<tr>
<td>Adult slaughter hen</td>
<td>3.2</td>
<td>0.0064</td>
</tr>
<tr>
<td>Broiler chicken</td>
<td>1.6</td>
<td>0.0032</td>
</tr>
<tr>
<td>Adult turkeys, medium-weight type:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>+ turkey cock</td>
<td>13.0</td>
<td>0.026</td>
</tr>
<tr>
<td>+ turkey hen</td>
<td>7.0</td>
<td>0.014</td>
</tr>
<tr>
<td>Adult duck</td>
<td>3.5</td>
<td>0.007</td>
</tr>
<tr>
<td>Adult goose</td>
<td>6.0</td>
<td>0.012</td>
</tr>
</tbody>
</table>
3.3. Extra Capacity

Beside the manure production from the animals, extra storage capacity in the urine or slurry tanks must be calculated for rainwater, spillage of drinking water, and water used for cleaning and sprinkling.

Rainwater
The capacities of the urine tanks take into account the volume of the rainwater of up to 0.5 m³ per DJP in the period of 6 months.

Spillage of drinking water and water used for cleaning
In pig herds where nipple drinkers are used the spillage of drinking water can be very high. If cleaning is carried out on a regular basis, the amount of water used is substantial, and must be added to the necessary capacity. Table 3.7 shows data on the amount of spillage and water used for cleaning that could be used when calculating the necessary storage capacity. Please note that especially on spillage of drinking water, the variations are very high.

Table 3.7. Spillage of drinking water and water used for cleaning.

<table>
<thead>
<tr>
<th>Production</th>
<th>Spillage of drinking water, Litres/animal/year</th>
<th>Cleaning water, Litres/animal/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>PIGS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lactating sows</td>
<td>0</td>
<td>400 (250 – 600)</td>
</tr>
<tr>
<td>Weaners (7-30 kg), partly or fully slatted floor</td>
<td>15 (0 – 30)</td>
<td>15 (10 – 20)</td>
</tr>
<tr>
<td>Weaners, solid floor and deep litter</td>
<td>15 (0 – 30)</td>
<td>0</td>
</tr>
<tr>
<td>Finishers (30-100 kg), partly or fully slatted floor</td>
<td>75 (0 – 250)</td>
<td>25 (15 – 40)</td>
</tr>
<tr>
<td>Finishers (30-100 kg), solid floor and deep litter</td>
<td>75 (0 – 250)</td>
<td>0</td>
</tr>
<tr>
<td>CATTLE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dairy cows, milking parlour</td>
<td></td>
<td>3000</td>
</tr>
</tbody>
</table>

1) The amount of spillage depends on the type of drinkers used. Drinking bowls give the lowest, and drinking nipples the highest spillage.

3.4. Recommendations on storage capacities

The recommended minimum capacity of manure storages is based on the figures described in sections 3.2 and 3.3 but also reflects experience about necessary storage capacity from many farms.

In general the capacity of manure storages should be sufficient for collection and storage for the period of at least 6 months. It is recommended to consider extra storage capacity. Extra capacity will give the farmer better opportunities of optimising the time of application of the manure to the fields. On farms with minimal storage capacity, the actual time for application is very often only determined by insufficient capacity.
Table 3.8. Recommended minimum storage capacities.

<table>
<thead>
<tr>
<th>Manure type</th>
<th>Recommended size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farmyard manure and deep litter</td>
<td>Area 3.5 m² per DJP</td>
</tr>
<tr>
<td>Urine, including run-off from solid manure and deep litter</td>
<td>Capacity 2.5 m³ per DJP</td>
</tr>
<tr>
<td>Slurry</td>
<td>Capacity 10 m³ per DJP</td>
</tr>
</tbody>
</table>

The recommended minimum storage capacity for solid manure can be calculated as 3.5 m² per DJP. The required area depends on the height of the dunghill, but in practice the average height of the dunghill should be calculated higher than 2 meters. In herds with cattle, sheep and horses the necessary capacity can be adjusted proportionally to the time the animals spend on grazing land.

With a herd size of 20 DJP’s the recommended storage area for farmyard manure should be at least 70 m². In order to prevent leakages and run-offs the dimensions of the storage must be larger than the actual capacity. The access ramp to the storage must be at least 2 meter long and have a slope towards the storage of 3 per cent (see example 8.1 and 8.2 in chapter 8). The storage capacity for urine and run-off from the manure storage should be at least 2,5 m³ per DJP.
4. Manure and deep litter storage facilities

4.1. Introduction

This chapter describes the various technical solutions for storages of solid manure, such as dung and deep litter. Concerning the storage of deep litter, the authors have decided that the storage of deep litter in livestock buildings is also considered a storage facility. In the following sections of this chapter the various technical solutions are described with the focus on the critical details concerning both the construction and the operation and maintenance of the storages.

4.2. Design and construction of storages for dung and deep litter

Manure storages should be located at the farm as to ensure easy transportation and forming of the dunghill. It is recommended that a dunghill is located in close connection with the livestock buildings. In order to reduce nuisances, such as odours, the dunghill should be located in the northern or north-eastern part of the farm. In case of open dunghills it is desirable to locate them near mature trees that would provide some shade. This will reduce the ammonia emission from the manure.

The location of the storage facilities for dung and deep litter is chosen individually for each farm taking into consideration the location of the existing buildings. In choosing the actual location of the storage facilities it is absolutely necessary to respect the minimum distances from the storage to buildings and other structures (see Figure 2.2).

Moreover it is necessary to:

- Determine the required size of the storage for farmyard manure;
- Determine the shape and dimensions of the storage;
- Take into consideration the manure removal method;
- Design the manure transportation route from the livestock building to the storage so as to make it straight and as short as possible;
- Eliminate intersections of the internal roads;
- Take into account the falling gradients in the area;
- Ensure access for the means of transport (loader, tractor with trailer etc.)
- Ensure free flow of rain water around the buildings;
- Ensure free flow of rain water run-offs from the gutter to the tank.

On smaller farms (less than 15 DJP) two types of facilities are commonly used. Figures 4.1 and 4.2 show examples of manure storages with a relatively low raised edge. Figures 4.3 and 4.4 show examples of manure storages used for larger herds.
4.3. **Shape and dimensions of storages for farmyard manure**

The shape of the storage should be chosen taking into consideration the following factors:

- The type of technical equipment used for transportation of the manure from livestock building to the storage
- Conditions specific for the given farm (in reference to the existing buildings);
- The method chosen for manure removal from the dunghill.

*Figure 4.1. Circular storage for farmyard manure.*
If the manure is transported from the livestock facility to the storage by means of a hydraulic scraper of the mole type, it is recommended to choose a circular storage. The manure is forced out through a centrally located outlet; consequently, it forms a conical heap. The storage is equipped with a raised edge designed for channelling the manure water to the sump and keeping the area around the gutter tidy. Depending on the size of the storage, a service road should be designed and built for the manure removal machine (e.g. a front loader, grab loader, etc.). It is possible to unload the manure from small-sized storages by means of a machine positioned outside the storage. An access road should be built around the storage.

Figure 4.2. Rectangular storage for farmyard manure.

Dimensions of the rectangular storage for farmyard manure should be adjusted to the manure storage technology in a way to minimise or eliminate altogether the manual work in the process of shaping the dunghill. The minimum storage width should be a multiple of the construction module and should equal 6 m. The assumed average height of the manure storage is 2 m.
Figure 4.3. Rectangular storage for farmyard manure with two sidewalls.

Figure 4.4. Rectangular storage for farmyard manure including storage tanks for liquid manure.
4.4. Storage of deep litter in livestock buildings

Deep litter systems in livestock buildings can be operated without separate storage facilities, since the deep litter is stored in the resting area for a period of 4 to 6 months. The thickness of the manure layer reaches up to 1.2 m. The entire resting area and simultaneous storage of manure in the building should not let urine penetrate into the soil, see Figures 4.5 and 4.6. Small amounts of urine, i.e. up to 20 - 30% of the total amount of urine excreted by the animals, are drained to a tank located outside the building.

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**Figure 4.5.** Livestock building with deep litter.

**Figure 4.6.** Storage of manure in the form of deep litter.

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### Storage of deep litter – characteristics

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comfort to resting animals</td>
<td>Substantial litter consumption</td>
</tr>
<tr>
<td>Construction of smaller urine tanks</td>
<td>Considerable amount of work needed for supply of bedding</td>
</tr>
</tbody>
</table>
5. **Storages for liquid manure**

5.1. **Introduction**

The following chapter describes the different technical solutions for storages of liquid manure, such as urine and slurry. The authors have decided that the storage of slurry underneath livestock buildings should also be described as a storage facility. Critical details concerning construction, operation and maintenance of storage tanks are highlighted.

5.2. **Design and construction of slurry tanks**

Prior to starting the design works the following key questions should be answered:

- What location has been selected for construction of the tank?
- What is the required cubic capacity of the tank?
- What type of the tank is required in terms of its foundation (a ground-based, partially sunken or underground tank)?
- What type of soil can be found on the planned construction site (down to the depth of 1 m below the level of foundation)?
- What method of tank filling/emptying will be used?
- What shape of the tank is required?
- Will it be an open or closed tank?
- What material will the tank be made of?
- What is the underground water level under the planned tank location site?

Having answered these questions one can start the design works followed by the actual tank construction. The most common practice is to build the storage tank of concrete. Since this construction prevails, the authors have decided to focus on concrete tanks in the following descriptions.

5.3. **Quality- and control systems**

**Quality management**

As it follows from the above paragraphs, it is a complicated matter to construct and manage a slurry tank that complies with all the regulations and instructions. Thus it is highly recommended to establish an inspection system.
### Minimum requirements for the inspection system

1. **The project:** A consulting engineer with an official certificate proving his expertise on statics, shall carry out the calculations on strength of the slurry tank.

2. **Components:** Companies subjected to impartial inspection manufacture the individual parts of the slurry tank.

3. **Construction site:** Construction at the construction site is subjected to the supplier’s internal inspection system, which includes all works from digging and construction to re-establishment of the surroundings.

4. **Impartial inspection:** The slurry tank is at all stages subjected to external spot inspection. An acknowledged inspection body performs the inspection, which is normally carried out unannounced on the construction site.

All these measures must secure:

- A high-quality slurry tank
- A fast building permit procedure at the local authority
- A slurry tank that can be insured against the economical claims on the farmer, if the tank breaks and gives damages to the environment (such an insurance is normal for farmers in several EU countries)

### Internal inspection of manure tanks

In order to secure the tightness and strength of the slurry tank throughout its entire life, it is important to inspect these features on a regular basis.

### In the internal inspection it is recommended that the farmers check:

- Tightness of the tank – check walls and the inspection pit for leakages.
- Overall condition of the tank – check the walls and bottom for cracks in the concrete. Check the reinforcement for corrosion. Check all joints. The tank must be emptied and cleaned thoroughly before the inspection can be performed.
- Check the cables and cable locks above and below ground level.
Periodic inspections
It is advisable to inspect the tank whenever its emptying takes place in order to detect as early as possible any signs of incipient wear and tear of the tank. It is also advisable to clean the tank at least every third year in connection with the emptying, if possible with a high pressure cleaner. Any damage detected during inspection should be repaired before the tank is filled again.

Special attention should be paid to flanges between bottom and wall as well as the flanges between individual wall parts, as these are the weakest points of the construction with the highest risk of leakage. Extension cables, cable protection and junctions should also be inspected thoroughly.

Regular inspections, with subsequent repairs if necessary, reduce the risk of major and expensive repairs as well as the costs of damages to the environment caused by leakages. If major damage is recorded, the supplier (contractor) should be contacted for advice concerning repairs.

5.4. Surroundings of storage tanks

The surroundings of the storage tank are of great importance for the durability of the tank in the long as well as the short term. In the following sections, various issues concerned the surroundings will be discussed.

Soil pressure
The surrounding ground height above the bottom plate must not be changed considerably. On the contrary, the ground height should be maintained at the level it was originally planned to be. It should be avoided to construct access ramps resting against the walls of the slurry tank, and also to undertake construction works close enough to the tank for load impacts to be transmitted and hereby to affect stability of the tank.
**Surface water**
3 to 4 metres from the tank, the surrounding ground must to be kept free from water (surface water, water from roofs and other sources).

**External water pressure**
In the case that the ground water makes an external water pressure on the tank, please ensure that:

- Either the tank is never emptied to a level below the ground water level
- Or the ground water level is lowered below the tank bottom before emptying the tank.

The ground water level is to be kept lowered until the tank has been refilled to a level above that of the external water level. Otherwise is a risk that the water pressure will break the bottom plate causing leakages of slurry into the environment.

**Anchorage**
In case of traffic around the tank, the ground has to be hardened so that the filling material around the tank does not change character (the road surface might crack and holes might appear in which rainwater, slurry, etc. would gather and remain on a permanent basis or seep along the tank’s outer surface).

Consolidation of the ground around the tank may not be closer than at least 10 cm from the tank. Between the tank and the consolidated area, material that is soft enough (as for instance sand) should be filled to prevent transfer of impacts from the consolidation to the tank.

**Mechanical impact**
The tank is to be protected from mechanical impact (e.g. collision). It is not allowed to mount any installations on the tank that can cause injuries on the construction.

**Vegetation**
Trees and bushes planted around the storage tank should be kept at a distance of at least 10-15 m for their roots not to damage the tank. Wild trees and bushes near the tank must be removed.

### 5.5. Operation and maintenance of storage tanks

The operation of storage tanks involves a number of risks of damaging the tank. Also there is a risk of injuries to the staff involved in operating the tank facility. In the following sections points that should be paid attention to are pointed out.

**Before first use**
Before filling the tank for the first time, please ensure that potential load alleviation devices for external water pressure are closed in accordance with rules and regulations. In case of water in the tank, the options are either to leave it there or to ensure that the ground water level is lowered below base level before emptying takes place.
**Filling the tank**
If the cover of the storage tank is a natural floating layer the tank should be filled through a submerged inlet (max 40 cm above the bottom). This will prevent the floating layer from breaking whenever slurry is pumped into the storage tank. See figure 6.1.

**Covering of tanks for liquid manure**
In order to reduce or prevent ammonia emission from storage tanks with liquid manure, the tank should be covered with a natural floating layer or an artificial cover. In the following part of the handbook, different solutions are described, and advantages and disadvantages are pointed out.

If straw is used for bedding in the livestock buildings, a natural floating layer will normally be formed on top of the slurry. Since, however, some manure systems do not involve the use of straw on a large scale, it may be necessary to use other techniques for covering the tank.

<table>
<thead>
<tr>
<th>Type of cover</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
</table>
| Floating layer of chopped straw | • Cheap  
• Easy stirring of slurry  
• The tank can be emptied completely  
• Well mixed with the slurry, the straw will not hinder field application | • Large amounts of straw required  
• Does not prevent rainwater from entering the tank  
• When the tank is full, some of the straw might be blown away  
• Risk of spreading wild oat |
| Clinkers of expanded clay      | • Easy to maintain  
• Effective, reduces the loss of ammonia up to 10%  
• High durability | • Does not prevent rainwater from entering the tank  
• May clog up pipes at tankers with trailing hoses |
| Floating cover of plastic      | • Easy to maintain  
• Tight surface  
• Provides extra capacity compared to a natural floating layer if rainwater is pumped away. | • The cover has to be removed (totally or partly) when stirring and emptying the tank  
• It may prove be difficult to put the cover on after it has been removed. |
| Concrete cover                 | • Easy to maintain  
• Provides extra capacity compared to a natural floating layer if rainwater is pumped away  
• High durability  
• No special equipment or permission is needed to drain off rainwater | • Very expensive  
• Cannot be mounted on all tanks |
| Tent cover                     | • Easy to maintain  
• Provides extra capacity compared to a natural floating layer if rainwater is pumped away. High durability (up to over a dozen years)  
• No special equipment or permission is needed to drain off rainwater | • Very expensive  
• Cannot be mounted on all tanks  
• Can cause some difficulties in the process of mixing the slurry |
Natural floating layer
The natural floating layer is formed by the dry matter content in the slurry (e.g. bedding and spillage of fodder). The slurry will normally divide into two fractions – one with a high dry-matter content and the other one almost without dry-matter. Depending on the type of bedding and fodder used, the fraction with a high dry-matter content will either sink to the bottom of the tank or rise to the surface. Normally the bedding rises to the surface while the fodder sinks to the bottom.

Figure 5.2. Natural floating layer formed by the dry matter content in the slurry.

Floating layer of chopped straw
A 20 cm floating layer can be established by adding approximately 10 kg of straw per m² of the surface. Thus a manure tank with a 25 m diameter needs approximately 5 tons of straw. The floating layer can be established by spreading chopped straw on the surface of the tank. Solid manure with high straw content is another possibility. In large storage tanks the manure has to be put on the surface with a telescopic loader in order to ensure an equal layer.

Since a floating layer of straw is not so stable, it requires regular inspections. Especially in large tanks, it can be necessary to add extra straw during the year to maintain the floating layer.
Clinkers of expanded clay
When using clinkers of expanded clay (e.g. Leca) with a particle size of 10-20 mm and a density of 220 kg/m³, the floating layer has to be approximately 10 cm thick.

The clinkers are floating upon the liquid manure; following a rain, storm and agitating they always rise to the surface again. The cover made of clinkers of expanded clay does not require daily maintenance, but the layer has to be inspected as often as that of straw.
**Floating plastic cover**
A floating cover of plastic foil floats directly on the surface of the slurry and follows its up- and downward movements. The plastic cover is supplied with a thick plastic border that secures the required tightness clinging to the walls. Rainwater gathers on the upper side of the foil and has to be pumped away. It is not recommended to allow the water to be pumped to the sewage system because of the risk of pollution if slurry gets on the top of the cover.

The floating plastic cover does not require any maintenance, but has to be inspected as often as the straw one.

**Never walk on the floating cover!**

**Concrete cover**
A concrete cover or deck above the pre fabricated slurry tank is normally made of pre fabricated concrete elements. If the storage tank is round, a pillar in the centre of the tank supports elements. It is very important that the manufacturer of the concrete deck should examine the manure tank for necessary strength. If the manure tank is “built on the site”, the concrete cover is often cast on the spot. The need for supporting pillar(s) depends of the size of the tank. Inspection and maintenance is not needed when using a concrete cover.
Figure 5.6. Concrete deck.

**Tent cover**

For round storage tanks a tent cover is also a possibility. A high central pillar is placed in the centre of the tank and the cloth is stretched out between it and the tank walls. If the tent cover is chosen, it is very important to follow the manufacturer’s instructions on how to assemble and maintain such structure. To ensure sufficient access for tractor mounted propellers for agitation of slurry, it is necessary to have more than one opening in the tent cover. Also the size of the openings must be large enough to ensure that equipment such as propellers and pumps doesn’t cause injuries on the cover.

Figure 5.7. Tent cover.
Ice impact load
In frosty periods of several days' duration it is important to prevent solid ice from forming against the tank wall. The risk of ice impact load damage is the highest in tanks where the dry matter content is low.

From our experience it follows that tanks with daily slurry supply and a floating layer of at least 15-20 cm do not face problems with loads from formation of ice if the slurry is supplied at the tank bottom (under the floating cover). The higher temperature in the supplied slurry as well as the insulation of the floating cover results in a slower formation of ice. Additionally, substances (e.g. salt in the feed) dissolved in the slurry lower the freezing point (compared to water) and the ice tends to be porous.

If, by accident, slurry is supplied on top of the floating cover, a layer of ice is built up. In extreme situations the ice can cause severe damage on the tank walls. The risk of damage is considerably increased if slurry is removed from the tank under a layer of ice as the ice will then crack and stream along downwards. This way, a bridging in the ice is formed and the consequence will be an increased impact load on the tank wall.

During extremely long periods of frost the floating layer's insulating ability along the tank wall can be increased by stacking some rows of small straw bales on top of the floating cover along the tank wall.

Never step down on the ice. The ice is often very inhomogeneous and porous and has a low load capacity!

If storage tanks are empty and not used in wintertime, their bottom should be covered with a thick layer of straw corresponding to winter mats – or with winter mats – in order to avoid frost heaving.

Damage/accidents
If a storage tank is exposed to unforeseen impacts such as collisions, heating in case of fire or similar events that might cause serious damage to the construction the tank supplier or relevant technicians should be contacted for further inspection of the consequences before the tank can be used again.

5.6. Safety requirements

The operation of storage facilities for liquid manure includes a number of risks of injuries on the staff. In the following sections different precautions that should be taken are described.

Wire fences, lids, hatches, etc.
Manure tanks are to be fenced in or sheltered to keep children and other trespassers away from dangerous places. If the tank wall is less than 1.8 m above the ground, a fence must be mounted.

Lids and hatches needs to be kept in safe condition and must not be removed without the use of tools or key. For effective airing of closed tanks before inspection, two openings and a fan are required. The dimensions of rectangular access openings must be either $0.8 \times 0.8$ m or $0.5 \times 1.0$ m. A circular opening must have the diameter at least $0.8$ m. Above one of the access openings there must be a permanent fixing/secure point for a block with a safety rope.
Please be aware that open access holes have to be secured to prevent anybody from falling inside. Working platforms at open tanks must be secured by a safety rail. If possible, access to the working platform should be locked. Otherwise, a 1.8 m high fence must be raised. If the tank cover has not been dimensioned for traffic of tractors and vehicles, a shield of at least 0.5 metre height must be mounted.

Slurry pumps and agitators must comply with safe operations to prevent the user from being exposed to dangerous slurry gases. Start and stop buttons must be situated least 1.5 m away from openings leading to the pit. Slurry pumps and agitators must also be designed and mounted as to make it possible for them to be lifted out of the tank for repairs.

**Safety boards**
Manure tanks must have safety boards warning about the danger of poisoning and informing about first aid procedures if accidents occur.

### 5.7. Collecting pits for liquid manure

The collecting pit is used as a temporary storage for slurry in the process of its transportation from the livestock buildings to the storage tank. Also, the collecting pit may be used in the process of spreading the slurry on arable land.

**Capacity**
The necessary capacity of the collecting pit depends on a number of factors. In general, the collecting pit should have a capacity of at least the amount of slurry in the largest slurry channel in the livestock building. If dry matter content in the slurry is high due to large amounts of straw or very low spillage of water, the slurry channels may be very difficult to empty. In such cases, it is very important to ensure the smoothest possible flow of the slurry. This also means that the resistance in the outlets of slurry pipes connecting the slurry channels in the livestock buildings with the collecting pit must be as little as possible.

If the slurry pump in the collecting pit also is used for filling the tanker used to spread the slurry, it is recommended to take the capacity of the tanker into consideration. Especially if the pump is used for mixing to ensure a homogeneous slurry before spreading, it is recommended that the capacity should be at least equal to that of the tanker.

**Construction**
There are many ways to construct a collecting pit, but the most common type is the one with concrete bottom cast in situ, on which a number of prefabricated concrete rings are placed.

All types must have a bottom and walls highly resistant to moisture, e.g. made of 150 mm of 25 MPa concrete.

The connection between the livestock building and the pumping pit must be designed in a way that efficiently ensures that gases liberated from the slurry/semi-liquid manure are not emitted into the livestock building or any other buildings where it can cause poisoning of animals and staff. Therefore the connection must be equipped with a water trap. In practice using a submerged inlet often does this. See figures 5.8 and 5.9.
5.8. Pipelines for slurry and urine

Designing, construction and operation of the pipelines shall comply with the European standards for external sewerage systems (EN 752 External Sewerage Systems and PN EN 752) and the equivalent Polish legislation. In the just mentioned set of standards the following sections are applicable to the pipelines:

- General Terminology and Definitions
- Requirements
- Planning
- Modernisation
- Operation and maintenance
Relevant elements have been taken from the above standards and adapted to the designing and operation of pipelines used for transportation of liquid manure.

**Key definitions:**

- **Falling gradient**: The ratio of vertical to horizontal projection of the duct length.
- **Gravitational system**: Sewerage system where the liquid flows due to the terrestrial gravity force and the ducts are designed for operation when partly filled.
- **Sewer trap**: A section of the sewer situated lower than the adjacent sewer sections.
- **Self – cleaning**: The system’s flow capacity facilitating the motion of solid fragments that would otherwise sediment in the pipelines.
- **Sewerage system**: A network of pipelines and auxiliary equipment/facilities designed for carrying the sewage (urine or slurry) away to the collecting pit and storage tank.

**Classification of pipelines and fittings**

- Classification by the type of transport: gravitational and pressure (or negative pressure) pipelines: Classification by the type of materials used: galvanised steel, PE, PVC, and aluminium alloy pipes.

**Table 5.1. Classification of pipes and fittings.**

<table>
<thead>
<tr>
<th>Diameter, (mm)</th>
<th>Function</th>
<th>Materials</th>
<th>Operating parameters</th>
<th>Other data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Circumferential rigidity, kPa</td>
<td>Roughness coefficient, k</td>
<td></td>
</tr>
<tr>
<td>160, 200, 250*</td>
<td>Gravitational</td>
<td>PVC of the N classpipe</td>
<td>up to 4</td>
<td>0.4 Bell-and-spigot joints</td>
</tr>
<tr>
<td>63, 75, 90, 110</td>
<td>Pressure</td>
<td>PVC, PN 6</td>
<td>8 kPa</td>
<td>0.01 to 0.05 Bell-and-spigot pipe joints</td>
</tr>
<tr>
<td>160, 225*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50, 63, 75, 90</td>
<td>Pressure</td>
<td>PE 80, PN 6</td>
<td>5</td>
<td>0.01 Welded joints</td>
</tr>
<tr>
<td>110, 125, 160,</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>180, 200, 225*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>51, 63, 76, 1,</td>
<td>Pressure</td>
<td>Seamless galvanised steel line pipes</td>
<td>0.8 to 1.5 bell-and-spigot pipe joints</td>
<td></td>
</tr>
<tr>
<td>88, 9, 108, 133,</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>159, 219, 1*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50, 75, 90, 110</td>
<td>Pressure</td>
<td>Aluminium alloy PA11</td>
<td>0.4 to 0.8 Quick-connection joints</td>
<td></td>
</tr>
<tr>
<td>130*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*External diameters.
Requirements on pipelines:

- Sewer traps: the pipelines carrying away slurry/urine from the livestock buildings to the sump have to be equipped with sewer traps protecting the system against backward movement of gases to the buildings; the traps should work properly regardless of the slurry level in the sump. The ventilation systems in the sumps and buildings should ensure 100% efficiency of the sewer trap operation.

- Falling gradients and flow velocities: the falling gradients in the gravitational pipelines should ensure a free outflow of slurry (falling gradient $s = 1.5\%$). The velocities in the pipelines should ensure self-cleaning of the pipelines and may not be less than $V = 0.7$ m/s.

- The pressure pipelines at points where the flow direction changes and the angle exceed $15^\circ$ (at bends, elbows, T-pipes and valves) should be protected with back-up blocks (fig. 5.10).

- The pipeline passages through the walls of sumps and storage tanks should be leak proof.

- To prevent freezing of slurry in winter, the pressure pipelines should be designed with reverse falling gradients so that after completion of the pumping cycle the slurry returns from the pipeline to the sump.

- The pipelines should be laid underground with due consideration to the frost penetration depths expected for the local climatic zone. The problem is the point where the pipes come to the surface, see Fig. 5.8.

- The pipelines should be laid in line with the best practice and requirements of the construction industry; the covering material compaction degree should not be less than 90% (measured by means of the modified Proctor's test), but under roads the proportion should be 92 to 94% on the Proctor's scale. In the case of pipelines laid at a level lower than 4.0 m below the ground level, it is sufficient to have 85% on the Proctor's scale (pipelines should be laid in line with the requirements of EN 805).

- The leakproofness of a pressure pipeline should be checked whenever the pipeline is laid, but prior to backfilling of the excavation, in line with the requirements of EN 805; the leakproofness of a gravitational pipeline should be checked in line with the requirements of EN 476 (pressure range of 0 to 50 kPa).
In case of slurry transportation, the pressure pipelines with diameter of up to 110 mm can work together only with pumps equipped with shredding devices designed for operation in unfavourable conditions.

**Fittings**
Ball valves can be used as fittings for pressure pipelines with diameters 50 and 63 mm, but above this upper limit gate valves should be used. Gate valves should also be used in gravitational systems. In pressure systems ball check valves should be used. In long pipelines (over 50 m), washing of the pipeline should be made possible from hydrant wells located on the pipelines. All the fittings should be protected against corrosion and have relevant conformity certificates allowing them to be operated at pressures of up to 0.4 MPa.

### 5.9. Types of Storage Facilities

Storage tanks for urine and slurry can either be constructed in situ or constructed of prefabricated elements of steel or concrete. In this section the most common types are described.

**Closed urine/slurry tanks**
In general the following types of closed tanks can be distinguished:

- Ground-based tanks
- Partially sunken tanks
- Underground (sunken) tanks
The cover of closed tanks is required to carry its own load, the snow load, the soil load and the vehicles load. In the case of underground closed tanks with construction that is not adapted to carry the weight of vehicles, the area around the tanks should be fenced and marked with warning signs. The fencing or another construction used should prevent vehicles from driving onto the tank.

An access opening and ventilation hole should be made in the tank cover. The minimum size of the access opening is a diameter of 600 mm. The access opening can also be used for inserting a pump or agitator into the tank; if this is the case, the size of the opening should be adjusted to dimensions the equipment used. The outlet of the ventilation hole should be located at least 0.5 m above the ground level. A simple option is to mount a straight pipe ended with a canopy (or without a canopy) in the cover. In the case of ground-based or partially sunken closed tanks standing out more than 0.5 m above the ground level, it is sufficient to make a ventilation hole in the tank cover. Closed tanks can be made of prestressed concrete, reinforced concrete, plain concrete, plastic or steel.

In order to ensure appropriate conditions for operating the storage tank, the following requirements should be met:

- Vehicles should be able to access the storage tank
- Access roads to the tank should be at least 3 m wide;
- Falling gradients should be made on the tank bottom oriented towards the spot where the pump is mounted.
- Falling gradient should be made around the storage tank to ensure that precipitation water flows away from the storage tank
- In the case of partially sunken and underground tanks, the excavation should be backfilled with an absorbent material that may not contain large or sharp stones.
Examples of closed tank types:
- Plain or reinforced concrete tank;
- Plastic tank;
- Prefabricated reinforced concrete tank.

Open tanks

The following types of the open tanks can be built:
- Ground-based tanks;
- Partially sunken tanks.

Open tanks can be built of the following materials:
- Plain concrete;
- Pre-stressed concrete;
- Reinforced concrete;
- Plastic;
- Steel.

In order to ensure appropriate conditions for operating the tank, the following requirements should be met:
- Vehicles should be able to access the storage tank
- Access roads to the tank should be at least 3 m wide;
- Falling gradients should be made on the tank bottom oriented towards the spot where the pump is mounted.
- Falling gradient should be made around the storage tank to ensure that precipitation water flows away from the storage tank
- In case of partially sunken and underground tanks, the excavation should be backfilled with an absorbent material that may not contain large or sharp stones.
- Ground-based or partially sunken open tanks less than 1.8 m high should be protected by means of fencing of at least 1.8 m height. Service platforms and open tank service access paths should be equipped with protective railing 1.1 m high with a rail located halfway up and another one at the height of 0.15 m above the platform.

Examples of open tank types:
- Pre-stressed concrete tank
- Reinforced concrete tank
- Prefabricated reinforced concrete tank
- Steel tank

Lagoons for slurry

Another alternative method / technology for storing liquid manure is a lagoon. A slurry lagoon is constructed as a large hollow in the ground covered with a waterproof foil. A similar foil floats on the surface of the slurry to prevent ammonia emission and nuisances from odours.
Advantages:
• Reduction of ammonia emission by 90% compared to open storage tanks
• Storage capacity increase by up to 25% - as rainwater is not collected
• Increased content of nitrogen in the slurry (up to 12%) - as ammonia emission is prevented
• Reduced field application costs, because of no rainwater in the storage
• No nuisances from odours
• Practical and maintenance-free storage.

Construction
To establish a slurry lagoon, a 1.5 m deep hollow is excavated and 1.5 m earth banks are raised around it. The bottom of the hollow must be levelled and the edges of the sidewalls must be planed off so they have a slope of 1:1.5 (~33°).

First, the bottom and sides of the hollow must be covered with a 1.0 mm protection foil (PVC, PE or PP). The foil is spread all the way up to the bank edge where it is anchored in the ground.

Then a drainage system is established by laying out 300 mm sand with built-in drains. Alternatively a drainage mat can be used. The drainpipes are installed at the sides of the hollow with a slope towards an inspection hole in the bank. Finally, the bottom of the hollow is covered with 1.5 mm bottom foil.

In connection with the drainage system an alarm system must be set up. The purpose of the alarm system is to react if the bottom foil is leaking manure.

The lagoon must be covered by a foil with ventilation openings corresponding to 80 cm² per 100 m². The ventilation openings leaks the gasses produced in the slurry and prevents any risks of explosions.
For agitating the slurry a stationary unit is mounted in the centre of the lagoon to avoid damage to the bottom foil. It is not possible to use any kind of propellers for agitation, since it will cause damage to the foils. Instead, a pump is used, flushing the slurry in the lagoon and by that diluting the dry matter in the liquid part.

To prevent children or others from access to the lagoon, the area must be secured by means of a solid fencing with a height of at least 1.8 m.

**Slurry storage in livestock buildings**

Slurry can be stored in the livestock building, underneath the slatted floor, as shown in Figures 5.14 and 5.15. Slurry is collected in a channel under the slatted floor for a period of 3 to 6 months depending on the technology used. As in the case of storage tanks located outside the livestock building, the bottom and walls of the channels have to be impermeable (leakproof).
**Figure 5.15.** Storage of slurry in a channel running along the feeding alley under the slatted floor.

### Storage of slurry in manure channels

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Little work required for daily maintenance operations</td>
<td>Costly construction of deep channels and the slatted floor which covers the channels</td>
</tr>
<tr>
<td>Slurry to be removed every 3 to 4 months</td>
<td>Poisonous gases may escape from slurry collected in the channels during handling</td>
</tr>
</tbody>
</table>
6. Equipment for handling manure

6.1. Introduction

The chapter describes the different technical solutions for the handling of slurry and liquid manure from the collecting pit to the storage tank. It also describes machines for agitating and pumping liquid manure from the storage tank to the tanker.

6.2. Equipment for handling liquid manure - slurry

If the storage tank for urine and slurry is located above the ground level, mechanical equipment must be used to bring liquid manure from the livestock buildings or collection pit to the storage facility.

Several different types of lifting and pumping techniques can be used. To minimise odour and loss of ammonia when pumping to the storage tank it is recommended to have a submerged inlet in the tank. In this case it is absolutely necessary to have an air inlet at the highest point of the pipe. Otherwise the slurry might be sucked back to the pumping pit when the pump is stopped. See example in Figure 6.1.

**Figure 6.1.** Pump system from collecting pit to storage tank.

**Centrifugal pumps**

The most common types of pumps are centrifugal pumps. There are several types of such pumps, driven by electric motor or by tractor. The most common type is the long shaft vertical pump, which consists of a pumping part submerged in the slurry and a motor or gearbox placed on the pumping pipe above the surface of slurry, Figure 6.2. Nowadays, the submerged pumps are used more and more often.
There are also several types of submerged pumps. In such cases the electric motor has a completely waterproof casing DB 68, Figure 6.3. The pumps are often constructed in a way that they easy can be disconnected from the pump pipe. It is an advantage when the pump is to be used in more than one place. Then only one pump pipe in each place is required.
It is important that the pump should keep the suction part free of straw or other types of foreign materials. Therefore the pumps should have a cutting device to prevent clogging in the pump housing. It can be a sharp edge on the pump-wheel working against a sharp edge in the bottom of the pumping house.

Another solution is to use a free flow pumping wheel (vortex). The vortex pump can pump slurry containing solid objects (straw, pieces of maize etc.) reaching its flow and pump space due to the placement of the wheel in the upper part of the pumping house.

Pumps can have different capacities depending on the power available. The pumping pipe can have a diameter from 50mm up to 250mm. The capacity of the most common pumps is shown in Figure 6.4. The largest tractor driven pumps with a 250 mm pumping pipe can pump up to 1,800m³ per hour.

Table 6.1. Capacity of slurry pumps depending on the content of straw in the slurry.

<table>
<thead>
<tr>
<th>Pumping capacity, (m³/hour)</th>
<th>Motor size, kW</th>
<th>2</th>
<th>3</th>
<th>5,5</th>
<th>7,5</th>
<th>11</th>
<th>15</th>
<th>25</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without straw</td>
<td>30</td>
<td>50</td>
<td>90</td>
<td>130</td>
<td>150</td>
<td>200</td>
<td>375</td>
<td></td>
</tr>
<tr>
<td>With straw</td>
<td>0</td>
<td>0</td>
<td>40</td>
<td>75</td>
<td>100</td>
<td>135</td>
<td>265</td>
<td></td>
</tr>
</tbody>
</table>

Advantages and disadvantages of centrifugal pumps

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Relatively simple construction</td>
<td>• Low efficiency at small pumping capacities</td>
</tr>
<tr>
<td>• Can handle slurry with straw or solid parts</td>
<td>• Expensive in use because of high power demand</td>
</tr>
<tr>
<td>of other bedding materials</td>
<td></td>
</tr>
<tr>
<td>• High pumping capacity</td>
<td></td>
</tr>
<tr>
<td>• Relatively low investment</td>
<td></td>
</tr>
</tbody>
</table>
Centrifugal pumps can also be placed in a dry chamber, (Figure 6.4). The solution is used in systems where the slurry is pumped directly from the livestock building to the storage tank.

In order to avoid damages on the pump, it is important that the slurry is free of stones, metal pieces and similar hard objects.

**Other pump types**
For special purposes, e.g. pumping over a long distance, it may be necessary to use a high-pressure pump.

The self-priming centrifugal pump has the pumping wheel placed in one side of the pump housing so that hard pieces like stones can pass the pump without damaging the pump, (Figure 6.5).

<table>
<thead>
<tr>
<th>Advantages ad disadvantages of self-priming centrifugal pumps</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Advantages</strong></td>
</tr>
<tr>
<td>• Relatively simple construction</td>
</tr>
<tr>
<td>• Can handle slurry with straw</td>
</tr>
<tr>
<td>• Medium high pumping pressure</td>
</tr>
<tr>
<td>• Relatively low investment</td>
</tr>
</tbody>
</table>
The monopump is a rotating positive displacement pump with a helix shaped steel rotor and a stator made of hard rubber, Figure 6.6. It can pump with a pressure up to approximately 10 bars. Because of the pulsating flow, it is recommended to mount special dampers in the pumping pipeline. It is self-priming; therefore it also can be used on a tanker.

## Advantages and disadvantages of monopumps

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Can pump with high pressure</td>
<td>• Expensive</td>
</tr>
<tr>
<td>• Self-priming</td>
<td>• Can be damaged by stones in the slurry</td>
</tr>
<tr>
<td></td>
<td>• High maintenance cost</td>
</tr>
<tr>
<td></td>
<td>• Vibrating flow</td>
</tr>
<tr>
<td></td>
<td>• Has no cutting device at the inlet</td>
</tr>
</tbody>
</table>

Figure 6.5.  Self-priming centrifugal pump.

Figure 6.6.  Monopump.
The rotary lobe pump is also a rotating positive displacement pump. It works like a gear-pump but instead of gearwheels it has two rotors of hard rubber, Figure 6.7. The shape of the rotors can be different. Because of the pulsating flow, it is recommended to mount special dampers in the pipeline. The rotary lobe pump is self-priming and is very suitable for self-filling tankers.

Advantages and disadvantages of rotary lobe pumps

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Can pump with high pressure</td>
<td>• Will be damaged by stones in the slurry</td>
</tr>
<tr>
<td>• Relatively simple construction</td>
<td>• High maintenance cost</td>
</tr>
<tr>
<td>• Self-priming</td>
<td>• Vibrating flow</td>
</tr>
<tr>
<td></td>
<td>• Has no cutting device at the inlet</td>
</tr>
</tbody>
</table>

Screw conveyor

A screw conveyor consists of an auger in a trough. It can be tilted up to 25 degrees, Figure 6.8. A screw conveyor can be used if the slurry only has to be lifted from one level to another e.g. from a collecting pit to the storage tank.

Advantages                                      | Disadvantages                                      |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Relatively simple construction</td>
<td>• Cannot be used for agitating</td>
</tr>
<tr>
<td>• Can handle slurry with straw</td>
<td>• Can only be used for lifting slurry from one level to another</td>
</tr>
<tr>
<td>• High capacity</td>
<td></td>
</tr>
<tr>
<td>• Relatively low price</td>
<td></td>
</tr>
</tbody>
</table>
Agitation of slurry
The heavy parts of the dry matter content in the slurry sink to the bottom of the slurry tank and form a solid mass, while the lighter parts float to the top of the tank and form a crust. Before emptying the storage tank, it is necessary to agitate the slurry in order to ensure a homogeneous mixture before spreading it.

There are differences between pig and cattle slurry. Pig slurry tends to separate much faster than cattle slurry. In some cases up to 50% of the sediments sink to the bottom of the tank just 15 minutes after the mixer is stopped. To prevent separation it is necessary to start the agitating system in pig slurry 0.5 hours before the pumping and continue throughout the emptying of the storage tank.

Cattle slurry stays homogeneous for several days after agitating, without forming a crust.

Mixing slurry with a pump
A pump can also be used for agitating the slurry in the storage tank. To ensure a sufficient agitation capacity, it is recommended to choose a pump with a pumping capacity of minimum 20% of the storage tanks capacity. For a 500m³ tank a pump should be used with a capacity of at least 100m³ per hour. The necessary power demand will be approximately 11kW depending on the amount of straw in the slurry.

A pump with submerged motor is more suitable for mixing than a pump with vertical shaft, since it is possible to adjust the placement of the pump.
In collecting pits it is most common to use the pump to mix the slurry before pumping it to the storage tank or flushing the slurry channels in livestock buildings. Some pumps have a special short and moveable pipe near the bottom of the pump, see Figure 6.2. This pipe can be adjusted from the top of the pump so that the jet from the pipe can be directed against the hardened parts of the slurry.

<table>
<thead>
<tr>
<th>Advantages and disadvantages of using pumps for agitation of slurry</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Advantages</strong></td>
</tr>
<tr>
<td>• The pump is often available on the farm</td>
</tr>
<tr>
<td>• Tractor-driven pumps have good agitating capacity</td>
</tr>
</tbody>
</table>
Figure 6.9. Tractor-propeller for underground tanks.

Figure 6.10. Tractor-propeller for aboveground storage tanks.

**Propellers with submerged motor**

An agitator can also be constructed as an electrically driven propeller where the propeller is mounted directly on the motor axle or with a reduction gear between the motor and the propeller. The propeller is mounted on a mast, which can be turned from side to side. The propeller is suspended on a wire, so it can be lifted up and down, Figure 6.11. Therefore, it can be used for mixing of both sediments and crusts. The power of the motor can vary from 1.5 to 15 kW.
Advantages and disadvantages of propellers with submerged motors for agitation of slurry

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Flexible in height and direction</td>
<td>• Relatively expensive</td>
</tr>
<tr>
<td>• Well suitable for agitating both sediments and crust</td>
<td>• Limited power of motor, thus not suitable for all tank sizes</td>
</tr>
<tr>
<td>• Needs no supervision</td>
<td></td>
</tr>
</tbody>
</table>

If the mixing was not done on a regular basis and an crust or bottom sediment has formed, the mixing time may be up to 4 hours, and mixing thickness – about 100 W/m³ of the tank capacity. Following regular mixing, the time needed to mix the slurry is 15 - 30 minutes with thickness of 2.8 do 3.7 W/m³ of tank capacity.

**Emptying the storage tank**

When liquid manure is to be brought to the field, this can be done by a tanker or the slurry/urine can be pumped directly to the fields through an umbilical system.

**Self-filling tankers**

A self-filling tanker can be a vacuum tanker or a tanker with a mounted filling pump, see Figure 6.12. If the storage tank is placed below the ground level, a relatively simple self-filling tanker can be used to bring the slurry to the field. If the storage tank is above the ground, it can be emptied directly if the tanker has a movable arm to lift the suction hose or filling pump over the edge of the storage tank.
In systems where the slurry flows back to the collection pit before use the self-filling tanker is not recommended, since straw or other materials can get stuck in the valve. Hence the valve cannot be turned off; this can result in pollution of surface waters if the slurry continues to flow.

**Tankers without filling device**
When a separate pump is used to fill the tanker, it should be placed in the storage tank. If the slurry tends to separate fast, the pump can be used for agitating while the tanker is out to the fields.

**Umbilical system**
If the fields surround the farm, slurry can be pumped directly to the spreading system through pipes and hoses. In order to overcome the resistance in the pipes, the pump should normally have the ability to perform a higher pressure.

**Remote control of pumps and agitators**
If a tractor-driven pump is used for pumping and agitating, it can be convenient to change from agitating to pumping by remote control. The remote control is a radio transmitter in the tractor with the tanker and a receiver in the tractor with the pump. The tractor driver can switch the pump from agitating to pumping position and back. A safety device can stop the pump after a certain time, which can be adjusted so the pump automatically stops when the tanker is full.

### 6.3. Handling equipment for solid manure

Table 6.2 shows parameters for the key equipment used for removal of manure from livestock buildings and for transportation to the manure storage.
Table 6.2. Parameters of machinery and equipment used for removal and storage of manure.

<table>
<thead>
<tr>
<th>Type of machinery or equipment</th>
<th>Capacity [t/h]</th>
<th>Number of stalls [pcs]</th>
<th>Working width [cm]</th>
<th>Lifting height [cm]</th>
<th>Transporta- tion velocity [m/s]</th>
<th>Recommended for</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front scraper</td>
<td>15.0</td>
<td>&gt; 100</td>
<td>165</td>
<td>280</td>
<td></td>
<td>Removal of manure from cowsheds, cow-runs, cattle-driving roads</td>
</tr>
<tr>
<td>Circular conveyor</td>
<td>4.0</td>
<td>20-60</td>
<td></td>
<td>0.2-0.6</td>
<td></td>
<td>Removal of manure</td>
</tr>
<tr>
<td>Shuttle conveyor</td>
<td>5.6</td>
<td>120</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydraulic</td>
<td>Up to 5</td>
<td>50</td>
<td></td>
<td></td>
<td></td>
<td>Removal of manure scraper from single- and multi-row cowsheds</td>
</tr>
<tr>
<td>Shovel device</td>
<td>Up to 5</td>
<td>15</td>
<td>70-90</td>
<td>0.3-0.6</td>
<td></td>
<td>Removal of manure</td>
</tr>
<tr>
<td>Universal scraper</td>
<td>4.0</td>
<td>60</td>
<td></td>
<td>0.6</td>
<td></td>
<td>Removal of manure and shaping of heaps up to 4 m high</td>
</tr>
<tr>
<td>Front loader</td>
<td>Up to 65</td>
<td>&gt; 50</td>
<td>370</td>
<td></td>
<td></td>
<td>Shaping of heaps and loading of manure onto vehicles</td>
</tr>
<tr>
<td>Grab loader</td>
<td>6-30</td>
<td></td>
<td>400</td>
<td></td>
<td></td>
<td>Shaping of heaps and loading of manure onto vehicles</td>
</tr>
</tbody>
</table>

Figure 6.13. Manure handling equipment: 1 – Scraper conveyor in a longitudinal channel, 2 – Scraper conveyor in a transverse channel, 3 – Fork scraper at the manure outlet.
Figure 6.14. Mechanical shovel: 1 – shovel, 2 – transmission rope, 3 – drive, 4 – guide roll, 5 – return roll, 6 – mast, 7 – deflector roll, 8 – breaker switch.

Figure 6.15. Scraper conveyors: 1 – feeding alley, 2 – longitudinal channel, 3 – transverse channel, 4 – dunghill.
Advantages and disadvantages of scraper conveyors

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Improved environmental conditions (excrements removed twice a day)</td>
<td>• Require construction of large tanks for liquid manure outside the building</td>
</tr>
<tr>
<td>• Construction of shallow channels is cheaper than construction of deep ones</td>
<td></td>
</tr>
</tbody>
</table>

**Tractor-mounted scrapers**

Tractor-mounted scrapers can be used for removal of excrements from dung channels and loading of manure onto the manure spreader in the case of manure stored inside the building (deep litter).

![Image](image.png)

*Figure 6.16. Removal of manure from dung channels by a front loader with a bucket scraper.*

Bucket scrapers are suitable when the dry matter content in the manure is low because of small amounts of bedding, while fork scrapers are more suitable when the straw content in the manure is high. Also, the fork scraper is better suited for removal of manure from deep litter systems.
Figure 6.17. Tractor-mounted front loader with fork scraper used for removal of manure from deep litter system.

Caution: It is advisable to operate the tractor at a low rotational speed of the engine crankshaft to ensure a minimum emission of exhaust gases and noise!

Other manure removal options
Fig. 6.18 shows a loader used for removal of manure from livestock facilities where animals are kept on deep litter, and designed for mounting on a tractor in the three-point linkage system.

Figure 6.18. Manure loader for mounting in the three-point linkage system.
Advantages of individual options:

- The use of mobile equipment guarantees effective removal of manure. In the case of a tractor failure, it can be replaced with another machine.
- If scraper conveyors are chosen, the noise emission is lower as compared to mobile equipment, and exhaust gas emission is eliminated altogether.
- Hydraulic driven conveyors of the “mole” type reduce the ammonia emission, since the surface of the heap is kept dry.
7. Treatment plants for manure

7.1. Introduction

This chapter gives a short and general description of the treatment of manure in biogas and composting plants. Biogas plants are multifunctional plants, which combine renewable energy production with agricultural and environmental advantages. Composting plants can be another way of treating manure to improve its quality.

Biogas is a gas that emerges in the process of anaerobic fermentation of animal excrements and nearly all organic waste products, especially those with a high fat content, with contribution of the methane bacteria. Biogas emerging in nature, especially from cellulose, is the so-called marsh gas as well the gas produced in garbage heaps during anaerobic fermentation of garbage.

### The chemical composition of biogas is as follows:

<table>
<thead>
<tr>
<th>No.</th>
<th>Component</th>
<th>Formula</th>
<th>Content [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Methane</td>
<td>CH₄</td>
<td>52 - 85</td>
</tr>
<tr>
<td>2</td>
<td>Carbon dioxide</td>
<td>CO₂</td>
<td>14 - 18</td>
</tr>
<tr>
<td>3</td>
<td>Hydrogen sulphide</td>
<td>H₂S</td>
<td>0.08 – 5.5</td>
</tr>
<tr>
<td>4</td>
<td>Hydrogen</td>
<td>H₂</td>
<td>0 - 5</td>
</tr>
<tr>
<td>5</td>
<td>Carbon oxide</td>
<td>CO</td>
<td>0 – 2.1</td>
</tr>
<tr>
<td>6</td>
<td>Nitrogen</td>
<td>N₂</td>
<td>0.6 – 7.5</td>
</tr>
<tr>
<td>7</td>
<td>Oxygen</td>
<td>O₂</td>
<td>0.1 – 0.2</td>
</tr>
</tbody>
</table>

Methane is an odourless and inflammable gas that is extremely noxious for the atmosphere. It destroys the ozone layer with twenty times the strength of carbon dioxide. However, if combusted in special installations, it is no longer harmful for the environment.

It is used as biofuel, for heating (biogas calorific value: 20-27 MJ/m³), lighting and for engines. For comparison, the calorific value of natura gas is 33 MJ/m³.

7.2. Biogas plants

**Technical description**

The dry matter in animal manure and slurry consists among other things of carbon bound in organic compounds. In the biogas process, a large amount of this organic material is transformed into a mixture of methane (CH₄) and carbon dioxide (CO₂) with traces of other gases, whereas the nutrients remain in the degassed slurry. This mixture of CH₄ and CO₂ is called biogas.
Biogas plants can treat animal manure and slurry together with other organic waste products – mainly from the food industry. In the description below, these raw materials are called the biomass.

The biomass is mixed in a pre-process tank, before it is pumped to the digester tank(s). It is heated to a temperature between 35 and 52°C. The average retention time in the digester(s) is typically 2-3 weeks. By then, approximately a half of the dry matter is converted to biogas, and the degassed biomass is then pumped to a storage tank. It should be noted that the total volume of the biomass is not reduced substantially during the process, as more than 90 % of the biomass is water.

Even after the biomass has been pumped to the storage tank, some biogas production may still occur. It can be recovered by covering the storage tank with a light, airtight membrane.

Pumps do all internal transport of the biomass in the plant. The mixture of slurry and organic waste must therefore have a dry matter content that allows pumping, i.e. not higher than 12-14%; solid manure – for instance poultry manure - can be mixed together with slurry for co-digestion.

The concept can be summarised as follows:

![Figure 7.1. Concept of a biogas plant.](image-url)
Utilisation of biogas
Biogas can be utilised in several ways. It can be burnt in a boiler to produce heat, or in a cogeneration unit to produce electricity and heat. In a few instances, biogas has been distributed to small pipe systems to be used in individual households; however, this is normally not considered a relevant option.

Biogas boilers
Boilers for natural gas can also be used for biogas after small modifications. Thus there are a variety of applicable boilers available on the market with a thermal output from a few kW to several hundred kW or even a couple of MW.

The efficiency of modern natural gas boilers is high, above 90% for the best boilers. From biogas with methane content of 65%, a heat production of up to 6kWh/m³ of biogas can thus be expected.

The biogas does not have to be cleaned of H₂S before it is burnt in the boiler. The H₂S content can however – together with other substances in the biogas – result in some disposed waste products from combustion inside the boiler, which then has to be cleaned periodically.

Cogeneration units
A cogeneration unit is in principle an engine coupled to a generator. Electricity is produced by a generator whereas heat is recovered from the different cooling systems of the engine and from cooling the exhaust gas from the engine.

Standard cogeneration units for biogas range from 7.5 kW (electrical effect) to more than 1MW; however, any diesel or natural gas engine can in principle be rebuilt or modified to use biogas.

The electrical efficiency of the cogeneration units has been improved considerably over the last couple of decades, but there is still large variation – especially depending on the size of the unit. It varies between app. 20% for the smallest units up to almost 40% for the most efficient large units. The electricity production from 1 m³ biogas with 65% methane varies thus between 1.3 kWh and app. 2.5 kWh. The heat production varies between 2.9 kWh and app. 4.2 kWh.

In most cases, the biogas has to be cleaned for its content of H₂S before it can be used in cogeneration plants. During combustion, H₂S reacts with oxygen to produce H₂SO₄ (Sulphuric acid), the presence of which in the engine causes severe corrosion and thus reduces the engine's lifetime. H₂S-cleaning of the biogas can be done in several ways, for instance with different types of filters containing iron oxides. The simplest way is, however, to pass the biogas through a space, where there is a surface of slurry present (for instance in a covered storage tank) and then to inject small amounts of air (4%) into that space. Certain sulphuric bacteria take up H₂S and the sulphur stays in the degassed material and not in the biogas.

Electricity can be used on the farm or sold to the public network. Similarly, heat can be used on the farm for heating dwellings and/or livestock buildings, or it can be used in (small) district heating systems in villages.
**Farm biogas plants or centralised biogas plants?**

There are two types of biogas plants for agricultural purposes. Farm biogas plants are established on a single farm and treat slurry from that farm only (or perhaps from a couple of neighbouring farms). Centralised biogas plants are typically of considerably larger size; they are located in areas with high density of pig and/or cattle production, and they treat slurry from most or all of the farms in the area.

The centralised biogas plants often have a considerable potential for using many types of waste products. The receiving system on a farm biogas plant is often much simpler, and therefore only some waste products can be used there.

Treating a mixture of slurry from many farms in centralised biogas plant offers a potential for better distribution of nutrients in the area; the disadvantage, instead, is the large amount of road transport involved in moving the slurry to and from the plant. The farm biogas plant, on the other hand, does not intensify road transport; there is, however, no considerable potential for better distribution of the nutrients either.

Heat from cogeneration in a farm biogas plant is typically used on the farm, whereas heat produced by centralised biogas plants is often used in small or medium-sized district heating systems.

It is thus clear that many factors has to be taken into consideration before deciding which type of biogas plant should be preferred in a given situation.

**Agricultural and veterinary aspects**

Properties of manure/slurry change during the biogas process. Organic matter is broken down; organic nitrogen is converted into ammonia etc. This results in potential advantages in terms of nutrient uptake by the crops. However, this also involves a risk of increased nutrient loss (e.g. ammonia evaporation) if the degassed slurry is not handled with care.

Addition of other organic wastes from the food industry to the biogas plant has the advantage of recirculation of nutrients back to the agriculture. There are, however, certain veterinary aspects that have to be taken into consideration.

**Safety measures, rules and regulations**

Working with biogas presents two potential types of hazards.

Hydrogen sulphide (H₂S) is an extremely poisonous gas, and even very small amounts present in the biogas may be lethal if biogas is inhaled. Same precautions should thus be taken as those generally described in Chapter 2.3.

Biogas may be explosive if mixed with air in a certain ratio (between 15-20% biogas in air). Under normal circumstances, this will not occur; it can happen, however, in special situations:

- When emptying digester tanks for repair
- Leakage from gas storage

Precautions must therefore be taken to avoid these risks.
“When emptying biogas tanks or fermentation chambers (digesters) for repair, the tanks should be thoroughly ventilated before entering the tank or working on the tanks.”

Under Polish law (Journal of Laws No. 132 item 877), safety zones around external walls of biogas tanks and fermentation chambers should be established as follows (depending on the capacity of the tank/chamber):

- Up to 50 m³: 3 m
- 50 – 100 m³: 5 m
- Over 100 m³: 8 m

A safety zone should be separated with a fence at least 1.8 m high and marked with a safety board: “Biogas works. Danger of explosion. Fire use and smoking prohibited”.

**General distance requirements**

Biogas tanks and fermentation chambers (digesters) with capacities less than 100 m³ should be located at a distance of at least:

1) 15 m from windows and doors of houses and from livestock buildings,
2) 8 m from other buildings,
3) 5 m from the boundary of an adjacent parcel,
4) 15 m from coal and coke bunker,
5) 15 m from other fermentation chambers and biogas tanks,
6) 15 m from grain and fodder silos (with capacities over 100 tons),
7) 5 m from structures other than buildings.

Biogas tanks and fermentation chambers (digesters) with capacities over 100 m³ should be located on plots destined exclusively for biogas-works, and distances referred to in paragraph 1 above should be at least doubled.

**7.3. Composting plants**

Production of compost (apart from anaerobic processing) may be an approach used in the slurry management process for the purposes of more intensive utilisation of this material. The principle of production is outlined in schematic Figure 7.2.
**Technical description**

Slurry is subject to aerobic processing that consists in mixing the slurry with combine-harvested straw cut into pieces, peat and other organic waste. Solid manure can be also composted. Mixed material is fed to a chamber where it stays for about 3 months and is sprinkled with fresh slurry throughout the fermentation period. Generally, at the initial stage of the composting process the anaerobic processes are triggered by methane bacteria inoculation from processed slurry produced in a biogas plant.
These processes result in quick decomposition (reduction) of complex carbohydrates, products and lipids to simple compounds and their mineralisation. At the next stage, composted material is aerated. The aerobic fermentation process commences in the straw mix material, accompanied by increase in temperature up to 50 to 60°C. At the end of the process the temperature drops. Then the material should be stirred and placed on a compost slab, because the entire material should be additionally aerated by means of a blower. The exposed to intensive aeration, composted material is stored for the period of one month.

For the entire composting process to be effective, appropriate key conditions conducive to this process should be maintained, namely:

- Temperature within the range of 50 to 60°C;
- Humidity of 40 to 50%);
- Oxygen demand supply of about 1 m³/1 kg of the composted mix;
- Optimum pH value = 6 to 7.5;
- Organic matter size reduction resulting in an accelerated rate of decomposition due to improved microbiological activity.

**Construction of fermentation chambers**

The walls of the composting chambers are designed and made of small-dimension rectangular elements. This solution does not require the use of boarding for erection of the walls. This type of construction ensures high degree of the wall’s leak proof ness because the hollow bricks are made on the vibrating table. The foundation for the retaining walls of the chambers is made on piles. This allows the investor to reduce concrete consumption by about 20 % and work by about 20 to 30%.

**Agricultural and veterinary aspects.**

During the composting process big amounts of nitrogen are released as ammonia, which represents a hazard to the environment. Composting plans can thus only be recommended if the composting chamber is a closed system with recovery of the ammonia.

As has been mentioned above, this technology produces (apart from compost) a post-fermentation reflux with a content of nitrogen considerably lower than in raw slurry. The reflux can be used for fertilisation of grassland or other crops.

Animal excrements have a considerable microorganisms content, including bacteria, viruses, parasites and fungi. Most of them cause diseases in humans as well as animals. Shown below is a list of diseases and parasites transferred to humans as a result of improper handling of animal excrements. The processing of excrements in biogas and composting plants renders most of the pathogenic factors harmless.
Diseases and organisms transferred through animal excrements [after CIGR Handbook of Agricultural Engineering. ASAE, USA, 1999, vol. II, s. 168]:

<table>
<thead>
<tr>
<th>Disease</th>
<th>Responsible Organism</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacterial</td>
<td></td>
</tr>
<tr>
<td>Salmonella</td>
<td><em>Salmonella spp.</em></td>
</tr>
<tr>
<td>Eptospirosis</td>
<td><em>Leptospiral pomona</em></td>
</tr>
<tr>
<td>Anthrax</td>
<td><em>Bacillus anthracis</em></td>
</tr>
<tr>
<td>Tuberculosis</td>
<td><em>Mycobacterium tuberculosis</em></td>
</tr>
<tr>
<td>Mycobacterium avium</td>
<td></td>
</tr>
<tr>
<td>Johnes disease, paratuberculosis</td>
<td><em>Mycobacterium</em></td>
</tr>
<tr>
<td>Brucellosis</td>
<td><em>Brucella abortus</em></td>
</tr>
<tr>
<td>Brucella melitensis, brucella suis</td>
<td><em>Ringworm</em></td>
</tr>
<tr>
<td>Listeriosis</td>
<td><em>Listeria monocytogenes</em></td>
</tr>
<tr>
<td>Tetanus</td>
<td><em>Clostridium tetani</em></td>
</tr>
<tr>
<td>Tularemia</td>
<td><em>Pasteurella tularensis</em></td>
</tr>
<tr>
<td>Erysipelas</td>
<td><em>Erysipelothrix rhusiopathiae</em></td>
</tr>
<tr>
<td>Colibacilosis</td>
<td><em>E. coli (some serotypes)</em></td>
</tr>
<tr>
<td>Coliform mastitis metritis</td>
<td><em>E. coli (some serotypes)</em></td>
</tr>
<tr>
<td>Rickettsial</td>
<td></td>
</tr>
<tr>
<td>Qfever</td>
<td><em>Coxiella bumeti</em></td>
</tr>
<tr>
<td>Viral</td>
<td></td>
</tr>
<tr>
<td>New Castle</td>
<td><em>Virus</em></td>
</tr>
<tr>
<td>Hog Cholera</td>
<td><em>Virus</em></td>
</tr>
<tr>
<td>Foot and Mouth</td>
<td><em>Virus</em></td>
</tr>
<tr>
<td>Psittacosis</td>
<td><em>Virus</em></td>
</tr>
<tr>
<td>Fungal</td>
<td></td>
</tr>
<tr>
<td>Coccidioidomycosis</td>
<td><em>Coccidioides immitus</em></td>
</tr>
<tr>
<td>Histoplasmosis</td>
<td><em>Histoplasma capsulatum</em></td>
</tr>
<tr>
<td>Various microsporum and trichophytan</td>
<td></td>
</tr>
<tr>
<td>Protozoal</td>
<td></td>
</tr>
<tr>
<td>Coccidiosis</td>
<td><em>Eimeria spp.</em></td>
</tr>
<tr>
<td>Balantidiasis</td>
<td><em>Balatidium coli</em></td>
</tr>
<tr>
<td>Toxoplasmosis</td>
<td><em>Toxoplasma spp.</em></td>
</tr>
<tr>
<td>Parasitic</td>
<td></td>
</tr>
<tr>
<td>Ascariasis</td>
<td><em>Ascaris lumbricoides</em></td>
</tr>
<tr>
<td>Sarcocystis</td>
<td><em>Sarcocystis spp.</em></td>
</tr>
</tbody>
</table>
**Example of a composting plant**

Composting chambers can be made as a silo sunken about 1 m below the ground level (Figure 7.3).

![Diagram of composting plant](image)

**Figure 7.3.** Example of composting plant: 1 – slurry pipeline, 2 – slurry tanker, 3 – pump, 4 – manure reflux basin, 5 – transverse channels for manure reflux disposal, 6 – longitudinal channels for manure reflux disposal, 7 – cover, 8 – air admission duct.

The walls of the composting facility are made of small-dimension concrete elements placed on a foundation made on piles. The front wall of the chambers is made of wooden beams and can be disassembled at any time. Thus a tractor with trailer (manure spreader) and grab/front loader can access the interior of the chamber for unloading purposes. A gutter runs all along the chamber bottom to the tank located outside the chambers; the tank collects the manure reflux. Dimensions of a single chamber are as follows: length 25 m, width 6 m, height 3 m. Both chambers can hold about 900 m³ of the compost material. As has been mentioned above, after a three months’ fermentation in the chambers the composted material is subject to further treatment on the compost slab (Figure 7.4.) equipped with a gutter into which air is fed by means of a pressure fan. At reloading from the fermentation chambers the entire material is additionally mixed with bark, sawdust and other additives, and crumbled. When the entire compost slab is filled, the material on the slab is subject to mechanical aeration for the period of one month.

The final product of the composting process shows a high degree of biodegradation (about 60%) and hygienic. It is safe bacteriological and chemically for both humans and the environment. After composting, humidity of the organic matter exceeds 60 %. Humidity of the entire material should be reduced to about 40%. In good weather, the material can be dried in the sun, with the thin layer of the compost spread on the concrete slab being continuously reshuffled. If the weather conditions are unfavourable, the compost can be additionally dried in a floor-heated drying room where warm air is supplied. The humidity level can be checked by means of the gravimetric drier.

The dried material should be sifted to eliminate mechanical contaminants, and crumbled into fine pieces. Material prepared this way is the key component of dressing. On the basis of this material two dressing mixes have been developed: BIOKOM-1 and BIOKOM-2. The former (pH value = 7.5) is designed for fertilisation of vegetables, field crops, garden crops, as well as crops cultivated in greenhouses and foil tunnels; the latter is designed for cultivation of coniferous plants (pH = 5.5).
Table 7.1. Quantitative composition of the BIOKOM-1 dressing.

<table>
<thead>
<tr>
<th>Component</th>
<th>Volume proportions (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compost</td>
<td>60</td>
</tr>
<tr>
<td>Peat</td>
<td>10</td>
</tr>
<tr>
<td>Coniferous tree bark</td>
<td>10</td>
</tr>
<tr>
<td>Hen droppings</td>
<td>10</td>
</tr>
<tr>
<td>Dolomite</td>
<td>10</td>
</tr>
</tbody>
</table>

Table 7.2. Quantitative composition of the BIOKOM-2 dressing

<table>
<thead>
<tr>
<th>Component</th>
<th>Volume proportions (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peat</td>
<td>50</td>
</tr>
<tr>
<td>Coniferous tree bark</td>
<td>10</td>
</tr>
<tr>
<td>Compost</td>
<td>30</td>
</tr>
<tr>
<td>Magnetite</td>
<td>5</td>
</tr>
<tr>
<td>Ammonium sulphate</td>
<td>5</td>
</tr>
</tbody>
</table>
8. **Technical construction examples**

The construction examples in this annex are based on both EU and Polish legislation. Also, the examples base on the constructions that can be recommended in view of all their advantages and disadvantages, construction and operation costs included.

**General requirements regarding foundation**

The foundation is an important part of the building and in each single project it must be calculated and dimensioned according to the specific soil conditions and climate zones.

The minimum depth of foundations on the non-heave ground amounts to 0.5 m below the ground level. Heave grounds are all the organic grounds as well as the grounds, where content of molecules with the substitute diameter $d<0.02$ mm is higher than 10%. According to such definition this group also includes clay, silt and clayey sand. The level of foundation on the heave ground should be lower than the level of frost penetration. Depending on the region of Poland, the necessary depth varies from 0.80 to 1.40 meters.

Buildings should be founded below the frost penetration level. The frost penetration zones in Poland are shown on a map attached to the standard PN – 81 / B – 03020 “Building grounds. Direct founding of structures. Static calculations and designing.”

*Figure 8.1. Depth of foundation (hz) for different zones in Poland.*
8.1. Manure storage with a low demarcation wall

Figure 8.2. Example of manure storage with a low demarcation wall of in-situ cast concrete.
Under Polish ordinances regulating animal production as well as the storage of manure, silage etc., the bottom of the manure storage must be made of a material that is highly resistant to moisture, as for instance 150 mm concrete 25 MPa, plus an effective waterproofing agent.

An appropriate run-off system must be established.

A 110 mm-PVC pipe with a 20 mm slope per 1 metre is capable of draining a maximum of 100 mm rainwater from an area of 360 m².

**Work instructions**

Before establishing the bottom of the manure storage, loamy soil from under the entire storage area must be removed as far as 0,5 metres outside its outer edges. Now the exact deposition of the installation can take place. The excavation of drain and foundation can be made.

Run-off shafts are to be placed as shown in the drawing for drainage of liquids to the collection pit and/or liquid manure or slurry tank.

The run-off shafts can be 315 mm-diameter PVC shafts or other certified shafts. A 110 mm-PVC pipe makes the effluent pipeline. The pipe should have a 20 mm slope per 1 metre. As a minimum, the foundation should be established at a frost-proof depth. Depending on the region of the country, the necessary depth varies from 0.80 to 1.40 metres. The material should be 25 MPa concrete.

Levelling with coarse-grained sand at a depth of 150 mm under settled construction can be done next. The non-capillary layer is laid out and carefully vibrated in order to avoid subsequent sinking.

**Bottom casting**

The bottom of the manure storage and the exit slope (ramp) are made of 150 mm 25 MPa concrete. The bottom of the manure storage and the exit slope (ramp) are reinforced with 150x150x6 mm welded reinforcement net, placed 40-50 mm from the bottom. The bottom of the manure storage and the exit slope (ramp) must have a slope towards the runoff of 30 mm per 1 metre.

Run-off shafts are to be covered with cast-iron slats (dome grating). Manure must not be placed at the exit slope (ramp). The demarcation wall must be at least 0.10 metres high.

**Field division**

Large concrete areas tend to crack because of shrinkage when the concrete dries. The cracking can be reduced if the floor is divided into crack joints of appropriate sizes. A single field should not be bigger than about 35 m², and its longer side may not exceed 6 metres.

**Crack joints**

The joints can be made by pressing a fitting as for instance a T-iron into the concrete when it is still moist but sufficiently settled for the joints to remain when the fitting is removed again.
**Casting**
The floor is cast between so-called conductors or already cast edges and is levelled to the upper edge, which indicates the finished floor surface height. Every second field (lane) is cast and when such fields (lanes) are sufficiently hardened their edges serve as conductors when casting the fields in between them.

The concrete is compressed and pulled off with a girder. After casting of the concrete, the joints are filled with asphalt. The concrete walls have to be made of 25 MPa concrete.

**Subsequent treatment**
After casting, the concrete must be efficiently protected from drying up by the use of plastic foil, curing agent or water. The covering must take place later not than half an hour after casting. The plastic foil must be kept in good condition and offer effective protection for at least 8 days.

**Surface treatment/maintenance**
The bottom of the manure storage should be protected by surface treatment, which must not be made until the concrete is at least 14 days old.

Concrete surfaces should be treated with an effective waterproofing agent, e.g. a fluoride product. It is important to follow the instructions from the supplier. The surface should be inspected once a year when the silo is empty. Any damages to the concrete from impact of a front loader or other equipment used in the storage must be repaired before the manure storage is used again.
8.2. Manure storage with a high demarcation wall

Figure 8.3. Example of manure storage with a high demarcation wall of in-situ cast concrete.
Under a Polish ordinance regulating animal production as well as the storage of manure, silage etc., the bottom of the manure storage must be made of a material that is highly resistant to moisture, as for instance 150 mm concrete 25 MPa, plus an effective waterproofing agent.

An appropriate run-off system must be established.

A 110 mm-PVC pipe with a 20 mm slope per 1 metre is capable of draining a maximum of 100 mm rainwater from an area of 360 m².

**Work instructions**

Before establishing the bottom of the manure storage, loamy soil from under the entire storage area must be removed as far as 0,5 metres outside its outer edges. Now the exact deposition of the installation can take place. The excavation of drain and foundation can be made.

Run-off shafts are to be placed as shown in the drawing for drainage of liquids to the pit and/or liquid manure pit, slurry tank or liquid manure tank.

The run-off shafts can be 315 mm-diameter PVC shafts or other certified shafts. A 110 mm-PVC pipe makes the effluent pipeline. The pipe should have a 20 mm slope per 1 metre.

As a minimum, the foundation should be established at a frost-proof depth. Depending on the region of the country, the necessary depth varies from 0.80 to 1.40 metres, (see Figure 8.1). The material should be 25 MPa concrete.

Levelling with coarse-grained sand at a depth of 150 mm under settled construction can be done next. The non-capillary layer is laid out and carefully vibrated in order to avoid subsequent sinking.

**Bottom casting**

The bottom of the manure storage and the exit slope (ramp) are made of 150 mm 25 MPa concrete. The bottom of the manure storage and the exit slope (ramp) are reinforced with 150x150x6 mm welded reinforcement net, placed 40-50 mm from the bottom. The bottom of the manure storage and the exit slope (ramp) must have a slope towards the runoff of 30 mm per 1 metre.

Run-off shafts are to be covered with cast-iron slats (dome grating). Manure must not be placed at the exit slope (ramp). The demarcation wall must be at least 1 metre high.

**Field division**

Large concrete areas tend to crack because of shrinkage when the concrete dries. The cracking can be reduced if the floor is divided into crack joints of appropriate sizes. A single field should not be bigger than about 35 m², and its longer side may not exceed 6 metres.

**Crack joints**

The joints can be made by pressing a fitting as for instance a T-iron into the concrete when it is still moist but sufficiently settled for the joints to remain when the fitting is removed again.
Casting
The floor is cast between so-called conductors or already cast edges and is levelled to the upper edge, which indicates the finished floor surface height. Every second field (lane) is cast and when such fields (lanes) are sufficiently hardened their edges serve as conductors when casting the fields in between them.

The concrete is compressed and pulled off with a girder. After casting of the concrete, the joints are filled with asphalt.

The concrete walls have to be made of 25 MPa concrete.

Subsequent treatment
After casting, the concrete must be efficiently protected from drying by the use of plastic foil, curing agent or water. The covering must take place not later than half an hour after the casting. The plastic foil must be kept in good condition and offer effective protection for at least 8 days.

Surface treatment/maintenance
The bottom of the manure storage should be protected by surface treatment, which must not be made until the concrete is at least 14 days old.

Concrete surfaces should be treated with an effective waterproofing agent, e.g. a fluoride product. It is important to follow the instructions from the supplier. The surface treatment should be inspected once a year when the silo is empty. Any damages to the concrete from impact of a front loader or other equipment used in the storage must be repaired before the manure storage is used again.

8.3. Collecting pit for urine and slurry made of prefabricated concrete rings

Figure 8.4. Collecting pit for urine and slurry made of prefabricated concrete rings.
Under a Polish ordinance regulating animal production as well as the storage of manure, silage etc., the bottom of the manure storage must be made of a material that is highly resistant to moisture, as for instance 150 mm concrete 25 MPa, plus an effective waterproofing agent.

**Excavation**
The excavation radius should be at least 800 mm larger than the planned tank’s external radius. The slope of the excavation must not be steeper than 1:2 for excavation depth under 5 meters. Incidentally, the excavation wall should always have a slope, which prevents dangerous soil slides from happening.

**Casting of the bottom**
The bottom is levelled with coarse sand before casting. The non-capillary layer is laid out and carefully vibrated in order to avoid subsequent settling.

The bottom is cast with 150 mm concrete 25 MPa.
The bottom well ring can also be supplied and mounted with the cast bottom.

**Subsequent treatment**
After casting, the concrete must be efficiently protected from drying up by the use of plastic foil, curing agent or water. The covering must take place later not than half an hour after casting. The plastic foil must be kept in good condition and offer effective protection for at least 8 days.

**Assembling**
The first well ring is levelled. Subsequently, casting with a 1:2 ratio concrete mortar is now possible. Now the remaining well rings can be mounted. The pre-fabricated well rings can be provided with for instance tongue and groove and sealed with butyl for improved tightness. The well should be covered with a tight concrete cover. In areas with much traffic, the well cover is dimensioned to bear the biggest likely load and provided with a hole to the stationary pump.

For inspection of the well and pump, the cover should be fitted with a loose, removable part or with a manhole covered with a steel plate.
8.4. Rectangular slurry tank constructed in situ

**Excavations**
Construction of underground or partially sunken tanks requires preparation of open excavations i.e. those with unprotected walls. Stability of the walls is ensured by an appropriately designed gradient of the slopes. The gradient can vary from 1:0.25 in silty soils to 1:0.75 in sandy soils. In the case of excavations deeper than 1.5 m, the walls should be appropriately protected, because their stability is not guaranteed here; another option is to use a gradient that would ensure stability of the slopes. The excavations should be marked and protected. They should be made immediately prior to construction of the tank boarding and placing the concrete. It is recommended to use a 0.10 m thick priming concrete of the B10 class with extension 0.10 to 0.50 m adjusted to the type of the tank foundation. It is important to avoid locating the tanks below the underground water level due to the costs and technical problems involved in this option. Construction of ground-based tanks requires removal of the organic soil layer from the tank location area; if the organic soil layer is thicker than the tank foundation depth, it should be replaced with a layer of sand or gravel. The replacement soil should be compacted accurately in layers 0.20 m thick.

**Foundations**
Depending on the region of the country, the necessary depth of the foundation varies from 0.80 metres to 1.40 metre (see Figure 8.1).
Boarding for concrete and reinforced concrete work
The boarding should be designed and made so as to transmit safely the loads it will be exposed to at the stage of casting and consolidation of the concrete mix. The boarding should successfully resist potential deformation or displacement caused by such loads; moreover, it should be tight to prevent any leakage of the concrete mix. Surfaces of the boarding should be covered with a layer of agent reducing adhesion of concrete to the boarding. This agent may not have a negative effect on fresh concrete.

Reinforcement in concrete construction
Before it is used, the delivered reinforcement steel should be checked for compliance with the design requirements. The bars should be clean, i.e. free of soil, grease, paint and loose rust. As far as possible, reinforcement should consist of continuous bars running all along a single construction element. Whenever this requirement cannot be met, individual bar sections should be joined by means of welding or should overlap as required by relevant Polish Standards (PN).

Reinforcement
Reinforcement should be covered with at least 3 cm of concrete. This requirement applies to the entire reinforcement including the separating bars and shackles. To this end, appropriate distance blocks should be used, e.g. made of concrete or plastic. Reinforcement placed in the boarding should be sufficiently rigid and stable to prevent its displacement or deformation while concrete is cast.

Concrete work
Both concrete prepared on the construction site and delivered factory-made concrete can be used for construction of the tanks. The concrete mix should enable the contractor to obtain concrete with properties required in the design. In the case of the ready-made concrete, the manufacturer should submit a conformity certificate to prove the quality of the delivered concrete mix. If the concrete mix is made on the construction site, procedures must be developed to ensure that the resulting mix has the required parameters.

Casting of concrete mix
The concrete mix should be supplied on a continuous basis and placed in layers 30 to 40 cm thick. The mix should be poured freely from a height of up to 1.50 m (not to be exceeded) to prevent segregation of the mix components. The contractor should be prepared to protect the freshly cast concrete against excessive drying and also against rain. Foil can be used for protection purposes.

Consolidation
Appropriate vibrators (immersed, surface or external vibrators) should be used for consolidation. Moreover, appropriate duration of the vibration treatment should be chosen to prevent segregation of the mix. Upper surfaces of individual layers should not be smoothed, except for the top layer.

Curing of fresh concrete
The curing of a freshly cast concrete should ensure maintenance of certain thermal and humidity conditions. In the summertime, fresh concrete should be protected against drying up. Humidity of the fresh concrete should be kept at a constant level for at least 7 days. The sprinkling of concrete should start 24 hours after the casting. It is advisable to cover the concrete mix with foil after initial setting of the mix. At temperatures below +5°C water should not be poured over the concrete; instead it must be covered with mats or heat-retaining material that would protect the concrete against excessive cooling.
Expansion joints
Expansion joints in the concrete tanks protect the construction against possible damage caused by uneven settlement of the soil, concrete shrinkage and deformations caused by thermal changes. It is important to ensure leakproofness of the expansion joints. The expansion joints should be at least 1 cm wide. It is a common practice to use plastic tapes for sealing the expansion joints. The tapes are embedded in concrete in both parts of the construction equipped with expansion joints. The tapes should be laid properly and the concrete around them should be consolidated accurately. It is a difficult task to make proper expansion joints given the need to ensure the leakproofness of the tank. Decisions to build tanks with expansion joints should be avoided whenever possible.

Protection of the concrete surface
To reduce the destructive effect of the environment on the concrete and ensure better tightness of the concrete construction, tightening coatings should be used. The coatings can be made of mineral and bituminous components. Another option is to use polymer coatings. The coatings should be made strictly in line with instructions provided by their manufacturers.

General comments on construction of the tanks
In the process of constructing monolithic tanks made of reinforced concrete, special attention should be paid to the following aspects:

- Use the concrete class consistent with the design (the minimum class is B20);
- Use leakproof concrete of appropriate consistency;
- Ensure the required covering of the reinforcement;
- Make leakproof corners, especially at the bottom/wall junction.

8.5. Circular slurry tank constructed in situ

Figure 8.6. Circular slurry tank constructed in situ.
Technical parameters of the tank:

**Cylindrical shape**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal diameter</td>
<td>560 cm</td>
</tr>
<tr>
<td>External diameter</td>
<td>590 cm</td>
</tr>
<tr>
<td>Wall thickness</td>
<td>15 cm</td>
</tr>
<tr>
<td>B25 concrete walls (without reinforcement)</td>
<td></td>
</tr>
<tr>
<td>Walls embraced with steel bands</td>
<td></td>
</tr>
<tr>
<td>Maximum tank height</td>
<td>360 cm</td>
</tr>
<tr>
<td>Bottom slab</td>
<td>25 cm</td>
</tr>
<tr>
<td>Thickness</td>
<td>25 cm</td>
</tr>
<tr>
<td>Diameter</td>
<td>620 cm</td>
</tr>
<tr>
<td>Bottom slab reinforced with steel</td>
<td>324.0 kg</td>
</tr>
</tbody>
</table>

**Excavations:**

The depth of the excavation depends on the type of the soil:

a) In sandy soils the excavation should be deep enough for the bottom of the tank to stand out 10 cm above the ground level, i.e. the excavation depth should be 25 cm.

*Figure 8.7. Excavations in sandy soils: 1-ground level, 2-sandy soil, 3-bottom slab of the tank (made of reinforced concrete), 4-lean concrete, and 5-compacted sand.*
b) In heavy soils (silts, clays, clayey sands) the excavation must be at least 55 cm deep.

![Figure 8.8. Excavations in heavy soils: 1-ground level, 2-heave soil, 3-bottom slab of the tank (made of reinforced concrete), 4-lean concrete, 5-sand brought from another location and compacted.](image)

The excavation diameter should be equal to the diameter of the bottom of the tank made of reinforced concrete, i.e. 620 cm.

**Construction of bottom of the tank made of reinforced concrete**

A layer of lean concrete 5,10 cm thick should be cast on leveled bottom of the excavation, i.e. on compacted sand. On the lean concrete, a 20 cm thick layer of B25 concrete should be cast, followed by reinforcement made of f 12mm reinforcing bars arranged so as to form a net with 15 cm × 15 cm mesh in the central part of the slab and 20 cm × 20 cm closer to the brim. The reinforcement should be immediately covered with a 5 cm thick layer of concrete. The concrete should be properly compacted e.g. by means of ramming. The concrete should be of a dense and plastic consistence. The surface of the slab should be evened up and smoothed. The part on which the tank wall will be erected should not be smoothed; on the contrary, it should be left non-floated for the vertical wall of the tank to bind properly with the bottom. After the concrete sets, a circle of 575 cm diameter should be made of a butyl rubber gasket on the bottom slab and nailed to the slab so that the gasket is positioned right in the middle of the wall.

Monolithic concrete tanks can be made with the UMZ device consisting of two concentrically mounted steel mantles connected by means of brackets. A sliding pipe is located in the centre. The space between the two mantles is filled with concrete mixture. After casting, compacting and initial setting of the concrete, the boarding (steel mantles) is lifted and a new layer of concrete is cast. The operation is repeated until the full tank height is cast.
After the tank has been made, the device should be disassembled

The device should be disassembled using portable scaffolding, e.g. the Warsaw type. It is inadmissible to use ladders, as the weight of some components of the device is 60 kg.

Maintenance of the device

After the tank has been made, all elements of the UMZ-3 device boarding should be accurately cleaned and covered with an anti-adhesion agent, e.g. Separbet or Olform. Hydraulic elements, especially hose ends, should be protected against exposure to sand, dust etc.
List of literature

- Ordinance concerning the technical requirements on agricultural structures and their location, Journal of Laws No. 132 item 877 of 7 October 1997.


- Ordinance of the Council of Ministers of 24 September 2002 defining types of ventures with potential considerable impact on the environment and detailed criteria for qualifying ventures as requiring the environmental impact report (Journal of Laws No. 179, item 1490 of 29 October 2002).

- Ordinance of Minister of the Environment of 23 December 2002 concerning detailed requirements on programmes aimed at reducing nitrogen emission from agricultural sources (Journal of Laws 03.4.44 of 15 January 2003).


- CIGR Handbook of Agricultural Engineering. ASAE, USA, 1999, vol. II.
Farm Standards are recommendations for design and construction of agricultural buildings based on EU requirements, findings from research and farming experience. Farm standards are developed on housing systems for cattle, pigs, poultry, sheep and horses and storage facilities for feed and manure.