Farmers Handbook

Use of liquid manure as an agricultural fertilizer in Southeastern Europe

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(Moldova, Romania, Serbia, Ukraine)

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Translation into the English language

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Completed in: November 2021

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PDF Version: https://www.mrgoettingen.de; http://www.biodeseuri.md/biodeseuri

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This project was funded by the German Federal Environment Ministry's Advisory Assistance Programme (AAP) for environmental protection in the countries of Central and Eastern Europe, the Caucasus and Central Asia and other countries neighbouring the EU. It was supervised by the German Environment Agency.
The responsibility for the content of this publication lies with the authors.

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Introduction

This handbook was created as a result of a campaign on the **value of manure for fertilization in agriculture.** It was developed by the Maschinenring Kommunalservice Göttingen and Spelleken Assoc. supported by the Federal Environment Agency carried out in the Republic of Moldova in summer and autumn 2020. The handbook was developed at the request of Moldovan farmers, and the project succeeded mostly due to their active collaboration. These guidelines are therefore also recognition to the people who are rebuilding south-eastern European agriculture in times of transformation. Moldova is a good example of EU-oriented agriculture in south-eastern Europe and is followed by other important countries such as Romania, Serbia and Ukraine. Their laws are based or will be mostly based on EU regulations, their products are delivered to the EU and all environmental protection conditions comply with EU requirements. The aim of this transformation is the improved and **interlocking cooperation between livestock and arable farms** with regard to liquid manure and solid manure.

This handbook shows how an environmentally and operationally compatible use of liquid manure in the country's livestock farms of the country can be interspersed with other areas of an agricultural sector. It defines **liquid manure as an agricultural fertilizer** (Chapter 1), describes the **possibility of environmental pollution** (Chapter 2) and the importance of **biogas plants** (Chapter 3) in the value chain. Chapter 4 explains the **storage** of liquid manure, the construction of the required **containers** and describes the separation of solids particles and liquid manure for more efficient transportation (Chapter 5). The handbook also contains information on the **research of different forms of manure** and the calculation of the application rate of different forms of manure (Chapter 6), the **best period for application and ban** for using the fertilizer during the year (Chapter 7) and gives practical tips for transporting the manure to the field (Chapter 8) and **applying** it to the ground (Chapter 9). Future expectations for the manure **marketing and logistics** in Southeastern Europe, using the Republic of Moldova as an example, are presented in Chapter 10; opportunities for **agricultural technology located in the region** are presented in Chapter 11. Chapter 12 contains important recommendations on the handling of **hazardous substances** in liquid manure. At the end, we summarize the most important tips into a **list of clues** (Section 13).

The following institutions contributed to the creation of this handbook: **Maschinenring Göttingen**, which was founded in 1965 and in 1995 created Maschinenring Kommunalservice (MRK) Göttingen as a subsidiary of MR Göttingen and Kassel. In total, about 1100 agricultural enterprises as members and about 250 biogas plants of different categories are coordinated in Germany in agricultural partnership. As a Limited Liability Company (GmbH), MRK Göttingen coordinates ten other service companies. These include, in addition to various services for the marketing of biogas on the electricity market, the planning and coordination of biogas plants, in particular the liquid manure distribution company GAG.

Spelleken Asoc. is a development consultancy from Alzenau in Lower Franconia that designs and implements complex projects in Southeastern Europe and Latin America. Spelleken Assoc. supports the Human rights Committee (HRC) in Southeastern Europe on a long-term basis. The authors of this handbook are the farmers **Dennis Uhlendorff** and **Jan Hampe** and the development economist **Hans-Gerd Spelleken**. Editing was carried out by experts from the Federal Environment Agency in Germany (UBA) and Marius Kleilein (HRC).

Chapter 1:
Liquid manure as a fertilizer

Manure is a mixture of excrement and urine of farm animals, especially pigs and cattle. In the past (used nationwide), as today (in small and medium-sized farms), manure consists of animal excrement mixed with straw.

Manure and animal excrement are not wastes! Quite the opposite, it is a natural and valuable organic fertilizer. Manure consists of nutrients and organic matter, dissolved in water, with a certain mineral content. It contains the core nutrients nitrogen, phosphorus and potassium (NPK-fertilizer). Manure gets its strong smell from the gases carbon dioxide, ammonia, methane and hydrogen sulphide released during excretion.

Before mineral fertilization became available, the solid manure and manure fertilization was the only way to stabilize or increase yields. The value of manure has been known for centuries and was common practice in the past. However, since

Invention of mineral fertilizer

Plants extract nutrients and mineral salts from the soil. The nutrients, thus, reach the harvested crops. Depending on the mineral composition of the soil, it is depleted after several harvests. But there is a countermeasure: **fertilization**.

The earliest literary mention of fertilization occurs in the Occident in Homer's Odyssey in the VIII century BC. In Odysseus' farm yard, a heap of dung smelled until its contents were spread over the fields.

Fertilization with green manure from nitrogen-collecting plants, which was then plowed into the ground, has been known since the Romans at the latest. Fallow land as a part of the triennial crop rotation was also a common measure in the Middle Ages to give to a cultivated area a break from a vegetation period. Meanwhile, due to weathering, minerals were released from the rock into the ground and were, thus, available to the following cultures.

Late medieval alchemists researched how to increase yields in agriculture. In modern times, the nutritional physiology of the plant and the nutrient supply of the soil were examined. After Justus von Liebig (1803 to 1873) formulated his findings on the need for fertilization, the losses of mineral salts in the soil were compensated by fertilization.
From 1905 to 1908, the chemist Fritz Haber developed the catalytic synthesis of ammonia. The industrialist Carl Bosch then succeeded in finding a process that enabled the mass production of ammonia. This Haber-Bosch method created the basis for the production of synthetic nitrogen fertilizer.

Since the Second World War, fertilizers with different compositions have increasingly come onto the market in industrialized and emerging countries. Their use became standard on modern farms, but came under pressure from public criticism in the 1980s because of environmental risks and natural alternatives[1].

[1] Sursa: https://www.planet-wissen.de

the introduction of a mineral fertilizer (see the topic box below), this knowledge has been forgotten.

Nitrogen, phosphorus and potassium are essential for good growth and high plant yields.

In addition to the nutrient and fertilizing effects, the manure has a decisive advantage compared to the mineral fertilizer: the organic substance contained in the manure contributes to the formation of humus in the soil. Humus provides a mechanism for capturing and accumulating humidity, increases soil fertility and, in the form of nutritious humus, serves as a stock fertilizer.

What is NPK-fertilization

The abbreviation **NPK** (in German) names the main nutrients that contribute to plant growth and increased yields in agriculture. These are found in valuable concentrations in mineral fertilizers as well as in liquid manure and solid manure.

N = nitrogen, can be present in both mineral and organic form. Nitrogen serves as a yield engine for the plant. Plants absorb nitrogen mainly in the form of nitrates; ammonium and urea can also be taken up directly. The so-called mineralization (breakdown of organic matter into inorganic matter by microorganisms) makes the organically bound nitrogen available for the plants. Nitrates can be washed out quickly by precipitation, whereas ammonium binds to clay minerals in the soil and is used to build up humus as well as to supply the plant with long-term nitrogen. The plant converts the nitrogen into proteins, which are necessary for growth and reproduction. A lack of nitrogen can be recognized by light green discoloration of leaves; the growth of a plant is markedly inhibited also due to the lack of nitrogen. Too much nitrogen leads to over-fertilization (blue-green leaf color, soft shoots), to leaching into the soil and, thus, to negative environmental effects on the groundwater. The plant's nitrogen uptake can also be inhibited by a lack of other nutrients, such as potassium.

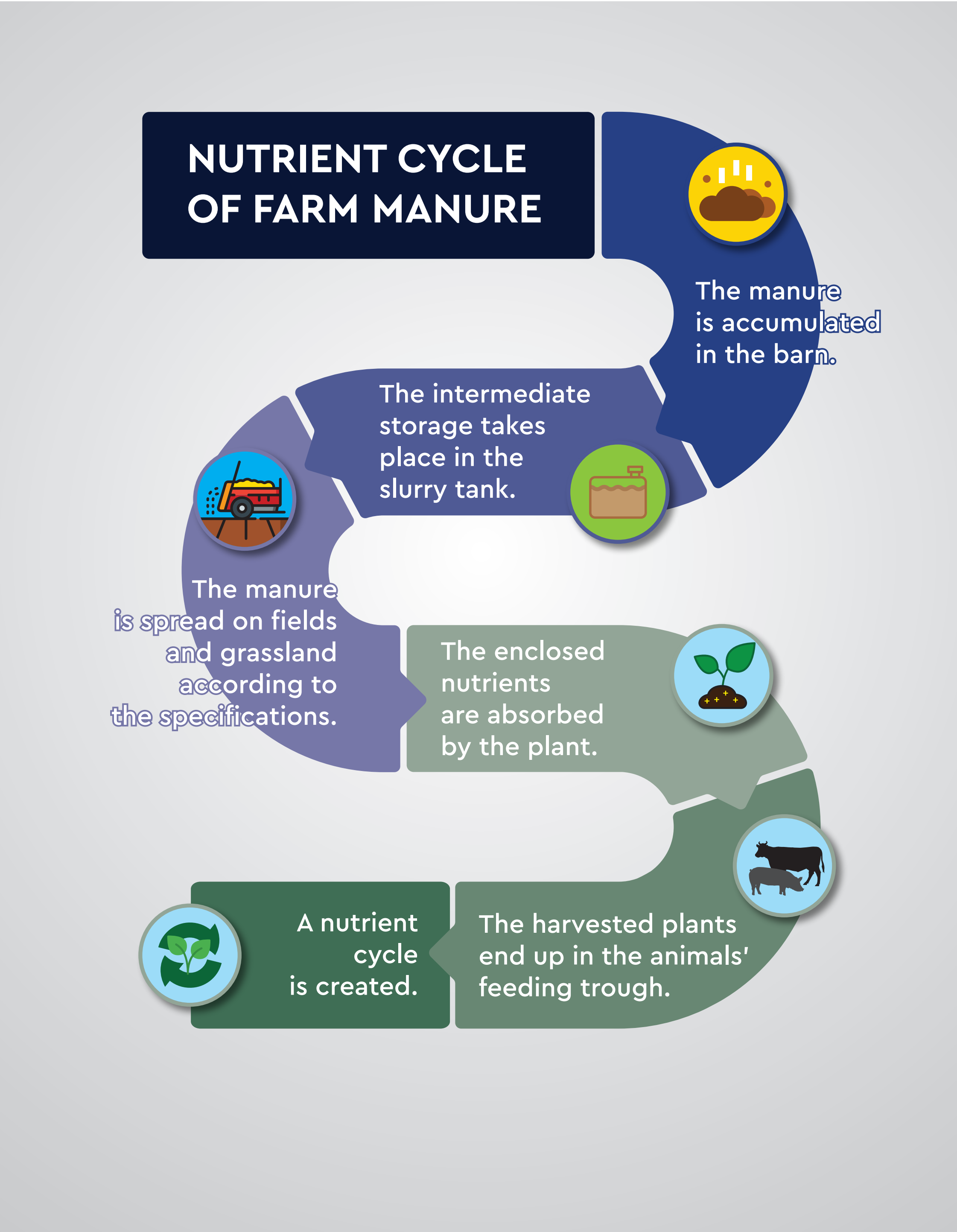
P = phosphorus, is present in the natural soil supply, but can only be partially absorbed by a plant. As a macronutrient, phosphorus is indispensable for plant metabolism. In addition to building up plant enzymes and the main function of many vitamin and protein syntheses, phosphorus is also used to form seeds and fruits. The availability of phosphorus depends on the pH value in the soil. Too high pH-value leads to the fixation of the phosphorus in the soil, whereby the phosphorus becomes unavailable for a plant. In addition to the benefits for a plant, phosphorus also serves to improve the soil structure in order to achieve good soil crumbling and soil mellowness. Both make the soil finer, especially, after plowing. A lack of phosphorus can be recognized by the shedding of older leaves and their red-purple discoloration. Root development is clearly reduced and the plant's metabolism is disrupted.

K = potassium (often also called potash = potassium carbonate, potassium oxide), like nitrogen and phosphorus, is a macronutrient for the plant and is used for plant photosynthesis. Potash promotes the formation and storage of carbohydrates. The water balance of the plant is favored by potash; it suffers less from drought stress. In addition, potash promotes the resistance of the plant both to disease and to the risk of deformation (kinking of arable crops) by stabilizing the supporting tissue of the plant. When there is a lack of potash, the plants often appear tired and limp, a kind of wilt occurs. Sometimes the leaves turn light green from the outer edges to the center.

Liquid manure used as a fertilizer can, thus, make a decisive contribution to increasing yields. In addition to the main nutrients NPK (nitrogen, phosphorus, potassium), the liquid manure also contains trace nutrients for plants and soil, which commercial mineral fertilizers do not offer.

Liquid manure is therefore a natural, valuable fertilizer that is automatically generated in animal husbandry. It, thus, becomes the core element of a nutrient cycle in cooperation between livestock and arable farms.

First, liquid manure is collected in the livestock farm and stored in a manure tank. It is then applied to the field as farm manure and gradually absorbed by the growing plants. The correspondingly better growing plants are used again as feed for animals after the harvest, so that the cycle closes (see Infographic 1).



Infographic 1: Nutrient cycle

Chapter 2:
Environmental impacts of liquid manure

Liquid manure can be both negative and positive. The former happens when its nutrients are not used systematically and professionally as nutrients, but are discharged into the soil and water in excessive quantities and unfiltered. This can lead to considerable damage to the ecological balance. And vice versa - it has a positive impact when it enriches the soil in the right dosage and, thus, increases the productivity of agriculture. This chapter concerns the curse to be averted.

Fig. 1: A floating colony of Phaeocystis algae (foam alge)

Above all, it must be avoided that the liquid manure gets into surface water or groundwater. There are generally three ways to infiltrate manure into water sources:
1. Leaking storage containers;
2. Incorrect application;
3. Excessive fertilization.

As a rule, liquid manure penetrates into surface waters through leaky storage containers. Then, the liquid manure reaches the surface, via the rain drainage ditches of the farms into the surface waters or seeps through directly below the storage facilities.

Furthermore, the liquid manure is sometimes applied to the agricultural areas in wrong time. For example, no application should be carried out on frozen soils or on soils saturated with water after heavy rainfall. Otherwise, especially in hilly terrain, there is a risk that some of the liquid manure will not seep into the ground, but rather run off the surface via the drainage ditches into the surface waters. Further, you will find some tips on an appropriate time period for applying liquid manure in Chapter 7.

If the amount of fertilizer applied continues to be too high, excess nitrogen and, in some cases, also phosphorus, accumulate and are washed out into the groundwater body and, thus, into the rivers. This process takes place very long-term over a period of 10 to 30 years. In this respect, of course, it takes time for this entry path to dry up again. Only when the pollution in the groundwater decreases, the nutrient input into the surface water will also normalize.

Fig. 2: Green algae in the North Sea

If liquid manure enters surface waters via the mentioned entry paths, the waters can "eutrophicate" and ultimately "go bad" over a longer process due to the excessive entry of the nutrients it contains. This means that too much organic matter, for example, in the form of algae, forms in a water body due to the additional input of nitrogen and above all phosphate. They use up most of the oxygen in the water and the other living organisms in the water can die due to the lack of oxygen. Eventually, anaerobic processes are formed, the water begins to stink and "goes bad".

But excess nitrogen is not just a single hazard for surface water, but also for groundwater. In the soil, nitrogen is converted to nitrate. This nitrate then seeps over time from the upper soil layer into the groundwater zone. This then leads to the fact that the current nitrate limit value (50 mg / liter) of the EU groundwater directive is exceeded.

Increased nitrate content in the groundwater then also leads to increased proportions in the drinking water, which is usually obtained from the groundwater. If a person then absorbs the nitrate through the drinking water, it turns into nitrites in a human body. Too high nitrite content in drinking water can be harmful in particular to the health of infants.

The use of fertilizers also releases nitrous oxide: because both liquid manure and solid manure, as well as mineral, i.e. industrially produced, fertilizers contain nitrogen. Once subjected to decomposing, these nitrogenous compounds produce, among other things, nitrous oxide[2].

Nitrous oxide

Nitrous oxide (N2O) is a greenhouse gas that is around 300 times more harmful to the climate than carbon dioxide (CO2). The main sources of nitrous oxide are nitrogenous fertilizers in agriculture and animal husbandry, processes in the chemical industry and combustion processes.

So agriculture is a major contributor to nitrous oxide emissions. A distinction must be made between direct and indirect nitrous oxide emissions. Direct nitrous oxide emissions derive from agricultural processes: emission of reactive nitrogen (Nr) from organic and mineral fertilizers and atmospheric nitrogen emission, as well as reactive nitrogen in soils from plant residues and biological nitrogen fixation of protein plants (legumes). Indirect nitrous oxide emissions appear when reactive nitrogen compounds, such as nitrate and ammonia, get into the surrounding natural areas. Nitrous oxide is produced from reactive N compounds in nitrification and denitrification processes. In crop production, nitrous oxide emissions are mainly due to the use of nitrogen fertilizers. In addition to the amount of nitrogen or lime fertilizer introduced, factors such as climate, temperature, soil properties and fertilizer technology determine the amount of greenhouse gas emissions caused.

On redesignated moors and grassland, the high humus content after fertilization results in a particularly high emission of greenhouse gases (in addition to nitrous oxide, also CO2). These greenhouse gas emissions can be reduced by improving N (nitrogen) productivity. By determining the fertilizing requirements of plants, including the humus balance and analyzing the nutrient content of organic fertilizers, N surpluses can be reduced. The Federal Environment Agency recommends reducing the nitrogen surplus on a 3-year average to 50 kilograms per hectare and year if the nitrogen only comes from mineral fertilizers. In the long term - to 90 kilograms per hectare and year if part of the fertilizer is manure[3]. Due to the Kyoto Protocol, which makes the reduction of greenhouse gases mandatory, the signatory states to the Framework Convention on Climate Change also have to take measures to reduce N2O emissions. The reduction of nitrogen surpluses is an important contribution to this[4].

[2] Source: https://www.lfu.bayern.de
[3] https://www.umweltbundesamt.de/sites/default/files/medien/5750/publikationen/2021-04-14_texte_33-2021_tierhaltung_bf_0.pdf
[4] Source: https://www.umweltbundesamt.de/en/topics/soil-agriculture/ecological-impact-of-farming/nitrous-oxide-methane

Chapter 3:
Biogas Plants

Since liquid manure is a versatile resource, there is also the possibility for the farmer to build a biogas plant (BGP). The liquid manure is channeled through this installation before it is spread on the field. The fermentation of liquid manure in the biogas plant produces energy (electricity and heat). These can be used for personal use or sold on the national electricity market.

In a biogas plant, organic materials such as liquid manure, solid manure, maize or sugar beet are decomposed anaerobically (oxygen-free) with the help of bacteria to produce a combustible biogas. A combined heat and power unit (HPU) can be operated with this biogas to generate electricity and heat. The so-called digestate from BGPs that remains after incineration can then be applied to the fields as a liquid fertilizer (farm manure). It is to be treated in the same way as the untreated farm manure, which is the subject of this handbook as a basic material.

Another alternative when using biogas plant is to process organic material (or just solid manure) into biomethane and feed it into the natural gas network. However, this often fails because of the contractual obligations to a natural gas provider (feed-in tariff) or because the existing networks are out of date. In Moldova in particular, there is no corresponding reference; Moldova-Gaz is only likely to be willing to have biogas fed into the network with considerable negotiating effort (applicable to South Eastern European countries, especially Serbia and Ukraine).

Biogas plants can represent an additional source of income for the farmer due to the possibilities of feeding biomethane into the gas network. In Germany, as a result, the income of farmers has increased by around 50% to the knowledge and in the network of the MRK. Even if this will not be primarily feasible in Moldova for the time being (applicable to South Eastern European countries, especially Serbia and Ukraine), biogas plants are still a possibility to generate the energy required on the farm and in the country in the form of electricity and heat and thus save costs. Since the fermentation of agricultural wastes does not release any CO2, biogas plants are important contribution to the energy transition (switching to alternative energy sources).

In Germany, 9,000 biogas plants produce around 5% of the country's total energy needs. This is quite a lot, because the electricity generated here is also suitable for base and peak loads. Suitable for base load means that biogas plants run continuously (over the day without nightly breaks and over the year without seasonal fluctuations) and, thus, feed electricity into the grid

Fig. 3: Rosdorf biogas plant

at a relatively constant rate. Suitable for peak loads means that the energy from biogas plants can also be requested from the control centers of the national power grids in times of high electricity demand.

As in most European countries, Moldova also has a licensing procedure for new biogas plants with the allocation of an electricity feed-in tariff (applicable to South Eastern European countries, especially Serbia and Ukraine). This procedure is functional and leads to an average tariff of approx. € 0.10 per kWh with legal protection for approx. 15 years.

When planning the system of a biogas plant, it is decided how economically and profitably the project will be. Planning based on modules offered by the system manufacturer is widespread. In Germany there are several hundred medium-sized and several thousand smaller companies that can design and build biogas plants. The assembly and construction of a system are similar to a large craft project in which up to 50 individual components are connected. This enables farmers to commission individual productions and solutions so that the biogas plant fits exactly to the respective farm. The authors of this handbook advise that the size of the biogas plant must be planned in such a way, that wastes from neighboring farmers or regional industrial companies can also be accepted, which e.g. give off spoiled milk or beet pulp as co-substrates.

Note: *As an example, in the Republic of Moldova, a substrate atlas www.biodeseuri.md was created in 2019 to promote knowledge and affinity of co-substrates.*

An individual planning of such types of systems should also be far-sighted so that future changes and leaps in growth or e.g. generation changes with corresponding effects on substrates and organizational structure can be anticipated. In the long term, a BGP based on this model is more economical.

A BGP can be based on pig, cattle or chicken manure. A capacity of approx. 250 kW corresponds to a farm with approx. 120 cows and approx. 60 hectares of arable land. For example, according to the authors' research, Moldova is likely to have systems from 250 kW upwards, although municipal systems up to approx. 4 MW can also make sense. A communal system requires willingness to modern, transparent and agile management, also on the part of the city or the district. The cost of the construction is around € 3,000 per watt, so that the construction of a 500 kW system in Moldova costs around 1.5 million € (applicable to South Eastern European countries, especially Serbia and Ukraine).

When procuring the components, the pumps and electronics in particular should be of the highest quality, while the concrete and cable work, as well as foils and other prefabricated components can be procured cheaply worldwide. The construction itself should take place under our own leadership and project supervision.

Likewise, the operation of a biogas plant is to be organized as an interaction of own competence in the basic functions, for example, a locally available specialist and a regionally available engineering company. In the capital cities there are individual educational institutions that already give knowledge in biogas plant control (example in Moldova is the Colegiu Ecologic in Chisinau), and individual companies are dealing with this specialist topic. If you want to build a biogas plant according to the „Bauherrnmodell" model (in this model, the investor does not act as a final recipient of the property, but as a builder), the MRK will be happy to help permanently within the framework of a maintenance or support contract (applicable to South Eastern European countries, especially Serbia and Ukraine).

Chapter 4:
Storage and Construction of Containers

The planning and construction of a liquid manure storage facility first requires an assessment of the necessary storage volume. The calculation is based on the number of livestock units on the farm, as well as the manure blocking period, the size of the area, the production quantities of the livestock and the determination of the fertilizer requirement. In Germany, a minimum storage capacity of six months is currently required and a minimum storage capacity of nine months is required for farms with a large number of livestock units without a corresponding area certificate. We recommend that Southeastern European companies start also planning today. This would give them an advantage if these requirements stipulated by the EU had to be applied nationally.

In Germany, minimum storage capacity is checked by the responsible supervisory authority during the building application phase. The responsible building authorities work closely with the supervisory authorities (e.g. the Chamber of Agriculture) during the application phase. The needs assessment is therefore calculated with the help of consultancy from authorities and associations or even with the help of the responsible supervisory authority.

In addition to the necessary basic structural standards, for example DIN (German Institute for Standardization) regulations for concrete quality and reinforcing steel quality, the location of the planned storage facility is also carefully checked in Germany, possibly together with a report on emissions. When it comes to the question of location, the currently applicable minimum distances according to the area plan to residential areas, rivers and ditches, main roads, wells and neighboring businesses also play an important role.

The production quantities of the livestock serve as the first guideline for calculating

The German Board of Trustees for Technology and Construction (KTBL)

In Germany, for example, the basis for calculating the livestock units is either the data from the Board of Trustees for Technology and Construction in Agriculture (KTBL) or data from the responsible supervisory authority.

The KTBL data represents extensive collection of data from specialized literature on agricultural planning accounting, which includes values from all areas of agriculture. These are mainly used for business evaluation.

These standards are called differently in every European country and should be requested from the competent authority before planning a liquid manure storage facility in Chisinau / Kiev.

the manure storage requirement. Infographic 2 shows the amount of manure produced per animal each year. Column one names the animal species, column two the amount of the produced product (milk or meat) per year or a different period as the basis for calculation, column three the amount of solid manure in cubic meters. Column four visually underlines the animal species.

MANURE ACCUMULATION IN ANIMAL HUSBANDRY

ANIMAL	MASS/PERIOD	VOLUME/YEAR	SYMBOL
COW (MILK)	10.000 L	21 m³	
YOUNG CATTLE	27 months	9 m³	
BULL FATTENING	KG 80–700 kg	6,7 m³	
BREEDING SOWS WITH PIGLETS	KG 28 kg	6 m³	
PIG FATTENING		1,5 m³	

Infographic 2: Solid manure accumulation in animal husbandry

In Germany, construction projects for manure storage facilities in floodplains, nature and landscape protection zones or ecological priority areas are prohibited. The subsurface should be such that it safely supports the planned structure, which is why a soil survey is required in Germany prior to construction.

The main wind direction as a key factor in emissions from livestock farming must also be taken into account. It makes sense to have a report on emissions drawn up or to have the site checked for emissions by a monitoring authority. The installation of an anti-emission roof can considerably facilitate the approval of such construction.

After the location and the storage volume, i.e. the container size, have been determined, further planning can be continued. Now the farmer can decide on a variant of the liquid manure storage facility and choose between prefabricated elements, ready-mixed concrete or steel containers. These have different properties, advantages and disadvantages, which are described below:

Fig. 4: Ground basin

Ground basins or lagoons are basins built into the ground made of dams, which are completely lined and sealed with impermeable plastic foil. Depending on the country and federal state, these are currently no longer approvable for the storage of liquid manure in the EU, since the risk of the liquid manure leaking is very high, as well as the emissions due to the large surface area. Existing pools should be checked regularly, especially for well-welded seams. The basins can be equipped with agitators. Depending on the region, the walls can be made of concrete or earth.

Reinforced concrete containers are most often used as liquid manure containers in the EU. Here, a high container is usually poured from reinforced concrete. This can stand above the ground or be built completely or partially underground. A distinction is made between two systems:

Fig. 5: Ready-mixed concrete containers

1. **Ready-mixed concrete construction:** Here the container is poured from concrete using a formwork system on site, hardens and can be put into operation after approx. four weeks.

Fig. 6: Precast container

2. **Precast walls:** here only the bottom of a container is poured on site. Then precast concrete elements are set in the form of a ring, the joints are connected and poured (sealed). Putting into operation is also possible four weeks later.

Fig. 7: Stainless steel container

Alongside with concrete containers, **steel containers** (see Fig. 7) are also common. These are comparable to the reinforced concrete containers. Depending on the construction company, this tank can also be built in the ground or on the surface.

Some of these containers can be expanded or enlarged as required. Compared to concrete containers, these are more expensive due to the stainless steel used, but also simpler in construction. The shelf life is slightly higher for steel containers. Comparative Table 1 (next page) summarizes the advantages and disadvantages of the most common construction methods of liquid manure storage facilities:

Fig. 8: Liquid manure drainage station with adjacent pit

A **drainage station**, an **adjacent pit** and **agitator** should be provided in the construction project of a liquid manure tank. The drainage station is to be built in such a way that the liquid manure can be fed back into the tank via the adjacent pit. For this, the installation must be equipped with a pipeline system. If the future container is to be built on the territory of an existing stable, the piping system and the pump must be coordinated with each other.

Comparative table 1: Liquid manure storage facilities

Name	Main feature	Advantages	Disadvantages
Ground basin	lower expense	inexpensive	no longer approvable
Ready-mixed concrete container	poured from concrete	custom-made	long hardening time
Precast container	made of precast concrete parts	quick assembly	few sizes available
Steel container	expansion possible	quick assembly	expensive

Pipelines must be designed so that they can withstand the pressure of the pumps. In Germany nowadays pressure pipes made of welded polyethylene, or welded stainless steel, or black steel are mostly used. Pipelines laid in the ground must be double-walled so that a possible leak can be monitored.

The wall penetrations in the container required for the pipes must be manufactured and sealed according to the current state of the art. Pipe penetrations through the bottom of the tank are prohibited. The bottom of the tank must remain intact.

Figure 8 shows a liquid manure drainage station with an adjacent pit: this is where the liquid manure tank is filled or drained later. The filling and draining plates of the liquid manure storage facility should be erected in such a way that they are protected against precipitation. The plates should be easy to clean. The place should be built in such a way that in the event of an accident there is no overflow into the surrounding area; the overflowing liquid manure must flow back directly into the storage container. A runoff or overflow of liquid manure, solid manure, silage seepage or fermentation residues and their penetration into the groundwater, into surface waters and into the sewage system must be reliably prevented. If necessary, the systems are to be secured against buoyancy[5].

Stationary (ground-fixed) systems are primarily used as liquid manure storage facilities. Locally modifiable systems are out of the question with regard to liquid manure and will not be discussed further here due to the very unclear legal situation. The possibility of using a so-called flexible manure bag as a permanent storage facility instead of a stationary system must be agreed with the authorities in advance.

The systems must be stable and permanently leak-proof against the expected loads. The generally recognized Code of Practice must be observed. This also applies to the pipelines and the manure cellar[6].

In general, the legal framework for the construction of liquid manure storage sites, as well as various areas of law must be coordinated with the associated building authority. A building application can only be submitted when all requirements have been met. For this it is necessary to consult a building planner.

Planners are freelancers with "authorization to present building documents" (so-called planning engineers). A planner also helps with costing and building tendering. After the building permit has been granted and the contract has been concluded and signed with the real estate development company, construction can begin. Above all, the building law and water law regulations must be complied with. It is advisable to hire a construction inspector and a safety coordinator for this.

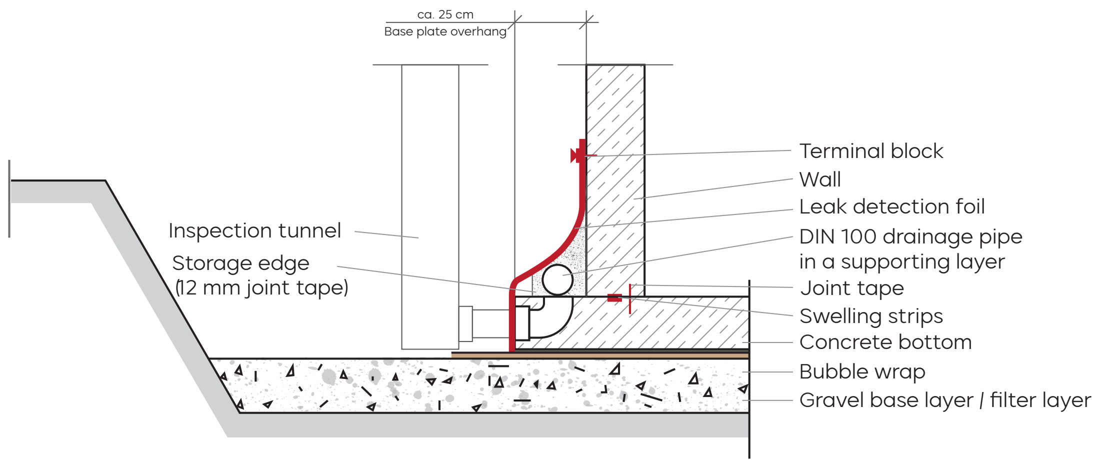
A leak test of the liquid manure storage facilities is planned prior to commissioning. In Germany, this is done through an ex-

[5] Source: https://www.landkreis-waldshut.de
[6] Source: https://www.landkreis-waldshut.de

pert opinion. To assess the tightness of the liquid manure storage facility, it shall be filled with water up to a height of 50 cm for at least 48 hours. Particular attention is paid to the tightness of the joints and the water level.

After approval, construction and commissioning of the liquid manure storage facilities, special attention must be paid to leak detection. This is possible using so-called leak detection systems (see the topic box on the next page) with or without surface sealing (see Infographic 3). In Germany, liquid manure containers must have leak detection according to the new regulation on solid manure, liquid manure and silage infiltrations (JGS). This serves to identify leaks, especially between the wall and the base plate (container bottom).

Infographic 3: Leak detection without surface sealing



Regular maintenance and control of the liquid manure storage facilities should be planned from the start. It helps to avoid accidents and, above all, additional costs. For this purpose, the liquid manure containers, basins and cellars should be checked by the operator every four weeks for leaks and changes, for example, for cracks in the concrete, manure level in the inspection tunnel or seams in underground containers. The pipelines should undergo a pressure test once a year. In some countries, an external auditor is also invited at annual intervals. In case of doubt, an engineering office should be consulted.

Special features of the construction of storage facilities in Germany: leak detection system

In Germany, liquid manure storage facilities are primarily subject to the Water Resources Act, ordinances on systems for handling water-polluting substances and the JGS information sheet (solid manure, liquid manure and silage infiltrations).

The construction of the storage facility must be built according to the latest regulations of the respective federal state. Particular attention should be paid to the details. In Germany, they include permanently elastic joints, a joint tape between the floor and the wall, corrosion resistance or specified concrete grades such as C25/30, XC4, XF1, XA1. The DIN (German Institute of Standardization) standards applicable in the context of the respective country must be observed.

In Germany, a so-called leak detection system is provided under the containers or solid manure channels and cellars: a plastic film is inserted under the bottom of the tank and its edges are folded up and attached to the walls of the tank. A drainage tube is placed in the resulting channel.

An inspection tunnel is built on the drainage pipe at specified points. The film is attached in such a way that no rainwater can penetrate. In the event of a leak (for example, between the wall and the floor), liquid manure would flow out in the drainage pipe. A leak can, thus, be detected via the inspection tunnel. This must be checked monthly.

Fig. 9: Drainage pipe with inspection tunnel

Chapter 5:

Separation

A separator separates the solids and the liquid part of the manure from each other. As a result, separated solid manure and liquid manure are produced. Put simply, the nutrient content of the liquid manure can be transported better because it is in the form of dry matter. The nutrient content can thus also be treated more economically, because storage is cheaper and transportation is more efficient. Only a base plate is required to store the dry matter.

Maschinenring Kassel has dealt intensively with the issue of separation and, in cooperation with a manufacturer of agricultural technology in Kassel, has developed the separator from Figure 10, i.e. a machine that separates solid manure from the liquid one.

A separator has a large liquid manure pump that can be connected to the liquid manure tank with inlet and outlet hoses. This pump conveys the liquid manure

Fig. 10: Separator in Kassel

into the separator which, like a sieve, filters the solid, coarse the substance out of the liquid manure, while the liquid manure is pumped back into the container. The solid sieved material is first deposited next to the separator. This material is then driven onto a manure plate and, later, spread as a fertilizer on the fields.

The remaining liquid part of the manure, the so-called digestate, is pumped back into the storage container until it can be spread on the fields.

THE ADVANTAGES OF SEPARATION ARE:

Improvement of the ability to agitate in the containers
The liquid manure in the storage facilities or the fermentation substrate in biogas plants become significantly more easy to agitate or mix as a result of separation, as solid particles (e.g. lignin / wood fibers or ash, in the fermentation substrate is everything that the bacteria cannot process) are extracted out of the liquid manure or fermentation substrate and only thinner manure remains.

Elimination of floating layers in containers
If stirring is insufficient or absent, the mass can be separated and form so-called floating layers form both in liquid manure storage containers and in biogas plants. Light fibers such as straw or maize float on top and stick together on the surface of the substrate. The floating layer can reach thickness of 2 to 3 meters. In case of liquid manure storage containers, the floating layer can be useful as it reduces emission of odor and ammonia. In biogas plants, however, this is problematic because methane gas that is produced remains to be blocked under floating layer. When emptying the container, in both options the contained mass must be stirred beforehand so that the floating layer is to be dissolved, otherwise the mass cannot be pumped out. If only the thinner liquid manure comes out of the separator during separation, it can be pumped onto the floating layer to keep it mobile.

Improvement of the pumpability
If the manure or the fermentation substrate is thinner after separation, it can be pumped more easily (less pressure, water runs faster than manure), for example, from one tank to the other within the biogas plant.

Reduction of storage requirements up to 20 - 30%
As a result of separation, approx. 20-30% of the liquid manure can be removed as solid matter. It looks like concentrated livestock manure and can be stored on a plane surface until it is applied with the manure spreader.

The thin manure always comes back into the container (a cycle). From a container with 2000 m^3 volume, about 400 m^3 of solid mass can be obtained as a result of separation, 1600 m^3 of liquid manure remains in the container.

Infographic 4 compares the properties of separated manure (column 1) with liquid manure (column 2) and solids (column 3). Line one indicates the percentage of dry material, while lines 2 to 5 indicate the mass (kg per m3) of the nutrients.

PROPERTIES OF THE SEPARATION

	RAW MANURE	LIQUID MANURE	SOLIDES
Dry material (%)	9,58	6,70	25,83
N-ges (kg/m³)	4,70	4,40	5,50
NH_4-N (kg/m³)	1,90	2,05	1,70
K_2O (kg/m³)	4,70	4,80	4,50
P_2O_5 (kg/m³)	1,60	1,50	2,40

Infographic 4: Properties of manure before and after separation

Chapter 6:

Planning manure application on soil

In order to avoid the environmentally harmful effects of the discharge of liquid manure into water sources, EU legislation prescribes the use of liquid manure as a fertilizer. It can be presupposed that current EU standards will sooner or later also be applied in Romania, Moldova, Serbia and Ukraine. Alongside with application by spreading, there are also standards for the incorporation of liquid manure (see Chapter 9) into soil. Loss of nutrients through improper application and too late incorporation can amount to 30% of the nutrient content and higher, according data presented by Maschinenring Kommunalservice GmbH and Chamber of Agriculture from Lower Saxony (Niedersachsen).

The liquid manure application must be adapted to the climate conditions. Application should be avoided, especially, at high outside temperatures, as stronger and faster outgassing takes place. In summer months, application should therefore be postponed to the evening hours, if possible. Sub-zero temperatures are also unsuitable for application, because frozen soil cannot absorb liquid manure.

Even if all of the manure arrives on and in the soil, it is crucial that it is applied when the plants are growing and need nutrients too. For this reason, spring is the best time for fertilization. Even in summer after harvesting, the application of some liquid manure on some areas can make sense, as fertilizer for subsequent crops or rapeseed or to increase straw rotting, if straws remain on the field. The need of nutrients is, surely, much lower than in spring and the application rate must be reduced accordingly. If these principles of professional liquid manure application are neglected, excessive nitrogen and phosphorus, which were not absorbed by the plants as nutrients, will reach groundwater.

Liquid manure of any kind must be examined before spreading. For this purpose, NPK (Nitrogen-Phosphorus-Potassium) macronutrients should be determined in the laboratory. The analysis is absolutely required because the nutrient values can fluctuate greatly depending on the farm structure. Even such factors as quantity and type of feed, animal species, animal breed, liquid manure storage time and rainwater have a considerable influence on the nutrient values. The dry matter content of the manure should also be determined. The higher the value of the dry matter content is, the higher the nutrient concentration. Exact nutrient values can only be determined with the help of a test. The average values for dry matter of pig manure are 3 to 7% and for cattle manure - 6 to 10%.

OVERVIEW OF THE MANURE'S INGREDIENTS

Fattening pig manure		Dairy and cattle manure
4–6 kg/m³	Total Nitrogen	3–5 kg/m³
2–4 kg/m³	Ammonium-N NH_4	1–3 kg/m³
2–4 kg/m³	Phosphate P_2O_5	1–2 kg/m³
2–5 kg/m³	Calium K_2O	3–5 kg/m³
1–2 kg/m³	Magnezium MgO	1 kg/m³

Dry matter content in pig manure from 3 to 7% and cattle manure slightly higher at 6 to 10%

Infographic 5: Properties of pig and cattle liquid manure

Infographic 5 shows the exact nutrient quantities of manure in comparison between pig (left) and cattle (right) breeding.

With the help of a laboratory test, the farmer can calculate the required application rate before to begin fertilization.

The laboratory test indicates how many kg of nitrogen (N) are contained per ton of manure. A large part of the total nitrogen, i.e. approx. 50 to 60%, is in the form of ammonium (NH4). The ammonium is immediately available for the plants upon application. The other part of the nitrogen is in organic form and must be mineralized first in nitrate (NO3) by soil organisms in order to become available for the plants. It can develop its fertilizing effect in the following year. The organic form of nitrogen mainly contributes to the humus build-up in the soil.

Therefore, to calculate the fertilization, the proportion of NH4 available to plants is of particular importance. It is to be considered as fertilization and indicated in the Register for agricultural land lot farming as nitrogen addition. The organically bound N content should be taken into account when calculating a dose of a fertilizer for the following year.

Calculation example: If a farmer wants to apply 50 kg of nitrogen per hectare of land, with a laboratory value of 5 kg of available N per ton of manure, they should apply 10 tons of manure per hectare.

In Europe, pig manure and manure from dairy and beef cattle make up the majority. Other farm manure such as that of poultry, sheep, horses and goats has mostly the form of solid manure and are not discussed in details in this handbook.

Register for agricultural land lot farming

A Register for agricultural land lot farming is a type of diary that the farmer has to present during inspections. It must contain details of all the agricultural areas of the household concerned. The farmer shall enter all essential work processes (fertilization (amount and type), plant protection (what and how much) and tillage) in this field record. The farmer shall use these details to evaluate the yield of each field and, thus, can assess the productivity and efficiency of the certain measures, e.g. fertilization. The Register for agricultural land lot farming is also available in Germany as an app for smartphones. Unfortunately, as we know at present, there is no corresponding software for Moldova (applicable to South Eastern European countries, especially Serbia and Ukraine).

In the fertilization process, phosphate, potassium and magnesium (PKM) must be taken into account at a value of 100%. Their content in the cultivated soils is to be examined several times in the annual cycle by means of soil samples. Fertilization is to be adjusted to the soil content class determined based on the results of the soil sample.

The following overview of the soil content classes shall be applied, the value C should be aimed for:

A: very low PKM value, greatly increased fertilization necessary;
B: low PKM value, increased fertilization necessary;
C: PKM value optimal, only maintenance fertilization necessary;
D: high PKM value, reduced fertilization in the future;
E: very high PKM value, no fertilization necessary;
F: extremely high PKM value, no further fertilization necessary.

Near-infrared spectroscopy (NIRS)

Near-infrared spectroscopy (NIR spectroscopy or NIRS for short) is a modern technique of a physical analysis based on spectroscopy in the range of short-wave infrared light. With the help of near infrared light (infrared rays) the medium to be examined is irradiated twice - by absorption and reflection. The parameters of the components can be deduced on the basis of the difference in the rays.

NIRS is important in liquid manure application, because a critical aspect when using liquid manure as a fertilizer is less precise determination of the nutrients compared to the mineral fertilizers from the chemical industry. However, now modern technology allows NIRS to measure the dry matter as well as the nitrogen values contained in the liquid manure directly in the liquid manure tank. The measurement can take place directly during pumping process or later during the application. In case of phosphorus and potash, which are predominantly bound, the measurement accuracy is not yet that high.

The NIRS device must be calibrated with the help of laboratory tests prior to the measurement. The advantage of this technology is that deviations in heterogeneous liquid manure can be detected quickly with the large number of necessary measurement processes. The disadvantage of this technology is currently in its inaccuracy.

Chapter 7: Period of ban on fertilizer spreading for using liquid manure

Application of the liquid manure is only environmentally friendly if soil and plants can absorb the nutrients. This can be applied not only from mechanical point of view, but more from a chemical and biological one.

To control the fertilization with manure, the community determines (the state, i.e. mostly the ministry responsible for agriculture, communicates to the agricultural associations) the so-called periods of ban on fertilizer spreading, i.e. periods during which the manure cannot be applied. In Germany, these deadlines are set forth in the Fertilizer Ordinance. Infographic 5 shows the ban period for manure application and the recommended period for manure application for different crops. The purpose is to ensure the best absorption of the material in the soil and plants.

Infographic 6 shows the liquid manure application for seven crops during the year, classified on five levels, as it is currently valid in Germany. Besides this, the period of total ban is also required; e.g. application on frozen ground is strictly prohibited. The infographic 6 comes from an official table from Germany, which was created on the basis of the farmers' economic experience: from a purely environmental point of view, fertilization in February is problematic and, it is recommended to avoid it, if possible.

During the period of low vegetation, in winter, the plants have no need for nutrients. So, in order to avoid the liquid manure nutrients become inefficient, the period of ban on fertilizer spreading is set forth in the laws, for example in Germany. During such period, the application of liquid manure is prohibited and is subject to substantial penalties relying on the Cross compliance (Compliance with the system of rules required to get assistance from the European Union).

Cross compliance refers to the certain EU agricultural payments in exchange for the fulfillment of the obligations in the areas of environmental protection, human, animal and plant health and animal welfare[7].

- **Grassland / meadows:** if sowing before 15th May, the ban period shall be applied from 1st November to 31st Ja-

[7] Source: https://www.bmel.de/EN/topics/farming/eu-agricultural-policy-and-support/cross-compliance-germany.html

	Rapeseed	Wheat	Barley	Beet	Fruit	Corn	Grass
JANUARY	⊗	⊗	⊗	⊗	⊗	⊗	⊗
FEBRUARY	+++	+++	+++	+	+++	+++	+++
MARCH	++	+++	++	+++	+++	+++	+++
APRIL	+	++	+	++	O	+++	+++
MAY	O	+	O	+	O	O	+++
JUNE	O	O	O	+	O	O	+++
JULY	O	O	O	O	+++	O	+++
AUGUST	+++	O	++	O	+++	O	+++
SEPTEMBER	+++	O	+	O	O	O	++
OCTOBER	O	O	O	O	O	O	+
NOVEMBER	⊗	⊗	⊗	⊗	⊗	⊗	⊗
DECEMBER	⊗	⊗	⊗	⊗	⊗	⊗	⊗

+++ – *very convenient* ++ – *convenient* + – *sufficient* O – *unconvenient* ⊗ – *forbidden*

Infographic 6: Manure application schedule

nuary. From 1st September to 1st November, a maximum of 80 kg N can be fertilized (see Chapter 6).

- **Arable land:** the ban period shall be applied from harvesting the last main crop before 31st January of the following year, for example, after harvesting maize, sugar beet or rapeseed.

In autumn, it is currently still allowed to fertilize:

- **Catch crops, winter rapeseed and field forage** which were sown before 15th September.
- **Winter barley** sown by 1st October. This fertilization may only be applied before 1st October. A maximum of 60 kg of total nitrogen (ammonium and nitrate together) or 30 kg NH4-N (ammonium nitrogen, see Chapter 1) may be fertilized[8].

Since the framework conditions for the application of liquid manure are still changing in many Southeastern European countries, we quote the following from the German Fertilizer Ordinance (as of 1st May, 2020):

- Fertilization with liquid manure is prohibited if the ground is flooded, saturated with water, frozen or covered with snow.
- Washing away of nutrients shall be avoided. This can be caused by heavy rain events or excessive snow.
- Distances from water bodies, 1 to 20 m from the top edge of the embankment, as well as distance from the slope to the top edge of the embankment of 3 to 30 m must be observed.
- Liquid manure shall be incorporated into the soil on an uncultivated arable land with a slope.

[8] Source: www.landwirtschaftskammer.de

- Liquid manure on uncultivated arable land must be applied within four hours.

- The total nitrogen from farm manure of animal origin must not exceed 170 kg per hectare and year.

We recommend adhering to these guidelines for Moldova in order to avoid nutrient loss and environmental pollution. As mentioned above, Moldovan regulations are likely to adapt to EU standards in the nearest future (applicable to South Eastern European countries, especially Serbia and Ukraine).

As what concerns the regulation of the total amount of nitrogen of 170 kg per hectare and year from an organic fertilizer, a fertilizer requirement assessment must be calculated every year at the beginning of vegetation period. The fertilizer requirement assessment is determined individually for each land field and each crop (type of fruit, e.g. wheat or rapeseed), whereby a minimum amount of nitrogen to be introduced (N (min) value) must be taken into account. The N (min) value reflects the mineral nitrogen directly available in the soil. In order to calculate the individual fertilization when determining the fertilizer requirement, this value shall be deducted from the 170 kg per hectare and year[9].

Failure to comply with the Fertilizer Ordinance leads to serious penalties, which can reach up to 50,000€ in Germany. Such amount of the fines imposed makes it clear how important the correct use of farm manure is.

The quantities of liquid manure and the nutrients applied are to be entered in the Register for agricultural land lot farming and are to be freely accessible to the supervisory authority at any time. The nutrients applied per m^3 of liquid manure shall be calculated using liquid manure tests in common agricultural laboratories. Especially, the dry matter content, NPK, magnesium (Mg) and sulfur (S) shall be tested.

[9] Source: https://www.lwk-niedersachsen.de/index.cfm/portal/96/nav/2280.html

Chapter 8:

Liquid manure transportation to the field

At present, there is a variety of options for transportation to increase the area performance of the manure application on the fields or to transport the liquid manure from the farms to the biogas plant.

The common practice is the transportation of the liquid manure in a separate vehicle while the spreading tank (liquid manure tank) remains on the field (Fig. 11).

External liquid manure supply barrels (sometimes also simple trucks) bring the liquid manure from the stable, from the liquid manure container or from the biogas plant to the edge of the field. Liquid manure is pumped from the transport tank into the soil fertilizer spreading container. So, the liquid manure spreader does not always have to leave the field and can be attached to the tractor with low tire pressure, which protects the soil, and driven in the field. This liquid manure tank only drives on roads when empty. The advantages are higher area coverage and less road pollution. This so-called liquid manure chain usually consists of a spreading barrel attached to the tractor, which remains on the field, and two trucks or tractors with transport barrels that serve as feeders.

Fig. 11: Pumping the liquid manure from the transportation tank to the spreading tank

Fig. 12: Liquid manure container

The use of a liquid manure container makes sense on larger areas. This large tub (see Fig. 12) is placed on the edge of the field in such a way that both the liquid manure truck (Fig. 13) and the spreading tank can drive up to it freely.

Fig. 13: Truck for liquid manure transportation

As a rule, there is space for two truck fillings, i.e. 60 m³ of liquid manure in the container. An additional advantage of this process is that the liquid manure delivery truck can pump its load into the container at any time and does not have to wait for the spreading vehicle. If necessary, you can renounce of one of the several trucks used for liquid manure transportation on the field.

The use of liquid manure trucks is very useful for larger distances between the liquid manure storage facility and the field, as well as high area coverage. It can transport up to 30 m³ of liquid manure. The liquid manure trucks are equipped with pumps for sucking and pumping. The liquid manure can also be delivered to biogas plants by trucks.

The so-called combiliners exist for several years. These are trucks that can transport both manure and bulk material. As a rule, these trucks have either an additional tub or a type of manure bag installed. In Germany, these combiliners are often used to transport liquid manure from regions specialized in cattle breeding to the regions with arable lands and to transport cereals back to the cattle regions.

Chapter 9:
Technique of application and incorporation

The right period (see Chapter 7), the right amount (Chapter 6) and the right technique of application are decisive factors for spreading liquid manure so that the nutrients it contains reach the plants with as little loss as possible.

Modern agricultural technology gives many options for conversion of the equipment used in manure handling. For example, in spring, when the fields have been already sowed, the liquid manure tank can also be equipped with a dribble bar system to fertilize the growing grain stock with liquid manure. After harvesting, a cultivator can be conversed in such a way that the liquid manure is to be incorporated into the soil with less loss. In this way, the gaseous emission of ammonia can be avoided which makes all the nutrients in the liquid manure be available directly for plants and reduce the odors caused by ammonia. This technology is widespread and is very cost-effective. The same liquid manure spreader can be used with both a dribble bar and a liquid manure cultivator.

Further we show different application techniques for liquid manure and their advantages and disadvantages:

Fig. 14: Tractor with liquid manure cultivator

Fig. 15: Trailing shoe in details

According to German laws, **the trailing shoe** is a recommended technique of application. It effectively brings the manure to the roots of the crop. The trailing shoe is attached to a rod. A shoe made of steel (mostly stainless steel) opens the ground, where the manure is spread into the obtained strips.

This type of application is lower in emissions than using a dribble bar system.

Dribble bar systems are a widespread and legally compliant application technique in Germany, for example, and can also be recommended. It consists in bringing the liquid manure close to the ground and in strips directly to the plant roots.

As in case of a trailing shoe, the advantage of the dribble bar spreader is also a high level of distribution accuracy, application close to the ground, large application areas and low ammonia emission. In addition, dribble bar spreaders can still be used without any problems in growing grain stocks. Compared to spreading on the soil surface, nutrient losses are significantly reduced. The trailing shoe is approx. 60% more expensive than the dribble bar application system. However, in some regions distribution with the trailing shoe is promoted by the Water Board.

Another application technique is the so-called **swivel distributor**. As in case of other techniques, a strong pump presses the liquid manure from the barrel directly into the swivel distributor. The distributor swivels back and forth due to a special folding mechanism and the pressure of the pump. The advantage here is that the liquid manure reaches the field in larger drops and, as a result, covers wider surfaces than with the above-mentioned techniques.

On the other hand, there are serious disadvantages, especially, high odor and the loss of nutrients through evaporation, which is why this technology is no longer used on cultivated arable lands in Germany since 1 February, 2020, and on grasslands, either, from 1 February, 2025. This technology can be used further on uncultivated arable lands, but the fertilizer must be incorporated into soil in no less than four hours. From 1 February, 2025, the period for incorporation into soil will be reduced to one hour after spreading on uncultivated arable lands[10].

Fig. 16: Tractor with dribble bar spreader

Fig. 17: Swivel distributor

[10] Source: https://www.landwirtschaftskammer.de/landwirtschaft/ackerbau/duengung/guelle/technik/index.htm

When using **impact head distributors,** the liquid manure is spread over a wide area on the ground. A barrel pump pushes the liquid manure out of the tank, the liquid manure hits a deflector plate and is thereby spread. Despite a deflector plate is significantly cheaper than a dribble bar or trailing shoe, it also creates a lot of **emissions**. The impact head distributor is less effective than the swivel distributor and causes more emissions.

Due to their clear disadvantages, both impact head distributors and swivel distributors are associated with considerable requirements and prohibitions and are considered out of date.

INCORPORATION OF LIQUID MANURE

There are various techniques with different advantages and disadvantages for the mechanical incorporation of the liquid manure into the soil. The aim of the incorporation is to avoid the gaseous emission of ammonia and thus make all the nutrients in the liquid manure reach the plants. In Germany, according to the Fertilizer Ordinance, it is currently the duty of every farmer to incorporate the liquid manure into the soil in no less than four hours after applying it on non-cultivated areas in order to minimize evaporation. Incorporation reduces significantly the odor caused by ammonia. The previously applied liquid manure can be incorporated using a disc harrow, plow or cultivator.

In case of **injection technology**, the liquid manure is spread and incorporated in one operation with a cultivator or compact disc harrow. However, this technology is controversial because it is very expensive, the coverage area is relatively small and diesel consumption is high. It is also called manure injector or manure cultivator and can be done before sowing. Many companies save one work step due to the injection technology. The direct incorporation of the liquid manure results in very few emissions.

Fig. 18: Impact head distributor (with deflector plate)

An alternative of liquid manure injection is the **strip-till process:** a cultivator lays the manure very deeply and in strips. This method is sometimes used with maize because the maize is sowed 75 cm between the rows. With the Stripp-Till cultivator, the manure can be spread up to a depth of 25 cm precisely on this 75 cm strip.

The **slot manure injector** is similar to a small compact disc harrow and is used before the liquid manure is spread. The soil to be fertilized, mostly existing crops or meadows, is furrowed by means of discs. The manure is then poured directly into these ground slots.

In order to reduce emissions during application, it is possible to pre-treat the manure by **acidification**. Mixing the liquid manure with sulfuric acid directly before spreading significantly lowers its pH value, which means that the nitrogen remains bound for longer. This leads to a more sustainable supply of nutrients to the plants after application and reduces emissions during application to almost zero, regardless of the technology used during application.

Because of the high aggressiveness of the acid and the resulting safety risks for people and the environment, acidification is only known in the so-called SYREN process. This Danish patent uses front hydraulics for the tractor, which can carry 1000 l of acid in so-called IBC units, and a pump technology that mixes

Fig.19: Slot manure injector

the acid directly into the liquid manure when it is spread. With approx. € 80,000 additional costs just for the process itself, plus the sulfuric acid logistics, the process has so far been too expensive for most farmers.

For some time now, GPS steering systems and Section Control have made it much easier for the manure tank drivers. With the help of this technology, you can avoid doubling the spreading, because the Section Control function switches off individual hoses as soon as the GPS transmitter detects that liquid manure has already been spread in the area currently being driven on.

Comparative table 2 shows the development of the application techniques and their advantages and disadvantages.

Comparative table 2: Development of application technology since 1967

Distribution phase	Key term / recommendation	Technology	Advantages	Disadvantages
1967 to 1980	Impact head	Wide distributor	Processed surface	Very high emission
1980 to 2000	Swivel distributor	Fold mechanism	Bigger drops	High emission
1990 to this day	Dribble bar system	large hose system	good longitudinal and transverse distribution	Medium emission
2000 to 2011	Trailing shoe	Stainless steel trailing shoe	High distribution (application) accuracy	
2011 to this day	Strip-Till process	Cultivator, compact disc harrow	Almost no emissions	Expensive
2018 to this day	Acidification	Sulfuric acid IBC	Complete absorption in the soil	Very expensive, dangerous

Chapter 10:
Marketing and logistics

The organizations in Moldova (applicable to South Eastern European countries, especially Serbia and Ukraine) allow resident livestock keepers and animal fattening farms to have access to the information about the surrounding arable farms. As a result, a farmer usually knows about different types of farms and working methods in the neighborhood. This is an enormous advantage for networking with one another, because the manure from the livestock farms is a cheap fertilizer for the arable farms, while the livestock keepers can earn additional income by selling the manure as a fertilizer. This can be an advantage for both types of farms, because overall there is an interest not only in using the liquid manure as a valuable fertilizer, but also in disposing of it in a cost-neutral and environmentally friendly manner.

However, since the different types of farms (agricultural ones and those of animal breeding) are unevenly distributed within the country, there can be greater distances between the liquid manure supplier and the recipient. As described in Chapter 8, suitable means of transport are required to facilitate the exchange of services for all parties involved. In Moldova, trucks or other inexpensive forms of transportation could be used, for example, to cover the long distance between the breeding farms in Anenii Noi and the arable land in Donduseni or Soroca. If, according to our rough estimate (see Infographic 6), Moldova's agriculture would be able to use a third of its fertilization from farm manure for the average term, then an average of up to 100 km of transport distance must be covered (applicable to South Eastern European countries, especially Serbia and Ukraine).

In Germany, for example, the large-scale distribution of liquid manure is becoming more and more necessary because the fertilizer ordinance limits the admitted application rate kg N / ha. For this purpose, fertilizers, especially liquid manure, cattle manure, chicken and poultry droppings is transported from the regions specialized in cattle breeding to so-called receiving regions, sometimes at long distances in Germany or even Europe. Such receiving regions are usually large arable areas but with a reduced percentage of animal breeding. The value of nutrients in farm manure is calculated between the supplier and the buyer.

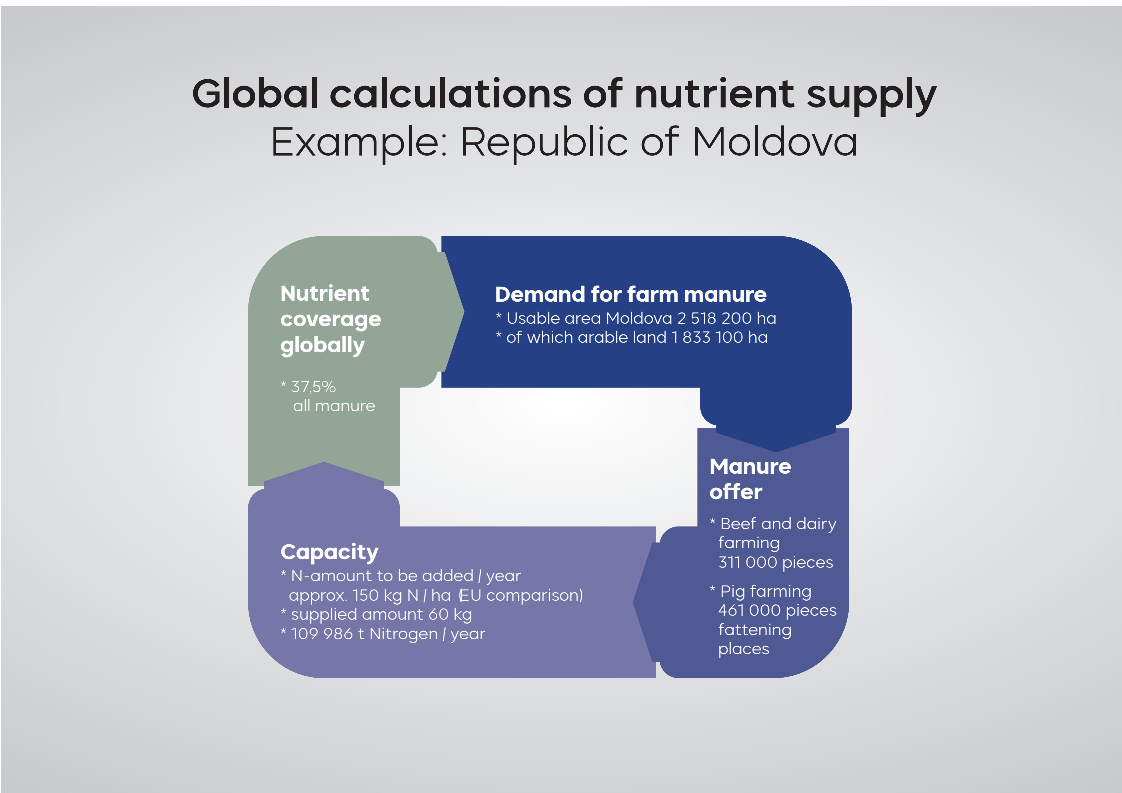
LIQUID MANURE EXCHANGE

In order to organize the marketing and logistics for redistributing liquid manure from suppliers to buyers, liquid manure or nutrients exchange was created. Such exchange (market) helps to distribute the accumulated nutrient quantities optimally, to relieve beef cattle farms and regions and to cultivate arable lands.

The liquid manure exchange regulates the pricing and exchange of liquid manure quantities between suppliers and buyers. The exchanges are organized as companies and can also operate electronically. Exchange employees deal with entering the supply / demand report in the database, marketing the manure among the farmers and then with the transportation. For this service and logistics organization, the manure exchange receives a margin of approx. 5% of the nutrient value, depending on the manure. Depending on the market situation, i.e. the amount of liquid manure offered and in demand, different scenarios can arise: the receiving farmer either has to pay for the liquid manure and the transportation, or he is given it for free or even gains money for acceptance of an existing surplus. This can happen in winter, for example, when the manure period of ban on fertilizer spreading applies and the manure storage facilities of the animal farms are full. The pricing at the liquid manure exchange is based on supply and demand, as well as the transportation distance.

An example to explain this: animal farmer A keeps 2,000 fattening pigs, but has only 30 hectares of arable land. These 30 hectares are not enough to absorb the nutrients from the manure produced on their own farm, so A decides to sell his pig manure. To do this, he uses a manure exchange and sells his liquid manure directly to the exchange. Farmer B, in turn, has 500 ha of arable land but does not have his own livestock. He is looking for inexpensive farm manure and addresses to the manure exchange as an order receiving company, after that the exchange deals with the formalities.

We recommend to found such exchanges in Southeastern Europe in order to give every farmer the opportunity, as a supplier or buyer of liquid manure, to contribute to



Infographic 7: Rough global calculations for Moldova (applicable to South Eastern European countries, especially Serbia and Ukraine)

the cycle of this valuable good as a fertilizer. Such an exchange can be founded as a private service company. An example from Germany is Maschinenring - support at the nutrient exchange - MR Germany[11].

Methodically, the brokerage takes place in an established exchange as follows:

- Advertisements can be placed by sellers or buyers and should contain the following elements: Amount of liquid manure offered / requested, nutrient offers or requests, storage offers or requests, details about the nutrient (nutrient type, storage location, information about the access to the storage location, etc.), amount and price, validity period of the advertisement, comments;

- An advertisement shall also contain information about the person (name, address, telephone).

  Based on the address, the advertisement is shown in a cartographic manner, so that it can be seen in which area offers or requests can be found.

- All advertisements placed can be compiled into an overview.

Infographic 7 (previous page) shows a rough global calculation for the Republic of Moldova. Taking into account a given area of arable land and an estimated total available capacity of liquid manure, assuming that the Moldovan soils are fertilized as intensively as in Germany, approx. 15% of the fertilizer requirement could be covered by liquid manure. If, on the other hand, the lower fertilization practice observed by the authors on site in Moldovan farms is taken as a basis, even 37.5% of the current (expensive) mineral fertilization could be replaced with the comparatively cheap and qualitatively more valuable liquid manure (applicable to South Eastern European countries, especially Serbia and Ukraine).

[11] URL address: https://www.maschinenring.de/leistungen/naehrstoffmanagement/naehrstoffvermittlung

Chapter 11:

Localization of Agricultural Engineering

The liquid manure spreading technology should be precisely, reliably and individually adjusted to the needs of the farms, as shown on the photos of the vehicles in Chapters 2, 8 and 9. A liquid manure tank with a capacity of 16,000 l costs between € 50,000 and € 200,000 in Germany. It is produced in small numbers and is designed for decades of use.

However, as the international comparison shows, agricultural technology does not have to be as expensive for liquid manure spreading as in Germany. In Southeast Europe there are already some traditional manufacturers of tractors and special agricultural technology who are ISO-certified and work professionally. These local, regional or national manufacturers could build inexpensive liquid manure containers, even avoiding previous mistakes made by Western European manufacturers.

In Infographic 8 we have shown the usual production of a liquid manure tank in Germany in ten steps.

These ten steps can be distinguished according to two criteria:

1. What part of the production can be carried out by the manufacturer of a liquid manure tank and does not have to be subcontracted to third parties or purchased? If there are strong partnership in the areas of container construction and chassis construction, as they are largely outsourced. Most of the vehicle manufacturers' electrical and control systems are domestically produced. Domestic electricians often develop individual solutions for circuits.

2. What part of the production can be done on site? Here we make assumptions of known, existing competence and productivity, resulting in the fact that price and performance could be right.

Vertical integration in vehicle construction

Production planning for a liquid manure tank

Depth of manufacturing business versus external

VERTICAL INTEGRATION IN % ECONOMICALLY IN GERMANY	PRODUCTIONS STEPS	VERTICAL INTEGRATION IN % FOREIGN TRADE IN SEE (REST: GERMANY)
30	Container construction (steel)	100
100	Welding work	100
30	Chassis and drive	70
100	Brakes and gears	70
100	Cabin and operation	55
100	Electrics	50
80	Electronics	30
80	Control (periphery)	80
100	Connection (Connectivity)	55
100	Street legal	100

Infographic 8: real net output ratio in the construction and assembly of a liquid manure tank

The percentages in the left column (green heading) indicate the average internally organized real net output ratio at German agricultural technology manufacturers per company. The percentages in the right column (blue heading) indicate the close range of real net output ratio locally in Southeastern Europe, whereby the rest could be bought in Germany, for example.

In order to be able to assess whether it is realistic to manufacture liquid manure containers in Southeastern Europe, the competence of the local companies in the various production steps is to be inquired about. According to our research, the container construction, the welding work and the road approval can be safely located in Southeastern Europe. High-precision steel construction and welding work are possible on site without any interdictions. The transportation approval of the containers largely depends on local regulations. Cooperation with local suppliers of chassis, drives, brakes and transmissions, which mostly buy parts from traditional suppliers from Western Europe, becomes more difficult. The supply of cabs, electric systems and connectivity depends mostly on the local industrial profile of the manufacturer, that of electronic systems depends on the vehicle brand, i.e. how much the German technology partner, for example, renounce of competence and control.

Overall, we expect that the high-quality necessary technology for the construction of liquid manure containers would be available locally in Southeastern Europe. The local construction of required equipment can reduce costs and facilitate transport and use of liquid manure. We expect corresponding pilot projects in the coming years.

Chapter 12:
Rules of Conduct

Dealing with manure is associated with risks for humans and animals. Incorrect processing can produce large quantities of toxic gases. This often occurs unnoticed. In addition to carbon dioxide, methane and ammonia, hydrogen sulfide represents a particular hazard. The colorless gas collects at the bottom of recipients or pits because it is heavier than air. The tricky thing about hydrogen sulfide: in higher concentrations, it can no longer be perceived because it paralyzes the sense of smell. In low concentrations it smells like rotten eggs. High concentrations of hydrogen sulfide occur most frequently when the liquid manure is stirred up in pits, manure cellars, manure containers or in any other recipients. Sufficient ventilation must be ensured in such cases. All of these are reasons for the urgent need to comprehensively instruct the personnel working with liquid manure. Special precautionary measures must be taken during maintenance and repair work, as well as when putting liquid manure containers and pits into and out of operation. If external companies carry out this work, they must be instructed by the management on possible dangers. When handling liquid manure, special precautions and regulations apply. Employees must be informed about these dangers, for example, through operating instructions.

Inhaling hydrogen sulfide can lead to unconsciousness and respiratory failure. Therefore, there is a particular risk in the places where liquid manure or manure gases can be released. This applies in particular to stables, slatted floors and places for stirring and extracting liquid manure from containers and liquid manure pits.

Furthermore, when processing liquid manure, carbon dioxide can also be released. If it is inhaled in too high a concentration, it can lead to suffocation.

In addition to these direct life-threatening and health-endangering sources of hazard, there is also a risk of explosion of methane when processing liquid manure.

The following rules of conduct serve to prevent accidents:

1. **Never stay inside the building** when stirring or pumping out the liquid manure (e.g. silo or biogas plant)!

2. Always make sure there is **sufficient ventilation**!

3. **Avoid** all potential **sources of ignition**!

4. When stirring or pumping, **pay attention to the weather conditions and wind direction**, so as not to be caught in the way of any gases that may be released!

5. While stirring or pumping the liquid manure, **watch the animals in the stables** from the outside and **stop stirring immediately if you witness any unusual behavior!**

6. If possible, **procure a gas measuring device** in order to be able to measure the liquid manure gases, if necessary.

7. There is a particularly high risk when entering pits or containers. **Never enter unaccompanied by security personnel, without wearing protective equipment, or in case of poor ventilation!**

8. **Pits must be well secured and marked!**

9. **Keep children away** from liquid manure recipients!

10. **Adhere to the operating instruction and company ruling!**

11. **Do not eat**, **drink** or **smoke** when handling **liquid manure**!

12. Keep in mind that **liquid manure expands when warmed** and produces **toxic gases**. Pipes can burst; please provide **sufficient ventilation** for such cases!

You can obtain further information from the responsible professional association in your country.

Infographic 9 (next page) shows the original representation of an operating instruction for liquid manure processing from Germany, which summarizes the most important sources of danger and rules of conduct.

Operating instructions
According to the Regulations on the handling of hazardous substances and the Occupational Health and Safety Regulations
Job / Field of activity: Liquid manure agitation (stirring) / inlet duct washing / working in liquid manure pits

hazardous substance: LIQUID MANURE / SLURRY
(gas mixture of hydrogen sulphate, carbon dioxide, methane and ammonia / liquid manure)

Dangers to humans and the environment

Danger of hydrogen sulphate poisoning (H_2S)	(gas heavier than air)
Danger of suffocation with carbon dioxide (CO_2)	(gas heavier than air)
Danger of explosion with methane (CH_4)	(gas lighter than air)
Health hazard with ammonia (NH_3)	(gas lighter than air)

Danger of explosion, suffocation, poisoning in pits and containers of liquid manure!
Liquid manure may contain substances such as fungi, bacteria, viruses, which may cause allergic reactions or serious infections.

Protective measures and rules of conduct

Protective measures and rules of conduct are usually based on specific conditions at work and the type and execution of liquid manure handling.

Do not eat, drink or smoke while working. Contaminated clothing must be changed. Before breaks or at the end of the working day, wash your hands and rinse contaminated body parts.

In case of gas emissions when stirring or pumping liquid manure:
- Ventilate the stable / room well. Open the doors. Turn on the fans to the maximum.
- Avoid sources of ignition. Do not smoke or use sources of open fire. Avoid electric ignition sources. Switch off the gas. Do not perform welding or cutting work. Do not do transillumination tests. Do not enter the stables during agitation (stirring), washing.

Risks of contact with liquid manure:
- Hand protection: protective gloves, resistant to chemicals
- Eye protection: goggles
- Body protection: rubber apron, protective clothing, rubber boots.

Additional rules, when entering liquid manure pits and containers:
- Respiratory protection: breathing device, independent of the environment
- Personal safety: Safety harness with tripod and winch. Two people will supervise the descent into the pit or liquid manure tank.

In case of accidents:

- Warn colleagues, inform superiors.
- If it is not possible to avoid the risks - stop agitation or pumping work.
- Do not enter liquid manure pits, basins, containers in order to save people or animals without protective equipment and breathing apparatus.
- Provide sufficient supply of clean air. Assess possible risks before entering liquid manure pits, basins, containers without protective equipment.

First aid

- Before taking any actions, take precautions regarding your own security.
- In case of inhalation: access to fresh air. In case of loss of consciousness, free the airways. Seek medical attention. Tell the doctor about possible hydrogen sulfate poisoning.
- In case of contact with eyes: remove contaminated clothing immediately, wash contaminated areas with water.
- If swallowed: Rinse mouth with water. Drink plenty of water.

Person who provided first aid:
Doctor:
Poison Information Center: 0228/19240
Emergency: 112

Correct disposal

Clean contaminated surfaces. Store, transport and distribute liquid manure in accordance with legal regulations.

Infographic 9: Operating Instructions for Hazardous Substances Ordinance

Chapter 13: Recommendations

1. Liquid manure is a precious thing. With or without prior use in a biogas plant, it should be used as a fertilizer for an agricultural and economic circle.

2. Dumping liquid manure into surrounding water or the groundwater has many negative environmental effects that must and can be avoided. Serious environmental damage can be punished and is subject to severe penalties.

3. The storage and further processing of liquid manure are neither expensive nor complicated. Affordable and good solutions can always be implemented locally, e.g. in ready-mixed concrete containers or, if necessary, using foil.

4. The time of application is important: in addition to the set inappropriate application time periods, the application time depends on the weather, precipitation and crops, because the positive effect of the liquid manure on the soil quality depends on whether and how well the nutrients can be absorbed. This knowledge is the core competence of the modern farmer.

5. The spreading technique in Western Europe has developed from the deflector plate towards ground-level incorporation using dribble bar systems. The suppliers' agricultural machinery for transportation and application is equipped accordingly. Agricultural technology is initially expensive, but as demand increases, it can be produced cheaply on site. Improvisation and collaboration help temporarily, for example by renting out machines or used technology. Associations and authorities facilitate the start of modern use of liquid manure and there is also the option of applying for funding projects.

6. In order to build a biogas plant, partners can be found in Southeastern Europe. In this way, economically and ecologically optimal systems can be developed that generate additional profits through renewable energy!

7. The advantages of liquid manure processing outweigh the fact that in Moldova, for example, a third of all fertilizer imports could be avoided if liquid manure was consistently used as fertilizer, conclude by Maschinenring

Kommunalservice GmbH, following the multiple researches of the studies in the field. This is clearly reflected economically and in the quality of the soil. It seems that the measurement of nutritional content of liquid manure is complicated to be determined as a chemical formula before the manure can be used. However, this initial additional effort of clarifying the chemical formula of the manure becomes a little effort in comparison with the effect of having the manure spread overall on the soil.

8. Cooperation with neighbors in the form of stock exchanges or local associations can build bridges between the cropping and livestock farms in a region, can reduce costs and maximize benefits.

9. Safety regulations and knowledge of possible dangers in manure handling protect against health risks.

Annex 1: Sources of information (associations, authorities and funding agencies)

Name of the institution	Name, Surname	Position	Phone	E-mail
MOLDOVA				
(AIPA) Agricultural Intervention and Payments Agency	Vadim Curmei	Director	+373 22 222 786	vadim.curmei@aipa.gov.md
(AIPA) Agricultural Intervention and Payments Agency	Sergiu Batiușca	Deputy Director	+373 22 222 786	sergiu.batiusca@aipa.gov.md
(AIPA) Agricultural Intervention and Payments Agency	Petru Tîmbur	Deputy Director	+373 22 222 786	petru.timbur@aipa.gov.md
(UCIMPA) Competitive Agriculture Project in Moldova MAC-P	Liviu Gumovschi	Executive Director	+373 22 244469	campu@campu.md
Academy of Sciences of Moldova	Andrieș Serafim	Academician in the field of agric.	+373 22 24 48 58	ipaps_dimo@mtc.md
Agrarian University	Liviu Volconovici	Rector	+373 22 31 2258	l.volconici@uasm.md
Agrarian University	Iurie Melnic	Pro-rector	+373 22 312 256	i.melnic@uasm.md
Center Development Agency	Viorel Jardan	CEO	+373 268 2 26 92	viorel.jardan@adrcentru.gov.md
Competitive Agriculture Project in Moldova MAC-P	Olga Sainciuc	Deputy Director Coordinator Comp. B and C	+373 22 222465	campu@campu.md
Competitive Agriculture Project in Moldova MAC-P	Eugen Voinițchi	Coordinator Comp. A	+373 22 222465	campu@campu.md
Ministry of Agriculture, Regional Development and Environment	Tatiana Nistorică	State Secretary	+373 22 204 503	tatiana.nistorica@madrm.gov.md
Ministry of Agriculture, Regional Development and Environment	Mihail Machidon	State Secretary	+373 22 204 501	mihail.machidon@madrm.gov.md
Ministry of Agriculture, Regional Development and Environment	Dorin Andros	State Secretary	+373 22 204 502	dorin.andros@madrm.gov.md
National Federation of Farmers of Moldova AGROinform	Aurelia Bondari	CEO	+373 22 235 698	abondari@agrofarm.md
National Institute for Economic Research	Eugenia Lucașenco	Department head	+373 22 50 11 00	eugenia_lucasenco@yahoo.com
North Development Agency	Mariana Cebotari	Planning specialist	+373 231 61980	spsp.adrnord@gmail.com
Organization for the Development of the SME Sector	Iulia Costin	CEO	+373 22 29 57 41	iulia.costin@odimm.md
South Development Agency	Maria Culesov	CEO	+373 241 2 62 86	adrsud@gmail.com
UKRAINE				
Agricultural consulting services	Oleksiy Orlov	Senior Consultant	+38 09500 96 251	oleksiy@farming.org.ua
Bioenergy Association of Ukraine	Maistrisin Vladimir	Director UABIO	+38 044 253 2856	info@uabio.org
Bioenergy Association of Ukraine	Taras Kachka	Minister	+38 044 253 1055	pr6@me.gov.ua
Ministry of Economy, Trade and Agriculture	Gheorghii Gheletuha	Director	+38 044 456 9462	info@biomass.kiev.ua
SEC Biomass	Volodymyr Makar	Director	+38 068 863 4687	office@uagra.com.ua
SERBIA				
Serbian Biogas Association	Danko Vukovic	President of the association	+38 169 5520 432	info@biogas.org.rs danko.vukovic@biogas.org.rs
Ministry of Agriculture, Forests and Waters	Branislav Nedimovic	State Secretary	+381 11 3620 115	predsednik.vlade@gov.rs
SERBIO National Biogas Association	Danko Vukovic	Director		office@serbio.rs
ROMANIA				
Ministry of Agriculture and Rural Development	Emil Dumitru	State Secretary	+40 213 072329	cabinetss.dumitru@madr.ro
Romanian Biomass and Biogas Association (ARBIO)	Mariana Stoicescu	Senior Consultant	+40 752 137 414	mariana.stoicescu@arbio.ro

Annex 2: Conversion rates for livestock units (LU)

Description	**LU**
Ponies and small horses	0,70
Other species of horses under 1 year	0,70
• From 1 to 3 years	0,70
• From 3 to 14 years	1,10
• From 14 years	1,10
Calves under 6 months	0,30
Young cattle 6 months - 1 year	
• Males	0,30
• Females	0,30
Cattle 1 year - 2 years	
• Males	0,70
• Females for slaughter	0,70
• Females for rearing and production	0,70
Cattle from 2 years	
• Males	1,00
• Females	1,00
- Heifers for slaughter	1,00
- Heifers for rearing and production	1,00
- Dairy cows	1,00
- Nurse cows and mother cows	1,00
• Cattle for slaughter and beef cattle	1,00
Sheep under 1 year, including lambs	0,05
Females under 1 year of age for rearing	0,10
Aries 1 year and older for rearing	0,10
Mutton (castrated male sheep) and other	0,10
Piglets	0,12
Pigs under 50 kg live weight	0,22
Pigs for fattening	
• 50 kg - 80 kg live weight	0,40
• 80 kg – 110 kg live weight	0,40
• Over 110 kg live weight	0,40
Pigs for rearing over 50 kg live weight, wild boar	0,33
• Sows, pregnant for the first time	0,33
• Other pregnant sows	0,33
• Non-pregnant sows	0,33
• Other non-pregnant sows	0,33
Laying hens 1/2 year and older	0,0183
Chickens and laying hens under 1/2 years	0,0044
Chickens and roosters for slaughter	0,0091
Geese	0,0067
Ducks	0,0231
Turkeys	0,0167

Annex 3: JGS regulation (Systems of storage and processing of liquid manure, slurry and silo)

Ordinance on systems for handling substances hazardous to water 1, 2 (AwSV)
Annex 7 (to Section 13 (3), Section 52 (1) sentence 2 number 1 letter a)
Requirements for storage and processing systems for slurry, liquid manure and silage

Reference: Civil Code volume I. 1 2017, 953 - 955)

1. Definitions

1.1. JGS systems include in particular liquid manure containers, collecting pits, earth basins, silos, mobile silos, slurry cellars and channels, solid manure plates, filling areas with the associated pipelines, safety devices, joint seals, coatings and linings.

1.2. Collection facilities are all structural and technical installations for the collection and transport of liquid manure, slurry and silage infiltrations. They also include the manure removal channels and pipes, adjacent pits, pumping stations and the feed pipe to the adjacent pit, provided they are not regularly dammed.

2. General requirements

2.1. Only building products, types or kits may be used for the construction of systems, for which the building inspectorate proof of usability is available, taking into account water law requirements.

2.2. Systems must be planned, constructed, designed and operated in such a way that:

a) Generally water-polluting substances according to Section 3 Paragraph 2 Clause 1 numbers 1 to 5 cannot leak,

b) Leaks in all parts of the system that come into contact with the substances specified in letter (a can be identified quickly and reliably,

c) escaping substances that are generally hazardous to water can be detected quickly and reliably in accordance with Section 3 Paragraph 2 Clause 1 Numbers 1 to 5 and

d) In the event of a malfunction, mixtures that may contain leaking substances hazardous to water are properly recycled or disposed of without causing any damage.

2.3. JGS systems must be impermeable to liquids, stable and resistant to the expected mechanical, thermal and chemical impacts.

2.4. The operator has to commission a specialist company according to § 62 with the construction and repair of a JGS system, unless he himself fulfills the requirements of a specialist company. This does not apply to systems for storing silage infiltrations with a volume of up to 25 cubic meters, other JGS systems with a total volume of up to 500 cubic meters or for systems for storing solid manure or silage with a volume of up to 1,000 cubic meters.

2.5. Construction of wooden containers or containers is not allowed.

3. Systems for the storage of liquid substances that are generally hazardous to water

3.1. Single-walled JGS storage systems for liquid substances generally hazardous to water with a total volume of more than 25 cubic meters must be equipped with a leakage detection system. Single-walled pipelines are permitted if they comply with the technical rules.

3.2. Collection and storage facilities are to be equipped with leakage detection systems according to number 3.1. In case of collection and storage facilities under stables, a leakage detection system can be dispensed with if the accumulation height is limited to the amount necessary for manure removal and, in particular, joints and seals are checked for their proper condition prior to commissioning.

4. Systems for storing solid manure and silage

4.1. The storage areas of systems for the storage of solid manure and silage must be bordered from all sides and protected against the penetration of surface runoff rainwater from the surrounding area. There are no requirements for silo accumulations stored in round or square bales and sealed with foil, especially if the silo is not extracted.

4.2. It must be ensured that livestock manure, silage seepage and rainwater contaminated with solid manure or silage is completely collected and properly disposed of as wastewater or recycled as waste, provided that they cannot be used in accordance with good fertilization practice.

5. Filling equipment and installations

5.1. Anyone who fills or empties a JGS system has to do the following:

a) to monitor this process and to convince oneself of the proper condition of the necessary safety devices before starting the work.
b) to adhere to the permissible load limits of the system and the safety devices when filling and emptying the containers.

5.2. It must be ensured that the rainwater, which is contaminated by substances generally hazardous to water during the filling process, is completely collected and properly disposed of as wastewater or recycled as waste, unless it can be used in accordance with good fertilization practice.

6. Obligations of the operator to monitor and report

6.1. If construction, decommissioning or re-equipment of a silo infiltration storage system with a volume of more than 25 cubic meters, another JGS system with a total volume of more than 500 cubic meters or a system of storage of solid manure or silage with a volume of more than 1,000 cubic meters are planned, the operator must notify the competent authority in writing at least six weeks prior to the said works. Sentence 1 does not apply to the construction of systems that require approval in individual cases according to other legal provisions or that have obtained such approval, provided that the approval also ensures that the requirements of this ordinance are met.

6.2. The operator has to regularly monitor the correct operation and the tightness of the systems as well as the functionality of the safety devices. If the monitoring according to sentence 1 reveals a suspicion of a leak, they must immediately take the necessary measures to prevent the substances from leaking. If there is a suspicion that water-polluting substances have already leaked in significant amounts and a risk to a water source cannot be excluded, the responsible authority must be notified immediately.

6.3. If the suspicion of leakage is confirmed or if substances hazardous to water emerge, the operator must immediately take measures to limit the damage and arrange for repairs to be carried out by a specialist company, unless he is a specialist company himself.

6.4. According to number 6.1, operators must have notifiable systems, including the pipelines checked for leaks and functionality by an expert before commissioning and by order of the competent authority. Operators must have underground basins checked by an expert every five years; in water protection areas - every 30 months.

6.5. The expert must submit a test report to the competent authority on the result of each test carried out by him in accordance with number 6.4 within four weeks. Based on the results of the tests, he has to classify the system into one of the following classes:

a) without defects;
b) with minor defects;
c) with significant defects;
d) with dangerous defects. The expert must immediately inform the competent authority about the dangerous defects.

6.6. The test report according to number 6.5 must contain information on the following:

a) Operator;
b) Location;
c) Identification of the system or installation;
d) System or installation classification;
e) Regulatory approvals;
f) Expert and the expert organization that appointed him;
g) Type and scope of the test;
h) Whether the test of the entire system has been completed, or which parts of the system have not yet been checked;
i) Type and extent of the defects found;
j) Date and result of the test and
k) Necessary measures and a proposal for a reasonable deadline for their implementation.

6.7. The operator has to remedy the minor defects found during the tests according to number 6.4 within six months of their discovery and, if necessary according to number 2.4, and by a specialist company in accordance with § 62. The operator must remedy significant and dangerous defects immediately. The elimination of significant defects requires a review by an expert. If the expert discovers a dangerous defect, the operator has to take the system out of operation immediately and, if this is necessary according to the expert, to empty it. The system may only be put back into operation once the competent authority has received confirmation from the expert that the deficiencies found have been successfully remedied.

7. Existing installations

7.1. For JGS systems that were already built on 1 August, 2017 (existing systems), the following applies from this date:
   a) Section 24 (1) and (2) and numbers 5.1 and 6.1 to 6.3,
   b) Numbers 6.4 to 6.7 with the provision that the competent authority can only order the inspection of the facilities and underground basins named there by an expert if there is a suspicion of significant or dangerous defects and
   c) Numbers 1 to 4 and 5.2, insofar as they contain requirements that correspond to the requirements that had to be observed on 31 July, 2017 according to the respective state regulations.

   In addition, these inspection obligations continue to apply to existing systems that were already subject to inspection under the applicable national regulations prior to August 1, 2017.

7.2. In case of existing systems with a volume of more than 1,500 cubic meters that do not meet the requirements of numbers 2 to 4 and 5.2, the competent authority can order technical or organizational adjustment measures,
   a) Which would remove these defects or shortcomings;
   b) Which are provided for these defects in the technical rules for existing installations or
   c) With which compliance with the requirements specified in numbers 2 to 4 and 5.2 is achieved.

   In the cases of sentence 1 letters b and c, the requirements of Section 62 paragraph 1 of the Water Management Act must be observed.

   This does not affect the authority to issue orders in accordance with Section 100, Paragraph 1, Clause 2 of the Water Management Act for all existing systems.

7.3. In case of existing systems with a volume of more than 1,500 cubic meters, in which retrofitting with a leakage detection system is not possible for technical reasons or can only be achieved with disproportionate effort, the tightness of the system must be proven by suitable technical and organizational measures.

7.4. In the orders in accordance with number 7.2, the authority cannot demand that the installation to be decommissioned or removed, or that adaptation measures to be required that are equivalent to a new construction, or to change the purpose of the installation. When eliminating significant or dangerous defects in a JGS container, the requirements of this ordinance must be observed. Otherwise, Section 68 (7) applies accordingly to existing systems.

7.5. In case of existing systems with a volume of more than 1,500 cubic meters, the operator must document compliance with the requirements according to numbers 6.2 and 6.3, in particular the type, scope, result, place and time of the respective monitoring, as well as the measures taken and the documentation of the competent authority to be presented on request.

8. Requirements in special areas

8.1. No JGS systems may be set up and operated in an officially protected region for water supplies and in protected areas. In these zones of protected areas, single-walled JGS storage systems for liquid substances that are generally hazardous to water may only be set up and operated if equipped with a leakage detection system.

8.2. JGS systems may only be installed and operated in established and temporarily secured floodplains if
   a) they cannot refloat or otherwise be damaged by floods and
   b) substances that are hazardous to water are not washed away by floods, are not released and cannot penetrate into a water source in any other way.

8.3. The competent authority can grant an exemption from the requirements according to numbers 8.1 and 8.2 if:
   a) the public interest requires this or the prohibition would lead to unreasonable hardship and
   b) if the protection purpose of the protected area is not impaired.

8.4. Further provisions in state ordinances for the establishment of protected areas remain unaffected.

PHOTO CREDITS

Number and name	Source
Fig. 1 - Fig. 1: A floating colony of Phaeocystis algae (foam alge)	Wera Leujak / UBA
Fig. 2: Green algae in the North Sea	Wera Leujak / UBA
Fig. 3 - Rosdorf biogas plant	Maschinenring Kommunalservice
Fig. 4 - Ground basin	AGW GmbH
Fig. 5 - Ready-mixed concrete containers	Wolf System GmbH
Fig. 6 - Precast container	SUDING Beton- und Kunststoffwerk GmbH
Fig. 7 - Stainless steel container	Erich Stallkamp ESTA GmbH
Fig. 8 - Liquid manure drainage station with adjacent pit	Sundermann GmbH & Co.
Fig. 9 - Drainage pipe with inspection tunnel	Maschinenring Kommunalservice
Fig. 10 - Separator in Kassel	Maschinenring Kommunalservice
Fig. 11 - Pumping the liquid manure from the transportation tank to the spreading tank	Maschinenring Kommunalservice
Fig. 12 - Liquid manure container	Maschinenring Kommunalservice
Fig. 13 - Liquid manure truck	Maschinenring Kommunalservice
Fig. 14 - Tractor with liquid manure cultivator	Maschinenring Kommunalservice
Fig. 15 - Trailing shoe in detail	Chamber of Agriculture North Rhine-Westphalia
Fig. 16 - Tractor with dribble bar spreader	Chamber of Agriculture North Rhine-Westphalia
Fig. 17 - Swivel distributor	Chamber of Agriculture North Rhine-Westphalia
Fig. 18 - Impact head distributor (with deflector plate)	Chamber of Agriculture North Rhine-Westphalia
Fig. 19 - Slot manure injector	Chamber of Agriculture North Rhine-Westphalia

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