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| **Title** | **Swedish farmers attitudes to reuse of digestion residues from anaerobic digestion and source-diverted urine** |
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| **Short CV for Introduction Purposes ( 100 words max)** | Elisabeth (left):<br>E works as a consultant for VERNA Ecology since 2002, mainly with different aspects of small-scale sanitation (e.g. urine diversion, agricultural reuse, legal/regulatory issues, planning), both nationally in Sweden and internationally. Before 2002 she worked at the Swedish Environmental Protection Agency with recycling of phosphorus from wastewater to agriculture. She holds a PhD in sanitary engineering and a MSc in environmental engineering.<br><br>Anna (right):<br>A works as consultant for VERNA Ecology since 2002, mainly with agricultural perspectives on systems for reuse of human excreta and source separated household waste. Anna has an MSc in horticulture, and has extensive experience in field trials and extension regarding organic fertilizers. |
| **Photograph attached ( jpg)** |   |

## Introduction

Source diverted fertilizers from human activities, e.g. urine and digestion residues, are relatively “new” fertilizers on the market for farmers in Sweden. These two fertilizers are similar in that they are liquid and with fertilizing properties close to those of liquid animal manure. However, the agricultural reuse of digestion residues is more widespread than the reuse of human urine in Sweden today. Thus, systems for reuse of digestion residues already exist and are more established than those existing for urine reuse in Sweden. Therefore, it is relevant to make use of experiences of reuse of digestion residues when building new systems for the reuse of urine.

In Sweden there are six larger plants for production of biogas where organic waste residues are anaerobically digested. The biogas plants use household waste, food industry residues, slaughterhouse residues, and manure as substrates. Handling systems for the digestion residue, including quality control, are well established in Sweden.

One important factor for the functioning of reuse of source diverted fertilizers is the final link in the chain, i.e. the farmer. However, this component of the system is often forgotten since systems usually are constructed/planned by technicians, planners or architects with little knowledge of farming.

This paper presents qualitative results of interviews with farmers receiving digestion residues from the six major biogas plants in Sweden and compares these results with existing experiences of agricultural reuse of urine in Sweden. We discuss aspects important to the farmers such as the market attitudes for agricultural products, including consumers, processing companies and agricultural co-operations, as well as odor and agricultural effect of the fertilizers.

## Method

Digestion residues with substrates from household waste, farm yard manure, food processing industries, and slaughterhouses were considered for this paper. Hence, anaerobically digested sewage sludge was not considered for this paper.

Telephone interviews were conducted with six Swedish farmers that all currently use digestion residue as fertilizer for cultivation. The areas covered in the interview were

1. Practical experiences of reuse of digestion residues
2. Yield
3. Knowledge gaps
4. Agreements and organization with biogas plant
5. Quality control issues
6. Acceptance to use human excreta as substrate
7. Challenges and success factors

One interview was also carried out with a representative for food industries concerning bullet 4 – 7 above.

Regarding urine, a comparison was made drawing on experiences generated during the last fifteen years of agricultural reuse of source diverted urine in Sweden.

## Results and discussion

### *Practical experiences of reuse*

#### Digestion residue

The interviewed farmers are in general very positive to using digestion residues for crop production. The digestion residue has less odor compared with non-digested liquid farm yard manure, which is mentioned as one of the advantages of digestion residues as fertilizer.

The digestion residues are usually transported from the biogas plant to the farmer by an entrepreneur who acts as an intermediate. A well-functioning communication between the farmer and entrepreneur is important from the farmer perspective.

The digestion residues are usually stored at the farm, in old, uncovered concrete farm yard manure pits. Uncovered storage of digestion residues poses risks of ammonia losses as well as rainwater dilution of the fertilizer, both of which are undesired since it will lower the fertilizing value. The tanks are uncovered mainly for economic reasons.

**Urine**
The more concentrated the urine the better from a farmer's perspective, since a diluted fertilizer increase the risk of soil compaction. Hence, it is important to avoid dilution of the urine during the collection (flushing of toilet bowl) and storage.

During the application of urine in field there is a noticeable odor, but this subsides within 24 h. At a short distance from the field the odor is not a problem.

## *Yield*

**Digestion residue**
The digestion residues are used for fertilizing cereals, rape seed, leys, vegetables and potatoes. The choice of crop depends on e.g. time of amendment, rainfall and other weather conditions.

The farmers usually calculate that 70-80% of the ammonia nitrogen (N) in the digestion residues is directly available to the plants, and compensate the plant's N need accordingly. In fact, this is an underestimation of the N effect of digestion residue. A review of Swedish field experiments using digestion residue showed that the efficiency of digestion residue N compared to mineral fertilizer varied between 68-146%, where most values were around 100% (Richert Stintzing and Kvarnström, 2005).

The farmers are all positive to the digestion residues fertilizing effect on the yields. One farmer says that the nutrients in digestion residues are more available to plants than liquid farm yard manure but that the fertilizing effect of digestion residues is more weather dependent than for a mineral fertilizer. A bit of rain after the digestion residue amendment is ideal, and helps spreading the nutrients evenly in the soil profile.

**Urine**
The N efficiency of urine is approximately 90% of that of mineral fertilizer (Johansson et al, 2001; Richert Stintzing et al, 2001; Rodhe et al, 2004). Hygienized urine is best used as a direct fertilizer for N-demanding crops, e.g. spring-sown cereals and leafy vegetables. It can also be used as N source for leys.

## *Knowledge gaps*

**Digestion residues**
The farmers express a need for more knowledge of N release dynamics, and ways to increase the period during the season when digestion residue can be spread. Another interesting area for development is on-site production of biogas for use in the farm vehicles.

**Urine**

From a farmer's perspective, there are a few knowledge gaps that remains to be filled regarding agricultural use of urine. Urine is a high quality fertilizer considering its extremely low content of heavy metals, compared to other fertilizers. However, urine can contain water-soluble medical residues and potential risks and market reactions related that needs to be addressed. Other challenges are how to minimize dilution of urine in flushing systems and how to organize collection, transport and storage more efficiently. Risks of salinization in soil, using urine as a fertilizer, which could possibly be an issue in arid climates, is not a problem in Sweden.

## *Contracts and organization of reuse*

**Digestion residues**

The contracts between the biogas plants and the interviewed farmers range from one to five years in length. Contract arrangements matching the crop rotation are recommended, which allows for more long-time planning for the farmers.

Different strategies for payment for the digestion residue are applied, from biogas plants not charging at all to biogas plants charging according to the nutrient content in the digestion residue. Farmers delivering farm yard manure to the plants are, however, never charged for the digestion residue. Overall, the willingness to pay for the digestion residue is low among the interviewed farmers, despite its positive qualities such as low odors and high fertilizing effect. Some of the farmers mention that the willingness to pay might increase if the digestion residue would be allowed for organic farming within the EU regulation.

**Urine**

There are systems evolving in Sweden where farmers are receiving urine on contracts from either household owners or municipalities. However, the legal situation is unclear, and there is uncertainty from mainly municipalities regarding who is responsible for the organization of reuse systems; the municipal department responsible for wastewater treatment or the municipal department responsible for solid waste handling? Currently different municipalities have different approaches towards this question and a range of policy varieties exists, depending on municipality. The willingness to pay for urine as a fertilizer among farmers is low, as for the digestion residues.

## *Quality control issues*

**Digestion residues**

The objective of digestion residue certification is to create confidence among different actors for the digestion residues as fertilizer. Quality control and certification are important issues for the agricultural reuse of digestion residues both from the farmer perspective and from the consumer perspective. The farmer needs to know the digestion residues content of nutrients and also to be sure that the digestion residue has not been contaminated through the transport and handling process. The consumers need to know that the produce has been grown using high quality fertilizers.

Four of the six interviewed farmers received digestion residues that are certified according to a rigorous quality control program, and the other two biogas plants are currently going through the process of the same certification. The four concerned farmers all consider the certification of the used digestion residue as positive for several reasons. The digestion residue certification is a quality label, which allows them to sell to several large purchasers of agricultural produce. The certification also helps in distinguishing digestion residue from anaerobically digested sewage sludge, a fertilizing agent with low acceptance in Sweden today. However, it is mentioned that not even the digestion residue certification is always enough to satisfy the quality demands from all purchasers. The representative from the food production industry stressed the importance of certification, and explains the possible lack of market response to the certification through the varying demands from different food industries (depending on e.g. type of produce), and also due to different legal/regulatory issues concerning different crops. In general, there is a lack of coordination between the actors.

**Urine**
There are good possibilities for establishing a system for certification of urine and other source diverted wastewater fractions. Currently the trade association for the food industries is involved in a process, together with a number of other stakeholders from both agriculture, food industry and the municipalities, which will produce an agreement between these stakeholders concerning agricultural reuse of, among other, digestion residues and urine. This document is prepared during this spring. The regulation for agricultural sludge reuse is currently under revision and will most probably in the future include other wastewater fractions too, such as source-diverted urine. The draft of this regulation contained several quality control measures for source-diverted urine.

## *Acceptance to use human excreta as substrates*

**Digestion residue**
On the question whether the farmers would accept to use digestion residue where human excreta is used as substrate half of them answered positively, under the condition that the human excreta as such was accepted by the agricultural processing industry and that the resulting digestion residue match current recommended limit values on heavy metals. The other half of the farmers were less positive and explained this with the fear of the digestion residue to be associated with anaerobically digested sewage sludge, if human excreta is used as substrate.

The basis for the food industry to accept digestion residue as a fertilizer in agriculture is that the substrates used for production of the digestion residue are of food origin. This attitude is partly due to consumer’s confidence but also in taking responsibility for organic waste generated through the produce processing. On the question whether human excreta can be considered such a substrate the food industry representative answered that if there is an accepted quality control system to guarantee the purity of the human excreta and the routines around handling the fractions it is possible to approve of use of human excreta as substrate in the digestion residue production.

**Urine**
Certification of urine or other source-diverted wastewater fractions will simplify the process of gaining acceptance of urine as a fertilizer within the agricultural sector.

## *Challenges and success factors for reuse of digestion residues and urine*

**Digestion residue**
A success factor mentioned by both the farmers and the food industry representative is the digestion residue certification. The certification is well-functioning and absolutely necessary according to the food industry representative. However, the knowledge of the digestion residue certification has to be increased within the agricultural produce purchasers, which should lead to less obstacles in the agricultural reuse of digestion residues.

One challenge is the low willingness to pay for the digestion residues among the farmers. Identification of factors that can increase the demand for the digestion residue is a major challenge.

The digestion residue storage poses a challenge, since the uncovered storage might lead to ammonia and biogas emissions as well as rainwater dilution of the digestion residue. Considering the low willingness to pay for the digestion residue, each cost (e.g. the coverage of storage) has to be weighed against the benefits (e.g. higher quality fertilizer, less emission of greenhouse gases).

Another success factor mentioned by the food industry representative could be the establishment of a trade forum where discussion about reuse of organic waste fractions, including digestion residues, can be held. A trade forum could possibly facilitate for involved actors to come to consensus on fertilizers approved for use in agriculture.

### Urine

In general, the attitudes of the farmers towards using urine has been positive, as long as they receive guarantees that the agricultural processing industry does not impose any restrictions, such as e.g. a compulsory waiting period between urine application and production of for example crops meant for human consumption, which is the case when sewage sludge is used as fertilizer. A challenge for the system for reuse of urine is the economic aspect. The economic value of the nutrients in the urine is roughly equal to the costs for transportation and storage. Hence, the farmer will not want to pay for the urine. There is an economic incentive for the farmer if he or she can act as an entrepreneur, charging the municipality of household owners for transportation and storage. In any case, the systems need a financial input to be attractive. These systems are evolving, and it is becoming evident that financial gain is not the driver for the time being.

## Conclusions

Both the digestion residue and the urine are highly efficient N fertilizers, suitable for a number of different crops. The N fertilizing effect of digestion residue was, however, underestimated by the interviewed farmers.

The establishment of quality control systems, such as certification systems, is extremely important for reuse of fertilizers of organic origin, such as digestion residues and urine, in the Swedish context. This has been shown to be a success factor for digestion residues, both according to the farmers and to the representative from the food industry. This should be established also for other wastewater fractions, such as source-diverted urine.

The willingness among farmers to pay for the digestion residue and the urine is low, in spite of their high fertilizing value. For digestion residues, the interviewed farmers stated that the willingness to pay could possibly increase if digestion residue is authorized for use in organic farming according to EU regulation. This probably holds true also for urine.

Knowledge gaps that remains to be filled for digestion residues are e.g. N release dynamics. For urine the minimization of dilution during flushing is important to solve, as is more clarity on municipal responsibility issues (who is actually responsible for the reuse system on municipal level in the Swedish setting?). Identification of factors increasing the demand for both digestion residues and urine for agricultural reuse is desirable.

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