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Slurry Management on Family Farms Using Acidification System to Reduce Ammonia Emissions

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1. Introduction

When discussing the problem of slurry influence on country side environment, it is important to provide some analysis of animal production, what has substantial influence on manure presence in close distance to houses and flats. In Figure 1 it is presented number of different animals, which are grown on farms in different countries of EU.

The size of a herd is either expressed in term of head (number of animal) or Livestock Unit (LSU) where one LSU is the grazing equivalent of one adult dairy cow. The data in Table 1 were used to convert from head to LSU when needed.

According to the data of Polish Ministry of Agriculture on March 2017 there were in Poland 3 732 616 cows in the age of more than 1 year old. When counting beef cattle of the same age there are 1 024 616 animals. Taking into account pigs, there are 11 824 300 animals of these breed. In these number there were 1 009 700 sows.

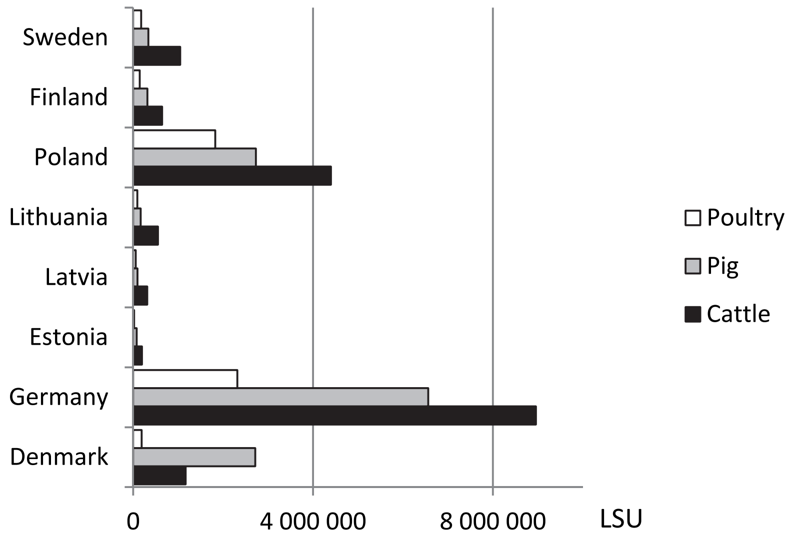

Fig. 1. Population of cattle, pig and poultry in different countries in LSU* (Eurostat 2014)
Rys. 1. Populacja bydła, świń i drobiu w różnych krajach w LSU (Eurostat 2014)
**The reference unit used for the calculation of livestock units (=1 LSU) – is the grazing equivalent of one adult dairy cow producing 3 000 kg of milk annually, without additional concentrated foodstuffs.*

Table 1. Conversion head to LSU (Eurostat 2014)
Tabela 1. Współczynnik przeliczania sztuk rzeczywistych na LSU (Eurostat 2014)

Bovine animals	Under 1 year old	0.4
	1 but less than 2 years old	0.7
	Male, 2 years old and over	1
	Heifers, 2 years old and over	0.8
	Dairy cows	1
	Other cows, 2 years old and over	0.8
Pigs	Piglets having a live weight of under 20 kg	0.027
	Breeding sows weighing 50 kg and over	0.5
	Other pigs	0.3
Poultry	Broilers	0.007
	Laying hens	0.014

Recently more and more livestock barns, in which animals are kept on slotted floor, instead of manure as organic fertilizer we gain here liquid manure – a mixture of manure, urine and water. The composition and value of natural fertilizer depend on the breeding technology, feeding and water delivery system. Cow manure and swine manure are different and they show different effect on environment. Slurry is, usually mixed with some bedding material and some water during management to give a liquid manure with a dry matter content in the range from about 1 to 10%. Although potassium is available almost immediately after the application of the manure to the soil, with nitrogen, and especially with phosphorus is not so easy. For phosphorus and a large part of nitrogen, they may be available for plants as nutrients, when a process of mineralization occurs, and generally speaking, must become the activity of soil micro flora to provide simple mineral compounds, that can be absorbed by the plant. So the activity of the soil micro flora depends on the degree of use of manure as fertilizer (Pain et al. 1994). Thus, many studies shows that the efficiency of nitrogen supplied in the slurry varies in very wide range from 30 to 70%. In addition to the mineralization we have to take into account the time – because we want to release the ingredients gradually, along with the course of the growing season. Here, nature favors us, because in the period from April to the end of August the temperatures are highest, which promotes the development of micro flora. To the development of micro flora was the most intense, you should provide them with more nutrient components. Slurry as organic fertilizer is used mainly before vegetation. It is important that large doses of manure (especially on light soils) is not preceded directly sown plants, as emitted from the manure ammonia can damage and even destroy the root system of rising plants. This assumes that the nutrients and organic matter contained in the slurry should help to increase soil fertility and increase crop yields without the risk of contamination with biogenic compounds of environmental ground water (Nyord et al. 2013).

The use of slurry in an uncontrolled way is a threat to the environment. European Union legislation allow for the use of natural fertilizers (solid manure, liquid manure, urine) an amount not exceeded 170 kg of nitrogen (N) in pure ingredient per 1 hectare of agricultural land per year (Lyngsø 2016). Requirements for agricultural construction sites, utilized for solid manure, slurry and urine storage, gives the Act of 10 July 2007 concerning fertilizers and fertilization technology. In case of utilization liquid manure for many years in doses exceeding the nutritional needs of plants, it can reveal symptoms of soil fatigue manifested by reduced yield of plants. It should, however, take into account the slurry in the fertilization of crops on the farm, as part of the supplementary nutrition. Well-applied manure improves soil physicochemical properties.

The amount slurry produced in EU countries brings all governments to establish special regulations to avoid its harmful influence on environment in country side surroundings.

2. Development of new technology for slurry treatment in the aspect of its harmful influence on environment

The international interest for slurry acidification is big and the current draft BREF (Reference Document for Best Available Techniques) has recognised slurry acidification, which will become a compulsory to Best Available Technic (BAT) in all EU member states. There are three main technologies, namely in-house, tank and in-field acidification. Their effects in reducing ammonia emissions from stables, stores and fields are substantial, and in the range of 40 to 64% according official tests, among other the Verification Statement (VERA) of technology verification programme set up in cooperation between Danish, German and Dutch environmental authorities (Biocover A/S 2012). Slurry acidification can be explained as equilibrium between the water bound ammonium (NH_4^+) and the volatile ammonia (NH_3) is moved towards ammonium by adding acid to the slurry. Normally, concentrated sulphuric acid is used, and the costs of the acid in many cases outweighed by savings on purchase of S fertiliser. The nitrogen that is captured via avoided ammonia evaporation is turned into savings on purchase of N fertiliser, or in higher crop yields. Slurry acidification also has a considerable climate effect by increasing the carbon sequestration in soil. Reducing the loss of nitrogen from agriculture is key to reducing eutrophication of the Baltic Sea. Most of the airborne eutrophication to the Baltic Sea comes from ammonia emissions, and in the Baltic State Region (BSR) almost all ammonia emissions are from livestock manure. Annual deposition of ammonia nitrogen to the Baltic Sea has been increasing during recent years and was greater in 2012 than in 1995. While emissions are decreasing slightly in some countries, Baltic Sea Action Plan (HELCOM 2013) calls for a reduction of 118,000 tonnes of nitrogen annually to the Baltic

Sea, and the Revised Gothenburg Protocol (UNECE 2012) calls for ambitious reductions in ammonia emissions from all Baltic See Region (BSR) countries. Slurry acidification also affects solid/liquid slurry separation efficiency positively; DM is higher, N lower and P higher in the solid fraction. A combined treatment should efficiently prevent gaseous emissions, increase fertilizer value of slurry and reduce transport and energy costs.

3. Acidification systems possible to utilize in practice

Acidification of animal slurry has proved to be an efficient solution to minimize NH_3 emissions in-house, during storage, and after soil application, as well as to increase the fertilizer value of slurry, without negative impacts on other gaseous emissions.

Mobile acidification equipment could be suitable for acidifying the slurry in storage during mixing just before spreading. Such equipment could be invested in by the farmer. Mobile equipment implies that the cost can be shared if the same equipment is used on several farms. The service could also be hired from a contractor, under the conditions that there is a contractor in the neighborhood providing this service.

Just to explain, why ammonia evaporation doesn’t exists, it can be explained by drawing the following equilibrium in slurry between ammonium salt and ammonia gas

$$NH_4^+ + OH \leftrightarrow NH_3 + H_2O$$

At pH=6,4 all mineralized N is found as ammonium, and no evaporation takes place (Fangueiro at al. 2014).

In Denmark, the slurry should after lowering the pH <6 be spread within 24 hours according to rules. As the spreading season last for longer times, this could mean a period of several weeks per year. Economical calculations are needed to compare which solution is most profitable for individual farms. When hiring the service of acidification, the technology will be available also for smaller farms. Also, if surplus storage volume is needed because of foaming when adding acid, may make the alternative non-profitable compared to the other two alternatives (Shi et al. 2001).

Orum Smeden’s appeared after in field acidification system as much simpler and cheaper. Using this equipment it causes foam formation in top of the slurry tank, what means that that part of storage capacity is reduced (Nørgaard et al. 2010). Such acidification is usually done a few hours or days before spreading on the field, what makes lower ammonia evaporation when spreading such slurry on crops. So far there are about 40 such installation working in Denmark.

In regards to the type of housing, different systems may be used within the same farm. Therefore, livestock within production having more than one type of housing system are counted once for each housing system used on the farm. However, some housing systems only represent a minor share of the actual production (Ribeiro 2009). In order to avoid this double counting, the number of places for each type of housing system is used.

For instance, many farms combine different housing system like having slatted floor for the milking cows but solid dung management (deep bed) for the cows about to farrow. Thus, the number of heads on each system changes during the year whereas the number of places is more of an average and represent that actual share of each system (Semitela et al. 2013).

To estimate the potential for each Slurry Acidification Technology (SAT), we should know for each country what are the most represented animal production systems including animal species and what are the most used manure management systems in these most common productions. The manure management systems include the housing types, the storage systems, and the spreading techniques. It is assumed, that the SAT is only used for slurry.

The last step of a manure handling system is the spreading stage. There are different technics for spreading slurry. Some of them like injection or incorporation have been proven to reduce ammonia emissions (Moset et al. 2012). Therefore, Slurry Acidification Technology (SAT) could be seen as an alternative to those techniques. Band-spreading is the used technique in Denmark to apply acidified slurry with as it place the slurry on the soil surface and gives a rather even distribution of the slurry transversal direction.

Figure 2 presents two slurry tanks, one for fresh slurry and one for acidified slurry. Each one has capacity of 12,5 m^3. It is experimental system, but it can be utilized for small family farms as stationary acidification system, where preparing acidified slurry just before spreading it in the field.

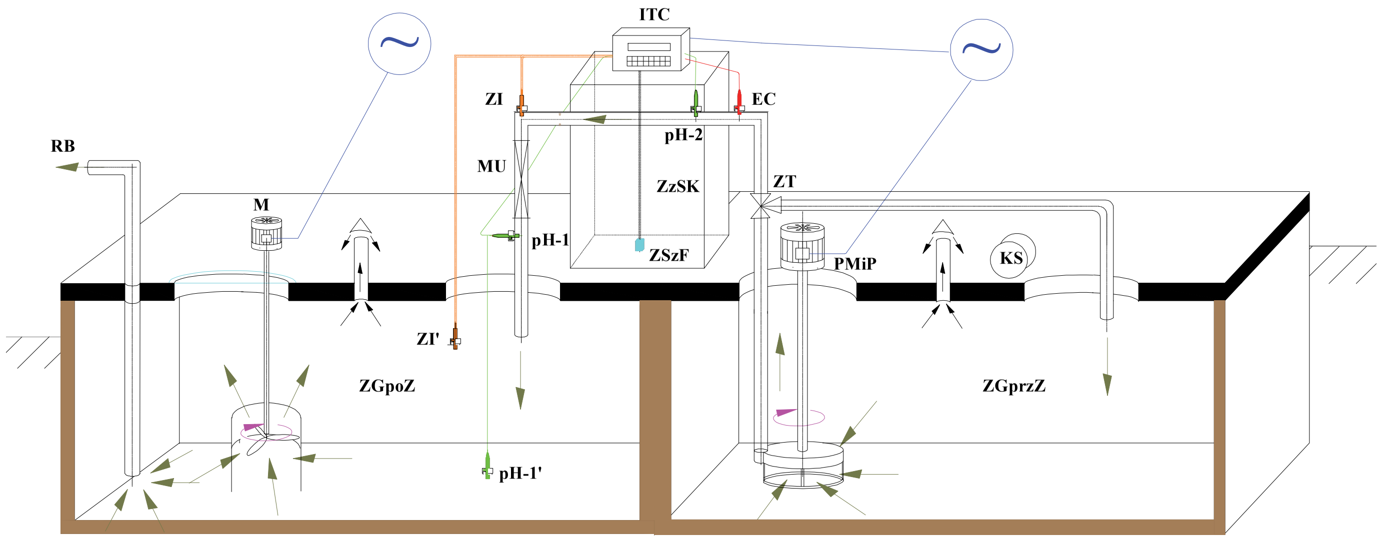

Fig. 2. Experimental pumping of fresh slurry to acidification tank (own elaboration); ITC – dosing pump with pH meter, ZzSK – container with acid, M – mixer, PMiP – pump, ZT – three way valve, ZGprzZ – tank with fresh slurry, ZGpoZ – tank with acidified slurry, RB – discharge pipe

Rys. 2. Przykładowy schemat przepompowywania gnojowicy do zbiornika z kwasem (opracowanie własne)

System contains: slurry pump, slurry mixer, acid pump, pH meter, nozzle, temperature meter, acid tank, electronic steering unit. Slurry from the barn is coming to right tank and when it is full, pump provides mixing and pumping all its capacity to left tank, where acidification process starts.

When slurry get proper pH level than tractor with tanker is coming and takes all acidified slurry into the field for spreading using trailing hoses. This type of experimental system will be very helpful when doing field experimentation on the small plots.

Figure 3 presents components from electronic system, which provides complete automated work, when providing acidification process. The whole system was elaborated with cooperation of FAPO Co. to provide all experiments in SAT Interreg project on experimental farm in Falenty near Warsaw.

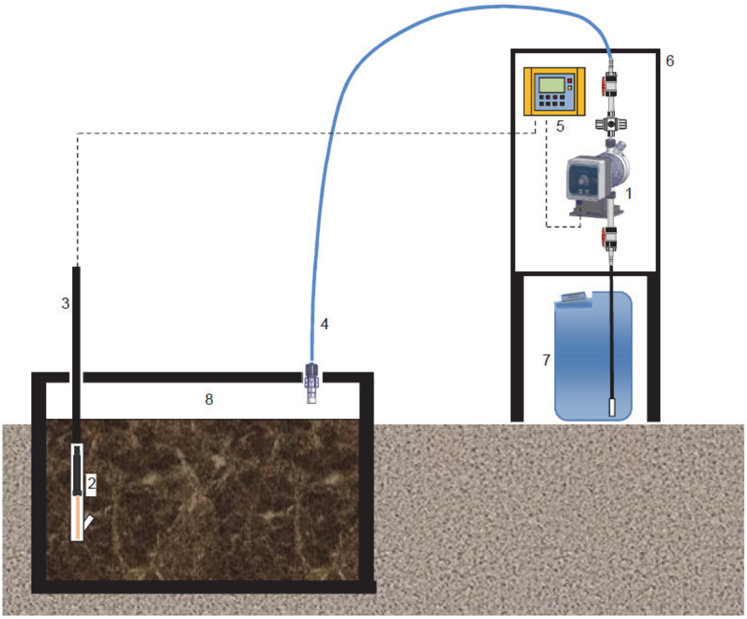

Fig. 3. Fully automated acid delivery system depending on the slurry pH content (FAPO and own elaboration); 1 – acid dosing pump type AMSPLUS, 2 – pH probe type EPHL, 3 – pH probe holder with perfusion system type PECAP-E, 4 – injection line with discharge valve, 5 – control box, 6 – safety cabinet, 7 – container with acid, 8 – slurry tank
Rys. 3. Zautomatyzowany układ dostarczania kwasu w zależności od zawartości pH w gnojowicy (FAPO i opracowanie własne)

Normal field acidification tests on a bigger scale will be provided with the help of Orum Semeden's acidified system presented on Figure 4. This system is quite simple in construction, not much automated units, what can be an advantage, when working in very difficult conditions. This system is very mobile and can be moved from farm to farm and preparing slurry to put acid, than mixing with acid and finally pumping to the tanker and spreading on the field using trailing hoses (Rotz 2004).

Fig. 4. Orum Smeden's "in storage" acidification system at work (Orum Semden's)
Rys. 4. System zakwaszania gnojowicy w zbiorniku firmy Orum Smeden podczas pracy **(**Orum Semden's)

Orum Smeden's system www.oerum-smeden.dk is based on a slurry mixer, equipped in pipes for adding 98% concentrated sulfuric acid. Slurry is pumped directly in the direction of activity of the mixer, what makes easer to obtain slurry mixture uniformity with acid. This is presented on Figure 5.

Acid pipes are located very close to the slurry mixing screw.

Fig. 5 Detailed view on acid discharge system of ORUM Co.– construction of “in storage” unit (Orum Semden’s)
Rys. 5. Widok urządzenia ORUM Co do rozprowadzania i mieszania kwasu w gnojowicy (Orum Semden’s)

4. Results and discussion

Description of processes when adding Sulphur acid to slurry is presented below:

NH_3(ammonia) + H+= NH_4+(ammonium)

NH_3= gas – may evaporate NH_4^+= salt – does not evaporate)

H_2SO_4 (Sulphur acid) = Hydrogen – Sulphur – Oxygen = Sustainable

The concept of reducing slurry pH to get lower nitrogen losses to the air relies on the equilibrium between NH_4 and NH_3 what is presented in Figure 6.

The effect of pig and cattle slurry acidification on equivalent of mineral fertilizer is presented on Figure 7.

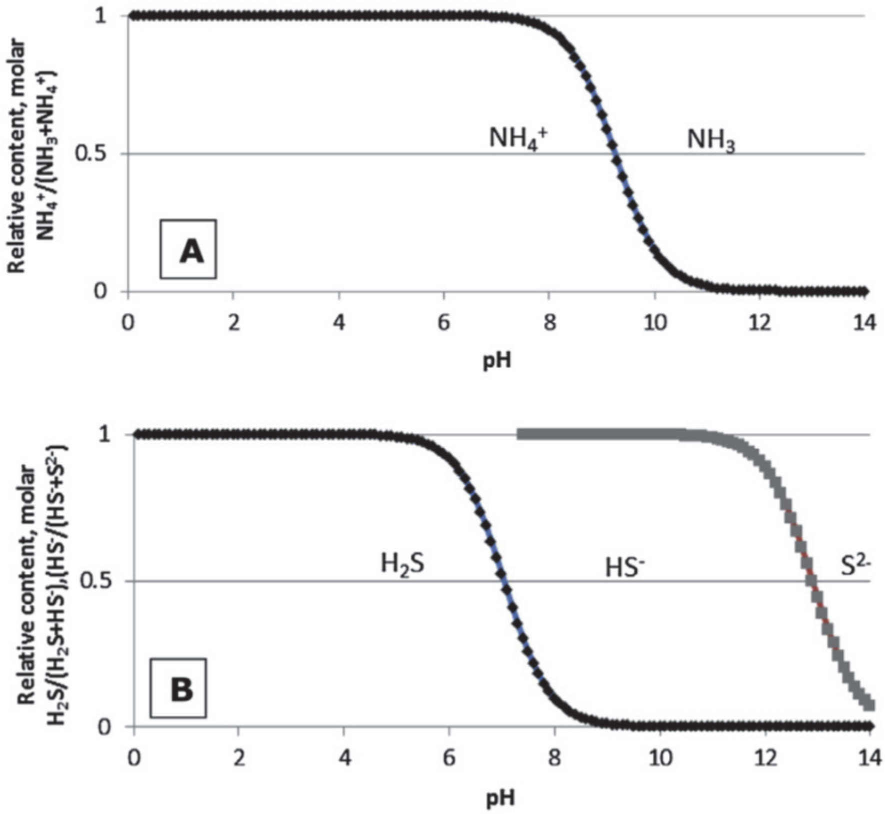

Fig. 6. Effect of slurry pH on its relative content of NH_4^+ (A) and H_2S (B) (Fangueiro et al. 2013)
Rys. 6. Wpływ zawartości pH gnojowicy na względną zawartość NH_4^+ (A) i H_2S (B) (Fangueiro i in. 2013)

There was a strong relationship between NH_3 emissions and ventilation rate during spring and autumn, but less so during summer where ventilation rates were generally high. It was concluded that the contribution from floors to NH3 emissions was <50%. There was some evidence for reduced CH_4 emissions from acidified slurry, but CH_4 emissions were generally low and apparently dominated by enteric fermentation (Moset et al. 2012). No effect on N_2O emissions was observed. The effect of acidification on emissions of H_2S differed between experiments. Implications of slurry acidification on the field state, depends also on N and S availability, and soil pH value (Roboredo et al. 2012).

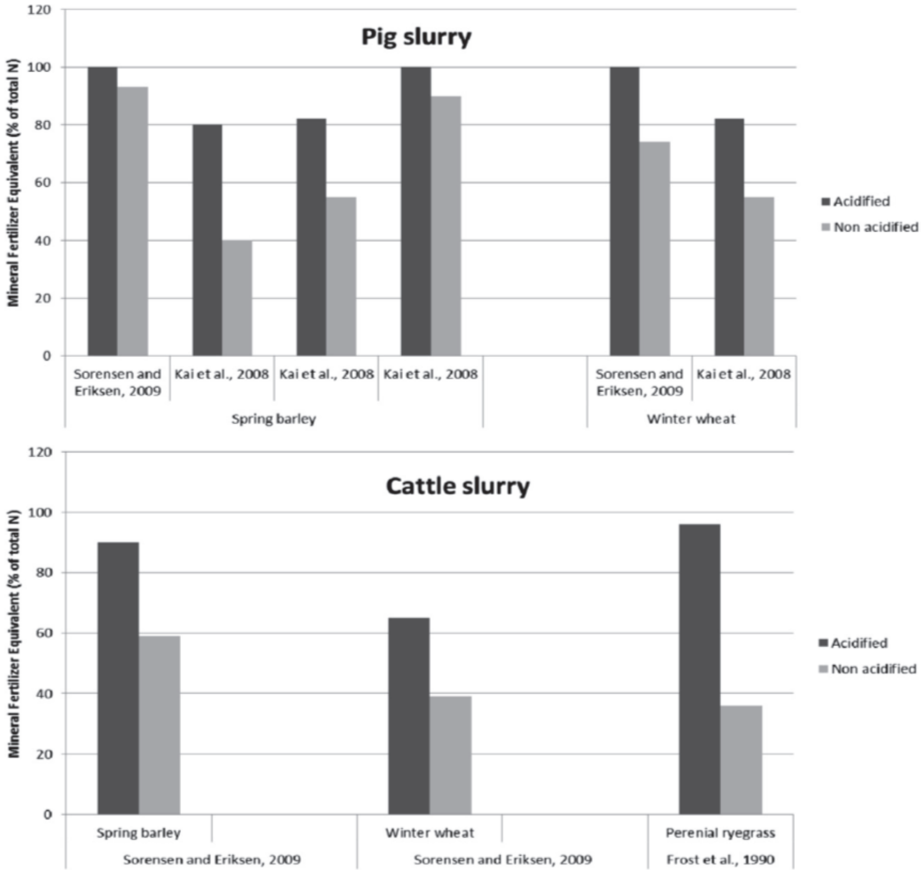

Fig. 7. Effect of pig and cattle slurry acidification on equivalent of mineral fertilizer (Fangueiro et al. 2014)
Rys. 7. Wpływ zakwaszania gnojowicy trzody chlewnej i bydła na równoważnik azotu w nawozie (Fangueiro i in. 2014)

5. Conclusions

1. Slurry acidification technology gives many advantages from the point of view soil fertilization and also the limiting of ammonia emission. Of course it requires provide safety procedures to avoid direct contact of farm workers with harmful activity of the acid. But heaving good acidification technology, which doesn't allow to have direct contact either in the storage area or in the field with the acid, this job is rather safe while fulfilling the procedures.

2. Acidification of animal slurry has proved to be an efficient solution to minimize NH_3 emissions in-house, during storage, and after soil application, as well as to increase the fertilizer value of slurry, without negative impacts on other gaseous emissions.
3. Furthermore, acidification impacts positively on other slurry treatments such as solid liquid separation or composting; upon the use of a non-sulphur containing additive, it may also impact positively on biogas production. Nevertheless, acidification of slurry might induce higher losses by leaching, due to solubilisation of mineral elements.
4. Alternatives to concentrated acids already exist but more research is still needed to improve both their technical and economic aspects. Moreover, the lack of specific equipment for the acidification of solid manures and the separated solid fraction narrows the possible fields of application of the treatment.
5. pH level of 5,5-6,4 is not very acidic, and no more acidic than rain water, which has a normal pH range from 4,5 to 8,5.
6. Corrosion of concrete in stables due to use of slurry acidification has never been an issue in Denmark, as it isn't for an outdoor concrete construction like this exposed to rain.
7. Acidification reduces NH_3 emission from pig houses by 70% compared with the standard housing treatment. Little loss was observed from stored slurry, and the NH_3 emission from applied slurry was reduced by 67%. In consequence, a 43% (S.E. 27%) increase in mineral fertilizer equivalent (MFE) was measured in field studies. The slurry acidification system is approved Best Available Technology (BAT) in Denmark.

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Zagospodarowanie gnojowicy w gospodarstwach rodzinnych z wykorzystaniem systemu zakwaszania w celu zmniejszenia emisji amoniaku

Abstract

Most of dairy and beef cattle when grown in barn with slotted floor is connected with high concentration of slurry what creates ammonia emission problems. The article presents some proposals for development of new technology in this area. Using slurry acidification technology in the barn, in the storage or in the field we can avoid many environmental problems concerning ammonia emission. Besides that we can save on overall fertilizers usage on the farm. Ammonia emissions is a major problem associated with animal slurry management, and solutions to overcome this problem are developed worldwide by farmers and scientists. An obvious way to minimize ammonia emissions from slurry is to decrease slurry pH by addition of acids or other substances acting in similar way. This solution has been used commonly in Denmark, and its efficiency with regard to the minimization of NH_3 emissions has been documented in some studies. Acidification reduced NH_3 emission from stored slurry to less than 10% of the emission from untreated slurry, and the NH_3 emission from applied slurry on the field was reduced by 67%.

Streszczenie

Większość bydła mlecznego i mięsnego utrzymywana jest w budynkach inwentarskich wyposażonych w podłogi szczelinowe co powoduje wysoką koncentrację gnojowicy i jest przyczyną emisji dużej ilości amoniaku. W artykule przedstawiono wybrane propozycje dla rozwoju nowoczesnych technologii w tej dziedzinie. Wykorzystanie technologii systemu zakwaszenia gnojowicy w budynkach inwentarskich, zbiornikach lub bezpośrednio na polu pozwala na zmniejszenie emisji amoniaku, co wpływa pozytywnie na ochronę środowiska. Ponadto, możemy zaoszczędzić na ilości nawozów stosowanych w gospodarstwie. Rozwiązaniem tego problemu zajmują się naukowcy, farmerzy na całym świecie. Oczywistym sposobem minimalizacji emisji amoniaku jest zmniejszenie pH gnojowicy poprzez dodawanie kwasów lub innych substancji, działających w podobny sposób. Takie rozwiązania stosowane są w Danii, a jego skuteczność minimalizacji emisji NH_3 zostało udokumentowane w pracach naukowych. Zakwaszenie zmniejsza emisje NH_3 przechowywanej gnojowicy do 10% w porównaniu z gnojowicą bez zakwaszenia, a emisja NH_3 w polu była mniejsza o 63%.

Słowa kluczowe:
nowe technologie, zakwaszenie gnojowicy, emisja amoniaku,
ochrona środowiska

Key words:
new technology, slurry acidification technology, ammonia emission,
environment protection