WASTE MANAGEMENT ISSUES, INCLUDING RECOVERY, AND SUSTAINABLE FOOD AND AGRICULTURE

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Summary

The use of different agricultural or industrial wastes is an important component of sustainable agriculture in order to close nutrient cycles on a global, regional and local scale. Farmyard manure or slurry are established as fertilizers in agricultural or horticultural production and substitute mineral fertilizers. Due to the lower nutrient use efficiency compared with mineral fertilizers, especially in the case of nitrogen substantial losses to the environment may occur and cause ground water contamination or eutrophication. Therefore all technical means to reduce such losses on the local and regional level have to be considered. Feedlots are of special concern in this context because there stocking rates are extremely high and only a limited area of arable land or pasture is available for the use of organic fertilizers. In such cases regional solutions have to be encouraged. The use of wastes from food as well as paper production is another option to close nutrient cycles but special care has to be taken in order not to transfer heavy metals or infectious material in the food chain. For those reasons the application of either agricultural or industrial wastes is in most countries strictly regulated by legislation.

1. Introduction

An efficient and environmentally sound waste management is an important component of sustainable development on the global and regional level. Nutrient cycles should be closed within and, if possible, also between different sectors of the economy. In the case of farm waste this is an established concept, which has been used for thousands of years in the form of organic fertilization and already roman sources on agriculture stress the importance of farm yard manure for soil fertility. Farm animals produce substantial amounts of waste which in the form of slurry or farmyard manure is used for fertilization of pastures as well as arable and vegetable crops. This is an important component of nutrient cycles on a global, regional and farm scale. Due to this practice, however, environmental problems occur especially in areas with high stocking rates. With the industrialization of Western societies, more recent concepts of nutrient cycling also include material fluxes between different sectors of the economy. For that reason waste from food processing as well as from paper production might be used in agriculture and forestry. In the case of those types of waste, special problems with the composition have to be considered in order to safeguard the long term sustainability. If waste and or waste water is directly applied to agricultural or horticultural fields, also potential health hazards must be taken into consideration. The potential problems related to the use of waste materials in agricultural production arise from the often low efficiency of the nutrient use compared with mineral fertilizers and the high costs of application which are due to the low concentration. In case of organically fixed nitrogen in waste materials, also the rate and timing of mineralization can be critical. Under certain circumstances, losses of nitrogen to the ground and drinking water might occur. In the case of industrial wastes, the heavy metals content might limit the use. Also, a possible contamination with infectious material such as bacteria might limit the use of waste water in agricultural production.

2. Farm Operation Waste

Animal husbandry is an important component of global agricultural production and contributes substantially to a balanced diet and well-being of humankind. On a global scale, the numbers of farm animals are enormous. Latest figures from the FAO (averaged over the years 2001 to 2003) estimate globally 1.3 billion cattle, 1.1 billion sheep and 900.000 million pigs. Additionally billions of various poultry are kept worldwide. In the production process, however, all farm animals produce waste in the form of urine and faeces which often - depending on the type of stable or bedding system – is mixed with water and straw. Therefore the waste comes either as slurry, farm yard manure or compost.

Even within those different types of organic wastes, the composition might vary considerably depending on the type and feeding of animals, the stable or bedding system and the biochemical processes before and during storage. For that reason it is not possible to give any kind of correct figures for the nutrient and water content of such wastes.

Correct estimates on the amount of agricultural wastes are very difficult to obtain, whereas in the case of mineral fertilizers the production figures are available. Since most animal waste is used directly on the farm, no detailed record keeping is possible and the content of the different nutrients within the slurry or farmyard manure is unknown. This uncertainty about the concentrations makes it extremely difficult to calculate the nutrient supply on the farm level, since normally the farm manager has no detailed information on the correct composition of the farm animal waste. One way to get at least some figures on the contribution of farm waste to the nutrient cycles is to calculate the necessary nutrients for animal food and than make a rough estimate of the slurry or farm yard manure produced. This may sound fairly crude; however, it is often the only possible calculation on a global, regional as well as on a farm level. Based on such estimates it becomes obvious that farm wastes in the form of farmyard manure or slurry contribute substantially to the fertilization of crops and pastures. In a lot of areas, however, the amount of organic fertilizers produced from farm animals is so high compared with the area of agricultural land in the vicinity that environmental problems occur.

The problem of nitrogen losses to the environment, which are important for all wastes in general but for farmyard manure and slurry in particular, is due to the very complex nitrogen cycle in the soil. Depending on the soil type and the environmental conditions, large quantities of nitrogen are incorporated into the soil in the form of organic compounds. This nitrogen might be mineralized to nitrate or ammonium. Both molecules are taken up by the plants with nitrate, however, being the much more mobile form of nitrogen in the soil. On the other hand nitrogen in the form of slurry or farmyard manure might be incorporated directly into the organic compounds of the soil or indirectly via decomposition of plant residues like straw, chaff or roots. This cycle is called the mobilization-immobilization-turnover. Losses to the environment mainly occur either as leaching in the form of nitrate or as gaseous losses in the form of nitrous oxides (N_2O). In mineral fertilizer the nutrients are readily available for the crops. This makes the calculation of the application rate according to the crop demand easier compared with the situation in organic fertilizers. Climatic factors not only affect the growth and development of crops but also the mobilization of nitrogen from slurry or farmyard manure. This makes calculations much more difficult compared with mineral fertilizers. Since farmyard manure contains considerable amounts of organic compounds compared with slurry it must be considered a long term fertilizer with additional positive effects on soil biology and soil structure. In contrast, slurry, due to its higher water content, is much more comparable with a fertilizer solution based on mineral fertilizers and hence has to be used in such a way.

Strategies to minimize nitrogen losses to the environment due the use of slurry or farmyard manure have to incorporate all aspects of agricultural production from the feeding of the farm animals, farm and crop rotation design to agronomic and technical means on the field. Recent research also shows that additives to slurry can substantially increase the nitrogen use efficiency and thus reduce nitrogen losses to the environment via leaching. In those approaches it has to be kept in mind, however, that the system is strongly affected by variable environmental factors such as temperature, rainfall and humidity etc. This makes any kind of forecasts and mathematical modeling extremely difficult. Whatever means to increase the nitrogen use efficiency are taken, some losses are unavoidable.

Nitrogen contamination of ground and drinking water in Europe is mainly a problem of areas with high stocking rates of cattle or pigs in parts of the Netherlands, France, Ireland, Denmark and Northern Germany. This underlines the importance of a whole farm assessment of the nitrogen fluxes on a regional and a farm level. Though aspects like stocking rates and feeding are mainly responsible for the difficult environmental situation, the adequate use of slurry and farmyard manure is an important component of this system. Recent research results from Germany have shown that a combination of maize and pastures substantially increase the nitrogen use efficiency on the farm level because maize takes up nitrogen from slurry much better than pastures or grassland. According to those results, the lowest nitrogen use efficiency occurs if animals are kept on pastures.

From an agronomic point of view, the right timing and choice of crops substantially improves the efficient use of slurry. Field experiments show that it is possible to achieve a nitrogen use efficiency of slurry similar to the figures know from mineral nitrogen fertilizers, if the slurry is "split applied" according to the sequential demand during the growing season. However, due to the greater operating expense, this is often only a theoretical option for practical farm management. Additionally, the right choice of crop is important for the increase of nutrient use efficiency. Rapid growth and a large demand for nitrogen in a particular developmental period is important. The application of farmyard manure or compost is much less critical compared with the situation described for slurry, because nitrogen from farmyard manure is only mineralized at a much slower rate and therefore the likelihood of losses to the environment is much smaller. On the other hand, the contribution of nitrogen from farm yard manure to the crop demand is smaller. It is important, however, to include the nutrients from farmyard manure in nutrient balance sheets because in the long term, depending on the environment after a number of years or decades, the nutrients are mineralized again and contribute to the nutrient supply for the crops. If this fact is not taken into account, the additional fertilizer application is often too high and again, leaching to the ground and drinking water might increase.

The last step to minimize losses due to the use of organic fertilizers includes technical means on the farm and the field level. Due to the higher water content and the rapid availability of nitrogen, slurry is much more critical from an environmental point of view than are farmyard manure or compost. The sufficient storage capacity for slurry is an important component of an environmentally sound use of organic fertilizers. Adequate storage capacity allows the farm manager to apply the slurry only according to the growth and development of the crops which ensures a higher rate of nitrogen use efficiency. If the storage capacity is not sufficient and the slurry is applied too early in the growing season, substantial losses of nitrogen are possible. Legislation in a lot of countries therefore regulates the necessary storage capacity.

The distribution of organic fertilizers within a farm or a region is another important technical and organizational aspect. Since the transport of farmyard manure or slurry is quite expensive farmers tend to concentrate the application on fields and pastures in the immediate vicinity of the stables. The same problem occurs in regions with high stocking rates, e.g. in Europe in parts of the Netherlands, of France or of northern Germany. In order to improve the nitrogen use efficiency it is imperative to distribute the organic wastes evenly – that is according to crop demands – on all fields of a farm. On a country or regional level it might be useful to transport farmyard manure or slurry to other regions with low stocking rates. However, due to high transportation costs in relation to nutrient contents, concepts to "dry" liquid manure prior to transportation need to be further explored.

Especially for the application of slurry a number of technical means for a reduction of nitrogen losses and improvement of the nitrogen use efficiency exist. Application should always be done by using drag hoses. This also avoids unwanted odor which is a nuisance to the general public as well as an environmental pollution. If the slurry is applied to bare soil, rapid soil tillage is also recommended in order to minimize ammonium losses. The environmental conditions during application are also important. Low temperatures (between 5 and 10 °C) and little wind help to reduce the losses. On the other hand, high temperatures and strong winds might cause substantial losses in the first hours after application.

Due to those potential negative effects of fertilizer application on the environment, many countries have established specific regulations and legislation. Often the amount and timing of fertilizer application is limited in order to minimize leaching and gaseous losses. This applies to mineral as well as organic fertilizers; however, due to the low nitrogen efficiency in organic fertilizers, special attention is often paid to this issue. In Germany for example the current limit is 170 kg N ha^{-1} in pasture and 170 kg N ha^{-1} on arable land from organic fertilizers per year and the application is not allowed from the beginning (arable land) to the middle of November (pastures) until the end of January. It is not allowed to apply organic fertilizers on frozen soil, on snow or on soils saturated with water. The application of fertilizer in general must be limited to the requirements of the crops and pastures. All farmers have to keep detailed records of their operations on a field to field scale and this especially applies to fertilizer application. Given the importance of the right timing of application during the growing season of the crops, the storage capacity on the farm is also often regulated. Though the environmental and legislative situation is very divers in a European and, of course, in a global scale, the principles are fairly similar over different environments.

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Biographical Sketch

Olaf Christen, born in 1961, currently holds the Chair of Agronomy and Organic Farming at the University of Halle-Wittenberg in Germany. He has studied agricultural science at the University of Kiel, Germany and completed his PhD in Crop Science in 1990. After working as a postdoctoral fellow at the Department of Agronomy and Soil Science, University of New England, Armidale, Australia, he returned to Kiel and continued his research. Since 2000 until now Olaf Christen is with the University of Halle-Wittenberg. Olaf Christen is also Director of the Institute of AgroChemistry at Wittenberg, a joint partnership between agricultural industry and the university Halle-Wittenberg. His research interests cover various aspects of sustainable agriculture, especially the effect of cropping systems and crop rotations on agronomic and environmental parameters and the whole-farm assessment of agricultural production. Olaf Christen is also active on various scientific and political committees on a national and international level.