FAO European Cooperative
Research Network

Recycling of Agricultural, Municipal and Industrial Residues in Agriculture

Network Coordinator: José Martinez, Cemagref, Rennes (France)

RAMIRAN 2002

Proceedings of the 10th International Conference of the RAMIRAN Network

General Theme: Hygiene Safety

Štrbské Pleso, High Tatras, Slovak Republic
May 14 - 18, 2002

Edited by Ján Venglovský and Gertruda Gréserová

ISBN 80-88985-68-4

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MANAGEMENT STRATEGIES FOR ORGANIC WASTE USE IN AGRICULTURE

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ABSTRACT

Organic wastes are utilized in agriculture mainly for improving the soil and for nutrient sources for growing crops. The major source of organic waste used in agriculture is animal manure, but food processing and other industrial processes and municipal wastes are also often applied to land. In the last 35 years, and especially in the last 10 years, there have been increasing environmental regulations affecting farms that have resulted in more animal manure treatment options to address the environmental concerns, and thus affecting characteristics of residues to be land applied. Farms are being evaluated for nutrient balances, and thus the entire nutrient and manure management system must be evaluated for best management alternatives. Because of inadequate available land on the farm of waste origin in some cases, organic wastes must be treated and/or transported to other farms. Some of the limitations for utilizing animal manure and other organic wastes are: 1) public acceptance (nuisance or environmental concern), 2) acceptable integration into agriculture, 3) quality control of residues being applied, 4) logistics and organization, 5) satisfying environmental regulations, 6) economic viability, and 7) sustainability. The environmental factors that appear to have the most potential impact on selecting management strategies in the next ten years are nutrient management to minimize water pollution, air emissions of ammonia and odorants, and pathogen control.

INTRODUCTION

Several regions with intensive animal agriculture in Europe and North America have nutrient management problems, with some animal production farms not having enough land for proper utilization of nutrients. In the U.S., for example, the average amounts of excess nitrogen and phosphorus per livestock operation about doubled between 1982 and 1997 (4,910 to 10,180 kg N/farm; 2,110 to 4,740 kg P/farm) (Kellogg et al., 2000). During this period the total number of livestock operations with excess nutrients decreased (from 83,155 to 65,751 for N; from 123,248 to 89,028 for P), but the number of large livestock operations (> 1000 AU) with excess nutrients increased (from 1,770 to 3,549 for N; from 2,603 to 4,779 for P). This reflects that many large livestock operations may need to export nutrients. Potential excess application of nutrients results in concerns with water quality impacts (surface and groundwater) and accumulation of phosphorus and metals in soil. In addition, potential transport of pathogens via air or water, and environmental concerns with air emissions of ammonia, methane, hydrogen sulfide, nitrous oxide, and odorants can affect waste management strategies and lead to alternative treatment schemes.

Besides environmental considerations, there are economic and regulatory factors that directly affect management strategies. In some cases, energy recovery from organic waste can be beneficial for certain objectives, but may have minimal benefit for nutrient management. There is also research on abstracting industrial products from organic wastes, but there has been relatively little progress in obtaining high value products from organic wastes. Regardless of which factors affect a particular site, much of the organic waste produced by animals will be applied to land. The land requirements can be impacted by various pre-treatment alternatives that may be needed to satisfy particular environmental concerns. Also, the availability of land will affect the transportation costs, and thus perhaps determine if additional pre-treatment is needed, such as composting, in order to obtain a higher value product that can be transported further. However, markets have to be identified or developed that can support the higher treatment cost. The economic factors and management skills required for alternative treatments and management schemes also determine whether on-farm treatment or a regional treatment facility is appropriate. Thus, selecting management strategies requires consideration of many factors.

Traditionally, the most common utilization for animal manure and food processing organic by-products has been application to land for improving the soil and using the nutrients for growing crops. This presents challenges because of:

- imbalance of nutrients in organic residues compared to crop needs,
- the relatively low nutrient concentration compared to chemical fertilizers,
- the variability in nutrient content, difficulty in quickly determining nutrient content, and predicting the availability of nutrients to growing crops,
- the often bulky nature of organic waste making it more difficult to haul and spread consistently, and
- satisfying environmental regulations on application amounts, application timing, and application methods, and
- possible environmental concerns, such as ammonia emission, odor, and pathogens.

These factors have resulted in much interest in separating the solid fraction of manure and composting manures and organic residues to reduce bulk, concentrate nutrients, reduce odor, kill pathogens and have a stabilized product for transport. By composting, a more valuable resource can be obtained, but markets must be developed and farmers must determine the extra processing to be manageable and economically viable.

In the last 10 years, there has been increased regulation of intensive livestock agriculture in Europe, North America, and in some Asian countries because of environmental concerns. This has resulted in using alternative treatment strategies for animal manure to address issues of excessive nitrogen or phosphorus, odor, ammonia emission, pathogens, etc.. Consequently, different residues or by-products result, which can either improve or lessen the utilization potential. Thus, strategies for organic waste utilization as a resource for agriculture must consider the entire management system, including the alternative treatments and the resulting products and their potential utilization.

MAJOR FACTORS AFFECTING MANAGEMENT STRATEGIES

For organic waste generated on site, such as with animal production farms, the management strategies start with the type of building and method of manure collection, and continue with the treatment options to satisfy environmental concerns and utilization strategies (Burton, 1997; Miner et al., 2000). For example, a slatted floor with under-floor slurry pit might have an aboveground outside storage tank that is covered, and slurry injection to land. Also, the slurry could be centrifuged to separate solids, or aerated, or undergo other treatments before land application. The treatment options could vary with environmental concerns, such as reduction of nitrogen (via nitrification/denitrification), reduction of odor and ammonia emissions (via covering storage or aeration treatment), or killing pathogens (thermophilic aerobic or anaerobic digestion). The management strategies for land application can also be affected by environmental concerns (such as reduction of odor and ammonia emission during application), and these factors can apply to other organic wastes from industry or municipal sources that are applied to land. In addition, for animal waste management systems, there are other additional factors that can affect management strategies, such as regulations, energy policies, animal welfare considerations, and economics. These factors are discussed in more detail below.

Environmental factors

The typical environmental factors to consider with animal manure management systems and also land application of other organic wastes are:

- Soil accumulation - phosphorus (P), copper (Cu), zinc (Zn), sodium (Na), and salts
- Forage accumulation - nitrogen (N) (possible fat necrosis in grazing animals) and nitrate N (possible nitrate toxicity to animals), and grass tetany (magnesium/potassium ratio imbalance)
- Surface water pollution - N, P, organic matter (exerting oxygen demand), and pathogens
- Ground water pollution - N, P, and pathogens
- Emissions to air - ammonia (NH_3), nitrous oxide (N_2O), methane (CH_4), hydrogen sulfide (H_2S), odorants and airborne pathogens

Some of these environmental factors have already resulted in regulations in some locations that farmers must meet with management strategies. For example, to prevent excessive N, P, Cu and Zn application to land, the farmer may consider diet manipulation strategies to increase digestibility and absorption of these compounds by the animals, but he will also need to develop nutrient management plans or nutrient budgets for his specific location. When the farm produces excessive nutrients for application on-farm, then treatment options can be added to reduce N (convert to dinitrogen gas) or partition nutrients into more concentrated or stable forms that can be transported elsewhere. For reduction in pathogens, ambient temperature anaerobic treatment or aeration treatment can have moderate effect, but lime treatment or high temperature aerobic or anaerobic treatment is required to essentially eliminate pathogens. To reduce odor, aeration treatment offers a viable, but somewhat expensive option. Also, different land application techniques are used to reduce odor and ammonia emission, such as injection.

Energy policies

Anaerobic digestion of manure can produce biogas that can be utilized in a boiler for heat and/or in an engine to generate electricity. Another benefit can be reduction of odor. However, nutrient content generally remains unchanged. The type of farm and number of animals greatly affect whether the energy can be used on-farm, but the payment for selling the energy often determines whether this is a viable management scheme. Some regions, like Denmark, have invested significant government money in anaerobic digestion (animal manure and other organic wastes such as food wastes) as a national energy policy.

However, many countries do not have a favorable energy policy to reward "green energy" enough to encourage farmers to invest in and operate anaerobic digesters and the associated equipment. Other possible energy recovery schemes are being researched, such as gasification of manure solids and conversion of gases to ethanol. This will require expensive processing plants, and likely some government subsidy to be developed. These energy recovery schemes offer opportunity to combine farm animal wastes and municipal or industrial organic wastes, however the transportation and hygiene factors present challenges. Generally, biogas recovery is considered potentially economical for only large farms and for regional facilities. However, if government energy policies were improved to support more "green energy" production, then moderate size farms might also consider this option.

Animal welfare

Because the management strategies start with the type of housing, animal management, and manure collection, animal welfare concerns can also impact management strategies for organic wastes. For example, if welfare concerns resulted in animals being reared on bedding, then the management options are limited to those that can handle solid manure and bedding, such as direct land application, high solids digesters, or composting. If ammonia or hydrogen sulfide emissions in the housing must be lowered for worker and animal welfare, then manure might have to be removed from the house more frequently, and this could affect the characteristics of the organic waste for further treatment options. If urine and feces need to be separated to reduce ammonia loss and odor in swine barns, then sloped belt collection systems may be considered (some are presently under development). This in turn could produce drier manure that could be more amenable to incineration or gasification, as well as composting. Also, if some animals are required to be out in the fields during at least parts of the year, manure management strategies are different when manure is spread out in pastures as compared to collection and storage from a barn.

Economics

Inherent in considering alternative management schemes for organic wastes are the costs and benefits. If regulations or environmental factors require additional treatment that increases costs of production and operation, then the farmer loses profit unless costs are shared with the government or other agencies. Although there have been sparse attempts to develop methods, it is difficult to determine environmental costs and benefits of alternative waste management policies. The costs of additional waste treatment are more easily passed to the consumer for industrial waste treatment or to taxpayers for municipal waste treatment, than it is to consumers or taxpayers for farm waste treatment. Government can offer incentives such as cost sharing of equipment or guarantee of not changing regulations for a period of time for improved waste treatment, but this is the exception more than the norm. Economics may also suggest that a cooperative or regional facility is needed for certain waste management schemes. However, farmer and public acceptance of this is important because transportation of organic wastes on public roads may present more community concerns, and farmers may choose other alternatives if the regional treatment system is not clearly advantageous both economically and for management efficiency.

Regulations

Regulations for management of organic wastes have usually been in the form of nutrient management plans, best management practices, and regulations for odor, air and water quality. Generally, environmental regulations progressed from surface water quality, to ground water quality, to air emissions. Concern with nitrogen transport via surface runoff and leaching has advanced to include phosphorus. Air emission concerns generally started with odor, but has expanded to include ammonia, nitrous oxide, methane, hydrogen sulfide, dust and particulates. Farmers wonder what to expect in increased regulations each year. This results in hesitation to change management systems until the regulatory changes are more evident, or regulation becomes effective. There is also concern that regulations may be developed based on inadequate scientific basis in some cases. The Netherlands offered incentives for reducing ammonia emissions by stating that farms that met a certain reduction would not have to meet new regulations on ammonia emission for a certain period of time. North Carolina (USA) government has promoted elimination of open anaerobic lagoons, and has put a moratorium on construction of new swine facilities while alternative management schemes are evaluated and demonstrated to be environmentally effective and cost effective. In general, there needs to be allowance for adequate scientific input to the legislative process and also adequate economic analyses of the costs and benefits of proposed legislation.

LIMITATIONS AFFECTING USE OF ORGANIC WASTE

Although utilization of organic waste in agriculture seems appropriate, there remain factors that significantly limit that strategy (Merillot, 1998). The limitations include:

1. Public acceptance - nuisance complaints for odor or flies, perceptions of decrease in land values, and perceptions of environmental degradation.
2. Integration into agriculture - use of organic wastes for fertilizer is often not as easy to apply, as reliable a nutrient source, or as economical to use as chemical fertilizers.
3. Quality control - lack of uniformity in products and assurance of pathogen control.
4. Economics - transportation costs, equipment costs, operational costs, specialized labor, and markets for compost or organic waste.
5. Logistics and organization - Scheduling for limited time periods allowed for land application, coordination of transportation and application, lack of cooperatives or other groups to organize on a regional basis the matching of waste sources with waste users.
6. Environmental regulations - Restrictions on application amounts and timing, and other regulatory requirements for transporting and/or selling organic waste products.

POSSIBLE APPROACHES TO ADDRESSING LIMITATIONS

The limitations mentioned above have generally existed for decades, with relatively little progress made in addressing some of them. Utilization of organic wastes occurs easily if there are clear economic incentives. However, the economic incentives are often marginal and sometimes negative. Better organization through farmer cooperatives, organic waste sellers, and government or other agencies could improve the economics. At least initially, more government subsidies may be needed to help distribute nutrients over a larger region by helping with transportation or costs of further processing.

Development of government policy and laws that consider environmental impacts, survival of agricultural producers of food, and food prices for consumers is difficult to formulate to satisfy the public. In some aspects, more regulation might be advantageous, such as setting specific but reasonable criteria for quality control of organic waste products, such as nutrient content and level of pathogen treatment. Such criteria will likely be required for certification of organic farming enterprises. Although some countries and local governments seek the advice of knowledgeable scientists in addressing environmental concerns, animal manure management, and utilization of organic wastes, unfortunately politicians not always make decisions with adequate input from scientists and engineers. Also, there needs to be more analyses done on watershed, and airshed, basis for nutrient distribution and environmental impacts to determine regional policies and regulations. With a regional analysis, it may become obvious that the concentration of animals or other organic waste sources is too great for a region, that processing and transportation costs are too high to transport the nutrients to other regions, and thus the number of animals in the region must be decreased. But if the number of animals must be decreased, who is going to pay the farmer for the loss of income? Also, large integrator companies that contract with growers may seek to move their business to other regions, thus affecting regional economies. Alternately, it might also be concluded that a regional composting plant or incineration plant might be economically feasible, with energy recovery and production of a mineral fertilizer from the ash. Development of strategies for using various mixes of agricultural (e.g., animal wastes) and industrial/municipal waste (e.g., food wastes) could enable a more economical solution, as well as a more balanced and consistent product (Burton, 1997; Martinez, 2000). Further development, validation and acceptance of expert systems and computer programs for regional analysis is needed to assist in making policies and decisions. The validity of the models will depend not only on the model construction but also on the accuracy of the data input to the model. Thus, researchers should continue to attempt to do economic analysis of research projects and case studies to supply data to these models.

SUMMARY

Management strategies for utilization of organic wastes starts with the source, such as animal housing and corresponding manure handling and treatment, because this determines the nature of the organic residues and by-products to be utilized. Selection of manure management and treatment options increasingly depends on environmental regulations for preventing pollution of land, water and air. Given the potentially large variation in organic waste materials from various sources, and sometimes within the same source, it is important to develop waste characteristics data bases and methods for quickly determining the nutrient content and nutrient availability for crops. Better organization and cooperation is needed between waste producers and waste users to schedule the appropriate application times and rates. More analysis needs to be conducted on a regional basis to develop regional management schemes to handle nutrients and protect the environment. Policies and regulation should be developed with inputs from scientists, both technical and social/economic scientists. One of the most important factors affecting transport and application of organic wastes in the future may be the consideration for treatment for pathogen control.

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