

Optimizing environmentally friendly biogas production from livestock manure for the reduction of greenhouse gas emissions (09-076SDU)

Executive summary

Livestock production is increasing and becoming specialized in Vietnam leading to the decoupling of livestock farming from plant production or fish farming. This has led to surplus liquid manure being discharged to waterways, and is the cause of local environmental problems in form of odor, insects, waterway eutrophication and risk of disease spreading.

The solution to the problem is the development of new management systems with environmentally friendly recycling of the manure. The advantage to the farmer being energy production, more efficient use of manure that reduces cost to fertilizer or increase in the value of manure sold in form of compost.

Decision support for optimal energy production with biogas digesters and for efficient manure recycling is now available for decision makers, extension officers and end users. Schemes for production of better compost are developed, which include addition of biochar during composting contributing to reduction of greenhouse gas emission, and treatment with urea that reduce the content of pathogens.

It is shown that mismanagement of biogas digesters causes increased greenhouse gas emission and don't reduce the content of pathogens in the manure. As farmers learn that biogas treatment reduces pathogens, they may use the biogas-manure in ways that actually increase the risks of pathogen spreading. The solution is training in better management and also in constructing better biogas reactors.

These findings are available in books, newsletters and articles in Vietnamese journals. The new knowledge has been disseminated through training courses for scientist and consultants and at workshops to public service officers. Vietnamese researchers have proven the high quality of the research by publishing in peer-reviewed international scientific journals and giving presentations at conferences. Thus, the researchers are continuing the research together with partners from Japan, USA, New Zealand and IAEA.

1. Introduction and background

During the project preparation phase of SUSANE II, it was identified that the existing biogas plants in North Vietnam was not working properly or were out of use (SUSANE 2008). The causes for this was that in North Vietnam the unheated biogas digesters produce little gas during winter due to low temperatures, on small farms the production of manure was too low for supporting production of energy needed for a family, and finally there were periods with no production of pigs on small scale farms. Calculations proved that retention time of manure in digesters were too short and this resulted in the low biogas productivity and in insignificant reduction in pathogens during winters. Furthermore, the project research showed that from the poorly managed biogas digesters there could be a large emission of the greenhouse gas (GHG) methane, and in consequence the technology may therefore increase GHG emission, instead of the intended reduction. Consequently, the project partners identified a need for development of new biogas technology and management that support a sustainable biogas production.

Furthermore, it was shown that on the farms studied the manure biogas digestate was frequently diverted directly into streams and fish ponds, assuming a sufficient hygienisation (purification) in the biogas process, but it was shown that with the improper operation, this practice could be very unsustainable, both in term of environmentally detrimental effects on local waterways and ponds, a loss of valuable nutrients and biomass which could have been used to enhance crop production if recycled to soils. Therefore the aim of the SUSANE II project phase was to develop a sustainable biogas production which should provide i) hygienic manure management as well as ii) appropriate land application to support crop production and iii) overall reduced greenhouse gas emission.

2. Results:

2.1. Capacity building

As mentioned earlier we find that developing research activities, where the partners from the very first month of the project must collaborate, is a constructive method to create synergy in the research.

After having trained three PhD in the phase I of SUSANE the project it proved most efficient to include these as post doc with the obligation to train the subsequent PhDs. The post docs were also contributing to managing the project and were teaching at courses and writing chapters to the Vietnamese textbook about manure management.

Knowledge gained in the project has been disseminated to a broad Vietnamese public and to the scientific community. The project partners have published 15 Vietnamese articles and a Vietnamese textbook about manure management, and given seven courses for undergraduate and postgraduate students. Farmers have been trained, through training-of-trainers and through collaboration with regional advisory services. In future the courses, textbook, articles and decision support will be used at the university, for training staff at the research institutes and for extension.

Twenty seven scientific articles have been submitted, are in press or in preparation for publication in international peer reviewed journals, so this also represents a significant rise in the international scientific profile of the involved Vietnamese institutes.

2.2. Survey of biogas production

Digesters was originally installed to provide biogas for cooking and lightening and to reduce odor emission from manures. The farmers used some of the biogas manure (digestate) as a source of nutrients for crops , but digestate was also discharged to the environment on 63 % of the interviewed biogas farms. It was also shown that biogas loss (emission) through leaks and broken tubes may account for *ca.* 10% of the biogas produced and due to intentional release of surplus biogas the emission may be as high as 46%.

2.3. Biogas production

During winter in northern Vietnam the amount of biogas produced is low due to the low temperature. A standard method to increase temperature is insulating the top of the digesters, but test showed that the temperature increase was too low to provide a larger biogas production. A computer model for predicting biogas production at low temperature conditions was developed and validated, and is now available for consultants and end-users. An example of model calculations is that heating with a combination of solar panels and short periods with biogas-heating can provide a net increase in production of biogas energy on farms with more than 20 pigs.

2.4. Biogas digestate as a fertilizer

Introducing biogas digestion on farms have reduced recycling of plant fertilizers to field and increased discharge of manure to environment from 16 % on non-biogas to 60% on biogas farms. This is due to too high rates of manure dilution on biogas farms, which results in low retention time, low nutrient values and high transport cost of digestate. The low nutrient value may contribute farmers being reluctant to transport the digestate to fields and use it as a fertilizer. However, the digestate had a high fertilizer value in rice-rice-maize crop rotations due to transformation of organic nitrogen into plant available ammonium.

2.5. GHG emission reduction

To enhance the use of the liquid manure it was mixed and composted with crop residue or a combination of crop residues and straw derived biochar. The methane emission in this treatment was three times lower and nitrous oxide 20 times lower than from solid manure composting. When applied to fields the digestate or digestate composted with biochar emitted the lowest amount of greenhouse gases (carbondioxide equivalent) per unit rice grain yield. The digestate composted with biochar also contributed most to soil C-sequestration. Producing biochar from rice straw is feasible in small-scale units in-field, but quantities will only sustain this solution for a smaller proportion of the digestate and cropping area.

2.6. Pathogen reduction

The concentration of fecal indicator bacteria (*Enterococci*, *E. coli*, and *Cl. Perfringens*) were reduced only by 1 or 2 log-units in the biogas digesters. Salmonella was found in both raw slurry and biogas effluent. In conclusion, the limited reduction of bacteria during biogas process represents risks to human health, especially due to the common practice of applying human excreta into the digesters and subsequent use of effluent to fertilize vegetable crops.

Adding 2-4% urea to pig manure and human excreta stored in heaps covered by a clay layer is a method to reduce pathogens in manure. The study proved that *E. coli* disappeared in heaps treated with urea at day 7 in the summer and day 15 in the winter, it was determined in the untreated heap at day 15 in summer and day 54 in winter. *Ascaris suum* (an intestinal parasite for pigs and humans) eggs were inactivated in heaps added urea at day 40 in winter. No viable eggs were found viable in urea and control heap at day 7 during summer.

2.7. Decision support and life cycle analysis (LCA)

A manure management model has been developed, that links the N flow from the N in the diets fed to grower-finisher pigs to the application of the manure in the field. The model assesses N contents and losses at each stage of manure management so that application of manure N can be adjusted to ensure optimal fertilizer value and reduce pollution risks. The model is a tool to adjust the N content of feeds, the pig population per agricultural area available, and to minimize N discharge and emissions.

The life cycle assessment (LCA) showed that with the present management the environmental impact of biogas livestock farms is larger than that of non-biogas livestock farms. This is due to methane emission from leaking biogas digesters, release of biogas and emission of methane from stored digestate and because more manure is discharged from biogas farms than on non-biogas farms leading to a greater need of mineral fertilizer on biogas farms. This causes an increased greenhouse gas emission from fertilizer production.

3. Conclusions

The benefits of biogas production are not realized on Vietnamese biogas farms due to mismanagement of biogas digesters. The project has shown that improving the construction and management of the digesters can greatly improve energy production, reduce pathogens in manure and reduce environmental impact. Water consumption in animal houses must be reduced and pumping or transport technologies for distributing liquid manure to fields must be implemented on these farms.

Composting with additives in form of biochar and urea can improve the compost quality much and contribute to reduce risk for diseases spreading and pollution.

LCA models are most valuable when assessing environmental impact when introduction of a new technology and decision support for design of digesters and managing manure regionally are a useful tool for developing new digesters and for planning livestock production

4. Implications:

Therefore, the government/ministries have taken action to provide knowledge about how to improve management and construction of biogas plants. There is a focus on improving the knowledge about fertilizer efficiency of manures (untreated, compost or digestate) and on developing methods to reduce greenhouse gas emission from manure management. Further, the government are including research in manure management in their research programs, and new courses at the institutes and university are being approved.

5. Recommendations:

It is recommended that there is an enhanced focus on correct construction and management of biogas digesters, to ensure sufficient and reliable biogas production and to minimize methane emissions to the atmosphere.

For the follow up on the policies regarding environmentally friendly manure management, it is recommended that direct discharge of digestate and manure to waterways are forbidden and that demands for retention time of manure in digesters are given.

Technologies must be developed, which provide better storage, transport and field-application of digestate and manure (e.g. pumping) for achieving higher fertilizer value.

The measures must in addition to enhancing fertilizer value of the manure and digestate also reduce pathogens in biogas digestate, and prevent transmission of pathogens to food crops as well as the external environment, e.g. water sources.

The institutions involved in this study may be a hub for training post graduates in the neighboring countries.