RECYCLING OF ORGANIC RESIDUES FROM AGRICULTURAL AND MUNICIPAL ORIGIN IN CHINA

Roelcke M.[1*], Nieder R.[1], Goldbach H.[2], Clemens J.[2], Heck P.[3], Mueller-Hansen K.[3], Lu H.Y.[3], Liu X.J.[4], Cui T.N.[5], Zhang F.S.[4]

[1]Institute of Geoecology, Technische Universität Braunschweig, Langer Kamp 19c, 38106 Braunschweig, Germany. Tel: +49 531 3915912. m.roelcke@tu-bs.de

[2]University of Bonn, Institute of Crop Science and Resource Conservation (INRES), Plant Nutrition, Karlrobert-Kreiten-Straße 13, D 53115, Germany. Tel. +49 228 732850. h.goldbach@uni-bonn.de

[3]Environmental Campus Birkenfeld, Trier University of Applied Sciences, Postbox 1380 55761 Birkenfeld, Germany.

[4]College of Resources and Environmental Sciences (CRES), China Agricultural University (CAU), Beijing 100193, P.R.China.

[5]Beijing University of Technology, Pingleyuan 100, Chaoyangqu, Beijing 100081, P.R. China.

1 INTRODUCTION

1.1 Background:

This Sino-German collaborative research and technology transfer project takes advantage of different interdisciplinary research groups and the involvement of German small and medium-sized enterprises to develop integrated strategies and solutions for the recycling of organic residues in China.

1.2 Research objectives:

The project aims at reducing pollution, abating greenhouse gas emissions, improving nutrient cycling, generating renewable energy and increasing regional added value in the Chinese countryside. The aim is an integration through a more holistic view of optimizing the various flows for best recycling of organic residues, best water management, high energy efficiency and a sustainable animal husbandry and crop production. Starting from the technical situation of selected model farms and pilot plants, an improvement of the regional situation, as well as intensive animal husbandry in peri-urban areas of large Chinese cities is envisaged. Two different approaches are pursued in this consortium.

2 MATERIALS AND METHODS

2.1 Nutrient Cycling Team

In one comprehensive and integrated approach planning, technical improvement of animal production techniques, feed optimization, manure storage and treatment for minimizing emissions, as well as hygienization, designation of organic fertilizers for specific usage, carrying capacity of cropland, economic factors, administrative issues and environmental regulations are taken into account and realized in a case study. The “Nutrient Cycling Team”, led by the universities of Braunschweig and Bonn and the China Agricultural University (CAU), first concentrates on an interdisciplinary and in-depth research of the different processes and flows involved, in a second step offering newly-adapted process lines and strategies. Finally, a balance between livestock production and cropland areas (including livestock densities) is to be achieved, with an integration of livestock and crop production. An exemplary pilot pig raising plant, with an annual production of about 80,000 pigs, has been selected in the Shunyi District of Beijing.

The Nutrient Cycling Team comprises a total of nine subprojects, five of which dealing with nutrient fluxes and balances, two with pollutants and risks, and two with environmental assessment, and transfer and extension, respectively. The subprojects are subsequently presented:

Nutrient fluxes and balances:

- **Farm-gate balance for animal production:** Subproject 1 covers the cycling of animal waste products *prior to* application to agricultural land (handling, storage and treatment) at the pilot animal production plant

close to Beijing. Main objectives are to describe the status quo with respect to the way of animal husbandry and production management and the resulting input/output balances of nutrients and harmful pollutants of these facilities.

- **Anaerobic digestion and subsequent nutrient separation in intensive animal husbandry:** The objectives of Subproject 3 are to contribute to a technology which maximizes nutrient re-use and minimizes the euthrophication potential and environmental pollution from animal production. The activities focus on anaerobic digestion as a treatment technology and on the export of nutrients in form of organic, organo-mineral and mineral fertilizers, substrates and irrigation water.
- **Composting of solid wastes from agriculture and agricultural industry after anaerobic fermentation:** The aim of Subproject 4 is the optimization and evaluation of composting processes for the production of organic fertilizer from pig manure with bulk material additives. The losses of ammonia gas emissions should be limited as much as possible.
- **Testing of products (substrates and compost) for horticultural and greenhouse production:** The objectives of Subproject 7 are to optimize the use and to further develop substrates and residues from intensive livestock raising for intensive ornamental and vegetable production.
- **Strategies for optimizing C, N, P and S balances and flows of an exemplary animal production plant as a basis for improved regional recycling concepts:** Subproject 2 deals with the cycling of treated animal waste products *after* application to agricultural land. Input-output calculations on plot, farm and regional scale are carried out. The aim is to increase the nutrient efficiency of animal excreta with respect to optimum plant and soil nutritional status.

<u>Pollutants and risks:</u>

- Hygienic Safety and Veterinary Public Health: The overall goal of Subproject 5 is to increase biosafety on the farm level by sophisticated waste management and application of advanced treatment of the effluents and improvement of herd-health. The main aims are to define the microbial risks on the farm level, to identify the points where the highest risks concerning the above given epidemiological pathways are given, to validate the treatment options given in the subprojects on aerobic digestion and composting under the aspect of hygienic safety, and to investigate the risks related to animal health care is the possibility of spreading pharmaceutics (antibiotics, drugs) used in animal treatment and in prophylaxis or their metabolites via urine and faeces.
- Soil and groundwater: Subproject 6 deals with accumulation and leaching of phosphorus (P), heavy metals (HM), and antibiotics following extended organic fertilization in light soils. It aims at elucidating and minimizing environmental risks associated with high density livestock raising. Major focus lies on the fate of manure-born P and feed-additives as HM (in particular copper) and antibiotics. One major objective is to record the evolution of the contents of P as well as HM and antibiotics in soils of the pilot farm with special reference to site history and spatial on-farm variability ("hot spots").

<u>Environmental assessment, transfer and extension:</u>

- Environmental assessment of development options and options to ameliorate waste treatment methods: The aim of cross-cutting Subproject 8 is to develop sustainable policy recommendations to optimize the environmental, economical and social state in the pilot farm and village. Activities comprise a microeconomic assessment using linear programming method for cost-benefit-analysis, environmental economic assessment by using discrete choice analysis to internalize the environmental costs in the production system, and participation process to agree on possible policy scenarios with local farm decision makers.
- Transfer and extension, setting up a quality assurance system in agriculture, an assurance system for laws and ordinances, environmental regulations, policy recommendations: The main focus of cross-cutting Subproject 9 is the transfer and extension of the results achieved in Subprojects 1-7 as well as the economical investigations in Subproject 8 into agricultural practice of Chinese peri-urban areas. This includes evaluation of a quality assurance system feeding strategies, waste management, soil management and plant production, scenarios with minimized environmental pollution as well as legal recommendations.

2.2 Recycling Team

In a second parallel approach five research sites in four different Chinese provinces and municipalities have been selected to develop technically feasible, economically viable and ecologically sound pilot recycling projects through regional material flow management, stakeholders' involvement, innovative financial schemes and technology transfer. The strongly application-oriented "Recycling Team" led by the University of Applied Sciences Trier (FH Trier) focuses on developing new, systemic material flow management concepts combined with micro-economic methods and strategies for establishing the pilot projects aiming at recycling organic residues, reducing pollution and increasing regional added value. This is to be achieved through the approaches of regional material flow management, stakeholders' involvement, innovative financing and implementation schemes (Public Private Partnership (PPP), Build Operate Transfer (BOT), Build Operate Own (BOO)) as well as technology transfer.

3 RESULTS AND DISCUSSION

The current paper focuses on approaches and preliminary results by the "Nutrient Cycling Team". First-hand accounts from China will be delivered and first research results will be shown.

3.1 Status quo

As a first step, the status quo of the matter (nutrient and pollutant) fluxes on the farm is being investigated. Fig. 1 shows the current matter fluxes of animal excreta on the pilot farm. The pigs are held on concrete platforms and the solid excreta are manually removed from the pigsties. The advantage of this Chinese *gan qing fen* system is that it can separate a high amount of the nutrients in the faeces. The stables are subsequently flushed with large amounts of water. The resulting liquid fraction is therefore highly diluted, with only low contents of organic matter. A part of the liquid fraction is anaerobically digested in a biogas reactor. In order to guarantee the necessary chemical oxygen demand (COD), part of the solids are re-added to the liquid fraction, while the remaining solids are composted. The fermentation residues are subsequently stored in an oxidation pond. They are then either used for irrigation purposes (cash crops) or flow into a lagoon, which is connected to a riverbed via a discharge sluice. At present, only a very limited testing of biogas sludge and compost for pathogens and pollutants is undertaken.

As to the cropland status, an ongoing monitoring of 26 plots comprising the 5 major cropping systems on the pilot farm as well as in the wider region (Shunyi and Huairou Districts of Beijing) has resulted in very high contents of available nutrients in most of the 0-200 cm soil profiles. This was particularly the case for mineral nitrogen ($N_{min} = NO_3^-\text{-}N + NH_4^+\text{-}N$), available phosphorus (Olsen P), dissolved organic carbon (DOC) and dissolved organic nitrogen (DON). Fig. 2 shows an example of N_{min} contents for plots under maize/Chinese cabbage rotations and for poplar plantations. These high contents in reactive N, P and C compounds pose a high risk for surface water pollution. The high soil N_{min} contents and application of NH_4^+-rich liquid effluents to cropland also cause gaseous N losses of NH_3 and N_2O. Groundwater pollution in the Beijing area is serious (e.g. Zhang et al., 1996). However, due to the constant lowering of the groundwater table and the subhumid climate, the groundwater recharge rate is probably quite low. With few exceptions, analyses of HM did not result in soil concentrations exceeding Chinese or German threshold levels.

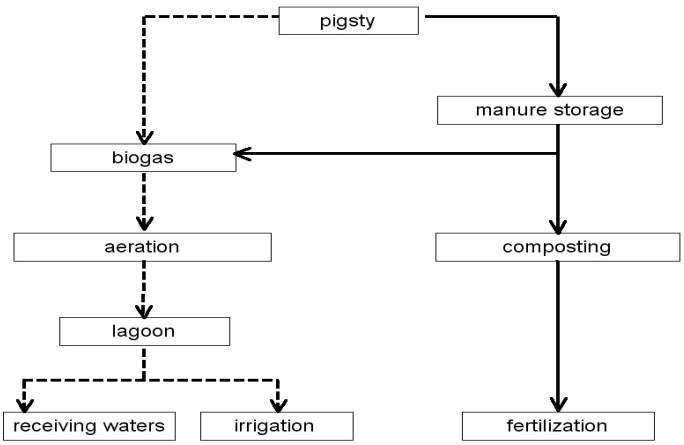

FIGURE 1 **Matter fluxes of excrements from pilot pig raising plant: --- liquid phase, — solid phase.**

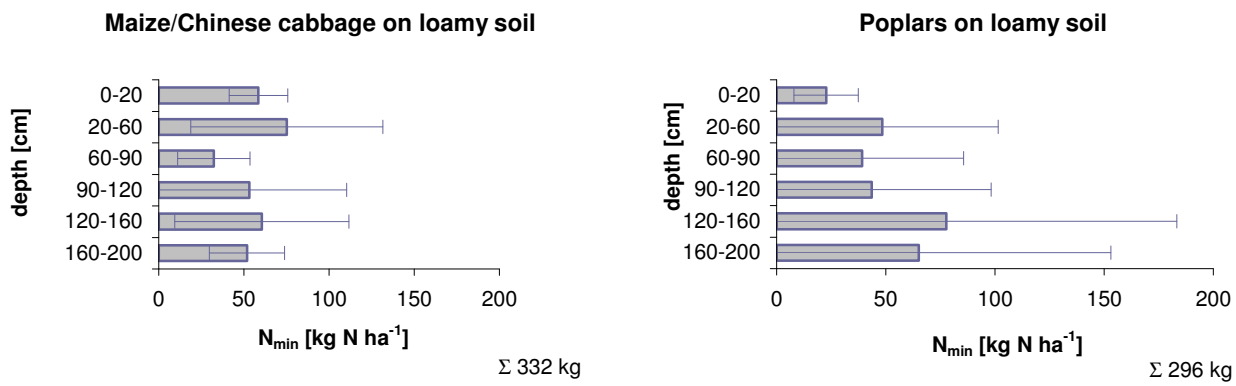

FIGURE 2 **Mineral nitrogen (NH_4^+-N +NO_3^--N = N_{min}) contents in field plots from Shunyi District under maize/Chinese cabbage rotation (3 plots) and poplar plantations (2 plots) on loamy soil in the 0-200 cm soil profile in March 2009 (means and standard deviations) (Heimann et al., unpublished).**

3.2 Optimized options for treatment

As second step, optimized options for treatment of the organic wastes are developed and tested, which allow for an export of nutrients from the pilot pig raising plant and their re-use in farms in the wider region. Such a procedure is urgently required in the short run, as is highlighted by the current situation of the cropland described above. Options are presented via composting of the solid phase and recycling of nutrients from the liquid phase via precipitation and stripping. These processes allow for the production of marketable organic or combined organo-mineral fertilizer products. These require uniform nutrient concentrations, availability and composition, as well as standards regarding hygiene and pollutant contents. In this respect, several organic residues are currently being investigated for their suitability as organic fertilizer products and steps are being taken for their approval and registration. Moreover, suggestions for the revision and improvement of currently existing Chinese organic fertilizer standards will be made as part of the project.

4 CONCLUSIONS

Experiences from the first year have shown that all solutions have to be site-specific, and that no standard concepts for aerobic or anaerobic treatment of organic wastes exist.

An intense exchange of knowledge and personnel has been initiated by this ongoing Sino-German research consortium. Several subprojects have successfully applied for mobility costs via the German Academic Exchange Service DAAD and the China Scholarship Council CSC. Moreover, funding from Chinese sources is additionally obtained for the investigation of upcoming questions.

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