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Mission to Thailand

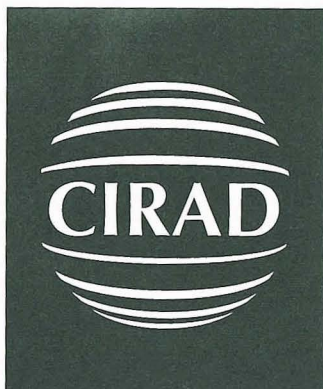
12 to 20 September 2001

Support Mission to DORAS (Development  
Oriented Research on Agricultural Systems)

Peri Urban Agriculture Programme

1. Urban waste composting  
Follow-up of Miss Nuanjun Pasda work for  
her Ph.D. Thesis in Kasetsart University
2. Agro-industrial waste processing

**H. Saint Macary and D. Montange**





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This mission was fielded within the framework of the Research Programme on Peri-Urban agriculture, funded by French Embassy, first to review the proposed work programme of the Ph.D. thesis of Miss Nuanjun Pasda, from Kasetsart University and have a meeting with Professor Supamard Panichsakpatana, dean of Agriculture Faculty, to discuss further development of our collaborative research on waste management. The second point of the mission was to identify possible ways of DORAS Project involvement in agroindustrial wastes processing in view of their use in Peri Urban Agriculture. Contacts have been made with private enterprises (CP Group) dealing with pig slurry and poultry manure valorisation. All these meetings and visits were organized by Jacques Pages, who participated to these activities.

## **1. Urban waste composting.**

### ***1.1. DORAS Co-operation with the Department of Land Development of the Ministry of Agriculture and Cooperatives***

As part of the capacity building and training role of CIRAD-KU collaboration with DORAS, a student, Miss Nuanjun Pasda, is carrying out a Ph.D. Thesis on a topic related to PUA Research Programme activities. The topic concerns the "Biological assessment of suitability for agriculture of different compost derived from Bangkok city sewage sludge": these sewage sludge being issued from wastewater (except septic tanks) treatment plants in Bangkok.

Miss Nuanjun Pasda will present her thesis in Kasetsart University. She is a researcher in the Ministry of Agriculture, Department of Land Development, Soil and Water Conservation Division, in the laboratory of Soil Microbiology within Organic Matter and Waste Products Subdivision (responsible: Dr Pitayakon Limtong). She was granted a Royal Golden Jubilee / French Embassy support for her studies. Her supervisor for the Ph.D. thesis in KU is Professor Supamard Panichsakpatana. Miss Pasda is realizing her experiments on an alternative basis: part in KU and part in CIRAD laboratory in France. The programme of work of Miss Pasda was thoroughly discussed with her and her advisers. It was agreed that she includes new experiments including maturation of the composts with earthworms. The experimentation approach proposition she will submit in her Thesis Proposal is provided in annex 1.

### ***1.2. Future programme***

Professor Supamard Panichsakpatana, dean of the Faculty of Agriculture at Kasetsart University, mentioned two subjects he would be interested in developing for a future collaboration between KU and CIRAD:

- Management of pig slurry for the production of compost and biogas. We indicated that CIRAD has some expertise in this area and discussed the possibility to set a pilot plant of biofiltration in a relevant place. Pr Supamard Panichsakpatana is convinced that this subject would be suitable to obtain an other Ph.D. thesis, may be with a Royal Golden Jubilee award and indicated that we could jointly look for funding for the construction of a pilot reactor.
- Effect on the environment of the "disappearance" of salt added to fresh water for growing tiger prawns. The tiger prawns are usually grown in brackish water in ponds prepared in mangrove zone with acid sulfate soils. However for several years, there



are many problems in these zones with a prawns' mortality due to water toxicity by accumulation of prawns excreta and medicines, increased acidity and appearance of a prawn-killer virus, surviving only in sea water. In order to avoid this mortality, prawns are now produced in fresh water with salt added to create favourable growing conditions. The fate of the salt added to fresh water is not clearly known. It might create environmental hazards. For example, different clays constitutive of some soils are subject to deflocculation. Moreover, some living organisms are susceptible to high concentrations of sodium and it might also be toxic for others.

A better knowledge of the dynamics of the salt added in the ponds is urgently needed, both for a good management of the soil and for a risk assessment.

## **2. Agroindustrial waste processing**

### ***2.1. Meeting in Bangkok***

A meeting was organized with Somponk Jenwitvichaikul, assistant vice-president, and Nared Chin-Inmanu, assistant vice president for agriculture machinery of Charoen Pokphand Engineering (CP Group).

The activities of CIRAD in waste management have been presented and discussed. Main concerns of the CP group, as far as waste management is concerned, are :

a/ Urban wastes management for a Thai town (Trat province). We indicated that this area is beyond CIRAD's mandate and expertise. However, we had contacted a French company in France involved in treatment of urban solid wastes (Valorga) and we suggested that the CP group contacts Valorga directly since Valorga had indicated their interest for a project in Thailand.

b/ Pig slurry management for a pig farm where processing presently includes biogas production and cleaning of waste water before release to fish ponds.

c/ Poultry manure, which is presently sold, after composting, as an organic fertiliser.

For items b) and c) we agreed that more information would be needed in order to see if CIRAD could make proposals for scientific activities or expertise. The sites mentioned by CP group were therefore visited.

### ***2.2. Poultry manure compost***

#### ***2.2.1. Visit of the factory***

The factory we visited is located near Lopburi. It processes poultry manure with the following procedure.

#	Operation <i>Product obtained</i>	Duration / Period	Remarks and questions
1	Collect of manure  <i>Chicken manure (mixture of faeces, feather and rice husk)</i>	June – October	Manure is bought to farmers during rainy season. Approximately 300 T/day. Price paid to chicken producers: 330 bahts / T. During dry season, manure is directly used by chicken producers in their fields. 80 % of the manure collected comes from CP-owned farms. Remaining comes from individual farms.
2	Initial preparation		Addition of urea (500 g / 20 m <sup>3</sup> ) and bacterial activator. Rehydration to 60% moisture.
3	Fermentation  <i>Raw material</i>	5 months / fermentation  July to March	Piles of compost are left in 2 locations (4 ha each). Piles are watered if necessary, to maintain moisture to 60%. Piles are turned upside down every month with a loader. Evaluation of maturation is made by estimating: loss of odour, decrease of temperature to 35°C, colour of the product, apparent decomposition of the rice husk. During the process, large volumes of waste water are drained and infiltrate the soil. In one location, this water is collected in a pond and used for watering some crops nearby with sprinklers.
4	Drying	Year long	Done near the fermentation area in small piles (first phase) and later at the factory (second phase). Necessary for grinding. Humidity must be decreased to 5-10 %.
5	Grinding  <i>Dust</i>		Two large hammer mills.
6	Pelleting  <i>Pellets or powder</i>		Powder from hammer mills needs to be rehydrated for pelleting. Chemicals ( ? ) added at this stage. Two pelleting machines (150 CV). Part of the powder is not pelleted (40%).
7	Storage		Bags of 50 kg. Production rate is 50 tons / day. In 2001, global production is 6000 tons. Objectives for the factory are 10 000 tons. At the time of our visit, the production of two months was stored.
8	Selling		Price of the product: pellets 4 bahts / kg ; powder 2.5 bahts / kg. Composition (NPK): 2-4-2
9	Use		Farmers are expected to use the product as a substitute for fertilizer and as a source of organic matter. Recommended rate of substitution: 50 kg of the product instead of 20 kg of fertilizer 15-15-15.



Two main questions are raised by the management of the factory:

- could the process of fermentation (which is actually a composting) be shortened?
- what are the solutions for disposal of waste waters produced during composting?

There are no simple answers to these questions, but the following comments can be made regarding them:

- The conditions of production we observed certainly induce variations in the composition of the compost; these variations can be due to several factors such as the initial quality of the chicken manure which can change according to sources or to time, but also the method of composting, the drying conditions, etc.
- Shortening the composting duration is probably possible if the aeration of the compost is improved; it could be done either by turning the piles more frequently or by injecting some air in the piles (several systems exist for this purpose).
- A more precise monitoring of the temperature could help to determine precisely the time necessary for the maturation phase; this should be done together with a monitoring of the quality of the compost.
- Recycling the waste water on the compost piles themselves could possibly induce economies of water, allow to recycle nutrients leached from the compost and preserve the environment. This would require to improve the collect of these waters (concrete floor of the composting area) and to study more precisely their composition and the effect of their recycling on the quality of the compost.

### *2.2.2. Actions to take / Proposals*

We took samples of the various products along the process (initial manure, composted material, powder, pellets) in order to analyse them and to have a better idea of the transformations occurring during the process. However this will only cover a very short period of time and will not answer to all the questions raised. We think that one major issue for the future of the compost produced is to be sure of its quality, all along the process and all along the year. We therefore propose to conduct a study on one complete cycle of production in order to monitor the parameters affecting the quality of the compost during the processing chain and to find, at each step, what are the ways for improving the quality of the final product.

As part of DORAS PUA Research Programme, we propose the following actions :

- assignment of one student for a campaign of measurements on the flux and the quality of the products;
- realisation of an experimental area protected from rainfall with recycling of the waste water and improvement of the aeration of one compost pile;
- follow up of the experimental area;
- comparison of costs and quality in the improved system and the present one.

## *2.3. Pig slurry processing*

### *2.3.1. Visit to a pig farm*

Visit to a pig farm of CP Group in Saraburi, 140 km North of Bangkok, with M. Pinit Sena, Project Department Manager, Great Agro Co, part of CP Group. The pig farm has a capacity of 12 000 pigs.

Piglets weighing 23 kg arrive at the farm and are kept for 16 weeks until they weigh 105 kg.



These 12000 pigs are producing 500 cubic meters of slurry daily (average of 42 litres per pig per day ; this value appears to be quite high). Since 3 months, the pig slurry of this farm is treated to produce i) biogas for electricity, ii) a basis for organic fertilizer preparation and iii) clean water for fish production.

The slurry treatment plant is composed of:

- 1 storage tank for slurry;
- 3 fermentors with gas storage included: concrete walls are topped by a rubber sheet with a water seal, this sheet being used for gas expansion and biogas pressure keeping. The slurry is kept for 5 days in the fermentor for methanisation, the methane produced being kept on top of the slurry before use in generator;
- Filtering / drying device of The effluents from the lower level of fermentors (40% of the total capacity of the fermentor containing suspended organic matter: this sludge is released in large batches with a sand filtering bottom. After 5 days of drainage/drying, the organic matter is harvested and sold (0.7 baht per kg) for organic fertilizer preparation. The drainage water is sent to cleaning ponds;
- upper part of the effluent (60% of the total capacity of the fermentor) are kept for 5 more days in cylindrical concrete fermentors equipped with methane recuperating devices. At the end of this "fast fermentation", effluents are released to the cleaning ponds.
- The drained water and cleaned effluent released to a series of 11 cleaning ponds are naturally depolluted, mainly by solar U.V. rays and plants absorption (phragmites, algae,...). After depollution, this water is used to grow fish in ponds near the pig houses.

This biogas production unit has been proposed to C.P. Group by Chiang Mai University, together with a German organism. A technical backstopping mission from these institutions should be arriving next month for follow-up of the functioning of the unit.

At the end of this visit, a lot of questions remained, such as the evolution of nitrogen content of the pig slurry and its repartition within the "organic fertilizer", the drainage water and the cleaned effluent released to the pond. Analyses should be realized (N,P,K content, BOD and COD, suspended organic matter,...) before releasing the water to the ponds. An other concern is the sand filtering device which might be susceptible to clogging due to the suspended organic matter.

### *2.3.2. Actions to take / Proposals*

The processing methods for pig slurry are numerous and should be chosen according to the type of production system and the results required (size of the farm, surface available for agricultural application, major elements to eliminate...). In order to provide efficient advises on the type of equipment to set, it is necessary to have a clearer view of the situation of pig husbandry in Thailand. It would be interesting to have a study on this subject. Within DORAS PUA programme, it could be possible to backstop a team composed of one Thai student and one French student for this study.

Regarding the farm we visited, if this is not already done by the Chiang-Mai university, it seems necessary to realise a study on the evolution of C and N contents in the slurry and their repartition into dried sewage sludge and wastewater.

As clogging of the sand filter might be an important concern for the future, we could propose to test a biofiltration process to filter the sludge coming out of the fermentor, before preparation of a good quality compost. Such a biofiltration device is used to filter sewage sludge or pig slurry in France through straw on which the suspended organic matter is kept. A pilot plant might be settled and research made to adapt it to the local conditions (i.e. type of straw or organic matter, such as sugarcane waste, duration of filtration, use of the organic matter for further composting...).



### **3. Contact with French Embassy**

A wrap-up meeting has been organised with François Megard, regional responsible for scientific co-operation, Jacques Morcos, attaché for sciences and co-operation, Anne Le Jaouen, scientific bilateral co-operation, Guillaume Lacombe, assistant of regional responsible for scientific co-operation.

We have done a rapid presentation of the main activities and findings of the mission, showing that the funding received from French embassy is used to increase the collaboration between research institutes from France and Thailand as well as to look for complementary resources from private companies dealing with waste management.

### **4. Summary of actions to take**

1. General framework of CIRAD-MoAC/NARI activities on waste management in Thailand: as a possible area of co-operation between CIRAD and MoAC/NARI, a paper on waste management has been drafted (cf. Annex 2).
2. Information to be given back to Valorga on the interest of the CP group on Valorga process.
3. Information to be given and contacts to be made between CIRAD specialists on aquaculture management (EMVT) and effects of salt on soil and the environment (AMIS Agronomie, Solemi) and the faculty of Agriculture.
4. Discuss proposition of 2.2.2. to CP group for a complete assessment of the poultry manure composting process, including analysis, testing of improved processes. After agreement at internal level, transmit the proposal to CP group.
5. Discuss proposition of 2.3.2. on surveying of actual situation of pig slurry treatment in Thailand in order to determine if filtration techniques can be of use in this context. After agreement at internal level, transmit two sub-proposals:
  - proposal to KU (Faculty of Animal Science) mainly on surveying and review of literature (work by two students).
  - proposal to CP group including a complete follow up of their present process (if not already done with Chiang Mai University).

## Thesis Proposal

### Biological assessment of suitability for agriculture of different compost derived from Bangkok city sewage sludge

Presented to the Graduate School, Kasetsart University to be approved as the research for the required thesis.

Degree of Doctor of Philosophy (Ph.D.)

Major Soils Science

By Miss Nuanjun Pasda

#### Thesis Committee

Prof.	Supamard Panichsakpatana Ph.D.	Thesis Adviser
	Pitayakon Limtong Ph.D.	Major Subject Adviser
Asst.	Prof. Savitree Limtong Ph.D.	Minor Subject Adviser
	Denis Montange Ph.D.	Abroad Adviser

## Introduction

Bangkok is the political, economical, cultural and touristic center of the country. Population is very high: about 7.5 million in 2000 and for the next twenty years, it should increase to 11.9 million. However, deterioration of environment has brought urban degradation that may even impact on the political issue. In the early 1990s, Bangkok Metropolitan Administration (BMA) began a major program of wastewater sewerage and wastewater treatment schemes to improve water quality. The initial project in Siphraja became operational in 1994 and currently nine further schemes are being implemented. There are all expected to be completed by 2003 and will provide service over a total area of 192 km<sup>2</sup>. However, with the completion of these schemes, the sewage sludge production will be increased. In 2000, it is assumed that sewage sludge production is 65 tons/day. During the next 5 years, this sludge will increase to 108 tons/day and 168 tons/day in 2010. So the sewage sludge problems will become more severe in the future.

Sewage sludge is the solid material that settles out during the various water treatment stages. It is an inevitable by-product of a wastewater treatment plant. So, sewage sludge contains a large amount of nutrients and their characteristic are varying according to origin, type, previous treatment and period of storage. It might be considered for agricultural purpose. However sewage sludge has limiting factors for use in agriculture (i.e. some heavy metals, pathogens, odour) so utilization of sewage sludge for compost making must be considered.



### ***The properties of sludge compost for use in urban areas are***

- the sludge compost must be hygienically safe
- the sludge compost must not create odor nuisance
- the sludge compost must have a soil-like friable consistency

So, the objective of this research is to find the appropriate method for sewage sludge compost production, taking into account that this compost must be safe for environment and improve soil fertility.

### **Objectives**

1. Study on evolution of chemical, physical and biological properties of the sewage sludge issued from wastewater treatment plant in Bangkok area, including monitoring of pathogens population and heavy metal concentration.
2. Study on appropriate methods for sewage sludge compost production
  - study on suitable type and rate of mixture material and aeration process for compost production.
  - study on microbial population changes and their activities in decomposition process of sewage sludge when composting.
  - study of effective micro-organisms and earthworms in decomposition process and effect on compost quality.
2. Study on suitable rate of sludge compost application for soil improvement and crop production in peri-urban agricultural area

### **Literature Review**

#### **The sewage sludge characteristics**

Sludge was produced from municipal wastewater treatment plants, which produce large amount of waste. According to Negulescu (1985) sludge can be classified according to several criteria into 2 groups: the first is mineral sludge in which the suspended mineral solids exceed 50% and the second is organic sludge in which the organic suspended solids exceed 50% and the general characteristics of sludge produced from 4 processes of wastewater treatment are:

1. Sludge produced from primary settling tanks is grey and has an objectionable odor. Fecal matter, paper, plastic bags and vegetable parings are in evidence. The sludge is sticky and does not drain freely.
2. Sludge produced in Settling tanks after chemical precipitation take its color from the chemicals employed. Its odour is less important than sludge coming from primary settling tanks.
3. Sludge produced in secondary settling tanks after biological filters is brown and flocculent. The sludge coming from low-rate biological filters contains many dead worms and its odor becomes quite offensive.
4. Sludge produced in secondary settling tanks after activated sludge units (excess sludge) is flocculent and air-dries slowly even when it is spread in thin layers. If the biological treatment is efficient, the sludge is golden-brown and has an earthy odour.

Sewage sludge exhibit wide variations in their physical, chemical and biological properties according to their origin, type, previous treatment and period of storage. In general, the sludge produced has a very variable composition, the total organic matter ranges from 30-70%,  $P_2O_5$  1-7% and  $K_2O_5$  0.05-0.4%. So sewage sludge can provide essential plant nutrients but it must be considered for some heavy metals and some pathogens.



### **Nitrogen and Phosphorus in sewage sludge**

Nitrogen and phosphorus are the most abundant major plant nutrients in sludge (Metcalf and Eddy, 1991). The nitrogen in treated sludge occurs in both organic and inorganic forms. So sewage sludge is used as a source of nitrogen. Sludge also has a relatively high phosphorus content. Phosphorus is efficiently used by crops. In addition, sludge also contains other nutrients such as micro nutrients (Cu, Fe, Zn) and organic matter. The composition indicates the suitability of the sludge for agricultural production.

### **Heavy metals in sewage sludge**

The heavy metals (Cd, Cu, Zn, Pb, Hg, Cr, Ni) are concentrated in the primary sludge and in the biomass of activated sludge. The heavy metals in sludge can be removed in various ways, such as mixing with agrowastes, specific micro-organisms and anaerobically digested sludges.

### **Pathogens in sewage sludge**

Sewage sludge may contain pathogens; they are one of the limitations of sludge use in agriculture. There are three kinds of micro-organisms in sewage which are of concern for their effects on human health: bacteria, viruses and parasites.

The U.S. Environment Protection Agency (EPA) also classifies sludge quality based on indicator bacteria. The class A indicator standard is less than 1,000 faecal coliforms per gram of dry sludge solids and the class B indicator standard is less than 3 million faecal coliforms per gram of dry sludge solid (Watsh, 1995). The class B sludge poses greater health risks. Sludge should be treated to kill the pathogens before using in agriculture. The conventional methods are pasteurisation, composting and lime treatment. Suss (1997) mentioned that the digested sludge may still contain, for example, *Salmonella*, which can survive for long periods outside their native environment.

### **The other characteristics**

Sludge is mostly not well-stabilized and has offensive odours. The moisture content in sludge is high. Moisture content in Siphra sludge is 80% (AIT Final report, 1998)

### **Utilization of sewage sludge in agriculture**

Sewage sludge is a resource due to its content of nitrogen, phosphorus and organic matter (Bayes *et al.*, 1988) and is effective for soil amendment. In western Europe, 40-50% of the sludge requires prior knowledge of interaction among sludge, soil and plant before use on agricultural lands (Hue *et al.*, 1988). Potential benefits of sludge in providing plant nutrients have long been recognized (Chang *et al.*, 1978). However, potential effects (e.g., introduction of heavy metals such as Cd, Cr, Hg) into the food chain are of concern (Lagan and Chaney, 1983). Sludge applied to land provides major plant nutrients such as N, P, K micro-plant nutrient such as Cu, Fe and Zn, and organic matter for improving the soil structure (e.g. better aeration and water holding capacity). The effectiveness of sludge as a soil-improving agent depends upon the composition of the sludge, the characteristics of the soil on which it is applied and the plant species to be grown. The raw sludge was found to cause a decline in the growth despite its higher nitrogen content. This is believed to be a combination of ammonium toxicity, phyto-toxic intermediary decomposition products and dissolved oxygen deficiency in the root zone caused by enhanced microbiological activity. The nitrogen content of raw sludge varies depending on the treatment method such as on dry weight between 0.8 and 5% for sludge produced by activated sludge unit (Negulescu, 1985).

Pathogenicity is one of the major concerns when sewage sludge is applied to crop land. In Ontario sludge must be stabilized (anaerobic digestion is a popular method for sewage



sludge stabilization) before application. However, waiting periods between sludge spreading and harvesting or grazing are still required: 2 to 6 months for grazing, 12 months for commercial sod production, and 15 months for small fruit (Sludge and Waste Utilization Committee, 1992). The U.S.EPA (1993) allows anaerobically digested sludge to be spread on farm land, providing the land is withheld from food production for 6 to 16 months period. They require further treatments to eliminate pathogens for lifting the restrictions on sludge application. Irradiation is a recognized method to eliminate pathogens in digested sludge (USEPA, 1993; Ward *et al.*, 1984). The potential for pathogen transition exists and can cause public health problem if land application is done improperly. Pathogen in land applied sludge will usually die rapidly, depending on temperature, moisture, and exposure to sunlight. To prevent disease transmission, sludge should not be applied to land during a year when edible crops are grown. Sludge application methods and rates should be designed based on the soil characteristics to reduce public health concerns

### **Compost**

Rynh (1992) has defined composting as a biological process in which micro-organisms convert organic material such as manure, sludge, leaves, paper, and food waste into a soil like material called compost. Composting seems to be a desirable treatment having the capacity of reducing the volume and weight by approximately 50% and resulting in a stable product that can be beneficial to agriculture (He *et al.*, 1992). Composting can be used to eliminate pathogens from sewage sludge. For pathogen destruction, the composting process should be carried out at high temperature ( $>55^{\circ}\text{C}$ ) for an extended period (USEPA, 1993). Composted sewage sludge also improves soil physical properties and has been shown to increase seedling growth of several tree species. Compost carries plant nutrients in various concentrations and functions as a fertilizer (Thacker, 1986 and Chaney, 1980). Major attention has been given to micro-nutrient and trace metal concentrations in composts (Someshwa *et al.*, 1991; Bellamy *et al.*, 1995). Composting time depends on the biological cycles of the micro-organisms involved. Although many types of organisms are required to decompose different materials, the necessary variety is usually present and organisms grow when environmental conditions are satisfactory.

### **Carbon and Nitrogen**

Carbon is a key requirement for composting (Richard, 1992). Carbon is energy source for micro-organisms that do the composting. Micro-organisms break down the organic matter and produce  $\text{CO}_2$ , humus and energy. Nitrogen is critical for microbial population growth, as it is a constituent of protein which forms over 50 percent of dry bacterial mass. If nitrogen is limiting, microbial populations will remain small and it will take longer to decompose the available carbon. So, the carbon to nitrogen ratio (C:N) of a material is an estimate of the relative amounts of these two elements it contains. Differing protoplasmic carbon to nitrogen ratios among microbes lead to differing ratios of degradation. Both bacteria and actinomycetes have protoplasmic C/N ratio of 5:1, while fungi has 10:1 ratio. Bacteria need 1-2% nitrogen to degrade a unit of carbon, actinomycetes need 3-6% and fungi need 3-4% (Miller, 1993).

### **Sample substrates**

Simple carbon compounds such as soluble sugars and organic acids are easily metabolized and mineralized (deBertoldi *et al.*, 1983) and so are degraded at the fastest rate by the micro-organisms. In this process, mesophilic micro-organisms are predominant and take only a few days.



## **Complex substrates**

After the easily-degraded substrates, hemicellulose, cellulose and lignin are broken down. Fungi and actinomycetes play an important role in the decomposition of cellulose and lignin. They excrete enzymes, hydrolyze cellulose and lignin into monosaccharides or oligosaccharides (Gray *et al.*, 1971). While hemicellulose is also a sugar polymer, it is fairly susceptible to microbial attack, compared to other polymers such as cellulose and lignin

## **Microorganisms in composting**

Many types of micro-organisms are required to decompose different materials. Micro-organisms metabolize organic compound in waste. However, not all of the breakdown in composting is biological in nature. Chemical and physical conditions also exert influence such as ultraviolet, temperature and pH level. Different communities of micro-organisms predominate during the various composting phases. During the first stages of composting, bacteria increase rapidly. Later actinomycetes, fungi and protozoans go to work. Microbial population is mostly determined by temperature and available food supply (Gray *et al.*, 1971). 25 to 40°C is the domain of mesophilic microbial activity (Bangstam, 1978). Thermophilic activity (40-65°C) usually appears after 5 to 10 days. Later in the process, after the peak temperature phase has passed and the temperature of material falls below 40°C, the mesophilic community returns.

## **Compost maturity**

Maturity of a compost is essential for optimal use as a soil amendment and a source of plant nutrients (Mathur, 1993). Immature composts pose problems of bad smells and fire during storage; as well as phytotoxicity and pollution when using.

Many methods have been proposed to estimate the degree of maturity of compost. According to Morel *et al.* (1984), the maturity of the compost may be assessed by the biological stability of the product. Three kinds of methods may be distinguished:

1. Respirometry
2. Analysis of biodegradable constituents : total organic carbon, polysaccharides
3. Study of biochemical parameters (ATP, enzyme activity)

Other methods for estimating the degree of maturity of composts: the final temperature drops, the degree of self-heating capacity, the amounts of decomposable, resistant organic matter in compost, the rise in redox potential, the decrease of oxygen uptake, carbon-dioxide evolution and starch test.

## **The composting process**

The time necessary for the composting process depends on several conditions:

### **Carbon-to-nitrogen ratio**

Carbon to nitrogen ratio (C/N ratio) of compost is used as an assessment of maturity and a large ratio is considered as an indication of immaturity. Carbon is a major component of the cellulose and lignin giving their strength to cell walls. Nitrogen is found in proteins and many other compounds inside plant cells. The 30:1 ratio in compost is the most desirable to supply the micro-organisms with the proper amount of carbon they need for energy and the proper amount of nitrogen they need for protein synthesis so they can function quickly.



## Temperature

Temperature is universally a determinant of metabolic activity (Finstein *et al.*, 1983). It has been recognized as a key environmental factor for composting conditions. Metabolic activity within compost pile, induces a temperature increase. Activity, represented by heat inside the compost 50-60°C, will remain intense until temperature becomes too high for living organisms to remain active. Then, as they stop their activity, heat, thus temperature, will progressively decrease. Heat output influences temperature because of the piles' insulation. There are many reports in the literature of the optimal temperature being in the range of 55 to 60°C (Waksman *et al.*, 1939; Wiley, 1957; Jeris and Regan, 1973; Finstein *et al.*, 1983).

## Oxygen

Oxygen is an environmental parameter. It is linked to the decomposition process. Oxygen serves as terminal electron acceptor in microbial respiration (deBertoldi *et al.*, 1983). So when there is a rapid composting the oxygen supply can minimize the odor because in anaerobic conditions, the reduced compounds of nitrogen and sulfur as amines, sulfamines, mercaptans produced are bad smells.

## Moisture

Moisture management requires a balance between these two functions: microbial activity and oxygen supply. During the composting process, operating temperature drive off water via evaporation and microbes use moisture for their growth. According to Suler and Finstein (1977), 50-60 percent moisture can induce highest decomposition rate. However the decomposition rate will be decreased if the moisture is 70 percent. So, during the composting process, water should be added to bring moisture into the optimum range.

## pH

According to Stuetzenberger *et al.* (1970), in the early stages of composting, the pH decreases to 5.3-5.7 and then it is slightly alkaline before gradually approaching neutrality at maturity (Gray *et al.*, 1971; Hellmann *et al.*, 1997). Mckinley and Vestal (1985) hypothesized that increased pH could be used as an indirect indicator of high microbial activity.

## Sewage sludge compost

Composting sewage sludge is being increasingly considered by many municipalities throughout the world because it has several advantages over other disposal strategies (Zorpas *et al.*, 1999). Firstly, the volume of organic materials decreases by about 30-50% during the composting process (Brady and Well, 1996) Secondly, pathogens can be killed due to the heat generated during the thermophilic phase (Wong *et al.*, 1995; Furkacker and Haberl, 1995; Finstein *et al.*, 1980). Moreover mature compost also contains natural organic chemicals and beneficial micro-organisms that kill or suppress disease-causing micro-organisms (EPA 530-R-98-008, 1998). Lastly, compost can be used as a soil conditioner as organic substances are found in sludge (Zorpas *et al.*, 1999).

During composting, increases in pH can cause loss of N by ammonia volatilization. This can be minimized by addition of materials of high C/N ratio, and total enclosure of the system minimizes release of strong odors. Heavy metals are the limitation of sewage sludge utilization. Heavy metals can be removed by many methods. Numerous studies have been extensively undertaken on the use of agricultural residues, for heavy metals removal through adsorption, ion exchange or chelation.

In a laboratory batch, a study is using char rice husk for the adsorption of  $\text{Cu}^{2+}$  and  $\text{Ni}^{2+}$  (Yeoh, 1987). So heavy metals should be removed from the sewage sludge compost. Some organic material mixture might be used to do this.

In this research, compost from sewage sludge will be observed and produced with the appropriated method in order to avoid the environmental risk.

## **Materials and Methods**

### **1. Sewage sludge characteristics and their changes**

- 1.1 Sewage sludge will be collected from central wastewater treatment plant in Bangkok every month. The sample will be transported to laboratory and kept in the refrigerator at 4°C until analysis. Rapid determination of pH, electrical conductivity and organic matter content will be realized on each sample.
- 1.2 Six times per year, the chemical, physical and biological characteristics will be analyzed in the laboratory in order to monitor the changes:
  - Chemical characteristics such as nutrient content (N, P, K, Ca, Mg, S) organic matter, organic carbon, CEC, pH, some heavy metals
  - Physical characteristics such as moisture content
  - Biological characteristics such as global micro-organisms population, some human pathogens

### **2. Improvement of composting process**

#### **2.1. Selection of adequate vegetal residues for sewage sludge composting**

The BKK sewage sludge will be mixed with various type and rate of mixture material for aeration process as below

- Pure Sewage sludge
- Sewage sludge + rice husk 2/1
- Sewage sludge + rice husk 1/1
- Sewage sludge + saw dust 2/1
- Sewage sludge + saw dust 1/1

Each sample will be put in containers with aeration and moisture controlled in an incubator with the temperature increasing slowly from 30°C to 55°C during 2 weeks and then kept until compost maturation (C/N ratio constant, 20:1). During incubation, samples will be taken every 7 days after mixing of the composting material.

#### **2.2. Effect of biological activators for sewage sludge compost production**

The sewage sludge compost production will be experimented in laboratory scale. Sewage sludge will be mixed with suitable type and rate of mixture material (chosen in exp 1) with various effective micro-organisms as follow:

- Sewage sludge
- Sewage sludge + mixture material
- Sewage sludge + mixture material + PD-1 (activator)
- Sewage sludge + mixture material + Bionic (activator)

The sewage sludge compost samples will be taken every 7 days during composting process at 55°C, 60% moisture content, aerated conditions and analyze chemical and biological characteristics

In order to know if there is an increase of micro-organisms population during composting, a separate parallel experiment using “Sewage sludge + mixture material + fresh sewage sludge compost” will be undertaken.

At the end of the thermophilic phase, improvement of organic matter decomposition by using specific earthworms will be studied during the maturation phase of compost making. For this, one half of the mixtures will be inoculated with earthworms while the other half will be left without earthworms.

## 2.3 Common parameters to be measured in compost experiments

Several parameters will be analyzed such as C/N ratio, moisture content, pH, micro-organisms population, CO<sub>2</sub> respiration, cellulase, protease, soluble proteins, polyphenols, nutrients (N, P, K, Ca, Mg, S), carbon content, organic matter, CEC. In order to create a specific database, Near Infrared Reflectance Spectroscopy (NIRS) analysis will be conducted on each sample.

Monitoring of heavy metals content.

Monitoring of some human pathogen populations.

## 3. Experiments on soils

### 3.1. Evolution of composts when mixed into a soil

Select the soil series in peri-urban agricultural area near Bangkok city

- Rangsit series: low fertility and acid soil in Phatumtani province
- Kamphaeng saen series: medium fertility texture: loamy and sandy loam in Nakornphatom province
- Map Bon series: low fertility texture loamy sand in Chachoeng saa province

Follow-up of Compost Organic Carbon and Nitrogen mineralisation when mixed with a soil: released CO<sub>2</sub> measured on a continued basis and mineral nitrogen analyzed at the end of incubation.

### 3.2. Field or Greenhouse Crop growing

One soil will be chosen from the Rangsit series, representative from peri-urban area from Bangkok. This soil sample will be collected to study influence of compost on the plant growth. The heavy metals accumulation in the soil and plant will be measured.

Planned experiment

- Randomized Complete Block Design (RCBD) with 3 Replications
- 3 Rates of compost: 10, 20 and 30 tons / hectare
- Rate of chemical fertilizer: according to extension recommendations
- Growing plant: vegetable

Treatment experiment

- Control (non sewage sludge compost and non chemical fertilizer)
- Chemical fertilizer
- 10 tons Sewage sludge compost
- 10 tons Sewage sludge compost + chemical fertilizer
- 20 tons Sewage sludge compost
- 20 tons Sewage sludge compost + chemical fertilizer
- 30 tons Sewage sludge compost
- 30 tons Sewage sludge compost + chemical fertilizer

Soil samples will be collected before and after growing crop to analyze nutrients (N, P, K, Ca, Mg, S) organic matter, CEC, some heavy metals, pH, moisture content and micro-organisms population.

Yield of crop should be recorded, along with yield components depending on the crop cultivar chosen, such as number of plants per square meter....

Samples of harvested plants will be collected to analyze nutrients and heavy metal content and plant uptake during this experiment.



## **Place and Duration**

- Places
1. Department of Soil Science, Faculty of Agriculture, Kasetsart University
  2. Soil Microbiology Laboratory, Organic Matter and Waste Product Subdivision, Soil and Water Conservation Division, Department of Land Development, Ministry of Agriculture and Cooperative
  3. CIRAD Laboratories, Montpellier, France

Duration: June, 2000 to May, 2005





## CIRAD – MoAC / NARI Partnership

Recycling of organic wastes in agriculture:  
compost production and quality assessment**1. Area of partnership**

The role of agriculture in recycling wastes from various origins (animal, urban, industrial) is becoming increasingly important.

The risks involved with such practices need to be evaluated. They are numerous: soil and water pollution, danger for health of consumers and loss of quality of products. On the other hand, recycled wastes can be useful as substitute for chemical fertilizers, as soil amendments or as cultivation carrier.

Methods for assessing these risks and advantages in various situations need to be developed.

In Thailand, the problem is raised in large urban areas such as Bangkok and its suburbs where various sources of organic matter are becoming problems. In agricultural areas, concentrations of animal husbandry can also create conditions for diffuse pollution. Among the major sources, one can mention:

- pig slurry
- poultry manure
- sewage sludge; until recently, processing of waste water was uncommon in Thailand. This technique is developing now, and the sewage sludge generated by these process must be eliminated.

These products are rich in organic matter, have a high nitrogen content and recycling them directly in agriculture can have environmental impacts. Mixing these wastes with available carbohydrate-rich compounds can lead to the production of composts which are less dangerous to health and environment, provided they are processed in proper conditions. As these products have a low added value, it is not possible to transport them on long distance, therefore they should be used in the vicinity of the production area. For example, peri-urban horticulture is demanding high quality composts for maximizing the vegetable production.

The collaboration proposed hereby concerns **research** on the evaluation of compost processing and on methods for assessing the quality of composts. **Training** of personnel from MoAC is part of the project.

**2. Partners identity**

CIRAD: CA and AMIS Department:

- Denis Montange, fertilizers and crop nutrition
- Hervé Saint Macary, cropping systems and soil pollution
- Robert Oliver, soil chemistry
- Jean Luc Farinet, waste processing

MoAC: Department of Land Development:

- Dr. Pitayakorn Limtong
- Miss. Nuanjun Pasda

### 3. Partners objectives

Two major objectives are fixed:

- develop techniques for monitoring the composting process and analytical tools for assessing the quality of composts from various origins
- evaluate the need for an efficient technology for depolluting the pig slurry from medium size farms by using biofiltration process.

### 4. Methodology

*Analytical methods for the quality of composts.*

Sewage sludge from the Bangkok areas will be used to prepare small amounts of compost, when blended with various agricultural residues (rice husk, saw dust) and in different conditions (temperature, size of the container, use of an activator). The maturation of the composts will be evaluated by following several analytical parameters including new techniques such as Near Infra Red Spectroscopy. These techniques will be also used with other composts from various origins (chicken manure, pig slurry) and results will be compared in order to evaluate which simple and convenient parameters can be used for a rapid and efficient characterization of composts.

### Technology for pig slurry treatment

CIRAD has an expertise on this subject with biofiltration process, which is officially accepted for use in France. It would however require adaptation to specific conditions of Thailand: since the basic principle is filtration of slurry by straw, it is proposed to set a pilot plant and to test available straw material (from rice, sugarcane, other crops...). The following items could be studied:

- effect of the quality of straw on general processing performances ;
- rate of depollution for the water phase;
- quality of the compost produced. For this last point, close links will be established with previous item “ *Analytical methods for the quality of composts*”.

### 5. Time frame and expected results

Characterization of composts from sewage sludge using various methods is already on-going by the way of co-direction of one Ph.D. student from DLD under supervision of KU. The Ph.D. is expected to be passed in 2005. At that time methods for a complete characterization of compost will be available.

For biofiltration device testing, two phases are proposed. In a first phase, a survey on the extension of pollution by animal wastes in the rural areas could be conducted and an assessment of the present techniques used for processing wastes realized. In a second phase, based on the results of the first phase, the setting of a pilot plant could be proposed in a convenient situation/location. When the pilot is set, experimentation and technology refining would be conducted. The total duration would be approximately 4 years.



## **6. Means requested to reach the objectives**

CIRAD will bring expertise and facilities in the France laboratories for special chemical analysis such as NIRS. CIRAD will make the biofiltration process available for construction of a pilot unit in Thailand.

On the Thai side, means to settle a biofiltration unit, as well as to carry out studies in the field in Thailand and support training session in France will have to be identified.

