



b

## **Progress Report 2005 and Application for Continuation in 2006**

For research projects financed by grants from  
The Directorate for Food, Fisheries and Agro Business  
under the Danish Ministry of Food, Agriculture and Fisheries

---

### 1. Research program

Research in organic farming 2000-2005 (DARCOF II)

---

### 2. Project title and number

CRUCIAL – Closing the Rural Urban Nutrient Cycle (III.3)

---

### 3. Head of project

Jakob Magid, Department of Agricultural Sciences - KVL

---

### 4. Participating institutes

|     |  |
|-----|--|
| DJF | Danish Institute of Agricultural Sciences    |
| DMU | National Environmental Research Institute    |
| KVL | Royal Veterinary and Agricultural University |

---

### 5. Other project staff

|            |   |
|------------|---|
| KVL        | Jacob Møller , Lasse Dam Rasmussen, Jesper Luxhøi, Lars Stoumann Jensen, Sander Bruun, Andreas de Neergaard |
| DMU        | Paul Henning Krogh, Thomas Larsen   |
| DJF-Foulum | Gitte Rubæk, Bent T. Christensen  |

---

## 6. Project period (month, year)

Start of project: August 2001  
End of project: June 2006

---

## 7. Midterm description of the project, its results and progress, and application for continuation in 2006

### A. Project summary

The original purpose with the project was and remains the establishment of a field-scale facility for assessing the feasibility of improved recycling of nutrients from urban areas to organic farms, in the form of a long-term field trial. By examining urban fertiliser pre-treatment, turnover in soil and impact on crop growth, the project should provide practically useful results. With the initiation of a monitoring programme for biological soil quality it will attempt to take eventual unforeseen ill effects of increased re-circulation into account. Finally project should provide a concrete platform for the public debate, and possibilities for the public to visit the field trials.

After some adjustments the development of the field trial (WP1) is well under way, and has been strongly appreciated by the public (e.g. The Danish Committee for Waste Management 'DAKOFA' has decided to attempt to seek continued partial support for the running of CRUCIAL's long-term field trials at the end of the project, based on financial support from their own members and from organizations that collaborate with them).

The work on pretreatment strategies (WP2) is focused on composting, and is addressing questions on survival of GMO material's, pathogens and optimal practices regarding compost quality. This has given rise to additional projects ('Short-Circuit' funded by EU-Life and 'Functional Compost' funded by DFFE) that allow further development of pretreatment processes.

Studies of C and N dynamics (WP3) are being carried out, both as laboratory, field and modelling interpretation studies. The measuring and monitoring needed for modelling has been more or less completed by now, and the model interpretation activity is being stepped up in the final part of the project, and extended to more general scenario studies of composted and anaerobically digested municipal waste on leaching of nitrogen, denitrification and soil C storage in typical Danish agroecosystems. Due to the initiation of a PhD study (2003-2006), detailed process studies of C and N dynamics will continue.

Agronomic research on P turnover in soil with applied Urban Fertilisers and its subsequent availability in pot trials (WP4) has been carried out according to plans, and reporting to scientific audience is under way.

The soil quality monitoring package (WP5) was terminated by the FØJO board in early 2003. However due to the interest from DAKOFA for raising funds for future support and the need to gain internal support from KVL for continuation of the field

trial after the end of project, a partial soil quality analysis of some urban fertilizer treatments is carried out presently and will be finalized during 2006.

It is noteworthy that the CRUCIAL project and the ensuing portfolio of projects is highly appreciated by KVL. Thus KVL has decided that a Professorship with obligations to deal with recirculation of nutrients and organic matter from urban to rural areas will be announced by the start of 2006

Furthermore a MSc. course on '**Urban Ecology**' has been developed at KVL and run for the first time in 2004. In 2005 the course was integrated in the educational reform programme and is now running under the name **Urban Ecosystems: structures, functions and designs**. Based on the large interest it has generated the first two years (34 and 29 registered students in 2004 and 2005, respectively) there is reason to believe that the course will be able to continue developing in the years to come. Thus, there is reason to believe that this educational activity will become long-term sustainable – and if this proves to be the case it will be a significant contribution to objective 2: *To facilitate the process of sustainable urban development, by providing a platform for public debate*

**Table A.1: Work package list (from application)**

| WP no. | Work package title  | participants     | Revised budget | Start | End  | Deliverable No: |
|--------|---|------------------|----------------|-------|------|-----------------|
| 1      | Establishment and running of Long-term field trials with urban fertilisers  | <u>KVL</u>       | 727            | 2001  | 2006 | 1-7             |
| 2      | Development of composting practises for food waste and human faeces   | <u>KVL</u>       | 2055           | 2001  | 2005 | 8-13            |
| 3      | C and N dynamics of urban fertilisers   | <u>KVL</u> , DMU | 1673           | 2002  | 2006 | 14-18           |
| 4      | Agronomic research on P turnover in soil with applied Urban Fertilisers and its subsequent availability in pot trials | <u>DJF</u>       | 462            | 2003  | 2004 | 19-21           |
| 5      | Soil quality monitoring programme   | <u>DMU</u> , KVL | 323            | 2001  | 2006 | 22-25           |

\* Responsible participants are underlined

## B. Objectives and expected achievements

| WP's | Objectives  |
|------|---|
| 1    | 1 To provide the field-scale facility for assessing the feasibility of improved recycling of nutrients from urban areas to organic farms  |
| 1    | 2 To facilitate the process of sustainable urban development, by providing a platform for public debate   |
| 2    | 3 To gain basic knowledge regarding co-composting of municipal solid waste and human faeces, with special emphasis on the effect of different mixing ratios and addition of green waste as structural material on self heating capacity, and nitrogen loss. |
| 2    | 4 To develop a 'High temperature – Low emission – Low cost' composting system that can be operated at farm level and at the same time comply with the upcoming EU regulation on the use of waste products in agriculture                                    |
| 2    | 4a Examining the potential of the composting process to reduce or eliminate GMO-materials   |
| 2    | 4b Examining claims that the effluent from the composting process has   |

|   |    |  |
|---|----|--|
|   |    | phyto-sanitary and other plant health promoting capabilities.<br>To provide sufficient amounts of composted material for the field trials in a quality that will comply with future EU-standards on agricultural use of urban waste  |
| 2 | 5  |  |
| 3 | 6  | To perform a comprehensive mesocosm study on urban fertiliser impact on nutrient cycling where the temporal and spatial dynamics of plant nutrient cycling is linked to the biological activity of soil organisms<br>To provide experimental data for modeling plant nutrient dynamics of soil receiving urban fertilisers via incubation studies and the mesocosm study mentioned above |
| 3 | 7  | Model interpretation and extrapolation of urban fertilizers laboratory and field trial data  |
| 3 | 8  |  |
| 4 | 9  | To assess the availability of P in urban wastes and characterize the fertilizer value of waste-derived P following introduction to arable soil   |
| 5 | 10 | To deliver an initial characterisation of soil quality in the field experiment<br>To initiate a long-term monitoring of soil biological quality in the field experiment  |
| 5 | 11 |  |

## C. Progress and results

### C.1 Description (summary) of main results and conclusions

#### WP1

##### Objective 1

The field-scale facility for assessing the feasibility of improved recycling of nutrients from urban areas has been re-structured.

Results from year 2002-2004 has been analysed (chemical analysis of plant materials and  $N_{\min}$ ), and are presented in Magid et al. (accepted) and will provide the backdrop for part of the modelling to be done in connection with WP3. Human urine has proved as a very reliable fertilizer – almost as efficient as mineral fertilizer, while sewage sludge and composted household waste seem to provide substantially lower mineral fertilizer equivalents than what was hypothesized at the outset of the project. The acceptability of human urine as a fertilizer has been further investigated in a literature review (Lindedam et al., submitted), by evaluating the oestrogen load on the environment from human urine spread on the field, compared with human urine going through a sewage plant treatment. The environmental impact from oestrogen from human urine is assessed to be considerably lower by applying to the field.

A concern with annual repeated use of urban fertilizers is the accumulation of heavy metals and other xenobiotics in soil. However, a core question in the CRUCIAL project is, whether concentrations of heavy metals at ecotoxicological limits actually impair key biological functions in the soil. In a worst case scenario, the concentration of heavy metals can accumulate to ecotoxicological limits within 11-13 years. In a more average case scenario, ecotoxicological limits may be reached within 38-41 years. Hence in neither of the scenarios the ecotoxicological limits can be reached within the timeframe of the project. To approach the ecotoxicological limits within 3-5 or 7-10 years for a worst case or average case scenario, respectively, plots with accelerated inputs of urban fertilizers are part of the experiment. Soil samples are currently being analysed in the laboratory at KVL for heavy metals, and in January 2006, the same soil samples will be analysed for biological functions (enzyme activity) at the

Institute of Soil Science, University of Hohenheim, Germany.

## Objective 2

There has been public interest in the field experiment, as indicated by reports in national daily newspaper articles, national and international radio and television broadcasts, and requests for input to DAKOFA's (Danish Committee for Waste Management) conference on Agricultural Waste Utilization, in relation to the 3<sup>rd</sup> action plan for the Environment, request for publication in special issue on long-term trials, in International Society of Organic Agriculture Research. Furthermore the CRUCIAL project and related work was presented at the 3<sup>rd</sup> ECOSAN World Conference in Durban, South Africa in May 2005.

### **A National Daily Newspaper (Berlingske):**

Andersen Pauli: Forskere ser en guldgrube i de danske kloakker. Berlingske fredag d. 5 oktober 2001

### **From the Danish Public Service Radio (Program 1)**

The 'Miljømagasinet' 19<sup>th</sup> april 2002, running title 'Urin kan blive fremtidens gødning' ('Urine may become a future fertiliser'), please refer to:

<http://www.dr.dk/p1/miljoemagasinet/arkiv.asp?action=showarticle&id=22147>

The 'Miljømagasinet' 21<sup>th</sup> march 2003

### **Urin fra 100 familier i Roskilde bruges om gødning**

<http://www.dr.dk/p1/miljoemagasinet/arkiv.asp?action=showarticle&id=17282>

### **A National Daily Newspaper (Politikken):**

7. august 2003: Urin fra mennesker er god gødning, forside, samt 1. sektion side 2

9. august 2003: Penge lige ned i kloakken

18. august 2003: Modvilje mod urin på marker, 1. sektion side 7

25 august 2003, Kloakker og veje slidt ned, 1. sektion, side 4

### **From the Danish Public Service Television (DR TV 1)**

Usædvanlig gødning, TV-Avisen, DR1, kl. 18.30 26 August 2003

### **From the Norwegian Public Service Radio (Program 4)**

Tiss på grønnsakene! 'Lektor Jakob Magid ved Landbohøjskolen i Frederiksberg i den danske hovedstaden sier uringjødsling kan ha en stor framtid, både i Danmark og i utviklingslandene. Men den bør skje i ordnede former. Folk skal ikke tisse direkte på salaten, understreker han'

<http://www.p4.no/txo/94227.asp>

**DAKOFA's konference om Vandmiljøhandlingsplan III og affaldsprodukter til jordbruget**, 23. Marts 2004, Markforsøg med slam og organisk affald – hvor stort er problemet? ved. Jakob Magid.

Magid, J., Luxhøi, J., Jensen, L.S., Møller, J. and Bruun, S. **Establishment of a long-term field trial with urban fertilizers – is recycling of nutrients from urban areas to peri-urban organic farms feasible?** Accepted for publication in International Society of Organic Agriculture Research.

Establishment of the course Urban Ecosystems in 2004 and in 2005 under the new statutory curriculum regulation at KVL the course was further adjusted to Urban Ecosystems: Structures, Functions and Designs

J. Magid, A. M. Eilersen, S. Wrisberg, and M. Henze. A technical theoretical framework for ECOSAN applied to the medium sized Danish town Hillerød. Oral presentation at 3<sup>rd</sup> World ECOSAN Conference, 24 May 2005 - Durban, KwaZulu Natal, South Africa

DAKOFA has decided to attempt to raise funding for continued support after 2006 for the running of CRUCIAL's long-term field trials especially those dealing with sewage sludge and composted municipal waste, based on financial support from their own stakeholders and from organizations that collaborate with them. This is due to the recognition of the need for such long-term experiments in relation to the problems that can be addressed regarding impact on soil quality and production system integrity.

## **WP2**

### **Objective 3**

Parallel with full-scale composting, laboratory experiments were continued in the composting lab at KVL. The aim of these experiments was to repeat previous experiments (last year) and study in more details the effect of mixing ratio of the feedstock on the composting process especially losses of N and temperature development profiles.

A pilot experiment investigated the effect of mixing ratio (and subsequent C/N-ratio) on carbon- and nitrogen loss during the composting process. Nitrogen loss was smallest at a C/N-ratio of 36 and was twice as big at a C/N-ratio of 46. Thus the presence of substantial amounts of household waste and faeces in the feedstock lowering the C/N ratio decreased nitrogen loss and demonstrated that these materials are very suitable for composting. Based on that result, an experiment in KVL's composting lab with six different mixing ratios of faeces, household waste and rape straw was set up. In this experiment ammonia in the spent process air was trapped and quantified at the end of the experimental period. Preliminary results demonstrated that total nitrogen loss in the form of ammonia was inverse proportional to the C/N ratio of the composting material. Subsequent data analysis showed a more complex relationship between total carbon- and nitrogen content and nitrogen loss. The relationship between total nitrogen content in the feedstock and the relative nitrogen loss was found to be exponential ( $p < 0.05$ ), i.e. low C/N ratios resulted in high relative nitrogen losses. In general, the nitrogen losses were small, 0.1 to 7% of the total nitrogen content of the feedstock. This should be seen in connection with the relatively limited carbon degradation of 5 to 36% of the initial content of the feedstock. In total, 87 % of the nitrogen loss was in the form of ammonia and the ammonia loss was highest during the thermophilic phase in connection with alkaline conditions.

Another topic of investigation has been to quantify the sanitising effect of composting a feedstock containing humane faeces. This work has been reported in Holmquist et al. (submitted to Journal of Applied Microbiology) The main result was to establish the relationship between temperature regime and survival of different microbial indicator organisms including a Salmonella phage 28B not used before in this context. The 90-values, i.e. the time needed to kill 90 % of the micro-organisms were plotted against the process temperature, and using this graph the treatment time/temperature regime necessary to sanitise the compost can be calculated for any temperature between 50 and 65 C. Parallel to this work - simulating composting of faeces material in full-scale composting plants - composting of faeces material in small-scale systems was also investigated. This has been reported in Tønner-Klank

et al. (submitted). The focus here was on survival of pathogens and indicator organisms in small-scale systems ranging from 3 m<sup>3</sup> and down to approx. 80 l. Several optimization experiments demonstrated that it was possible to increase the performance of the composting systems by adding easily degradable material, improve the aeration rate and isolate the containers with polyurethane mats. This resulted in faster die-off of pathogens and parasite eggs, but total sanitation of the material was not achieved. The conclusion was that small-scale composting of material containing humane faeces is not recommendable from a health point of view. In contrast, large-scale composting as described in Holmquist et al. and composting using the HI-Lo systems are hygienically safer and have the potential to sanitize the compost. In this case, the compost can be applied to agricultural soils without restrictions.

#### **Objective 4**

The on-farm HI-LO composting system (High temperature, low emission, low cost) is continuing trials to demonstrate if it meets specifications. The current experiments clearly support that emissions and odour from the systems are very low. However it is difficult to ensure that the temperature reaches 70 °C in the rim of the container, and it may be necessary to install an external heat source in order to do so. On the other hand it seems that the EU is in the process of relaxing the requirements that were originally set for 'category 3' urban wastes in which case it will be possible to develop an improved on farm composting facility without the added cost of external heating.

The focus of the experiments so far has been to monitor the HI-Lo systems performance regarding the ability to reach high temperature, the degree of nitrogen retention and carbon mineralization rate.

A new method to ensure representative sampling of the compost material during a composting run has been tested with good results. In connection with a composting run in the summer of 2004 the feedstock of the HI-LO composting system was supplemented with 15 "litterbags" made of plastic potato sacks. The litterbags contained approx. 1 kg of feedstock in the same proportions as in the container as a whole. During the composting run litterbags in triplicate were sampled and subsequently subjected to analysis of dry matter content, total nitrogen and total carbon content. In this way, the inherited heterogeneity of the feedstock could be overcome and reliable data on nitrogen retention and degradation of organic matter generated. This new technique awaits final assessment, but preliminary results are promising and it should in this way be possible to monitor the composting process with higher time resolution than normally in connection with full-scale experiments due to the much less cumbersome sampling technique associated with retrieving the litterbags in contrast to taking representative samples from the entire feedstock.

Based on the results from the composting runs so far a mass balance regarding carbon, nitrogen and water has been calculated. From this the nitrogen retention capacity of the system and the carbon mineralization can be estimated. It is also possible to estimate the energy balance from data of mean temperature of the feedstock, the amount of water condensed in the heat exchanger and the amount of carbon mineralized. Data from four composting experiments with different feedstock and mixing ratios was used in an internal report describing the energy balance of the Hi-Lo system with special emphasis on the temperature effects of using different feedstock.

The main conclusion was that the energy released by the compost, approx. 4 kw, was too low to generate the high temperatures necessary to sanitise the entire compost material. This could not be ascribed to limiting oxygen conditions, but was more likely caused by low quality of the source separated household waste. This in turn had the result that heat loss through the walls of the composting container exceeded the heat generated by the composting process and the temperature in the compost matrix began decreasing approx. five days after initiation of the experiments without the temperature reaching 70C in the entire compost material.

The heat exchanger has proved efficient to condense water from the hot process air, but it has also shown decreased efficiency in hot weather due to decreasing temperature gradients. This is especially a problem when the composting container is exposed to sunlight and it will be necessary to physically place the HI-LO system in the shade to get the maximum performance out of the system in future applications.

#### **Objective 4a**

Studies of degradation of transgenic DNA and screening for horizontal gene transfer from GMO-plant material during composting have been completed. These have proven to be more challenging and intriguing than we had ever imagined, and a number of hard won lessons have been learned (Rasmussen et al., 2005; Rasmussen et al., in prep).

*In the following some of lessons are summarized:*

Initial results indicated very fast decomposition of non-transgenic DNA, compared to transgenic DNA. We later realized that the basis for comparison might be faulty, since the primer for non-GMO material targeted a 1000 base-pair strand; whereas the primer for the GMO DNA targeted a 325 base-pair strand, which should theoretically be able to survive longer during decomposition. We designed a new primer (325 bp) for the non-GMO plant DNA and found quite similar decomposition rates.

In a 100 day decomposition experiment we found clear indications of horizontal gene transfer (HTG) of the GMO material to *Bacillus*. In order to be sure that this was not based on some mistake or strange artefact, we decided to do a completely independent (in time) replication of the experiment, and again found clear signs of HTG. In order to confirm the finding we decided that it was necessary to pure culture these *Bacillus* strains, and subsequently isolate and sequence the DNA strand that reacted with the PCR primer. Much to our surprise we found that the DNA from *Bacillus* reacting with the primer was in fact not from the GMO plant material, but sufficiently alike to induce a reaction.

Compared to decomposition of GMO DNA in soil, composting greatly increased breakdown of GMO DNA. No GMO DNA could be detected in compost after 10 days of reaction whereas it could easily be detected in soil after 77 days.

#### **Conclusion**

If the persistence of transgenic DNA in the environment is considered as the only risk factor, composting is a 'DNA-safe' method to treat GM plant residues.

However, even though transgenic plant DNA was not detected in bacterial isolates in our experiments, we cannot conclude that horizontal gene transfer did not take place.

The 300 isolates tested proved to be too low a number to be conclusive. The numbers of isolates tested were based on the screenings indicating high transfer, but the screenings were biased apparently because some *Bacillus* species gave PCR products matching the transgenic DNA. Thus, it is still an open question if composting constitutes a safe way of disposing of GM plant residues. Furthermore, these experiments give rise to other interesting questions, e.g., the behaviour of GM plant materials decomposing in waste piles or manure yards under composting-like conditions and the possibility of horizontal gene transfer to indigenous bacteria at the comparably lower temperatures present at these environments. Finally, it must be noted that the plant material we used (*Arabidopsis*) consisted of very fresh green material with decomposition characteristics that are far from those which would be typical of mature straw or other residues from field grown plants. We would expect slower decomposition in such materials, and thus longer time exposure to HTG even in a best case composting scenario. This is just another reason to seek a continuation (beyond the scope of the current project) with further adjustments of methodology and more types of GMO plant materials to be tested.

These questions need to be assessed if the risk associated with the use of GM plants is to be thoroughly investigated.

#### **Objective 4b**

We have performed a pilot experiment using compost tea extracts on spinach, and attempted to discern eventual effects into nutrient effects, hormonal effects and microbial effects. The results indicated that the yield effect was related to transfer of protein bound nutrients (N and S), but must be considered preliminary.

In the literature, one of the theories for plant health promoting capabilities of compost, is increased chitinase activity, possibly due to specific microorganisms. We have performed an experiment where we have linked microbial genetic- and functional diversity in compost: DGGE-profiling separated different types of compost regarding chitinase activity (Poulsen et al., in prep).

We are currently actively pursuing the idea of reviewing the state of the art on compost teas from Asian and US organic farmers, that have increased the use of this technology. A partnership is being developed for this purpose with Steve Scheuerell, Evergreen College, Olympia, Washington,

#### **Objective 5**

We have chosen to supply the field-trial with composted municipal waste from SOLUM's AIKAN facility, rather than relying on the our own meso-scale composting facility. Partly this is due to the real difficulties in obtaining human faeces or faecal sludge in sufficient quantities to supply the field experiment with a reasonably balanced mixture of household wastes and faecal waste. However in the longer term it will be possible to keep up supplying the field trial from these outside sources which is a clear benefit for its long-term nature, and a reason for systematic use from early on.

## WP3

**Objective 6**

Two mesocosm experiments have been performed using degassed household waste as well as composted household waste as representative urban fertilizers. Results on mesofaunal growth from the first experiment are currently being written up as part of Thomas Larsen's PhD study, in a working paper (Larsen et al., in prep), and shows substantial differences in the way degassed and composted municipal waste affects the dynamics of mesofaunal growth. Results on C and N transformation from the second experiment are currently being subjected to computer modelling (Luxhøi et al., in prep). The results show substantial N immobilization after application of urban fertilizers to soil, followed by a re-mineralization. Based on the relatively low C/N ratio of the fertilizers the initial N immobilization is unexpected. In fact C and N transformation from the urban fertilizers behave very different compared to C and N transformation from plant residues. Since our computer model is optimized to predict C and N transformation from plant residues, we are currently working on the parameterization of the computer model to predict C and N transformation from urban fertilizers.

The PhD study has continued this line of work, along with some very fundamental methodological studies on the validity of various types of isotope techniques (natural abundance and pool dilution of enriched food sources in food web studies). To obtain dual-labelled organic material, we have used green manure instead of urban fertilizer, which has been written up in Larsen et al (submitted).

**Objective 7**

The Daisy model has been tentatively parameterized for urban fertilisers based on the mesocosm study, other laboratory incubation studies and a study of available literature on compost decomposition experiments. Based on this and on previous efforts in model interpretation and scenario-analysis with Daisy we were requested and given some additional funding to assist a research team from the Danish Technical University by simulating the long-term effect of adding MSW compost to soil in a number of different agricultural settings.

As it is described in Objective 8, uncertainties regarding the mineralization pattern of some of the organic fertilizer has complicated the Daisy simulation and interpretation of the results. There seems to be substantial differences in the mineralization patterns of primary organic materials, e.g. plant residues, and more humified organic materials, e.g. compost and sewage sludge. The fact that Daisy has been developed with regard to plant residues and animal manure, has turned out to be a constraint to the simulation. We therefore have two tasks to fulfil:

**Firstly**, a sensitivity analysis must be made in order to clarify if it is at all possible to simulate the field experimental results based on the laboratory studies conducted on the urban fertilizers so far. Based on that we will try to publish the model interpretation of the field experiments, and assess needs for further model development and longer duration laboratory studies. This can be done before the end of project.

**Secondly**, due to the disparity between primary organic sources and the urban fertilisers that have so far become apparent, we must initiate longer duration laboratory

experiment, in order obtain data sets for mineralization of Carbon and Nitrogen from selected urban fertilizers over a period of 5-600 days. Such experiments can be initiated, but not completed before the end of project. This additional experiment will be completed using internal funding. However, due to this unforeseen development we request an additional period of 2 months before completion of the final report (no additional cost), so the project will be finalized by June 2006.

#### **Objective 8**

A scenario analysis has been carried out employing the agro ecosystem model Dasiy to simulate leaching of nitrogen, denitrification and carbon storage caused by application of composted or anaerobically digested (biogasification) municipal solid waste, to various Danish farm types and soils under different climates. This scenario analysis is valuable in a larger environmental perspective when the consequences of land application of urban fertilizers are compared with alternative waste management strategies. The work has been carried out in collaboration with the research group developing the waste management model EASEWASTE at Dept. of Environment and Resources, DTU. The simulations have served the waste management model EASYWASTE. At the moment the scenarios are also to be incorporated in the further development of the Swedish ORWARE model in the associated EU-LIFE project 'Short-Circuit'.

*This application of the CRUCIAL project is an important and unexpected benefit that will impact models that are currently used in Scandinavian policy making.*

An internal report has been produced describing the scenario analysis. The paper describing the scenario analysis has recently been accepted for publication in the journal Environmental Modelling and Assessment. Furthermore, an associated paper made in collaboration with DTU describing how the results of the scenario analysis has been incorporated in the waste management model EASEWASTE developed at DTU has been submitted to Waste Management and Research. These documents have been uploaded in their current condition to the orgprint database.

The scenario results are surprisingly complex and the main findings is that the emission coefficients are very sensitive to the animal density of the farm rotation in which the waste is applied (due to redistribution of existing animal manure within the farm), but also sensitive to soil type and type of waste (composted vs. digested waste). Based on these first results we have refined the scenarios to include more graduated animal densities and this will be included in the final report. The strength of the simulations is that they show the combined effect of the input of C and N with the municipal waste product on crop productivity, N utilization and soil C sequestration, including also interactions between all the plant and soil processes. Therefore the simulation results give a more detailed and refined picture of the environmental consequences of municipal waste product application to arable land, than what has been seen before in decision support systems.

The modelling of the field trials with the Daisy model was initiated in the beginning of 2005. Preliminary results of simulations has been produced, however, uncertainties regarding the mineralization pattern of some of the organic fertilizer has complicated the interpretation of the results. A very early draft manuscript describing the simulations has been produced.

**WP4****Objective 9**

Analyses of soils from field experiment in (WP1) were not carried out, due to changes in timing and priorities in (WP1 and) WP4, that were accounted for in connection with the mid-term review.

All experimental work was finalised in 2004. Data has been analysed and presently an international scientific paper is being prepared.

**Results**

Analyses of data have revealed the following, which will be discussed further in the paper being prepared presently:

1. Treatments with equal amounts of P in different types of organic amendments affected the P concentrations in the plant tissue in the first cut of rye grass, the cumulated dry matter yield and crop P off-take.
2. Responses in dry matter yield and crop P off-take to the organic amendment treatments differed distinctly from the soil P test responses: In the crop, the sludge-Fe amendment resulted in increased crop P off-take and dry matter yield, while the soil P tests generally showed little or no response.
3. Manure treatments had significant effects on manganese concentrations in plant tissue
4. The soil P tests (Olsen P, Resin, Pw, E1min) responded differently to the equal amounts of P added with different organic amendments.
5. The resin P method was the most responsive soil P test method and Olsen P the least

A paper will be submitted to the journal "Waste Management" ultimo 2005 (Working title: Responses in crop and soil P tests to waste-derived phosphorus" and selected results is expected to be included in the presentation " Fosforbalance i praksis – effekter på miljø og jordbrug" at the Plantekongres in Herning 2006.

**WP5****Objective 10**

For soil quality characterization of the field, soil samples in three depth has been collected, for analysis of heavy metals. The analysis of heavy metals is being carried out in the laboratory at KVL during autumn 2005

For monitoring of soil biological quality in the field experiment, a contact to Professor Ellen Kandeler, University of Hohenheim, Institute of Soil Science (one of the leading soil biologist worldwide) has been established. During a two week study visit in January 2006 to University of Hohenheim, Jesper Luxhøi will bring soil samples from the field for determination of enzymatic activity. Thereafter, assays for determination of enzymatic activity will be established at KVL for to ensure long-term monitoring of soil biological quality of the field experiment..

## C.2 Fulfilment of deliverables and milestones

| WP1 Establishment and running of Long-term field trials with urban fertilisers                             | Time schedule            | Deviations, if any*  |
|--|--------------------------|----------------------|
| <b>Deliverables</b>  |                          |                      |
| Annual reports 2001-2005   | 2001 – 2005              | Final report in 2006 |
| Materials and protocol for guided tour (public relations)  | May 2002                 |                      |
| Report on crop yields and quality, and soil N <sub>min</sub> status over 2002 – 2004 (input needed in WP3) | Dec 2004                 |                      |
| <b>Milestones</b>  |                          |                      |
| Establishment of permanent grass strips  | Oct. 2001                | March 2002           |
| Spreading of fertiliser with high N availability (to be repeated yearly)                                   | Apr. 2002 – 2006         |                      |
| Sowing of crops (to be repeated yearly)  | Apr. 2002 – 2006         |                      |
| Characterization of crop growth (to be repeated yearly)  | May - August 2002 – 2005 |                      |
| Public presentation of the field experiment (to be repeated yearly, and on request)                        | Jun. 2002 – 2005         |                      |
| Spreading of fertilisers with low N availability (to be repeated yearly)                                   | Nov. 2002 – 2005         |                      |

| WP2 Development of composting practises for food waste and human faeces   | Time schedule according to application | Deviations, if any*     |
|---|--|-------------------------|
| Deliverables  |  |                         |
| Composted MSW and faeces for use in the field experiment each year from autumn/winter 2002  | Oct 2002 & onwards                     | Mar 2003 & onwards      |
| Report on best practice for full-scale co-composting of municipal solid waste and human faeces based on laboratory scale experiments and trials with meso-scale experiments on KVL's experimental station | Dec 2003                               |                         |
| Presentation at conference  | 2004                                   | April 2003 and Sep 2004 |
| Scientific manuscript on composting trials  | Jul 2004                               | Dec 2004                |
| Report on phyto-sanitary effects of compost effluent  | Jul 2005                               | December 2005           |
| Scientific manuscript on GMO materials in compost   | Jul 2005                               |                         |
| Establishment of a composting facility at KVL's experimental station  | Apr. 2002                              | Sep 2002                |
| Milestones  |  |                         |
| First meso-scale composting trial completed (to be repeated each year)  | Oct. 2002                              | Dec 2002                |
| Laboratory studies on composting completed  | July 2004                              | Sep. 2004               |
| Laboratory studies on GMO material in compost completed   | Dec. 2004                              | Sep. 2004               |
| Trials with compost effluent completed  | Dec. 2004                              |                         |

| WP3 C and N dynamics of urban fertilisers   | Time schedule according to application | Deviations, if any* |
|---|--|---------------------|
| Deliverables  |  |                     |
| Contributions to status and final project reports   | Oct 2002 & onwards                     |                     |
| Synthesis report comprising the mesocosm system elements  | Dec 2003                               |                     |
| Popular presentation  | 2004                                   |                     |
| Four scientific papers  |  |                     |
| Milestones  |  |                     |
| Comprehensive mesocosm study completed  | Dec. 2003                              |                     |
| Further incubation studies on quality and temperature effects on temporal patterns of nutrient fluxes completed   | July 2004                              |                     |
| Model interpretation of relevant parts of the aforementioned milestones   | Dec. 2004                              | Dec 2005            |
| Simulation completed of the field trials based on parameterisation of urban fertilisers, climate data and relevant crop modules and concomitant testing of the predictive capability based on data from the field (WP1) | July 2004                              |                     |

| WP4 C and N dynamics of urban fertilisers              | Time schedule according to application | Deviations, if any*                         |
|--|--|---|
| <b>Deliverables</b>                                    |  |   |
| Contributions to status and final project reports      | Oct 2003 & onwards                     |   |
| Popular presentation                                   | 2004                                   |   |
| Presentation at conference                             | 2004                                   | Plantekon-gres, 2006                        |
| International scientific paper                         | 2005                                   |   |
| <b>Milestones</b>                                      |  |   |
| Characterization of waste completed                    | 2004                                   |   |
| Pot experiment completed                               | 2004                                   |   |
| Analyses of soil from field experiment (WP1) completed | 2004                                   | Resources relocated to other WP4-activities |
| Final report submitted                                 | Dec. 2005                              | May 2006 (contribution to final report)     |

| WP5 Soil quality monitoring programme  | Time schedule according to application | Deviations, if any*                                   |
|--|--|---|
| <b>Deliverables</b>  |  |   |
| Contributions to status and final project reports  | Oct 2002 & onwards                     |   |
| Report on soil characteristics, and motivated recommendation for the lay-out of the field trials | Dec 2002                               | Oct 2002  |
| Report on urban fertiliser impact on soil quality  | 2004                                   | Can not be delivered                                  |
| <b>Milestones</b>  |  |   |
| Establishment of soil archive  | Sep. 2001                              |   |
| Layout of plots  | Oct. 2001                              | March 2002 revised Dec. 2002                          |
| Sampling of plots for faunal and other biological characterisation (soil quality baseline study) | Oct. 2002                              |   |
| Completed baseline study   | Mar. 2003                              | Can not be delivered                                  |
| Sampling of plots for faunal and other biological characterisation                               | Aug. 2004                              | Can not be delivered                                  |
| Completed soil quality impact study after 3 years of treatment/fertilisation                     | Oct. 2005                              | Can not be delivered – <i>but possibly approached</i> |

\* *Deviations are to be further discussed in D*

#### D. Description of deviations and subsequent adjustments of plans

There are few deviations worthy of mention in relation to the earlier reports on the project.

In the 2004 status report it was agreed that the end of project should be prolonged into 2006.

Compared to previous reports the project is largely on schedule.

#### WP3

As it is described in Objective 8, uncertainties regarding the mineralization pattern of some of the organic fertilizer has complicated the Daisy simulation and interpretation of the results. There seems to be substantial differences in the mineralization patterns of primary organic materials, e.g. plant residues, and more humified organic materials, e.g. compost and sewage sludge. The fact that Daisy has been developed with regard to plant residues and animal manure, has turned out to be a constraint to the simulation. We therefore have two tasks to fulfil:

Firstly, a sensitivity analysis must be made in order to clarify if it is at all possible to simulate the experimental results obtained from the laboratory studies conducted on the urban fertilizers so far. Based on that we will try to publish the modelled results and develop an assessment of needs for further model development and longer duration laboratory studies. This can be done before the end of project.

Secondly, due to the deficiencies that have so far become apparent, we must initiate longer duration laboratory experiment, in order obtain data sets for mineralization of Carbon and Nitrogen from selected urban fertilizers over a period of 5-600 days. Such experiments can be initiated, but not completed before the end of project. This additional experiment will be completed using internal funding. However, due to this unforeseen development we request an additional period of 2 months before completion of the final report (no additional cost), so the project will be finalized by June 2006.

Some delay has occurred with regard to the publication of the first meso-cosm study. This is in part due to occurrences such as parental leave. In the status report from previous years 4 publications have been set as output's from this work package, although the timing for some reason has not been specified exactly. Currently it seems likely that the work package will be delivering at least 9 peer reviewed publications, probably more, by the time Thomas Larsens PhD study is finally completed (2006-2007)

Status for publication in WP3 is currently

Larsen, T., Magid, J., Krogh, P.H., Gorissen A. (Submitted). Very low uptake of organic N from dual-labelled ( $^{13}\text{C}$  and  $^{15}\text{N}$ ) green manure by wheat. Submitted to Soil Biology & Biochemistry.

Larsen, T., Magid, J., Krogh, P.H., Gorissen A. (In prep). Wheat and soil fauna assimilation of C and N derived from organic fertilizers. To be submitted in November.

Larsen, T., Magid, J., Krogh, P.H. (In prep). Collembolan N turnover and temporal equilibrium of C and N. Experimental work in progress.

Larsen, T., Magid, J., Jahn, T. (In prep). Investigation on isotope effects in yeast. Experimental work in progress.

Larsen, T, Krogh. P.H., Luxhøi J., Jensen L.S. and Magid J. (working paper, 1<sup>st</sup> draft under revision) *Integrating foodweb dynamics with nutrient and energy flows in soil: exploratory trials with composted and degassed municipal sorted waste, To be submitted to Biology and Fertility of Soils – All data has been collected, and the writing of the manuscript is in progress*

Luxhøi J., Jensen L.S. and Magid J. (working paper) Decomposition of degassed and composted household waste. To be submitted to J. Compost Science *All data has been collected, model interpretation of incubation trials and the writing of the manuscript is in progress*

Bruun, S., Hansen, T.L., Christensen, T.H., Magid, J., Jensen, L.S. (Accepted) Application of Processed Organic Municipal Solid Waste on Agricultural Land – A Scenario Analysis. Accepted for publication in Environmental Modeling and Assessment.

Bruun, S., Jensen, L.S., Luxhøi and Magid J.(working paper) Urban Fertilizer Efficiency – model interpretations of 4 years field trials with Human Urine, Composted Municipal Waste, Sewage Sludge and reference organic fertilisers. *All data from harvested yield (dry matter, C and N content) as well as soil N<sub>min</sub> has been collected and analyzed. The Daisy model is being set up to run the crop rotation, and based on the parameterization of fertilisers during the first years and the models ability to predict yields during the last years an interpretation of fertilizer potential from the various sources of nutrients will be made.*

As for WP5 the execution of this package was terminated by the decision of the FØJO board in early 2003, and thus it cannot be completed. However 'a completed soil quality impact study after 3 years of treatment/fertilisation: Can not be delivered – *but possibly approached*'. Based on the recognition from outside stakeholders from DAKOFA (Danish Committee for Waste Management) and their decision to attempt to find economic means for partial support for continuation of the trial after the end of the CRUCIAL project, it is desirable that at least some analysis of changes in soil quality in the plots are done within the framework of CRUCIAL. Hard data would also increase the likelihood of Departmental support for continuation, as well as support from other KVL Departments. Therefore the project has tentatively allocated 51.000 kr. for analysis during 2005 of soil samples from selected field plots, and hopefully this sum can be gainfully used in connection with student projects that are currently in the pipeline.

## Project publications and other products

### 1. Products from Organic Eprints archive

Magid, Assoc. Prof. Jakob (2002) [Hard and soft science issues to be negotiated to improve urban metabolism](#). Paper presented at Urban areas – Rural areas and recycling – the organic way forward?, Royal Veterinary and Agricultural University, 20–21 August 2001; To be published in Magid, Jakob; Granstedt, Arthur; Dýrmundson, Ólafur; Kahilouto, Helena and Ruissen, Theo, Eds. *DARCOF report nr. 3*. DARCOF.

Magid, Assoc. Prof. Jakob (2002) [Byernes affaldshåndtering og næringsstofkredsløb](#) [Urban waste management and nutrient cycles], in Jensen, E.S.; Vejre, H.; Højbjerg Bügel, S. and Emanuelsson, J., Eds. *Visioner for Fremtidens Jordbrug*, chapter 10, page pp. 181-202. Gads forlag.

Møller, J.; Backlund, A.; Jørgensen, L.T.; Forslund, A. and Dalsgaard, A. (2003) [OVERLEVELSE AF INDIKATORORGANISMER OG SMITSTOFFER I KOMPOSTTOILETTER OG VED SIMULERET CENTRALISERET EFTERKOMPOSTERING AF AFFØRING FRA MENNESKER](#) [SURVIVAL OF INDICATOR ORGANISMS AND PATHOGENS IN COMPOST TOILETS AND DURING SIMULATED CENTRALISED COMPOSTING OF FAECES FROM HUMANS]. Økologisk byfornyelse og spildevandsrensning, Dept. of Agricultural Sciences, KVL.\*\*

Holmqvist, A.; Møller, J. and dalsgaard, A. (2003) [LATRINE COMPOSTING – A HYGIENIC EVALUATION](#). Poster presented at Ecosan - 2end >nternational Symposium on Ecological Sanitation, Lübeck, germany, April 7-11 2003.\*\*

Møller, J.; Forslund, A. and Dalsgaard, A. (2003) [REDUCTION OF FAECAL MICROBIOLOGICAL INDICATORS IN DIFFERENT COMPOST TOILETS](#). Poster presented at Ecosan - 2end International Conference on Ecological Sanitation, Lübeck, germany, April 7-11 2003.\*\*

Reeh, U. and Møller, J. (2002) [EVALUATION OF DIFFERENT BIOLOGICAL WASTE TREATMENT STRATEGIES](#), in Magid, J.; Lieblein, G.; Granstedt, A.; Kahiluoto, H. and Dyrmondsson, O., Eds. *Urban Areas - Rural Areas and Recycling - The organic way forward?*. DARCOF Report no. 3.\*\*

Magid, Jakob; Eilersen, Ann Marie; Wrisberg, Simon and Henze, Mogens (2004) [Possibilities and barriers for recirculation of nutrients and organic matter from urban to rural areas: a technical theoretical framework applied to the medium sized town Hillerød](#). Working Paper, Plant and Soil Laboratory, Department of Agricultural Sciences, The Royal Veterinary and Agricultural University, Thorvaldsensvej 40, 1871 Frederiksberg C, Denmark.\*

Quitau, Maj-Britt; Moeller, Jacob and Magid, Jakob (2004) [Attitudes towards utilization of composted domestic waste, sludge, urine and faeces as manure in agriculture](#). Report, National Environmental Research Institute of Denmark, Dept. of Policy Analysis.

Magid, Jakob; Rasmussen, Lasse Dam and Moeller, Jacob (2004) [Measuring degradation of transgenic DNA and screening for horizontal gene transfer from GMO-plant material during composting](#). Poster presented at 1st international Conference on SOIL AND COMPOST ECOBIOLOGY, Leon – Spain, September 15th-17th, 2004.

Holmkvist, A; Møller, J and Dalsgaard, A (2005) [Thermophilic composting – a hygienization method of source-separated faecal toilet waste](#). [preprint]\*

Bruun, S.; Hansen, T.L.; Christensen, T.H.; Magid, J. and Jensen, L.S. (2005) [Application of Processed Organic Municipal Solid Waste on Agricultural Land – A Scenario Analysis](#) [Bruun, S., Hansen, T.L., Christensen, T.H., Magid, J., Jensen, L.S]. [preprint]\*

Lindedam, J.; Jensen, K.S.; Luxhøi, J. and Magid, J. (2005) [Østrogener fra human urin i miljøet](#) [Oestrogens from human urine in the environment]. *Jord og Vand*.\*

Magid, J.; Luxhøi, J.; Jensen, L.S.; Møller, J. and Bruun, S. (2005) [Establishment of a long-term field trial with urban fertilizers – is recycling of nutrients from urban areas to peri-urban organic farms feasible?](#). *Long-term field experiments of organic farming*.

Rasmussen, L.D.; Møller, J. and Magid, J. (2005) [Survival of DNA from a transgenic plant during composting](#). Working Paper.

Poulsen, P.H.B; Møller, J. and Magid, J. (2005) [Linking microbial genetic- and functional diversity in compost: DGGE-profiling separated different types of compost regarding chitinase activity](#). Working Paper.\*\*

Møller, J.; Bruun, S. and Magid, J. (2005) [Three new systems for recycling of urban organic waste to agriculture](#). *DARCOFenews(1)*. Online at <<http://www.darcof.dk/enews/mar05/recycle.html>>\*

Rasmussen, L.D.; Møller, J. and Magid, J. (2004) [Composting rapidly degrades DNA from genetically modified plants](#). *DARCOFenews(2)*. Online at <<http://www.darcof.dk/enews/june04/gmo.html>>

Larsen, T.; Magid, J.; Krogh, P.H. and Gorissen, A. (2005) [Very low uptake of organic N from dual-labelled \(13C and 15N\) green manure by wheat](#). Submitted to *Soil Biology and Biochemistry*.

Larsen, T.; Magid, J.; Luxhøi, J.; Jensen, L.S. and Krogh, P.H. (2005) [Integrating foodweb dynamics with nutrient and energy flows in soil amended municipal sorted waste](#). Working Paper.

Tønner-Klank, L.; Møller, J.; Forslund, A. and Dalsgaard, A. (2005) [MICROBIOLOGICAL ASSESSMENTS OF COMPOST TOILETS: IN-SITU MEASUREMENTS AND LABORATORY STUDIES OF THE SURVIVAL OF FECAL MICROBIAL INDICATORS USING SENTINEL CHAMBERS](#). *Waste Management and Research*.\*

Luxhøi, J.; Bruun, S.; Jensen, L.S. and Magid, J. (2005) [Modeling C and N mineralization during decomposition of degassed and composted household waste](#)

## 2. Other products (oral presentations, public meetings, field days, etc.)

A national workshop on 'Composting Plant Residues and Human Waste in support of High Value Organic Plant Production' was organised by the CRUCIAL project on 28th February 2002 at KVL.

Wrisberg Simon, Eilersen Ann Marie: Nye håndteringsystemer til recirkulering af spildevand og organisk affald fra byer. Foreningen Dansk Byøkologi juni 2001. nr.2 årgang 4.

Association of Organic Farmers theme lectures 7<sup>th</sup> November 2001  
Nutrients in circulation – how can urban fertilisers contribute, Jakob Magid, KVL

Magid J. (2003) Closing the Rural Urban Nutrient Cycle – Services from Peri-Urban Agriculture in Containing and Managing Risk from Urban Metabolism. Invited speaker at Bertebos conference 'Ecosystem services in European agriculture: Theory and practice', 14-16 September, 2003, Falkenberg,

## Sweden

Presentations for 2 high-school groups on separate occasions in September 2001, Jakob Magid, KVL

Presentations for 3 high-school groups on separate occasions in february- april 2002, Jakob Magid, KVL

Presentations for 4 high-school groups on separate occasions in november- December 2002, Jakob Magid, KVL

Presentations for 3 high-school groups on separate occasions in february – april 2003, Jakob Magid, KVL

DAKOFA's konference om Vandmiljøhandlingsplan III og affaldsprodukter til jordbruget, 23. Marts 2004, Markforsøg med slam og organisk affald – hvor stort er problemet? ved. Jakob Magid

J. Magid, A. M. Eilersen, S. Wrisberg, and M. Henze. A technical theoretical framework for ECOSAN applied to the medium sized Danish town Hillerød. 3<sup>rd</sup> World ECOSAN Conference, 24 May 2005 - Durban, KwaZulu Natal, South Africa

## F. Scientific education

1. A European Science Foundation LinkEcol grant supported visting scientist, Dr Michaël Coeurdassier. He has conducted a study to evaluate the quantitative effects of decreasing the diversity, using pesticides as a tool, on the foodweb structure of the soil communities (particularly microarthropods, earthworms and bacteria) and the possible consequences of community structure modifications on soil functions, i.e. decomposition of cow dung and N cycling.
2. Thomas Larsen has been employed by October 1<sup>st</sup> 2003, to undertake a 3 year PhD program entitled 'Soil Ecological Modelling of Urban Fertilizer Turnover'. This is funded jointly by KVL-DMU and SOAR
3. A MSc. Course on the '**Urban Ecology**' has been developed at KVL, and is currently (2004) running for the first time. Based on the large interest it has generated this first year of implementation (34 registered students) there is reason to believe that the course will be able to continue developing in the years to come

## G. National and international cooperation

Institute of Plant Science, Group Plant Nutrition, Swiss Federal Institute of Technology, Zurich (Prof. Emmanuel Frossard). All isotopic exchange kinetic experiments and ICP-MS analyses have been carried out at the Group of Plant Nutrition (Prof. Emmanuel Frossard) during June 14 to August 19, 2004 by senior scientist Gitte Rubæk and senior technician Karin Dyrberg. This cooperation has allowed an expansion of the analytic work in WP4 and will result in a jointly authored scientific publication.

The CRUCIAL project is part of a portfolio hosted by:

NUTRAP  
CENTRE FOR APPROPRIATE TECHNOLOGIES FOR NUTRIENT RECYCLING FROM HUMAN  
WASTE TO AGRICULTURE IN PERI-URBAN AREAS

A number of research departments have signed the MOU and take part in its activities. For further information on NUTRAP please refer to: [www.agsci.kvl.dk/nutrap](http://www.agsci.kvl.dk/nutrap)

Via the EU-Life funded activity, of which CRUCIAL is an integral part, a collaboration has been developed with:

- The Department for Industrial Ecology, Royal Technical University (KTH), Stockholm, Sweden
- Aarstiderne A/S
- Krogerup Avlsgaard A/S
- Dansk Jordforbedring, SOLUM Gruppen A/S

Furthermore international collaboration has emerged in two areas:

The project leader of CRUCIAL has delivered input to an integrated waste management plan for Kuching ( Sarawak state, Malaysian Borneo). The Sarawak government has recently decided that ecological sanitation will be the main pillar of the waste management, and that conventional sanitation will be used only in the central business district. Upon successful implementation of pilot scale projects for some housing and institutional areas, the state has decided to enlarge an ecological sanitation scheme to 250.000 people in the first instance. Jakob Magid has been asked to provide further input into this process, by Kuching's Sustainable Urban Development Project.

The Environmental Engineering Group, Swedish University of Agricultural Sciences, Professor Håkan Jönsson and co-workers

## H. Critical reflection on the project

The project is unfolding in a highly satisfactory and in many respects unexpectedly fruitful manner.

CRUCIAL is the core project in a portfolio that seeks to reinvent urban waste management to allow for improved recycling of nutrients and organic matter from urban areas to organic farms. Based on the CRUCIAL activity it has been possible to further initiate a number of projects that add to these activities:

- i. The EU life funded project Short-Circuit (2003-2005),
- ii. A pilot project involving ecological sanitation in the capital of Sarawak, Bornean Malaysia (2004-2005), and
- iii. A DFFE project seeking to investigate possibilities for producing 'Functional compost' with assured disease suppressive and plant nutritional qualities. This last project is an interdisciplinary collaboration with plant pathologists and the commercial compost producer 'Dansk Jordforbedring' – SOLUM A/S (2004-2008)

Furthermore the CRUCIAL project has allowed participation in the public debate and investment of time in organizational development for example within KVL and DAKOFA (Danish committee for waste management). This has resulted in three potentially important decisions:

- iv. KVL has decided to offer a Professorship with special obligations to deal with recirculation of nutrients and organic matter from urban to rural areas. This will be announced in the international press by early 2006
- v. DAKOFA has decided to attempt to seek continued partial support for the running of CRUCIAL's long-term field trials (especially with those dealing with MSW compost and sewage sludge), based on financial support from their own members and from organizations that collaborate with them. Although this support will probably be rather limited it may facilitate the continued support from KVL's internal sources and therefore contribute significantly to the continued operation of the long-term trial.
- vi. An M.Sc. Course on the '**Urban Ecology**' has been developed at KVL. Based on the large interest it has generated this first year of implementation (34 registered students) there is reason to believe that the course will be able to continue developing in the years to come

While the above mentioned points are manifest outside the project proper, but emanating from the projects activities some more fundamental scientific gains have been made within the projects own framework.

#### **GMO survival during composting**

In connection with the project revision we offered to study the breakdown of transgenic plant material during composting and we have done so successfully although it has become abundantly clear that this area presents a challenge both with regard to methodology and with regard to assuring the integrity of organic farming systems, that we cannot possibly meet within the CRUCIAL project. Discussions with other research teams (national and international) have shown that this is an area that is considered sufficiently important to gain priority in the coming years.

We are sure that our results will stand up to the most careful scrutiny from outside. However with the current state of our knowledge we cannot say with certainty that we have proven that GMO material will not be transferred to bacteria that are naturally competent in taking up naked DNA, and multiply during the composting process. Although the likelihood for this to happen appears to be low, there is a great uncertainty due to lack of knowledge. Similarly we are very aware that there is a complete lack of knowledge about HTG (horizontal transfer of genes) when it comes to digestion of feed containing GMO material. Therefore we have developed an expression of interest to FØJOIII, in which we recommend that these questions be considered for further studies.

#### **PhD program on 'Soil Ecological Modelling of Urban Fertilizer Turnover'**

The Ph.D. study on energy flows through food webs in soil has also given rise to fundamental methodological studies and development, the key question being whether or not we can rely on isotopically enriched materials in studies of fluxes (as claimed by agronomically oriented researchers) or only on natural abundance studies (as claimed by traditional soil ecological researchers).

Thus in two separate areas the project will contribute to fundamental knowledge creation, which was not foreseen in the original project proposal.

Finally the model simulations that have been carried out so far have served the waste management model EASYWASTE. At the moment the scenarios are also to be incorporated in the further development of the Swedish ORWARE model in the associated EU-LIFE project 'Short-Circuit'.

*This application of the CRUCIAL project is an important and unexpected benefit that will impact models that are currently used in Scandinavian policy making.*

All in all the project management is confident that the project will deliver the outputs that were originally intended, and in all likelihood ensure a continuation of key activities beyond the scope of FØJ0II.

## 8. Budget

A. Account for any change in budgets

B. Budget for the whole project (1.000 DKK)

Total consumption of funds from DARCOF and expected consumption this year and coming years

| Year                 | Consumption before 2003 | 2003 | 2004 | 2005 | 2006 | Total |
|----------------------|-------------------------|------|------|------|------|-------|
| <b>Man-months</b>    |                         |      |      |      |      |       |
| Scientific personnel | 21,8                    | 17,9 | 24,6 | 15,3 | 1,5  | 81    |
| Technical personnel  | 0,8                     | 2,4  | 5,0  | 1,6  | 1,2  | 11    |

| Year                              | Consumption before 2003 | 2003 | 2004 | 2005 | 2006 | Total |
|-----------------------------------|-------------------------|------|------|------|------|-------|
| <b>Salaries</b>                   |                         |      |      |      |      |       |
| Salary (coordination)             | 30                      | 20   | 50   | 70   | 40   | 210   |
| Scientific personnel              | 804                     | 612  | 804  | 511  | 0    | 2730  |
| Technical personnel               | 20                      | 61   | 73   | 40   | 30   | 224   |
| <b>Other operational costs</b>    |                         |      |      |      |      |       |
| Transport af 'By-gødninger'       | 149                     | 224  | 170  | 81   | 40   | 664   |
| Special field operations          | 31                      | 2    | 8    | 15   | 35   | 91    |
| Composting facility and equipment | 45                      | 0    | 15   | 35   | 20   | 115   |
|                                   | 125                     | 46   |      |      |      | 171   |

|  |             |             |             |            |            |             |
|--|-------------|-------------|-------------|------------|------------|-------------|
| Characterisation of the experimental field | 110         |             |             | 51         |            | 161         |
| Direct costs                               | 1314        | 964         | 1120        | 803        | 165        | 4366        |
| Indirect costs (20% of direct costs)       | 263         | 193         | 224         | 161        | 33         | 873         |
| <b>Total</b>                               | <b>1576</b> | <b>1157</b> | <b>1344</b> | <b>964</b> | <b>198</b> | <b>5239</b> |

## 9. Signatures and stamps

| Name        | Institute                  | Date            | Signature |
|-------------|----------------------------|-----------------|-----------|
| Jakob Magid | Agricultural Sciences, KVL | 1. oktober 2005 |           |

## Appendix I. Detailed budget

### A. Budget for each participating institute (1.000 DKr)

| <b>Institution 1 (KVL)</b> | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | Total |
|----------------------------|------|------|------|------|------|------|-------|
| Salary (coordination)      | 0,5  | 0,3  | 0,5  | 1,0  | 1,0  | 1,5  | 4,9   |
| Scientific personnel       | 2,3  | 9,8  | 6,3  | 16,8 | 9,2  | 0,0  | 44,3  |
| Technical personnel        | 0,0  | 0,8  | 0,0  | 2,4  | 1,6  | 1,2  | 6,1   |

| <b>Institution 1 (KVL)</b>                 | 2001       | 2002       | 2003       | 2004       | 2005       | 2006       | Total       |
|--|------------|------------|------------|------------|------------|------------|-------------|
| Salaries                                   |            |            |            |            |            |            |             |
| Salary (coordination)                      | 20         | 10         | 20         | 50         | 70         | 40         | 210         |
| Scientific personnel                       | 80         | 337        | 216        | 565        | 326        |            | 1524        |
| Technical personnel                        | 0          | 20         | 0          | 9          | 40         | 30         | 99          |
| Other operational costs                    | 22         | 70         | 171        | 111        | 70         | 40         | 484         |
| Transport af 'By-gødninger'                |            | 31         | 2          | 8          | 15         | 35         | 91          |
| Special field operations                   |            | 45         | 0          | 15         | 35         | 20         | 115         |
| Composting facility and equipment          |            | 125        | 46         |            |            |            | 171         |
| Characterisation of the experimental field |            | 110        | 0          |            | 51         |            | 161         |
| Direct costs                               | 122        | 748        | 454        | 758        | 607        | 165        | 2854        |
| Indirect costs (20% of direct costs)       | 24         | 150        | 91         | 152        | 121        | 33         | 571         |
| <b>Total</b>                               | <b>146</b> | <b>898</b> | <b>545</b> | <b>910</b> | <b>728</b> | <b>198</b> | <b>3425</b> |

| <b>Institution 2 (DMU)</b> | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | Total |
|----------------------------|------|------|------|------|------|------|-------|
| Scientific personnel       | 0,0  | 5,7  | 6,0  | 2,5  | 5,1  |      | 19    |
| Technical personnel        | 0,0  | 0,0  | 0,0  | 0,0  |      |      | 0     |
| <b>Institution 2 (DMU)</b> | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | Total |
| Scientific personnel       |      | 201  | 216  | 89   | 185  |      | 691   |
| Technical personnel        |      |      |      |      |      |      | 0     |

|                                      |            |            |            |            |            |
|--------------------------------------|------------|------------|------------|------------|------------|
| Other operational costs              | 27         | 19         | 19         | 11         | 76         |
| Direct costs                         | 228        | 235        | 108        | 196        | 767        |
| Indirect costs (20% of direct costs) | 46         | 47         | 22         | 39         | 153        |
| <b>Total</b>                         | <b>274</b> | <b>282</b> | <b>130</b> | <b>235</b> | <b>920</b> |

| <b>Institution 3 DJF Foulum</b> | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | Total |
|---------------------------------|------|------|------|------|------|------|-------|
| Scientific personnel            |      |      | 1,7  | 4,3  |      |      | 6,0   |
| Technical personnel             |      |      | 2,4  | 2,6  |      |      | 5,0   |

| <b>Institution 3 DJF Foulum</b>      | 2001 | 2002 | 2003       | 2004       | 2005 | 2006 | Total      |
|--------------------------------------|------|------|------------|------------|------|------|------------|
| Scientific personnel                 |      |      | 60         | 150        |      |      | 210        |
| Technical personnel                  |      |      | 61         | 64         |      |      | 125        |
| Other operational costs              |      |      | 10         | 40         |      |      | 50         |
| Direct costs                         |      |      | 131        | 254        |      |      | 385        |
| Indirect costs (20% of direct costs) |      |      | 26         | 51         |      |      | 77         |
| <b>Total</b>                         |      |      | <b>157</b> | <b>305</b> |      |      | <b>462</b> |

| <b>Institution 4 FSL</b> | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | Total |
|--------------------------|------|------|------|------|------|------|-------|
| Scientific personnel     |      | 3    | 3    |      |      |      | 6     |
| Technical personnel      |      |      |      |      |      |      |       |

| <b>Institution 4 FSL</b>             | 2001       | 2002       | 2003       | 2004 | 2005 | 2006 | Total      |
|--------------------------------------|------------|------------|------------|------|------|------|------------|
| Scientific personnel                 | 75,7       | 110        | 120        |      |      |      | 306        |
| Other operational costs              | 15         | 15         | 24         |      |      |      | 54         |
| Direct costs                         | 91         | 125        | 144        |      |      |      | 360        |
| Indirect costs (20% of direct costs) | 18         | 25         | 29         |      |      |      | 72         |
| <b>Total</b>                         | <b>109</b> | <b>150</b> | <b>173</b> |      |      |      | <b>432</b> |

**Comments:**

C. Budget for co-financing from each participating institute (1.000 DKK)

Name of Institute: KVL – Department of Agricultural Sciences KVL-DAS)

| Year                 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | Total |
|----------------------|------|------|------|------|------|------|-------|
| Scientific personnel | 0.5  | 0.5  | 0.5  | 0.5  | 0.5  | 0.25 | 2.5   |
| Technical personnel  | 1.0  | 1.0  | 1.0  | 1.0  | 1.0  | 0.5  | 5.0   |

| Year   | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | Total |
|--|------|------|------|------|------|------|-------|
| Scientific personnel                         | 18   | 18   | 18   | 18   | 19   | 10   | 101   |
| Technical personnel (basic field operations) | 22   | 23   | 23   | 24   | 24   | 12   | 128   |
| Alternative costs using 11.5 hectares        | 92   | 96   | 100  | 103  | 108  | 111  | 610   |
| Use of machinery                             | 25   | 26   | 27   | 28   | 29   | 15   | 150   |
| Direct costs                                 | 157  | 163  | 168  | 173  | 180  | 148  | 989   |
| Indirect costs                               | 31   | 33   | 34   | 35   | 36   | 30   | 198   |
| Total financing from KVL-DAS                 | 188  | 196  | 202  | 208  | 216  | 178  | 1187  |

**Comments:**