

## **Progress Report 2004 and Application for Continuation in 2005**

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

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### 1. Research program

Research in organic farming 2000-2005 (DARCOF II)

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### 2. Project title and number

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

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### 3. Head of project

Jakob Magid, Department of Agricultural Sciences - KVL

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### 4. Participating institutes

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

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### 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

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### 6. Project period (month, year)

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

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### 7. Midterm description of the project, its results and progress, and application for continuation in 2005

## 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) is being carried out according to plans.

Soil quality monitoring (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, it is recommended that soil quality analysis of some urban fertilizer treatments is considered for 2005.

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 special obligations to deal with recirculation of nutrients and organic matter from urban to rural areas will be announced by the end of 2004

Furthermore a MSc. Course on '**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

**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>FSL</u> , <u>KVL</u>	2055	2001	2005	8-13
3	C and N dynamics of urban fertilisers	<u>KVL</u> , <u>DMU</u>	1673	2002	2005	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> , <u>KVL</u>	323	2001	2005	22-25

**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.
2	5	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
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
3	7	To provide experimental data for modeling plant nutrient dynamics of soil receiving urban fertilisers via incubation studies and the mesocosm study mentioned above
3	8	Model interpretation and extrapolation of urban fertilizers laboratory and field trial data
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
5	11	To initiate a long-term monitoring of soil biological quality in the field experiment

## C. Midterm results and progress

### 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 the 4 growth seasons are being analyzed (chemical analysis of plant materials, and analysis of the  $N_{\min}$  from soil from this autumn) and will provide the backdrop for part of the modelling to be done in connection with WP3.

##### 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'd action plan for the Environment.

#### **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 uringjødning 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

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.

A stakeholder workshop 'Attitudes towards utilization of composted domestic waste, sludge, urine and faeces as manure in agriculture' was arranged in connection with the supportive activities in the EU-Life project (January 2004)

## **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.

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.

### **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.

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. We are sure that our results will stand up to the scrutiny of a very critical audience, and are currently preparing a manuscript for *Nature Biotechnology*.

*In the following some of the hard won 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.

### **Objective 5**

We have chosen to supply the field-trial with composted municipal waste from SOLUM's AIKAN facility, rather than relying on 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**

Mesocosm experiments have been performed using degassed household waste as well as composted household waste as representative urban fertilizers. This trial is currently being written up as part of Thomas Larsen's PhD study, in a working paper with the title *'Integrating foodweb dynamics with nutrient and energy flows in soil: exploratory trials with composted and degassed municipal sorted waste'*. The PhD study is continuing 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).

**Objective 7**

The Daisy model has been 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.

**Objective 8**

A scenario analyses 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. 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. These simulations will be used to estimate coefficients to be used for the description of these processes in the EASYWASTE model, but also to be incorporated in the further development of the ORWARE model in the associated EU-LIFE project 'Short-Circuit'. The first draft of an internal report has been produced in August 2004 (uploaded to the orgprint database), and the final report will be completed within 2004.

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 included in the model. Therefore the simulation results give a more detailed and refined picture of the environmental consequences of municipal waste product application to arable land.

The modelling of the field trials is expected to begin during early 2005.

## WP4

### Objective 8

All experimental work has been finalised, except Olsen P analyses on soils. Sampling strategy in the pot experiment was modified as the planned sampling in 2004 was reduced to one sampling. Instead subsoils were sampled after termination of the experiment, and analysed for Olsen P, as we suspect that the subsoil might have influenced the P uptake of the crops.

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.

## WP5

The soil quality characterization of the field has been performed and delivered

Monitoring of soil biological quality in the field experiment has been initiated

## C.2 Fulfilment of deliverables and milestones

WP1 Establishment and running of Long-term field trials with urban fertilisers	Time schedule	Deviations, if any*
Deliverables		
Annual reports 2001-2005	2001 – 2005	
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	
Milestones		
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	
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		See section D
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	
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 P turnover in soil applied with Urban fertilisers and its subsequent availability in pot trials	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	2005, awaiting suitable conference
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	

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.

Compared to previous reports the project is mostly on schedule, if not ahead of schedule.

This goes for the work packages WP1 to 4, in which the only major deviation not mentioned in previous reports is the decision to base the MSW treatments in the field experiment on outside sources (Solum's newly established plant AIKAN), that can reliably deliver the product in the longer term. The decision was partly based on the long-term reliability and needs for delivery, and partly on the difficulties we faced in obtaining sufficient quantities of human fecal sludge for a reasonably balanced production of MSW-fecal compost in our meso-scale composting facility (the HI-LO system).

Upon request a note on the publication activities within WP3 is presented.

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, and in part due to a change in the project where Thomas Larsen was employed as a PhD student rather than as a research assistant, and required to develop other methodology and take courses rather than just doing the originally planned work. 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. Following the logic of the package description it is however clear that all 4 could not be expected by 2004. Currently it seems likely that the work package will be delivering at least 6 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, 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*

Larsen, T, Krogh. P.H., and Magid J. (working paper) *Isotopic fractionation of <sup>15</sup>N . <sup>13</sup>C and <sup>14</sup>C and temporal equilibrium in Collembola. Data is currently being produced and analyzed.*

Larsen, T, Krogh. P.H., and Magid J. (working paper) *The influence of Collembola on nutrient release and plant uptake of organic nitrogen from easily degradable organic material. Data is currently being produced and analyzed.*

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 completed and the writing of the manuscript is to begin early in 2005*

Bruun, S., Jensen, L.S. and Magid J.(working paper) [Simulations of the effects of application of composted and anaerobically digested municipal waste on leaching of nitrogen, denitrification and soil C storage with the agroecosystem model Dasiy](#). *Based on the report that has been published in E-prints an extended scenario analysis will be carried out during 2005, to include more intermediate farming systems than the extreme variants in the current scenario study – this should give a basis for a more balanced 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**

#### **English**

Holmqvist, Annika and Dalsgaard, Anders and Møller, Jacob (2004) [Thermophilic composting - a hygienisation method of source-separated faecal toilet waste](#). [preprint]

#### **Peer-reviewed and accepted**

#### **English**

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 and Granstedt, Arthur and Dýrmundson, Ólafur and Kahilouto, Helena and Ruissen, Theo, Eds. *DARCOF report nr. 3. DARCOF.*\*

Reeh, Ulrik and Møller, Jacob (2001) [Evaluation of different biological waste treatment strategies](#). Paper presented at NJF SEMINAR NO. 327: URBAN AREAS - RURAL AND RECYCLING – THE ORGANIC WAY FORWARD?, Royal Veterinary and Agricultural University, Copenhagen, Denmark, 20–21 August 2001.\*

### Dansk - Danish

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

### Not peer-reviewed

#### English

Holmqvist, A. and Møller, J. and Dalsgaard, A. (2003) [LATRINE COMPOSTING – A HYGIENIC EVALUATION](#). Poster presented at ECOSAN 2end International Symposium on Ecological Sanitation, Lübeck, Germany, 7-11 April, 2003.\*\*

Magid, Dr. Jakob and Rasmussen, Dr. Lasse Dam and Moeller, Dr. 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 (submitted to orprints), September 15th-17th, 2004.

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

Bruun, Dr. Sander and Jensen, Dr. Lars Stoumann (2004) [Simulations of the effects of application of composted and anaerobically digested municipal waste on leaching of nitrogen, denitrification and soil C storage with the agroecosystem model Dasiy](#). Report, Department of Agricultural Sciences, Royal Veterinary and Agricultural University.

Magid, Jakob and Eilersen, Ann Marie and 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.\*

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Møller, J. and Backlund, A. and Jørgensen, L.T. and Forslund, A. and Dalsgaard, A. (2002) [OVERLEVELSE AF INDIKATORORGANISMER OG SMITSTOFFER I KOMPOSTTOILETTER OG VED SIMULERET CENTRALISERET EFTERKOMPOSTERING AF AFFØRING FRA MENNESKER](#). Økologisk byfornyelse og spildevandsrensning, Dept. of Agricultural Sciences, The Royal Veterinary and Agricultural University.\*\*

Quitau, Maj-Britt and 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.

### 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 håndteringssystemer 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

## 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

### **Critical reflection on the project**

The project is currently 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 the end of 2004 or early 2005
- 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. A MSc. 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.

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 FØJOII.

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## 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
Man-months						
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
Salaries						
Salary (coordination)	30	20	50	50	40	190
Scientific personnel	804	612	819	501	0	2735
Technical personnel	20	61	124	40	30	275
Other operational costs						
Transport af 'By-gødninger'	31	2	15	15	35	98
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	1314	964	1152	773	165	4368
Indirect costs (20% of direct costs)	263	193	230	155	33	874
<b>Total</b>	<b>1576</b>	<b>1157</b>	<b>1382</b>	<b>928</b>	<b>198</b>	<b>5241</b>

## 9. Signatures and stamps

Name	Institute	Date	Signature
Jakob Magid	Agricultural Sciences, KVL	30 <sup>th</sup> September 2004	

## Appendix I. Detailed budget

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

#### Appendix I. Detailed Budget

#### A. Budget for each participating institute

<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	50	40	190
Scientific personnel	80	337	216	580	316		1529
Technical personnel	0	20	0	60	40	30	150
Other operational costs	22	70	171	70	70	40	443
Transport af 'By-gødninger'		31	2	15	15	35	98
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	790	577	165	2856
Indirect costs (20% of direct costs)	24,4	149,6	91	158	115,4	33	571
<b>Total</b>	<b>146</b>	<b>898</b>	<b>545</b>	<b>948</b>	<b>692</b>	<b>198</b>	<b>3427</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>	<b>2001</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>	<b>2005</b>	<b>2006</b>	<b>Total</b>
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>

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

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
<b>Total financing from KVL-DAS</b>	<b>188</b>	<b>196</b>	<b>202</b>	<b>208</b>	<b>216</b>	<b>178</b>	<b>1187</b>

**Comments:**