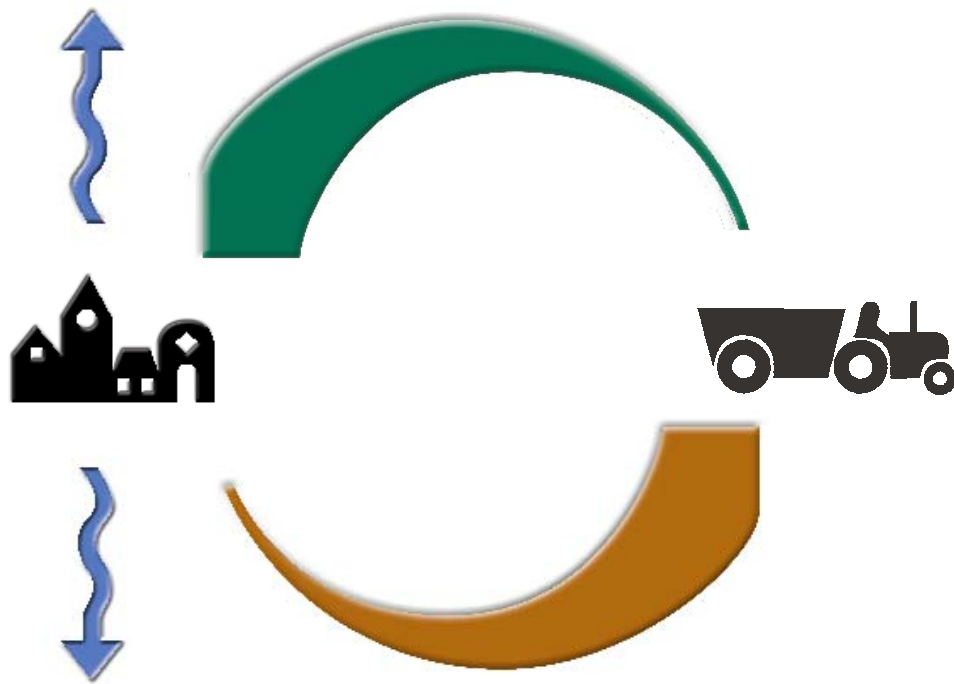


CRUCIAL



CLOSING THE RRURAL-URBAN NUTRIENT CYCLE

INVESTIGATION OF URBAN FERTILISER PRE-TREATMENTS,
AGRONOMIC RESEARCH ON URBAN FERTILISER TURNOVER IN SOIL
AND IMPACT ON CROP GROWTH, AND INITIATION OF A MONITORING
PROGRAMME ON SOIL QUALITY CHANGES WROUGHT BY USING URBAN
FERTILISERS IN LONG-TERM FIELD TRIALS

List of Abbreviations

DJF	Danish Institute of Agricultural Sciences
DMU	National Environmental Research Institute
DTU	Danish Technical University
FSL	Danish Forest and Landscape Research Institute
FØJO	Danish Research Centre on Organic Farming
KVL	Royal Veterinary and Agricultural University

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Summary

In society as a whole there is a wish to support a sustainable development. In recent years the public has been concerned with agriculture, and the population has been particularly supportive of organic farming in their consumer behaviour. To this date there has been rather less concern with the sustainable functioning of the urban areas, and only a few persons have started to talk about 'organic cities'. However it is generally recognised that the urban areas are practically dissociated from the rural areas when looking at returning nutrients. Recently organic farmers refused to accept sewage sludge, and conventional farmers followed suite for a time, which led to severe problems in the urban areas.

This proposal forms part of a coherent effort to re-invent urban waste management with the view to close the rural urban nutrient cycle. It will ensure 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. With its emphasis on urban fertiliser pre-treatment, turnover in soil and impact on crop growth, it will 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. Additionally it will provide support to planned research on human and animal health aspects, in connection with agricultural waste utilisation. Finally the work presented in this proposal will provide at concrete platform for the public debate, and possibilities for the public to visit the field trials.

Research Group

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Introduction

In the industrialised world, waste management systems have developed to maturity without primary concern for recycling. These systems have originally been designed to ensure a high local hygienic standard. More recently environmental concerns have been the driving force behind a technological development of sewage treatment with biological removal of N, P and organic matter. This technology addresses some immediate problems in the aquatic environment, but the sewage sludge from the treatment plants contain considerable quantities of xenobiotic compounds and heavy metals, and only a fraction of the nutrients that entered the urban areas, thus making the sludge a non-attractive fertiliser source. In recent years there has been concern about the sustainability of this state of affairs as regards wastewater handling, as well as concern about the fate of the final waste deposits in the environment. More specifically Danish organic farmers made a point of refusing to accept sewage sludge as a source of nutrients. This sparked a heated debate, and for a time all farmer organisations refused to accept sewage sludge on their fields, leading to severe problems in urban areas. One of the consequences of this conflict is that municipalities are increasingly seeking alternatives to

returning sewage sludge to the land (e.g. burning or dumping), in order to rid their dependence of farmers acceptance.

Another consequence has been that the issue of 'closing the urban-rural nutrient circle' as part of a sustainable development has received increasing attention among Danish organic farmers. This issue had been identified already in the early days of the organic movement in Denmark, but never been a top priority. It was accentuated by a strong Swedish accentuation of agricultural use of human urine from source separating toilets that provided inspiration to look at implementing such techniques in Danish urban areas. One additional factor that has increased the priorities of the issue was the growing realisation that current day organic farmers have a strong bias towards milk production, due to the natural integration of the clover-grass in the production system, that is essential for ensuring an ample supply of fixed atmospheric nitrogen. If more stockless organic farms (e.g. vegetable and grain production for human consumption) are to become economically sustainable, it is important to find ways of using the land with less emphasis on clover grass. One of the ways of doing this is to increase the amounts of nutrients that can be re-cycled from urban areas in a form that is acceptable for organic farming.

Thus in the autumn 1997 the Organic Food Council granted 0.5 mio. DK kr. for a project entitled 'Preparation of long-term fertilisation experiments with urban and industrial waste' (translated). In September 1998 the project delivered a report containing reviews (in Danish) on 'urban fertiliser' potentials and on the state of the art on agricultural use of urban waste products in North- and Central Europe (Magid et al., 1998). The Organic Food Council had asked to be given a project proposal detailing activities that were necessary for ensuring an improved re-circulation of nutrients from urban areas to organic farms.

Meanwhile, a number of other related activities have gained support from other bodies. Thus as part of the implementation of the Danish Parliaments Action Plan for Ecological Urban Development and Sanitation KVL has been given the responsibility to lead a detailed 'Appraisal of the possibilities and barriers for increased recycling of nutrients from urban to rural areas'. This activity promotes the collaboration between agricultural sciences, veterinary microbiology, engineering sciences and social sciences (ca. 4½ man years over 2 years, 1999-2000). It entails a responsibility for co-ordination and monitoring of a number of smaller urban ecology demonstration projects, mainly dealing with sanitation, apart from making an overall technical, biological and economical analysis of the consequences of changing the urban waste management. Furthermore the Danish Technical University, DTU, has been given charge of a project entitled 'Assessment of sustainable waste management in sewer-less housing' (1999-2000, 4 - 5 man years). These activities are mutually supportive, and there is a considerable overlap in the persons that are involved in the projects. Finally the governing bodies of KVL have decided that the area of improving the re-circulation of nutrients from urban areas to farmland is to be given priority as a strategic research topic in the coming years. In line with this decision they decided to allocate funds for a PhD study, dealing specifically with health issues related to the agricultural use of 'urban fertilisers'.

Independently of this, the Department for Agricultural Sciences has committed itself to this area of research by reserving 11 hectares of newly acquired farm land for working with 'urban fertilisers' and further promised that it will pay the basic costs of such experiments (normal tillage and harvesting of plots) for a period of 10-12 years, provided that external funding for more costly specific management operations could be obtained together with funding for related research in a starting phase (4-5 years). Thus the importance of working with this area has received general recognition at KVL, and among other research bodies and ministries, and based on the foreseeable difficulties in working with only one ministry it has been decided to work towards creating a more comprehensive and holistic research program on the issue as will be detailed below.

Central to the strategy for working towards closing the urban-rural nutrient cycle has been the formation of **NUTRAP** - CENTRE FOR APPROPRIATE TECHNOLOGIES FOR NUTRIENT RECYCLING FROM HUMAN WASTE TO AGRICULTURE IN PERI-URBAN AREAS.

At present the following institutions that have signed a memorandum of understanding (Annex 1) to this end:

The Departments for Agricultural Sciences and Veterinary Microbiology, KVL
The Department for Environmental Science and Engineering, DTU and
The National Environmental Research Institute (DMU)

Based on prolonged deliberations and discussions 6 interdependent and inter-linked priority areas for research have been identified and presented in the statement of interest to the FØJO (Danish Research Centre on Organic Farming) board. They have been ordered based on their perceived relevance for FØJO in the table below:

Sub-theme	Area of activity
A	Basic agronomic field trials with related research in soil quality and agronomic aspects of utilising fertilisers from cities of the 'present and the future'
B	Survival and propagation of virulent pathogens related to the 'on-farm' use of urban fertilisers
C	General socio-economic analysis and assessment of changing urban waste management
D	An expanded analysis of epidemiological and environmental risks by the propagation and possible accumulation of toxic compounds (xenobiotica and heavy metals) and diseases
E	Developing technical solutions for changing urban waste management (including social and health issues)
F	Collaboration with private companies with the view to develop mature products and technical solution for national and export use

The aforementioned projects financed by the Ministry of the Environment ('Appraisal of the possibilities and barriers for increased recycling of nutrients from urban to rural areas' and 'Assessment of sustainable waste management in sewer-less housing') touch upon the sub-themes B, C and E. However these projects are rather short term in light of the overall task that must be faced. We believe that it will require a sustained effort for the coming 8-12 years if major changes in society's waste management are to be attained.

FØJO's board and the 'Farmers User Group' has indicated its willingness to support a substantial activity under sub-theme A, registering their confidence in our ability to promote work in the other sub-themes as well. In the discussions leading to this commitment was a strong recognition of the priority area A and it was furthermore recognised that KVL is willing to provide a PhD study in Veterinary Microbiology to support sub-theme B.

Additionally there was a discussion on the relevance of including activities concerned with pre-treatment of urban fertilisers. Some voiced the opinion that this would rightly fall outside FØJO's priorities (Farmers User Group opinion), while others argued that it was appropriate while at the same time allowing entry of relevant institutions. Thus based on the institutional setting of the applicants it was agreed that an attempt should be made to include two activities related to the pre-treatment of urban waste (sub-theme E), namely bio-gas production and composting.

State of the Art

This section is to a large extent based on the review that the Organic Food Council requested (Magid et al., 1998).

Identification of Urban fertiliser potentials

Recycling from the food and other bio-processing industry waste has been estimated to be approximately 99% in Denmark (Danish EPA, 1998) since waste from this sector is either used for fodder or fertiliser directly or after bio-gas production. Based on this assessment it was decided that there was little need to include industrial wastes in long-term fertiliser trials with the view of improving re-circulation.

However the waste management in urban households, service sector and other industries poses a separate challenge. State of the art systems are based on collection of solid waste (often separated in an organic and non-organic fraction) and treatment of waste-water. The sewage systems receives black water (physiological fraction), grey-water (washing and cleaning), and storm water runoff. The composition of waste sources from households in Scandinavia (Table 1) clearly indicates that the urine and faeces fraction contains by far most of the nutrients in the household waste. Thus night soil together with the solid organic household waste theoretically constitutes ca. 1 % of total household waste volume, but contains 82-87% of the nutrients. By removing this nutrient rich household waste the need for nutrient removal from sewage would be minimal or non-existent (see Figure 1).

Table 1. The composition of waste sources from households in Scandinavia (grams per person per day) and their relative contribution to weight and nutrient content. Modified from Magid et al. (1999).

	Total	Physiological Faeces	Urine	Kitchen Liquid	Solid	Bathroom Grey water
Dry matter	235	35	60	40	80	20
Chemical Oxygen Demand	220	60	15	45	90	10
Biological Oxygen Demand	90	20	5	30	30	5
Nitrogen	15,7	1	11	1	1,7	1
Phosphorus	2,8	0,5	1,5	0,2	0,3	0,3
Potassium	4,7	1	2,5	0,4	0,4	0,4
Contribution to waste weight (%)		0,1	0,8	7	0,3	91,7
Contribution to N in waste (%)		6	70	6	11	6
Contribution to P in waste (%)		18	54	7	11	11
Contribution to K in waste (%)		21	53	9	9	9

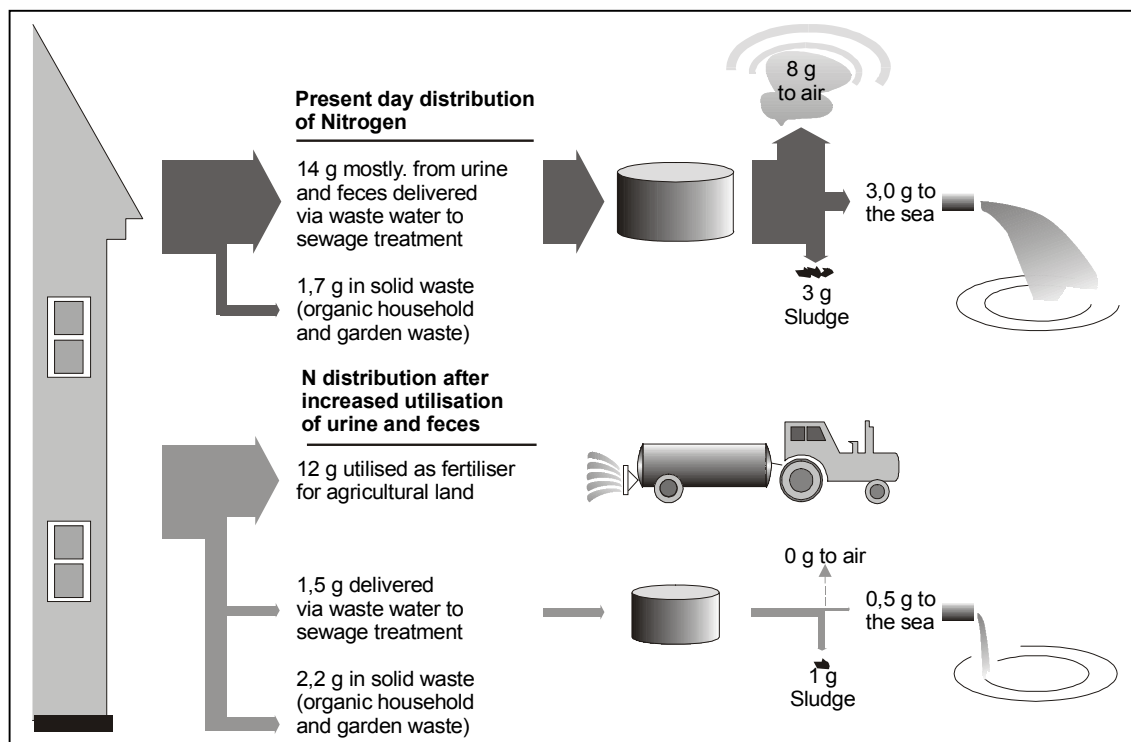


Figure 1. Conceptual diagram of Nitrogen distribution from households (pr. person pr. day) in present day and future sanitation systems (delivered by Eilersen and Henze, IMT, Danish Technical University)

In practise systems need to be developed in order to manage this nutrient rich household waste from urban areas, but a realistic estimate based on minimal flushing systems indicates the volume of this nutrient rich waste to be no more than 2-3 m³ person⁻¹ yr⁻¹, as the volume of urine (450 l), faeces (60 l) and organic household waste (150 l) in itself will be less than 0.7 m³ person⁻¹ yr⁻¹. In Scandinavia such systems have been

developed and tested for rural areas without sewage systems, and currently trials with such systems are being made in urban areas.

Nutrient recycling is not the only consideration with respect to waste handling. It is important to look at the total waste generation as well as the total waste handling system, and attempt to reach an overall optimal system. Recycling nutrients in it self probably does not balance the costs of implementing changes in waste management, if handling of other waste streams gives growing problems.

Table 2. Average concentrations of nutrients and heavy metals (mg/kg dry matter) for sewage sludge, compost, human excreta and pig and cattle slurry. From Magid et al. (1998).

Component	Sewage sludge	Compost	Human excretion	Pig slurry	Cattle slurry
Nitrogen	45.000	9.000	130.000	127.000	55.000
Phosphorus	32.000	2.000	20.000	28.000	11.000
Potassium	3.000	3.500	35.000	72.000	50.000
Cadmium	1,5	0,3	0,2	0,5	0,6
Mercury	1,4	0,1	0,7	< 0,1	< 0,1
Lead	57	30	0.3	3	4
Nickel	25	10	1.7	14	8
Chromium	40	10	0.4	10	3
Zinc	775	150	120	1.500	150
Copper	300	50	15	630	65

The urban fertilisers that can be derived from the nutrient rich household waste fraction compares favourably to sewage sludge and pig slurry with regard to content of heavy metals (Table 2). By the way, the reason for the high content of copper and zinc in pig excreta are related to their use as food additives. It helps control diarrhoea when the small piglets are weaned, and the use of these metals are continued throughout the feeding. Although no ill effects are suspected on the pigs and their consumers, it has been shown that even moderate increases in Zn and Cu in the soil can have adverse effects on key biological processes, as will be discussed below.

The maximum amount that can be recycled from the urban areas would cover no more than 10% of the current day nutrient input to agriculture (Magid et al., 1998). While this figure may seem small it should be seen in the context that Danish agriculture is based on imports of feed and fertilisers, that are necessary to ensure the present production of meat and milk products for exports, and therefore the off-take of our urban population appears small. It can be discussed if this general state of affairs in Danish agriculture is long-term sustainable. It is however undeniable that recovering 10% of the current day agricultural nutrient flow could sustain a considerable food production for local consumption.

Table 3. Overview of the findings on present day and future urban fertilisers (based on Magid et al. 1998)

	Product	Comment
Cities of today	sewage sludge	Rich in P, but poor in most other nutrients, notably N, K, S and some of the micro-nutrients. Considered a dubious fertiliser because it is very unbalanced, and contains unknown quantities of xenobiotics. Problems with heavy metals may occur in the longer term. Hygienic risks have been considered in the currently implemented law on agricultural use of waste products.
	composted household waste	There have been problems with too high content of heavy metals (mostly solved). Little hygienic risk beyond the initial pre-composting handling. If the compost is dominated by garden waste it may work better as a soil conditioner, than as a fertiliser. Hygienic risks have been considered in the currently implemented law on agricultural use of waste products.
	ashes from bio-fuel heat and electricity plants	Rich in K and S and some micro-nutrients. In the combustion plant a sorting of the ashes takes place. Some of these should be avoided, since they contain high amounts of heavy metals
Cities in the future	sewage sludge	See above. Will be present in the cities for many years to come, due to the high investment in the present day infrastructure. May become less problematic, if xenobiotics will become increasingly phased out of the matter streams
	human urine	Well balanced nutrient source. With appropriate storage it does not impose hygienic risk to handlers, nor to consumers of fertilised product, according to Swedish health authorities. Hygienic risks have <u>not</u> been considered in the currently implemented law on agricultural use of waste products. Therefore it <u>cannot be used presently</u> in agriculture
	composted faeces/household waste mixture	See above. Introducing human faeces may increase risks during handling, whereas risk afterwards are unknown
	degassed faeces/household waste mixture	Has not been successfully implemented in Denmark either with or without human faeces. Health risk are not well known, but considered acceptable based on general knowledge. Current installations are mainly fed with animal manure, fat containing industrial wastes and/or sewage sludge
	ashes from bio-fuel heat and electricity plants	See above

Choice of fertilisers, fertilisation strategy and crop rotation(s)

The urban fertilisers that are mentioned in Table 3 are all considered relevant. Based on ongoing work we believe that the combination of organic household waste and human faeces constitutes a particularly important material for urban fertiliser, because it would provide the cities of the future with a solution to the disposal problems that would occur, if urine is taken as a separate fraction. Therefore we consider it justifiable to work with this type of material even though it is not immediately available.

Until FØJO had indicated its interest in supporting the work outlined in this proposal, one of the unresolved issues was how to get hold of sufficient amounts of either degassed or composted organic urban waste (including human faeces) to use in the field experiment. Due to the uncertainty connected with urban sewage sludge, there is a real need to obtain urban fertilisers that are not mixed with this product. The problem pertained particularly to the degassed products, since we have no functioning bio-gas plant running on urban waste products in the country besides those that are based on sewage sludge. There is a real need to develop experience with the running of such systems (without sewage sludge or animal manure), since the one plant that was built with this purpose (nearby Helsingør) had to be closed down due to functional and environmental problems. On the other hand the largest functioning composting facility is now closing down the composting activity and delivering the source separated municipal waste to be de-gassed together with sewage sludge. This is due to a general government policy aiming at increasing the amounts of urban waste

to be used in bio-gas production. Thus, for the next few years it will be difficult to obtain pure fertilisers from the 'cities of today'.

Apart from the above mentioned urban fertilisers, the inclusion of relevant 'organic' reference treatments are considered necessary, in order to make these treatments more immediately comparable to fertilisers that are currently used. Thus the complete list of treatments to be included is as follows:

Urban Fertiliser treatments

1. Human Urine
2. Composted Organic Household Waste (including Human Faecal material)
3. Degassed Sewage Sludge with addition of ashes from local Bio-fuel Electricity and Heating Plants

Reference treatments

4. Cattle Slurry (Organic)
5. Deep Litter (Organic)
6. No addition of fertiliser (soil nutrient mining / extractive strategy)

The field trial will be laid out with 39 plots (ca. 2500 m² each) and thus be able to accommodate 13 treatments (with 3 replicates) when fully developed.

Pre-treatment investigations

The most imminent threat to the environment and the ecosystem integrity is related to transfer of disease vectors from urban fertilisers to animals or humans. Undoubtedly, development of improved urban nutrient cycling will be impossible in Danish society until it is considered to be safe. As outlined above, these issues will be dealt with over time, presumably beginning in the autumn 2000 with a PhD project sponsored by KVL. One justification for the field experiment is the services it can provide this type of research. Since we were given the mandate to include issues related to pre-treatment we have been examining possibilities to include health aspects directly in this work. On a meeting with officials from the Danish Environmental Protection Agency it was indicated that some experimental work was underway regarding disease vector survival during bio-gas production. Furthermore they stated that they would be interested in supporting work on this aspect of composting of human faeces and household waste, after an on-going literature review on this issue had been completed. However due to our time and budgetary constraints we have been advised to leave out this aspect of the current proposal, since there is a understanding that under all circumstances it must be addressed in the near future when a more coherent picture of the problems has emerged. There is also a clear recognition that the initiation of activities described below are supportive of these research needs.

Composting treatments

Co-composting of source-separated municipal solid waste (MSW) and human faeces is not described in any depth in the scientific literature. In contrast, composting of MSW is relatively well documented and there also exists a few investigations describing composting of faeces alone (e.g. Namkoong & Hwang, 1997). Compost quality is to a large extent dependent on the composition of the starting material (Johansson et al., 1997). Consequently, there is a need to generate knowledge regarding co-composting of faeces and MSW to determine e.g., the optimum mixing ratios to generate a sufficiently self heating compost, to what extent addition of structural material is necessary to achieve this and how process parameters influence the nutrient loss during composting etc. In addition to the process itself, the temperature development is important for the ability to generate a hygienic end product.

Laboratory experiments are well suited to answer such questions due to the possibility of conducting larger numbers of parallel experiments under well-defined conditions not feasible in full-scale composting practice. A new laboratory composting system (Møller et al., 1999a and b) has been constructed at FSL. The system includes 6 computer-controlled composting reactors (approx. 8 litres each), with individual control of process temperature and aeration rate. It is, therefore, possible to investigate in depth the influence of temperature on the composting process, e.g. by letting the compost follow a pre-defined temperature profile. A gas analyser provides measurements of oxygen as well as carbon dioxide concentration in the process air,

making possible on-line determination of oxygen consumption, carbon dioxide production and accumulated carbon loss. In this way, it becomes possible to determine the influence of oxygen/carbon dioxide concentration on the composting process. Furthermore Nitrogen losses will be documented.

In order to provide the long-term field trial with urban fertiliser compost a meso-scale composting facility will be developed at the experimental station. In view of the general commitment to increase the use of renewable energy sources the general trend in society will most probably support increased bio-gas production at the expense of composting treatment. However composting practices have traditionally been viewed as essential in organic farming systems, as a means of promoting the agro-ecosystem health (Howard, 1940; Balfour, 1943). The health promoting effects of composts have been documented repeatedly since (e.g. a review by Husmann, 1998). We consider it to be of importance to create a basis to document these effects even further, since they may be essential for providing a justification for composts as 'high value' products in organic farming systems as well as in home gardens. We want to re-examine the original 'Indore'-method, and complement this with a modern 'state of the art' practise.

Establishing the Long-term Field Trial

Oversight committee

In order to attain the long-term goal of sustainable urban-rural co-development it is important to ensure a strong link between the services provided by the researchers, and the needs and interests of the end users, the organic farmers. We anticipate that over a longer period the long-term experiment will have to accommodate changing needs, and even though we wish to keep up certain urban fertiliser treatments for prolonged periods the field trial is planned with enough plots to accommodate additional treatments in the future. Other aspects of the trial, such as crops, tillage practises etc. may be subject to change over time. We will form an oversight committee including farmer representatives and with members from the research institutions that are actively involved in promoting recycling of nutrients from the cities. This committee will be responsible for reviewing the initial experimental design, and for any changes that may occur with time. Furthermore the committee will be responsible for assessing the knowledge that can be built from the experiment, with regard to the effects of the urban fertilisers on agro-ecosystem productivity and integrity¹.

Fertilisation strategy

Since elucidation of cumulative effects on soil quality, as well as diseases and other environmental problems is a major issue in the long term, it is necessary to keep on using the same fertilisation treatment on a given plot over time. Therefore the field trials will resemble classical long-term fertilisation trials in this respect. However, there is a limit to how unbalanced a fertiliser can be if it is to be a meaningful treatment in the longer term. The sewage sludge in itself is too unbalanced to work as a stand-alone fertiliser (see Table 4). For that reason we decided that a mixture with ash from Bio-fuel plants would be more appropriate.

Table 4. Assessment of fertiliser contribution to crop nutrition based on delivery of 170 kg N_{tot} ha⁻¹ (common EU-norm to be implemented via the nitrate-directive). (Translated from Magid et al., 1998)

Spring barley with undersown clover	Removal - grain and straw at 4.5 t ha ⁻¹ grain harvest	Cattle slurry	Deep litter	Human Urine (diluted)	Composted household waste	Biogas processed household waste	Sewage sludge
Dry matter %		5.7	31	0	58	6.47	18
Applied amount tonnes/ha		65	21	65	14	34	22
kg tot-N/ha		170	170	170	170	170	170
kg N/ha utilized ¹	160	105	43	128	23	115	43

¹ Agro-ecosystem integrity: risks for disease transfer, for negative environmental impact, and for negative long-term impact on soil quality and fertility

Kg P/ha	20	39	34	15	31	20	130
Kg K/ha	90	183	215	52	67	71	11

¹ The degree of Nitrogen utilisation is estimated based on empirical evidence from Danish on farm trials (Landsforsøgene, 1997) and a number of Swedish experiments with human urine, e.g. Kirchmann and Petterson (1995)

From Table 4 it is apparent that some of the fertilisers contain considerable amounts of easily available nitrogen (1,3,5) while others contain little easily available nitrogen (2,4,6), and therefore it will not be surprising if these groups of treatments give somewhat different yields. In the implementation of the field trial the decision on the amounts of fertiliser to be delivered to a given crop, will largely depend on its need for P and K. In order to accommodate urban fertiliser treatments with little easily available nitrogen, it has been seen as necessary to look closely at which types of crop rotations that would be able to make use of both types of fertilisers in a meaningful way.

The Crop Rotation

The crop rotation in itself is not a treatment *sensu stricto*, since in a given year principally only one crop will be grown on the 11 ha experimental area, unless there is a research need that can be accommodated in subplots by varying the crop type. This will allow the treatments to be compared on a yearly basis, but only on one crop per year. More importantly it will allow the use of 39 large plots (ca. 2500 m²) that can be physically isolated by permanent grass strips, and this again will ensure that soil is not moved from one plot to the other due to tillage operations. Tillage related mixing has been recognised as an Achilles heel of long-term trials when looking at effects on soil quality. Apart from avoiding tillage related mixing of treatments the benefit from large plots include the possibility of performing ‘grazing’ experiments to look at disease transfer related to intake of crop and soil. Furthermore the amount of crop produced in each treatment will be sufficient to perform feeding trials on e.g. sheep or pigs to check for disease transfer.

The following crop rotation has been developed to illustrate a selection that would be relevant for a farm with no animal husbandry, in which the income would be derived from sale of products for human consumption, as well as fibre and energy:

Year 1	spring wheat with clover undersown (food and bio-fuel)
Year 2	hemp (fibre and oil)
Year 3	peas for human consumption followed by fodder radish (nitrogen catch crop)
Year 4	medium early potatoes followed by a vetch/rye mixture for green manure

The underlying assumption is that the crop rotation detailed above is robust in terms of weed and pest management, and that a reasonable nitrogen supply can be ensured in treatments where the fertiliser itself does not contain ample amounts in easily available form. Hemp is a rather unusual crop for the moment, but has been included based on the assumption that organic farms in the future will need and want to produce some non-food products.

Fertilisers with a high content of available nitrogen will be delivered to the field in spring, Fertilisers with a low content and a potential for inducing N immobilisation will be delivered during autumn on the growing catch crop (e.g. fodder radish) or green manure (vetch-rye and clover-grass mixtures).

It is expected that the clover undersown spring wheat during the first year will collect 120-150 kg N ha⁻¹ (from the atmosphere and the soils base mineralisation) and that 30-40% of this will be taken up by the following crop (hemp). The peas for consumption will not need addition of N, and may be expected to yield almost equal amounts in each fertiliser treatment. Depending on how successfully the grain filling phase is completed, the remaining pea material will be expected to contain 100-200 kg N ha⁻¹. Therefore it should be followed by a nitrogen catching crop (fodder radish), that will also take up nitrogen from such fertilisers that are delivered during the autumn. Finally the use of the vetch/rye mixture following potatoes is expected to assimilate 100-130 kg N ha⁻¹ depending on the climate and the accumulated soil fertility.

Urban fertiliser turnover

In recent years the Plant Nutrition and Soil Fertility Laboratory (KVL) has emphasised characterisation of organic matter turnover and impact in cropping systems (Jensen et al. 1996, 1997; Magid et al. 1996, 1997 a, b, 1998; Mueller et al. 1997 a, b; Mueller et al., 1998). In this project we will look closely at the urban fertilisers applying the most recently developed techniques for studying gross fluxes of N (Jensen et al., submitted), in tandem with studies of enzyme activities that relate to carbon and nitrogen transformation in soil (Kandeler et al., 1999). We will measure the crops utilisation of urban fertilisers in the growing season, and the mineral N in soil during the winter season. Apart from interpretation of treatments from direct measurements a dynamic simulation of the crop rotation with the simulation model DAISY (Magid and Kølster, 1995; Jensen et al., 1999) will be performed, based on parameterisation of the urban fertilisers from laboratory studies. In this manner a more integrated assessment can be performed, that can be generalised to other rotations and soil types.

Routine methods for testing the levels of plant available Pi in soils have been developed for conventional cropping systems based on relatively P-rich soils. These methods are generally accepted as an adequate means of maintaining soil P levels in an optimum range and identify needs for further P additions in mineral fertilizers. In organic farming systems relying on soils with less abundant P, microbial and other labile Po pools achieve increased importance for supplying plant available Pi (Oberson et al., 1993, 1996). Macroporous anion-exchange resin extraction has been found to be a useful tool in isolating and quantifying labile Po and plant available Pi fractions in soil (Rubæk & Sibbesen, 1993), and more general use of resin based methods in soil nutrient testing has been advocated (Somasiri & Edwards, 1992; Skogley, 1994) as resins often provide better relationships to plant uptake of nutrients than conventional chemical extraction methods (Skogley & Dobermann, 1996). The amount of resin extractable Po shows significant seasonal variations reflecting not only plant uptake and addition of P but also microbially driven P turnover (Rubæk & Sibbesen, 1995). Studies relying on a combination of resin extraction, isolation of organomineral soil size separates and ³¹P-NMR spectroscopy suggest that the resin method isolates a structurally and functionally reasonably uniform pool of labile Po and that this pool of easily mineralizable Po is predominantly of microbial origin and mainly associated with clay-sized organomineral complexes (Guggenberger et al., 1996; Rubæk et al., 1999).

In the present study the resin method together with a selection of conventional chemical soil tests are used to assess the availability of P in fresh and bioprocessed types of urban waste.

Perceived threats to the Environment and to the Ecosystem Integrity

As stated above, the most imminent threat to the environment and the ecosystem integrity is related to transfer of disease vectors from urban fertilisers to animals or humans. However since the 'Urban metabolism' is far from understood and not really under control it is not possible to foresee which unintended effects the use of urban fertilisers may have on soil quality and the surrounding environment. This is a further justification for developing the long-term trial, in order to ensure that any such effects can be observed in time to prevent problems in the larger context. Unknown quantities of unknown organic xenobiotic compounds can occur in sewage sludge. Similarly human urine will contain certain quantities of medicinal substances that have been secreted from the kidneys, as well as chemicals from whatever detergent that has been used for cleaning the toilet. Heavy metals are part and parcel of modern life, e.g. copper tubes in buildings, zinc on roofs and many other surfaces and in cosmetics and shampoo. Thus in sewage sludge the heavy metals cannot be avoided in concentrations above what would be expected if the only contributing factor was the content in food delivered from agriculture. Even in human urine it is conceivable that contamination from tubes and storage tanks may occur. There is little available knowledge on long-term effects of various xenobiotics. However, in recent years a considerable knowledge has been gained on the effect of moderate increases in heavy metal concentrations in soil on some key biological processes.

Generally heavy metals in soils are only plant available to a very limited extent, due to their reactivity within the soil matrix. Many of these are described as micro-nutrients (e.g. Cu and Zn), since they are only taken up in very small quantities and are essential for the completion of the plant life cycle. Therefore only few observations of damages to plants or to animals and humans through the transmission of heavy metals in the food chain via plants have been reported. On Woburn experimental farm, the Market Garden Experiment was established in 1942, at a time where the supply of industrial nitrate was strictly limited to use for ammunition, due to the ongoing war. Among the treatments examined was heavy metal contaminated sludge from London's sewage works. These experiments were terminated after 20 years at which time the heavy

metal concentration had increased substantially in a number of treatments. These plots were used afterwards to study uptake of heavy metals in various crops, and virtually no ill effects were observed, except in red beet, that is especially sensitive to certain heavy metals (McGrath, 1987).

Therefore, it came as a surprise when clover sown in the sludge treatments was sickly and yellow, while clover growing on uncontaminated plots was healthy and dark green (McGrath, 1994). Closer inspection of the diseased clover revealed that the roots had not formed normal pink nodules that legumes usually form with nitrogen fixing bacteria. These observations could be repeated in the laboratory, while poor growth of clover could be alleviated by addition of inorganic nitrogen. Use of ^{15}N clearly indicated that clover growing in contaminated soils had lost its N-fixing capability (McGrath et al., 1988). Furthermore plants growing in the contaminated soils failed to form VA-mycorrhizal associations. These results have been corroborated by independent observations from sludge treated soils from Braunschweig, and has led to a comprehensive European effort to understand the causes for these very considerable reductions in soil quality. One of the crucial issues in this regard has to do with the very long term impact of heavy metal accumulations in soil, since they are not 'bio-degradable'. Thus according to Witter (1996) it will take anything from a few thousand years up to 180.000 years for soils to decontaminate naturally, once they have been loaded with a certain (moderate) amount of heavy metals.

One of the most important lessons from the work on heavy metal impact on key biological soil functions was the realisation that addition of heavy metals to soil did not result in acute toxicity, and only prolonged exposure (18 months) provided effects comparable to those observed in the field trials (Chaudri et al., 1993). It is currently believed that the delayed response of nitrogen fixing bacteria to heavy metal pollution is caused by the transfer of plasmids from resistant Rhizobia to non resistant forms, and that the transfer of this plasmid results in a deactivation of the bacterial nitrogen fixing capacity, while at the same time delivers heavy metal resistance (Ken Giller, personal communication). This work like no other, demonstrates the need for long-term field experiments for proper evaluation of unintended effects on soil quality, and ecosystem integrity.

Changes in soil quality occurs gradually, and will often not be measurable until the soil has been treated systematically over a number of years. Therefore the long-term trials with urban fertilisers must continue far beyond the 5 year period, since we can only initiate a soil quality monitoring program within this time-frame.

The microbial biomass is the 'Needles Eye' for organic matter turnover, and reacts more quickly than other organic pools in the soil on changes in environmental conditions (Jenkinson, 1988). Potential enzyme activities in soil and the metabolic quotient ($q\text{CO}_2$) are sensitive indicators of the microbial potential activity and diversity (Kandeler et al., 1996). A number of studies on soil microbial biomass have been performed within the research group (Jensen et al., 1996, Mueller et al., 1998) and the study of enzyme activities is currently being developed in collaboration with Prof. Ellen Kandeler (Stuttgart-Hohenheim). In combination with the expertise on food webs in soil, developed at DMU (Krogh and Løkke, 1997; Krogh et al., 1997 and 1998; Scott-Fordsmand et al., 1997; Wiles and Krogh, 1998) we will be able to establish a comprehensive monitoring programme on urban fertiliser impact on soil biological quality.

Objectives and expected achievements

1. To provide field-scale facility for assessing the feasibility of improved recycling of nutrients from urban areas to organic farms
2. To facilitate the process of sustainable urban development, by inviting the public to visit the Long-term Trials (Public relations)
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, nitrogen loss and oxygen consumption.
4. To determine the influence of different temperature regimes on compost quality (nitrogen availability, compost maturity) including comparison of thermophilic composting versus mesophilic composting practice.

5. To provide sufficient amounts of composted material for the field trials using the traditional organic 'Indore' practise as well as modern composting practises
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
7. To provide experimental data for modelling plant nutrient dynamics of soil receiving urban fertilisers via incubation studies and the mesocosm study mentioned above
8. To parameterise selected urban fertilisers to the DAISY model and test the explanatory / predictive power of this model by simulating the detailed measurements from the field trials
9. To assess the availability of P in urban wastes and characterize the fertilizer value of waste-derived P following introduction to arable soil
10. To deliver an initial characterisation of soil quality in the field experiment
11. To initiate a long-term monitoring of soil biological quality in the field experiment

Description of work packages including methods

Table 5: Work package list

Work-package No	Work package title	Responsible participant	Budget DK kkr.	Start	End
1	Establishment and running of Long-term field trials with urban fertilisers	KVL	1700/3000 ¹	2000	2004 ⁽⁺⁾
2	Development of composting practises for food waste and human faeces	FSL	800 ²	2000	2004
3	C and N dynamics of urban fertilisers	KVL	1920 ³	2001	2004
4	Agronomic research on P and K turnover in soil with applied Urban Fertilisers and its subsequent availability in pot trials	DJF Foulum	500	2002	2003
5	Soil quality monitoring programme	DMU	1162 ⁴	2000	2004

¹ Including the commitment from Department of Agricultural Sciences to provide 11 ha land to the long-term field trial, and sponsor the costs of certain basic field operations on the land. ² Cost sharing: 456 kkr. from FSL / 344 from KVL. ³ Cost sharing: 1200 kkr. from KVL / 720 from DMU. ⁴ Cost sharing: 480 kkr. from DMU / 682 from KVL

⁽⁺⁾ The field trial will be continued beyond 2004

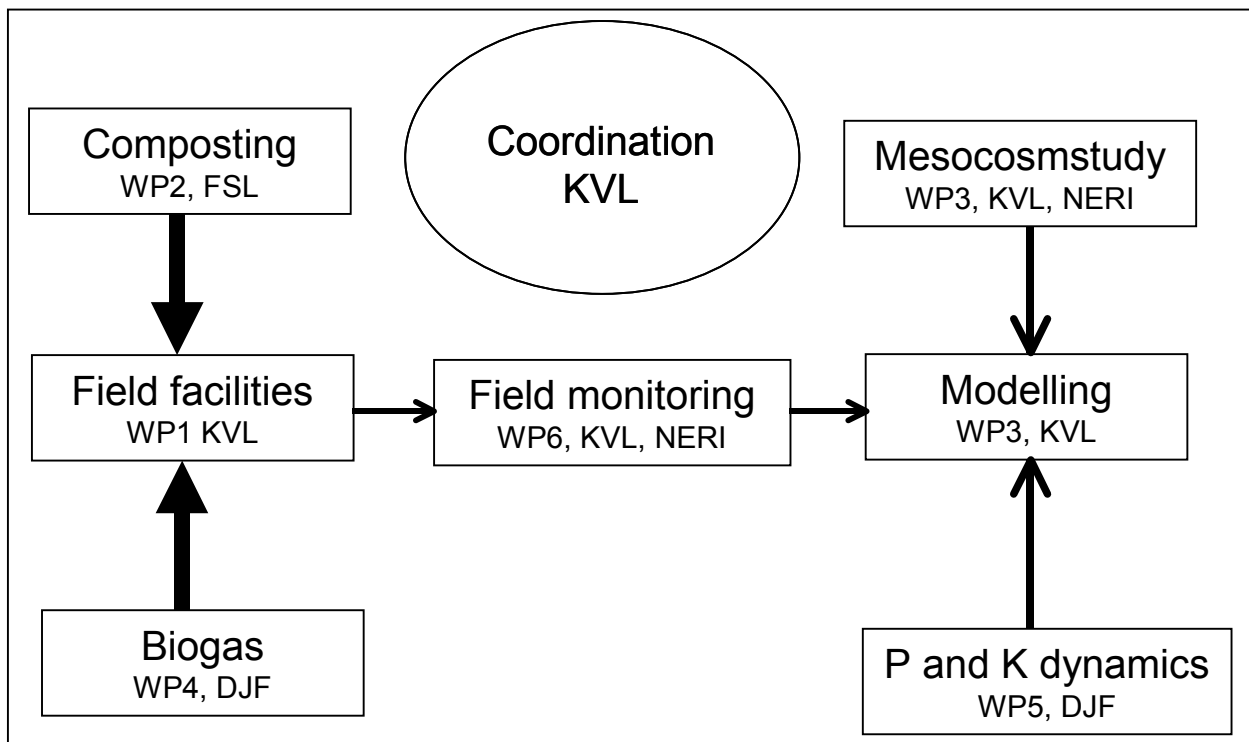


Figure 2. Organisation of the project.

Table 6: Description of work packages**WP1: Establishment and Running of Long-term field trials with Urban Fertilisers**

Work package number:	1
Start date or starting event:	Sept. 1. 2000
Responsible person:	Jakob Magid
Contributing persons:	Jens Færge, Niels Erik Nielsen, Hanne Lipzack Jakobsen, NN
Person-months:	20 KVL

Objectives

To provide the field-scale facility for assessing the feasibility of improved recycling of nutrients from urban areas to organic farms
 To facilitate the process of sustainable urban development, by inviting the public to visit the Long-term Trials

Description of work

Logistical support for procurement of urban fertilisers and reference treatments (see state of the art and WP2 & 4). Establishment of permanent grass strips in between plots (definition of plot layout see WP6). Delivery and spreading of urban and reference fertilisers to the plots. Tillage and sowing operations. Harvesting of main crops to determine biomass yield (twice during crop development, and at normal harvest date). Sampling of intermediate crops (green manure/N-catch crop) before spring tillage to determine nutrient capture (shoot and root biomass). Sampling of soil (1 m depth, in selected treatments to determine mineral N during autumn, winter and spring). Analysis of sampled soil (N_{min}) and plant materials (N,P,K,S). Development of a guided tour, including posters other presentation materials. Servicing of media, farmer user groups, NGO's, high-school classes and other parts of the public with an interest in the field experiment.

Deliverables

Annual reports
 Public service facility established (Materials and protocol for guided tour)
 Report on crop yields and quality, green manure / N-catch crop yields and plant nutrient return to soil, and soil N_{min} status over 2000 – 2003 (input needed in WP6)

MILESTONES

Oct. 2000	Establishment of permanent grass strips
Apr. 2001 - 2004	Spreading of fertiliser with high N availability (to be repeated yearly)
Apr. 2001 - 2004	Sowing of crops (to be repeated yearly)
May - August 2001 – 2004	Characterization of crop growth (to be repeated yearly)
Jun. 2001 – 2004	Public presentation of the field experiment ((to be repeated yearly, and on request)
Nov. 2001 - 2004	Spreading of fertilisers with low N availability (to be repeated yearly)

WP2: Development of composting practises for food waste and human faeces

Work package number:	2
Start date or starting event:	Sept. 1. 2000
Responsible person:	Jakob Møller
Contributing persons:	Jens Færge, Jakob Magid, NN
Person-months:	21 (FSL), 7 KVL

Objectives

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, nitrogen loss and oxygen consumption.
 To determine the influence of different temperature regimes on compost quality (nitrogen availability,

compost maturity) including comparison of thermophilic composting versus mesophilic composting practice. To investigate the influence of oxygen concentration on the composting process including determination of the minimum aeration rate ensuring aerobic condition and allowing self heating to take place. To provide sufficient amounts of composted material for the field trials using the traditional organic 'Indore' practise as well as modern composting practises

Description of work

The small scale composting experiments will be conducted using the 6 computer-controlled composting reactors at FSL. Basic experiments with co-composting of urban waste and humane faeces will include determination of the ability to self-heat by different mixtures as well as determining the mixture's oxygen consumption. In these experiments process temperatures will not be controlled, as opposed to the aeration rate that will be kept constant during the experimental period. The recorded temperature and oxygen consumption profiles will thus reflect the quality of the composting mixture e.g., a rapid increase in temperature followed by a long period of elevated temperature indicates the presence of easily degradable carbon as well as nutrients in sufficient quantities. In this way, the most suitable mixture of MSW, faeces and structural materials can be found and used in connection with the full scale composting at the field site. Other experiments will be designed to determine the loss of nitrogen through ammonia-volatilisation by collecting and quantifying NH₃ in the process air leaving the reactors.

Another range of experiments will focus on the influence of process temperature on the resulting compost quality. The compost will be subjected to different temperature regimes ranging from extreme thermophilic conditions up till 70 °C to mesophilic conditions where the temperature will not exceed 35 °C. During these experiments oxygen concentration in the reactors will be kept at a sufficient high level to prevent this parameter to become limiting for the composting process. Based on these experiments the nitrogen loss and the time required for the compost to mature will be determined as a function of process temperature.

Finally, the effect of oxygen concentration on the composting process will be determined in a series of experiments. Here, oxygen concentrations will be controlled at various levels ranging from micro-aerophilic concentrations to ambient concentration.

At KVL's research station a composting facility will be built for providing the field experiments with sufficient amounts of composted material (MSW and faeces and possibly urine) using the traditional organic 'Indore' practise as well as a modern high temperature composting regime.

Deliverables

Contributions to status and final project reports

Composted MSW and faeces for use in the field experiment each year from autumn 2001

Report on best practice for full-scale co-composting of municipal solid waste and humane faeces based on laboratory scale experiments and trials with meso-scale experiments on KVL's experimental station

A conference presentation

A scientific paper

MILESTONES

Apr. 2001

Oct. 2001

July 2002

Establishment of a composting facility at KVL's experimental station

First meso-scale composting trial completed (to be repeated each year)

Laboratory studies on composting completed

WP3: C and N dynamics of urban fertilisers

Work package number:

3

Start date or starting event:

Feb 1, 2001

Responsible person:

Jakob Magid

Contributing persons:

Jakob Magid, Paul Henning Krogh, Lars Stouman Jensen, NN

Person-months:

17 (DMU), 29 (KVL)

Objectives

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
Provide experimental data for modelling plant nutrient dynamics of soil receiving urban fertilisers via incubation studies and the mesocosm study mentioned above
Parameterise selected urban fertilisers to the DAISY model and test the explanatory / predictive power of this model by simulating the detailed measurements from the field trials

Description of work

A mesocosm system for decomposition of urban organic fertilisers will be run under controlled conditions. The system will be designed so the real heterogeneity of organic matter is included. During a simulated growing season and a simulated decomposition period the following chemical parameters will be quantified: NO_3^- , NH_4^+ , PO_4^{3-} , K^+ , SO_4^{2-} . The following biological parameters will be measured: mites, collembolans, enchytraeids, microbial activity, soil microbial biomass C and N. Gross mineralisation and immobilisation of N will be elucidated in incubation studies using ^{15}N concomitantly with measurements of the C turnover, and activity measurements of enzymes connected to the carbon and nitrogen cycles. This work will be a highly integrated effort involving both KVL and DMU. At a later stage additional minor incubation studies will be carried out at KVL to complement and further detail the lessons learned from the aforementioned comprehensive study. Of special relevance are the turnover processes at the temperature ranges found during late autumn and spring. Relevant parts of the data (particularly C and N fluxes) will be applied to parameterise the DAISY model and integration of the results obtained from the field studies will be based on these parameters.

Deliverables

Contributions to status and final project reports
Synthesis report comprising the mesocosm system elements
Popular presentation
Presentation at a conference
Five scientific papers

MILESTONES

Dec. 2001: Comprehensive mesocosm study completed
Jul. 2003: Further incubation studies on quality and temperature effects on temporal patterns of nutrient fluxes completed
Dec. 2003: Model interpretation of relevant parts of the aforementioned milestones
Jul. 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)

WP4: Assessment of plant availability of phosphorus in urban wastes

Workpackage number:	5
Start date or starting event:	January 2002
Responsible person:	Bent T. Christensen (BTC)
Contributing persons:	Gitte H. Rubæk (GHR)
Person-months:	12

Objectives

To assess the availability of P in urban wastes and characterize the fertilizer value of waste-derived P following introduction to arable soil.

Description of work

The work is divided into three activities.

Activity 1: The types of waste selected for the field experiment associated with WP 1 are analysed for contents of different P forms (total-P, P_o , P_i , and plant available P_i and P_o) using standard chemical analyses and resin extraction. Other relevant chemical parameters (e.g. cations) are determined by ICP-AES. During incubation under controlled conditions in the laboratory, the dynamics of labile P_i and P_o pools are assessed by resin extractions to reveal the P mineralisation/immobilization potential of the waste types. Pig and cattle manures are included as reference materials.

Activity 2: The types of waste employed in activity 1 are mixed individually with soils of different P status in proportions simulating agricultural practice. The soil/waste mixtures are used in a pot experiment sown to grass. The pots are placed in an outdoor facility where soil moisture can be controlled. Successive grass cuts and soil samples are taken during the growth period. Plant P uptake and soil microbial P, resin extractable P_i and P_o are determined at each sampling. Pools of soil P defined by standard soil tests are determined at the beginning and end of the pot experiment. Soils admixed with animal manure and unamended soil are included as reference treatments.

Activity 3: Soil samples from the WP 1 field experiment are analysed for P pools of significance to crop uptake using methods described under Activity 2. Results are related to plant P contents at crop harvest.

Deliverables

Contributions to status and final project reports

One paper intended for publication in refereed international scientific journal

Popular presentation of results intended for farmers and advisors

One presentation of results at an international conference/workshop

MILESTONES

1. Characterization of waste completed
2. Pot experiment completed
3. Analyses of soils from field experiment (see WP 1) completed
4. Final report submitted

WP6: Soil quality monitoring programme

Work package number:	6
Start date or starting event:	Sept. 1, 2000
Responsible person:	Paul Henning Krogh
Contributing persons:	Jakob Magid, Paul Henning Krogh, Lars Stouman Jensen, NN
Person-months:	11 (DMU), 12 (KVL)

Objectives

To deliver an initial characterisation of soil quality in the field experiment

To initiate a long-term monitoring of soil biological quality

Description of work

Initial characterisation of soil

The field site will initially (as a pre-project activity) be sampled in a 20x20 m grid pattern (350 points) at two depths (A_o and B horizon). This soil will be stored in an archive and used both in connection with initial

characterisation and for later reference. Soil samples will be analysed for texture, organic C and N, and extractable P and K.

The data obtained in this manner are to be used in laying out field plots in blocks with known soil properties. Based on plot pattern and surface curvature a number of penetrometer readings will be made later on to give a rough indication of physical properties with depth over the whole eleven ha field.

After analyses of data from the initial characterisation, parameters and replicate numbers will be finally decided for the monitoring programme.

MONITORING

The following biological parameters will be measured: mites, collembolans, earthworms, microbial activity, soil microbial biomass C and N, Invertase, Xylanase, Aryl-sulphatase, de-aminase

Data collected in the experimental design will be analysed by ANOVA.

Deliverables

Contributions to status and final project reports

Report on soil characteristics, and motivated recommendation for the lay-out of the field trials

Report on urban fertiliser impact on soil quality

MILESTONES

Sep. 2000: Establishment of soil archive

Oct. 2000: Layout of plots

Oct. 2000: Sampling of plots for faunal and other biological characterisation (soil quality baseline study)

Mar. 2001: Completed baseline study

Aug. 2003: Sampling of plots for faunal and other biological characterisation

Dec. 2003: Completed soil quality impact study after 3 years of treatment/fertilisation

Implementation and time schedule

Table 7: Deliverables list

Deliverable No	Deliverable title	Delivery date	Meeting	Nature
	WP1			
D1	Annual Reports for 2000-2004	Dec 2000-4		Re
D2	Materials and protocol for guided tour (public relations)	May 2001		O
D6	Report on crop yields and quality, and soil N _{min} status over 2000 – 2003 (input needed in WP3)	Jul 2003		Re
	WP2			
D8	Composted MSW and faeces for use in the field experiment each year from autumn 2001	Oct 2001 & onwards		O
D9	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 2002		Re
D10	Presentation at conference	2003		
D11	Scientific manuscript on composting trials	Jul 2003		Pu
	WP3			
D12	Synthesis Report comprising the mesocosm system elements	Jun. 2002		Re
D13	Scientific manuscript on the faunal contribution to nutrient release from urban fertilizers to plants	Jun. 2003		Pu
D14	Scientific manuscript integrating faunal interactions with measured fluxes, microbial and enzyme activities	Dec. 2003		Pu
D15	Scientific manuscript on quality relationships and nutrient release patterns	Dec. 2003		Pu
D16	Popular presentation	2003		O
D17	Presentation at conference	2003		Oral
D18	Scientific manuscript on temperature relationships (3-12 °C) on nutrient release	Apr. 2004		Pu
D19	Scientific manuscript on model interpretation and field trial validation	Oct. 2004		Pu
	WP4			
D23	Popular presentation	2003		O
D24	Presentation at conference	2003		Oral
D25	International scientific paper	2004		Pub
	WP5			
D26	Report on soil characteristics, and motivated recommendation for the lay-out of the field trials	Mar. 2001		Re
D27	Popular presentation	2003		O
D28	Presentation at conference	2003		Oral
D29	Report on urban fertiliser impact on soil quality	Jun. 2004		Re

Table 8: Time table

Collaborative partners

The collaborative NUTRAP framework and the efforts to create a large integrated research programme on re-inventing urban waste management with the view to close the rural urban nutrient cycle, has been described in the introductory section.

REVISED after approval by the FØJO board

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Annex 1 - CV's of selected researchers

JAKOB MAGID

(born 8 July, 1961)

Education

M.Sc. Horticulture June 1986, Ph.D. from the Plant Nutrition and Soil Fertility Laboratory, KVL, December 1991

Appointments

Researcher at National Environmental Research Institute 1986-1991

Assistant Professor at the Plant Nutrition and Soil Fertility Laboratory, KVL 1991-1995

Research fellow at DLO-Institute for Agrobiological and Soil Fertility, Wageningen, 1993-1994

Associate Professor at the Plant Nutrition and Soil Fertility Laboratory, KVL 1995 –

Managing Director (½ time) for the university consortium (KVL / KU / RUC) on Sustainable Land Use and Natural Resource Management (SLUSE) 1998 -

Research

Nutrient cycling and balances in agricultural, set-aside and natural land, with emphasis on turnover and losses of C, N and P. Development and testing of methods to elucidate these processes have been a priority, and in recent years work has been done using model-interpretation of the field studies and functionality of crop rotations, with special reference to organic farming systems. Most recently integrated interdisciplinary efforts have been done in the SLUSE consortium (natural, agricultural and social sciences), and a similar integrated effort is being developed on 'Recirculation of nutrients from urban to rural areas' (agricultural, health, technical and social sciences).

Teaching

Responsible for teaching in 'Environment, Natural Resources and Agriculture' and previously co-responsible for teaching in 'Organic Farming'. Co-teacher on 'Applied Plant Nutrition' and 'Crop Growth Factors and Crop Physiology'. Supervisor for a number of M.Sc. and Ph.D. students.

Publications

28 papers in international journals with referee, 4 papers submitted and in review.

4 invited chapters in refereed books.

Assignments

Referee for 8 international journals

Referee for selection and final evaluation of Scandinavian research programmes

Member of the selection committee for research on organic farming (for KVL)

Member of KVL's Board for Developing Countries

Selected references

Magid J. and Kølster P. (1995) Modelling nitrogen cycling in an ecological crop rotation - an explorative trial. *Biological Agriculture and Horticulture* **11**,77-87.

Magid J., Tiessen H., and Condron L. M. (1996) Dynamics of Organic Phosphorus in Soils under Natural and Agricultural Ecosystems. Chapter 11. In: *Humic Substances in Terrestrial Ecosystems*. (A. Piccolo, Ed), Elsevier, Dordrecht, 429-466.

Magid J., Gorissen A., and Giller K. E. (1996) In search of the elusive 'active' fraction of soil organic matter: Three size-density fractionation methods for tracing the fate of homogeneously ¹⁴C-labelled plant materials. *Soil Biology and Biochemistry*, **28**, 89-99

Mueller T., Magid J., Jensen L.S., and Nielsen N.E. (1998) Soil C and N turnover after the incorporation of chopped maize, barley straw and blue grass in the field: Evaluation of the DAISY soil-organic-matter submodule. *Ecological Modelling*, **111**, 1-15

Magid J, Dalsgaard A, and Henze M (1999) Reinventing urban waste management – integration of health, recycling and environmental concerns. In: Proceedings from FAO/IBSRAM's conference on 'Peri-Urban Agriculture', Accra, Ghana, 2-6 August, 1999

PAUL HENNING KROGH

(born August 20, 1956)

Silkeborgvej 28, DK-8000 Århus C

Education

M.Sc. Biology/Chemistry, University of Odense June 1985.

Ph.D. Department of Terrestrial Ecology and University of Århus, October 1994.

Employment

Scientific assistant. Danish Institute of Agricultural Sciences, Dept. Crop Physiology and Soil Science 1988.

Scientist National Environmental Research Institute, Silkeborg, 1990-

Coordinator of Soil Fauna Research Group, National Environmental Research Institute, 1997

Senior Scientist, National Environmental Research Institute, Silkeborg, 1998

Research activities

Dr. Paul Henning Krogh is the co-ordinator of R&D activities of the Soil Fauna Research Group at the Department of Terrestrial Ecology. The group does basic and applied research on soil fauna ecology, ecophysiology and ecotoxicology. He does ecological and ecotoxicological studies on microarthropods in agricultural land and disturbed habitats. Ecological interactions between microflora and mesofauna are studied in soil, in mesocosms, and in field experiments. Ecological risk assessment is an important advisory and research task for the Danish EPA. The key aim of the group is the assessment of ecological soil quality of habitats exposed to stress of various kinds. Functional properties along with biodiversity of soil fauna are the main indicators used in assessment studies.

Educational activities

Supervisor of masters students and PhD students and visiting scientist.

Publications

About 25 scientific papers and 20 reports.

Membership of Steering Committees

Danish EPA projects on environmental contaminants

Center Committee of "Centre for sustainable Land Use and Management of contaminants, Carbon and Nitrogen"

Center Committee of the "Centre for Contaminated Soils and Sediments (BIOPRO)"

Board of the "Centre for Contaminated Soils and Sediments (BIOPRO)"

Selected references

Bauguer Bascuas A. J., J. Jensen, and P. H. Krogh. 2000. Effects of the antibiotics oxytetracycline and tylosin on soil fauna. *Chemosphere*, **40**, 751-757.

Krogh, P.H. and Axelsen, J.A. (1998). Test on the interaction between the gamasid mite *H. aculeifer* and the prey collembolan *F. fimetaria*. In Løkke, H. and Van Gestel, C.A.M. (Eds.). Handbook of soil invertebrate toxicity tests. pp. 239-251, John Wiley & Sons, Ltd.

Krogh, P.H., Holmstrup, M., Petersen, S.O. and Jensen, J. (1997). Ecotoxicological assessment of sewage sludge in agricultural soil. Danish Ministry for the Environment, The Danish Environmental Protection Agency.

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CURRICULUM VITAE: BENT TOLSTRUP CHRISTENSEN

- 9. May 1952: born in Glim near Roskilde, parents farmers
- September 1972: matriculated at University of Copenhagen, biology
- December 1979: cand. scient. degree in biology/ecology (equiv. Ms.)
- ultimo 1980: guest researcher at Merlewood Research Station (UK)
- January 1981: scientist at Askov Experimental Station, The Danish Institute of Plant and Soil Science
- July 1988: appointed Head of Department for Plant Nutrition and Physiology, Askov
- January 1994: Head of Organic Matter Research Group, Research Centre Foulum
- 1995-1997: Co-ordinator of Danish Centre for Root Zone Processes financed by The Danish Environmental Research Programme
- 1995-2000: Head of research programme: Rhizodeposition in Arable Soils - Effect of Climate Change, financed by The Agricultural and Veterinary Research Council

Experience

External censor (B.Sc., MA, Ph.D., Docent) at the Universities of Copenhagen, Odense, Aalborg and Aarhus, The Royal Veterinary and Agricultural University, Swedish University of Agricultural Sciences, and University of Guelph. Member of evaluation committees for assistant and associate professorships and research professor (University of Copenhagen, The Royal Veterinary and Agricultural University), research director (National Environmental Research Institute), and scientist and senior scientist positions (Danish Institute of Agricultural Sciences, Risø National Laboratory). Member of research programme committees on Green Fields, Sustainable Agriculture (Danish Ministry of Food, Agriculture and Fisheries), The Danish Environmental Research Programme (Soil Surface/Upper Soil Layers), The Danish Agricultural and Veterinary Research Council (Microbial Processes in the Rhizosphere), and evaluation panel for the Square Grid Project.

Peer reviewer and evaluator of research proposals for Danish, Swedish, UK, USA and Australian research granting bodies. Appointed foreign member of The Royal Swedish Academy of Agriculture and Forestry. Member of Editorial Board for Applied Soil Ecology, Soil Use and Management and Field Crops Research, and referee on 68 papers for 12 different journals.

Publications

Author, senior-author and co-author on 121 publications of which 43 are in international, refereed scientific journals and 19 are book chapters or conference proceedings. Most publications relate to decomposition of plant residues, soil organic matter turnover, nitrogen cycling in arable soils, leaching of nitrate and volatilization of ammonia from animal manure.

- Christensen, B.T., Meyer, N.I., Nielsen, V. & Søgaard, C.* (1996): Biomasse til energi og økologisk jordbrug. Rapport nr. R-002, Institut for Bygninger og Energi, Danmarks Tekniske Universitet, Lyngby.
- Christensen, B.T.* (1997): Kvælstofomsætning i jord - Hvorfor tager det tid at reducere nitratudvaskningen. *JordbrugsForskning* 1, nr. 2, september/oktober, 7-11.
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- Thomsen, I.K. & Christensen, B.T.* (1998): Cropping system and residue management effects on nitrate leaching and crop yields. *Agriculture, Ecosystems & Environment* 68, 73-84.
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CURRICULUM VITAE: JACOB MØLLER

Birth: 15 of July, 1956

Nationality: Danish

Address: Danish Forest and Landscape Research Institute
Hoersholm Kongevej 11
DK-2970 Hoersholm
E-mail: jam@fsl.dk

EDUCATION

1996 Ph.D. in microbiology, University of Copenhagen

1992 M.Sc. in microbiology, University of Copenhagen

EMPLOYMENT

1997- Researcher, Danish Forest and Landscape Research Institute, Hoersholm

1996-1997 Research Assistant Professor, University of Copenhagen

1993-1996 Ph.D.-student, University of Copenhagen

1992-1993 Research assistant, University of Copenhagen

MAIN RESEARCH ACTIVITIES

Investigation of the composting process with emphasis on the influence of biological as well as physical/chemical factors on compost quality. In order to do that a new lab-scale computer controlled composting system has been developed.

LIST OF RECENT PUBLICATIONS

Møller, J., Wagner Jørgensen, L., Tristante, D, Halkjær, L. and Reeh, U. (1999) An air-cooled laboratory composting system with independent control of temperature and oxygen status. In: J. Petersen and S.O. Petersen (eds.) Use of municipal organic waste. Proceedings of NJF-Seminar no. 292, 23-25 November 1998, Agricultural Research Centre, Jokioinen, Finland.

Møller, J., Miller, M., and Kjølner, A. (1999) Fungal-bacterial interaction on beech leaves: influence on decomposition and dissolved organic carbon quality. *Soil Biology and Biochemistry* 31:367-374.

Møller, J., Wagner Jørgensen, L., Halkjær, L. and Reeh, U. (1999) A fully computerised laboratory system for investigating degradation of xenobiotic organic compounds during composting of msw. Poster and conference abstract. International Composting Symposium, September 19-23, 1999, Halifax, Canada.

Reeh, U., Bergen Jensen, M. and Møller, J. (1999) Effect of compost mulching versus incorporation on leek yield and quality. Poster and conference abstract. International Composting Symposium, September 19-23, 1999, Halifax, Canada.

