Dry toilet compost and source separated urine as fertilizers – experiences from Finland

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Abstract

Human excreta use as a fertiliser in food production is no longer a natural and sustainable process as it has been during the long history of agriculture. There has been a remarkable change from self-sustaining local agriculture to the highly industrialised production of food. Properly managed reuse of human excreta, however, would enable sustainable food production without increasing nutrient imbalances and run-off in agricultural soils. Currently the use of these fertilisers in large scale food production in Finland and Europe is not possible, since the current legislation does not acknowledge human excreta as eligible fertilisers. Yet, the increased costs of food production force us to seek for more rational alternatives for fertilizer use. This paper discusses the chemical, microbiological and quality issues regarding of foodstuffs when organic fertiliser products – source separated urine and dry toilet compost are used as fertilizers.

Introduction

Human excreta reuse in food production is no longer a natural and sustainable process as it has been during the history of agriculture in Finland and many other western countries. This paper discusses the possibilities of recycling human excreta in food production in the light of present legislation in European Union area and in Finland. The aim is to show that human excreta, when properly managed, is a safe fertiliser for many crops. Properly managed reuse would enable sustainable food production without increasing nutrient imbalances and run-off in agricultural soils and thus prevent eutrophication and pollution of waster bodies.

The earliest form of permanent agriculture everywhere in the world has been slash-and-burn cultivation and this was also the case in Finland (Suomen maatalouden historia, 2003). The increased demands by a growing population lead to clearing of more forest areas for cultivation, followed by soil exhaustion and eventually severe impoverishment of the soil (Suomen maatalouden historia, 2003, Havas, 2007).

In many western countries including Finland reclaiming and recycling of human and animal excreta did not require any special measures in the 18th and 19th centuries, when 85 % of the population was working in close connection with agriculture. The amount of waste per capita was also smaller than today as more than 80 % of the energy in diets was derived from vegetables. Household water was carried from wells, and heating energy provided by wood. Reuse of recycled nutrients was also a balanced process. Chemical fertilisers were not available and human and animal excreta were a valuable source of nutrients for all crops. It was also obvious that no unnecessary dilution of excreta to waste-water took place. Production of organic waste was not significant and if any was produced it was efficiently utilized and recycled (Suomen maatalouden historia, 2003, 2004a)

The intensification, mechanisation and efficiency in cultivation methods started at the beginning of the 20th century leading also to increasing use of inorganic commercial fertilisers. The average yields per hectare have doubled or even tripled in Finland during the period 1910-2005. This trend reflects more efficient crop breeds as well as the more intensive use of fertilisers in agricultural land. The use of inorganic nitrogen (N), phosphorus (P) and potassium (K) fertilisers has increased dramatically since the end of 1940's. In the year 2000 the total fertiliser use per hectare was 150 kg N and 20 kg P out of which 53 % of nitrogen and 50 % of phosphorus was added as inorganic commercial fertilisers (Marttila, 2005). At the same time human diet changed so that more milk and meat products are consumed. This development has lead to regional nutrient imbalances, since agriculture has specialized in either livestock or crop farming. Environmental balance, in terms on nutrient reuse, no longer exists.

Agriculture and environment today

Due to improved and more efficient municipal and industrial waste-water treatment in Finland, agricultural run-off has become the most important factor in inland water pollution by nutrients. In spite of measures taken in agriculture to reduce nutrient run-off from farmlands, agriculture is still responsible for more than 50 % of all nitrogen and more than 60 % of phosphorus discharges to bodies of water (Maatalouden vesistökuormitus, 2007). Therefore the most urgent need to reduce nutrient load is in the industry of agriculture. One suggested measure to reduce nutrient leaching to watercourses is "reducing the leaching of nutrients into watercourses through appropriate fertilization and manure storage and usage practices". Reduction of erosion and maintaining the soil structure are other important measures listed by the Ministry of the Environment (2005).

Use of human excreta as fertiliser

Even though legislation and regulations concerning optimal fertiliser use and reducing run-off from agriculture have developed, efforts are scattered and lack centralised control. This has even lead to legislation that is contradictory, and, unlike the past, the mechanisms to substantially carry out nutrient reuse no long exist. The nutrient balance in agriculture still shows a constant surplus. At the same time however, holistic mechanisms for nutrient recycling and reuse of nutrients have become uncertain. Whether or not reuse really takes place, is not always carefully considered. Large amounts of nutrient containing sludge and manure are used in landscaping and garden construction (Fertiliser Product Act, 2006) - in other words, buried out of sight and out of mind.

If all human and animal excreta, waste-water and bio-waste could be reused as fertilisers, locally in balance with production, it would reduce the need for artificial phosphorus fertilisers to ⅓ of present usage. In addition, supplemental fertilising would for the most part be additional nitrogen, since nitrogen often evaporated during the storage of manure and excreta, or during the waste-water treatment process. The present way of linear flow of waste-water and human and animal excreta through ecosystems instead of the recycling of nutrients has to be changed.

Experimental setup

To demonstrate the use of human excreta as fertiliser an experiment was conducted during growing season 2007 where dry toilet compost, separated urine and combination of these fertiliser products were used as fertilisers for cabbage (*Brassica oleracea* var. Napoli) and potato (*Solanum tuberosum* var. Nicola). For comparison artificial fertiliser and no-fertiliser treatments were used. Compost and urine was collected from separating dry toilets from private households. Compost was about two-years old and urine was stored for several months before use. Amount of each fertiliser product used in this experiment was in accordance with Finnish legislation concerning environmental protection in agriculture – 80 kg N/ha for potato and 175 kg N/ha for cabbage. Microbiological quality was determined using Salmonella sp., faecal coliform bacteria, enterococci and clostridia as bacterial indicators and coliphages ATCC 13706 and ATCC 15597 as virus indicators. In addition heavy metal concentrations of the fertiliser products, soil and vegetables were determined. In addition the yield and the taste of the potatoes and cabbages were analysed.

Results

The use of dry toilet compost and source separated urine does not seem pose any significant microbiological risk for the cabbage and potato. From urine and compost no *Salmonella* was found. The amounts of faecal coliform bacteria, enterococci, clostridia and coliphages ATCC 13706 and ATCC 15597 in both fertiliser products, urine and compost, were very low (Table 1). From potatoes and cabbage only enterococci were found from compost fertilised (408 cfu/g) potato and in combined urine and compost fertilised potato (88 cfu/g). These can also be of natural origin, not necessarily from the fertiliser products. Otherwise no other pathogen indicators were detected in the vegetables.

Table 1. Occurrence of pathogen indicators as CFU (colony forming units) or PFU (plaque forming units) in fertiliser products (mean of four parallel samples).

Samples	Salmonella sp.	Faecal coliforms	Enterococci	Clostridia	Coliphage ATCC 15597	Coliphage ATCC 13706
Urine	0 CFU/25 ml	0 CFU/40 ml	0 CFU/20 ml	14 CFU/ml	97 PFU/ml*	65 PFU/ml*
Compost	0 CFU/25 g*	0 CFU/1 g**	0 CFU/1 g**	112 CFU/1 g**	0 PFU/1 g**	0 PFU/1 g**

*Detection limit 1 bacterium or 1 coliphage virus particle in sample size given in the table.
** Detection limit10 bacteria or 1 coliphage virus particle in sample size given in the table.

The fertiliser treatments did not result in significant differences of potato yield (Figure 1). Cabbage instead grew the best where urine and combined urine and compost were used as fertilisers (Figure 2). This shows that cabbage, which requires a lot of nitrogen to grow clearly benefits from the soluble nitrogen in urine.

The taste panel did not find any significant differences in the taste of the potato and cabbage. This indicates that the taste of organically fertilised foodstuffs is equally good to products fertilised with artificial fertilisers. The results also showed that the use of the fertiliser products did not affect the heavy metal concentrations neither in the soil nor in potato and cabbage. All heavy metal concentrations studied were way below the limit values, both in vegetables and in soil (Figure 3).

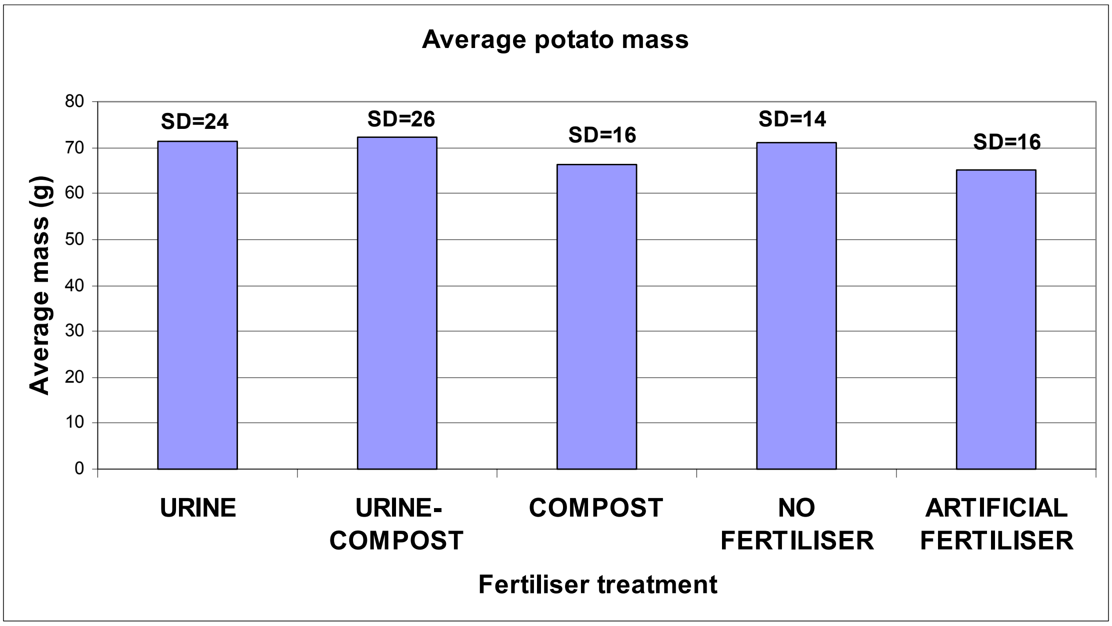

Figure 1. Average potato mass (g) in different fertiliser treatments.

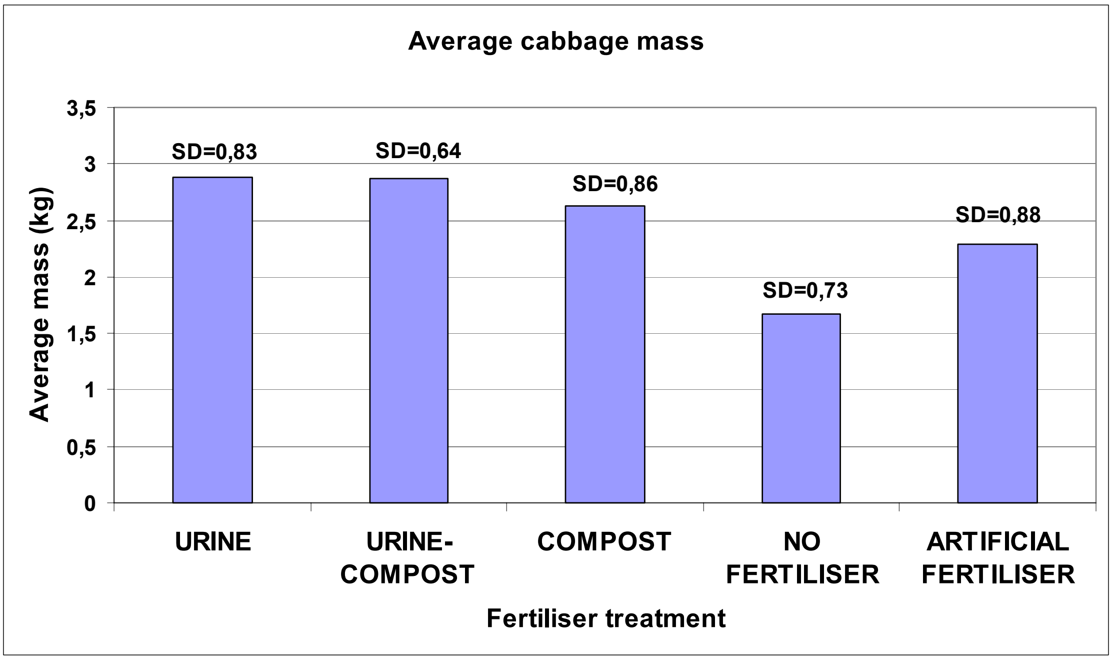

Figure 2. Average cabbage mass (g) in different fertiliser treatments.

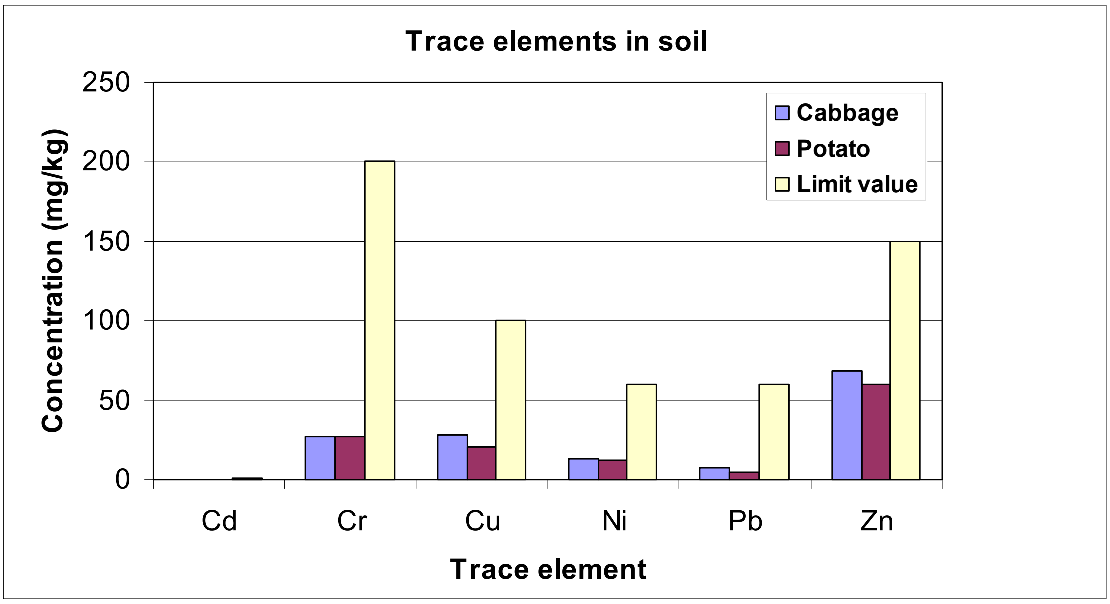

Figure 3. Concentrations of heavy metals (mg/kg) in soils of cabbage and potato and corresponding limit value for agricultural soils in Finland.

Conclusions and future research needs

Our findings in this study indicate that human excreta a) when source separated and b) correctly managed, stored and used, is a safe and sustainable fertiliser in food production. The use of the fertiliser products does not pose any significant pathogen risk, at least for Salmonella, faecal coliform bacteria, clostridia and enterococci and certain virus indicators, neither for the user of the fertiliser nor to the consumer of the crops. Crop plants, that require a lot of nitrogen for their growth, clearly benefit from the use of urine. Urine is rich in nitrogen and it is already in soluble form. The results also indicate that the use of pure human excreta compost and urine does not increase the soil heavy metal content. One must bear in mind, however, that this can be confirmed only in long-term follow-up studies. Based on this and also other studies all over the world, there are strong indications that the use of human excreta as fertiliser should be reconsidered, also in Finland.

The study shows that in terms of food and work safety human excreta can be used as a productive fertiliser in food production. The large scale use of these organic fertilisers does require, however, significant political and technical decisions.

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