From Waste to Wealth and Health: Evaluation and Community Appreciation of Human Urine as Fertilizer in Ho Municipality of Ghana

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Abstract

Urine has been used as equal or better substitute for inorganic fertilizer for crop production around the world. Collection of urine for application to crops has been made possible, in one way, through Urine Diversion Dry Toilet systems (UDDT). UDDT offers a solution for two major problems in the developing countries including Ghana. That is, improving state of sanitation and offering a safe and affordable fertilizer for increased food production towards greater food security. Current statistics reveal that Ghana is significantly lacking behind on Millennium Development Goal targets with less than 10 per cent of rural population having access to improved sanitation.

North-South Local Government Cooperation of City of Lahti in Finland and Ho Municipal Assembly in Ghana have identified ecological sanitation development as a key area for cooperation. Currently, the cooperation is providing essential support to meet sanitation and hygiene needs as well as to introduce nutrient recycling for increased crop production in Ho Municipality.

The feasibility of UDDT solutions and nutrient recycling has been studied through implementation of school and household pilots. The school pilot has been ongoing since 2009 and is currently extended to six schools. A household pilot was launched in 2014 to support training of latrine artisans and the technical development of household UDDT models. The Agricultural Engineering Department of Ho Polytechnic and the Ministry of Food and Agriculture (MoFA) have been involved in the pilot to study and evaluate the possibilities of improving the local food security through the utilisation of the organic fertilizers for small scale vegetable and cereal production.

During 2011-2014, the studies have involved comprehensive field trials and laboratory testing. The trials have confirmed the advantage of crop response to urine in the yields of vegetables (cabbage, garden egg and chilies) and cereal crop (corn) used. The urine grown crops also had higher protein and lower fat contents showing prospects for the promotion of health when consumed. The urine grown crops passed the Ghana food safety standards confirming them wholesome for human consumption.

In 2014, data was gathered to assess the community acceptance of the use of the urine in crop production. Eight of the MoFA farming zones with an average of 700 farming households in each were selected based on proximity to the urine demonstration farms in the Municipality. Purposive sampling procedure was used to administer interview questionnaires to farmers and T.Os of the farming zones exposed to the demonstration to study the perceptions of environmental, socio-cultural, food security, safety and economic aspects of urine fertilizer use. The responses were analysed using descriptive statistics.

Findings suggest that majority of the farmers and the Technical Officers was astonished at the crops positive response to urine. Reservations were, however, expressed by farmers concerning the stench of the urine during application. Still, the results indicate a definite readiness to adopt the use of urine fertilizer if it could be readily available and accessible. This calls for multiplying the UDDT's in these communities for higher and safer food security and improved sanitation.

KEY WORDS: URINE FERTILIZER, FOOD SECURITY, SOCIAL ACCEPTANCE, NUTRIENT RECYCLING, URINE DIVERSION DRY TOILET

Introduction

Farming is the major occupation of over 70 per cent of households in the Ho Municipality. The soils of the area are generally low in plant nutrients and do not support high yields of crops (MoFA, 2013). Some form of soil improvement for higher crop yields is needed. Timely availability, ability to purchase and adequate usage of chemical fertilizers raises very serious challenges in Ho Municipality. This accounts in part for the general low yields of crops leading to low incomes for majority of farming households explaining in part the widespread poverty and poor health in the area.

Urine has been used as equal or even better substitute for inorganic fertilizer for crop production around the world (Esrey *et al*, 2001). Collection of urine for application to crops is possible through Urine Diversion Dry Toilet systems (UDDT). UDDT offers a solution for two major problems (Werner *et al*, 2004). That is, improving state of sanitation and health and offering a safe and affordable fertilizer for increased food production. Current statistics reveal that Ghana, a developing country, is significantly lacking behind on Millennium Development Goal targets with less than 10 per cent of rural population having access to improved sanitation (The United Nations Global Survey for a Better World. Summary of Results: March, 2013).

Mnkeni *et al* (2004) reported that the major nutrients present in urine, that is Nitrogen, Phosphorus, and Potassium are present in forms that are directly available to plants and are as effective as mineral fertilizers when used as a nutrient source for plants. Nitrogen element is the nutrient that most frequently limits growth and yield and plays an important role in quality of crops. It is almost deficient in most soils of Africa and most of the tropics (Jules, 1974).

All growth attributes that directly or indirectly affect vegetative growth and quality are affected by cultural practices like fertilizer application (Goldsworthy et al., 1974). Kalifa *et al*. (1981) studied the effect of nitrogen on an open-pollinated variety of corn which was given as ammonium nitrate applied as nitrogen source. His results indicated that ammonium nitrate fertilizer increased the number of days to mid- tasseling, mid-silking and shelling percentage. Singh *et al* (1986) found that the biological yield, content and uptake of nitrogen in grain and stover of maize were highest with nitrogen as urea applied in two split dressings.

Sawi (1993) and Omara (1989) observed that nitrogen had significant effects on chemical composition of vegetative and final seed yield and some yield components such as number and weight of cobs/m^2 and weight of seeds per cob. In addition nitrogen had significant effect on seed protein content and leaf protein content. Gasim (2001) found that the addition of nitrogen increased vegetative fresh and dry yield and also increased percentage of crude protein in plants. Similar effects of Nitrogen fertilizer application on vegetable crops have been reported by Tweneboah (1998). Werner *et al* (2004) again have reported that urine has up to 80 per cent of the fertilizer value and contains approximately 90 per cent of the total nitrogen excreted, 55 per cent of the total phosphorus and a substantial portion of the potassium. They also observed that microbiologically, crops grown in urine-treated soils are likely to be safe for human consumption.

The adoption of ecological sanitation to mitigate poverty and poor health in Sub-Saharan Africa is becoming popular (Esrey *et al*, 2001). In Ghana, human excreta (urine and faeces) are culturally seen as waste product, filthy, unhealthy, and unhygienic to touch. To promote the potential use of human urine in ecological sanitation in the locality as a cheap and preferred option for chemical fertilizer calls for advocacy.

Background: Urine Diversion Dry Toilet systems (UDDT) in Ho Municipality

The case study area, Ho municipality, is located in Volta Region in the South-Eastern part of Ghana. Ho town is the capital of the municipality and the regional capital of Volta Region. Ho municipality has 2660 m^2 of land and a population of 271 881, with an annual growth rate of 1.17 per cent. (Ghana

Statistical Service 2010; Ho Municipal Assembly 2012, 6−8.) The Medium Term Development Plan (MTDP) 2010−2013 states that in Ho Municipality, 35 per cent of the inhabitants dwell in urban towns, whilst the rest 65 per cent live in rural areas. Over 70 per cent of the poor live in rural areas and more than half of the population in the municipality fall under the extreme poverty line, which is annual 700 Ghana Cedis (less than 200 euros). The extreme poverty focuses especially on the food crop farmers. (Ho Municipal Assembly 2010.)

North-South Local Government Cooperation of City of Lahti in Finland and Ho Municipal Assembly have identified ecological sanitation development, involving UDDT usage, as a key area for cooperation. Currently, the cooperation is providing support to meet sanitation and hygiene needs as well as to introduce nutrient recycling for increased crop production in Ho Municipality. This necessitated a pilot programme of the provision of UDDTs and community demonstration farms for first-hand experience in using the urine and the decomposed faeces as fertilizer. (Järvelä 2012; Kauhanen, Mäkelä, Järvelä & Aalto 2012.)

In the course of the pilot that started in 2009, UDDT facilities have been constructed in seven schools in Ho Municipality; project has supported the construction in six schools while one private school has adopted the technology independently. The user experiences from the schools have been positive. Sanitation facilities have proven to decrease absenteeism and the user convenience of UDDT has been evaluated positively. (Järvelä 2012; Aalto 2015; Kauhanen et al. 2012.)

Over the project period, various studies have been conducted to assess the economic, social, environmental and technical suitability of the UDDT technology in the conditions of Ho. Results in all aspects have been promising compared to other improved sanitation technologies promoted in the area, i.e. KVIP and WC. Furthermore, there is a genuine interest and commitment to the promotion of the DT technology in the Ho Municipal Assembly. This is best demonstrated by the fact that construction of new institutional dry toilets has been included into the Municipal Environmental Sanitation Strategy and Action Plan (MESSAP) of Ho. (Järvelä 2012; Kettunen 2014; Järvelä, Mäyränpää, Sekgetho, Shabangu & Maluleke 2013.) Once the suitability to local conditions had been established, a household pilot was launched in 2014 to support training of latrine artisans and the technical development of household UDDT models. (Järvelä 2012; Aalto 2015.)

The fertilizers produced by the dry toilet system have been tested on practical field conditions and the findings have been very promising and indicate great potential in the use of the organic fertilizers. The Agricultural Engineering Department of Ho Polytechnic and the Ministry of Food and Agriculture (MoFA) have been involved in the pilot to study and evaluate the possibilities of improving the local food security through the utilisation of the organic fertilizers for small scale vegetable and cereal production. MoFA has coordinated the practical farmers' demonstrations of urine fertilizer since 2013. (Järvelä 2012; Aalto 2015; Kauhanen et al. 2012.)

Currently, the stakeholders in Ho are looking to expand the school UDDT program to all new schools in the area while launching a wider program for household advocacy. The advocacy work is a joint effort of sanitation awareness and promotion of organic fertilizers calling for collaborative approach between the Environmental Health and Agricultural Extension Officers in Ho. (Aalto 2015.)

Methodology

The 2011 and 2012 ecological sanitation trials were carried out to determine the fertilizer substitution potential and microbiological safety as well as nutrient contents of vegetables and maize grown in soils fertilized with human urine. Findings would inform advocacy in the adoption of UDDT in the promotion of ecological sanitation in the municipality.

Three (3) vegetable crops namely cabbage (Brassica eleracea), pepper (Capsicum frutescens), garden egg (Solamum melongena) and maize (Zea mays) were used for the trials during the major cropping seasons of 2011 and 2012 (May – September) at the field of the Agricultural Engineering Department of Ho Polytechnic. The urine treatment response to growth, yield, nutritional content and wholesomeness characteristics were studied in relation to chemical fertilizer (NPK). Various growth and yield parameters were measured and urine treated crop samples were subjected to chemical and microbiological analysis and compared to prevailing levels and standards.

For both trials (2011 and 2012), the treatments consisted of human urine and standard NPK chemical fertilizer: 400kg/ha for cabbage and maize, 220 kg/ha for pepper and garden egg. Also a control test of 0.00kg/ha fertilizer was included in the treatments. Two (2) splits doses of both urine and the chemical fertilizer were carried out at the end of the 2nd and 6th weeks after planting. The treatments were arranged in a completely randomized block design with three replications. Plot size was two meters squared giving a spacing of 60cm for each of the crops.

Urine samples were tested for nutrients and microbiological contaminants (E. coli, total coliforms and total coliphages). Treatment means for the various parameters were determined at harvest and subjected to Analysis of variance (ANOVA). Urine treated crop samples were subjected to chemical and microbiological analysis for nutritional content and food safety compliance using GS ISO International acceptable methods in Ghana.

Picture 1. Application of urine during a community field demonstration in Ho Municipality (Picture by Haikola, H. 2014)

In 2014, two farms were chosen from each of the eight Ministry of Food and Agriculture (MoFA) farming zones in Ho Municipality for field demonstration sites. The farming zones have an average of 700 farming households and were selected based on proximity to the UDDT facilities. Urine, chemical fertilizer and control treatments applied to various vegetables and maize depending on the preferences of the farming zone. Demonstration farms were established in each zone and farmers were given the opportunity to participate in the application and observance of the growth and yield trends during the major farming season (May to September). To assess the community appreciation, purposive sampling procedure was used to administer interview questionnaires to 120 of the farmers and MoFA Technical Officers (T.Os) of the farming zones. The perceptions of the interview respondents concerning environmental, food security, safety and economic aspects of urine usage as substitute for chemical fertilizer (NPK) were analysed using descriptive statistics.

Results and Discussion

Growth Parameters

The results revealed that urine and chemical fertilizer application significantly affected growth parameters positively during the two seasons. The urine treatment, however, seemed to have some level of advantage over the chemical fertilizer treatment in its impact on the growth parameters (Table 1 to 5). In the case of pepper and garden eggs, there were no significant differences in plant height for the urine and chemical fertilizer treatments for the two seasons (Table 1). The urine treatment however resulted in far higher branching than the other two treatments for garden egg (Table 2) accounting for the higher leaf area index, fruiting and total dry matter yield leading to the higher yields obtained. Cabbage also showed similar trend for leaf area index, and total dry matter yield (Table 3, 4 and 5).

All the crops responded positively to urine treatment. Urine treated egg plants and pepper significantly developed more branches, had greater leaf area index, total dry matter and fruit yields than both the chemical fertilizer and control treatments. Nitrogen formed a prominent component of both manures. These results agree with the report of Esrey *et al* (2001) that urine serves as equal or even better substitute for inorganic fertilizer for crop production around the world. Werner *et al* (2004) also indicated that urine has up to 80 per cent of the fertilizer value and contains approximately 90 per cent of the total nitrogen excreted. These reports therefore confirm the advantage of urine as revealed in the present study. The fact that the control treatment performed poorly seem to confirm the report of Jules (1974) that nitrogen element is the nutrient that most frequently limits yield and plays an important role in quality of economic crops and that it is almost deficient in most soils of Africa and most of the tropics.

Table 1. Effect of urine and chemical fertilizer on plant height (cm) of pepper, garden egg and maize 2011 & 2012 trial

Crop	**Urine**		**Chemical Fertilizer**		**Control**	
	2011	**2012**	**2011**	**2012**	**2011**	**2012**
Pepper	59a	60a	61a	58a	49b	46b
Garden egg	80a	79a	84a	82a	61b	55b
Maize	190a	188a	184a	186a	160b	150b

$P < 0.05$

Table 2. Effect of urine and chemical fertilizer on number of branches of pepper and garden egg 2011 & 2012 trial

Crop	**Urine**		**Chemical Fertilizer**		**Control**	
	2011	**2012**	**2011**	**2012**	**2011**	**2012**
Pepper	59a	61a	61a	59a	49b	47b
Garden egg	65a	67a	53b	55b	36c	39c

$P < 0.05$

Table 3. Effect of urine and chemical fertilizer on fruit yield of pepper and garden egg 2011 & 2012 trial (Unit = Number of fruits per plant)

Crop	Urine		Chemical Fertilizer		Control	
	2011	2012	2011	2012	2011	2012
Pepper	165a	168a	143a	153a	86b	90b
Garden egg	96a	93a	65b	70b	45c	50c

$P < 0.05$

Table 4. Effect of urine and chemical fertilizer on leaf area index of pepper, garden egg and cabbage 2011 & 12 trial

Crop	Urine		Chemical Fertilizer		Control	
	2011	2012	2011	2012	2011	2012
Pepper	4.60a	4.50a	4.27a	4.37a	3.55b	3.50b
Garden egg	17.51a	18.00a	12.81b	12.01b	10.65b	10.85b
Cabbage	10.34a	11.67a	8.54b	8.14b	7.10b	7.30b

$P < 0.05$

Table 5. Effect of urine and chemical fertilizer on total dry matter yield (kg/ha) of pepper, garden egg, cabbage and maize 2011 & 2012 trial

Crop	Urine		Chemical Fertilizer		Control	
	2011	2012	2011	2012	2011	2012
Pepper	4740a	4440a	4751a	4652a	3890b	3589b
Garden egg	9531a	9844a	8975b	8855b	6500c	6005c
Cabbage	4556a	4896a	4032b	4260b	3500c	3600c
Maize	19062a	21321a	18590a	17980b	12000c	13050c

Nutrient contents of economic yield

There were pronounced differences in protein and fat contents in all the crops for the urine and chemical fertilizer treatments. Although some variation was seen, overall the urine treated crops had the highest levels for protein and lowest levels for fat for the two seasons (Table 6a&b).

Table 6a. Chemical analysis (nutrient content) of cabbage, garden egg, pepper and maize grown with urine and chemical fertilizer in 2011 trials

Crop		Moisture g/100g	Ash g/100g	Fat g/100g	Protein g/100g	CHO g/100g	Energy Kcal/100g
Cabbage	**U**	94.5	0.48	0.06	2.42	2.55	20.30
	F	92.0	0.70	0.10	1.50	5.70	25.00
G. egg	**U**	88.7	0.56	0.10	2.87	7.77	43.50
	F	91.4	0.60	0.40	1.20	6.40	29.00
Pepper	**U**	80.7	0.81	1.30	0.47	16.72	80.50
	F	78.3	1.30	2.20	2.80	15.40	80.00
Maize	**U**	13.3	1.39	3.8	9.23	72.28	360.2
	F	11.1	1.30	3.9	8.80	75.10	359.0

U = Urine treatment, F = Chemical fertilizer treatment

Source of standard values for F (Chemical fertilizer treatment): Eyeson and Ankrah (1975).

Merill and Watt (1955).

Table 6b. Chemical analysis (nutrient content) of cabbage, garden egg, pepper and maize grown with urine and chemical fertilizer in 2012 trials

Crop		Moisture g/100g	Ash g/100g	Fat g/100g	Protein g/100g	CHO g/100g	Energy Kcal/100g
Cabbage	**U**	91.8	0.74	0.10	1.92	5.44	30.30
	F	92.0	0.70	0.10	1.50	5.70	25.00
G. egg	**U**	92.2	0.39	0.10	1.14	6.17	30.10
	F	91.4	0.60	0.40	1.20	6.40	29.00
Pepper	**U**	85.6	0.78	1.00	2.15	10.47	59.50
	F	78.3	1.30	2.20	2.80	15.40	80.00
Maize	**U**	23.0	0.95	3.20	7.93	64.92	320.20
	F	11.1	1.30	3.90	8.80	75.10	359.00

U = Urine treatment, F = Chemical fertilizer treatment

Source of standard values for F (Chemical fertilizer treatment): Eyeson and Ankrah (1975).

Merill and Watt (1955).

These findings suggest that the protein content in the cabbage and garden eggs can be higher for the urine than the chemical fertilizer while the fat content was significantly lower for the urine than the chemical fertilizer (Table 6a&b). The results that are revealed in this study seem to be explained by the reports of Sawi (1993) and Omara (1989) who observed that nitrogen had significant effects on chemical composition of vegetative and final seed yield as well as the report of Gasim (2001) who found that the addition of nitrogen increased vegetative fresh and dry yield and also increased percentage of crude protein in plants. Use of urine for growing cabbage and garden eggs in particular, hold prospects for producing high protein and low fat foods through the UDDT system in ecological sanitation.

Microbiological contaminant levels

The food safety tests for the two season trials have shown that use of urine in producing crops for human consumption is safe (Table 7). This indicates that the scepticism that have been harboured by many people about the safety of eating crops grown with human urine is not right. Acceptability of crops grown with human urine for consumption is advocated.

Still, the contamination risks are prevented only when the UDDT system is used based on recommended maintenance guidelines. Misuse of the facility could result in cross-contamination of the urine fertilizer. Therefore, sufficient and relevant training should be ensured for all new users of UDDT technology.

Table 7. Microbiological analysis of urine grown cabbage, garden egg, pepper and maize 2011 & 2012 trials

Crop	Microbes	Microbiological Acceptable limits (cfu/g)	Contamination Status (cfu/g)	
			2011	2012
Cabbage	Mould & Yeast	10^4	2.3×10^4	6.1×10^4
	Coliform count	10^5	2.1×10^4	5.3×10^4
	E. coli	10^2	0.00	< 10
Garden egg	Mould & Yeast	10^4	1.1×10^5	6.4×10^3
	Coliform count	10^5	8.1×10^3	4.2×10^3
	E. coli	10^2	0.00	< 10
Pepper	Mould & Yeast	10^4	1.1×10^4	3.7×10^3
	Coliform Count	10^5	9.6×10^4	310
	E. coli	10^2	0.00	< 10
Maize	Mould & Yeast	10^4	1.2×10^4	2.0×10^4
	Coliform Count	10^5	3.2×10^3	1.1×10^4
	E. coli	10^2	0.00	< 10

Community appreciation of human urine as fertilizer

Out of the 120 farmers and Technical Officers who expressed their opinion on human urine as fertilizer, 70 per cent were males and 30 per cent females. Ninety six percent (96%) were within the adult age group of 21 and 60 years. The average family size of these farmers was 7. Seventy eight percent (78%) of the farmers have been into farming more than 15 years and seventy three percent (73%) have had varying degrees of formal education and therefore could appreciate the concept of the use of human urine as fertilizer.

Ninety three percent (93%) grow maize and vegetables with farm sizes between 1 and 20 acres. Eighty three percent (83%) said their expectations were not met in terms of yields and therefore would welcome any innovation that will increase their yields. Incomes made from their crops ranged from as low as 200 Ghana Cedis ($54) to above 5000 Ghana Cedis ($1351) for a farming season. All attributed their low outputs to input constraints.

Seventy one percent (71%) of the respondents said they were not using or under using chemical fertilizer because of the price and 29 per cent said even if they could afford, it was normally not available when they needed it. This suggests a strong case for urine as an emerging alternative because of the possibility of its availability. Ninety eight percent (98%) of the farmers indicated that they were aware the urine was applied as a substitute for chemical fertilizer. This is due to the purposive sampling that meant that the sample would consist of farmers located near the demonstration sites.

Concerning the judgment of farmers on the comparison of the growth and yield of crops grown with urine, chemical fertilizer and control (zero treatment), 96 per cent of the farmers said they observed that the crops treated with urine gave remarkable higher yields followed by the crops treated with chemical fertilizer, while the control (zero treatment) crops were the least. Seventy eight percent (78%) of the farmers said difficulty in conveying the urine to the field of application and the smell of the urine during application were their problem with its usage. Despite this 76 per cent of respondents expressed full acceptance of the urine for use as fertilizer for growing their crops, while 16 per cent were undecided and 8 per cent rejected its usage. This response shows that if the problem of the bulky nature of the urine and the smell can be addressed farmers will switch over to its use for its benefits because all the respondents (100%) indicated that urine when adopted as nutrient source for crops will result in higher yield for wealth creation, livelihood improvement, food security, as well as environmental health improvement leading to enhanced social dignity.

Ninety five percent (95%) of the respondents were in support of the urine diversion toilets being promoted in their communities. Ninety seven percent (97%) of the respondents indicated that they have decided to store their own urine for use in growing their crops in future and that they were aware that they should store the urine in closed airtight plastic containers.

Conclusion

Both growth and economic yield advantage of the use of human urine from UDDT systems in the production of crops is confirmed in the present study. Use of urine for growing cabbage and garden eggs holds prospects for producing high protein and low fat foods. Human urine can be substituted for chemical fertilizer in the production of crops if higher productivity, as well as safe and higher quality food crops is desired. UDDT for ecological sanitation is appropriate and the outcomes could be disseminated throughout Ho Municipality for promotion of urine based fertilizer as a substitute to chemical fertilizer. Solving the sanitation challenge with technology that enables local production of organic fertilizer is a win-win situation that has created strive and motivation for the sanitation development in Ho.

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