

32 DIVERTING TOILET SYSTEMS – QUALITY OF COLLECTED URINE MIXTURE COMPARED TO OTHER ORGANIC FERTILIZERS

Arne Backlund

A & B Backlund ApS, Ordrupvej 101, DK-2920 Charlottenlund, Denmark

Annette Holtze

Storstrøm County, Technology & Environment, Parkvej 37, DK-4800 Nykøbing F.

ABSTRACT

Storstrøm County and A & B Backlund ApS are cooperating in four wastewater projects running since 1998 concerning source control, diverting toilet technology and analysis of collected human urine mixture and composted human faeces. Results from one of the projects are presented in this paper. A & B Backlund ApS is working with further four national and international projects and are planning for further projects. The projects are carried out in an Action Plan administrated by the Danish Environmental Protection Agency (EPA). Danish EPA is not responsible for the conclusions or expressed views in the reports.

The collected user experiences in the Danish projects show that the diverting technology are accepted in a housing area, is running very well in a public place and are even highly appreciated in allotment gardens (even if further technical improvement should be made). This paper presents contents of nutrients, heavy metals, organic compounds and microorganisms found in urine mixture compared to findings in organic fertilizers used in danish agriculture. The analysed urine mixture was of high quality.

No-mixing toilets, diverting toilets, separation toilets, composting toilets, biological toilets, waterless urinals, wastewater treatment, ecological engineering, ecological sanitation, human urine, human faeces, nutrients, heavy metals, pathogens, compost, sludge, manure, anaerobically processed biomass

INVOLVEMENT IN DANISH PROJECTS

The Danish EPA is administrating an action plan with ecological recycling of nutrients in wastewater from cities to agriculture and ecological solutions for rural areas.

Storstrøm County and A & B Backlund ApS are co-operating in four projects in the action plan.

Storstrøm County is a "green" county and has already for many years been involved in many activities among others in ecological sanitation systems for rural areas (3). Storstrøm county has also interest in international co-operation in projects and is represented by Arne Backlund, A & B Backlund ApS at the conference, ECO-TECH. Three Storstrøm County projects are dealing with diverting sanitary technology systems and systems have been established in the county: 1) Composting of human faeces collected from a diverting double flushing toilet 2) Collecting of human urine from double flushing diverting toilets and a waterless urinal (13) 3)

Vacuum toilet systems for local collection of human faeces and central anaerobic digestion treatment.

A & B Backlund ApS are working with further four diverting toilet system projects in the action plan 1) R & D regarding diverting sanitary systems, waterless urinals and separation of faeces from flushwater (4). 2) Ecological handling of human urine and human faeces and greywater in allotment gardens by using no mixing toilets without flush and willow evaporation beds without discharge for greywater (6). 3) R & D of composting in compost toilet systems. 4) Fertilising of willows with urine mixture from diverting toilets (7). Two further composting projects are expected to be carried out 2002 – 2003.

REFLECTIONS IN A MODERN RISK SOCIETY

Flushing away human nutrients as waste in a modern risk society is a risk flushing away, wasting a sustainable future. We could stop operating in a disposal paradigm as a reflex to hygienic problems approximately 150 years ago and start to reflect. The history of utilising human rest products goes thousands of years back in history. Ecological engineering and ecological sanitation is a road to develop safe sanitation systems suitable for designing high quality fertiliser from human rest products. Wastewater and sludge are risks inherited from a disposal paradigm with disposal technology and are not automatically suitable for recirculation to agriculture. We can not solve the problems with the same sort of thinking that created the problems. Flushing and dilution is no solution to pollution. Modern risks are social constructions to be reflected and not handled by reflex. Human urine as waste or a wasted resource that is one of the questions (10), (12), (17).

ECOLOGICAL SANITATION – HUMAN URINE AND FAECES

Ecological sanitation must among others be safe and secure recycling of human nutrients of high quality back to agriculture.

Table 1 shows that even if human urine is only less than 1,5 % of the volume of household wastewater it contains most of the nutrients and only a very small part of the heavy metals.

Table 1 Distribution of mass, nutrients and heavy metals in domestic wastewater (19)

Parameter	Unit	Urine	Faeces	Greywater
Mass	kg/year	550	40	40 000
Nitrogen	%	80	11	9
Phosphorous	%	55	28	17
Potassium	%	60	16	24
Copper	%	1.407	15.290	83.303
Chromium	%	0.333	0.657	99.010
Nickel	%	0.347	3.602	96.051
Zinc	%	0.099	24.397	75.504
Lead	%	0.063	0.662	99.275
Cadmium	%	0.579	5.355	94.066
Mercury	%	3.030	46.060	50.910

Table 2 shows the contents of heavy metals related to Danish limit values. Especially the values for urine are very much under the limit values.

Table 2 Heavy metals in human urine and human faeces in relation to dry material (DM) and compared to Danish limit values (13), (19)

Parameter	Unit	Urine	Faeces	Limit values
Copper	mg/kg DM	1.690	22.333	1 000
Chromium	mg/kg DM	0.469	0.406	100
Nickel	mg/kg DM	0.119	1.500	30
Zinc	mg/kg DM	0.731	219.000	4 000
Lead	mg/kg DM	0.032	0.406	120
Cadmium	mg/kg DM	0.018	0.206	0.8
Mercury	mg/kg DM	0.023	0.422	0.8

Human urine is only considered a potential health problem due to potential cross contamination by faecal material. Table 3 shows values for indicator bacteria's in fresh human faeces.

Table 3 Contents of indicator bacteria in human faeces (14), (15)

Indicator bacteria	Unit	Content in faeces
Total koliforms	Cfu/g	10 000.000 – 1 000 000 000
E.coli	Cfu/g	10 000 000 – 1 000 000 000
Enterococci	Cfu/g	100 000 – 1 000 000

NO MIXING TOILETS AND WATERLESS URINALS

Human beings with two outlets for urine and faeces are constructing toilets with only one inlet. Mixing is the answer to an often forgotten question. Why mixing? No mixing toilets and waterless urinals are possibilities to continue where our natural physical process ends with reflected handling and processing of our human restproducts. We must consciously design restproducts.

EXPERIENCES WITH AND FUNCTIONING OF SYSTEMS

"Museumsgården" (Møn)

Museumsgården is a museum open in the summer season. The museum collects human urine mixture in two 5-m³ tanks from visitors using four flushing diverting toilets "WM-DS" and one waterless urinal. The typicle visitor is a one-time visitor. The system installed in 1998 has been functioning very well and due to very good information there has been no problems with the use of the system (13).

Allotment gardens

89 diverting toilets, eight different models, without water flush and typically 25-l containers for collecting urine were installed in 1999 – 2000. Specified user experiences with functioning of the different parts of the systems and handling of human urine and human faeces were collected from 81 of the installations. The families has agreed to join the project,

has chosen and installed the diverting toilet them selves and further on also handled human urine and faeces them selves. All of the interviewed families were either satisfied or very satisfied with the systems (6).

Hyldespjældet and Svanholm

9 diverting flushing toilets "WM-DS" were installed in 1998 in 9 flats with totally 12 grown ups and 10 children in Hyldespjældet and two toilets "WM-DS" were in the same year installed at the organic farming estate "Svanholm". The toilets have been accepted but the users would like further development of the water flush for urine, the water lock and the user friendliness for the children (1), (16), (18).

CONTENTS IN COLLECTED AND STORED HUMANE URINE SOLUTION COMPARED TO OTHER ORGANIC FERTILIZERS

Table 4 shows electrical conductivity and content of nutrients in different urine mixtures.

Table 4 Electrical conductivity and content of nutrients in EPA projects (6), (11), (13), (16)

Parameter	Unit	Møn T0	Møn T4	Møn T6	Hyldes.	Svanh.	Allotm.
El.conductivity	ms/m	1 500	1 500	1 400	1 400	1 730	3 000
Nitrogen	mg/l	1 800	1 500	1 600	2 000	2 500	5 400
Phosphorous	mg/l	74	77	68	100	170	360
Potassium	mg/l	680	670	590	430	1 200	1 100
Ammonium	mg/l	1 800	1 500	1 600	1 500	2 200	5 100
Calcium	mg/l	36.6			20,4		9.67
Magnesium	mg/l	<1.80			<1.80	0.2	<1.8
Sodium	mg/l	616			756		1 700

T(x): Month of storage without further supply

In table 5 the content of nutrients in "Møn" is compared to contents in other organic fertilisers. It is obvious that especially the concentration of P is very low in "Møn"

Table 5 Contents of nutrients in collected urine mixture "Møn" compared to other organic fertilisers(11), (13), (19)

Parameter	Unit	Urine	Møn, T0	Waste water Sludge	Compost	Pig manure	Cattle manure
DM-percent.	%	3.98	0.3384	13.648	66.434	6.739	11.899
Nitrogen	mg/kg Mass	7 300	1 800	5 897	5 944	9 058	7 377
Nitrogen	mg/kg dDM	130 000	532 544	43 500	9 000	127 000	55 000
Phosphorous	mg/kg Mass	670	74	4 297	1 399	1 812	857
Phosphorous	mg/kg dDM	16 700	21 893	30 300	2 000	28 000	11 000
Potassium	mg/kg Mass	2 000	680	421	2 448	3 261	6 188
Potassium	mg/kg DM	35 000	201 183	3 600	3 500	72 000	50 000

Table 6 shows contents of heavy metal compared and related to Danish limit values on the basis of dry material. The contents in "Møn" are by far the lowest.

Table 6. Contents of heavy metals in organic fertilisers compared to "Møn" and Danish limit values (6), (11), (13)

Parameter	Unit	WW Sludge	Househ. Compost	Pig manure	Cattle Manure	MønsT0	Danish Limit v.
Cadmium	Mg/kgsDM	2.0	0.3	0.5	0.6	>0.0118	0.8
Mercury	Mg/kgsDM	1.4	0.1	<0.1	<0.1	-	0.8
Lead	Mg/kg DM	71	32	3	4	0.49	120
Nickel	Mg/kg DM	23	9	14	8	1.25	30
Chromium	Mg/kg DM	32	11	10	3	0.49	100
Zinc	Mg/kgsDM	760	150	1.500	150	45.86	4 000
Copper	Mg/kgsDM	262	50	630	65	3.05	1 000

In table 7 the levels are compared on the basis of N which would be the interesting parameter Using urine mixture as a fertiliser. The values for urine mixture are far below the values for other fertilisers.

Table 7. Heavy metals in urine mixture "Møns" compared to other organic fertilisers. Concentrations in mg/kg N. (11), (13)

Parameter	Unit	MønsT0	WW Sludge	Housh. compost	Pig Manure	Cattle Manure
Cadmium	mg/kg N	<0.02	32.9	35	3.6	8.5
Chromium	mg/kgsN	<0.91	929	1 118	72	45
Copper	mg/kgsN	5.72	17 857	5 588	2 640	1 097
Mercury	mg/kg N		31.4	12		
Nickel	mg/kg N	2.34	571	1 000	96	116
Zinc	mg/kg N	86.11	7 000	16 471	6 120	1 742
Lead	mg/kg N	0.92			24	58

Table 8 shows contents of PAH, DEHP, NPE and LAS found in different urine mixtures.

Table 8. Contents of PAH, DEHP, NPE and LAS, in human urine mixtures in EPA projects (11), (13)

Parameter	Unit	MønsT0	MønsT4	Møn T6	Hyldesp. T0	Svan-holm	Allotm.g. T0
PAH	ug/l	0.000	0.069	0.34	0.094	<10	0.85
DEHP	ug/l	2.4	20	5.4	3.0	29.0	20
NPE	ug/l	0.0	9.8	11	0.0	<15	27
LAS	ug/l	<20	<20	<20	<20	<0.030	<0.02

In table 9 contents are compared and it is shown that urine mixture is far below sludge and compost and at the same level as manure.

Table 9. Contents of LAS, PAH, NPE and DEHP in "Møn" compared to contents in sludge, compost and manure. Concentrations in mg/kg N (6), (13)

Parameter	Unit	Møn T0-T6	WW Sludge	HH Compost	Pig Manure	Cattle Manure
LAS	mg/kg N	<12.5	61 429	2 353		
PAH	mg/kg N	0 - 0.2	143	59	0,16	0.32
NPE	mg/kg N	0 - 6.9	357	59	8	16
DEHP	mg/kg N	1.3 - 13.3	857	1 176		

In table 10 contents of microorganisms in urine mixtures are compared

Table 10. Contents of microorganisms in urine mixture "Møn's" and other urine mixtures (6), (13)

Parameter	Unit	Time Tmonth	Møn	Hyldebjerg.	Allotment garden
<i>Bacterial Indicators</i>					
Kimalt 37 grader	cfu/ml	T0	16 000	9 700	470 000
		T1	900	1 000	100
		T2	500	100	<100
		T3	700	<100	
		T4	500	<100	
		T5	600	500	
		T6	670	3100	
Termotol. Coliforms	cfu/100 ml (mg)	T0 T1	<2		<1 <1
E.coli	cfu/100 ml	T0 T1 T2	<1 <10 <10	<10 <10 <10	
Enterococci	cfu/100 ml	T0	1 800	3 300	1 500 000
		T1	350	320	40
		T2	<10	340	<10
		T3	<1	4	
		T4	<10	<10	
		T5	10	10	
		T6	50	<10	
<i>Infect. Bacteria</i>					
Campylo- bacter	c/10 g (ml)	T0-T2	Neg.	neg.	neg.(T0-T1)
Salmonella	c/10 g (ml)	T0-T2	Neg.	neg.	i.p. (T0-T1)
<i>Parasites</i>					
Cryptosp. Parvum	Positive/ Negative (antal pr. ml.)	T3	Pos.(6)	pos.	neg. (T1)
		T4	Pos.(11)	pos.	
		T5	Pos.(11)	pos.	
		T6	Pos.(5)		
Giardia	pos./neg.		Neg.	neg.	neg.
Duodenalis	pos./neg.		Neg.	neg.	neg.
Other ind. Parasites	pos./neg.		Neg.	neg.	neg.

In table 11 contents of microorganisms in "Møn" are compared to contents in manure, sludge and treated biomass. It is shown that contents in "Møn" was very much lower.

Table 11. Contents of microorganisms in "Møn" compared to manure, sludge and treated biomass (2), (8), (9), (13), (20)

Parameter	Møn T2 (T6)	Pig Manure	Cattle Manure	Aerobic Stabilised WW sludge	Anaerobic Digested WW sludge	Treated biomass from biogas plants
Kimtal Cfu/ml	500 (670)	340 000 to 100 000	2 000 000 to 32 000 000			70 000 to 24 500 000
Enterococci. Cfu/100 ml	<10 (50)	220 000 to 43 000 000	1 300.000 to 48 000 000	200.000 to 29 000 000	70.000 to 1 400 000	<1 000 to 83 000 000
Campyl. bacter c/10 g	Neg.	Pos. In 53,5 % of livestock	pos. In 50% of livestock			
Salmonella c/10 g	Neg.	Up to 280 000	up to 280 000	130 to 5 000	20 to 300	pos. ins4 out of 53 sampl.
Gardia c/ml	Neg.	0 – 300	0 – 100			
Cryptos. c/ml	Up to 11	0 – 200	0 – 100			

SWEDISH RECOMENDATIONS

In Sweden "Swedish institute for Infectious Disease Control" recommends a storage time for urine mixture for minimum 1 or 6 month depending on storage temperature and fertilized crop. For using the urine produced in the family in their own garden no storage should be necessary (15)(16).

CONCLUSIONS

The analyzed urine mixture "Møn" was compared to other organic fertilizers. The results show that the quality of the urine mixture was very high. There was no sign of a high cross contamination from faeces to the urine system (13).

REFERENCES

1. Agenda Center Albertslund, Povl Markussen 2001: "Urinopsamling og -anvendelse i Hyldepjældet". Økologisk byfornyelse og spildevandsrensning nr. 10, Miljøstyrelsen 2001

2. Andersen, J. S., Hald, T 2001: "Risikovurdering ved anvendelse af vandingskanoner til udspredding af gylle fortyndet med vand". Miljøprojekt nr. 606, 2001. Miljøstyrelsen.
3. Ansbæk, J., Vandmiljøkontoret 1997: "Hvad er bæredygtig spildevandsrensning?" og "Eksempler på bæredygtig spildevandsrensning" Art. i TÆT PÅ Nr. 19 oktober 1997. Storstrøms Amt/TEKNIK OG MILJØ
4. Backlund, A. 2001: Udvidelse af vidensgrundlaget vedrørende.....(Manuscript to EPA report)
5. Backlund, A. m.fl. 1999: Spørgeskema til brug ved telefoninterviews med og besøg hos projektdeltagere i M 226-0057.
6. Backlund, A m.fl. 2001: Økologisk håndtering af urin og fækalier i kolonihaver ved hjælp af kildesortering toiletter. Manuscript to EPA report.
7. Backlund, A. 2001: Third individual progress report FAIR CT97-3947 "Biomass short rotation willow coppice fertilized with nutrient from municipal wastewater (BWCW). Ed. Stig Larsson in report with the same title.
8. Bendixen, H.J. et al. 1995: Smittstoffreduktion i biomasse. Det veterinære forsøgsprogram i biogasfællesanlæg, Bind 1: Hovedrapport 1995. Landbrugs- og Fiskeriministeriet. Veterinærdirektoratet
9. Bendixen, H.J. udateret; Hygiene Aspects Of Anaerobic Digestion Of Mixed Wastes. Requirements in Danish Biogas Plants.
10. Drangert, J.-O., Bew, J. Winblad, U. 1997: Ecological Alternatives In Sanitation. Proceedings from Sida Sanitation Workshop. Balingholm, Sweden 6 – 9 August 1997. Publications on Water resources: No 9. Sida Swedish International development Cooperation Agency. Department for Natural Resources and the Environment. Stockholm. Sweden.
11. Eilersen, A.M., Magid J., Tjell J.C. 1998: Genanvendelse af affald på jord s. 493 – 510 i "Affaldsteknologi". Ed. T.H. Christensen. Teknisk forlag. København.
12. Esrey, S.A., Gough, J., Rapaport, D., Sawyer, R., Simpson-Hébert, M., Vargas, J., Winblad, U. 1998: Ecological Sanitation. Sida. Swedish International Development Cooperation Agency. Stockholm. Sweden.
13. Holtze, A., Backlund, A.: Opsamling af urinblanding fra kildesortering toiletter og et vandfrit urinal på Museumsgården. Manuscript to EPA report.
14. Höglund, C. 2001: Evaluation of microbial health risks associated with the reuse of source-separated human urine. Royal Institute of Technology (KTH). Swedish Institute for Infectious Disease Control (SMI). Department of Water and Environmental Microbiology. Stockholm. Sverige.
15. Jönsson, H., Vinnerås, B., Höglund, C., Stenström, T. A., Dalhammar, G., Kirchmann H. 2000: Kålsorterad humanurin i kretsloop. VA-FORSK RAPPORT 1/2000, Stockholm, Sverige.
16. Kolby, E., Jansen J.L.2001: "Udnyttelse af næringssalte i urin på Svanholm gods". Økologisk byfornyelse og spildevandsrensning nr. 4. Miljøstyrelsen 2001
17. Lange, J., Otterpohl, R. 1997: Abwasser - Handbuch zu einer zukunfts-fähigen Wasserwirtschaft. Donaueschingen-Pföhren. Tyskland.
18. Rex, Tue 2000: Et casestudie af urinopsamling og – udbringelse i Hyldebjerg. Institut for Planlægning. DTU.
19. Vinnerås, B. 2001: Faecal separation and urine diversion for nutrient management of household biogradable waste and wastewater. Swedish University of Agricultural Sciences. Department of Agricultural Engineering. Report 244.
20. VKI – Vandkvalitetsinstituttet 1997: "Hygiejniske aspekter ved behandling og genanvendelse af organisk affald". Miljøprojekt nr. 351. Miljøstyrelsen.