Annex V: Humanure Composting

The applicants are applying the principles set out in *The Humanure Handbook, 4th Edition*, which is freely available from the author's website[1]. In line with the applicant's commitment to environmentally-sustainable farming and living, they have fully moved away from defecating and urinating in drinking water. (If anyone were to begin the process – without any prior examples – to invent a sanitation system today, it is inconceivable that they would choose to pollute drinking water, and by extension, our rivers and watercourses, with human effluent.)

As explained in the book:

> *"… human excrement is actually a recyclable resource. It has value as food for microbes. The microbes eat it, along with just about any other organic materials we can throw at them, and they convert it to compost. When composting is used as a sanitation system, sewage can be eliminated, as can diseases associated with fecal contamination of the environment; toilets can be located comfortabl[y] indoors where they're safe and convenient; and they can be odor-free. There is no waste as nothing is being wasted, and the result is compost suitable for growing food."*
>
> *Chapter 12: Compost Toilets and Dry Toilets, pp. 140-1*

The author explains in some detail the difference between humanure composting, and a composting toilet, pointing out that none of the so-called 'composting toilets' on the market today are actually doing the composting. Rather, with humanure sanitation, the toilet is merely a collection receptacle, and the composting happens elsewhere.

The principles are very simple:

- Human effluent is collected in a bucket with a toilet seat;
- Each time the 'toilet' is used, a layer of cover material* is applied;
- When the toilet bucket is full, it is emptied into a designated receptacle, and may or may not be topped off with food waste from cooking processes, to be kept until several buckets are emptied at the same time;
- When that time comes, all the buckets are emptied into a designated humanure compost bay**;
- The new layer within the compost bay is then covered with a full layer of cover material (the applicants use straw), protected with a piece of mesh to deter animal interference with the material, and provided with rain shelter, and left to break down;
- Regular monitoring of the core temperature can provide reassurance that the necessary aerobic conditions and the generation of mesophilic and thermophilic heat by microorganisms is happening, and that toxic pathogens will be successfully eliminated;

[1] https://humanurehandbook.com/contents.html

- Providing the material in the bay has reached sufficiently high temperatures for enough time, then after approximately one year, nutrient-rich, non-toxic compost will be ready for use to grow food.

* Cover materials include any organic matter which will effectively smother the deposit, ensuring that no air can escape, and therefore, no bad odours are emitted. This also prevents the attraction of flies and other pests. The applicants have used:

- Chopped straw;
- Shredded cardboard;
- Grass clippings;
- Wood ashes;
- Wood pellets; and
- Sawdust

Odour and pests are simply not a problem, which is a clear indication that the balance of the organic materials in the toilet is appropriate for the purpose.

** The designated humanure compost bay on Oak Court Farm is situated behind the hedge between the two fields on the site. It is surrounded by pallets, lined with a thick layer of straw, and all the humanure deposits are placed into the centre, then more straw is laid on top and around it.

The humanure bay can also be used to compost other farm resources, particularly including:

- Livestock/poultry bedding and excreta;
- Carcass remains after culling and processing, including bones, feathers, etc.;
- Oils previously used for cooking;
- Petroleum-based 'waste' products, such as stale petrol, etc., providing the balance within the bay is maintained.

> *"Compost microorganisms not only convert organic material into compost and eliminate disease organisms in the process, but they also degrade toxic chemicals into simpler, benign organic molecules. These chemicals include gasoline, diesel fuel, jet fuel, oil, grease, wood preservatives, polychlorinated biphenyls (PCBs), coal gasification wastes, refinery wastes, insecticides, herbicides, TNT, and other explosives*."
>
> *Chapter 10: Compost Miracles, p.103*

(By using humanure composting to process livestock/poultry excreta, the applicants can mitigate the potential increase in phosphate levels which are a known challenge, particularly with poultry waste.)

In the same area, there is a second bay, containing straw ready for application whenever the buckets are emptied, and an IBC of previously harvested rainwater, for washing out the buckets. The water used to wash out the buckets is added to the humanure bay, to ensure

no contamination in other areas, and to provide the microorganisms with necessary water for their survival, since the bay is provided with a rain shelter.

The benefits of this system, the applicants suggest, are evident and numerous:

- No water is wasted flushing toilets;
- No sewage treatment is required;
- No sewage needs to be transported;
- No risk of effluent run-off into rivers and watercourses (as is happening all too frequently with more 'standard' sanitation systems in recent years);
- Nutrient-rich compost is being produced, which can be used to avoid having to buy inputs in future years to support the operations of the business.

The Humanure Handbook presents important scientific data, demonstrating that:

> "*Humanure is not any more dangerous than the body from which it is excreted. The danger lies in what we do with the excrement, not in the material itself. […] When we discard humanure as a waste material and pollute our soil and water supplies with it, we are using it improperly, and that is where the danger lies. When we constructively recycle humanure by composting, it enriches our soil, and […]" actually makes life easier for us.*"
>
> *Chapter 13: Worms and Disease, p.170*

A number of useful tables are provided in this chapter. Potential pathogens in humanure fall into four general categories: viruses, bacteria, protozoa, and worms. The tables are reproduced below, for ease of reference:

Table 1: POTENTIAL PATHOGENS IN URINE

Healthy urine on its way out of the human body may contain up to 1,000 bacteria, of several types, per milliliter. More than 100,000 bacteria of a single type per milliliter signals a urinary tract infection. Infected individuals will pass pathogens in the urine that may include:

Bacteria	**Disease**
Salmonella typhi	Typhoid
Salmonella paratyphi	Paratyphoid fever
Leptospira	Leptospirosis
Yersinia	Yersiniosis
Escherichia coli	Diarrhea

Worms	**Disease**
Schistosoma haematobium	schistosomiasis

Source: Feachem et al., 1980; and Franceys, et al. 1992; and Lewis, Ricki. (1992). *FDA Consumer*, September 1992. p. 41.

Table 2: MINIMAL INFECTIVE DOSES For Some Pathogens and Parasites

Pathogen	**Minimal Infective Dose**
Ascaris	1-10 eggs
Cryptosporidium	10 cysts
Entamoeba coli	10 cysts
Escherichia coli	1,000,000-100,000,000
Giardia lamblia	10-100 cysts
Hepatitis A virus	1-10 PFU
Salmonella spp.	10,000-10,000,000
Shigella spp.	10-100
Streptococcus fecalis	10,000,000,000
Vibrio cholerae	1,000

Pathogens have various degrees of *virulence*, which is their potential for causing disease in humans. The minimal infective dose is the number of organisms needed to establish infection.

Source: Bitton, Gabriel. (1994). Wastewater Microbiology. New York: Wiley-Liss, Inc., p. 77-78. and *Biocycle*, September 1998, p. 62.

p. 178

Table 3: POTENTIAL VIRAL PATHOGENS IN FECES

Virus	Disease	Can Carrier Be Symptomless?
Adenoviruses	varies	yes
Coxsackievirus	varies	yes
Echoviruses	varies	yes
Hepatitis A	Infectious hepatitis	yes
Polioviruses	Poliomyelitis	yes
Reoviruses	varies	yes
Rotaviruses	Diarrhea	yes

Rotaviruses may be responsible for the majority of infant diarrheas. Hepatitis A causes infectious hepatitis, often without symptoms, especially in children. Coxsackievirus infection can lead to meningitis, fevers, respiratory diseases, paralysis, and myocarditis. Echovirus infection can cause simple fever, meningitis, diarrhea, or respiratory illness. Most poliovirus infections don't give rise to any clinical illness, although sometimes infection causes a mild, influenza-like illness which may lead to virus-meningitis, paralytic poliomyelitis, permanent disability, or death. It's estimated that almost every-one in developing countries becomes infected with poliovirus, and that one out of every thousand poliovirus infections leads to paralytic poliomyelitis.

Source: Feachem et al., 1980

Table 4: POTENTIAL BACTERIAL PATHOGENS IN FECES

Bacteria	Disease	Symptomless Carrier?
Campylobacter	Diarrhea	yes
E. coli	Diarrhea	yes
Salmonella typhi	Typhoid fever	yes
Salmonella paratyphi	Paratyphoid fever	yes
Other *Salmonellae*	Food poisoning	yes
Shigella	Dysentery	yes
Vibrio cholerae	Cholera	yes
Other *Vibrios*	Diarrhea	yes
Yersinia	Yersiniosis	yes

Source: Feachem et al., 1980

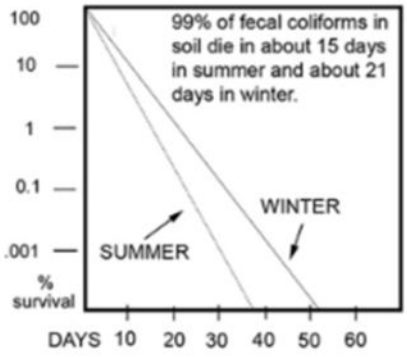
p.180

Table 5:
POTENTIAL PROTOZOAN PATHOGENS IN FECES

Protozoa	Disease	Symptomless Carrier?
Balantidium coli	Diarrhea	yes
Entamoeba histolytica	Dysentery, colonic ulceration, liver abscess	yes
Giardia lamblia	Diarrhea	yes

Source: Feachem et al., 1980

SURVIVAL TIMES OF FECAL COLIFORMS IN SOIL



Source: Recycling Treated Municipal Wastewater and Sludge Through Forest and Cropland. Edited by William E. Sopper and Louis T. Kardos. 1973. p. 82. Based on the work of Van Donsel, et al., 1967.

Table 7:
AVERAGE DENSITY OF FECAL COLIFORMS EXCRETED IN 24 HOURS
(millions/100 ml)

Human	13.0
Duck	33.0
Sheep	16.0
Pig	3.3
Chicken	1.3
Cow	0.23
Turkey	0.29

Source: Agricultural Waste Management Field Manual. United States Soil Conservation Service. August 1975. P.16-12.

p.182

Table 6:
POTENTIAL WORM PATHOGENS IN FECES

Note: hum. = human; intes.=intestinal; Chin.=Chinese; Vietn=Vietnam

Common Name	Pathogen	Transmission	Distribution
1. Hookworm	*Ancylostoma doudenale* *Necator americanus*	Hum.-soil-human.	Warm, wet climates
2. ----------	*Heterophyes heterophyes*	Dog/cat-snail-fish-hum.	Mid. East/S. Eur./Asia
3. ----------	*Gastrodiscoides*	Pig -snail- aquatic vegetation-hum.	India/Bangla./Vietn./ Philippines
4. Giant intes. fluke	*Fasciolopsis buski*	Human/pig-snail- aquatic vegetation-human	S.E. Asia/China
5. Sheep liver fluke	*Fasciola hepatica*	Sheep -snail - aquatic vegetation -human	Worldwide
6. Pinworm	*Enterobius vermicularis*	Human-human	Worldwide
7. Fish tapeworm	*Diphyllobothrium latum*	Human/animal-copepod - fish-human	Mainly temperate
8. Cat liver fluke	*Opisthorchis felineus* *O. viverrini*	Animal-aquatic snail- fish-human	USSR/Thailand
9. Chin. liver fluke	*Chlonorchis sinensi*	Animal/human-snail-fish- human	S.E. Asia
10. Roundworm	*Ascaris lumbricoides*	Human-soil-human	Worldwide
11. Dwarf tapeworm	*Hymenolepsis* spp.	Human/rodent-human	Worldwide
12. ----------	*Metagonimus yokogawai*	Dog/cat-snail-fish-hum.	Jap./Kor./Chi./ Taiw./Siberia
13. Lung fluke	*Paragonimus westermani*	Animal/human-snail - crab/crayfish-human	S.E. Asia/Africa/ S. America
14. Schistosome, bil.	*S. haematobium*	Human-snail-human	Africa, M. East, India
----------	*Schistosoma. mansoni*	Human-snail-human	Afr., Arabia, Ltn. Amer.
----------	*S. japonicum*	Animal/hum.-snail-hum.	S.E. Asia
15. Threadworm	*Strongyloides stercoralis*	Hum.-hum. (dog-hum.?)	Warm, wet climates
16. Beef tapeworm	*Taenia saginata*	Human-cow-human	Worldwide
Pork tapeworm	*T. solium*	Human-pig-human or human-human	Worldwide
17. Whipworm	*Trichuris trichiura*	Human-soil-human	Worldwide

Source: Feachem et al., 1980

p.183

"*The viruses, bacteria, protozoa, and worms that can be excreted in humanure all have limited survival times outside of the human body.*"

p.187

The tables reproduced below reveal the survival times for these pathogens in soil:

Table 8:
SURVIVAL OF ENTEROVIRUSES IN SOIL

Viruses - These parasites, which are smaller than bacteria, can only reproduce inside the animal or plant they parasitize. However, some can survive for long periods outside of their host.

Enteroviruses - Enteroviruses are those that reproduce in the intestinal tract. They have been found to survive in soil for periods ranging between 15 and 170 days. The following chart shows the survival times of enteroviruses in various types of soil and soil conditions.

Soil Type	pH	% Moisture	Temp. (C)	Days of Survival (less than)
Sterile, sandy	7.5	10-20%	3-10	130-170
		10-20%	18-23	90-110
	5.0	10-20%	3-10	110-150
		10-20%	18-23	40-90
Non-sterile, sandy	7.5	10-20%	3-10	110-170
		10-20%	18-23	40-110
	5.0	10-20%	3-10	90-150
		10-20%	18-23	25-60
Sterile, loamy	7.5	10-20%	3-10	70-150
		10-20%	18-23	70-110
	5.0	10-20%	3-10	90-150
		10-20%	18-23	25-60
Non-sterile, loamy	7.5	10-20%	3-10	110-150
		10-20%	18-23	70-110
	5.0	10-20%	10	90-130
		10-20%	18-23	25-60
Non-sterile, sandy	5	air dried	18-23	15-25

Source: Feachem et al., 1980

Table 9:
SURVIVAL OF E. HISTOLYTICA PROTOZOA IN SOIL

Protozoa	Soil	Moisture	Temp (C)	Survival
E. histolytica	loam/sand	Damp	28-34	8-10 days
E. histolytica	soil	Moist	?	42-72 hrs.
E. histolytica	soil	Dry	?	18-42 hrs.

Source: Feachem et al., 1980

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Table 10:
SURVIVAL TIMES OF SOME BACTERIA IN SOIL

Bacteria	Soil	Moisture	Temp.(C)	Survival
Streptococci	Loam	?	?	9-11 weeks
Streptococci	Sandy loam	?	?	5-6 weeks
S. typhi	various soils	?	22	2 days-400 days
Bovine tubercule bacilli	soil & dung	?	?	less than 178 days
Leptospires	varied	varied	summer	12 hrs-15 days

Source: Feachem et al., 1980

Table 11:
SURVIVAL OF POLIOVIRUS IN SOIL

Soil Type	Virus	Moisture	Temp.(C)	Days Survival
Sand dunes	Poliovirus	dry	?	Less than 77
Sand dunes	Poliovirus	moist	?	Less than 91
Loamy fine sand	Poliovirus I	moist	4	90% red. in 84
Loamy fine sand	Poliovirus I	moist	20	99.999% reduction in 84
Soil irrigated w/ effluent, pH=8.5	Polioviruses 1, 2 & 3	9-20%	12-33	Less than 8
Sludge or effluent irrigated soil	Poliovirus I	180 mm total rain	-14-27	96-123 after sludge applied
			-14-27	89-96 after effluent applied
		190 mm total rain	15-33	less than 11 after sludge or effluent applied

Source: Feachem et al., 1980

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Table 12:
SURVIVAL TIMES OF SOME PATHOGEN WORMS

Soil	Moisture	Temp. (C)	Survival
HOOKWORM LARVAE			
Sand	?	room temp.	< 4 months
Soil	?	open shade, Sumatra	< 6 months
Soil	Moist	Dense shade	9-11 weeks
		Mod. shade	6-7.5 weeks
		Sunlight	5-10 days
Soil	Water covered	varied	10-43 days
Soil	Moist	0	< 1 week
		16	14-17.5 weeks
		27	9-11 weeks
		35	< 3 weeks
		40	< 1 week
HOOKWORM OVA (EGGS)			
Heated soil with night soil	water covered	15-27	9% after 2wks
Unheated soil with night soil	water covered	15-27	3% after 2wks
ROUNDWORM OVA			
Sandy, shaded		25-36	31% dead after 54 d.
Sandy, sun		24-38	99% dead after 15 d.
Loam, shade		25-36	3.5% dead after 21 d.
Loam, sun		24-38	4% dead after 21 d.
Clay, shade		25-36	2% dead after 21 d.
Clay, sun		24-38	12% dead after 21 d.
Humus, shade		25-36	1.5% dead after 22 d.
Clay, shade		22-35	more than 90 d.
Sandy, shade		22-35	less than 90 d.
Sandy, sun		22-35	less than 90 d.
Soil irrigated w/sewage		?	less than 2.5 yrs.
Soil		?	2 years

Source: Feachem et al., 1980; d.=days; <=less than

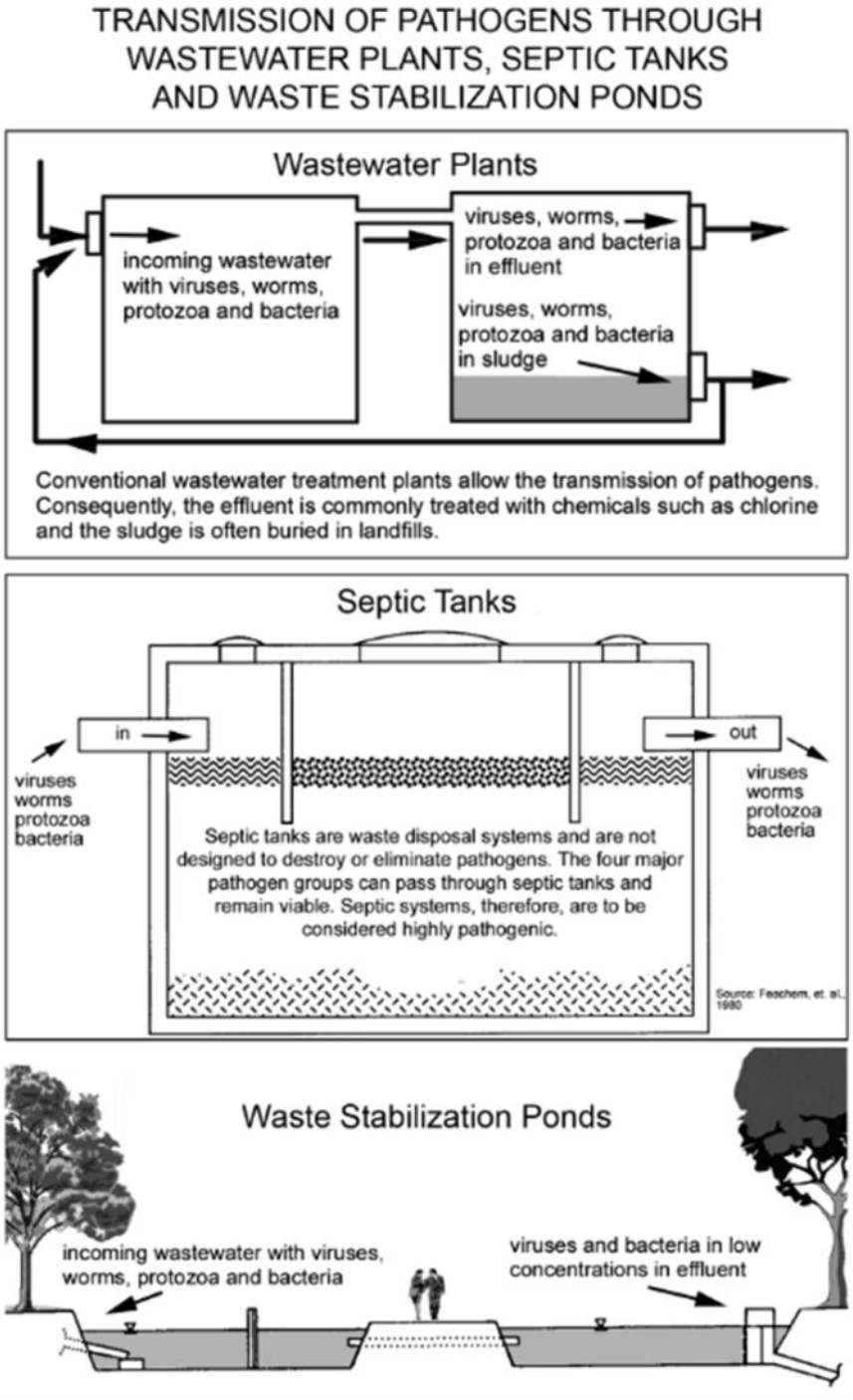
Table 13:
PARASITIC WORM EGG DEATH

Eggs	Temp.(C)	Survival
Schistosome	53.5	1 minute
Hookworm	55.0	1 minute
Roundworm	-30.0	24 hours
Roundworm	0.0	4 years
Roundworm	55.0	10 minutes
Roundworm	60.0	5 seconds

Source: Compost, Fertilizer, and Biogas Production from Human and Farm Wastes in the People's Republic of China. (1978), M. G. McGarry and J. Stainforth, editors, International Development Research Center, Ottawa, Canada. p. 43.

p.190

As indicated earlier, the current perilous state of our nation's waterways has been the subject of increasingly heated public debate over the past several years. The fundamental problem appears to be the use of water as a vehicle for transporting effluent waste from large communities. The following illustration demonstrates just how unsanitary this is:



p.194

Indeed, the applicants were warned by one of their neighbours recently that, following heavy rainfall, the River Gwenfro carries sewage run-off which has overflowed from the storm drains. Since the applicants are seeking to improve the riparian habitat along the stretch of the Gwenfro which is part of their landholding, they will be seeking advice on how to mitigate this, to ensure the protection of the water quality for its wildlife residents.

The process of composting – providing the correct balance of materials is achieved – ensures that:

> "*Complete pathogen destruction is guaranteed by arriving at a temperature of 143.6°F (62°C) for one hour, 122°F (50°C) for one day, 114.8°F (46°C) for one week, or 109.4°F (43°C) for one month. It appears that no excreted pathogen can survive a temperature of 149°F (65°C) for more than a few minutes. A compost pile may rapidly rise to a temperature of 131°F (55°C) or above or will maintain a temperature hot enough for a long enough period of time to destroy human pathogens beyond a detectable level.*" *p.196.*

There is limited UK guidance (RPS 318 is aimed at "operators who treat solid waste from portable composting toilets at the depot where the toilets were hired"), but it does provide slightly different temperature thresholds "a minimum of 70°C for 1 hour or 60°C for 48 hours"[2]. This maybe difficult to achieve given the very limited scale of the humanure activities on site.

German guidelines provide yet another set of limits for the thermophilic processing, which appear to be more in line with the available scientific data: minimum temperatures of 55°C for 2 weeks, 60°C for 6 days, or 65°C for 3 days[3]. This appear to a be conservative and achievable guideline to work to.

Indeed, beyond the removal of pathogens. research suggests that humanure composting also reduces the number of antibiotic resistance genes (ARGs) in the microbiome of the compost pile. This is likely due to the lack of an advantage to such genes in the pile, compared with other competitive evolutionary strategies[4]. Given the increase in ARGs in the environment, and particularly the emergence of an increasing number of AR pathogens, this is an important additional benefit of humanure processing.

The applicants will be keeping records of temperature readings from the humanure composting bay, and leaving each humanure bay for a whole year, to ensure that no pathogens could possibly remain within the compost, before it is used. (Having an on-site toxicologist in Tom Pruen, BSc, AppChemSci, PGDip, Tox. provides further reassurance.)

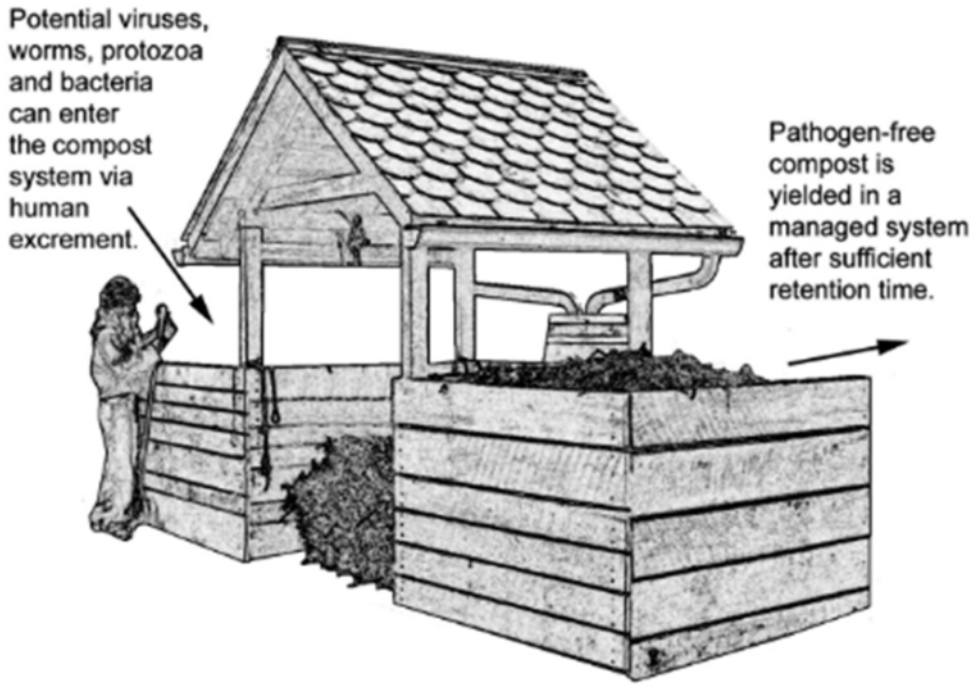
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[2] https://www.gov.uk/government/publications/treating-solid-waste-from-composting-toilets-rps-318

[3] *Bioabfallverordnung in der Fassung der Bekanntmachung vom 4. April 2013 (BGBl. I S. 658), Die Zuletzt Durch Artikel 3 Absatz 2 der Verordnung vom 27. September 2017 (BGBl. I S. 3465) Geändert Worden Ist. Bonn: Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection*

[4] Werner KA, Poehlein A, Schneider D, El-Said K, Wöhrmann M, Linkert I, Hübner T, Brüggemann N, Prost K, Daniel R, Grohmann E. Thermophilic Composting of Human Feces: Development of Bacterial Community Composition and Antimicrobial Resistance Gene Pool. Front Microbiol. 2022 Feb 18;13:824834. doi: 10.3389/fmicb.2022.824834. PMID: 35250940; PMCID: PMC8895236.

TRANSMISSION OF PATHOGENS THROUGH WELL-MANAGED COMPOST



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Further tables illustrate pathogen survival by composting and other methods of disposal:

Table 14:
PATHOGEN SURVIVAL BY COMPOSTING OR SOIL

Pathogen	Soil Application	Unheated Anaerobic Digestion	Dry Toilet (Three mo. min. retention time)	Composting
Enteric viruses	May survive 5 mo	Over 3 mo.	Probably elim.	Killed rapidly at 60C
Salmonellae	3 mo. to 1 yr.	Several wks.	Few may surv.	Dead in 20 hrs. at 60C
Shigellae	Up to 3 mo.	A few days	Prob. elim.	Killed in 1 hr. at 55C or in 10 days at 40C
E. coli	Several mo.	Several wks.	Prob. elim.	Killed rapidly above 60C
Cholera vibrio	1 wk. or less	1 or 2 wks.	Prob. elim.	Killed rapidly above 55C
Leptospires	Up to 15 days	2 days or less	Eliminated	Killed in 10 min. at 55C
Entamoeba histolytica cysts	1 wk. or less	3 wks or less	Eliminated	Killed in 5 min. at 50C or 1 day at 40C
Hookworm eggs	20 weeks	Will survive	May survive	Killed in 5 min. at 50C or 1 hr. at 45C
Roundworm (*Ascaris*) eggs	Several yrs.	Many mo.	Survive well	Killed in 2 hrs. at 55C, 20 hrs. at 50C, 200 hrs. at 45C
Schistosome eggs	One mo.	One mo.	Eliminated	Killed in 1 hr. at 50C
Taenia eggs	Over 1 year	A few mo.	May survive	Killed in 10 min. at 59C, over 4 hrs. at 45C

Source: Feachem et al., 1980

Table 15:
THERMAL DEATH POINTS FOR COMMON PARASITES AND PATHOGENS

PATHOGEN	THERMAL DEATH
Ascaris lumbricoides eggs	Within 1 hour at temps over 50C
Brucella abortus or *B. suis*	Within 1 hour at 55C
Corynebacterium diptheriae	Within 45 minutes at 55C
Entamoeba histolytica cysts	Within a few minutes at 45C
Escherichia coli	One hr at 55 C or 15-20 min. at 60C
Micrococcus pyogenes var. *aureus*	Within 10 minutes at 50C
Mycobacterium tuberculosis var. *hominis*	Within 15 to 20 minutes at 66C
Necator americanus	Within 50 minutes at 45C
Salmonella spp.	Within 1 hr at 55C; 15-20 min. at 60C
Salmonella typhosa	No growth past 46C; death in 30 min. 55C
Shigella spp.	Within one hour at 55C
Streptococcus pyogenes	Within 10 minutes at 54C
Taenia saginata	Within a few minutes at 55C
Trichinella spiralis larvae	Quickly killed at 55C

Source: Gotaas, Harold B. (1956). Composting - Sanitary Disposal and Reclamation of Organic Wastes . p.81. World Health Organization, Monograph Series Number 31. Geneva.

p.199

"*Two primary factors lead to the death of pathogens in humanure. The first is temperature. A compost pile that is properly managed will destroy pathogens with the heat and biological activity it generates.*

The second factor is time. The lower the temperature of the compost, the longer the retention time needed for the destruction of pathogens. Given enough time, the wide biodiversity of microorganisms in the compost will destroy pathogens by antagonism,

competition, consumption, and antibiotic inhibition provided by the beneficial microorganisms."

And

"A thermophilic compost pile will destroy pathogens, including worm eggs, quickly, possibly in a matter of minutes. Lower temperatures require longer periods of time, possibly hours, days, weeks, or months, to effectively eliminate pathogens. One need not strive for extremely high temperatures in a compost pile to feel confident about the destruction of pathogens. It may be more realistic to maintain lower temperatures in a compost pile for longer periods of time…".
p.205

"*When humanure is composted, human pathogens are destroyed and the humanure is converted into a hygienically safe form suitable for human food production.*"
p.206

The applicants are confident that their sanitation arrangements using this method are sound, particularly because of the notable absence of odour or flies around the humanure bay, or the toilet facilities. Although the applicants will be monitoring and recording temperature regularly, by keeping the humanure bay for a year (once filled), they can be confident that all human pathogens will have been completely destroyed.

Furthermore, this approach aligns with national and local policy requirements around sustainable living and agricultural activity.