A STUDY OF OWNER-BUILT COMPOSTING TOILETS IN LISMORE, NSW

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Abstract

This paper describes a study of 20 owner-built composting toilets, built to three generic designs (the large continuous flow Minimus, the large Farallones Batch and the small Barrel Batch) in the Lismore region, New South Wales. The toilets were assessed for owner satisfaction and for compliance of composted end product with the national standard for composting toilets AS/NZS 1546.2:2001. Fifteen of the 20 owners rated their toilet's performance as either "excellent" or "good". The only "poor" rating came from the owner of a Barrel Batch system who had not been adding bulking material. While the three generic toilet designs appear to be basically sound, some toilets required structural adjustment after commissioning. Most problems with toilet management were overcome by minor modifications to management practice on the part of the owner. The study raised a number of questions regarding the standard's requirements for composted end product.

Keywords

Barrel Batch, Farallones Batch, Minimus, owner-built composting toilets, regulatory requirements, resource recovery, source control.

1 Introduction

For most of the 20th Century the major concerns in relation to sanitation and greywater management were with human convenience and the protection of public health. In recent decades environmental protection has emerged as a major issue. Even more recently the Ecological Sanitation movement has drawn our attention to the fact that sustainable societies will need to pay more attention to "closing the loop" by returning excreted nutrients to agricultural soils. Otterpohl (2003) points out that 90% of the nitrogen, 50% of the phosphorus and some 60% of the potassium in the conventional domestic combined wastewater stream is contained in faeces and urine, which occupy only about 1% of the total volume. A number of technologies are currently being developed to take advantage of this concentrated source of nutrients, carbon and energy. Among them are urine-separating toilets (0.2 L flush), ultra low flush vacuum toilets (0.5 L flush) and waterless composting toilets (zero flush). These technologies conserve water and recover resources at source while also meeting the requirements for human convenience as well as public and environmental health protection.

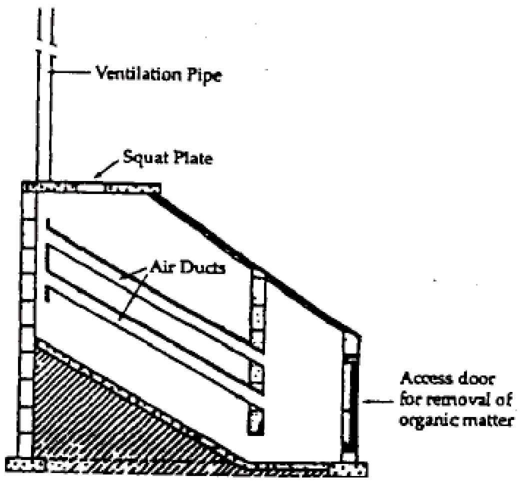

Figure 1: Typical Minimus continuous flow composting toilet. Height = 2 m.

The use of composting toilets is increasing slowly in the state of New South Wales. In 2000 over 1300 domestic on-site systems (roughly 0.5% of total systems in NSW) included a composting toilet (Davison et al. 2001). Some 20% of these (roughly 250 units) were in the Lismore local government area in northern NSW. Approximately 70% of these composting toilets are not factory-built but are constructed either by the owner, or by a local contractor, usually to one of a number of locally adapted generic designs. The most popular owner-built composting toilet design is the "Minimus", a relatively large (~2,000L) continuous-flow device modelled on the commercially available Clivus Multrum. It is usually built in concrete block (Figure 1). Also popular is the "Farallones Batch" system, a relatively large (~2,000L) two-chamber batch device, also commonly constructed in concrete block (Figure 2). Less popular is the "Barrel Batch" system, a batch device based on relatively small (~200 litre) readily available plastic chambers such as wheelie bins or pickle barrels (Figure 3).

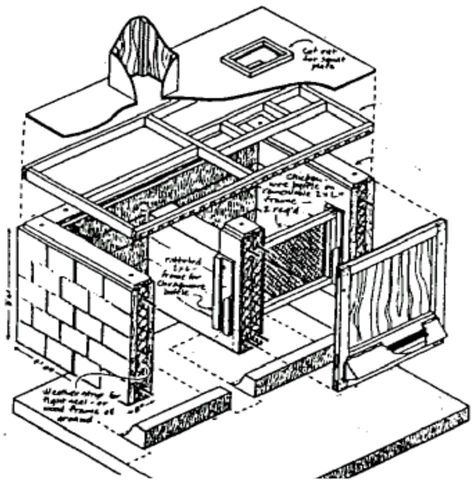

Figure 2: Typical Farallones Batch device - Chamber height ~1m.

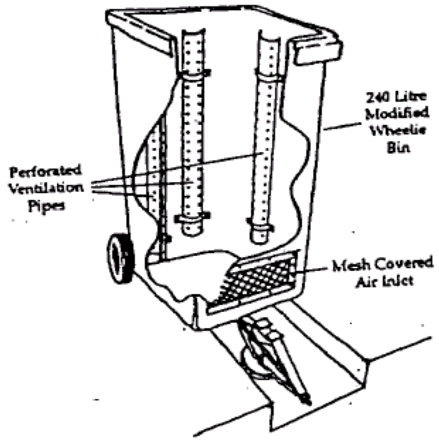

Figure 3: Barrel Batch device – a modified 240 L wheelie bin

Early concerns on the part of local and state government health officials regarding the amenity and safety of owner-built composting toilets were allayed when a study of helminth survival in six composting toilets (four of them owner-built) by Safton (1993) led to the conclusion that "with the possible exception of viruses, the humus end product could be considered pathogen free". The design, construction and performance of composting toilets in Australia and New Zealand is governed by a standard, AS/NZS 1546.2:2001, which requires that each model of toilet be tested for soundness of design and construction and that the end product of at least one unit be tested against the criteria set out in Table 1. This process is economically feasible in the case of standard runs of mass produced toilets but becomes unduly expensive in the case of owner-built toilets which, despite the fact that they tend to be based on generic designs, are each unique in some way. For this reason, few owner-built composting toilets have been assessed against the criteria set out in the standard.

Table 1: AS/NZS1546.2:2001. Composted end product requirements (3 x 2 = 6 samples)

Characteristic	Performance criterion
Consistency	All 6 samples shall contain no recognisable faecal material
Odour	There shall be no offensive odours from the end product immediately following removal from the chamber
Moisture content at base of pile in removal zone	Not to exceed 75% by weight (all 6 samples)
Pathogen indicators (a) Thermotolerant coliforms (b) Salmonella spp.	 Less than 200 per gram dry weight (all 6 samples) Not detectable (all 6 samples)

This paper reports on a study of the performance of 20 owner-built composting toilets and one mass produced toilet from the point of view of (a) owner satisfaction, (b) soundness of design, (c) soundness of construction, (d) level of management and (e) end product compliance with AS/NZS 1546.2:2001. A second aim is to comment on the appropriateness of the performance requirements set out in AS/NZS 1546.2:2001.

2 Methods

A total of 20 owner-built composting toilets (13 Minimus, 5 Farralones Batch and 2 Barrel Batch) and one mass produced toilet (Clivus Multrum) were inspected and three samples of finished product taken per toilet between June and October 2002. These 21 toilets are subsequently referred to as the "Overall Group". An additional three samples of composted end product were taken from eight of the toilets (five of the Minimuses, two of the Farallones and the Clivus Multrum in order to accord fully with procedures specified in AS/NZS 1546.2:2001 which requires that two lots of three end product samples be taken for testing. This subset of eight units is subsequently referred to as the "Intensive Group". All six samples from the eight Intensive Group toilets were analysed individually. For budgetary reasons the three samples from the 13 remaining toilets were pooled to create one composite sample. The samples were tested for pathogen indicators, consistency, moisture content and other physico-chemical parameters. The owners of each of the 21 toilets were also asked to answer a 40 question survey relating to issues such as system design, ventilation, odour problems, leachate and greywater management, bulking material, residence time, reason for choosing a composting toilet, performance of the system, visitor response etc, as well as operation and maintenance. The study is described more fully in Walker (2002).

3 Results and Discussion

3.1 The householder-composting toilet relationship

Thirteen of the toilets in the Overall Group were less than five years old at the time of the study, six were 5-10 years old and two were greater than 10 years old. Eighteen of the 21 units inspected were passively ventilated. Two of the Minimuses had been retrofitted with wind driven extractor fans. The single mass produced Clivus Multrum in the study used a mains powered fan as a standard fitting. All but two householders (both owners of passive Minimuses) considered the ventilation of their toilet to be adequate. Apart from the Clivus Multrum all ventilation pipes were 90-100 mm diameter. Approximately 50% of the ventilation pipes were painted black to enhance upward movement of air. In twelve cases bulking material was added to the heap after every use. Four households practised daily and four practised weekly bulking material addition. The owner of one of the small Barrel Batch units added no bulking material to his toilet with consequent odour problems. Wood shavings and sawdust were used as bulking material in 20 of the households, newspaper in four, grass clippings in three and dry leaves in three. Kitchen scraps were added to the compost heap in twelve of the households. Five of the owners had added worms to their heap, and two were in the habit of adding agricultural lime periodically.

Estimates of the mean residence time of material in the toilets ranged from as much as 34 months for the Minimus design down to 13 and 15 months for the Farallones and Barrel Batch designs respectively. Thirteen of the householders reported that their toilet had at some time produced a "slightly unpleasant" odour. Seven reported either "non-offensive" or no odours. The Barrel Batch unit subject to zero bulking material addition produced an odour classified as "offensive". Of those householders reporting odours, ten undertook no additional remedial management action, four increased the rate of bulking material addition, one improved ventilation of the compost heap, one improved ventilation of the room and one reduced urine input. All 21 householders applied the composted end product to fruit tress or non-edible plants and none applied it to vegetables. This contrasts with a previous study of composting toilet owners in the Lismore area by Pollard et al. (1997) who found that two out of the thirty householders surveyed applied finished product to vegetable gardens.

Table 2 summarises the assessments of the toilet owners themselves and the reactions of their visitors to the composting toilets. It can be seen that the only owner who gave a rating of "poor" was the Barrel Batch owner who experienced odour problems as a result of not adding any bulking material. A conclusion that is drawn from this is that the small size of the Barrel Batch units deters householders from adding bulking material in an effort to maximize time between change-overs. Pollard et al. (1997) came to a similar conclusion regarding the importance of composting chamber size in the achievement of a quality end product and a satisfied user. It is suggested that small units like the Barrel Batch be restricted to households with a maximum of two permanent members. Forty percent of toilet owners reported "complete acceptance" of the composting toilet by all visitors. A further 40% reported "reserved acceptance", that is some initial hesitation on the part of one or more visitors followed by a willingness to participate once the process and requirements had been explained. Only 20% of owners had experienced "total rejection" by one or more visitor.

Table 2: Owner assessment and visitor response to composting toilet vs toilet design

Toilet Design	Householder assessment				Most negative visitor response		
	Excellent	Good	Average	Poor	Complete acceptance	Reserved acceptance	Total rejection
Minimus	4	4	5		5	6	2
Farallones	4	1			2	2	1
Barrel Batch		1		1		1	1
C. Multrum	1				1		
Total	9	6	5	1	8	9	4

3.2 End product quality

Table 3 contains results pertaining to end product quality for each of the 21 toilets in the study. The study sites are presented in four groups according to toilet design. Three of the designs (Clivus Multrum, Farallones Batch and Minimus) were represented in the Intensive Group. In each case the intensively monitored units (6 samples) are placed at the top of their design group. The two right hand columns show that in all but two cases, the compost heap temperature was actually lower than the ambient air temperature. Carbon to nitrogen ratios averaged about 10:1 for the two continuous flow designs (Multrum and Minimus) and 15.5 and 13.6 respectively for the Barrel and Farallones Batch designs. The poorer drainage in the continuous flow toilets, with consequent higher leachate retention, may be the reason for the higher nitrogen content in these units. USEPA (1997) suggests that the optimum C:N ratio for compost materials is 30:1, considerably higher than the ratios recorded in the finished product. There are two possible explanations for the difference: (i) householders are using sub-optimal quantities of carbonaceous bulking material, or (ii) the C:N ratio at the top end of the chamber is roughly in the optimum range and the removal of carbon to the atmosphere is proportionately greater than the removal of nitrogen.

3.3 End product quality and the standard

At Site A the Clivus Multrum failed the moisture and coliform criteria in five of the six samples. While it was found that the leachate drain in this toilet had become partly blocked, the main reason for the high moisture content appeared to be the owner's practice of raking the pile each week with a garden rake and subsequently hosing the rake off while holding it over the compost pile. While none of the Barrel Batch units were in the Intensive Group, comment has already been made on the odour at Site C. Based on the one sample taken from this toilet it appears clear that it would have failed on consistency and coliform concentration.

Two of the five Farallones toilets (Sites, D and E) were in the Intensive Group. Site D was the only one of the eight intensive units to fulfill the moisture content (<75% by weight) requirement on all six samples. Site E was the only one of the eight to pass the coliform test (<200 cfu/g) on all six samples. The five intensively sampled Minimuses (Sites I to M) all had at least one moisture test >75% and two coliform tests >200 cfu/g. On the other hand four of the intensive Minimuses had an average moisture content <75% and all five had a geometric mean coliform count < 200cfu/g. The Minimus at Site N had by far the highest individual coliform reading at 60,000 cfu/g. This was also the youngest of the 21 units as sampling occurred at only 6 months after commissioning. It was discovered that the initial loading of straw and peat moss into this toilet had been inadequate with the result that faecal material was rolling down the slope and into the humus chamber. This was the only unit, apart from the Barrel Batch unit (Site C) with an odour problem. Once again the problem was found to be a result of user inexperience, rather than with toilet design or construction.

Notwithstanding the fact that the most glaringly inadequate performances (Sites C and N) were a result of user inexperience and poor management, it was apparent that several of the units were structurally deficient in at least one respect. For example the surface of the compost pile in a Farallones Batch toilet (Site D) was observed to contain droppings of the species *Mus musculus* (the house mouse). Rodents had also been observed inside two of the Minimus toilets (Sites T and U) about one year before the study. This problem was overcome when the ventilation opening in the lower access door was reinforced with bird wire.

It is clear from the results set out in Table 3 that all three owner-built toilet designs are basically workable if constructed well and loaded and managed appropriately. On the basis of the one composite sample tested for the 13 non Intensive toilets at least one unit in each of the designs appeared to have the potential to meet the standard requirements. One of the two Barrel Batch toilets (Site B) yielded end product with a composite sample (from three points in the heap) that satisfied all five criteria (odour, consistency, moisture, coliforms and Salmonella). A similar result was achieved for three of the five Farallones Batch toilets and six of the thirteen Minimuses. It is ironic that none of these potentially successful toilets was in the Intensive Group. At the structural level issues like rodent-proofing of ventilation openings need to be addressed. This is a problem that can be overcome by Councils insisting that do-it-yourself builders work from accredited working drawings. Excellent plans and construction details for both the Minimus and Farallones Batch units exist and are available at a reasonable price. The large owner-built units (Minimus and Farallones) appear to work satisfactorily under passive ventilation. This makes them more robust in power failure situations (eg solar powered homes during prolonged wet weather). On the other hand occasional off-odours can be experienced. It most likely that the frequency of off-odour events would be reduced if vent diameter was increased from its current 90-100 mm. Table 4 summarises the design, structural and management issues for each model. It is most likely that improved communication regarding management aspects will see a reduction in the sort of problems encountered during this study.

Table 3: Summary of end product quality for the 21 units surveyed. Results for eight Intensive Group units are based on 6 samples. Results for the other 13 units are based on a composite sample taken from three points in the heap. Bold italic entries indicate non compliance with the standard. Group means and medians are presented in plain bold script.

toilet design	Site #	age (yrs)	no. of samples	Odour	consist-ency (faecal material present?)	average moisture content		thermotolerant coliforms			Salmo-nella	average Carbon/ nitrogen ratio (:1)	av. pH	Ambient temp. (°C)	Compost temp. (°C)
						% dry wt.	# samples >75%	geometric mean cfu/g	median cfu/g	#samples >200cfu/g					
Clivus Multrum	A*	2	6	OK	no	***80.2***	***5***	***857***	***1568***	***5***	none	10.1	6.0	21	15
Barrel Batch	B	1	1	OK	no	69.2	0	2	2	0	none	14.6	7.2	21	15
	C	2	1	***BAD***	***YES***	63.2	0	***2720***	***2720***	***1***	none	16.4	7.5	17	13
	group					**66.2**		**74**	**1361**			**15.5**	**7.4**	**19**	**14**
Farallones Batch	D*	0.8	6	OK	no	59.3	0	65	4	***2***	none	18.1	6.3	18	16
	E*	1.5	6	OK	no	75.2	***4***	4	4	0	none	12.6	6.4	14	17
	F	0.7	1	OK	no	66.3	0	12	12	0	none	17.9	6.3	13	9
	G	2	1	OK	no	71.1	0	136	136	0	none	12.4	6.1	16	16
	H	0.8	1	OK	no	59.8	0	2	2	0	none	6.9	7.4	14	13
	group					**66.3**		**15**	**4**			**13.6**	**6.5**	**15.0**	**14.2**
Minimus	I*	1.5	6	OK	no	***80.7***	***5***	25	6	***2***	none	12.6	5.1	21	16
	J*	18	6	OK	no	70.6	***1***	48	75	***2***	none	7.2	5.8	18	12
	K*	17	6	OK	no	74.8	***4***	37	32	***2***	none	10.8	6.1	18	14
	L*	5	6	OK	no	72.6	***1***	193	178	***4***	none	7.4	9.0	16	13
	M*	1.5	6	OK	no	69.4	***3***	122	***395***	***3***	none	11.1	5.4	16	14
	N	0.5	1	***BAD***	***YES***	45.0	0	***60000***	***60000***	***1***	none	11.3	7.3	20	16
	O	5.5	1	OK	no	68.3	0	3	3	0	none	8.5	7.3	19	12
	P	5.5	1	OK	no	26.1	0	1	1	0	none	8.3	6.4	19	13
	Q	5.5	1	OK	no	61.4	0	2	2	0	none	6.7	4.4	21	15
	R	5.5	1	OK	no	68.4	0	3	3	0	none	11.2	5.6	21	14
	S	5	1	OK	no	65.8	0	***548***	***548***	***1***	none	11.4	5.9	18	16
	T	4	1	OK	no	70.8	0	65	65	0	none	12.9	4.5	19	17
	U	2	1	OK	no	72.8	0	3	3	0	none	10.7	7.9	19	17
	group					**65.1**		**35**	**32**			**10.0**	**6.2**	**18.8**	**14.5**

* = Intensive Group

3.4 Appropriateness of end product requirements in AS/NZS1547:2000

The introduction and diffusion of any new technology or practice into society involves an iterative process of adjustment and familiarization on the part of a number of stakeholders. The R&D, manufacturing, sales, and regulatory sectors as well as the consuming public engage in a process of familiarization and assessment. Probably the most difficult task falls on the shoulders of the regulators whose job it is to set the indicators and levels which establish the technology's environmental and public health credentials. This section of the paper examines the requirements for end product quality specified in the national standard with a view to reviewing their appropriateness.

Table 4: Summary of design, construction & management issues of models surveyed

	Model	Design	Structural	Comments on Management
Clivus Multrum	Manufactured Continuous flow large	Already approved in NSW	Already approved in NSW	Management practices contributed to overly moist end product
Barrel Batch	Owner built Batch small	Size limits number of users. Needs frequent change-over	OK	Should be limited to small households with a strong family member as change-over operation requires some strength. The only design to receive a "poor" rating from one owner
Farallones Batch	Owner built Batch large	Large size a plus. Passive ventilation could be improved	rodent proofing of doors and vents	Appeared to be well managed. Received best householder assessment.
Minimus	Owner built Continuous flow large	Large size a plus. Passive ventilation could be improved	rodent proofing of doors and vents	Owner inexperience caused short circuiting of faecal material in one instance. Improved instructions regarding Initial startup of unit would overcome this.

The requirements for consistency (no obvious faecal material in end product) and odour (no offensive odours in end product) are reasonable and obvious. The two toilets that failed on these criteria had problems, both attributable to poor operation.

The requirement regarding Salmonella appears at first glance to be similarly reasonable. However Tranter (2002 pers. comm.) reports that in the NSW Northern Rivers Health Service area, within which the present study was carried out, the incidence of Salmonellosis in the population is less than 5%. It is therefore quite likely that no Salmonella were detected in any of the samples because none of the heaps were infected with these bacteria in the first place. This poses questions regarding the usefulness of Salmonella as an indicator of composting toilet efficacy. Could the money spent on this test be better spent on something else?

The intent of the requirement that moisture content be < 75% by weight no doubt reflects the need to maintain an aerobic environment in the heap favourable to organic matter breakdown and inimical to the generation of unpleasant odours. An examination of Table 3 reveals that the Farallones Batch toilet, in which the heap is supported on a well drained, permeable mesh false floor, averaged only two failures (moisture>75%) per (Intensive Group) unit. On the other hand the continuous flow Minimus, in which the finished product sits on the impermeable base of the unit, averaged almost three failures per intensive group unit. The sampling procedure prescribed in AS/NZS1546.2:2001 requires that, in continuous flow systems "three samples be taken along and as close as possible to the base of the pile in the removal zone". It was observed during sampling that the material in this part of the removal zone is usually the wettest in the removal chamber because the base of the heap is also the place where leachate collects on its way to the leachate drain. In other words, while the material may have been at optimal moisture content when it was in the composting chamber, subsequent contact with leachate while it waits to be removed will elevate the moisture content. The question that arises in this case is: "where is the best place from which to take the sample if the major concern is with promoting optimal conditions for aerobic breakdown?"

All but one of the eight Intensive Group units failed to achieve end product thermotolerant coliform readings <200cfu/g on all six samples. Interestingly the worst performance in this respect came from the already approved mass produced Clivus Multrum (failed 5 out of 6). Presumably it had passed on all six samples in a previous test. Questions that arise here are: (i) Why is the cross-bar set at 200cfu/g and not 400 or 100? (ii) why all six tests and not the geometric mean or median? (iii) why penalise the product when it was (in the case of this Clivus Multrum) a management issue which can be overcome by user education?

Conclusion

Fifteen of the 20 owner-built composting toilet owners rated their toilet's performance as either "excellent" or "good". The only "poor" rating came from the owner of a Barrel Batch system who was not adding bulking material to the heap. While the three generic toilet designs appear to be basically sound, some toilets required structural adjustment after commissioning. Attention needs to be paid to rodent proofing of air vents and access doors. Passive ventilation of large units should improve if larger pipes (eg 150 mm) are used. Most problems were overcome by minor modifications to management practice on the part of the owner. With regard to the standard: the criteria for odour and consistency appear to be appropriate. The use of Salmonella as a criterion for disinfection is questioned. The criteria for moisture content and thermotolerant coliform levels could also be reviewed and adjusted slightly in light of the study.

Acknowledgment

Lismore City Council financially supported this study. Special thanks to Andy Edwards and Tony Kohlenberg of that Council.

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