Auditing an intensive care unit recycling program

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ABSTRACT

Background: The provision of health care has significant direct environmental effects such as energy and water use and waste production, and indirect effects, including manufacturing and transport of drugs and equipment. Recycling of hospital waste is one strategy to reduce waste disposed of as landfill, preserve resources, reduce greenhouse gas emissions, and potentially remain fiscally responsible. We began an intensive care unit recycling program, because a significant proportion of ICU waste was known to be recyclable.

Objectives: To determine the weight and proportion of ICU waste recycled, the proportion of incorrect waste disposal (including infectious waste contamination), the opportunity for further recycling and the financial effects of the recycling program.

Methods: We weighed all waste and recyclables from an 11-bed ICU in an Australian metropolitan hospital for 7 non-consecutive days. As part of routine care, ICU waste was separated into general, infectious and recycling streams. Recycling streams were paper and cardboard, three plastics streams (polypropylene, mixed plastics and polyvinylchloride [PVC]) and commingled waste (steel, aluminium and some plastics). ICU waste from the waste and recycling bins was sorted into those five recycling streams, general waste and infectious waste. After sorting, the waste was weighed and examined. Recycling was classified as achieved (actual), potential and total. Potential recycling was defined as being acceptable to hospital protocol and local recycling programs. Direct and indirect financial costs, excluding labour, were examined.

Results: During the 7-day period, the total ICU waste was 505 kg: general waste, 222 kg (44%); infectious waste, 138 kg (27%); potentially recyclable waste, 145 kg (28%). Of the potentially recyclable waste, 70 kg (49%) was actually recycled (14% of the total ICU waste). In the infectious waste bins, 82% was truly infectious. There was no infectious contamination of the recycling streams. The PVC waste was 37% contaminated (primarily by other plastics), but there was less than 1% contamination of other recycling streams. The estimated cost of the recycling program was about an additional $1000/year.

Conclusion: In our 11-bed ICU, we recycled 14% of the total waste produced over 7-days, which was nearly half of the potentially recyclable waste. There was no infectious contamination of recyclables and minimal contamination with other waste streams, except for the PVC plastic. The estimated annual cost of the recycling program was $1000, reflecting the greater cost of disposal of some recyclables (paper and cardboard v most plastic types).

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There is increasing recognition of the importance of environmental sustainability within the health care sector.[1-5] Health care is responsible for substantial waste production.[1,3] In the United Kingdom, about 5.5 kg of waste is produced per patient per year.[3] In the United States, over 7000 tonnes of health care waste is produced per day.[2] Ultimately, such waste production will contribute to the depletion of available landfill space[6] and is associated with other adverse environmental and health effects.[7,8] Further, health care leaves a sizeable carbon footprint,[9-10] including use of hospital equipment, pharmaceuticals, waste management, travel and direct energy use.[10] About 3% of total CO_2 emissions in the UK in 2004[10] and 7% of total CO_2 emissions in the US in 2007[9] were attributable to health care.

Recycling of waste is one strategy to conserve natural resources and reduce landfill and the carbon footprint.[4,11] The use of recycled materials usually expends less energy in manufacturing, transport and disposal of waste.[11] An audit of waste generated by hospitals in the US found that over 50% of hospital waste is potentially recyclable.[12] About 20%–40% of operating room (OR) waste[13-15] and 44% of intensive care unit waste may be recyclable,[16] but there is a paucity of data on effectiveness of recycling in the ICU.

A recent audit of a recycling program implemented in our hospital's operating suite showed that the program was efficacious, with about 55% of potentially recyclable waste being recycled, without incurring additional cost.[15] It was unclear, however, that these findings would also apply to recycling within the ICU.

The aims of our audit were to examine the amounts of:

- recyclable waste within our ICU that is actually recycled
- ICU waste incorrectly disposed of, including infectious waste
- non-labour financial costs of the ICU recycling program.

Methods

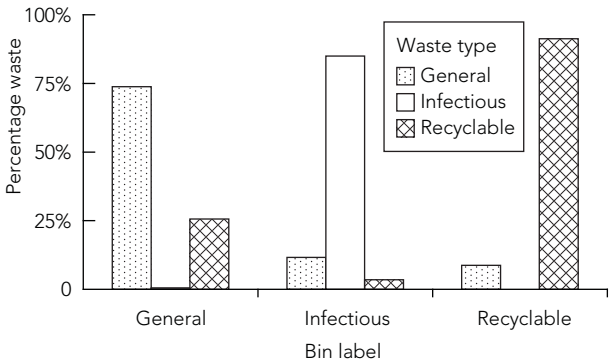
We began a recycling program in April 2013 at our 11-bed ICU at the Western Hospital (a 360-bed, university

Table 1. Waste as found in each bin type and contamination (ie, incorrect waste found in the bin)

Waste stream	Weight, kg	Weight of waste contaminated with other waste/recycling, kg (%)
Total	*505*	*114 (23%)**
General waste	268	88 (33%)
Infectious	161	24 (15%)
Recyclables†‡	73	2.4 (3%)
Paper (bin)	19	0.1 (0.4%)
Cardboard§	20	0
Mixed plastic	22	0.3 (1%)
Polyvinyl chloride	5	2 (37%)
Commingled	3	0
Polypropylene wrap	4	0

* Total amount of waste incorrectly disposed of. † None of the recycling streams were contaminated with any infectious waste. ‡ 0.5 kg of the recycling contamination was landfill, the remainder was recyclable waste incorrectly disposed of. § Cardboard boxes containing consumables.

Figure 1. Breakdown of waste as found within the bins



teaching hospital in Melbourne, Australia). All forms of surgery except cardiac and neurosurgery are performed at our hospital. The ICU recycling program was based on the program recently implemented in our hospital's operating suite[15] and was divided into five streams:

- paper and cardboard
- mixed plastics:
  - mixed polyethylene and polypropylene
  - polyvinyl chloride (PVC)
  - polypropylene surgical wrap
- commingled (a mixture of paper, aluminium, steel, glass and plastics).

The remainder of the ICU waste was disposed of into general waste bins or infectious waste bins. Infectious waste was defined as any waste containing human tissue and/or blood.[17]

The mixed plastics included a variety of plastics used within the ICU, eg, plastic wraps, bottles and plastic ampoules. Some items were deemed unsuitable for recycling by the recycler, eg, polyurethane (not valued), and plastic syringes (concern about infection transmission). Common examples of PVC included intravenous (IV) fluid bags and oxygen tubing. Polypropylene is used to wrap sterile gowns, drapes and procedural kits. In commingled recycling, all materials (eg, tins, plastic bottles) are collected together to be sorted later by the recycler. There was thus some overlap between plastic within commingled materials and the mixed plastics stream. Glass drug ampoules and single-use metal instruments (eg, scissors) were not routinely recycled.

Before recycling, each ICU patient bed area had one each of a general waste and an infectious waste bin, with half this ratio for high dependency unit (HDU) beds. After recycling began, one additional bin for paper and cardboard, and another for mixed plastics was provided at each bed area, again with half this ratio for HDU beds. Additional paper and plastic bins were distributed around the ICU. PVC, polypropylene and commingled items were a minority of the recyclables, and thus only central bins were provided. In the ICU staff tearoom, three recycling bins were provided: paper, plastic and commingled. The recycling program did not extend to other non-clinical areas, such as administration. Staff were encouraged to dispose of paper and plastic in bins specific to one type of recyclable item, but it was also appropriate for paper and mixed plastic recyclables to be placed into the commingled bin.

The recycling program was started in April 2013, with education provided to clinical and environmental services staff about correct recycling, bin placement and disposal. After allowing 3 months for adjustment to the new program, we performed an audit of the waste generated in the ICU over 7 days from August to October 2013. Due to clinical work responsibilities, the 7 days were not consecutive, although each day of the week was audited.

All ICU waste generated over the 7 days was removed and audited in a separate non-clinical area. Sharps bins were not examined. Waste from each stream was sorted into general waste, infectious waste, paper and cardboard, mixed plastic, PVC, polypropylene, commingled, sharps and syringes. Products which were made of recyclable materials, but which recyclers deemed unsuitable (most often since the products were composed of multiple plastics), were classed as general waste (or infectious if contaminated). For example, renal replacement fluid bags were composed primarily of PVC, but also contained other plastics and were

Table 2. Total weight of waste within each waste stream (after sorting) and amount of each disposed of appropriately (ie, into the correct bin)

Waste stream	Total weight, kg (% total)*	Appropriate weight, kg (% appropriate)†
Total	*505 (100%)*	*386 (76%)‡*
General (landfill)	222 (44%)	179 (81%)
Infectious	138 (27%)	137 (99%)
All recyclables	145 (29%)	70 (49%)
Mixed plastic	51 (10%)	22 (42%)
Paper and cardboard	68 (14%)	39 (57%)
PVC	14 (3%)	3 (21%)
Commingled	5 (1%)	2 (44%)
Polypropylene wrap	6 (1%)	4 (68%)

* Total weight of waste stream as a percentage of total ICU waste.
† Weight of waste disposed of correctly as percentage of total weight of that waste stream. ‡ Total amount of waste disposed of correctly.

thus deemed unsuitable for recycling and so went into general waste. Noticeable volumes of non-infectious fluid (> 10 mL) were emptied into a separate container and weighed. Infectious fluid was not separated from infectious waste or, if found in non-infectious waste, was removed, bagged and put into the infectious waste. After sorting, waste was weighed (to ± 10 g). Investigators wore protective gowns, gloves and eyewear while sorting the waste. Cardboard boxes were collected and weighed.

For the purpose of the audit, waste designated as commingled (but not originating from the commingled recycling bin) was defined as aluminium and tin cans. Other recyclable waste was sorted into the paper, mixed plastic and PVC categories. Although plastic syringes are not presently accepted for recycling by our recyclers, all non-infectious syringes were weighed separately to determine their contribution to waste.

During the study period, several patients had conditions that meant staff needed to observe contact precautions when caring for them, eg, colonisation with vancomycin-resistant enterococci (VRE); according to our institution's policy, contact precautions required staff to wear non-sterile gloves and gowns when interacting with the patient. All waste associated with patients who required contact precautions was disposed of into the infectious waste.

We did not perform any inferential statistical analysis of the data, as we were weighing waste for 7 non-consecutive days. We chose 1 week's analysis to use, as this was feasible and was likely to be more indicative of the average for an entire year than sorting waste for just 1 day.

Table 3. Costs of waste and recycling disposal in $AUD[15]

Waste stream	Total cost per kg
General waste	$0.24
Infectious waste	$0.98
Paper and cardboard	$0.57
Plastic (polypropylene)	$0.10
Plastic (mixed)	$0.22
Plastic (polyvinyl chloride)	$0.00
Commingled	$0.76

Results

For the 7 days, the total ICU waste found was 505 kg; consisting of general waste, 268 kg (53%); infectious waste, 161 kg (32%); and recyclables, 73 kg (15%) (Table 1). Of the 73 kg found in the recycling streams, there was 70 kg of correct recycling, ie, 2.4 kg contamination (3%) (1.9 kg with other recyclables, 0.5 kg with general waste and no infectious contamination). The proportion of weights of actual recycling:potential recycling was 73 kg:145 kg (49%).

Of the 88 kg of contamination of the general waste, 28 kg was paper and cardboard (11% of all general bin waste), 27 kg was mixed plastic (10%) and 8 kg was PVC (3%). Waste from the infectious stream (1.5 kg), polypropylene stream (1.8 kg) and commingled stream (2.8 kg) each contributed less than 1% of the general bin waste (Figure 1).

Within the infectious waste bins, most of the contamination was general waste (17 kg [11%]) (Figure 1). The 5 kg within the PVC stream had 2 kg of contaminants, including 1.3 kg of mixed plastics on one of the 7 days. It is likely that a bedside mixed-plastics bin was inadvertently emptied into the PVC bin on that day. There was minimal contamination of the other recycling streams (Table 1).

After sorting through all bins, the amounts and proportions of waste were: 222 kg of general waste (44%), 138 kg of infectious waste (27%) and 145 kg of potentially recyclable waste (29%) (Table 2). The 222 kg of general waste included 5 kg of glass (1%), 5 kg of syringes (non-infectious) (1%) and 14 kg of non-infectious fluid (2.8%). Of the potentially recyclable waste, 68 kg was paper and cardboard (47%), 51 kg was mixed plastic (35%), 14 kg was PVC (10%), 5 kg was commingled (3.5%) and 6 kg was polypropylene (4%).

In the 7 days audited, there was a mean of 10 patients in the unit each day (range, 9–11 patients), with a mean of five patients (range, 3–8 patients) requiring mechanical ventilation and a mean of one patient per day (range, 0–2 patients per day) requiring haemofiltration. For the year 1 July 2012 to

30 June 2013, there was a mean of nine ICU patients per day and 4.5 patients requiring mechanical ventilation, with a mean of 2.5 patients per week requiring haemofiltration. In the audited 7 days, there was a total of 15 bed-days occupied by patients requiring contact precautions due to VRE, compared with an average of 10 bed-days per week for 2012–13.

The financial cost of disposal of waste and recyclables from each of the streams is shown in Table 3. These costs include bin purchase, collection and transport of the waste, but not labour. There was considerable variation in the costs of different waste and recycling streams due to different contractual arrangements, carting and bin hire fees. Recycling of paper, cardboard and commingled waste is more expensive than disposal of landfill, but the recycling of plastics is less expensive, as the local plastic recyclers provide free pick-up. Based on the weights of recyclables in our audit, the cost of recycling per year in our ICU is about $1000.

Discussion

We audited waste disposal in our 11-bed ICU for 7 non-consecutive days, using the established recycling program. We showed that half a tonne of ICU waste was generated, with proportions being: 53% general waste, 32% infectious waste and 15% recyclables. Almost half (70 kg of 145 kg) the material suitable for recycling was actually recycled. There was minor (3%) contamination of the recycling streams, and no infectious contamination.

The estimated cost of recycling for 1 week in our ICU was about $20 per week, or $1000 per annum. This cost is due to the expense of several recycling streams. In particular, at our hospital, paper and cardboard formed half of the actual recycling and are more than twice as expensive as general waste to dispose of. Less than 1% of infectious waste was found outside the infectious bins, but 18% of the waste found in the infectious waste bins was not infectious (compared with 13% in the previous audit).[16] As shown in Table 3, infectious waste disposal is four times the cost of general waste disposal and improving compliance would be financially advantageous. For example, based on the results of this audit, if the amount of contamination of the infectious bins could be halved, this would lead to a saving of nearly $500 per year.

The proportion of potentially recyclable waste that was recycled was less than our hospital audit of OR recycling.[15] The OR is a much greater source of sterile instrument wrap (polypropylene) than the ICU. Such polypropylene is readily recycled and is financially attractive to recyclers. In our earlier ICU study,[16] the total amount of potentially recyclable waste was greater (240 kg v 145 kg), there was more paper and cardboard (114 kg v 69 kg) and more PVC (47 kg v 14 kg). In our earlier study, syringes were considered potentially recyclable; however, the 5 kg of syringes found in this study were considered unsuitable. In the earlier study, renal replacement fluid bags were potentially recyclable but because they were deemed difficult to recycle, they were designated general waste in this study. The difference in the amount of recycling between the two audits is mostly explained by the differing amounts of paper and cardboard and PVC, but the reasons for this difference are not entirely apparent. The volume of cardboard boxes may fluctuate due to variability in the delivery of consumables to the unit, although this does not fluctuate more than 50% from week to week (Angela Rees, ICU equipment nurse, Western Hospital, Melbourne, Australia, personal communication, October 2013).

Our study has limitations. We did not consider the different clinical and non-clinical areas (eg, tearoom) within the ICU separately and did not measure waste from administrative areas. The additional time and labour required for recycling was unmeasured. Although not directly comparable, it has been previously shown that identifying out-of-date stock within the operating suite to send to less developed nations (waste sorting similar to single-stream recycling) did not significantly delay OR turnaround times.[18] The impact of this program on the operation of the ICU is unknown. We were unable to audit the 7 days continuously, auditing each day of the week separately instead. All recycling bins were within 5 m of each bed area. Sharps bins were not examined, and it is possible that some potentially recyclable waste was disposed of in them. All statistics used were descriptive; we did not perform inferential analyses as it is uncertain whether a 7-day audit indicates routine waste and recycling for all weeks. Nevertheless, we suggest that this audit gives a reasonable indication of management of waste and recycling within our ICU. Finally, although we have attempted to quantify the volume of recycling achieved, and the financial cost to our institution, we did not measure other, more intangible, benefits, such as the financial and environmental benefits of resource recovery of plastics, reduction in CO_2 emissions related to recycling, and effects (if any) on staff morale. Thus, the overall benefit to society of an ICU recycling program remains unmeasured.

Based on the results of this audit, we could recycle up to 4 tonnes from our ICU per year. With a recycling program already established in our hospital's operating suite,[15] setting up a recycling program within the ICU was not difficult. Given that the ICU only contributes about 5% of total hospital waste,[16] expanding the recycling program to the rest of the hospital could achieve considerable recycling. The benefit of this recycling is difficult to quantify. Recycling

leads to a reduction in CO_2 emissions, as less energy is expended in the manufacturing of products from recycled materials.[11] Recycling also reduces landfill and conserves natural resources.[9-11] Further, exposing staff to recycling may lead to better compliance with recycling outside of work;[19] anecdotally, most of our staff were supportive of ICU recycling.

There is scope for improvement of ICU recycling, given that 50% of potentially recyclable waste was disposed of in recycling bins, but there are potential barriers to recycling, including bin space, education, motivation and financial costs. There is limited ICU space and there are now four different bins in each ICU bed area (landfill, infectious waste, paper and cardboard, and mixed plastic). This adds complexity to waste disposal with a greater likelihood of incorrect disposal, although this appeared rare in our audit. There is only one PVC bin within the ICU (given limited ICU space and the low PVC volume) and staff must leave their bed areas to access it. In an emergency setting, it would be difficult to expect staff to separate rubbish into individual components and dispose of them in the correct bins. Some staff suggested leaving all rubbish in a separate pile and sorting it later, although this practice is unlikely to be widely adopted. Anecdotally, ICU tearoom recycling could be improved, although the presence of foodstuff hampers correct waste separation. Composting would be challenging, but possible.

Paper and cardboard recycling is more expensive than disposal of landfill, thus, increasing the recycling of paper and cardboard will increase the cost to the hospital. Paper towel is a major component of the paper and cardboard waste stream, so alternatives for hand drying could be considered, eg, hand dryers and hand sanitiser rubs.[15] The cost of recycling varies according to individual hospital contracts and the recycler's location.[15]

Importantly, the results of this ICU audit differ from our OR waste audit, which showed that it was financially advantageous to recycle in the OR. The OR audit showed a higher proportion of recycling (23% of total OR waste), greater polypropylene recycling (50% of all OR recycling) and a much higher baseline of infectious waste, which was reduced after recycling started (48% reduced to 32%). The OR waste had more polypropylene plastic, which is easy to recycle due to its self-evident composition (surgical wrap), and is considered valuable to recyclers and correspondingly less expensive than general waste for the hospital to dispose of. Significant financial savings were achieved in the OR after recycling by reducing the proportion of infectious waste to similar levels found in this ICU audit. Such financial savings were not possible in the ICU as the level of infectious waste contamination with non-infectious waste was already much lower than in the OR and did not improve with the advent of recycling.

Sustainability within the health care sector involves a multifaceted approach, of which recycling is only one component. Recycling is unlikely to save hospitals large financial amounts, but reducing and reusing where clinically possible can have significant environmental and financial effects, particularly if studied comprehensively with the scientific method of life-cycle assessment.[20] Other avenues that could be considered to improve ICU sustainability would include examining water use (eg, for linen), electricity use (eg, reducing non-essential use at night, switching off vacant isolation rooms) and procurement (eg, excess packaging). Even more broadly, the unsustainability of ineffective therapies which do not improve patient care within the ICU could be considered.

Conclusion

We have shown that ICU waste can be safely and effectively recycled. There was minimal contamination of the recycling streams, lthough actual recycling was only half of the potential. Contrary to our audit of OR waste, our ICU recycling program is costing our hospital about $1000 per year. Reasons for this cost discrepancy include a different composition of recyclables in the ICU compared with the OR, and less opportunity to reduce the already relatively well sorted, expensive infectious waste in the ICU compared with the OR before starting recycling. Detailed audits of area-specific hospital recycling programs reveal different outcomes. We encourage investigation of why it often remains more financially expensive for hospitals to recycle than to discard such resources as garbage.

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Competing interests

None declared.

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