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Education

# An Educational Intervention to Reduce Regulated Medical Waste: The Inpatient Medicine and Outpatient Dermatology Settings

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## ABSTRACT

**Background:** Improving regulated medical waste (RMW) management is crucial for enhancing planetary health and cost savings. We sought to assess an educational intervention on clinical staff understanding and behavior regarding RMW management.

**Methods:** This two-month (2023–2024) controlled, prospective educational intervention at the University of Pennsylvania Health System surveyed healthcare workers, including physicians, nurses, and medical assistants, from four inpatient medicine floors and two dermatology clinics. Half of the medicine and dermatology settings were controls. The intervention included in-person staff training sessions and printed materials (posters, bin stickers) describing waste segregation and RMW's environmental, health, and cost impacts. A deidentified online survey pre- and post-intervention measured RMW knowledge and behaviors. The primary outcome was a change in performance on survey questions on proper RMW disposal and RMW's negative externalities. Secondary outcomes were self-reported changes in environmental beliefs and waste stewardship motivators and behaviors, qualitative responses around stewardship barriers, and the impact of clinical role on intervention efficacy.

**Results:** Average baseline inpatient knowledge scores were 6.17 of 9 versus 7.51 for outpatient. The inpatient intervention increased the odds of answering each question correctly by 3-fold (odds ratio: 3.71, 95% CI: 2.218–6.401, $p < 0.001$). The outpatient clinical role was associated with receptivity to the intervention: the intervention effect was 12.7 times stronger for nursing staff than for physicians (95% CI: 1.86, 263.29, $p = 0.024$). The intervention improved the overall understanding of RMW's negative environmental impact.

**Conclusions:** An educational intervention can improve understanding of RMW's proper disposal and environmental impact, particularly among nursing staff, and inform future interventions.

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## 1 | Introduction

The healthcare sector contributes significantly to carbon emissions, generating 8–9% of total U.S. emissions and producing an estimated 479 million metric tons of $CO_2$ equivalents annually [1–3]. This is largely attributable to the sector's extensive use of resources, which includes generating and processing regulated medical waste (RMW), or "red bag waste" [4]. Improving healthcare sector sustainability through appropriate RMW stewardship is imperative to improve healthcare's environmental stewardship and promote public health and operational efficiency [4–6].

The processing of RMW—items with blood or other potentially infectious material—emerged due to public concern over medical waste contaminating U.S. shorelines [7]. While intended to protect, RMW processing can be harmful to ecosystems and human health. Traditional RMW incineration methods release pollutants into the atmosphere linked to respiratory illnesses, cancers, and other chronic conditions [7, 8]. Less harmful methods, such as autoclaving and chemical treatment, still have substantial environmental footprints compared to municipal waste processing [6]. RMW must be discarded at specific licensed sites, leading to additional emissions from shipping waste across states.

The economic burden of managing RMW is also considerable. Hospitals spend an average of $790 per ton of RMW, over 10 times the cost of processing municipal waste, about $60 per ton in 2022 [9]. Healthcare systems may thus achieve threefold benefits—environmental stewardship, human health protection, and cost savings—through improved RMW stewardship.

Poor clinical staff knowledge of waste segregation guidelines is detrimental to appropriate RMW stewardship [6, 10–14]. Educational interventions may increase staff knowledge and compliance with waste segregation, and optimization of existing waste disposal containers may decrease costs [4, 11, 13, 15–21]. Despite the fact that roughly 75% of U.S. RMW is generated in non-surgical healthcare settings, most existing literature focuses on in-hospital operating room waste [4, 13, 17–20]. Our study aims to explore knowledge, perceptions, and barriers to RMW stewardship and the impact of a standardized educational intervention for clinical staff.

## 2 | Materials and Methods

In this quality improvement study, we evaluated the impact of an educational intervention at a large academic medical center on medical staff attitudes, understanding, and behaviors regarding RMW management and environmental stewardship.

### 2.1 | Cohort Selection

Participants included healthcare workers at least 18 years old from the University of Pennsylvania Healthcare System. Employee positions included physician, nurse, certified nursing assistant, and medical assistant. The inpatient cohort included non-physician staff from four general medicine floors at the Hospital of the University of Pennsylvania, as they were most consistently at the study site over the span of 2 months and dealt most directly with RMW. The outpatient cohort included all staff from dermatology clinics at the Perelman Center for Advanced Medicine and Penn Medicine Radnor, as both physician and non-physician staff were consistently at each location over months and interfaced with procedures generating RMW. We received IRB approval prior to data collection.

### 2.2 | Intervention Design, Components, and Administration

A diagram of the intervention methods is in Figure 1. The intervention included investigator-led in-person staff training sessions with distributed huddle sheets, and the placement of printed reminders (e.g., stickers on all RMW bins posters in high-visibility locations throughout care units). Training and posters contained information on waste segregation guidelines and the environmental and cost impacts of RMW processing. Bin stickers highlighted appropriate waste segregation and called for environmental stewardship (Figure 2). This intervention was implemented over 2 months (late 2023–early 2024). Clinical staff from two inpatient medicine floors and one outpatient dermatology clinic received the intervention, while staff from two neighboring inpatient medicine floors and another outpatient clinic were controls (not exposed to printed materials or in-person trainings).

An algorithm describing appropriate RMW disposal was finalized by health system leadership prior to the intervention (Figure 3) and included input from system administrators and staff in infection control, environmental health and safety, industrial hygiene, and waste management.

### 2.3 | Survey Design, Components, and Administration

#### 2.3.1 | Survey

To evaluate how the educational intervention impacted staff knowledge and attitudes around RMW stewardship, an online questionnaire was administered by email to all medical staff in the study locations via convenience sampling before and

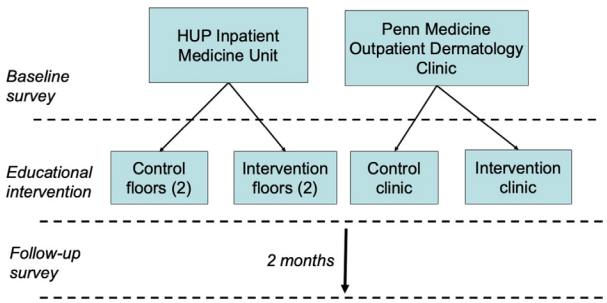


**FIGURE 1** | Educational intervention schema. Outline of the educational intervention design, illustrating control and intervention groups across inpatient medicine and outpatient dermatology units. HUP: Hospital of the University of Pennsylvania.

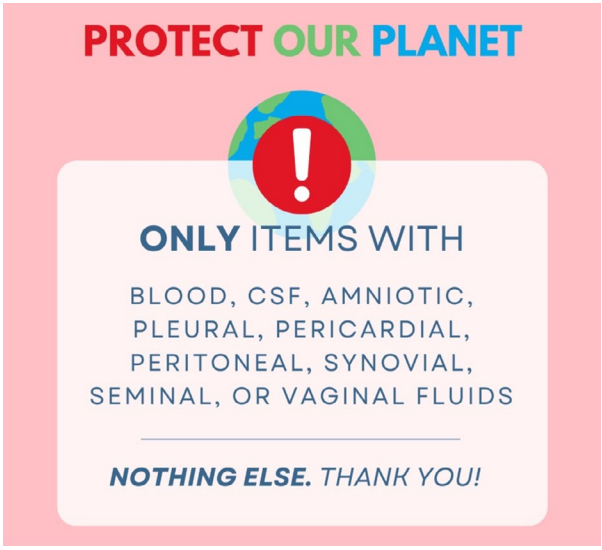


**FIGURE 2** | Regulated medical waste bin lid stickers in educational intervention. These stickers were printed and placed on the lids of all regulated medical waste bins around the intervention floors and clinics. CSF: cerebrospinal fluid.

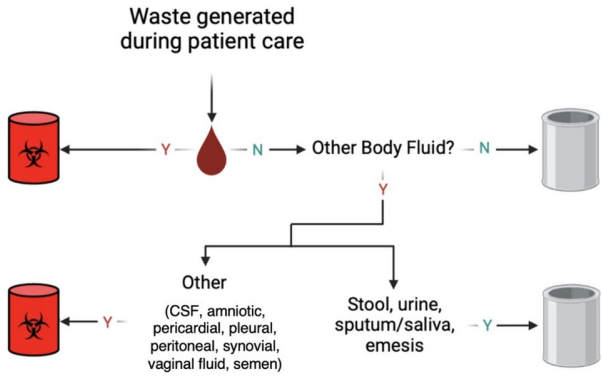


**FIGURE 3** | Regulated medical waste disposal algorithm. This algorithm was approved following discussions with the hospital's infectious disease, industrial hygiene, environmental health and safety, and waste management teams. CSF: cerebrospinal fluid.

immediately after the two-month intervention. The deidentified questionnaire assessed RMW stewardship behavior, knowledge, attitudes, and perceived barriers. See the Supporting Information for the survey instruments (inpatient and outpatient). Consent was obtained prior to survey administration, with information on the study's purpose, confidentiality, voluntary participation, and withdrawal procedures.

Participants were asked about their practices around sorting waste into red (RMW) and white (municipal) bins to assess behavior. Questions also evaluated the convenience and perceived barriers to waste disposal into the correct bins. Participants were asked to identify which items should be disposed of in RMW versus municipal bins to assess knowledge of the disposal algorithm. Participants also evaluated true/false statements regarding the environmental and cost impacts of disposing of RMW. Questionnaire items around attitudes and beliefs gauged participants' agreement with statements about personal and professional environmental stewardship.

Data confidentiality was strictly maintained, with responses anonymized via REDCap and access limited to the research team. Participants had the option to withdraw consent at any point before submitting responses.

### 2.3.2 | Data Analysis

**2.3.2.1 | Primary Outcome.** Our primary outcome was knowledge acquisition, captured by a change in the percentage of correct answers on nine knowledge-based survey questions. These questions contained correct/incorrect response options testing understanding of the RMW disposal algorithm, the environmental impact of RMW, and the financial impact of RMW. Analyses were conducted using R version 4.3.0. The "lme4" package was used for mixed effects model fitting.

We analyzed the effects of the educational intervention on the primary outcome separately in the inpatient and outpatient settings using logistic mixed effects models. Our logistic regression models evaluated the increase in odds of answering any given question correctly across all nine questions, with data from all questions incorporated into the logistic mixed effects model. These mixed effect models accounted for the fact that some subjects completed the survey both before and after the study period, while others only completed the survey either before or after. These models estimated the effect of exposure to the educational intervention on the odds of answering a given question correctly while controlling for longitudinal repeated surveys using subject-level random intercepts, different baseline question difficulty using question-level random intercepts, and the fixed effect of seeing the survey twice.

Notably, both linear and logistic mixed effects regressions were considered for this analysis. Logistic mixed-effects models were ultimately chosen to better reflect the bounded nature of the primary outcome—since nine questions were included in the primary outcome, individuals could only obtain scores between zero and nine. We include results from a linear mixed effects regression in the Supplement to demonstrate the robustness of findings to model choice and distributional assumptions.

**2.3.2.2 | Exploratory Outcomes.** To explore which specific knowledge areas were most affected by the educational intervention, we analyzed the intervention's effect on each question individually. We used mixed effect logistic regression models; *p*-values were not corrected for multiple comparisons, as results were considered exploratory. A total of 11 such analyses were conducted—the remaining 7 questions (2 in the inpatient cohort, 5 in the outpatient cohort) could not be tested due to the relatively small sample size, noted in our manuscript's limitations section.

We also conducted an analysis using mixed-effects logistic models to assess the interaction between job position and the effect of educational intervention in the outpatient setting. We hypothesized that, in the outpatient setting, the effect of the educational intervention could be stronger for nursing staff and medical assistants than for physicians, since academic physicians and physician-scientists may spend less time in the clinic, be less available for training sessions, and interact less with

RMW. We used the same model as in the primary outcome, with the addition of an interaction term between job position and intervention.

We used mixed effects linear regression models to evaluate the effect size of the intervention on variables representing beliefs about the environment and attentiveness to waste disposal behavior. Environmentalism was measured using the sum of four survey questions eliciting pro-environmental behaviors and a sense of personal environmental responsibility. We created variables that represented the self-reported tendency to throw municipal waste in the red bins and the frequency of thoughts about appropriate waste streams when discarding waste.

Perceived motivators for proper RMW disposal were analyzed using one-sample t-tests to obtain means and confidence intervals for relevant baseline questions. Additionally, we reviewed open-ended responses for those who selected "Other" to the question, "Why do you sometimes put the wrong item in the red bin?"

## 3 | Results

### 3.1 | Baseline Cohort Data and Survey Response Rate

Table 1 describes the study cohort that completed both baseline and follow-up surveys. In the inpatient arm of the study, we attained 30.7% (31/101) and 26.4% (29/110) baseline survey response rates (28.3% overall) and 35.5% (11/31) and 93.1% (27/29) follow-up response rates (63% overall) among the control and intervention floors, respectively.

In the outpatient arm of the study, the baseline survey response rates were 42.5% (17/40) and 38.0% (46/121) for the control and intervention clinics, respectively, or 38.4% overall baseline response. The follow-up outpatient survey response rates were 64.7% (11/17) and 39.1% (18/46) for the control and intervention clinics, respectively, or 46.0% follow-up response.

The highest proportion of follow-up data was collected from RNs in all study settings except for the outpatient intervention clinic, with the highest proportion of responses from attending physicians.

### 3.2 | Understanding of RMW Disposal Algorithm and Impact

For our primary outcome, the baseline number of correct answers was 6.17 out of 9 for the inpatient group and 7.51 out of 9 for the outpatient group. On average, the odds of answering these knowledge-based questions correctly after the educational intervention in the inpatient setting were 3.71 (95% CI: 2.22, 6.40), as high as the odds before exposure. In the outpatient setting, exposure to the intervention did not significantly increase the odds of answering a given question correctly ($p = 0.30$). However, exploratory analysis suggested an interaction between job position and intervention exposure. The intervention effect was significantly stronger for nursing staff than for physicians (odds ratio: 12.7; CI: 1.86, 263.29; $p = 0.024$), controlling for baseline differences in RMW disposal knowledge between nursing staff and doctors. Sensitivity analyses for these outcomes using a linear mixed effects regression are included in the Supporting Information. The percentage correct by site and study arm for all nine questions is reported in Table 2.

On average, the odds of correct response in the inpatient setting significantly increased following the intervention for questions about the disposal of emesis (4.02 higher odds; CI: 1.47, 13.92), sputum (3.24; CI: 1.05, 10.05), and stool and urine (7.65; CI: 1.49,

**TABLE 1** | Cohort demographics.

| | Control floors | | Intervention floors | |
|---|---|---|---|---|
| | **Baseline (*n* (%); total *n* = 31)** | **Follow-up (*n* (%); total *n* = 11)** | **Baseline (*n* (%); total *n* = 29)** | **Follow-up (*n* (%); total *n* = 27)** |
| Inpatient medicine arm | | | | |
| % RNs | 23 (74%) | 10 (91) | 22 (76) | 24 (89) |
| % CNAs | 8 (26) | 1 (9) | 7 (24) | 3 (11) |
| | **Control clinic** | | **Intervention clinic** | |
| | **Baseline (*n* (%); total *n* = 17)** | **Follow-up (*n* (%); total *n* = 11)** | **Baseline (*n* (%); total *n* = 46)** | **Follow-up (*n* (%); total *n* = 18)** |
| Outpatient dermatology arm | | | | |
| % Attending MDs | 2 (12%) | 1 (9) | 22 (48) | 13 (72) |
| % Resident/Fellow MDs | — | — | 11 (24) | 2 (11) |
| % RNs | 9 (53) | 6 (55) | 9 (20) | 1 (6) |
| % MAs or CNAs or Other | 6 (35) | 4 (36) | 4 (9) | 2 (11) |

Abbreviations: CNA, certified nursing assistant; MA, medical assistant; MD, medical doctor; RN, registered nurse.

**TABLE 2** | Primary outcome variables.

| | Control floors | | Intervention floors | |
|---|---|---|---|---|
| | **Baseline (number correct (%); total *n* = 31)** | **Follow-up (number correct (%); total *n* = 11)** | **Baseline (number correct (%); total *n* = 29)** | **Follow-up (number correct (%); total *n* = 27)** |
| Inpatient medicine arm | | | | |
| Saliva/emesis | 9 (29%) | 5 (46) | 8 (28) | 19 (70) |
| Stool/urine | 10 (32) | 5 (46) | 6 (21) | 20 (74) |
| Expectorated sputum from patient in isolation | 5 (16) | 2 (18) | 9 (31) | 14 (52) |
| Blood-soaked glove | 29 (94) | 11 (100) | 27 (93) | 27 (100) |
| Vaginal fluid | 25 (81) | 8 (73) | 23 (79) | 23 (85) |
| Cerebrospinal fluid | 23 (74) | 9 (82) | 22 (76) | 18 (67) |
| RMW enviro impact | 13 (42) | 3 (27) | 12 (41) | 22 (82) |
| RMW cost impact | 20 (65) | 9 (82) | 23 (79) | 26 (96) |
| Red bin foundation[a] | 30 (97) | 11 (100) | 29 (100) | 27 (100) |
| | **Control clinic** | | **Intervention clinic** | |
| | **Baseline (number correct (%); total *n* = 17)** | **Follow-up (number correct (%); total *n* = 11)** | **Baseline (number correct (%); total *n* = 46)** | **Follow-up (number correct (%); total *n* = 18)** |
| Outpatient dermatology arm | | | | |
| Gauze with non-bloody pus | 7 (41%) | 9 (82) | 16 (35) | 10 (56) |
| Used mask from COVID-19 patient | 12 (71) | 9 (82) | 31 (67) | 12 (67) |
| Glove with small amount of blood | 15 (88) | 8 (73) | 32 (70) | 13 (72) |
| Skin marker that touched infectious lesion | 14 (82) | 9 (82) | 39 (85) | 14 (78) |
| Non-bloody gloves and emollient sticks | 16 (94) | 11 (100) | 43 (94) | 17 (94) |
| Bloody wound dressing | 17 (100) | 11 (100) | 43 (94) | 17 (94) |
| RMW enviro impact | 13 (77) | 10 (91) | 29 (63) | 15 (83) |
| RMW cost impact | 17 (100) | 10 (91) | 41 (89) | 17 (94) |
| Red bin foundation[a] | 16 (94) | 11 (100) | 38 (83) | 15 (83) |

Abbreviation: RMW, regulated medical waste.
[a]Represents a question that assessed foundational knowledge of whether participants understood that only certain types of waste should be put into the red bins, with the rest going into municipal bins.

39.27). Exposure to the educational intervention increased the odds, on average, of correctly answering that RMW disposal generates more air pollution than municipal waste disposal in both the inpatient ($p = 0.011$) and outpatient ($p = 0.072$) settings.

### 3.3 | Intrinsic Environmentalism

We calculated an "environmentalism score" by converting Likert scale survey responses into a numeric scale and summing them. The score summed a participant's answers to the survey questions that assessed personal responsibility for and belief in the value of environmental stewardship, including in the workplace. The baseline environmentalism score for the pooled study population was 15.4 (95% CI: 14.9, 15.9), approximating a survey response of "agree". This was not significantly influenced by exposure to our educational intervention ($p = 0.297$).

### 3.4 | Waste Disposal and Consideration

A variable summing all self-reported reasons (from pooled inpatient and outpatient settings) for inappropriately disposing of municipal waste in the RMW bins demonstrated an intervention

effect of −0.321 ($p = 0.189$), with directionality indicating a decrease in the tendency to throw municipal waste in the red bin. The intervention did not significantly influence the frequency of thought about proper waste disposal streams when discarding waste at work.

### 3.5 | Perceived Motivators

At baseline, survey participants in the outpatient setting ranked "understanding of the negative environmental impacts of putting items in the red bag bins that don't belong" as the most important motivator for proper RMW disposal, with a mean score of 2.27 (95% CI: 1.89, 2.65) on a scale of 1–6 (1 = most important). The second most important motivator was "convenience in the room [of the proper bins]," with a mean score of 2.32 (95% CI: 1.88, 2.76). Convenience was defined to encompass elements such as bin location in the room, bin size, or an open versus closed container. On average, receiving a personal reward for RMW reduction was the least important motivator, with a mean score of 4.22 (95% CI: 3.82, 4.63). Penalties for inappropriate RMW disposal and a departmental award for RMW stewardship were ranked in the lower half of motivators, while understanding the higher cost of processing RMW ranked in the top half.

### 3.6 | Qualitative Insights

We received 10 inpatient and 12 outpatient open-response answers from those who selected "Other" for "Why do you sometimes put the wrong item in the red bin?"

Six of the 10 inpatient respondents cited the white bin being too full as the reason for inappropriately using the red bin. One participant wrote, "Often the white bins are full, so we use the red instead". Others mentioned being in a rush or having trouble breaking the habit of putting non-hazardous items, such as non-bloody stool and urine, in the red bins.

The most frequently cited reason in the outpatient setting involved setup for in-office procedures or Mohs micrographic surgery. Procedure rooms have lidless rolling kick-buckets lined with red bags—a combination of convenience and cultural norms contributes to all procedure waste going into these buckets. As one respondent stated, "The 'culture' of the department is to throw essentially all trash that has touched the patient into the medical waste bin".

## 4 | Discussion

Our findings support the use of educational intervention to improve the medical staff's understanding of the environmental impact and appropriate disposal of RMW. This intervention was low-cost and nondisruptive, aside from an input of 10–15 minutes away from clinical duties for the initial training session. It did not significantly alter the workflow or layout of the clinical space and only required printed paper and bin stickers. It also provided insights into perceived motivators and barriers to proper RMW stewardship. Given our intervention's multi-setting design and the universal necessity of RMW management, these findings may be applicable across healthcare settings.

In the inpatient setting, exposure to our educational intervention was associated with higher odds of correctly responding to knowledge-based RMW stewardship questions, which aligns with Bilo et al.'s findings of improved ICU staff (e.g., physicians and nurses) scores on a test of solid waste disposal after an in-person educational session [22]. Secondary analyses revealed the greatest odds of improvement in knowledge of the disposal of non-hazardous bodily fluids and the connection between RMW disposal and generation of air pollution.

In the outpatient setting, we found the intervention effect may be more pronounced among non-physician nursing staff, as there was no significant marginal intervention impact when physicians and other medical staff were grouped. This may indicate that non-physician clinical staff were more receptive to the intervention, perhaps due to greater training around waste disposal throughout routine patient care. This hypothesis is corroborated by a study that found that hospital nursing staff were more knowledgeable and retained more knowledge around healthcare waste management standards than physicians [23]. However, our in-person training sessions likely reached more nurses and medical assistants than physicians. For all outpatient staff, secondary analyses revealed the greatest improvements in knowledge of the connection between RMW disposal and air pollution.

Exposure to the educational intervention was not associated with significant changes in beliefs or attitudes around environmental stewardship, nor with a significant change in the frequency of thought about proper waste disposal streams at work. On average, clinical staff ranked convenience and understanding of environmental impact as the top self-perceived motivators for RMW stewardship; penalty and reward systems were viewed as less efficacious. The qualitative data collected by our survey revealed additional contributors to improper waste disposal—such as overflowing municipal bins and conveniently placed open RMW kick-buckets—which represent targets for future interventions. Algorithmic knowledge may be less important in inappropriate waste disposal, secondary to convenience and physical constraints within time-pressured clinical environments.

This study laid the foundation for improving clinical staff awareness around RMW stewardship and revealed areas for quality improvement: ensuring sufficient availability of inpatient empty municipal bins and rethinking the layout of RMW buckets in the outpatient procedural setting. Generally, physical space interventions represent the next step beyond education in improving waste stewardship. Addressing inconvenience and applying nudge theory through choice architectural interventions like reducing RMW bin size, leaving only municipal bins lidless, and replacing in-room RMW bins with baggies to take to a hallway receptacle will likely lead to greater reductions in RMW production [24–27].

### 4.1 | Limitations

Our results rely on survey data, making them vulnerable to subjectivity and self-reporting bias. Direct measurement of the

relative weight of RMW or bin contents is an important outcome to include in future studies of RMW stewardship interventions. While we were unable to directly control the number of survey respondents in our study, leading to a relatively small sample size, we sent reminders and enlisted clinical directors to encourage participation. Differential response rates across clinical roles and intrinsic motivation around the study topic may have led to differences in baseline and follow-up demographics. Additionally, we were unable to directly reach all intervention staff with training sessions due to clinical demands and misaligned schedules. We attempted to mitigate this by communicating with nursing managers and distributing huddle sheets, but this may have missed outpatient physicians. We excluded dual-appointed outpatient control staff and confirmed that inpatient staff remained assigned to one floor, but it is possible that controls may have seen educational materials if they visited intervention sites. This study aimed to improve knowledge, and future research should assess for translation to behavioral change.

This study reveals that knowledge gaps around proper RMW disposal and its environmental impact can be closed through minimally disruptive educational interventions. We find avenues for future quality improvement by targeting convenience and the physical positioning of waste bins.

## Conflicts of Interest

Misha Rosenbach is the co-chair of the American Academy of Dermatology's Climate Change and Environmental Issues Expert Resource Group; he is speaking for himself and not on behalf of the Academy. He has served as a consultant for Merck, J&J, and Novartis and received research support from Processa. None of the other authors declare no conflicts of interest.

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**Supporting Information**

Additional supporting information can be found online in the Supporting Information section.