ORIGINAL ARTICLE

# Perceived Awareness Versus Actual Knowledge of E-Waste and Its Disposal Practices Among Medical Students at a Tertiary Care Teaching Institution in Uttar Pradesh, India

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**Citation:** Anubhav Agrawal, Reema Kumari. Perceived Awareness Versus Actual Knowledge of E-Waste and Its Disposal Practices Among Medical Students at a Tertiary Care Teaching Institution in Uttar Pradesh, India Indian J Comm Health. 2026;38(3): Page Number 592 - 598 https://doi.org/10.47203/IJCH.2026.v38i03.014

**Article cycle: Received:** 23/04/2026; **Accepted:** 20/06/2026; **Published:** 30/06/2026



**Abstract:**

**Introduction:** The rapid expansion of electric devices has subsequently led to rise in e-waste, posing significant environmental and public health challenges due to hazardous substances and unsafe disposal practices. Medical students represent an important group as future public health professionals, still evidence on their objective knowledge and practices remains limited. **Objective:** To assess perceived awareness, actual knowledge, and disposal practices related to e-waste among medical students. **Material & Methods:** It's a cross-sectional study among medical students in Uttar Pradesh, India using a pretested questionnaire including sociodemographic characteristics, awareness, knowledge, perceptions, and disposal practices of e-waste. Data were analysed using descriptive and non-parametric tests. McNemar test was used for differences between perceived and actual knowledge, and Spearman's correlation for relationship between knowledge and disposal practices. A p-value < 0.05 was considered significant. **Results:** Among 256 medical students, self-reported awareness of e-waste was high (91.8%); however, objective knowledge was limited across domains, including hazardous materials (12.1%), health risks (5.9%), environmental effects (9.8%), and regulatory provisions (0.8%). A substantial gap between perceived and actual knowledge was observed across all domains ($p < 0.001$). Unsafe disposal practices were common, particularly batteries with domestic garbage (51.2%). A weak positive correlation of borderline statistical significance was observed between knowledge and safe disposal practices (Spearman's ρ (rho) = 0.125; $p = 0.045$). **Conclusions:** Despite higher awareness, knowledge gaps and unsafe methods of disposing e-wastes among the students was prevalent. Strengthening environmental competencies in education and establishing institutional e-waste management mechanisms is essential to mitigate long-term environmental and public health risks.

**Key-words:** Electronic Waste Management; Hazardous Waste; Medical Students; Public Health; Waste Management

## Introduction:

Human society is moving towards a luxurious and technology driven lifestyle which is empowered by Electrical and Electronics Equipment (EEE), further leading to its overconsumption.[1,2] This usage pattern was further intensified during COVID-19 by lockdown period, Work from home, e-learning and distant classes.[3] Despite growing concerns and discussions on environment, rapid growth of e-waste is posing a greater public health challenge to the nature.[4] E-waste is discarded Electrical and Electronics Equipment which are intended for disposal.[5,6] E-waste has grown substantially over the past two decades mainly due to shorter product lifecycle and frequent replacement of modern devices.(2)

Globally, there is substantial increase in the already enormous amount of e-waste generated every year. India's position in the global electronics sector is unique as its second largest producer of mobile phones and fifth largest contributor to global e-waste volume. India produces approximately 2 million tonnes of e-waste annually which accounts for 4% of the global volume.(1)

E-waste has a highly complex composition with more than

1000 hazardous and non-hazardous compounds including toxic metals, xenobiotics and other organic compounds.[4] Improper handling and disposal of e-waste contributes significantly to environmental contamination and pose significant risks to human health through the release of hazardous substances into air, water, and soil.[6]

In India, e-waste disposal in universities, particularly computers, remains a concern due to rudimentary disposal practices and is further aggravated by lack of awareness, insufficient regulatory enforcements, lack of funds and reluctancy in the part of Government and relevant agencies to address the critical problem. This results in potential environment and public health risks.[4,6]

Various studies from across the world including India have assessed knowledge, perceptions and practices related to e-waste among students from medical and other universities, reporting good awareness regarding the term e-waste but limited knowledge of hazardous substances, health and environmental impacts, regulatory provisions and disposal methods. Indian studies have further documented prevalence of unsafe disposal practices despite good awareness, indicating the gap between perceived knowledge and actual behaviour. Several international literature also indicate towards similar awareness-practice mismatch relying on self-reported awareness without evaluating the objective understanding. .[3,7,8]

Importantly, evidence driven objective understanding of awareness and practices related to e-waste amongst students of medical institute- who represent future public health professionals and potentially an influential group in the discussion of environmental change, remains limited. Therefore, this study aims to assess perceived awareness, actual knowledge, perceptions, and disposal practices related to hazardous e-waste among students at a medical institute in Uttar Pradesh, India, with a focus on environmental and public health implications.

**Material & Methods:**

This cross-sectional study was conducted among students of King George's Medical University (KGMU), Lucknow, Uttar Pradesh India. Study was conducted for three months from July to September 2024. Participants were enrolled by purposive sampling technique. The study included undergraduate and postgraduate students aged 18 years and above. All students who were present during the study period and willing to participate were included in the study. Students who were absent during data collection or did not provide informed consent were excluded.

A total of 256 participants fulfilled the eligibility criteria and were included in the final analysis. As this was an exploratory institutional survey, no formal sample size calculation was performed. The study included students from the 2021, 2022, 2023, and 2024 admission batches, corresponding to Final Professional Part II, Final Professional Part I, Second Professional, and First Professional MBBS years, respectively, during the study period.

Pre-tested, semi-structured questionnaire was used for data collection, which was developed based on relevant literature and guidelines related to e-waste and reviewed by faculty members from the Department of Community Medicine for face and content validity. Necessary modifications were incorporated prior to pretesting. Internal consistency of the knowledge domain was assessed using Cronbach's alpha, which was found to be 0.721, indicating acceptable reliability of the scale. The questionnaire was administered offline in classroom settings after obtaining written informed consent from eligible participants.

Questionnaire consisted of sections like socio-demographic profile, knowledge related to e-waste, perceptions and disposal practices. The knowledge section consisted of 23 items, primarily open-ended in nature. Responses were reviewed and coded based on predefined criteria derived from relevant literature and guidelines, with correct responses assigned a score of one and incorrect or "don't know" responses scored as zero. Domain-specific actual knowledge was assessed using multiple items. Participants providing at least two correct responses within a domain were classified as having met the minimum predefined knowledge criterion for that domain.

Perceptions were assessed using a five-point Likert scale ranging from strongly agree to strongly disagree. Disposal practices were categorized as safe or unsafe based on established guidelines, and a composite safe practice score (range: 0-4) was calculated based on the number of safe practices reported.

Data was analysed using Statistical Package for Social Sciences (SPSS), version 24. Descriptive statistics were presented as frequencies and percentages for categorical variables. For group comparisons, mean ranks were reported along with Mann-Whitney U and Kruskal-Wallis test statistics. Normality of continuous variables was assessed using the Shapiro-Wilk test ($W = 0.914$, $p < 0.001$). The difference between perceived and actual knowledge was evaluated using the

McNemar test. Correlation between knowledge and safe disposal practice scores was assessed using Spearman's rank correlation coefficient. A p-value <0.05 was considered statistically significant.

The study was conducted as an academic survey under the supervision of faculty members from the Department of Community Medicine. Participation was voluntary, and written informed consent was obtained from all participants prior to data collection. The survey was administered anonymously using a pretested questionnaire. No personally identifiable information was collected, and confidentiality of the participants' responses was maintained throughout the study.

Results: A total of 256 participants were included in the study. Of these, 136 (53.1%) were males and 120 (46.9%) were females. The majority of participants belonged to the 21-25 years age group (64.8%). Most participants were from the MBBS stream, and the 2022 batch constituted the largest proportion (Table 1).

The knowledge score was similar across most socio-demographic categories. A statistically significant difference was observed with respect to gender (147.82 vs. 111.45 mean rank; Mann-Whitney U = 5841.0, p < 0.001), indicating variation in knowledge scores between male and female participants. However, no significant association was found between knowledge scores and age group (p = 0.125), native residence (p = 0.711), course (p = 0.459), academic stream (p = 0.977), or batch year (p = 0.150) (Table 1).

**Table 1. Association of Sociodemographic Variables With Knowledge Scores Among Study Participants (n = 256)**

| Variable | Category | n (%) | Mean Rank | p-value | Effect size |
|---|---|---|---|---|---|
| Gender | Male | 136 (53.1) | 111.45 | <0.001 | r = 0.25 |
| | Female | 120 (46.9) | 147.82 | | |
| Age group (years) | 17–20 | 74 (28.9) | 113.88 | 0.125 | $\varepsilon^2 = 0.008$ |
| | 21–25 | 166 (64.8) | 134.24 | | |
| | ≥25 | 16 (6.3) | 136.53 | | |
| Native residence | Rural | 76 (29.7) | 131.11 | 0.711 | r = 0.02 |
| | Urban | 180 (70.3) | 127.40 | | |
| Course | Undergraduate | 248 (96.9) | 129.11 | 0.459 | r = 0.05 |
| | Postgraduate | 8 (3.1) | 109.63 | | |
| Academic stream | MBBS | 215 (84.0) | 128.44 | 0.977 | r = 0.002 |
| | Others | 41 (16.0) | 128.80 | | |
| Batch | 2021 | 15 (5.9) | 157.40 | 0.150 | $\varepsilon^2 = 0.009$ |
| | 2022 | 187 (73.0) | 130.33 | | |
| | 2023 | 17 (6.6) | 127.21 | | |
| | 2024 | 37 (14.5) | 108.15 | | |

**Note:** Group comparisons were performed using the Mann-Whitney U test and Kruskal-Wallis test. A p-value < 0.05 was considered statistically significant. Effect size was expressed as r for Mann-Whitney U test and epsilon squared (?$^2$) for Kruskal-Wallis test.

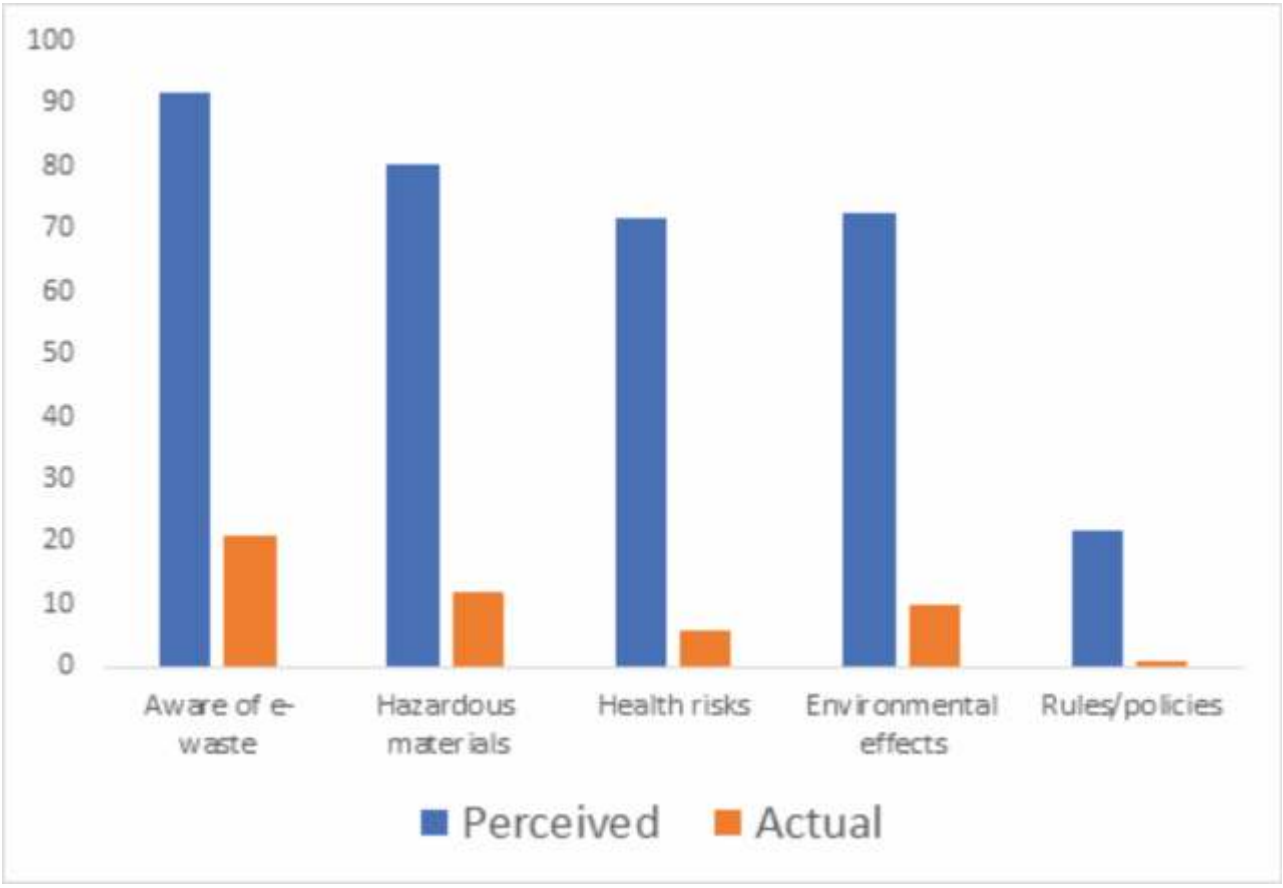


**Figure 1. Comparison of perceived and actual knowledge of e-waste among medical students.**

A high proportion of participants reported perceived awareness across domains; however, actual knowledge was substantially lower (Figure 1). Domain-wise comparison revealed a significant discrepancy between perceived and actual knowledge in all domains, as assessed using the McNemar test ($p < 0.001$ for all domains). The proportion of participants demonstrating adequate actual knowledge was particularly low for domains related to health effects, environmental impact, and regulatory provisions, highlighting a considerable knowledge gap despite high self-reported awareness (Table 2).

**Table 2. Comparison of Perceived Knowledge and Actual Knowledge of E-Waste Among Medical Students (n = 256)**

| Domain | Perceived Knowledge n (%) | Actual Knowledge n (%) | Difference (%) | p-value |
|---|---|---|---|---|
| Aware of e-waste | 235 (91.8) | 54 (21.1) | 70.7 | <0.001 |
| Hazardous materials | 205 (80.1) | 31 (12.1) | 68.0 | <0.001 |
| Health risks | 183 (71.5) | 15 (5.9) | 65.6 | <0.001 |
| Environmental effects | 185 (72.3) | 25 (9.8) | 62.5 | <0.001 |
| Rules/policies | 56 (21.9) | 2 (0.8) | 21.1 | <0.001 |

**Note:** Perceived knowledge was assessed through self-reported responses. Actual knowledge was derived from domain-specific items, with ≥2 correct responses indicating minimum adequate knowledge. The McNemar test was applied to assess paired differences, with $p < 0.05$ considered statistically significant.

Regarding perceptions, 96.9% of respondents agreed that materials used in electronic products are harmful, and 95.3% agreed that e-waste contributes to environmental hazards. 94.5% agreed that citizen participation is necessary for minimizing e-waste, and 91.5% believed that awareness programs in educational institutions can improve e-waste management. Only 26.5% agreed that e-waste management is primarily the responsibility of government agencies, while 52.0% disagreed or strongly disagreed (Table 3).

**Table 3. Perception Toward E?Waste Management Among Medical Students (N = 256)**

| Variable | Strongly Agree n(%) | Agree n(%) | Neutral n(%) | Disagree n(%) | Strongly Disagree n(%) |
|---|---|---|---|---|---|
| Materials harmful | 150 (58.6) | 98 (38.3) | 7 (2.7) | 0 (0.0) | 1 (0.4) |
| Environmental hazards | 151 (59.0) | 93 (36.3) | 8 (3.1) | 4 (1.6) | 0 (0.0) |
| Govt responsibility | 27 (10.5) | 41 (16.0) | 55 (21.5) | 107 (41.8) | 26 (10.2) |
| Citizen participation | 124 (48.4) | 118 (46.1) | 9 (3.5) | 3 (1.2) | 2 (0.8) |
| Lack of information | 107 (41.8) | 130 (50.8) | 16 (6.3) | 1 (0.4) | 2 (0.8) |
| Awareness programs helpful | 122 (47.7) | 112 (43.8) | 18 (7.0) | 4 (1.6) | 0 (0.0) |

With respect to disposal practices, 130 students (50.8%) reported selling electronic items to second-hand markets, 81 (31.6%) exchanged old devices for new ones, and 62 (24.2%) sold items to recyclers. Environmentally unsafe practices were also prevalent: 131 students (51.2%) disposed batteries with domestic garbage, 51 (19.9%) discarded e-waste with household waste, 9 (3.5%) reported burning e-waste, and 6 (2.3%) dumped e-waste in rivers and canals. (Table 4).

**Table 4. Distribution And Classification of E-Waste Disposal Practices Among Medical Students (N = 256)**

| Disposal Method | Yes n (%) | Classification |
|---|---|---|
| Sold to second-hand market | 130 (50.8) | Safe |
| Exchanged for new device | 81 (31.6) | Safe |
| Sold to recycler | 62 (24.2) | Safe |
| Donated | 19 (7.4) | Safe |
| Kept unused at home | 43 (16.8) | Neutral |
| Disposed with domestic garbage | 51 (19.9) | Unsafe |
| Batteries thrown with garbage | **131 (51.2)** | **Unsafe** |
| Dumped in canal/river/sea | 6 (2.3) | Unsafe |
| Burned/incinerated | 9 (3.5) | Unsafe |

**Note:** Classification of disposal practices was based on the E-Waste (Management) Rules, Government of India, and relevant World Health Organization recommendations. Multiple responses were allowed; therefore, percentages may not add up to 100%.

A weak positive correlation of borderline statistical significance was observed between knowledge scores (0-23) and safe disposal practice scores (0-4) (Spearman's ? = 0.125; 95%; p = 0.045), which indicates that higher knowledge levels were associated with a greater likelihood of environmentally safer disposal practices.

**Discussion:**

The current study establishes the presence of knowledge and environmentally safe disposal practices gaps regarding harmful e-waste among medical students, even when the level of self-perceived knowledge was high. Similar mismatch has been reported in other studies carried out in a student population in both Indian and foreign institutions. Studies carried out in Zimbabwe, Bangladesh, and Malaysia shows that although the concept of e-waste was familiar to university students, knowledge regarding the harmful components, effects on health, and methods of disposal had been limited.[7-10]

The prevalence of poor knowledge levels recorded in this study is similar with studies done both among medical and health science students in Indian contexts. The absence of adequate knowledge about hazardous components of e-waste, government rules and regulations, and appropriately disposing of e-waste has been documented in studies done at Coimbatore, Pune and Lucknow along with other parts of the country.[1,6,11] Similar levels of knowledge deficit have also been found in nursing students, suggesting that knowledge deficits about e-waste do not belong to a particular group alone.[12]

Although the perceptions regarding hazardous potential of electronics materials and environmental effects were generally positive in this research, the practices of disposing them in a harmful manner did not stop. This notable gap between awareness and practice has been established in previous researches in India as well as in the overseas literature. Research studies carried out among medical undergraduate students, and other universities, have observed unsafe e-waste disposal practices like throwing in household waste, and improper handling of batteries, despite being aware of potential dangers in the environmental degradation.[3,5,9] In the context of public health, these practices are concerning, since they lead to bioaccumulation of toxic substances in the environment further enabling long term human exposure through soil, water and food.[4]

The weak but significant association between knowledge and safe disposal practice supports findings from earlier studies, which have found that knowledge has a very limited effect on behaviour.[1,8] Several studies have indicated that factors linked to institutional framework-such as lack of accessible collection centres, working disposal systems within educational institutions, and limited operational regulations-plays an important role in continued unsafe practices.[1,10,11] This highlights the need for interventions not just towards raising awareness but for a systemic support of institutions with regards to infrastructure.

Medical students represent an important section of the society with regard to issues of environment and communities, since they form a group of crucial healthcare and public health influencers. But they still continue to demonstrate improper waste practices, which have been documented in this study and a number of studies carried out in India previously, indicating a lack of early opportunities for proper intervention.[4,13] Incorporating e-waste and related issues of environment and health into medical education, and facilities for collection and recycling at institutions, have been recommended in a number of studies as a successful means of ensuring proper behaviour for a safer environment.

**Conclusion:**

This study reinforces existing evidence that improper handling of electronic wastes among students, is a significant environmental and public health concern. Despite the higher awareness, there are still knowledge gaps and unsafe methods of disposing of wastes among the students.

**Strengths:**

Major strength of study is the comparison between perceived and actual knowledge using the McNemar test, as it highlights the discrepancy between self-reported awareness and factual knowledge. The use of appropriate non-parametric statistical methods further strengthens the validity of the findings.

**Limitations:**

The study however lacks generalizability since it was conducted in a specified institute with no proper stratification of study population and purposive sampling further leading to selection bias. Social desirability bias is another factor owing to the nature of study based on self-reported perception, awareness and practices. Self-reported responses may also result in recall bias. In addition, the cross-sectional study design limits the establishment of causal relationships.

**Recommendation:**

A coordinated approach including curriculum integration, institutional accountability, improved regulatory awareness, and accessible disposal infrastructure is necessary to address these challenges. Strengthening environmental health competencies among future healthcare professionals would play a critical role to mitigate the long-term ecological and public health impacts associated with hazardous electronic waste.

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**Conflict of Interest:** None

**Funding:** None

Use of AI: Artificial intelligence tools were used only for language editing and formatting assistance. All content, analysis, and interpretations were performed by the authors.