

## University Students' Knowledge of the Hazardous Waste Sources and their Impacts on the Natural Environment

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### **Abstract:**

*The hazardous waste is generated from discarded consumer products, chemicals, pharmaceuticals, pesticides, personal care products, electronic products, industrial by-products, sludge, and waste oils. Hazardous products have the potential to harm humans or the environment. While education is key to addressing this issue, this paper responds to this gap by investigating a small sample of pre-service university students' (n=74) knowledge of the hazardous waste sources and their impacts on the natural environment. A quantitative-method questionnaire revealed that the level of knowledge of hazardous waste was not good among most of the students. Students' knowledge means scores show significant differences with respect to gender in favor of female students and with respect to the field of study in favor of science-related programs. Accordingly, the study suggests introducing some relevant extracurricular activities besides the enhancement of concepts related to environment, pollution and waste management in university syllabi. Additionally, academic institutions and other concerned organizations should conduct intense information dissemination on waste and its management. A recommendation for further relevant studies is drawn.*

**Keywords:** *Hazardous waste, Hazardous waste sources, Environmental contamination*

**Introduction:** Industrialization plays a noteworthy role in enlightening a nation's economy and, subsequently, the lifestyle of its fellow citizens. It has produced severe consequences due to excessive waste generation and disposal. A considerable quantity of solid, liquid, and gaseous waste generated during the manufacturing process is hazardous. Hazardous waste is defined as material that contains chemical goods that have been abandoned (Barton and Ainerua,

2020) or a product with properties that make it dangerous or capable of having a harmful effect on human health or the environment (EPA, 2025).

According to relevant literature, a waste is termed hazardous when it exhibits one of four characteristics - ignitability, corrosivity, reactivity, or toxicity (Kumar, 2023 and EPA, 2016). The United States Environmental Protection Agency EPA developed a regulatory definition and process that identifies specific substances known to be hazardous and provides objective criteria for including other materials in the regulated hazardous waste universe. This identification process can be very complex, so EPA encourages generators of waste to approach the issue using the series of questions described below (Chauhan et al. 2024)



The United Nations Environmental Programme (UNEP) has indexed waste in the category of hazardous material if they acquire one or more of the characteristics that may lead to the consequences (UNEP, 2025), such as, fires during routine management; corrosive upon exposure to air, or in some particular environment; chemical reactions that lead to toxic gas emissions into the atmosphere and Long-term environmental, geological, and ecological disaster effect.

In a resolution adopted by the General Assembly on 25 September 2015 (UN, 2015); UN adopted the 17 SDGs as part of the 2030 Agenda for Sustainable Development. These global goals aim to achieve a better future by addressing interconnected issues like poverty, inequality, climate change, environmental degradation, peace, and justice by the year 2030.

Education for Sustainable Development (ESD) puts education at the forefront of action by equipping individuals with the knowledge, skills, values, and attitudes to address environmental, social, and economic challenges for a more sustainable future. It involves integrating topics like climate change and

biodiversity into learning, and fostering skills such as critical thinking, problem-solving, and collaborative action. The goal is to empower people to understand, minimize and proactively manage harm resulting from hazardous waste pollution.

The focus of this paper sits in a formal teacher education program, with the working assumption that pre-service teachers are future agents of social influence and change. If they possess the requisite knowledge to address hazardous waste pollution, once in schools, they may be able to positively influence their school community. Comparatively, low levels of knowledge may hinder attitudes and, by default, their competence and confidence to teach others.

### **Conceptual Background and Literature Review:**

The cumulative need for people products has led to an upsurge in the number of industrial businesses worldwide. However, manufacturing processes can release waste and disposals (mainly hazardous) and, as a result, pose a lot of threat to the environment and health. These wastes can take various forms, including solids, liquid and gases, each posing unique challenges for safe disposal and management.

Based on the nature and severity of the risks they pose, the EPA classifies hazardous waste into the following categories (Gupta and Gupta, 2023; EPA, 2016):

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#### **1. Listed Waste**

These waste materials originate from public and commercial manufacturing processes. They can be classified into four categories: F-list, K-list, P-list, and U-list waste.

- **F-list waste**

They are non-specific source waste and result from industrial and manufacturing processes, including cleaning and degreasing solvents, and electroplating and metal-finishing operations, such as spent anodes, filters, dust from grinding operations, and wastewaters.

- **K-list waste**

These are source-specific, consisting of sewage or sludge from specific businesses like companies and are mostly released by wood preservation, pharmaceutical manufacturing, explosives, and pesticide manufacturing industries.

- **P and U list waste**

P- and U-List wastes are manufacturing chemicals you can throw away when they are still in use. P-list wastes are acutely hazardous wastes that are harmful even in small quantities.

## 2. Characterized Waste

These wastes can lead to explosions and toxic fumes when heated, compressed, or mixed with water. They are defined and associated with four properties: ignitability, corrosivity, reactivity, and toxicity.

## 3. Universal Waste

Universal waste is produced frequently, including batteries, mercury-containing devices, insecticides, and bulbs. The main classifications of universal wastes include: flammable solids or liquids; radioactive gases and organic peroxides.

## 4. Mixed Waste

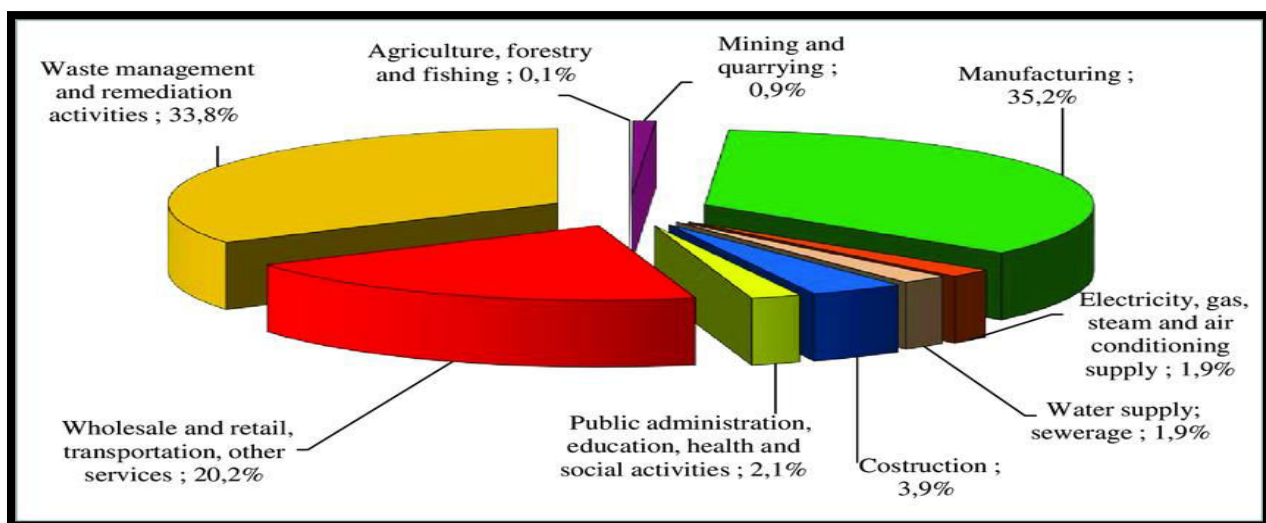
This waste is frequently created at laboratories or other comparable facilities and comprises dangerous or radioactive components.

## 5. E-Waste

These wastes represent gadgets and electronic accessories in the market, electronic garbage, among other electrical elements that are unwanted, non-functional, or nearing the end of their useful life.

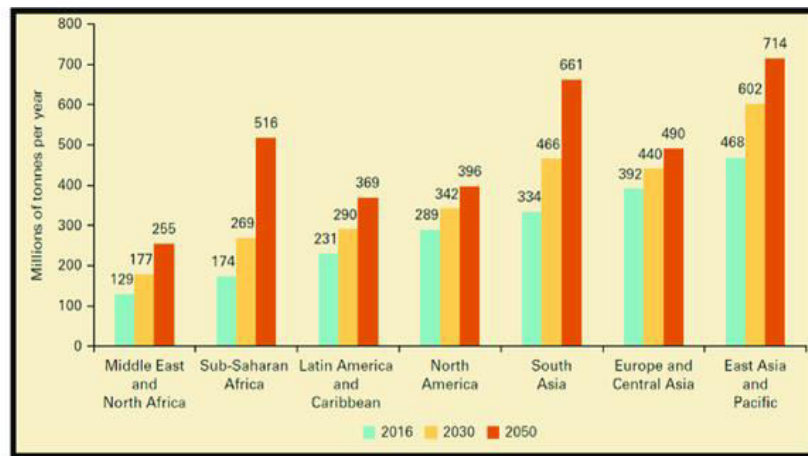
Other materials, such as old toasters, coffee machines, coolers, TV sets, printing presses, and old laptops, are also considered e-waste. Such components are dangerous and harmful due to their metal parts, leading to lead accumulation in landfills and water bodies.

Waste is generated from various sources, with manufacturing accounting for the largest global share (around 35.2%), followed by waste management and remediation activities (33.8%) and wholesale and retail and transportation (20.2%). Other significant sources include construction (3.9%), public administration, education, health and social activities (2.1%), electricity, gas, steam and air conditioning supply (1.9%) and water supply and sewerage (1.9%). Figure (1) below.



Statistics indicate that the rate of accumulation of hazardous waste is increasing day by day, and its damage has become clear to everyone. As estimated by the UN's fourth Global E-waste Monitor (UNITAR, 2025), about 50 million tons of electronic hazardous waste (E-waste) are generated every year around the world, rising five times faster than documented waste recycling. A record 62 million tons (Mt) of this waste was produced in 2022, up 82% from 2010; on track to rise another 32%, to 82 million tons, in 2030.

The amount of waste generated from different sources varies from country to country, affecting their environment and wildlife health. This is directly linked with industrialization, urbanization, and economic development. The countries with high incomes and economies are urbanized and subsequently produce more waste per capita compared to the low-income countries (Kumar et al., 2023) The World Bank projects (Fig.2) that global waste generation will upsurge by 70% to 3.4 billion tons by 2050, with significant rises expected in some region like Sub-Saharan Africa (tripling) and South Asia (doubling). High-income countries currently produce the most waste per person, producing 34% of the global total despite being a smaller part of the population, while East Asia and the Pacific currently produce about 23%.



This waste poses a significant threat to human health or the environment (water, air, soil) when imperfectly treated, transported, stored, or managed/disposed of (Zhang et al., 2022).

If not well-managed, the unpredictable negative outcomes of this waste will have the potential to cause permanent damage to the environment and public health, deplete the ozone layer and cause irreversible damage to domestic water sources. This could result in a reduction of the productivity of global ecosystems at a time when millions of people are looking for livelihoods and sustenance to be provided by the environment (Alabi, Pasa and Adebayo, 2023).

The potential consequences of these disposal wastes on public health are also moving to the fore. It is difficult to establish this impact without the availability of reliable risk assessment methods. However, the potential for adverse health effects in the population contacting hazardous household wastes may involve any organ system, depending on the following: dosage, age, gender, bodyweight, Psychological status, Genetics, Weather conditions and Immunological status and presence of other diseases. (Misra and Pandey, 2004).

Several health effects of primary concern may affect populations exposed to hazardous waste. These include as indicated by (Alabi et al., 2023): carcinogenesis (i.e. causing cancers), genetic defects, including mutagenesis (i.e. causing alterations in genes which are transmitted from one generation to another or causing heritable genetic damage), reproductive abnormalities including teratogenesis (i.e. causing damage to developing fetus not necessarily related to toxic effects on mother), alterations of immunobiological homeostasis, Central Nervous System (CNS disorder) and congenital anomalies.

### **Important Educational Conventions for a Safe Environment**

Whilst the implementation of legislation is crucial for managing waste generated by industries and households, education is vital for anyone generating, handling, or transporting hazardous waste, including industrial workers, educators, and students.

It is vital to equip learners with the knowledge, skills, values, and attitudes to address global environmental challenges and to work towards a more sustainable future. It is a lifelong learning process that empowers individuals to make informed decisions and take collective action for environmental integrity, economic viability, and social justice.

Literature pinpointed several key areas of hazardous waste education (The Commission, 1996; Haghi et al., 2024; Mandpe et al., 2025):

- Institutional staff: Schools are expected to conduct specific workshops or campaigns to train teachers on handling and dealing with hazardous waste, and how to equip their students with the appropriate related skills and proper disposal of hazardous materials procedures.
- Identification and classification: the curriculum should cover various types of waste, including biomedical, radioactive, and household hazardous waste. This would acquire learners' ability to identify hazardous waste based on their characteristics like ignitability, corrosivity, reactivity, and toxicity.
- Handling and storage: Some related classroom/ laboratory practical activities and inquiries may develop skills related to proper hazardous waste manipulations and safe handling.

- Regulations and compliance: while regulations provide the ethical and legal framework to protect the environment, education informs and empowers the public to understand and comply with these regulations, fostering a culture of environmental responsibility and sustainable practices.
- Waste minimization: school programs that teach children practical skills and promote a culture of responsibility would teach students' skills and knowledge to reduce, reuse, and recycle, leading to more sustainable waste management and a healthier environment.

### **Study Problem Statement**

The rise in living standards and the continuous development in the global economy led to the depletion of resources and increased waste generation per capita. Waste unsustainable practices, exacerbated by rapid urbanization and financial and institutional limitations, negatively impact public health and environmental sustainability.

Literature urges a more sustainable waste management approach, which prioritizes practices such as reduced production, waste classifications, reuse, recycling, and energy recovery over the common practices of landfilling, open dumps, and open incineration. This is more inclusive and environment-friendly and has less negative impact on human health and the environment than the common practices (Abubakar et al., 2022 and Kabera and Nishimwe, 2019).

Despite efforts to educate the public about hazardous waste and its impact, there is a significant gap between awareness and behavioral change. Many community members remain unaware of proper disposal methods, or, if aware, they do not practice these methods due to socio-cultural barriers and distrust in governmental authorities (McKenzie-Mohr, 2000). This study seeks to explore these gaps, focusing on university student teachers' knowledge of the hazardous waste sources and their impacts on the natural environment.

Meanwhile, hazardous waste knowledge and awareness studies in higher education are limited and have received less attention. Thus, in this study, university students would definitely benefit. Since the students are spending 4-5 years in their university between their program courses and extracurricular activities (the sources of their awareness and practices), the researcher would like to determine the level of hazardous waste knowledge and its impact on the environment among university students.

### **Thus, the following study questions have been posed:**

1. What is the level of knowledge among university students regarding hazardous waste?

2. Is there a statistically significant difference (at 0.05) between students' average scores with respect to their gender?
3. Is there a statistically significant difference (at 0.05) between students' average scores with respect to their field of study?

### **Significance of the Study**

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This study contributes to the literature on hazardous waste and its proper management by addressing the intersection of higher education programs and people's life responsibilities. By examining the role of the university, which posits that a future workforce can enhance this matter. (Flores and Moreno,2024)

This study provides insights into how higher education programs influence awareness of the environment, its elements and pollution. The findings have significant implications for academic staff and the university community, and in return, the impact would be constructive for the study population's pupils at schools.

This study would also underscore the importance of embedding environment-related subjects into academic programs, supported by extracurricular activities, in fostering students' knowledge of hazardous waste and its impacts. Moreover, the study's recommendations for improving public education and awareness activities can inform the development of more effective strategies for dealing with hazardous waste, not only in Oman but in other similar contexts globally.

### **Subjects and Methods**

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#### **Research Design**

This cross-sectional study was performed in April 2025 at Sultan Qaboos University after securing ethical approval for conducting this study. The study will utilize descriptive – quantitative approach through the use of the Hazardous Waste Awareness and Practices Questionnaire developed by the researcher.

#### **Respondents of the Study**

The target sample size was 200, selected randomly from different disciplines from the College of Education at Sultan Qaboos University, Oman. They were chosen from the second year of study onwards based on the assumption of their knowledge about hazardous waste resources and their environmental impacts gained from both the university programs and the university's academic and non-academic surroundings. 123 valid respondents were received through total enumeration. Sample description based on study variables showed 76 males, 47 females with respect to gender and 57 in science-based programs, 66 in humanities-based programs with respect to field of study.

**Research Instrument**

The questionnaire, consisting of 47 items, was developed by the researcher; patterned from books and relevant studies on hazardous waste, is divided into three parts. Part 1 has a total of 15 statements focusing on waste resources. More so, part 2 has a total of 15 items that focus on the impact of waste on the natural environment. Lastly, part 3 has a total of 17 items that deal with Waste Management.

The questionnaire was also pre-tested earlier on a group of 10 university students outside the study sample, and based on their responses, questions were modified before it was distributed in its final form to the participants.

Expert validation of the questionnaire was done through a panel of juries, ensuring its content, clarity, and relevance are appropriate for the study purpose, whereas reliability was assessed through using Cronbach's Alpha, giving a value of 0.89, indicating excellent internal consistency.

**Data Gathering Procedure**

Using Google Form, the students were oriented on the purpose of the study, and their responses on the questionnaire will be treated with utmost confidentiality and will solely be used for the purpose of the study. After their informed consent was taken for participation, a self-administered anonymous questionnaire was used for data collection to assess the knowledge of students regarding hazardous wastes and their environmental impacts.

**Analysis of Data**

After the study was conducted, the data obtained from the questionnaire was accessed into the SPSS program. The following statistical analyses were then used to analyze the data and extract the results.

Descriptive statistics such as percentages and frequencies are used to measure participants' knowledge of hazardous waste and its environmental impacts.

The maximum possible score which could be obtained was 47, and the minimum was 0. The summation of the scores allotted to the most essential hazardous waste knowledge formed the basis of the overall knowledge of students about hazardous waste. The accumulation of points allotted to disagree responses was used to decide the cut-off score for poor performance. Similarly, the cut-off value for moderate performance was based on the cumulative points allotted to agree responses made less than the maximum score of 47. The score between 32 and 47 was considered good, 16-31 as moderate and 0-15 as poor knowledge about first aid. The incompletely filled questionnaires were excluded from the analysis. Likewise, and inline with the University academic regulations, a score of 80% or higher is considered high cognitive level, 60% to 79.99% is considered medium cognitive level, and below 60% or less is considered low cognitive level.

## Results and Discussion

This section presents the findings of the study, organized around the three research questions that guide this investigation. The results are drawn from quantitative data assessing the study sample's knowledge of hazardous waste and its impacts on the environment and investigating differences in this knowledge with respect to both gender and field of study.

Question 1: University students' knowledge of hazardous waste

The gathered data were tallied and tabulated. Response frequencies and percentages were obtained and computed for both items and themes. Table 1 shows the frequency and percentage of knowledge on the scale as a whole, whereas Table 2 shows the results per themes.

Factor	Respondents	No. of Items	Freq.	Per %
Knowledge of hazardous waste	123	47	1962	60.7

The table indicates that the percentage of students' knowledge about hazardous waste is (60.7%), which displays a very low moderate level of knowledge among participants.

This can be attributed to a mixed understanding of what qualifies as hazardous and how to handle it safely, as well as potential gaps in university course contents or, awareness campaigns and extracurricular activities. If exists, non-major courses often centre on everyday items (like electric devices, paints, cleaners, and plastic wastes) and may not extend to industrial or more complex chemical wastes. Students often understand basic dangers like flammability or toxicity, but may lack specific knowledge about identifying all types of hazardous materials, their long-term health impacts, or complex disposal methods.

Similarly, only 26.3% and 35% of senior secondary school Indian students were aware of waste minimization and e-waste (Heena, Khan and Kaur, 2023).

Contrariwise, findings of Hmzah et al. (2022) show that the average level of knowledge among Malaysian students was 89.8%.

Theme	Respondents	No. of Items	Freq.	Per %
Waste Resources knowledge	123	15	673	60.5

Environmental Impact of Waste knowledge		15	784	63.1
Waste Management Practices		17	505	58.7

When comparing students' knowledge across the three themes, we find that they have slightly more knowledge about the impact of these wastes on the environment than knowledge about the other themes. Yet, their knowledge of waste management and disposal ranked last and was at a low level.

This result can be explained by the fact that students are already familiar with pollution, its causes, types, and effects on air, soil, and water, as well as the damage it causes to wildlife and air pollution resulting from burning waste. This knowledge was acquired during their school years, as well as through media, communication, and awareness campaigns.

In contrast, students' knowledge of waste management was at a lower level due to a lack of their education: many waste management problems at their studying stages stem from a lack of instruction on how to handle waste properly and show low awareness of the risks associated with household hazardous waste.

Likewise, Philippine high school students have low knowledge of the different laws relevant to waste management (Molina and Catan, 2021).

Inversely, a study of (Billo, 2021) showed that science education students at Federal University of Technology, Nigeria have high waste disposal management techniques.

### **Question 2: Differences in students' knowledge of hazardous waste according to their gender**

Research has found that females are more inclined to foster bonds with nature and possess a higher level of concern for the environment than males (Triantafyllidis and Darvin2021). The literature on the gender differences in student knowledge of hazardous waste shows diverse results, with some studies finding females have higher knowledge, while others show no significant difference. However, there is a trend for females to have greater knowledge and more positive attitudes, particularly in studies focusing on general solid waste management. Conversely, some studies on specific types of hazardous waste, like those in medical labs, found no significant gender differences in knowledge of safety procedures, though males reported incidents more frequently (Tikka, Kuitunen, and Tynys, 2000).

In this study, results revealed a significant difference (at  $p < 0.05$ ) in participants' knowledge of hazardous waste with respect to gender in favor of female students, as shown in Table 3.

Variable	No. of students	Mean	SD	t.value	Sig.
Male	76	12.64	4.97	4.53	0.00
Female	47	17.04	5.61		

This result could be traced to the fact that females are socialized to be more caring, altruistic, cooperative, and helpful, while males are socialized to be more independent and competitive (Li, Wang and Saechang, 2022). Commonly, women are “closer to nature”, caring for the land, water, forests, and other aspects of the environment. As stated by Setiawan et al. 2023, p.379) “Feminism is the ultimate solution to the world's ecological and social problems. Environmental justice is gendered because women suffer the most from poverty, human rights violations, and environmental destruction. Climate change disproportionately affects women due to the combined feminization of poverty and environmental degradation caused by climate change, while their adaptive capacity is limited by the exclusion of their needs and perspectives from climate change.

Question 3: Differences in students' knowledge of hazardous waste according to their field of study

A study conducted by Blok et al., 2015) showed that the workplace in a green university environment is largely determined by pro-environmental behavior. Students who were raised with science-based programs have significantly different levels of general environmental awareness, even though they were exposed together with institutionalized education (He et al., 2011). Students' knowledge of hazardous waste varies significantly by field of study, with students in science, technology, engineering, and mathematics (STEM) fields generally having higher knowledge levels than those in social sciences or other fields (Stöckert and Bogner, 2021).

Results showed a significant difference (at  $p < 0.05$ ) in participants' knowledge of hazardous waste with respect to the field of study in favor of science-based programs, as shown in Table 4.

Table 4 (T) test comparing the mean scores of students in the knowledge of hazardous waste					
Variable	No. of students	Mean	SD	t.value	Sig.
Science-based programs	57	17.33	4.70	6.33	0.00
Social Sciences-based programs	66	11.72	5.05		

This result can be attributed to the fact that studying science-relevant courses would provide more exposure to concepts and theories related to the environment and waste, giving them a more in-depth understanding. These programs include direct study of elements and their chemical properties, lab safety, and environmental science, which are fundamental to understanding what makes waste hazardous.

Such programs comprise mandatory training on proper laboratory procedures, the use of personal protective equipment (PPE), and the handling of chemicals, which inherently covers hazardous waste principles. This knowledge is reinforced through practical experience in labs, where they handle potentially dangerous materials and learn specific disposal protocols.

Similarly, in environmental engagement and knowledge, students from Syiah Kuala University, Indonesia, majoring in science were higher than in social science (Yusuf and Fajri, 2022).

### **Conclusion and Limitation**

This is one of the first studies to explore university students' knowledge of hazardous waste and its impact on the environment at the regional level. This study analyzed 74 student teacher questionnaires from a total population of 350 from the College of Education, Sultan Qaboos University, Oman.

Results showed that the level of knowledge about hazardous waste was not good among most of the students. This study thus identified the need for introducing some relevant extracurricular activities besides the enhancement of concepts related to environment, pollution and waste management in university courses. Students' knowledge means scores show significant differences with respect to gender in favor of female students and with respect to the field of study in favor of science-related programs.

Findings, principally, suggest that academic institutions and other concerned organizations should conduct intense information dissemination on waste and its management.

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