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ASSESSMENT OF WASTE MANAGEMENT PRACTICES: A CASE STUDY AT IMPERIAL COLLEGE OF ENGINEERING, KHULNA FOR SUSTAINABLE WASTE MANAGEMENT

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ABSTRACT

This paper focuses on the campus of Imperial College of Engineering (ICE), Khulna where waste was sorted into five main categories: cardboard, plastic, metal, glass and organic material. Over a 20-day period, the weights of each waste type were measured, along with the mixed waste generated from the campus. The average daily quantities were determined as 35.475 kg for separated waste and 43 kg for mixed waste, resulting in a separation rate of 83%. The collected data underwent analysis using excel, economic models and mathematical equations. This analysis determined the total quantities and calculated the potential revenue from selling each waste type, taking into account the capital cost, expenses and savings. The equal payment series method was then applied, resulting in a projected present worth value of 31,19,354 in five years, assuming the interest rate is 5%, indicating the research high feasibility. This research contributes valuable insights to the development of a sustainable waste management strategy at ICE, Khulna and it serves as a potential model for other institutions seeking effective solutions to waste management challenges.

***Key words**: University Campus, Waste Management, Strategy Development, Sustainability*

INTRODUCTION

Waste management (WM) is a challenge in the majority of the world's nations. Some challenges include reduced solid waste (SW) creation, separation, behavioral modification, collection, transportation, treatment, recycling and disposal of SW materials. Solid waste management (SWM) and planning are gradually shifting due to the escalating environmental issues and the emphasis on material and energy recovery. Currently, the primary goal is to create SW control systems that are inexpensive, maintainable and consider various management techniques (Gakungu et al., 2012). WM involves collecting, transporting, handling, or disposing of unwanted products and resources. According SW can include organic and inorganic (recyclable and non- recyclable) materials generated by various social activities but no longer valuable to the original consumer. Depending on the type and amount of consumption in a community, different SW components apply to different communities. Residential, commercial, industrial, institutional, building and demolition, agricultural and nuclear waste are the major categories of SW. These must be managed properly to reduce SW impact on the environment and people. Planning, organizing, directing and regulating resources people, money and materials manage an organization to accomplish its goals and objectives (Mubark, 2015). It makes decisions and takes actions that affect the organization's performance and ability to achieve its goals. Effective management can improve an organization's profitability, productivity and efficiency. Part of this is building and sustaining relationships with stakeholders, including shareholders, customers and employees. SWM as the collection, transportation and disposal of SW products, leads to a comprehensive understanding of the subject. It handles industrial waste as well as residential and commercial waste. SWM aims to reduce the harmful effects of waste on the environment and public health. There are several ways to accomplish this, including recycling, composting and landfilling (Wilson, 1997).SWM is a system of interconnected appropriate technologies and methods for generating, collecting, storing, processing, transferring and disposing of SW with the lowest possible cost and risk to human and environmental health (Soufan, 2012). Proper waste collection and distribution to a designated disposal site are essential for SWM (Tayeh et al., 2021). Non-biodegradable waste does not undergo natural degradation. Based on (Roy et al., 2019), they consist of pens and plastic materials. In classrooms with available waste bins, students often throw their waste there. The waste is then collected from that bin and dumped in the nearest landfill or

dustbin. Apart from the students, the staff work hard to keep the campus clean. Regulatory agencies sometimes monitor the entire system. People are sometimes less concerned about littering in poor countries like Bangladesh. Students in educational institutions are often seen throwing garbage wherever they want despite the presence of dustbins. Once again, waste cans are not always accessible. Despite some theoretical information in WM books, students rarely put this knowledge into practice. There is a lack of concern by institutional organizations about the current situation. According to (Sarder, 2017), sustainability is the application of methods, materials and structures that will not deplete resources or harm the environment. Along with "integrating natural systems with human patterns, continuity, individuality and place-making," it also "characterizes a concept and attitude in development that sees a site's natural land, water and energy resources as integral aspects of design." This, along with "integrating natural systems with human patterns and continuity, individuality and place-making," "characterizes a concept and attitude in development that sees a site's natural land, water and energy resources as integral aspects of design". Many colleges and universities have recently joined the sustainable development movement by participating in a nationwide competition for green campuses. As a result, more educational institutions focus on sustainability projects due to their growing environmental concerns. The subjects that scored highest in nine categories were governance, energy and climate change, college food and recycling, green building, student engagement, transportation, endowment transparency, investment priorities and shareholder engagement. The majority of food service directors, associate directors, managers and other college and university staff members have adopted initiatives like (1) tray-less dining; (2) recycling programs; (3) grab-n-go packaging; (4) purchasing seasonal, local and organic foods; and (5) composting food waste, realizing their responsibility to promote sustainability (Zhou, 2010). Considering this backdrop, the study plans to research waste generation, reduction, reuse, recycling, handling, collection and disposal on the Imperial College of Engineering (ICE) campus in Khulna.

METHODOLOGY

Site Selection

Imperial College of Engineering- affiliated with Rajshahi University (College Code: 385), a renowned engineering college located in Khalishpur industrial area of Khulna Division, Bangladesh. Established on October 18, 2017 to impart quality engineering education. Imperial College of Engineering (ICE) campus has five departments- Department of Civil Engineering, Department of Mechanical Engineering, Department of Electrical and Electronics Engineering, Department of Computer Science and Engineering and Department of Textile Engineering. ICE academic building is a ten-storied building with around 60 classrooms, office rooms, teacher's room, principal's room, spacious library, separate laboratories for each department and a spacious auditorium on the top floor. Besides, there is another two-storied building on the other side of the academic building, which has a cafeteria on the ground floor and a canteen on the upper floor. ICE campus generates a huge amount of waste every day, which is polluting the campus environment.

Data Collection

Primary Data Collection

In order to get the clear understanding of the waste management system detailed field survey of sustainable waste management system (SWMS) of ICE campus will be conducted.

Waste Sampling

Waste sampling is conducted by collecting and classifying waste samples from various locations on campus over a period of time (eg, four weeks).

Waste Characterization

One month waste Characterization study which is conducted to determine the quantity and category of waste generated. Waste is sorted into two main categories: Bio-degradable Wastes & Non-degradable Wastes. Then, the weight of each waste type is measured separately. The primary objective was to determine the exact amount of each type of waste generated by this campus. To facilitate accurate data collection, five containers were strategically placed, each in a volume capacity of 50 litters. These containers were specifically allocated for the segregation of five distinct categories of waste, namely metal, cardboard, plastic, glass and organic matter. This approach ensured the systematic classification of waste, which allowed for efficient measurement and analysis. The data collection period covered a total of 20 working days. Although this period may be although relatively brief, it was chosen considering several factors affecting data availability. For example, the semester in which the data were collected saw numerous strike days, which limited the overall number of

workdays available for the study. Additionally, the holy month of Ramadan followed directly after a 15-day collection period, during which the cafeteria & canteen was closed. In this situation selection was required a short time frame for data collection.

Questionnaire Survey

To encourage active participation of students, a dedicated campaign was launched to raise awareness about research studies. The campaign used various social media platforms and targeted relevant student groups, urging them to actively cooperate in solid waste segregation. The initiative aimed to instill a sense of responsibility among the student body and garner their support in implementing sustainable waste management practices. During the initiation of the quantitative survey, valuable technical assistance was received from the campus academic building, cafeteria, & canteen service staff. Their cooperation was instrumental in ensuring a smooth initiation of the data collection process.

Key informative interview (KII)

To gather comprehensive insights into the ICE Campus initiative and to obtain valuable information for the research project, interviews were conducted with various key stakeholders in the waste sector. Interviews included persons holding various positions, technical staff working in landfills, waste traders in local markets, as well as employees of the general services department of the ICE Campus. Engaging with these individuals offers a multifaceted understanding of solid waste management practices, policies and challenges. Their expertise was focused on initiatives undertaken to ensure proper collection, transport and disposal of waste within the respective jurisdictions. Engaging with local market waste traders provides valuable perspective on the economic aspects of waste management. These individuals provide insight into the dynamics of waste recycling, market demand for specific types of recyclable materials and associated costs and benefits. Understanding the commercial aspects of waste management contributes to an overall analysis of the feasibility and economic viability of sustainable waste management practices. In addition, interviews with staff from the ICE Campus General Services Department provided an insider's perspective on the university's current waste management practices.

Secondary Data Collection

For secondary data collection, various sources will be taken into consideration. For quantitative and qualitative data, information will be collected from Imperial College of Engineering (ICE) authority and students. Journals, articles, photos, reports, will be taken into consideration for data.

Strategy Development

Cost-benefit Analysis

According to information provided by the General Services Department of the Management System ICE Campus, the campus has four large containers for waste disposal. One of these containers has a capacity of 50 kg, while the other three containers each have a capacity of 150 kg. These containers are emptied three times a week as part of the waste management routine. The average cost associated with disposal of waste from these containers is approximately 10000 Tk per disposal cycle. It is important to note that these costs include costs related to transportation and proper disposal of collected waste. The disposal frequency of three times per week ensures that waste generated within the ICE campus is managed quickly and effectively, contributing to a clean and well-managed environment. This information from the General Services Department highlights the infrastructure and operational aspects of waste management at the ICE Campus. Understanding disposal capacity and frequency, as well as associated costs, is critical to evaluating the efficiency and effectiveness of waste management systems.

Financial Analysis

The collected data, including waste quantities, unit prices, expenses and capital requirements are utilized in financial analysis. This analysis involves the application of Excel, economic models and mathematical equations to determine the potential revenue from selling each waste type. The equal payment series method is employed to project the present worth value of the waste management project over a five-year period, assuming an interest rate of 5%. In the data collection process, an important aspect considered was the assessment of costs associated with waste management. Various cost factors were gathered, which are integral to understand the economic impact of different waste materials.

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Data Analysis

The data was analyzed qualitatively and quantitatively. The quantitative data was filled in an Excel data sheet and subjected to simple descriptive statistics. The qualitative data was organized and summarized from the responses obtained from the interviews and secondary data.

RESULT AND DISCUSSION

Analysis the Sources and Types of Waste Generated Characteristics

Analyzing the sources of waste at the ICE campus is essential for understanding how waste is generated and managed and for developing effective strategies to minimize waste or improve sustainability. For this reason, I was selecting three suitable areas on the ICE campus to ease my research work. Then step by step we found out the types of waste and their characteristics. The waste collector team played a vital role in this work. Here's a breakdown of potential sources of waste and types of waste generated & their characteristics on ICE campus and a detailed analysis of each:

Table 1 Sources & Types of waste from the ICE campus.

Source **Academic Building Area**	**Types of waste**
Classrooms	Paper, plastic, glass
Office rooms	Paper, plastic, glass
Teacher's room	Paper, plastic, glass
Principal's room	Paper, plastic, glass
Per floor	Paper, plastic, glass, leather
Library	Paper, plastic, glass
Auditorium	Paper, plastic, glass
Photocopy & Computer compose room	Paper
Environmental Engineering lab	Chemical reagents, paper, glass, plastics
Electrical & Electronics lab	E-waste, Paper, glass, plastics
Computer Hardware lab	E-waste, Paper
Mechanical Workshop	Paper, plastics, wood
Textile Engineering lab	Leather, textile waste, paper, plastics
Prayer room	Paper, Plastics
Toilets	Sanitary waste
Common room (girls)	Paper, plastics, glass
Ground sorting room	Paper, plastics, glass, wood
Cafeteria	Organic waste, paper, plastics, metals
Canteen	Organic waste, paper, plastics, metals

Table 2 Waste generated on the ICE campus and its characteristics

Type	Characteristics	Recyclability
Paper & cardboard	Biodegradable waste	Recyclable
White, Colored, Newspaper, Magazines, Books Printed materials, Tissue paper, Cement bags, Cartons, Other cardboard		
Plastics, Polythene &Packaging foils	Non-degradable waste	Recyclable
Plastic materials-cans, Polythene, Bags, Bucket, Beakers, Pipettes & burettes, Spoilt plastic chair, Tubes, Cables, Pen, Foam		
Glass	Non-degradable waste	Recyclable
Bottles clear, Bottles green, Bottles amber		
Metals	Biodegradable waste	Recyclable
Aluminum cans, Metal mixed, Tin Cans, Plates, Buckets, Spoons, Pots, Boxes, Electronic equipment		
Textile	Non-degradable wast	Recyclable
Clothing samples		

Leather (shoes & bags)	Non-degradable waste	Recyclable
Organic	Biodegradable waste	Recyclable
Food waste, Organic mixed		
Hazardous	Non-degradable waste	Non-recyclable
Cleaner, Batterie, Reactive agents, Chemical reagent		
Construction/demolition	Non-degradable waste	Recyclable
Gravel & sand, Rock, Wood, Others		
Sanitary waste	Non-degradable waste	Non-recyclable
E-waste	Non-degradable waste	Non-recyclable
Electric cables, Printer cartridge, Old computers, Smartphones		

Quantity Analysis of Mixed Waste

The average amount of waste generated daily was calculated by weighing the mixed waste bins on the ICE campus over a twenty-day period. The results demonstrate the amount of waste generated at this specific location, showing that the average daily amount of mixed waste generated on the ICE campus was 43.0 kg/day. The data collected provides important insights into the type and amount of waste generated on the ICE campus, which can help with the development of efficient waste management plans. In order to reduce the environmental effect of this waste, it could be feasible to identify areas where waste reduction and recycling activities may be performed by better understanding the patterns of waste formation in this environment.

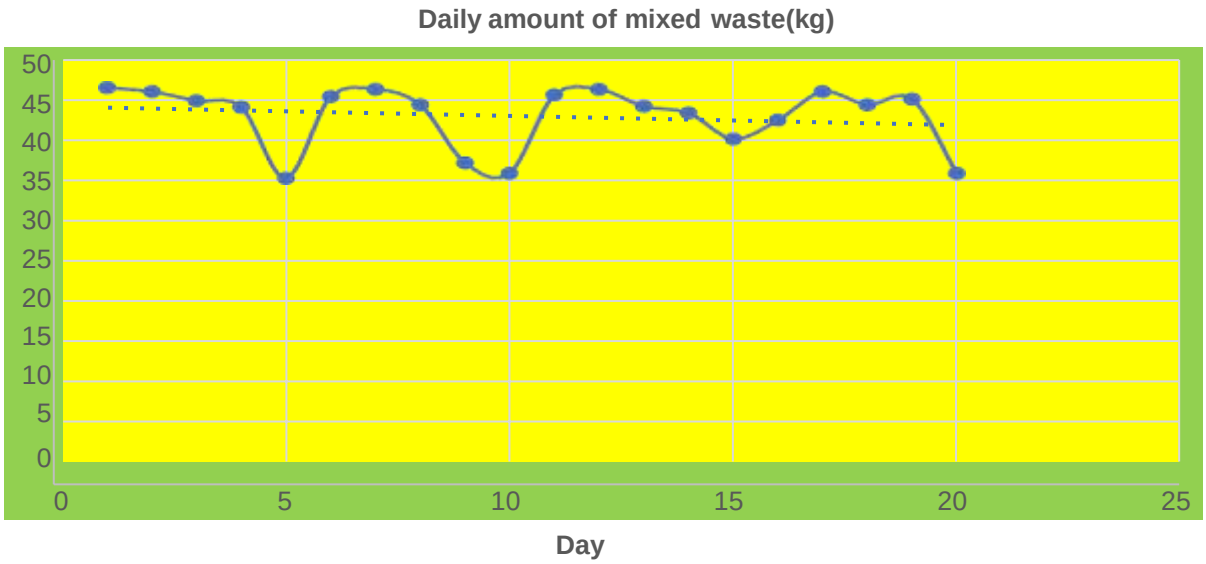

Figure 1 Trend line of daily amount of mixed waste

Quantity Analysis of Separated Waste

To determine the proportions and quantities of different waste categories in the ICE campus, a methodical approach was adopted. First, the waste was observed and the ICE campus administrator was consulted to identify the most frequently items. Based on this information, the waste was separated into five main categories: glass, metal, cardboard, plastic and organic. Over a period of 20 days, separate containers were provided for each category and the weight of the waste in each container was measured at the end of each day. After gathering the data, adjustments were made and the information was analyzed. The results revealed that the average percentages of the different waste categories were 83% for cardboard, 10% for plastic, 6% for organic,1% for glass and 1% for metals. Furthermore, by applying mathematical equations to the data, it was determined that the average daily quantity of waste generated in the ICE campus was 35.475 kg per day and that the percentage of separation is 83%. This systematic approach to waste analysis provides valuable information for the development of effective waste management and reduction strategies.

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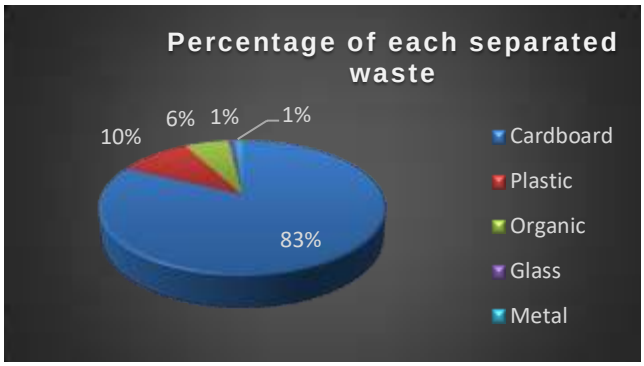

Figure 2 Percentage of each separated waste

Figure 3 Percentage of separated waste to mixed waste

Prediction of Waste Quantities for Quantities for a Semester

To predict the quantity of waste generated during a semester, an estimation was made based on the assumption that the semester would consist of 80 working days. The quantity per day for each waste category was then determined and multiplied by the total number of working days to arrive at an estimated quantity of waste for the semester. The results of this analysis showed that an estimated 2359.6 Kg of cardboard waste, 283.2 Kg of plastic waste, 169.2 Kg of organic waste,14.8 Kg of glass waste and 11.2 Kg of metals waste would be generated, resulting in a total of 2838 Kg of waste.

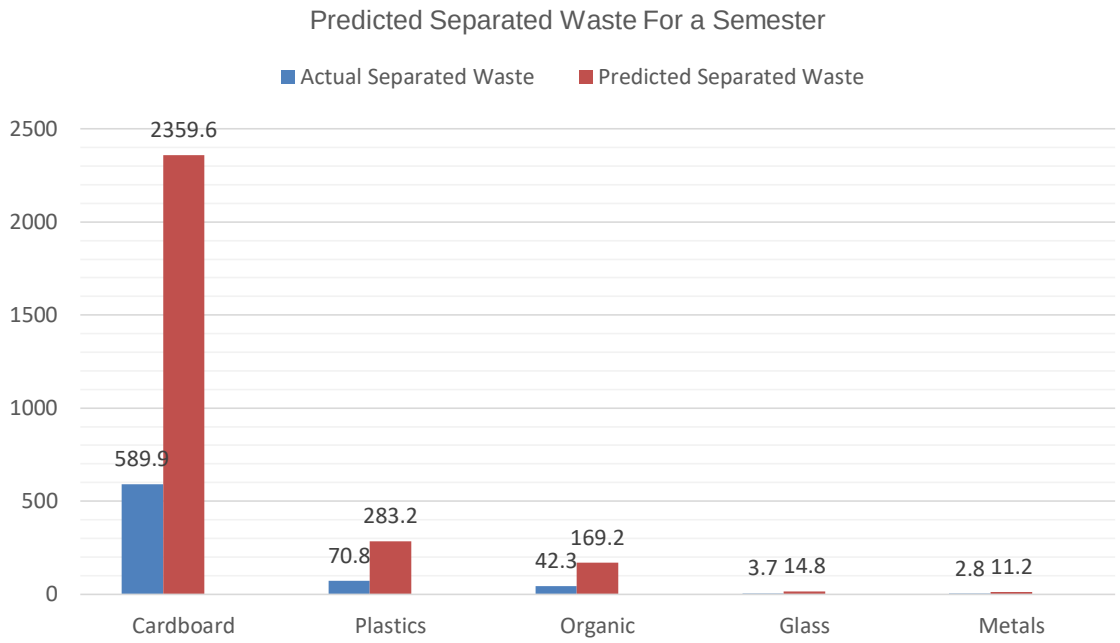

Figure 4 Comparison between actual separated waste & predicted separated waste

Projection of Semester Waste Amounts Assuming Complete Waste Separation

Furthermore, an additional estimation was made to predict the quantity of waste for each waste type for the semester. It was assumed that the total amount of waste generated from mixed and separated waste sources would be collected in the separation container. The analysis showed that an estimated 2843 Kg of cardboard waste, 342 Kg of plastics waste, 204 Kg of organic waste, 18 Kg of glass waste and 14 Kg of metals waste would be generated, resulting in a total of 56760 Kg of waste for the semester. By estimating the quantity of waste generated for each waste type, it becomes easier to develop and implement effective waste management strategies to promote sustainability.

Strategy Development

Predicted Revenue Estimation

A detailed analysis of revenue generation from waste recycling has been conducted. By multiplying the quantities of waste with the respective unit prices obtained from the local market, the expected revenue for a semester has been projected. The findings indicate that the anticipated revenue for

cardboard, plastic, glass and metal stands at BDT 28,500, BDT 2,800, BDT 216 and BDT 1120 respectively. Notably, no revenue is projected for organic waste. Consequently, the total revenue projected for a semester amounts to BDT 32,636. Furthermore, considering the academic year consisting of two semesters and a summer semester (equivalent to 2.5 semesters), the expected revenue for the entire year reaches BDT 81,590.

Initial Capital Cost Estimation

A thorough assessment of the initial capital cost has been carried out; the findings revealed a requirement for the installation of 5 indoor integrated containers to replace the existing ones. By multiplying this quantity with the corresponding market price, the estimated total cost for these containers amounts to BDT 2250. Additionally, it was identified that the project necessitates the addition of 4 outdoor containers. After multiplying this quantity with the relevant market price, the projected total cost for these containers reaches BDT 900.Consequently, the cumulative capital cost for the project is determined to be BDT 3150.

Potential Savings

An evaluation of the potential savings has been conducted. The estimated savings are derived from the cost of waste disposal, taking into consideration the deduction of the cost associated with organic waste disposal. According to information gathered from the services administrative staff, the cost of waste disposal is determined to be BDT 8000 per month. Considering that waste is disposed of three times a week, the cost is multiplied by. Additionally, factoring in the duration of 16 weeks for each semester and a total of 2.5 semesters, the calculation is performed. Based on the percentage breakdown of different waste types and deducting the proportionate share of organic waste (multiplied by 0.94), the total estimated savings per year amount to BDT 90,2400. These projected savings reflect the potential cost reductions that can be achieved through efficient waste management practices. By implementing sustainable waste disposal strategies and reducing the amount of waste requiring external disposal, ICE campus can significantly minimize the associated expenses. The substantial annual savings of BDT 90,2400 serve as an incentive for the university to prioritize sustainable waste management, further reinforcing its commitment to environmental responsibility and financial efficiency.

Research's Feasibility Estimation

To apply the present worth analysis based on the given data, we can use the following equation:
$P = A \times [1 + i)\ n - 1] / [i \times (1 + i)\ n] \ n - Capital\ cost$
Where, P is the present worth value, A is the net annual cash flow (revenue - expenses + savings), i is the interest rate or rate of return n is the number of years
Using the provided values: A = 848090 (Revenue - expenses + savings), Capital Cost = 31,50 BDT, i = 5% (0.05), n = 5 years
Let's calculate the present worth value (P):
P = 848090 × [(1 + 0.05)5 − 1] / [.005 × [(1 + 0.05)5] − 31,50
P is approximately equal to BDT 33,19,354.

Research's Environmental Assessment

According to (Rabl et al., 2008), the study estimated the environmental damage cost associated with solid waste to be 2,909.04 BDT per ton. Based on the provided information, the total environmental damage cost. Assuming a waste generation of 3.4 tons annually, the cumulative environmental and health damage cost is determined by multiplying the waste generation (3.4 tons) by the environmental and health damage cost per ton (2,909.04 BDT).
Thus, the total environmental damage cost amounts to BDT 10,007.09.

DISCUSSION

Questionnaire Findings

The questionnaire analysis provided valuable insights into the awareness, attitudes and behaviors of ICE campus students towards solid waste management. Respondents acknowledged solid waste as a pressing concern, with a majority facing waste-related difficulties in their surroundings.
In conclusion, the questionnaire analysis highlights the need for addressing knowledge gaps, providing incentives and improving waste management infrastructure. It is essential to promote awareness, increase waste separation rates and foster a culture of sustainable practices among ICE campus students. By implementing effective waste management strategies, ICE campus can contribute to pollution reduction, resource conservation and improved health outcomes in alignment with sustainable development goals.

Economical Aspects

The data analysis of the proposed waste management system yielded promising economic results. The annual revenue amounted to BDT 81,590, which was derived from the sale of recyclable products such as cardboard, plastic, glass and metal. Organic waste was excluded due to the absence of market demand and logistical constraints associated with composting. In addition to revenue, this system provides potential cost savings of BDT 90,2400 annually through reduced disposal costs and improved operational efficiency. These savings can be reinvested to support system improvements or other initiatives. The project cost was estimated at BDT 3,150 using a 5-year present value analysis using a 5% interest rate, confirming its financial viability and potential for positive net cash flow. The findings emphasize the cost-effectiveness and sustainability of the project. Through strategic partnerships and market exploration, the revenue stream can be further expanded. This initiative is consistent with environmental and resource optimization goals, providing a solid foundation for policy implementation.

Environmental Aspects

The study estimates the environmental and health costs of inadequate waste management at Rs 10,007.09 crore, highlighting pollution, resource depletion and ecosystem degradation. Sustainable practices such as waste reduction, recycling and proper disposal can mitigate these impacts, are consistent with circular economy principles and improve cost-effectiveness. Adopting responsible waste management reduces pollution, conserves resource and protects public health, underscoring its important role in achieving long-term environmental and social sustainability.

CONCLUSION

This study on waste management practices at ICE, Khulna highlights critical insights into the existing systems and presents a roadmap for sustainable and cost-effective waste management on campus. In this study, it was found that:

Revealing Existing Practices

The assessment has unveiled the current waste management practices, including methods of waste segregation, collection, disposal and recycling. While some efforts toward waste handling exist, several gaps were identified, such as insufficient waste segregation, limited recycling initiatives and a lack of awareness among stakeholders.

Challenges Identified

1. Poorly defined protocols for waste segregation.
2. Limited infrastructure for managing recyclable and organic waste.
3. Inefficiencies in waste collection frequency and methods.
4. Lack of stakeholder engagement in sustainable waste practices.

RECOMMENDATION

Based on the comprehensive research conducted on sustainable solid waste management at ICE campus, the following key recommendations have been identified to guide ICE campus in prioritizing sustainability, environmental considerations and economic aspects in their waste management practices:

1. Implement a robust waste separation program across the campus, including the cafeteria and other relevant areas, with clear guidelines for proper waste sorting and disposal, emphasizing the separate collection of recyclable materials.
2. Establish a comprehensive recycling program with accessible recycling bins for different types of waste materials, collaborating with local recycling traders for proper collection, processing and recycling.
3. Invest in suitable containers, collection systems and disposal facilities designed for different waste categories, strategically placing them to optimize waste collection efficiency and promote adherence to waste separation practices.
4. Foster partnerships and collaboration with local authorities, waste management companies and stakeholders to facilitate knowledge sharing, access to expertise and potential funding opportunities, enabling the adoption of best practices and exploration of economic benefits.
5. Promote awareness and education through the incorporation of waste management and environmental education into ICE campus curriculum, organizing awareness campaigns, workshops, seminars and involving students in social works courses and competitions with prizes.

6. Conduct a detailed cost-benefit analysis to ensure the long-term feasibility and economic viability of the solid waste management project, considering investment costs, operational expenses, potential revenue streams, cost savings and environmental benefits.
7. Introduce composting systems to manage organic waste effectively, establishing designated areas or facilities for composting and utilizing the compost for campus landscaping or community gardens.
8. Prioritize sustainable procurement practices by including sustainability criteria in procurement policies, favouring products with minimal packaging, recyclable materials and reduced environmental impact.

In conclusion, by implementing these recommendations, ICE campus can make significant strides in sustainable solid waste management, reducing its environmental footprint, promoting responsible waste disposal and contributing to the well-being of the campus and the surrounding community. These recommendations align with global sustainability goals and demonstrate ICE campus commitment to environmental stewardship. It is essential for ICE campus to take proactive measures, engage stakeholders, invest in infrastructure and foster awareness and education to ensure the long-term success of their sustainable waste management initiatives, setting an example for other institutions and making a lasting impact on environmental preservation for future generations.

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