



Enhancing Environmental Sustainability Through the Integration of TVET in Sustainable Solid Waste Management (SWM)

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Abstract

Solid waste Management (SWM) is a critical environmental challenge in developing nation. Its Inefficient management is a major socio-economic causing degraded ecosystem livelihoods due to rapid population growth, urbanization, and lifestyle changes. Despite the global importance of solid waste, developing countries face challenges in addressing this issue. This paper explores the role of Technical and Vocational Education and Training (TVET) in promoting sustainable Solid Waste Management (SWM) in developing nations. It highlights the potential of TVET to bridge the gap between education and practical waste management solutions, focusing on skill development, policy frameworks, and community engagement using a qualitative research design. Key institutional documents, policy frameworks, and training curricula were evaluated to determine how sustainability is integrated into TVET programming. The findings confirm that TVET plays an important role in improving environmental sustainability through skill-based solid waste management practices. It shows that TVET is becoming more widely recognized as a transformational instrument for advancing sustainable waste management practices through skill development, awareness creation, and community-based innovation. However, to maximize its impact, there is a need for improved institutional support, revised curriculum, and public-private partnerships that could improve training, entrepreneurship, and infrastructure development.

Keywords: Solid Waste Management (SWM), Technical and Vocational Education Training (TVET), sustainability



Introduction

Waste refers to any material, substance, or by-product that is no longer useful or wanted by its owner and is discarded (Olayiwola et. al., 2023). It can originate from various human activities; such as residential, industrial, commercial, institutional, hospital, agricultural, and construction or demolition activities. Wastes are generally classified into three main forms: gaseous, liquid, and solid, depending on their physical state. Solid waste, in particular, is non-liquid and non-gaseous discarded material resulting from human and animal activities. Solid waste encompasses a wide range of materials such as household garbage, packaging, plastics, paper, food scraps, and yard debris, medical waste, hazardous waste glass, metals, e-waste (Olayiwola et. al., 2023). In Nigeria, terms such as garbage, trash, refuse, and rubbish are commonly used to describe solid waste. The sources of solid waste are categorized as residential, industrial, commercial, institutional, construction and demolition (C&D), medical, agricultural, and other miscellaneous origins.

Solid Waste Management (SWM) is widely recognized as one of the most pressing challenges confronting municipal authorities globally (Derdera & Ogato, 2023). This is largely due to factors such as population growth, rapid urbanization, industrialization, economic development, lack of household participation, and widespread poverty (Muhammad et. al., 2024; Olayiwola et. al., 2023; UNEP, 2020). According to Oroye (2020), urbanization and industrialization significantly increase the volume of waste, thereby complicating SWM efforts. Fernandoa, & Zutshi, (2023); Salima et. al., (2023) also identify additional challenges, including increasing



waste generation, inadequate collection systems, improper disposal methods, lack of legislation, insufficient financing, weak organizational leadership, the common perception that waste services should be provided free of charge, outdated equipment, poor staffing, and lack of technical expertise. These challenges have contributed to poor waste management practices, often resulting in open dumping in streets and waterways, as well as open burning, all of which pose serious risks to public health, the environment, and long-term sustainability.

Nigeria, controlled methods like sanitary landfilling, incineration, composting, anaerobic digestion, and recycling are not widely adopted. Instead, open dumping, open burning, and indiscriminate disposal into water bodies are prevalent. This uncontrolled waste disposal is unsustainable, illegal, and hazardous to both environmental and public health (Muhammad & Marzuki, 2024; Muhammad et. al., 2024). Improper domestic waste handling and inadequate solid waste infrastructure have led to increased health threats in urban areas. Indiscriminate waste disposal fosters the proliferation of disease vectors, such as flies, mosquitoes, and rodents, which transmit diseases like cholera, typhoid, and malaria. Open burning contributes to air pollution and respiratory health issues, especially among vulnerable populations like children and the elderly. Studies show that continuous exposure to smoke from open waste combustion increases the incidence of bronchial and pulmonary illnesses. Unregulated waste disposal methods are key drivers of environmental degradation in Nigeria (Muhammad et. al., 2024). Indiscriminate dumping leads to soil and water contamination, while open burning contributes to air pollution and greenhouse gas emissions. Groundwater and surface water contamination is another concern,



as leachates from unmanaged dump-sites introduce biological, chemical, and physical pollutants into surrounding water bodies, threatening aquatic ecosystems and public water supplies

Environmental sustainability is the responsible interaction with the environment to prevent depletion or degradation of natural resources and ensure long-term ecological quality. Sustainable practices reduce greenhouse gas emissions, slow global warming, and reduce extreme weather events. Sustainable solid waste management (SWM) is vital for maintaining a healthy ecosystem, supporting life, agriculture, and livelihoods, and fostering economic growth by preventing resource crises and fostering green jobs. Integrating Technical and Vocational Education and Training (TVET) into sustainable SWM practices offers a viable solution for enhancing environmental sustainability. Technical and Vocational Education and Training (TVET) is a comprehensive education program that prepares individuals for specific trades, crafts, and careers in various industries and services (Ayonmike et al., 2015; Chukwu et al., 2024). It emphasises hands-on training and practical experience (Muoghalu & Ahmad, 2023; Chukwu et al., 2024), preparing learners for occupations like engineering, agriculture, ICT, health, and construction. It plays a crucial role in national development by aligning education with labor market demands (Onwusa, 2021).

TVET institutions can play a significant role in sustainable SWM by equipping learners with the technical skills and knowledge necessary for modern waste management practices, including recycling technologies, waste reduction, and environmentally friendly disposal methods. This aligns with global efforts to achieve the United Nations Sustainable Development Goals (SDGs), particularly SDG 4 (Quality Education) and SDG 11 (Sustainable Cities and Communities). This



study explores the potential of TVET in advancing sustainable solid waste management in Nigeria and investigates how vocational education can be harnessed to foster environmental sustainability.

Objectives

The objectives of this study are to;

- i. assesses the current integration of solid waste management content in TVET curriculum,
- ii. identify key skills for effective waste management,
- iii. examine challenges and opportunities in using TVET as a sustainable solid waste management

Materials and Methods

Appropriate methods were applied in ensuring that relevant studies were captured. Several electronic databases such as Google, Google Scholar, JSTOR, Springer, Taylor and Francis, Wiley Online, ScienceDirect, and Social Science Citation Index were searched. Likewise, journals in the fields of environment and waste management, including Journal of Environmental



Studies, Journal of Material Cycles and Waste Management, Cleaner Waste Systems, Nigerian Journal of Environmental Education etc. Also, pertinent environmental studies, technical education and waste management conferences proceeding were also searched and utilized.

Inclusion Criteria

Studies that meet specific criteria were considered relevant to the studies and were included in the review. First, primary studies can be qualitative or quantitative. Second, the studies had to incorporate extensive understanding of the policy, institutional, and instructional frameworks that promote sustainability in TVET. Also, studies incorporating institutional practices, and challenges associated with integrating TVET with sustainable solid waste management were also considered and included. These were the criteria used in searching and selecting articles for the review.

Data Collection

The data were gathered through in-depth document analysis in addition to the selected articles, key institutional documents, policy frameworks, and training curricula were evaluated to determine how sustainability is integrated into TVET programming.

Document Analysis

Documents were painstakingly analyzed enabling an extensive understanding of the policy, institutional, and instructional frameworks that promote sustainability in TVET. Documents from the organisation relevant to the problem were analysed to get further facts and information. The official websites of the affiliated organisations were also checked to collect published reports.



Results and Discussion of Findings

Roles of TVET in Sustainable Solid Waste Management (SWM)

TVET contributes to SWM capacity building by training waste management personnel in modern waste collection, sorting, recycling, and disposal techniques; safe dismantling, recycling and disposal of e-waste (Bukhari et al., 2018), landfill management, and biogas generation. Akinwale & Ogunbiyi (2022); Hamid et al. (2024); Oviane & Ehirheme (2020) also emphasised that it promotes innovation and technology by promoting research and development in waste-to-energy technologies, composting, material recovery and reducing dependency on fossil fuels. Singh et al (2021) stated that TVET encourages small-scale businesses in recycling and upcycling industries and educates the public on sustainable waste management practices through TVET-driven outreach programs. TVET (Technical and Vocational Education and Training) is a crucial tool in promoting environmental sustainability by creating a skilled workforce, promoting sustainable waste practices, and driving community-based solutions for solid waste management. It bridges the gap between education and sustainable development, equipping students with practical skills and knowledge to implement sustainable waste practices, reduce environmental impact, and promote green economies. TVET programs prepare students for green jobs in ecological services, such as recycling plant operators, waste collection and sorting professionals, environmental health technicians, composting, and bioenergy technicians. TVET can change mindsets by integrating environmental education into curricula, emphasising the 3Rs (Reduce, Reuse, Recycle), waste-to-energy technologies, and circular economy principles. Trained TVET



graduates can design and implement local solutions to manage waste, especially in underserved or rapidly urbanising areas.

TVET curricula can also include modules on environmental laws, waste policy frameworks, and regulatory compliance. Structured TVET courses can upskill public sector employees on enforcement and monitoring of SWM regulations. Integrating environmental education into vocational training can help shift cultural perceptions about waste and sustainability. It can prepare future leaders and technical officers to engage constructively with political actors and community stakeholders. TVET can include on sustainable leadership, ethics, and accountability in environmental governance. Governments and development agencies support greening TVET to meet sustainability goals, especially under the UN SDGs, including: SDG 4(Quality Education), SDG 11 (Sustainable Cities and Communities), and SDG 12(Responsible Consumption and Production)

Effectiveness of Technical and Vocational Education and Training (TVET)

TVET-based solid waste management (SWM) programs are gaining recognition for their effectiveness in addressing local waste challenges and promoting sustainable environmental practices. These programs integrate vocational education and training with sustainable waste management strategies, enhancing community engagement (Islam & Singh, 2024), technological innovation, and financial sustainability. Culturally sensitive approaches, educational campaigns, and participatory initiatives are crucial for raising awareness and fostering local ownership of waste management practices (Vetrivel et al., 2024). Technological innovation, such as mobile



apps for waste tracking and decentralised waste treatment systems, can enhance operational efficiency in areas with limited infrastructure (Islam & Singh, 2024; Gupta et al., 2023). Case studies show that technology-enabled strategies, like waste segregation, can lead to significant cost savings and operational improvements in waste management systems (Gupta et al., 2023). Financial sustainability is essential for sustaining TVET-based SWM programs (Islam & Singh, 2024), and collaboration between government bodies, local stakeholders, and tourism operators can create a supportive framework for sustainable waste management practices (Vetrivel et al., 2024).

However, challenges such as inadequate infrastructure and limited community awareness remain, necessitating urgent attention to maximise the potential of these programs in fostering sustainable waste management practices.

Challenges in integrating Technical and Vocational Education and Training (TVET) Into Sustainable Solid Waste Management (SWM)

The integration of sustainable solid waste management (SWM) practices into Technical and Vocational Education and Training (TVET) curricula faces several challenges, including technical, financial, and human resource issues (Bui et al, 2020; Okeke, 2020; Solomon & Igbadi, 2022; Cyril, 2008; Ayonmike et al., 2015). Technical difficulties include inadequate facilities for practical training and outdated teaching materials (Bui et al., 2020). Financial constraints, such



as limited funding for SWM research and curriculum development, restrict institutions' ability to innovate and implement sustainable practices (Yadav et al., 2021). Human resource limitations include a shortage of qualified staff knowledgeable about sustainable practices, leading to ineffective teaching and a lack of engagement with sustainability topics (Bui et al., 2020; McGrath & Russon, 2023). Information sharing issues between educational institutions and industry stakeholders can result in outdated curricula that do not reflect current sustainable practices or technologies (Zamban & Matte, 2024). Cyril (2008) and Ayonmike et al. (2015) in their study identified areas of challenge faced by TVET institutions in Nigeria in integrating waste management into SWM, to include low awareness of waste management careers, and resistance to waste-related occupations, regulatory and institutional barriers to certification and accreditation, lack of collaboration between TVET institutions, industries and municipalities and cultural attitudes. Others include rapid technological advancements, weak infrastructure, and poor policy implementation (Olayiwola et al., 2023; Oroye, 2020). In Lagos, waste generation is over 13,000 metric tons of waste daily, but only 40% is collected due to inadequate waste collection systems and poor enforcement of regulations (Lawal et al., 2021). A study by Adeyemi et al. (2019) revealed that in Ibadan, 60% of waste generated is improperly disposed of, and wastes are dumped in drainage channels, causing flooding and disease outbreaks. Abuja faces challenges with waste sorting and disposal, with residents lacking awareness of proper waste disposal techniques and municipal waste services insufficient to meet demand (Adebayo & Olarewaju, 2020). Kano's informal waste sector plays a crucial role in waste collection, but poor integration with formal systems limits efficiency. Also, lack of recycling infrastructure hinders sustainable waste management efforts. Industrial waste, particularly from the oil sector, poses a



major challenge in Port Harcourt, with limited government intervention (Okonkwo et al., 2022). These challenges highlight the need for effective waste management strategies in TVET institutions to address the challenges of waste management in Nigeria and beyond.

TVET has been successfully integrated into sustainable solid waste management initiatives in Germany (Schulz & Meyer, 2019), Sweden, India, and Nigeria. Olayiwola et al. (2023) stated that Germany offers dual training programs that combine theoretical learning with practical experience in waste management, producing a skilled workforce for recycling and waste recovery industries. Sweden emphasises circular economy principles and apprenticeships with waste management companies, while India empowers waste pickers through structured training (Olayiwola et al., 2023)

Nigerian educational institutions have initiated pilot programs to train students in composting and plastic recycling, promoting sustainable waste management practices and generating employment opportunities, particularly in the informal sector. Notable examples include Yaba College of Technology, Federal Polytechnic, Ado-Ekiti, (NCF, 2023), University of Lagos, Nile University of Nigeria (Plastic Odyssey, 2023), Lagos State Public Primary Schools under the clean our world (COW) project (EnvironNews Nigeria, 2023s, Polytechnic Ibadan, and Auchi Polytechnic. The French Embassy has funded innovative plastic waste management solutions across multiple Nigerian universities, enhancing technical skills for effective waste management (French Embassy in Nigeria, 2023)

Policy Making in Technical and Vocational Education and Training (TVET)



Nigeria's TVET frameworks need revision to incorporate sustainable development goals and environmental mandates. This can be achieved by revising the National Solid Waste Management Policy, which already instructs the Environment and Education Ministries to include solid waste issues in curricula. The policy should mandate "greening" technical training, such as recycling, resource efficiency, and climate resilience. TVET institutions need stronger governance structures with sustainability oversight to address fragmented oversight. Quality assurance bodies like NBTE should adopt internationally-inspired models, adopting outsourcing QA policies and regular joint reviews of TVET performance. Nigeria needs to address funding and staffing gaps in TVET, secure budgetary commitments, and empower institutions to mobilise resources. A sustainable funding model should include government budgets, donor grants, and private sector contributions. TVET can create a Green Skills Fund to underwrite green training, prioritise sustainable infrastructure (Winny & Ezenekwe, 2024), and offer incentives like tax breaks and scholarships. International donors and NGOs can co-finance curriculum reform and teacher upskilling.

Technical and Vocational Education and Training TVET Sustainable Waste Management SWM Enhancement Through Collaboration

The impact of TVET-based Solid Waste Management (SWM) programs can be significantly enhanced by fostering partnerships between government, private sectors, and communities (Rani & Yendluri, 2024; Onukwulu et al., 2025). According to Slehkie & Dongjie (2021) and Ikhwan (2022), engaging multiple stakeholders, including local governments, waste service providers, and community members, ensures that diverse perspectives and expertise are integrated into



SWM strategies. Community involvement in decision-making processes encourages ownership and responsibility, leading to more effective waste management practices (Vasconcelos et al., 2022). Collaboration allows for the pooling of resources, such as funding and human capital, which can enhance the capacity for waste management initiatives (Ikhwan, 2022). Stakeholder collaboration is crucial for improving waste management systems. Slehkie & Dongjie (2021) and Ikhwan (2022) stated that effective communication and collaboration among stakeholders, including government authorities and waste service providers, enhance policy implementation and sustainable practices.

Review of Nigeria's Technical and Vocational Education and Training (TVET) in Sustainable Solid Waste Management (SWM)

Nigerian TVET curricula, primarily polytechnics and vocational colleges, include SWM in their curriculum. The National Diploma in Environmental Science & Management Technology (NBTE) includes a 2-credit course on "ESM 222 – Solid Waste Management" (NBTE, 2019), and Higher National Diploma programs include "Sanitation and Waste Management" (ESM 414). SWM topics are taught through theory and limited practical coursework. Practical training in SWM is limited, with the NBTE course outlines allocating only 1 hour/week for practical work (NBTE, 2021). There is little published evidence that many TVET campuses have specialised recycling labs, composting units, or waste-treatment facilities. But hands-on exposure likely depends on site visits or SIWES internships.

TVET institutions in Nigeria are partnering with UNESCO's UNEVOC Centre to promote green campus practices and support waste management training (NBTE, 2023). Private-sector



partnerships, such as the World Bank-backed Nigeria Climate Innovation Centre, are collaborating with companies like Coca-Cola to deliver circular-economy and waste management workshops for youth and entrepreneurs. Initiatives like the Plastic Recycling France-Nigeria project are also promoting campus recycling (Plastic Recycling Project Nigeria–France, 2023). Students and faculty are increasingly involved in waste management outreach, with student clubs and volunteer programs organising cleanups and awareness campaigns. NBTE recommends formalising these efforts and involving students in academic projects.

Nigeria's SWM education is primarily centred in southern Nigeria, with initiatives focusing on Lagos-based programs and policy efforts (NCIC, 2022). Institutions like the Federal Polytechnic Oil & Gas, Bonny, have expanded environmental programmes in the oil-rich south (Federal Polytechnic of Oil and Gas, Bonny, 2022). Northern TVET schools have less reported activity in this area. Polytechnics and colleges with environmental or engineering mandates lead on SWM training, with nationally accredited programs ensuring consistency. Nigerian TVET curricula cover solid waste topics, especially in Environmental Science/Technology programs, with dedicated courses and practical components. Collaboration with government and industry is increasing, with students and staff getting involved through campus initiatives.

According to Ayeni (2015), the TVET sector in Nigeria, including Solid Waste Management (SWM) education, is criticised for its laissez-faire approach, leading to inadequate attention and support. The study compared TVE systems in ten countries and found that Nigeria's system lacks infrastructure, curriculum, training methods, financing, and motivation. To address these challenges, the authors recommend adopting a dual system of education, combining classroom



learning with practical work experience, collaborating with registered organisations, and hosting a national conference. Onwusa (2021) and the study of Babic et al. (2022) suggest strategies to strengthen TVET include developing an indigenous curriculum, establishing strong school-industry linkages, improving teacher training, and promoting entrepreneurial skills. The European Climate Change Initiative is implementing an educational-professional project to enhance knowledge and skills in waste management.

Strategies for Effective Integration to Enhance TVET's Role in SWM

TVET plays a crucial role in sustainable waste management (SWM) by developing specialised curricula, strengthening industry-academia collaborations, funding waste management training facilities, public awareness campaigns, policy reforms, waste management entrepreneurship courses, and digital learning platforms.

The future of TVET in SWM lies in adopting technological advancements and innovative waste management strategies, such as AI, big data analytics, and IoT. Smart waste collection systems, blockchain, and automated sorting technologies are emerging trends that TVET institutions should incorporate into their curricula. Fostering international partnerships and exchange programs can facilitate knowledge transfer and skill enhancement.

Conclusion

Sustainability in waste management requires continuous education and skill development. TVET integration into Sustainable Waste Management (SWM) can promote environmental sustainability by reducing waste, recycling, and promoting a circular economy. TVET programs



enhance circular economy principles by promoting waste reuse and resource efficiency. They also encourage green jobs and entrepreneurship by allowing skilled individuals to establish waste recycling businesses. Proper waste disposal and treatment, taught through TVET, help reduce pollution and greenhouse gas emissions. Collaboration between governments, educational institutions, and industries is crucial to strengthen TVET's role in SWM, ensuring a cleaner, healthier environment for future generations. Integrating TVET into sustainable SWM is vital for developing a skilled workforce, reducing environmental pollution, and promoting economic opportunities in the waste sector. Policymakers, educators, and industry stakeholders must collaborate to enhance TVET's contribution to effective waste management.

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