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D2.3. Gap Analysis

Structured report of Demand / Supply Gaps in Green Waste Management Skills

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Abstract	This deliverable presents the findings of a desk research and key informant interviews of stakeholders in the green waste management sector in Nigeria and Ghana. The aim was to conduct a skills gap analysis to identify the skills that are currently lacking in the Green Waste Management supply chain in Ghana and Nigeria and to develop a curriculum for technical courses and business training programs that focuses on addressing the skill deficiencies, while improving the competitiveness of small and medium enterprises in the sector.
Keywords	Waste management, skills gap analysis, TVET

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EXECUTIVE SUMMARY

The waste management sector plays a vital role in environmental sustainability and public health. However, it faces significant challenges due to a multi-dimensional skills gap that hinders the effective management, processing and disposal of waste. The various stages of the waste management value chain (including waste generation, collection, aggregation, processing and recycling) require increasing levels of technical expertise, analytical proficiency, behavioural skills and digital competence. However, one critical point of concern is the lack of the technical skills required for the optimal operation and maintenance of the equipment and machinery used for waste management and disposal. This report analyses the skills gap in order to identify the competencies that are currently short in the Green Waste Management supply chain in Ghana and Nigeria. The analysis was conducted by using primary research methods as for instance a desk research and focus group interviews.

The research findings revealed the following:

- Skill requirements for youth employment in the waste management sector;
- Machineries, technologies and tools used by stakeholders in the waste management sector;
- Technical skills requirements for green waste management.

The Deliverable concludes with a detailed identification of lacking skills and their impacts on the effectiveness of the sector, whilst providing structured training and capacity-building programmes for the Waste Management Sector stakeholders based on the highlighted needs assessment.

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ABBREVIATIONS

AfDB	African Development Bank
CPD	Continuous Professional Development
GHG	Green House Gases
LAWMA	Lagos Waste Management Authority
MRFs	Material Recovery Facilities
SDG	Sustainable Development Goals
SWSL	Solid Waste Sorting Line
TVET	Technical Vocational Education and Training
WMS	Waste Management Sector

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1 INTRODUCTION

Waste management is a terminology used in describing various schemes and programmes for collection, transportation, processing, management, recycling and safe disposal of wastes [1]. It facilitates improved health and wellbeing since it reduces the harmful effects of waste on the environment. It protects our natural resources, biodiversity and human life. Indeed, waste management is important in achieving the Sustainable Development Goals (SDGs), particularly those that connects with: improving good health and wellbeing (SDG3); clean water and sanitation (SDG6); decent work and economic growth (SDG8); reduced inequalities (SDG10); sustainable cities and communities (SDG11); responsible consumption and production (SDG12); climate action (SDG13); life below water (SDG14); life on land (SDG15); and peace, justice and strong institutions (SDG16) [2,3]. To achieve these SDGs with strong connection to waste management, it is essential that the Waste Management Sector (WMS) is strengthened with the requisite tools and skilled manpower that can guarantee the attainment of these goals.

Technical skills are the foundation for waste management careers. The effective prevention, mitigation and control of wastes on human health and the environment presupposes that the various players in the sector ought to have a minimum level of (technical, digital, behavioural and analytical) skills and competencies required to tackle the increasing challenges of waste management [4,5]. The WMS is highly dynamic and based on the heterogeneity of the waste streams; therefore, it requires varying skills, experience and educational qualifications which are highly influenced by the waste types and technology to be used. The WMS is also perceived as a sector that can help address youth unemployment due to its ability to absorb high numbers of skilled and unskilled workforce [6].

Indeed, how do we develop the key skill-sets required in the youth employment journey in the waste management sector? How can industry opportunities be exploited to address identified skills shortages by ensuring greater youth employment?

Finally, this report is aimed to identify existing skills gap within the WMS in Nigeria and Ghana and proffer solutions that will address the current and future skill requirement of the sector.

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2 BACKGROUND

In this section we look at the issues of increasing youth population in Africa and improving the education/qualification system and their impact on the supply of skills for the waste management sector with specific case studies from Nigeria and Ghana.

2.1. RISING YOUTH POPULATION IN AFRICA

Africa has a young population with an estimate of 60% of its population being under the age of 25. The African Development Bank (AfDB) estimates that Africa's youth population is expected to reach about 830 million by 2050[1]. This poses more opportunities than challenges. If properly harnessed, Africa would be able to guarantee current and future workforce to support its development. The AfDB argues that the majority of Africa's youth do not have stable economic opportunities. It further argues that about 10 – 12 million youths in Africa enter the workforce each year with only about 3.1 million jobs created [7]. This leaves a vast number of the youths unemployed [8]. Figure 1 shows Africa's historical and projected population growth which should underpin the development agenda of the region.

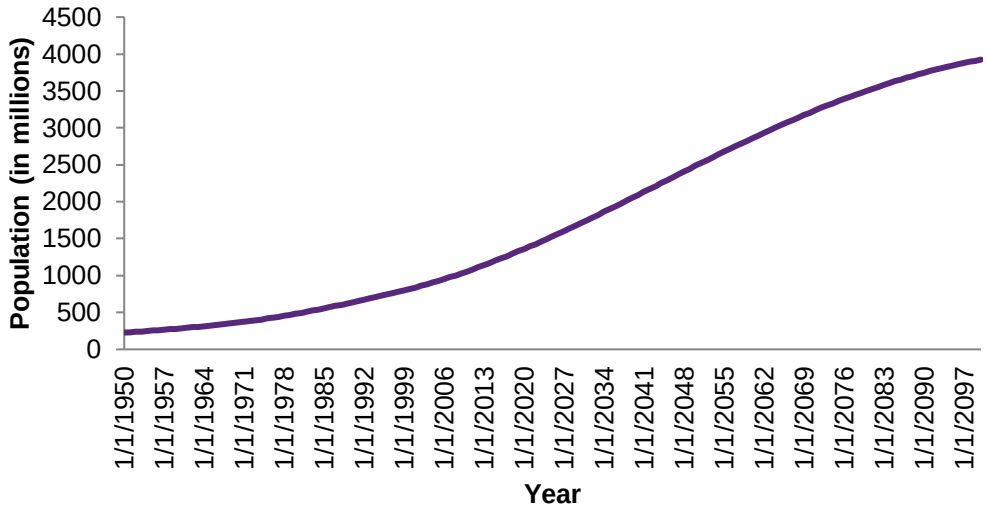

Figure 1: Africa's historical and projected population growth (1950 – 2100)[2]

2.2. THE CHALLENGE OF LACK OF QUALITY FORMAL EMPLOYMENT

Although formal education is important, we have noticed the emergence of an educated but under-skilled workforce in some of the leading countries in Africa. Undoubtedly, there is a need for education that focuses on the integral development of the person, including the skills and competences required for employment and enterprise. The education system in some African countries guarantees the acquisition of qualifications but not necessarily the underpinning requisite skills. In Nigeria and Ghana, the manufacturing and industrial services sector has so far complained about the decline in the skill component of the training obtained in many tertiary

[1] AfDB (2016) Jobs for Youth in Africa: Catalyzing youth opportunity across Africa. https://www.afdb.org/fileadmin/uploads/afdb/Images/high_5s/Job_youth_Africa_Job_youth_Africa.pdf

[2] African Population Growth Rate 1950 – 2023. United Nations World Population Prospects www.macrotrends.net

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education institutions. They also complain about the high cost of retraining graduates in the technical skills required for industrial enterprise. The situation is very similar in the waste management sector [9].

The education and qualification system in Nigeria (as shown in Figure 2) have concentrated more on issuance of certification, but have suffered a decline in the acquisition of the skill component of the programs. This is clearly reflected in the low pride of place that is given to the Technical and Vocational Education and Training (TVET) system. Monotechnics and polytechnics that enjoyed the pride of place as centres of learning with respect to skills acquisition are now competing to gain university status, thus relegating their stronghold as superior centres of learning in hands-on industry-relevant skills. Indeed, most TVET schools have now been reduced to senior secondary schools for specific acquisition of some mono-trades such as leather work, plumbing, etc. This poses some challenges and also present some opportunities to relaunch the TVET system and position them as centres for the acquisition of industry-relevant skills and qualifications at the post-secondary level, which helps to ensure a steady supply of industry-ready workforce.

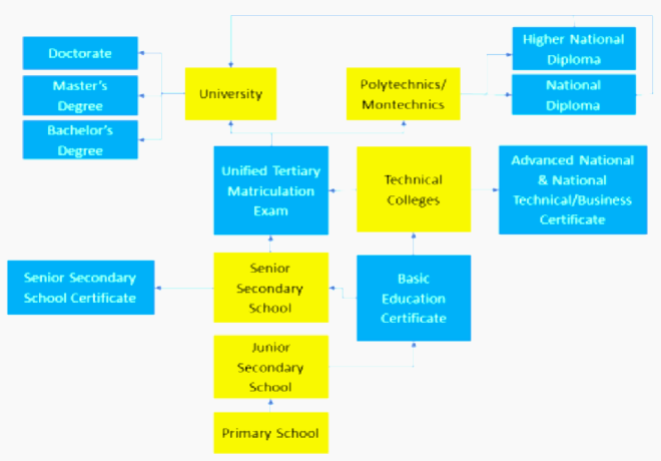

Figure 2: Education and Qualification System in Nigeria [10]

According to the 2021 Ghana TVET Report[3], Ghana needs a skilled and competent workforce such as artisans and technicians to fill the skills gaps in the various sectors of the economy. This is one of the reasons why the Commission for TVET is mandated as set out in the Education Regulatory Bodies Act, 2020 (ACT 1023)[4] to administer, promote and regulate technical and vocational education and training activities in Ghana including the development of an industry-led curriculum for effective delivery. The Act also enjoins the Commission to issue certification in line with the National Technical and Vocational Education and Training Qualifications Framework (NTVETQF) which addresses promotion, academic progression, and job placement issues among TVET graduates and places them at levels comparable to their general education graduate colleagues. A study (Takyi, Amponsah, Asibey and Ayambire, 2021)[5] revealed that the current educational system in Ghana is skewed more towards formal academic development to the neglect of vocational and technical training, especially in the informal sector. In as much as the Commission through Ghana's Education Ministry is making every effort to bring the TVET up-to-speed with general education, it still has to contend with issues of access and the number of graduates the fewer TVET institutions are able to produce into the economy every year. It is reported that Ghana has 238 public TVET Providers at the Pre-Tertiary level as against 722 public Senior High Schools.[6]

[3] Commission for Technical and Vocational Education and Training (2021). Ghana TVET Report https://ctvet.gov.gh/wp-content/uploads/2022/09/GHANA-TVET-REPORT-2021SIGNED.pdf

[4] Education Regulatory Bodies Act, Act 1023 of Ghana's Parliament (2020)

[5] Takyi, S. A., Amponsah, O., Asibey, M. O., & Ayambire, R. A. (2021). An overview of Ghana's educational system and its implication for educational equity. International Journal of Leadership in Education, 24(2), 157-182

[6] Gyamfi, B. (2021). Full List of High Schools (SHS) in Ghana. Retrieved on 27/06/2023 via ghstandard.com

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3 METHODOLOGY

In this research, we collected data and other relevant information from two main sources:

- **Desk-based research** on skill need requirements for waste management and the existing skills gap in the waste management sector;
- **10 Focused group (key informant) interviews** comprising participants representing the key stakeholders in the waste management value chain, in Nigeria and Ghana, made up of waste producers, collectors and aggregators, processors and recyclers, and other stakeholders in the waste regulation and policy space.

For the desk research, the analysis focused on obtaining publicly available reports from relevant government, private and multilateral organisations on industry skills shortages in relevant sectors. Some relevant sources included (See References):

- African Development Bank
- World Bank
- Nigeria's Federal Ministry of Trade and Investment
- Nigeria's Federal Ministry of Environment
- Lagos Waste Management Authority (Partner of the project)

The selection of participants for the focus group interviews (from Nigeria and Ghana) was based on the following criteria:

- People with subject matter expertise on waste and environmental management issues;
- Those who are currently active participants in the waste management value chain;
- Practitioners and policy workers in the waste management sector;
- Academics and researchers in the waste management industry.

Figure 3 shows the various players of the waste management value chain in Nigeria and Ghana that were represented in the focus group interviews.

Figure 3: The waste management value chain in Nigeria and Ghana

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4 FINDINGS

In this section, the salient findings of our research are presented around four main themes:

- Skill requirements for youth employment in the waste management sector;
- Machineries, technologies and tools used by stakeholders in the waste management sector;
- Technical skills requirements for green waste management.

3.1. SKILL REQUIREMENTS FOR YOUTH EMPLOYMENT IN THE WASTE MANAGEMENT SECTOR

Skills requirement for youth employment in the WMS can be grouped into four (4) categories (as shown in Figure 4):

1. **Analytical skills**: this refers to the ability to understand complex ideas, adapt effectively to one's environment, learn from experience and reason. It includes skill sets such as writing, critical thinking, numeracy, problem solving, reading and decision making. Analytical skills are very important in waste management because the ability to collect, process and interpret data from different sources (such as surveys, laboratory, environmental and waste audit assessments) are crucial in their operations and management. Key players that are hands-on in the waste management sector requires basic skills for collection, sorting, costing, book keeping, conversion, processing and reporting of their operations. Analytical skills are related to the ability to apply critical thinking and problem solving to identify and proffer solutions to environmental issues, as well as producing reports in appropriate formats that can help decision makers and other stakeholders in the sector to take the most appropriate action.

2. **Behavioural skills**: this refers to the ability to navigate interpersonal and social situations effectively. It includes skill sets such as communication, leadership, creativity and entrepreneurial skills. Interpersonal skills which are closely related to behavioural skills are valuable since many stakeholders in the waste management sector need to work collaboratively to address environmental issues associated with waste management. Communication among stakeholders (using the right means, language and tone), listening and obtaining feedback, and responding professionally and constructively are critical aspects of this skill-set.

3. **Digital skills**: this refers to particular types of technical skills entails the ability to find, evaluate, use, share and create contents using digital devices such as computers and other smart devices[7]. This skill-set may range from basic level (sending emails) to advanced level (providing digital remote technical support). Digital skills are becoming increasingly important in WMS due to the increased need for interdependence and collaboration to tackle environmental issues across geographies. The need for remote support is on the rise and digital skills provide the necessary toolkit for such support.

4. **Technical skills**: this refers to knowledge, expertise and interactions required to perform a specific job, including the mastery of the materials, tools and technologies. This skill set ranges from understanding of basic Science, Technology, Engineering and Mathematics (STEM), technical and vocational skills, and financial/accounting skills. This report will focus more on addressing the technical need requirements for green waste management.

[7] University of Nevada (August 9, 2022). What are Digital Skills https://digitalskills.unlv.edu/digital-marketing/what-are-digital-skills/#:~:text=Digital%20skills%20are%20defined%20as,such%20as%20computers%20and%20smartphones

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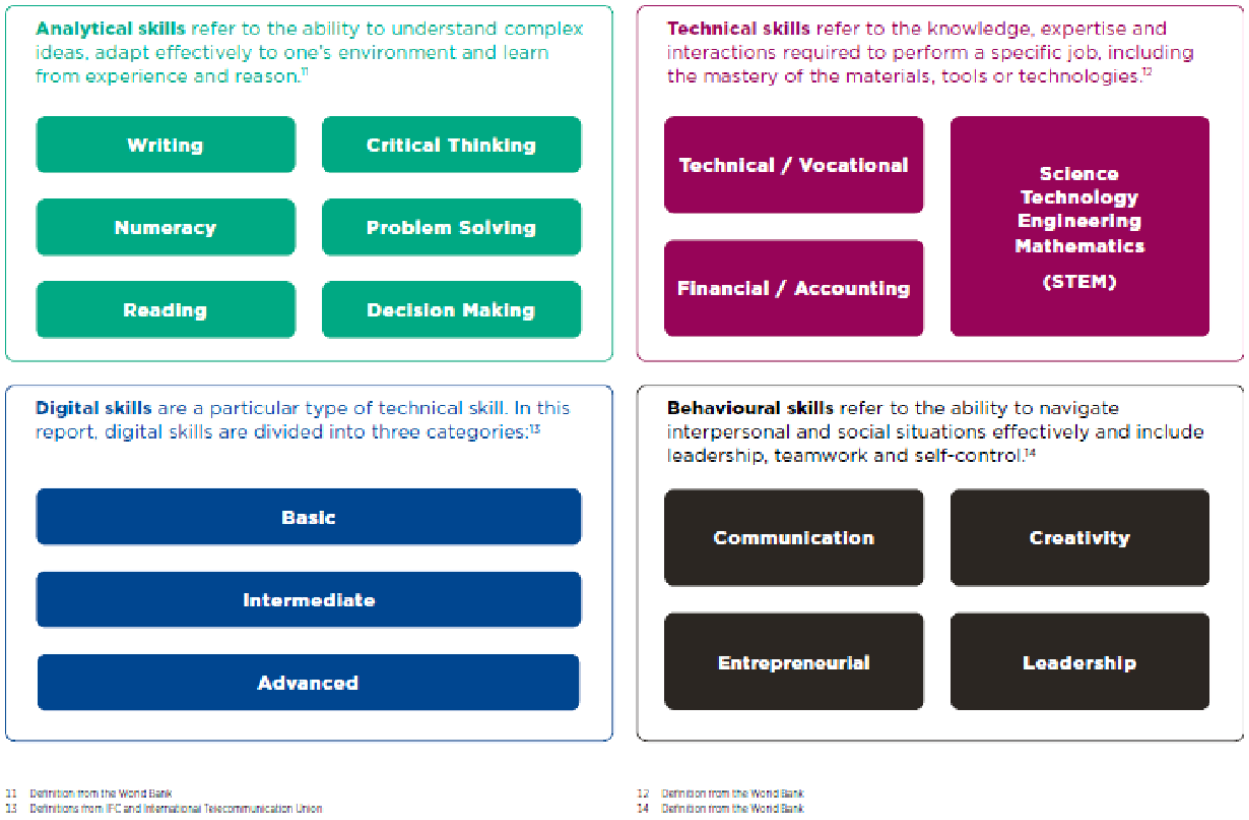

Figure 4: Key skill-sets required in the youth employment journey[8]

3.2. MACHINERIES, TECHNOLOGIES & TOOLS USED BY STAKEHOLDERS IN THE WASTE MANAGEMENT SECTOR

The waste management sector plays a critical role in ensuring proper waste handling, resource recovery, and environmental sustainability. Various stakeholders are involved in different stages of the waste management process, each requiring specific technologies, machineries and tools to carry out their responsibilities effectively. This section provides an overview of the technologies, machineries, and tools utilized by different stakeholders in the WMS in Nigeria and Ghana.

3.2.1. Waste Generators

Waste generators, including households, commercial establishments and industries, contribute to the initial stage of waste generation. While their involvement in technology and machinery may be limited, certain tools can facilitate responsible waste disposal. These may include:

- **Waste Segregation Bins**: waste generators can use separate bins or containers to facilitate the segregation of different waste streams, such as recyclables, organic waste, and non-recyclables. These bins can be colour-coded or labelled to ensure proper waste sorting;

8 GSMA (July 2020) Report on Understanding Skills Gap facing youth employment. https://www.gsma.com/mobilefordevelopment/blog-2/understanding-the-skills-gap-facing-youth-employment-through-the-mobile-industry/

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- **Composting Equipment**: waste generators can employ various composting tools and equipment to process organic waste into compost. This may include compost bins, compost tumblers, or composting machines that aid in the decomposition and transformation of organic matter into nutrient-rich compost;

- **Biogas Digesters**: some waste generators (particularly agricultural or industrial facilities) can utilize biogas digesters to convert organic waste into biogas through anaerobic digestion. Biogas can be used for energy generation, reducing dependency on traditional fossil fuels;

- **On-site Waste Treatment Systems**: certain waste generators, such as large institutions or industrial facilities, may implement on-site waste treatment systems to manage specific types of waste. Examples include:
    - On-site wastewater treatment plants for treating and recycling wastewater generated within the premises;
    - Mechanical or biological treatment systems for managing organic or hazardous waste produced on-site.

3.2.2. Waste Collectors

Waste collectors are responsible for collecting and transporting waste from various sources to disposal or treatment facilities. They rely on specific technologies and machineries, including:

- **Waste Collection Trucks**: waste collectors employ various types of trucks to collect and transport waste from different sources. These include:
    - **Rear-loading trucks**: these are the type mostly used in Nigeria. They are equipped with a rear hydraulic compactor and are commonly used for collecting household waste from residential areas;
    - **Front-loading trucks**: featuring a front hydraulic lifting mechanism, these trucks are suitable for collecting waste from large bins or commercial areas;
    - **Side-loading trucks**: These trucks have a side-loading mechanism, often used for collecting waste from narrow streets or areas with space constraints;

- **Collection Bins and Containers**: waste collectors use bins and containers to collect and temporarily store waste during collection rounds. These may include large roll-off containers, wheeled bins, or specialized containers for different waste streams (recyclables, organic waste, hazardous waste);
- **Waste Sorting Equipment**: waste collectors employ various tools and equipment to facilitate waste sorting and separation at collection points. These may include:
    - **Grippers and grabbers**: Used to handle and separate bulky or oversized items;
    - **Sorting conveyors**: Helps in the manual sorting of recyclable materials from the waste stream;
    - **Magnetic separators**: Used to extract ferrous metals from mixed waste;

- **Safety Equipment**: waste collectors require personal protective equipment (PPE) to ensure their safety while handling waste. This includes gloves, masks, safety boots, high-visibility vests, and other protective gear to minimize health hazards and potential injuries;

Weighing Systems: waste collectors require weighing systems or scales to accurately measure and record the weight of waste collected especially the recyclable collectors. This information is valuable for incentives, billing, reporting, and waste management analysis.

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3.2.3. Waste Treatment Facilities

Waste treatment facilities in Nigeria and Ghana focus on processing and managing waste through various methods. Some common technologies, machineries, and tools used in these facilities include:

- **Landfill Equipment**:
  - **Bulldozers**: used for pushing and compacting waste, creating and maintaining waste cells, and covering waste with soil or alternative cover materials;
  - **Excavators**: utilized for digging, levelling, and shaping landfill areas, as well as assisting in waste placement and compaction;
  - **Compactors**: heavy machinery used to compact waste in landfill cells, reducing its volume and maximizing landfill capacity;
  - **Rollers**: for compacting the top lateritic soil or alternative cover material during routine maintenance to get a well compacted and stabilised access road to the waste cells;
  - **Landfill Liners**: impermeable barriers, often made of clay or synthetic materials, used to line landfill cells and prevent leachate from contaminating the soil and groundwater;
  - **Pay loader**: used for moving soil in large volumes during construction of access roads on landfill as well as for loading and managing waste.

- **Incineration Equipment**:
  - **Incinerators**: advanced incinerators equipped with emission control systems, including scrubbers, filters, and electrostatic precipitators, to safely and efficiently combust solid waste while minimizing air pollution and emissions;
  - **Waste Heat Recovery Systems**: some incineration facilities utilize waste heat recovery technologies to capture and use the heat generated during the incineration process for energy generation or other purposes.

- **Composting Equipment**:
  - **Shredders**: machines used to shred and break down organic waste into smaller pieces, promoting faster decomposition during the composting process;
  - **Mixers and Turners**: equipment employed to mix and aerate compost piles, ensuring proper moisture levels, temperature control, and microbial activity for efficient decomposition;
  - **Screening Equipment**: used to separate finished compost from larger materials or contaminants, producing high-quality compost suitable for agricultural use.

- **Anaerobic Digesters**:
  - **Pumps and Agitators**: essential equipment for mixing and homogenizing the organic waste within anaerobic digesters, ensuring efficient decomposition and biogas production;
  - **Biogas Utilization Systems**: equipment used to capture, store, and utilize the biogas generated during the anaerobic digestion process for energy production or other applications;
  - **Digestate Handling Equipment**: equipment employed for the management and processing of digestate, the residual material left after anaerobic digestion, which can be used as a nutrient-rich fertilizer.

- **Hazardous Waste Treatment Equipment**:
  - **Chemical Treatment Systems**: equipment used for the chemical treatment of hazardous waste to neutralize, stabilize, or remove harmful substances before safe disposal;
  - **Encapsulation Systems**: tools and machinery employed for encapsulating hazardous waste in inert materials, such as concrete or polymer, to prevent leaching or release of contaminants.

- **Leachate Treatment Systems**:

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- **Leachate Collection and Storage Tanks**: infrastructure used to collect and store leachate, the liquid that drains from landfill waste, before treatment or disposal;
- **Leachate Treatment Equipment**: technologies such as sedimentation tanks, biological treatment systems, and chemical processes are employed to treat leachate and remove contaminants before proper discharge or reuse.

- **Waste Water Treatment Systems**:
  - **Pre-treatment Equipment**: including screens, grit chambers, and settling tanks to remove large debris, grit, and suspended solids from wastewater before further treatment;
  - **Biological Treatment Units**: utilised for the removal of organic matter and pollutants from wastewater through processes such as activated sludge, trickling filters, or sequencing batch reactors;
  - **Disinfection Systems**: employed to treat wastewater using methods such as chlorination, ultraviolet (UV) disinfection, or ozonation, ensuring the elimination of harmful pathogens before discharge.

- **Monitoring and Control Systems**:
  - **Environmental Monitoring Equipment**: instruments and devices used to measure and monitor various environmental parameters, including air quality, water quality, noise levels, and gas emissions from waste treatment facilities;
  - **Control Systems**: automation and control technologies used to monitor and regulate waste treatment processes, optimizing efficiency, and ensuring compliance with environmental regulations.

3.2.4. Recycling facilities

Recycling facilities focus on the recovery of valuable materials from waste. The technologies, machineries, and tools employed in recycling include:

- **Sorting Equipment**:
  - **Trommel Screens**: used to separate waste materials based on size and shape;
  - **Magnetic Separators**: employed to remove ferrous metals from the waste stream;
  - **Eddy Current Separators**: used to separate non-ferrous metals such as aluminium and copper;
  - **Optical Sorting Machines**: utilised to identify and sort materials based on their optical properties, such as colour or transparency;
  - **Air Separation Systems**: employed to separate lightweight materials, such as paper and plastic, from heavier materials.

- **Balers and Compactors**:
  - **Vertical Balers**: used to compress and bale recyclable materials, such as cardboard, paper, plastic bottles, and aluminium cans, into compact bundles for ease of storage and transportation;
  - **Horizontal Balers**: similar to vertical balers but designed for high-volume operations, these machines produce larger bales of recyclable materials;
  - **Compactors**: employed to compress and reduce the volume of bulky waste materials, making them more manageable for storage and transportation.

- **Shredders and Granulators**:
  - **Shredders**: machines used to shred materials such as paper, cardboard, plastic, and metal into smaller pieces, facilitating further processing and recycling;

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  - **Granulators**: utilised to granulate plastic waste into small pellets or flakes, which can be used as raw materials for manufacturing new plastic products.

- **Optical Sorting Systems**:
  - **Near-Infrared (NIR) Sorters**: these systems use near-infrared technology to identify and sort recyclable materials based on their composition and optical properties;
  - **Colour Sorting Machines**: employed to separate materials based on their colour, allowing for more precise sorting of plastics and other coloured materials.

- **Washing and Cleaning Equipment**:
  - **Plastic Washing Lines**: used to wash and clean plastic materials, removing dirt, contaminants, and labels, preparing them for further processing;
  - **Glass Washing Machines**: employed to clean and remove impurities from glass fragments or cullet, making them suitable for recycling into new glass products.

- **Pelletising Equipment**:
  - **Plastic Pelletisers**: machines that melt and extrude plastic materials into small pellets, which can be used as raw materials for manufacturing new plastic products;
  - **Wood Pelletisers**: utilised to compress and shape wood waste into compact pellets, which can be used as fuel or bedding materials.

- **Material Recovery Facilities (MRFs)**:
  - **Conveyor Systems**: used to transport and transfer materials throughout the recycling facility, ensuring efficient and continuous material flow;
  - **Hoppers and Bins**: employed for the temporary storage and accumulation of recyclable materials at various stages of the sorting and processing process;
  - **Control Systems**: automation and control technologies used to monitor and regulate the sorting and processing operations, optimizing efficiency and quality;
  - **Sorting Lines**: these are automated lines where waste is sorted into categories, according to material or recyclability. A solid waste sorting line (SWSL), also known as a dirty material recovery facility (dirty MRF), processes recyclables from a stream of raw solid waste.

- **Quality Testing and Monitoring Equipment**:
  - **Density Separators**: used to separate materials based on their density, ensuring the removal of lightweight contaminants;
  - **Moisture Sensors**: employed to measure the moisture content of materials, ensuring they meet quality standards for recycling;
  - **Spectrometers and Analysers**: utilized to analyse the chemical composition of materials, ensuring their suitability for recycling and compliance with quality requirements.

3.2.5. Waste Management Consultants and Planners

Waste management consultants and planners contribute to the development and implementation of waste management strategies. They utilize various tools and technologies, including:

- **Waste Auditing Tools**: waste characterisation equipment, sampling methods, and data analysis software help assess waste composition and volume, aiding in waste management planning and resource allocation;
- **Modelling and Simulation Software**: specialized software allows consultants to simulate waste management processes, evaluate system performance, and develop strategies for waste reduction and resource recovery specific to each geographical/country context.

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3.3. TECHNICAL SKILLS REQUIREMENTS FOR GREEN WASTE MANAGEMENT

The waste management sector faces significant technical skills gap challenges across its value chains. These gaps in technical expertise hinder the efficient and sustainable management of waste. Addressing these skill deficiencies is crucial for improving waste management practices and achieving environmental sustainability.

In this section, we present and summarize our findings on the technical skills requirements for effective Green Waste Management for three essential segments in the waste management value chain, that are:

- Waste collection and transportation;
- Waste sorting and segregation;
- Waste recycling and resource recovery.

3.3.1. Technical Skills Requirements for Waste Collection and Transportation

The waste collection and transportation value chain require skilled professionals who possess technical competencies such as efficient waste collection techniques, waste sorting and segregation methods, proper use of waste collection equipment (e.g., compactors, trucks), and knowledge of route optimization for effective waste transportation. The technical/vocational requirements as well as the requisite technical skills requirements for **waste collection and transportation** are summarized in Table 1.

Table 1: Technical Skills Requirements for Waste Collectors and Aggregators in Green Waste Management

S/n	Technical/ Vocational Requirements	Technical Skills Requirements
1	Equipment Operation	• Proficiency in operating and manoeuvring waste collection vehicles, such as garbage trucks, compactors, and skip loaders; • Familiarity with the controls, features, and safety protocols of specific waste collection equipment; • Knowledge of proper operating techniques to ensure efficient and safe waste collection.
2	Maintenance and Repairs	• Basic mechanical skills to perform routine maintenance tasks on waste collection vehicles, including checking fluid levels, inspecting tires, and lubricating moving parts; • Ability to troubleshoot common equipment issues and perform minor repairs, such as replacing belts, filters, or hydraulic components; • Knowledge of preventive maintenance schedules and the ability to follow them to ensure equipment longevity and optimal performance.
3	Electrical skills	• Basic understanding of electrical systems and circuits to troubleshoot and repair electrical components in waste collection vehicles and equipment; • Knowledge of electrical safety procedures and protocols when working with electrical systems; • Proficiency in reading electrical diagrams and schematics to identify and diagnose electrical issues; • Ability to test and measure electrical parameters, such as voltage, current, and resistance, using appropriate tools and equipment.
4	Mechanical skills	• Proficiency in mechanical systems and components to diagnose and repair mechanical issues in waste collection vehicles and equipment; • Knowledge of preventive maintenance procedures for mechanical systems to ensure optimal performance and longevity;

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		• Ability to use hand and power tools effectively for tasks such as tightening bolts, replacing parts, and adjusting mechanisms; • Understanding of mechanical principles, such as force, motion, and friction, to troubleshoot mechanical problems and make necessary adjustments.
5	Hydraulic skills	• Basic understanding of hydraulic systems and components used in waste collection equipment, such as compactors and lifting mechanisms; • Ability to identify and repair hydraulic leaks; replace hydraulic hoses; and perform routine maintenance on hydraulic systems; • Proficiency in reading hydraulic diagrams and understanding the principles of hydraulic pressure, flow, and control; • Knowledge of hydraulic safety procedures to prevent accidents and ensure safe operation of hydraulic equipment.
6	Diagnostic and Troubleshooting skills	• Ability to analyse and diagnose technical issues in waste collection vehicles and equipment using diagnostic tools and equipment; • Strong problem-solving skills to identify the root cause of equipment malfunctions and implement appropriate repairs; • Familiarity with troubleshooting techniques and methodologies to systematically address technical problems.
7	Safety Awareness and Compliance	• Comprehensive knowledge of safety regulations and procedures specific to waste collection operations; • Understanding of safety mechanisms and interlocks present in waste collection equipment to ensure safe operation; • Ability to recognize potential hazards and take appropriate measures to mitigate risks during equipment operation and maintenance.
8	Communication and Documentation	• Effective communication skills to coordinate with team members, supervisors, and other stakeholders; • Ability to maintain accurate records, such as collection logs, mileage, and maintenance reports; • Familiarity with digital platforms and software for reporting and data management.
9	Waste Collection and Transportation	• Understanding of waste segregation and proper handling practices to minimise contamination and maximise recycling opportunities; • Knowledge of environmental regulations and waste management policies to ensure compliance. • Understanding types of waste, quantities of waste, source of waste • Knowledge of material streams and quality requirements for the utilisation of wastes • Identification and weighing system • Ability to bring and collect systems • Familiarity with methods for the calculation of refuse charges • Ability to define collection round (tour) planning • Knowledge of transfer stations, intermediate storage • Structure and function of special refuse collection points • Hazardous goods transport: marking, banning of collective loading, loading safety • Accompanying documents • Storage of wastes

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3.3.2. Technical Skills Requirements for Waste Sorting and Segregation Facilities

Within the waste sorting and segregation value chain, there is a need for skilled personnel with expertise in waste characterization, sorting methodologies, and knowledge of recyclable and non-recyclable waste streams. Technical skills in operating sorting equipment, such as conveyor belts and automated sorting systems, are also essential for maximizing the efficiency of waste segregation processes. The technical/vocational requirements as well as the requisite technical skills requirements for **waste sorting and segregation facilities** are summarized in table 2.

Table 2: Technical Skills Requirements for Waste Treatment Facilities in Green Waste Management

S/n	Technical/ Vocational Requirements	Technical Skills Requirements
1	Equipment Operation and Maintenance	• Proficiency in operating and maintaining waste treatment equipment, such as incinerators, autoclaves, composting systems, and anaerobic digesters; • Knowledge of equipment controls, settings, and parameters for effective and safe operation; • Understanding of preventive maintenance schedules and procedures to ensure optimal performance and minimize downtime; • Ability to troubleshoot equipment malfunctions, diagnose issues, and perform necessary repairs or coordinate with maintenance technicians.
2	Electrical skills	• Basic understanding of electrical systems, circuits, and wiring used in waste treatment equipment; • Proficiency in reading electrical schematics, diagrams, and technical manuals; • Knowledge of electrical safety practices and protocols when working with high-voltage equipment; • Ability to troubleshoot electrical issues, identify faults, and perform repairs or coordinate with qualified electricians.
3	Mechanical skills	• Strong mechanical aptitude to operate and maintain mechanical equipment and components in waste treatment facilities; • Proficiency in using hand and power tools for maintenance, repair, and adjustment tasks; • Knowledge of mechanical systems, including motors, gears, belts, and bearings; • Ability to diagnose mechanical problems, perform preventive maintenance and conduct repairs as necessary.
4	Hydraulics skills	• Basic understanding of hydraulic systems and components used in waste treatment equipment, such as pumps, valves, and actuators; • Proficiency in reading hydraulic schematics and diagrams to troubleshoot and repair hydraulic systems; • Knowledge of hydraulic principles, including pressure, flow, and fluid dynamics; • Ability to diagnose hydraulic issues; replace seals and hoses, and perform routine maintenance tasks.
5	Instrumentation and Control Systems	• Familiarity with instrumentation and control systems used in waste treatment facilities, such as sensors, transmitters, and control panels; • Understanding of process control methodologies, including feedback loops, PID controllers, and data acquisition systems; • Proficiency in calibrating and configuring instruments, monitoring process variables, and optimizing system performance.
6	Safety and Compliance	• Strong knowledge of safety protocols and procedures specific to waste treatment operations; • Understanding of hazard identification and risk assessment techniques; • Adherence to safety guidelines and regulations to ensure a safe working environment; • Knowledge of waste treatment regulations and compliance requirements.

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7	Problem Solving and Troubleshooting	• Analytical thinking and problem-solving skills to identify and resolve technical issues that arise in waste treatment processes; • Ability to troubleshoot equipment malfunctions; diagnose faults; and implement effective solutions; • Aptitude for systematic and logical troubleshooting to minimise downtime and optimise equipment performance.
8	Waste Sorting	• Ability to determine quality requirements on the wastes to be utilised, take into account processes for the treatment of wastes with the aim of creating marketable intermediate and end products • Utilisation routes of wastes (e.g. plastics, metals, paper, cardboard, glass, drinks cartons, batteries, fluorescent tubes, electrical scrap, old wood)

3.3.3. Technical Skills Requirements for Waste Recycling and Resource Recovery Facilities

The recycling and resource recovery value chain requires skilled professionals who are knowledgeable about recycling technologies, waste processing methods, and quality control standards for recycled materials. Technical skills in operating recycling machinery, such as shredders, balers, and extruders, are essential for effective material recovery and the production of high-quality recycled products. The technical/vocational requirements as well as the requisite technical skills requirements for **waste recycling and resource recovery facilities** are summarized in table 3.

Table 3: Technical Skills Requirements for Waste Recycling Facilities in Green Waste Management

S/n	Technical/ Vocational Requirements	Technical Skills Requirements
1	Sorting Equipment Operation and Maintenance	• Proficiency in operating and maintaining sorting equipment such as conveyor belts, Trommel screens, optical sorters, and magnetic separators; • Understanding of the mechanical components, electrical systems, and hydraulic systems within the sorting equipment; • Ability to troubleshoot mechanical and electrical issues; replace worn-out parts; and perform regular maintenance tasks.
2	Shredding and Granulating Equipment and Maintenance	• Knowledge of operating and maintaining shredders, granulators, and crushers used in the recycling process; • Proficiency in adjusting equipment settings, monitoring feed rates, and ensuring efficient material processing; • Ability to identify and address mechanical issues; perform blade sharpening or replacement; and maintain optimal machine performance.
3	Compacting and Baling Equipment Operation and Maintenance	• Understanding of the operation and maintenance of compactors, balers, and briquetting machines; • Proficiency in monitoring hydraulic systems, adjusting compression settings, and maintaining proper machine alignment; • Ability to troubleshoot hydraulic problems; replace hydraulic seals and hoses; and perform preventive maintenance tasks.
4	Material Handling Equipment Operation and Maintenance	• Familiarity with operating forklifts, loaders, and other material handling equipment used to transport recyclable materials; • Knowledge of safety procedures and best practices for loading and unloading materials safely and efficiently; • Proficiency in performing routine maintenance, such as fluid checks, tire inspections, and equipment cleaning.
5	Quality Control and Testing	• Understanding of quality control measures for recyclable materials, including visual inspections and sample testing; • Knowledge of material characteristics and specifications to ensure compliance with industry standards; • Proficiency in using testing equipment, such as moisture analysers or material composition analysers, to assess material quality.

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6	Maintenance and Repair skills	• Basic electrical, mechanical, and hydraulic skills to perform routine maintenance and repairs on machinery and equipment; • Ability to troubleshoot and diagnose issues; replace faulty components; and perform necessary adjustments; • Knowledge of preventive maintenance procedures to minimize downtime and optimize equipment performance.
7	Safety and Compliance	• Strong knowledge of safety protocols and regulations specific to recycling facilities; • Understanding of hazardous materials and the proper handling and disposal procedures; • Adherence to safety guidelines and use of personal protective equipment (PPE) to ensure a safe working environment.
8	Electrical skills	• Basic understanding of electrical systems and circuits to operate and troubleshoot electrical components of recycling machinery; • Proficiency in reading electrical schematics, diagrams, and technical manuals; • Knowledge of electrical safety practices when working with high-voltage equipment; • Ability to diagnose and repair electrical faults or coordinate with qualified electricians.
9	Mechanical skills	• Strong mechanical aptitude to operate and maintain mechanical equipment in recycling facilities; • Proficiency in using hand and power tools for maintenance, repair, and adjustment tasks; • Knowledge of mechanical systems, including motors, gears, belts, and bearings; • Ability to diagnose mechanical problems, perform preventive maintenance and conduct repairs as necessary.
10	Hydraulics skills	• Basic understanding of hydraulic systems and components used in recycling machinery, such as pumps, valves, and actuators; • Proficiency in reading hydraulic schematics and diagrams to troubleshoot and repair hydraulic systems; • Knowledge of hydraulic principles, including pressure, flow, and fluid dynamics; • Ability to diagnose hydraulic issues, replace seals and hoses, and perform routine maintenance tasks.
11	Problem solving and Analytical skills	• Analytical thinking and problem-solving skills to identify and resolve technical issues that arise in recycling processes; • Ability to troubleshoot equipment malfunctions; diagnose faults; and implement effective solutions; • Aptitude for systematic and logical troubleshooting to minimize downtime and optimize equipment performance.
12	Waste Recycling	• Ability to monitor and control processes for mechanical, chemical and thermal treatment of wastes. • Mechanical treatment • Thermal utilisation • Chemical treatment

Finally, other relevant segments of the waste management value chain include:

- **Waste treatment and disposal**: professionals involved in **waste treatment and disposal** value chain need technical skills in waste treatment technologies, including composting, anaerobic digestion, and incineration. They should have expertise in operating and maintaining waste treatment facilities, monitoring environmental emissions, and ensuring compliance with waste disposal regulations and best practices. The technical skills as provided in tables 2 and 3 are relevant for professionals in this segment of the waste management value chain;

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- **Environmental monitoring and remediation**: professionals involved in the environmental monitoring and in remediation initiatives need technical skills for conducting environmental assessments, analysing soil and water samples, and implementing remediation strategies. Skilled professionals should be knowledgeable about environmental monitoring equipment, data analysis techniques, and the application of environmental remediation technologies.

3.4. MAPPING TECHNOLOGIES AND SKILLS IN THE WASTE MANAGEMENT SECTOR

In this section, we provide a mapping of the dominant technologies/equipment in use for waste collection, processing and management with the most crucial stakeholders in the green waste management value chain. Through this mapping, we were able to draw out some relevant skills required to optimally use the existing technologies for improved output as presented in table 4. Indeed, this mapping is very crucial in designing relevant technical/vocational skills programs aimed at addressing the skill gaps in the WMS.

Table 4: Technology-Skills Mapping in the Waste Management Sector

Sector Stakeholder	Technologies/ Equipment	Required Skills
Waste Collectors	Waste Segregation Equipment	• Basic understanding of waste segregation principles; • Knowledge of operation and maintenance of waste segregation equipment; • Ability to identify recyclable and non-recyclable materials.
	Collection Vehicles and Equipment	• Basic mechanical skills for vehicle operation and maintenance; • Understanding of hydraulic systems; • Ability to perform routine inspections, diagnose and troubleshoot mechanical issues.
Waste Treatment Facilities Operators	Sorting Equipment	• Proficiency in operation and maintenance of sorting equipment; • Knowledge of mechanical, hydraulic and electrical components; • Ability to calibrate and troubleshoot equipment.
	Shredding and Granulating Equipment	• Competence in operation and maintenance of shredders, granulators, and crushers; • Familiarity with mechanical systems; • Ability to perform preventive maintenance and repairs.
	Compacting and Baling Equipment	• Understanding of hydraulic systems; • Ability to adjust compression settings; • Troubleshoot hydraulic problems; • Perform maintenance tasks; • Ensure safe operation.
	Incinerators and Composting Equipment	• Knowledge of combustion or composting processes; • Proficiency in operating and maintaining equipment; • Understanding of environmental regulations and emission control measures.
	Water Treatment Systems	• Understanding of water treatment processes; • Knowledge of operation and maintenance of water treatment equipment; • Ability to monitor and control water quality parameters.
Recycling Facilities Operators	Sorting and Separation Equipment	• Proficiency in operation and maintenance of sorting equipment such as conveyor belts, optical sorters, and magnetic separators;

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		• Understanding of mechanical and electrical component and systems.
	Shredding and Granulating Equipment	• Competence in operation and maintenance of shredders, granulators, and crushers; • Ability to diagnose and rectify mechanical problems and conduct regular maintenance tasks.
	Compacting and Baling Equipment	• Proficiency in hydraulic systems; • Ability to adjust compression settings; • Troubleshoot hydraulic malfunctions; • Perform preventive maintenance.
	Material Handling Equipment	• Competence in operating forklifts, loaders, and other material handling equipment; • Adherence to safety procedures for material transportation.

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5 IMPACT OF SKILL GAPS

The lack of technical skills in the WMS has resulted in significant impacts that hinder effective waste management practices and pose challenges to achieving environmental sustainability. The following are some of the **key impacts** resulting from the shortage of technical expertise:

1 The absence of technical skills in **waste collection and handling** processes leads to inefficiencies. Inadequate training and knowledge of proper waste segregation techniques, handling of hazardous materials, and utilization of inappropriate equipment result in ineffective waste collection, increased collection times, and improper disposal practices. This inefficiency contributes to waste accumulation, environmental pollution, and public health risks [11];

2 The skills gap in **recycling and resource recovery** stifles the development and implementation of effective recycling programs. Insufficient knowledge of recycling technologies, waste separation methods, and market dynamics for recycled materials hampers the establishment of efficient recycling facilities and reduces overall recycling rates. The lack of technical skills prevents the optimisation of resource utilisation and exacerbates waste management challenges [12,13];

3 The shortage of specialised skills in **handling hazardous waste** poses significant risks to public health and the environment. Insufficient knowledge of hazardous waste identification, storage, transportation, and disposal leads to improper handling practices. These results in increased potential for environmental contamination, health hazards for waste management workers and communities, and long-term ecological damage;

4 The skills gap hinders the **adoption and utilization of advanced technologies in waste management**. Lack of technical expertise in emerging technologies, data analytics, and automation impedes the integration of innovative solutions. The inability to leverage technological advancements prevents the optimisation of waste management processes, resource utilization, and overall operational efficiency;

5 The skills gap in **waste management policy development, implementation, and enforcement** undermines effective waste management practices. Insufficient capacity to analyse policies, engage stakeholders, monitor compliance, and enforce regulations compromises the effectiveness of waste management policies. This leads to inconsistent practices, non-compliance by waste management stakeholders, and an overall lack of adherence to environmental regulations;

6 The cumulative impacts of the lack of technical skills in waste management are evident in **environmental pollution and public health concerns**. Inefficient waste management practices contribute to increased pollution of land, water bodies, and air, resulting in adverse impacts on ecosystems and human health. Improper waste disposal practices, inadequate recycling efforts, and insufficient control of hazardous waste exacerbate these environmental and health risks.

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6 ADDRESSING THE SKILL GAPS IN THE WASTE MANAGEMENT SECTOR

Addressing the effect of the technical skills gap in the WMS requires a comprehensive and multi-faceted approach. Here are some **strategies that can be employed to mitigate the impact of the skills gap and enhance waste management practices in Nigeria and Ghana**:

1 **Technical Training and Capacity Building**: implement specialised technical training programs and capacity-building initiatives to provide waste management professionals with the necessary skills and knowledge. These programs should cover areas such as waste collection techniques, waste sorting and segregation methods, recycling technologies, waste treatment processes, and environmental monitoring [14];

2 **Vocational and Trade Skills Development**: promote vocational and trade skills development by establishing partnerships between educational institutions, vocational training centres, and industry stakeholders [15,16]. This collaboration can facilitate practical, hands-on training programs that focus on developing technical competencies required for operating and maintaining waste management equipment and machinery;

3 **Continuous Professional Development**: encourage continuous professional development within the waste management sector by providing opportunities for ongoing training, workshops, seminars, and certifications [17]. This helps professionals stay updated on emerging technologies, best practices, and regulatory requirements, enhancing their technical expertise and keeping them abreast of industry advancements;

4 **Knowledge Sharing and Collaboration**: foster collaboration between industry stakeholders, government agencies, educational institutions, and research organizations to create platforms for knowledge sharing, information exchange, and collaborative problem-solving. This can be done through the establishment of industry forums, conferences, and research partnerships that promote the dissemination of technical knowledge and facilitate innovation in waste management practices;

5 **Industry-Academia Partnerships**: strengthen the collaboration between academia and the waste management industry to align educational curricula with industry needs. Engage waste management professionals in curriculum development, offer internships and apprenticeship programs, and facilitate industry placements to bridge the gap between theoretical knowledge and practical skills;

6 **Technological Adoption and Innovation**: encourage the adoption of advanced technologies and innovation in waste management processes [18]. This includes promoting the use of digital tools, data analytics, automation, and smart waste management systems to optimize operations, improve efficiency, and enhance resource utilization. Training programs should be designed to equip professionals with the skills necessary to leverage these technologies effectively;

7 **Policy Support and Regulation**: develop and enforce comprehensive waste management policies and regulations that emphasize the importance of technical skills and competence [19–21]. Implement mechanisms for monitoring and enforcing compliance with waste management standards to ensure that skilled professionals are involved in all aspects of waste management activities;

8 **Public Awareness and Education**: raise public awareness about the importance of proper waste management practices and the role of skilled professionals in ensuring effective waste management [22,23]. Conduct education and outreach campaigns to promote waste reduction, recycling, and responsible waste disposal practices among the general public.

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9 CONCLUSION

The waste management sector in Nigeria and Ghana is facing significant **skill gap challenges**, **particularly in technical expertise,** that impede the effective management of waste. The lack of proficiency in technical areas such as waste auditing and data analysis, environmental regulations and compliance, innovative technologies, and safety and hazardous waste management hinders the sector's ability to achieve optimal waste management practices. Addressing these skill gaps is crucial for improving waste management efficiency, reducing environmental degradation, mitigating health risks, and unlocking the potential for sustainable practices.

To bridge these gaps, a multi-faceted approach is necessary. This includes the **implementation of comprehensive training and capacity building programs that focus on developing the technical skills** and competencies required in waste management.

Indeed, **collaborations and** partnerships between educational institutions, industry stakeholders, and government agencies can play a pivotal role in enhancing technical skills within the sector. By aligning educational curricula with industry needs, offering practical training opportunities, and facilitating knowledge exchange, the waste management sector can nurture a workforce equipped with the necessary technical skills to address the complex challenges it faces.

Furthermore, **leveraging innovative technologies and fostering a culture of continuous learning and professional development** are essential components of addressing the technical skills gap. Embracing emerging technologies, such as digital tools, data analytics, and automation, can optimize waste management processes and improve operational efficiency.

By prioritising the development of technical skills, investing in contemporary training initiatives innovations, and recurrent capacity building the waste management sector can overcome the current skill gaps, enhance waste management practices, ensure compliance with environmental regulations, and pave the way for a more sustainable and efficient waste management system.

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