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ENVIRONMENTAL ASSESSMENT OF HEAVY METALS, PHTHALATE ESTERS, AND POLYCHLORINATED BIPHENYLS AT WASTE DISPOSAL SITES

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Abstract.
Municipal solid waste has been identified to be major source of persistent organic pollutants and heavy metals thereby constituting major environmental, social and economic problems worldwide, according to Department for Environment Food and Rural Affairs of Nigeria. Waste can be defined as any material lacking direct value to the producer and so must be disposed of or any material that is thrown away as unwanted materials (according to United Nations International Children's Emergency Fund). Similarly, it can be regarded as anything human beings consign to the garbage or dispose of in any manner. It consists of organic matters such as papers, rags, discarded packages, food, Solid scraps, garden refuse, inorganic materials such as worn-out appliances, junk automobiles, furniture, industrial Waste, debris of constructions, and mixed Waste as electronic and medical wastes. These wastes originated from various sources, including municipal, Industrial, Agricultural, wastewater treatment plants, and Institutional such as schools, hospitals, markets, and residential estates. The quantity of solid waste has increased significantly, and its character has changed due to accelerated urbanization, industrialization, and population growth in most cities of developing countries. Municipal Solid Waste collection and disposal are particularly problematic in growing country cities, unlike in developed countries where there are better management systems. Solid waste generation is related to economic growth but is more correlated to industrialization and population size. This article provides a detailed review of scientific and technical periodicals devoted to pollution from urban landfills.

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Introduction

The approach mainly used to manage solid waste in developing countries is uncontrolled dumpsite and open burning [1]. The uncontrolled dumpsite is a substantial waste mismanagement, generating severe environmental and public health problems. Besides, it is a cost-effective and easy method. Only now, the issues from waste tend to be more potent than in the past when the population increased as well as the technology of waste management had yet to develop enough to address these problems in this region. Dumpsite rehabilitation by landfill mining is a developing method that can solve waste management problems by reducing adverse effects or serving and filling demand; however, this is not currently widespread in developing countries. There are factors to be considered before dumpsite rehabilitation is affected; these include the potential of toxicity, stabilization level of solid waste, and feasibility of doing so [2]. Most of the toxic compounds in dumpsites can contaminate the surrounding environment through the contaminants embedded in the leachate, and this is responsible for the main problem of the improper design of all kinds of dumping sites. After the leachate is released, if the toxic compounds are adsorbed by soils rather than dissolved in the water, they contaminate the surrounding soil. By extension, it will also infect the groundwater and surface water [2].

In our full study, the toxicity investigation in terms of heavy metals, i.e., Persistent Organic Pollutants (POPs), is conducted with solid waste, decomposed solid waste (soil), sediments, water, and leachate samples from a dumpsite across three local government areas of Kwara state as well as samples from the surrounding environment of that dumpsite-like surface and groundwater, sediment and soil. The data about toxicity and potential for risk are `essential information in decision-making to upgrade any dumpsite. Solid waste generation is related to economic growth but is more correlated to industrialization and population size. Part of our study presented below consists a literature review devoted to municipal dumpsites contamination.

Types of Soil Contamination

The World Health Organization [3] identified 10 (group of) chemicals of significant public health concern and for each of them has provided risk management recommendations: Air pollution, Arsenic, Asbestos, Benzene, Cadmium, Dioxin and dioxin-like substances like Poly Aromatic Hydrocarbon, Furan, Dichloro-Diphenyl-Trichloroethane (DDT), Benzene Toluene Ethylbenzene and Xylene (BTEX) and Phthalate Esters. These substances offered the greatest threat to human health first. The grid presented in Figure 1 shows the chemicals of major public health concerns identified by the WHO; it should be noted that some known health effects from these chemicals are based on cases where sources other than soil were the cause (e.g., drinking polluted water and Sediments).

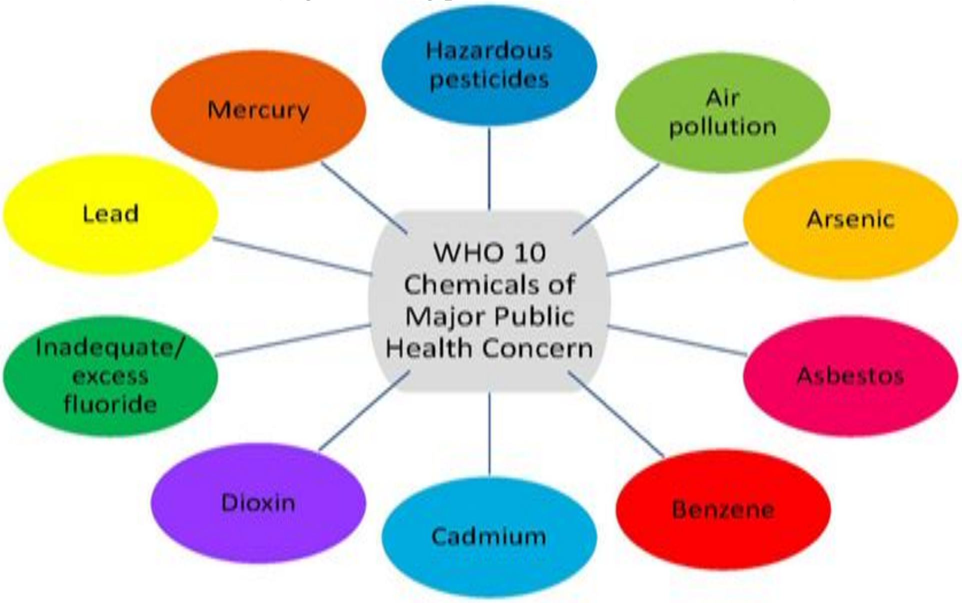

Figure 1 – Major Chemical of Public Health Concern [3]
Рисунок 1 – Основные химические вещества, представляющие опасность для здоровья населения [3]

Heavy Metals and Persistent Organic Pollutants

Heavy Metals

Heavy metal is a member of an ill-defined subset of elements that exhibit metallic properties, mainly transition metals, some metalloids, lanthanides, and actinides. One definition is metals with a density greater than 5 g/cm³ and a specific gravity greater than five; recently, it has been naturally occurring metals having an atomic number greater than 20 and an elemental density greater than 5 g/cm³ [4]. Regarding their roles in biological systems, heavy metals are classified as essential and nonessential. Crucial heavy metals are necessary for living organisms and may be required in the body in relatively low concentrations. Nonessential heavy metals have no known biological role in living organisms. Examples of essential heavy metals are Mn, Fe, Cu, and Zn.

In contrast, the heavy metals Cd, Pb, and Hg are toxic and are regarded as biologically nonessential [4]. Heavy metals Mn, Fe, Co, Ni, Cu, Zn, and Mo are micronutrients or trace elements for plants that

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are essential for growth and stress resistance as well as for biosynthesis and function of different biomolecules such as carbohydrates, chlorophyll, nucleic acids, growth chemicals, and secondary metabolites [4]. Heavy metals are relatively scarce in the Earth's crust but are present in many modern life aspects. They are used in, for example, golf clubs, cars, antiseptics, self-cleaning ovens, plastics, solar panels, mobile phones, and particle accelerators. Moreover, they cannot be degraded or destroyed. As trace elements, some heavy metals (e.g., copper, selenium, zinc) are essential to maintain the human body's metabolism. However, at higher concentrations, they can lead to poisoning. However, some of the heavy metals and environmental effects are as follows; Heavy metals are among the most investigated environmental pollutants. Almost any heavy metal and metalloid may be potentially toxic to the biota, depending upon the dose and duration of exposure. Many elements are classified into heavy metals, but some are relevant in the environmental context. A list of the environmentally pertinent most toxic heavy metals and metalloids contains Cr, Ni, Cu, Zn, Cd, Pb, Hg, and As [4]. Heavy metal pollutants most common in the Environment are Cr, Mn, Ni, Cu, Zn, Cd, and Pb [5]. China has suggested four metals, i.e., Cr, Cd, Pb, Hg, and the metalloid As, as the highest priority pollutants for control in the "12th 5-year plan for comprehensive prevention and control of heavy metal pollution" [5]. Some other heavy metals are also hazardous to live organisms depending upon the dose and duration of exposure [5]. For example, Ag is more toxic than Hg to freshwater fish.

Persistent Organic Pollutants (POPs)

Many POPs were widely used during the boom in industrial production after World War II when thousands of synthetic chemicals were introduced into commercial use. These chemicals benefitted pest and disease control, crop production, and industry. These same chemicals, however, have had unforeseen effects on Human Health and the Environment. Many are familiar with well-known POPs, such as PAH, PCBs, P.E.s, DDT, and dioxins. POPs consist of both intentionally and unintentionally produced chemicals [6].

Intentionally produced chemicals

Intentionally produced chemicals currently or once used in agriculture, disease control, manufacturing, or industrial processes. Examples include PCBs, which have been helpful in a variety of industrial applications (e.g., in electrical transformers and large capacitors, as hydraulic and heat exchange fluids, and as additives to paints and lubricants), and DDT, which is still used to control mosquitoes that carry malaria parasite in some parts of the world [6].

Unintentionally produced chemicals

Unintentionally produced chemicals, such as dioxins, result from industrial processes and combustion (for example, municipal and medical Waste incineration and backyard burning of waste).

Many POPs were widely used during the boom in industrial production after World War II when thousands of synthetic chemicals were introduced into commercial use. These chemicals benefitted pest and disease control, crop production, and industry. On the other hand, Persistent Organic Pollutants have several adverse effects on the environment, which are enumerated below [6].

Biomagnification in Action: A 1997 study by the arctic monitoring and assessment program exit EPA website, called Arctic Pollution Issues: A State of the Arctic Environment Report, found that Caribou in Canada's Northwest Territories had as much as ten times the levels of PCBs as the lichen on which they grazed; PCB levels in the wolves that fed on the caribou were magnified nearly 60 times as much as the lichen. POPs work their way through the food chain by accumulating in the body fat of living organisms and becoming more concentrated as they move from one creature to another. This process is known as "biomagnification". When contaminants found in small amounts at the bottom of the food chain bio magnify, they can pose a significant hazard to predators that feed at the top of the food chain. This means that even minor releases of POPs can have substantial impacts. An illustration of the biomagnification process is shown in Figure 2.

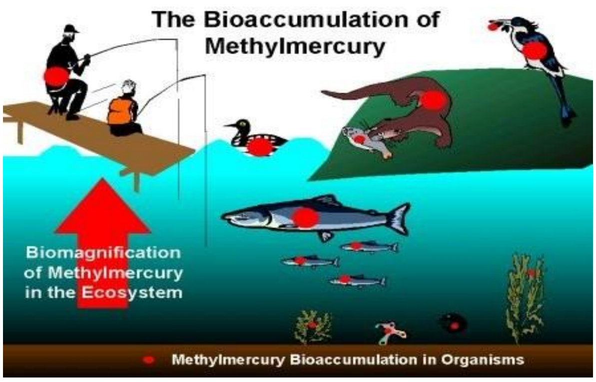

Figure 2 – Bioaccumulation and Biomagnification in Aquatic Animals [8]
Рисунок 2 – Биоаккумуляция и биомагнификация у водных животных [8]

Heavy Metals and Persistent Organic Pollutants in the Environment

Heavy metals

Contamination of surface and groundwater by heavy metals and Persistent Organic Pollutants results in the deterioration of water quality, which affects human Health and the Health of the aquatic ecosystem [5, 7]. Heavy metals in the marine environment threaten organisms thriving in the area and the ecological integrity of the habitat, particularly as trace metals may enter the food chains, persist in the background, bioaccumulate, and bio-magnify.

Though some heavy metals in lower concentrations play essential roles in the metabolic processes of living organisms, high concentrations have been observed to be toxic to human and aquatic life [9, 10]. High concentrations of heavy metals in water sources may lead to adverse effects such as deformities, cancer, and inadequate health of aquatic animals and their terrestrial predators [11].

Heavy metals above specific concentrations in humans may lead to health problems, including liver diseases, kidney problems, and Geno-toxic carcinogens [12]. Metals enter rivers and lakes through a variety of sources such as eroded minerals within sediments, leaching of ore deposits, decomposing dead organic matter, the fallout of atmospheric particulate and volcanism extruded products or anthropogenic sources, including the discharge of liquid and solid waste, industrial or domestic effluents, channel and lake dredging, etc. [13]. Heavy metals enter the human body through several routes, such as food chain, direct ingestion, dermal contact, fume inhalation, and particles through the mouth and nose [14, 15]. To effectively assess water quality, it is crucial to identify the potential human health effects of pollution in water.

The traditional methods for evaluating health effects directly compare the measured values with permissible limits. However, it needs to be sufficiently reliable to provide detailed hazard levels and identify contaminants of the most concern. Health risk assessment is vital for estimating the potential health impact in aquatic ecosystems caused by various pollutants [15, 16]. This method has been applied to evaluate exposure to contaminated water's potential adverse health effects [11]. Although ingestion is considered the primary route of exposure to chemical contamination in drinking water sources, inhalation and dermal absorption are increasingly regarded as essential exposure pathways. Lakes have been observed to have important multi-usage components, including drinking water sources, irrigation, shipping, fishing, landscape entertainment, and hydro-energy production [17].

Metal contamination in aquatic environments remains an issue of great concern due to its toxicity, comprehensive source, abundance, persistence in the background, and subsequent accumulation for an extended period in aquatic habitats. Over the past century, heavy metals have been discharged into the world's rivers and estuaries because of rapid industrialization and urbanization [18]. River sediments are essential for assessing fabricated contamination in rivers, where heavy metals flow into lakes. Sediments usually provide helpful information for environmental and geochemical pollution status [18]. Heavy metals may settle in the sediments and gradually released into the water, generating one of the most critical problems in aquatic environments [19]. Total heavy metal concentration in sediments can be used for the identification of pollution sources and pollution levels, and ecological sediment is an integral part of restoring and maintaining biological integrity; it should always include the determination of the extent or degree of pollution by a given heavy metal.

Consequently, analyzing river sediments helps study metal pollution in a given area [20]. The geoaccumulation index (Igeo), enrichment factor (E.F.), contamination factor (C.F.), potential ecological risk (PER) or Risk Index (R.I.), and pollution load index (PLI) are among the different statistical indexes that can be used to determine the source and magnitude of metal pollution. Numerous researchers considered these parameters for assessing metal pollution [21]. All these studies were of practical significance in terms of environmental protection.

The Ichkeul Lake (northern Tunisia) represents an original aquatic ecosystem whose biological balance has been altered due to rapid anthropogenic development, anarchic urbanization, industrialization, and municipal wastewater dumped directly into the lake, which can seriously affect water and sediments. Furthermore, various unknown sources of pollutants can be emitted by industries that can negatively affect the ecosystem. Indeed, in the existing literature on ecosystems in Bizerte, Tunisia, some previous studies have assessed the water quality of the Bizerte lagoon. This may help to develop practical water protection measures and better management of human activities in the Ilorin metropolis and its feeder rivers.

Risk System and Ecological Risk Assessment

What is a system in ecological risk assessment

Thermodynamically, a system is any part of the universe isolated for the course of study, and there are three types of systems. An *Open system* is a system that allows the exchange of energy and matter, e.g., ecological, planetary, and solar systems. In contrast, a Closed system does not allow an exchange of energy and value, e.g., a flask of hot water and Isolated systems, which will enable the business of power. Still, there is no exchange of matter, e. g a cup of open hot water.

Ecological systems as an example of open systems

This is an aspect of physical and biological science that deals with the interaction of living, i.e., Animals and plants with non-Living things such as Water, Air, Energy, and Sound in a single community, generally referred to as ecosystems Examples include Micro, mexo, and hexo ecological systems.

Ecological Risk Assessment

This is the process of identifying health risks (Hazard) and risk factors that have the potential to course harm (hazard Identification) with six significant elements: Hazard Identification, Receptor Identification, Exposure Assessment, Toxicity Assessment, Risk Characterization or Risk Communication, and Risk Management.

Quantitative health risk assessment

Human exposure risk pathways for an individual to trace metals contamination could be through three main pathways: inhalation via nose and mouth, direct ingestion, and dermal absorption through skin exposure. Common exposure pathways to water are dermal absorption and ingestion routes. Exposure doses for determining human health risk through these two pathways have been described in the literature and can be calculated using different health risk equations.

Statement of the Research Problem

Solid waste results from a rapid population increase, massive urban areas expansion, and a changing lifestyle. The Ilorin metropolis has experienced rapid urbanization, sprawling settlements, and population growth. These, in turn, have triggered an increase in solid waste generation. An increase in population and income increases the production of goods and services; thus, more waste is discharged into the environment.

Against this background, the purpose of this study was to classify the solid waste into (1) hazardous and Nonhazardous, (2) organic/ inorganic, and (3) biodegradable/ non-biodegradable and evaluate the soil and sediment pollution level and its consequent impacts on both ground and surface water qualities. The study Risk Assessment is also vital as there is no doubt that the intake of these toxic compounds through contaminated water and products from contaminated soil and sediments negatively impacts humans and thereby affects their productivity. Also, heavy metals and Persistent Organic Pollutants (POPs) have been identified as significant sources of environmental pollution worldwide, which usually result in a series of health hazards for plants and humans. Hence It is essential to quantify the concentration of heavy metals and POPs and determine possible environmental impact and health risks due to human exposure to organic and inorganic pollutants.

Justification and Relevance of the Study

Most toxic compounds in dumpsites contaminate the environment through the contaminants in the leachate. This is a consequence of the improper design of the location of dumpsites, particularly in developing countries. After the leachate is released and the toxic compounds like Persistent Organic Pollutants (POPs) such as Benzene Toluene Ethylbenzene and Xylene (BTEX), polychlorinated biphenyls, Dioxin (PCBs), phthalates phenol Methane (CH_4), Hydrogen Sulfide (H_2S), Methyl Mercaptans CH_3SH as well as heavy metals, are adsorbed by soils and sediments rather than being dissolved in the water, it will contaminate the surrounding soil/sediments and by extension, the surface and groundwater system [22].

The intake of these toxic compounds through contaminated water and products from contaminated soil negatively impacts humans, affecting the ecosystem. To this extent, a need exists to prevent this occurrence through studies of this kind. There is a need to evaluate the gradual building up of organic and inorganic pollutants in an aquatic organism (Bio-accumulation of POPs and Heavy Metals) as well as an increase in the concentration of these pollutants (Biomagnification)

With the outcome of this study, it would be possible to establish the extent of soil and groundwater contamination by leachates from dumpsites. This will trigger the need for necessary positive steps through improving policy formulation and decision-making inefficient waste management techniques.

Literature review

Definition of Solid Waste

Municipal Solid Waste (MSW) is collected by or on behalf of a local authority. It comprises mainly household waste, and it may include some commercial and Industrial wastes. At the International level, various organizations, including private and government, are engaged in research and development in the field of waste management. International agencies like World Health Organization (WHO), Environmental Protection Agency (USEPA), and United Nations Environment Program (UNEP) define waste from a different perspective. However, the most globally acceptable definition is that of the United States Environmental Protection Agency, which describes *wastes* as any garbage or refused Sludge from a wastewater plant, water supply treatment, or air pollution facilities and other discarded material, including solid, semisolid, liquid or gaseous material resulting from industrial, commercial, mining and agricultural operations and country activities. New technologies for waste management and its disposal, including its characterization, are continuously being investigated by researchers within the context of the sustainable development Agenda of the United Nations.

Types and Sources of Solid Waste

Solid waste includes Animal, hazardous, industrial, medical, food, and nonhazardous. Waste can also be categorized as municipal (household), commercial, and institutional wastes. Household waste originates from private residences; commercial waste originates from wholesale, retail, or service establishments such as restaurants, stores, markets, theaters, hotels, and warehouses; and institutional waste materials are created from stores, schools, hospitals, research institutions, and public buildings.

Classification of Solid Wastes

Solid wastes have been classified under the headings such as Sludge from sewage treatment plants, spent household wastes, Construction and demolition wastes, vegetative wastes, Animal and food processing wastes, and dry industrial Wastes. An emerging waste class is e-wastes. Some researchers have reported that nearly half of the world's population lives in urban areas, causing tremendous pressure on the local Environment.

Recent Statistics on Solid Waste

Research has shown that around the world, waste generation rates are rising. In 2016, the world's cities generated 2.01 billion tons of solid waste, amounting to a footprint of kilograms 0.74 per person per day. With rapid population growth and urbanization, annual waste generation is expected to increase by 70% from 2016 to 3.40 billion tons in 2050. Compared to those in developed nations, residents in developing countries, especially the urban poor, are more severely impacted by unsustainably managed waste. In low-income countries, over 90% of waste is often disposed of in unregulated dumps or openly burned. These practices create severe Health, safety, and environmental consequences. Poorly managed

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waste is a breeding ground for disease vectors, contributes to global climate change through methane generation, and can even promote urban violence.

Managing waste properly is essential for building sustainable and livable cities, but it remains challenging for many developing countries and cities. Effective waste management is expensive, often comprising 20-50% of municipal budgets. Operating this essential municipal service requires integrated systems that are efficient, sustainable, and socially supported through the following strategy.

The World Bank finances and pieces of advice on solid waste management projects using a diverse suite of products and services, including traditional loans, results-based financing, development policy financing, and technical advisory. World Bank-financed waste management projects address the entire waste lifecycle – from generation to collection, transportation, treatment, and disposal. As the world hurtles toward its urban future, the amount of municipal solid Waste (MSW), one of the most important byproducts of an urban lifestyle, is growing even faster than the rate of urbanization. Ten years ago, 2.9 billion urban residents generated about 0.64 kg of MSW per person per day (0.68 billion tonnes per year). This report estimates that these amounts have increased to about 3 billion residents generating 1.2 kg per person per day (1.3 billion tonnes per year). By 2025 this will likely increase to 4.3 billion urban residents generating about 1.42 kg/capita/day of municipal solid waste (2.2 billion tonnes per year).

Objectives that guide the Bank's Solid Waste Management Projects and Investments include:

Infrastructure: The World Bank provides capital investments to build or upgrade waste sorting and treatment facilities, close dumps, and construct or refurbish landfills, and feed bins, dumpsters, trucks, and transfer stations.

Legal structures and institutions: Projects advise on suitable policy measures and coordinated institutions for the municipal waste management sector.

Financial sustainability: By designing taxes and fee structures and long-term planning, projects help governments improve waste cost containment and recovery.

Citizen engagement: Behavior change and public participation is critical to a functional waste system. The World Bank supports designing incentives and awareness systems to motivate waste reduction, source separation, and reuse.

Social inclusion: Resource recovery in most developing countries relies heavily on informal workers, who collect, sort, and recycle 15-20% of generated waste. Projects address waste picker livelihoods through strategies such as integration into the formal system and the provision of safe working conditions, social safety nets, child labor restrictions, and education.

Climate change and the Environment: Projects promote environmentally sound waste disposal. They support greenhouse gas mitigation through food loss and waste reduction, organic waste diversion, and the adoption of treatment and disposal technologies that capture biogas and landfill gas. Waste projects also support resilience by reducing waste disposal in waterways, addressing debris management, and safeguarding infrastructure against flooding.

Health and safety: The World Bank's work in municipal waste management improves public Health and livelihoods by reducing open burning, mitigating pest and disease vector spreading, and preventing crime and violence.

Knowledge creation: The World Bank helps governments plan and explore locally appropriate solutions through technical expertise, data, and analytics. A Global Snapshot of Solid Waste Management to 2050 captures the latest trends in waste management. The World Bank's waste management engagement spans multiple development areas: energy, environmental sustainability, food and agriculture, Health and population, social protection, transportation, urban development, and water.

Results from World Bank Evaluation

Since 2000, the World Bank has committed over $4.7 billion to more than 340 solid waste management programs in all six regions of World Bank engagement. Recent or committed infrastructure lending and technical assistance have supported numerous initiatives in different parts of the world.

East Asia and the Pacific

In Indonesia, a $100 million loan from the world bank has supported a $1 billion national program to reform waste management practices for around 70 participating cities, impacting approximately 50 million people. The loan supported the strengthening of local policies and institutions, closure and

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rehabilitation of old and informal dumpsites, and installation of sustainable disposal sites, including modern sanitary landfills with landfill gas collection mechanisms.

China, a results-based incentive program, has motivated household kitchen waste separation. The $80 million loans have also supported the Construction of a modern anaerobic digestion facility to ferment and recover energy from organic waste, which was expected to benefit 3 million people.

Vietnam. Investments in solid waste management are helping the city of Can prevent the clogging of drains, which could result in flooding. Similarly, in the Philippines, investments are helping Metro Manila reduce flood risk by minimizing solid waste ending up in waterways. By focusing on improved collection systems, community-based approaches, and providing incentives, waste management investments are contributing to reducing marine litter, particularly in Manila Bay.

Europe and Central Asia. In *Belarus*, a $25 million loan from World Bank supported introducing a regional approach to solid waste management. The loan aimed to help construct regional waste management facilities, close relevant dumpsites, and provide more technical assistance to the sector.

In Azerbaijan, World Bank loans supported the rehabilitation of the leading landfill site and the establishment of a state-owned waste management company, increasing the population served by the formal solid waste management system from 53% in 2008 to 74% in 2012. Support also led to further sustainable waste management practices, helping achieve a 25% recycling and reuse rate.

In Bosnia and Herzegovina, World Bank loans financed the rehabilitation of existing disposal sites, the development of regional landfills, wild dump closures, and supportive equipment. The loans helped increase access to the formal waste management system from 25% to 66% of the population through infrastructure investments and technical assistance on SWM issues.

Latin America and the Caribbean. In *Argentina*, $40 million in loans and grants helped to reduce and adequately treat food waste through partnerships with food banks and retailers, close over 70 dumpsites, and construct 11 waste facilities.

In *Saint Martin*, the World Bank provided a $25 million emergency debris management grant focusing on dumpsite management and broader sectoral support. There is ongoing support to develop a national solid waste management strategy and investment plans to further develop the stable waste management sector in an integrated manner.

In *Jamaica*, community participation and waste collection services improved in 18 communities through results-based financing and infrastructure investments. Waste activities also led to job creation and contributed to a crime prevention and reduction program.

The Middle East and North Africa. In Morocco, a series of Development Policy Loans totaling $500 million improved citizen engagement and transparency, strengthened private sector partnerships and accountability, increased fee collection, and supported better working conditions for – and the social inclusion of – 20,000 informal workers.

In the West Bank, loans have supported the Construction of three landfill sites that serve over 2 million residents, enabled dump closure, developed sustainable livelihood programs for waste pickers, and linked payments to better service delivery through results-based financing.

South Asia. In Nepal, a results-based financing project of $4.3 million increased user fee collection and improved waste collection services in five municipalities, benefitting 800,000 residents. In Pakistan, a composting facility in Lahore aimed at market development was supported with a 5.5-million-dollar project and the sale of emission reduction credits under the Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCCC). Activities resulted in reductions of 150,000 tonnes of carbon dioxide equivalents and expansion of daily compost production volume from 300 to 1000 tonnes per day.

*Sub-Saharan Africa***.** In Liberia, $10.5 million has been committed to improving waste collection and constructing a new sanitary landfill and transfer station.

In Burkina Faso, the World Bank has supported the solid waste sector with over $67 million in loans since 2005, supporting waste sector planning and constructing two landfills. The capital city, Ouagadougou, now collects an average of 78% of waste generated, significantly higher than the 46% average in Sub-Saharan Africa.

The World Bank 2012 Urban Development Series publication stated that waste generation is approximately 62 million tonnes a year, with each person generating an average of 0.65 kg/day. By

2025, the report projected that urban waste generation in the region would be 161.27 million tonnes annually. Going by this report and Nigeria's population, the country generates 43.2 million tonnes of waste annually, and by 2025 a projected population of 233.5 million. Nigeria will generate an estimated 72.46 million tonnes of waste annually at a projected rate of 0.85 kg/capita/day. This means that Nigeria's annual waste generation will almost equal her crude oil production, which currently stands at approximately 89.63 million tonnes annually. Also, at an estimated yearly waste generation figure of 72.46 million tonnes, Nigeria will generate about one-fourth of the total waste produced in Africa. This is scary, and if proper attention is not paid to this enormous challenge, Nigeria might become the "waste capital of Africa".

Nonetheless, this challenge can be a blessing because waste is a resource in disguise. If its potential is appropriately tapped, waste management can create employment, enable power generation, and contribute to economic diversification, which Nigeria direly needs. It is achievable because we have examples of countries already utilizing their waste judiciously. A few examples of such countries are; China which in Shanghai alone, turns 50% of the waste generated into power generation, electrifying 100,000 homes; Incheon, South Korea, where in its Sundown landfill, which receives about 20,000 tonnes of daily waste converts same to electric power, has a water recycling and desalination facility and has created over 200 jobs. The Sudokwon landfill is reported to serve as a model of how waste resources can best be tapped to achieve a positive impact. Other examples are; Los Angeles, California, which also produces electric power enough for 70,000 homes in its Puente Hills landfill; Germany, whose sophisticated waste processing systems through recycling, composting, and energy generation have already saved the country 20% of the cost of metals and 3% of the cost of energy imports; Austria, though a small country, is doing big things in waste management, primarily through recycling; Sweden, whose recycling is so revolutionary that the government had to import waste; and Flanders, Belgium which possesses the best waste diversion rate in Europe with 75% of their waste being reused, recycled or composted. Furthermore, Flanders's per capita waste generation rate is more than twice that of Nigeria at 1.5 kg/day. Along with population explosion, municipal expansion, economic development, and improvement of people's living standards, the amount of Municipal Solid Waste (MSW) has been increasing rapidly, and its compositions have become more worrisome. According to the statistics presented by the United States Environmental Protection Agency, Municipal Solid Waste generated from residences, industries, business, and institutions were over 236.2 million tons before recycling, which is two times more than the volume of Waste in the year 1960 (88.1 million tons). This has been estimated to be approximately 1.8 kg of waste per day per person in 2003. The composition of Municipal Solid Waste, some of which are plastics and metals, for instance, may cause serious environmental problems, and health hazards, without proper treatment, due to river contamination, heavy metal pollution, etc. Notably, inadequate waste management and immature treatment technology may worsen this situation in large regions of developing countries.

MSW contains some valuable materials, such as plastics, metals, glass, etc., most of which can be easily recycled, so separation processes have been introduced into the pre-treatment of Municipal Solid Wastes. Moreover, most of the materials recycled can be reused by companies or returned to the market, thereby saving the cost of waste treatment, which is just the essential benefit of the recycling process. The recycled materials would be reformed or reused as substitute raw materials in the related field. Recycling is a cost-effective way to manage Municipal Solid Waste [23]. The study has shown that human and environmental factors, including investment and residents' attitudes, can influence decision-makers choices. To avoid ecological risks, the economic and social performance of the MSW management facility should be considered [24] integrally 0.49 kg, with households accounting for 90% of the urban waste. It has high organic content consistent with waste generated in developing countries such as Ghana, China, Jordan, and Palestine [25].

It has been observed that there is a steady increase in waste quantity and variety due to population growth and industrialization. In contrast, the basic solid waste management system based on collection, transportation, and disposal must be more efficient and effective, especially in urban centers. It was reported that to balance the three aspects with the help of listing the present factors and analyzing the impacts; the sustainable waste management scheme will be appropriately made to fill the local condition [26].

The composition of Waste in Nigeria suggests a recyclable content of over forty percent, with a recycling rate estimated at 8-22% by the informal sector. Other disposal options that have been enumerated include open dumping, burning, and compositing [26]. It was reported that temporary waste storage within a household or at communal sites is highly irregular, and collection of co-mingles waste is carried out by the state and local government directly via contractors or informal waste managers [27]. More than 50% of the population disposes of waste at communal sites, which are open dumps. Lorries, tippers, loaders, trucks, tractors, pushcarts, and wheelbarrows typically transport waste. Collecting and transportation account for 70-80% of total waste management costs in Nigeria, mainly funded by the government [27]. Waste recovery and disposal operations as an appraisal of waste management in Nigeria development and evaluation of an index-based tool for classification of solid Waste. Further variety, according to USEPA (1986), solid waste can be considered hazardous waste if they exhibit any of the following four characteristics; Ignitability, Corrosiveness, Reactivity, and Toxicity. Universal wastes are hazardous wastes that can be collected under streamlined conditions. Examples include batteries, pesticides, mercury-containing equipment, and bulb lamp wastes. In contrast, the other waste category is nonhazardous Waste (USEPA, 1986). Multi-hazardous Waste is Waste that contains any combination of chemical, radioactive, or biological hazards that require special management considerations because the treatment method for one of the hazards may be inappropriate for the treatment of another or may be regulated by one or more of the agencies such as EPA, TCEQ and/or TDSHS (USEPA, 2006). Under Texas regulations, nonhazardous wastes are classified into three. The Texas Commission on Environmental Quality (TCEQ) regulates the first Class of Waste, potentially threatening human Health and the Environment if not adequately managed. Examples are water contaminated with ethylene glycol, soils contaminated with petroleum hydrocarbon, ignitable liquids above 150, semisolids, and solids, when combined with water, exhibit corrosive properties (see Fig. 3).

The second Class of Waste is often accepted at local landfills. Examples of debris that fall under the Class are depleted aerosol cans, surgical non-radioactive mechanical waste, and food waste and packaging that result from plant production manufacturing or laboratory operations (Hazardous).

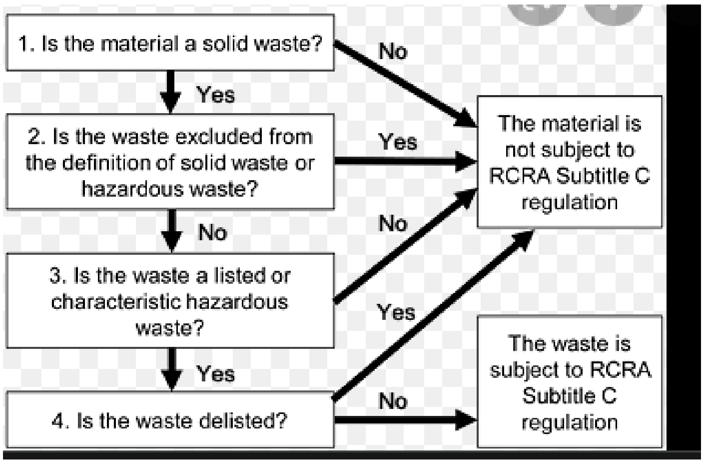

Figure 3 – Criteria for Waste Classification into Hazardous and Nonhazardous (Adapted from WHO, 2016)
Рисунок 3 – Критерии классификации отходов на опасные и неопасные (адаптировано из ВОЗ, 2016)

The third Class of wastes are insoluble, do not react with other materials, and do not decompose. Examples of debris that fall under this Class are chemically inert and insoluble substances that pose no threat to Human Health or the Environment. These include rocks, bricks, glass, dirt, some insoluble solid waste materials, and non-Hazardous plastics.

Municipal Solid Waste or nonhazardous wastes are described by three terms which include; Garbage usually consists of highly decomposable products, such as food waste products; Waste, which comprises various bulky waste items such as tree stumps or branches, discarded mattresses, and old or non-working appliances, and rubbish purifying or slowly decomposable or combustible items, such as

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paper, glass, metal, cans, and wooden products. It should also be noted that this category refers to waste from urban and rural areas and city and country jurisdictions. Municipal Solid Waste (MSW) does not include debris from Construction or demolition, wastewater treatment sludge, or nonhazardous industrial wastes [28].

Characteristics of Hazardous Waste

The regulations explaining these characteristics and the test methods to detect their presence are found in Part 261, Subpart C. Waste handlers can use the test methods referenced in Subpart C to determine whether a waste displays characteristics; they are not required to do so. In other words, any handler of industrial waste may apply knowledge of the waste's properties to determine if it exhibits a characteristic instead of sending it for expensive laboratory testing. As with listed wastes, characteristic wastes are assigned waste codes. Ignitable, corrosive, and reactive wastes carry the waste codes D001, D002, and D003, respectively. Wastes displaying the characteristic of toxicity can take any of the waste codes D004 through D043.

Ignitability

Ignitable wastes are wastes that can readily catch fire and sustain combustion. Many paints, cleaners, and other industrial wastes pose a fire hazard. Most ignitable wastes are liquid in physical form. EPA selected a flash point test to determine whether the liquid Waste is combustible enough to deserve regulation as hazardous. The flash point test determines the lowest temperature at which a chemical ignites when exposed to flame. Many wastes in solid or non-liquid physical form (e.g., wood, paper) can also readily catch fire and sustain combustion. However, EPA did not intend to regulate most of these non-liquid materials as ignitable wastes (USEPA, 2021). Non-liquid Waste is only hazardous due to Ignitability if it can spontaneously catch fire under normal handling conditions and can burn so vigorously that it creates a hazard. Certain compressed gases and chemicals called oxidizers can also be ignitable. Ignitable wastes carry the waste code D001, among the most common hazardous wastes. The regulations describing the characteristic of Ignitability are codified at §261.21.

Corrosivity

Corrosive wastes are acidic or alkaline (basic) wastes that can readily corrode or dissolve flesh, metal, or other materials. They are also among the most common hazardous waste streams. Waste sulfuric acid from automotive batteries is an example of corrosive waste. EPA uses two criteria to identify dangerous corrosive wastes. The first is a pH test. Aqueous wastes with a pH greater than or equal to 12.5 or less than or equal to 2 are corrosive under EPA's rules. Waste may also be corrosive if it can corrode steel in a specific EPA-approved test protocol. Corrosive wastes carry the waste code D002. The regulations describing the corrosivity characteristic are found in §261.22.

Reactivity

A reactive waste is one that readily explodes or undergoes violent reactions. Typical examples are discarded munitions or explosives. In many cases, there is no reliable test method to evaluate a waste's potential to explode or react violently under common handling conditions. Therefore, EPA uses narrative criteria to define the most reactive wastes. It allows waste handlers to use their best judgment in determining if a waste is sufficiently reactive to be regulated. This is possible because reactive hazardous wastes are relatively uncommon, and the dangers they pose are well known to the few waste handlers who deal with them. A waste is reactive if it meets any of the following criteria: it can explode or violently react when exposed to water when heated, or under normal handling conditions.

Emissions from Solid Waste

The Department reported the primary emissions from Waste for Environment Farm and Rural Affairs. Landfills with either flaring or energy production from the collected gas produced similar positive carbon emissions. However, these were substantially lower than open dumping and sanitary landfills without flaring or energy production. However, this does not mean surface water or groundwater emissions are less critical. Emissions to air could be broken down into substances released because they are in the waste or produced during its decomposition. Examples include methane, methylene, volatile organic compounds and metals, and implications from burning waste or gases derived from garbage (for example, carbon monoxide, oxides of nitrogen, and sulfur dioxide). Some substances can arise from both kinds of sources, for example, dioxins and furans, and particulate matter, which are generally referred to as Volatile Organic Matter (VOC).

Emissions to water could take place in several ways, primarily through landfills. Water already in the wastes, or rainwater falling onto a dump, acquires ("leaches") contaminants from the debris and is known as "leachate" collected and treated on-site or at a sewage treatment before being released to a river or the sea. Some leachates seep slowly from the landfill and mix with water in the site's soils.

Landfill gas (LFG) is a natural byproduct of the decomposition of organic material in landfills. LFG is composed of roughly 50 percent methane (the primary component of natural gas), 50 percent carbon dioxide (CO_2), and a small amount of non-methane organic compounds (USEPA, 2022). Methane is a potent greenhouse gas, 28 to 36 times more effective than CO_2 at trapping heat in the atmosphere over 100 years, per the latest. In 2020, methane (CH_4) accounted for about 11% of all U.S. greenhouse gas emissions from human activities. Human activities emitting methane include leaks from natural gas systems and raising livestock. Methane is also emitted by natural sources such as natural wetlands. In addition, biological processes in soil and chemical reactions in the atmosphere help remove CH_4 from the atmosphere. Methane's lifetime in the atmosphere is much shorter than carbon dioxide (CO_2), but CH_4 is more efficient at trapping radiation than CO_2. Pound for pound, the comparative impact of CH_4 is 25 times more significant than CO_2 over 100 years. Globally, 50-65% of total CH_4 emissions come from human activities.

Methane is emitted from energy, industry, agriculture, land use, and waste management activities. Emissions from waste management operations are dependent on the material being treated. This means there is a limit to which emissions from individual facilities can be evaluated in a non-site-specific study because of the variation between different facilities. The timing of emissions from landfills is different from the other types of facilities considered. Carbon dioxide is one of the main contributors to global warming; it is emitted when Municipal Solid Waste decomposes or is Incinerated. In contrast, the emissions from other facilities happen simultaneously as the waste is processed. It has been reported that landfill emission occurs at a lower rate but over a more extended period.

Landfill produces methane emission, a much more potent greenhouse gas than carbon dioxide. This landfill is a significant source of methane gas as a waste product of the waste management option with the most critical global warming impact, even though an increasing proportion of landfill gas is burnt, which converts the methane to carbon dioxide. Oxides of nitrogen known as "NOx" are produced when Municipal Solid Waste or gases derived from Municipal Solid Waste are burnt. NOx includes nitrogen dioxide, which is, as a matter of concern, reducing air quality in urban areas.

Emissions of oxides of nitrogen also contribute to acid rain and excessive eutrophication that increases nutrients in rivers and lakes, stimulating excessive growth of algae and crowding out other species. Particulate is also emitted when waste is burnt. The particulate matter is eventually deposited onto the soil or river around the dump site. Delicate particulate matter is a concern for urban air quality because the increase in levels of particulate matter in the air is linked to general indicators of ill Health, such as hospital admissions for respiratory ill Health. Arsenic has been identified as one of several metals which can be emitted from waste management facilities, particularly when waste is burnt. If exposure is high enough, metals can have a range of effects on Health (for example, arsenic can cause cancer of the kidneys, lungs, and bladder).

Solid Waste Characterization

Characterization is sorting the overall waste at a particular point into different categories/components, which are measured individually and added together to give the total quantity. Characterization can be through visualization or hand sorting, but the latter provides a more accurate result. Waste characterization also means finding the essential components of the different/individual components such as paper, glass/bottles, food waste, textiles/clothing materials, polythene bags, e-waste, rubber, wood, sanitary, medical, etc., discarded in a waste stream. The evaluation of the composition of solid wastes can be complex because of their heterogeneous nature, which makes strict statistical procedures challenging to execute correctly. Consequently, field procedures based on direct observation and random sampling are employed to evaluate the composition. Waste composition results provide reliable details on municipal solid Waste (MSW) generation trends and the specific weights of individual waste components. It also provides the essential information required for proper decision-making and further improving waste management strategies. There exist other factors that contribute to every successful waste management system, but for their adequate comprehension, there should be a qualitative research approach [29]. The quantity of solid waste has increased significantly, and its character has changed due to accelerated urbanization, industrialization, and population growth in most cities of developing countries [30]. Ilorin metropolis has, over the years, experienced rapid urbanization, sprawling settlements, and rapid population growth, which in turn have triggered an increase in the generation of solid waste. Solid waste results from the rapid rise in population, massive expansion of urban areas, and the changing lifestyle. Population and income increase the production of goods and services; thus, effluents are discharged into the Environment.

The United States Environmental Protection Agency defines waste as any garbage or refuse Sludge from a wastewater plant, water supply treatment, or Air pollution control facilities and other discarded material, including solid, liquid, semisolid, or gaseous material resulting from industrial, commercial, mining and agricultural operations, and country activities. Various sources of waste were enumerated as solid waste resulting from animal wastes, hazardous wastes, industrial and medical wastes, food waste, and nonhazardous wastes Other sources of waste include municipal (household), commercial, and institutional waste originating from the community consisting of household waste from private residences, commercial waste, which creates in wholesale, retail, or service establishments such as restaurants, stores, markets, theatres, hotels, and warehouse, and institutional waste materials originated from schools, hospital, research institutions, and public building. Solid wastes have been classified under the headings such as Sludge from the sewage treatment plant, spent household wastes, and Construction and demolition wastes. Vegetative Waste, materials from plant nurseries and gardens, Animal and food processing wastes, Dry industrial wastes, and other categories include a septic tank and sewage sludge. A recent addition to the classes is e-wastes (electronic).

Municipal solid wastes (MSW) include everyday waste, such as packaging yard wastes, glass paper, food sieves, appliances, and batteries. It should also be noted that this category refers to waste from urban and rural areas and city and country jurisdictions. Municipal solid Waste (MSW) does not include debris from Construction or demolition, wastewater treatment sludge, or nonhazardous industrial wastes [28]. Wastes are classified into two, namely, general or municipal Waste and Hazardous Waste. The waste classification system is founded on the risk any waste poses to humanity and its Environment. The waste classification system comprises waste regulations and laws, waste classification, and its management regulation and disposal [31]. Thus, the classification system helps distinguish between unnecessary hazardous Waste and Waste of limited risk, requiring utmost precaution and less attention during disposal. The categories of the classified waste include organic Waste (agricultural and Animal refuse), industrial residues, mining/extraction waste, Construction and demolition debris and sewage sludge, etc. The types of general waste and their sources are summarized in Table 1.

Treatment of Municipal Solid Waste

Waste is an inevitable byproduct of our use of natural resources. The amount that makes–up waste in any given area depends on factors such as the local population density, economic prosperity, time of year, type of housing, and whether there are local waste minimization initiatives such as home composting as well as other methods of municipal waste treatment [32].

Compositing

It uses micro-organisms to break down organic waste in the presence of air, usually to produce compost suitable for adding to solids or as a pre-treatment step. Compositing is usually carried out on a pre-suited Municipal Solid Waste or specific organic Waste, for example, wood and kitchen waste. Compositing can occur in the open air, known as "Window" compositing or in-vessel systems. These enable the composition process to be automated, and any e-waste made readily controlled. Composting and materials recycling facilities (MFRs) have been investigated for possible exposures to micro-organisms and lung diseases like bronchitis.

Mechanical Biological Treatment:

This is a composition process involving a mix of sorting, separation, cutting, or grinding the waste into smaller pieces, and compositing; the residual materials may be used as compost, incinerated with energy recovery, or landfilled.

Anaerobic digestion

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This is the decomposition of organic waste in an oxygen-free atmosphere. This produces gas comprising mainly methane and carbon dioxide, which is burnt for electricity generation. This digested waste material can be composted and spread onto land.

Table 1. Types of general Waste and their source (according to [4])
Таблица 1. Типы общих отходов и их источник (по данным [4])

S/N	Waste Composition	Waste generator	Sources
1.	Food waste (mixed)	Household	Residential
2.	Inert matter	Institutions, Stores, hotels, restaurants, markets, etc.	Institutional and commercial centers
3.	Paper and cardboard	Institutions, Stores, hotels, restaurants, markets, etc.	Institutional and commercial centers
4.	Textile and gunny bags	Construction sites, industries and manufacturing companies.	Industrial
5.	Wood	Construction sites, industries and manufacturing companies.	Industrial
6.	Construction waste	Construction sites, industries and manufacturing companies.	Industrial
7.	Glass	Household	Residential
8	Leather	Household	Residential
9	Metal – Ferrous	Household	Residential

Aerobic

This is the decomposition of organic waste in the presence of atmospheric oxygen to produce methane and carbon dioxide, which is also burnt for electricity generation, and the digested waste material can be composted and spread onto land.

Thermal Classification

This is a process in which a portion of the waste is burnt in a reactor at a high temperature. Most of the organic material in the waste is converted into carbon monoxide, hydrogen, and methane. Pyrolysis involves indirect heating of the waste in an oxygen-free atmosphere. This turns organic materials into simple gases, oils, and char. The char produced in both cases can be further reacted with air and steam to produce hydrogen and carbon monoxide gases which can be burnt to produce heat, which is usually used to produce electricity. The remaining ash can be reused or sent to a landfill. One U.K. process operating has been reported using this approach, which uses a combination of both pyrolysis and gasification.

Incineration

This involves burning waste to reduce the volume of solids (typically by 70%) and generate heat or electricity. The resulting ash can again be reused or sent to a landfill. The residue from air pollution control systems used at waste incineration processes is time ash, typically about 4% of the weight of waste processed. It has been observed that hazardous material typically needs to be disposed of at a landfill licensed to accept this kind of waste. The use of energy generated from incineration will reduce the need to generate power from other sources.

Sources of Leachate

An assessment of heavy metal contamination in soil due to leachate migration from an open dumping site in Ariyamangalam, Tiruchirappalli, Tamilnadu was reported in [33]. The new solid waste composition study showed that samples from the open dumpsite contained about 90-95% combustible materials and a non-combustible fraction is about 1-5%. The composition of existing solid Waste from the old dumping area showed a significant variation at all depths and locations. The dead leaves, wood chips, and soil were found to be 40-60 and 15-40 %, respectively. The plastic and paper compositions were 8-15 % and 0.5-15 %, respectively. Debris waste composition was 5-18%. The physicochemical characteristics of leachate showed that the range of COD varied from 26.880 mg/l to 45.0 mg/l 120 mg/l, and the BOD/COD ratio was less than 0.1 mg/. The reported leachate results confirmed the methanogenic condition of the dumpsite [33].

Environmental assessment of urban drainage, sewage, and solid waste management in Barddhaman, West Bengal, was investigated [34]. The study demonstrated the correlation between urban population growth and the urban drainage system. This provides a brief outlook of worldwide population pressure and temporal development of population, analyzing the worldwide surface and the urban drainage system quantitatively; in [35] it was studied the heavy metals in the leachate of five municipal landfills and the health effects associated with the heavy metal in Sultanate of Oman.

Indices for groundwater contamination risk assessment near hazardous waste landfills in China were reported by [36]. The indices investigated were source term, underground media, leachate properties, risk receptors, landfill management quality, and a risk assessment indices system consisting of 38 cardinal indicators were established. The levels of Zinc (Zn), Cadmium (Cd), Chromium (Cr), Lead (Pb), Selenium (Se), Iron (Fe), and Mercury (Hg) were found to be greater than the drinking water standards. Geo-environmental site characterization at a waste disposal site was also examined using traditional geotechnical in situ techniques in Kuwait, and the result indicated that the soil and groundwater at the waste disposal site have neither liner nor a cover system. It was concluded that the waste would continue to generate leachate for many years and contribute to soil and groundwater contamination [37].

Impact of Leachate on the Environment

It has been reported that the presence of pollutants such as Methane (CH_4), Hydrogen Sulphide (H_2S), and Methyl Mercaptans (CH_3SH) in the Environment can damage cause damage to properties like electronic pieces of equipment, sensitive computers, server rooms [6]. The researcher also reported that the improper disposal of solid waste could lead to the spread of infectious diseases and destruction of the biosphere as a whole. Various researchers also analyzed sewage characterization and its impacts on water bodies [38]. Studies revealed the status of urban water bodies and associated health concerns in Pune, India, and the impact of discharge wastewater effluents on the physicochemical qualities of a receiving watershed in a typical rural community of the Eastern Cape Province of South Africa [38].

Over the 12 months duration study, they measured various parameters of treated effluent. They found that chemical oxygen demand, nitrate, nitrite, orthophosphate, dissolved oxygen, and turbidity crossed the standard permissible limits [38]. Groundwater contamination due to subsurface disposal of sewage and downstream migration of the infiltrated precipitation and sewage effluent to the water table has been reported in East Portland, Oregon, studied and revealed the impact of diverse anthropogenic activities and the monsoon effect on the bacterial population of river Yamuna in the Delhi stretch. In [39] there was studied soil and groundwater contamination due to sewage sludge land application. The leaching of chemical compounds (HNO_3, $N\text{-}NH_4$, POP) and trace elements from sewage sludge and their migration through the soil profile were investigated. The study showed that nitrogen compounds, such as nitrate (NO_3^-) and ammonium (NH_4^+), as well as some heavy metals (Ni and Cd) originating from the sewage sludge, can reach deeper than 0.8m and cause the contamination of potential shallow aquifers. The assessment of wastewater discharge Impact from a sewage treatment plant on Lagoon Water, Lagos, Nigeria, was studied. The water was found to be polluted from the University treatment plant, thereby endangering the health of residents who use it for recreation and food production purposes [40].

The Physicochemical Study of compositions of landfill leachate and groundwater pollution at a landfill in Yemen revealed that some bore wells were contaminated with landfill leachate, where the physicochemical parameters determined were above the standard acceptable levels [41]. Another research [5] was conducted by leachate characterization and assessment of groundwater pollution near a Municipal Solid Waste landfill site in Yemen and reported moderately high concentrations of chemicals in groundwater [41]. This indicates that groundwater quality is being significantly affected by leachate percolation.

The variation in the properties of leachates from MSW landfill sites was investigated, and the researcher concluded that solid waste management had been a severe problem in urban centers [42]. Waste taken to a dumpsite for disposal often leads to the formation of residual leachate, which causes severe problems by contaminating the nearby land and water resources, especially in developing countries like Nigeria that have not been able to address these problems due to the high costs involved. In [43] it was examined the effects of solid waste on underground water quality in Benin metropolis, Nigeria. Authors recommended recycling solid waste instead of being taken to dump sites.

The periodic monitoring of leachate quality at two large dumpsites in Chennai, India, and four smaller dumpsites from Sri Lanka was reported in [44]. Authors concluded that the computation of leachate pollution potential (LPP) and its variations could be a reliable evaluation method. This was demonstrated as individual leachate quality parameters for seasonal and site-specific variations [45]. A related study highlighted some health implications of solid waste disposal concerning a dumpsite in Lagos, Nigeria [46] in Lagos, Nigeria. Their study described the correlation of the exposure factors (smoke, odor, and dust) with the health hazards of its workers. They found a positive correlation between eye irritation and dust and between difficulty in breathing and smoke; likewise, between typhoid and dysentery and malaria and dysentery.

The percentage of diseases dumpsite workers and scavengers were 86% eye irritation, 66% difficulty in breathing, 48% asthma, 90% cough, 10% pneumonia, 82% malaria, 46% typhoid, 44 % dysentery, 42 % cholera, and 96 % fatigue. A comparative study of the characterization of landfill leachate at selected dumping sites in Kuwait has been reported [44] and the physicochemical analysis result obtained revealed that wells could serve as indicators of the performance of a particular landfill site. A monitoring system such as monitoring wells could be established, and treatment facilities should be built to avoid surface and groundwater contamination. Geophysical studies have been suggested to know more about the groundwater flow path from these landfill sites to the surroundings for effective pollution control.

The Multiple Extraction Procedure (MEP), or rapid extraction procedure toxicity test methods for evaluating solid waste, was reported by USEPA in 1982. At the same time, long-time biological monitoring of environmental quality around a solid waste landfill with lichens has also been used [47]. The lichen monitoring might provide essential information to enhance the implementation of environmental impact assessment supporting industrial regulatory procedures, especially concerning waste management. It has been investigated and reported an evaluation of the physicochemical properties and distribution of Cu, Cd, Cr, Fe, Mn, Pb, Ni, and Zn in soils in Malawi [48]. The Landfills leachate treatment review was reported. The opportunity, which focuses on state of the art in landfill leachate treatment and provides a comparative evaluation of various treatment processes, new treatment alternatives, and conventional technology improvement, are highlighted and examined [49]. Evaluation of the ecotoxicity of solid wastes using rapid leaching tests and bioassays was reported in [49]; the study showed that leachate monitoring might provide essential information to enhance the implementation of environmental impact assessment, supporting industrial regulatory procedures, most especially when waste management is concerned. The impact of municipal landfills on the surface and groundwater quality in Bulawayo, Zimbabwe, was investigated to evaluate the leachate pollution level and its consequent effects on ground and surface water quality [50] and it was reported that the leachate pollutants found in both surface and groundwater included metals [51] and organic compounds that are hazardous to both human and the Environmental Health, and the study also together with landfill water balance was suggested to be helpful in the preliminary design and management of leachate quality from the landfill to reduce pollution emissions.

The toxicity of an industrial landfill's leachate: chemical analyses, risk assessment, and in vitro assays were investigated, and it was reported that the risk assessment of pollutants from landfills is becoming a major environmental issue in Europe, due to a large number of sites and to the importance of groundwater protection. Furthermore, there needs to be more knowledge of the environmental, ecotoxicological, and toxicological characteristics of most contaminants in landfill leachates. Understanding leachate composition and creating an integrated strategy for risk assessment are currently needed to face the landfill issues correctly and to make projections on the long-term impacts of a landfill, with particular attention to the estimation of possible adverse effects on human Health and the ecosystem [52].

Treatment of Leachate and Solid Waste

The composition and treatment of leachates from sanitary landfills were studied in [52]. It was suggested that the kind of treatment used to treat landfill leachate depends fundamentally on the age of the landfill. Biological therapy is adequate when the dump is young, but physical-chemical treatment is needed when the leachate is produced in an old landfill. Urban Waste also impacts the soils in the dumping area or where the contaminated water is used for irrigation. The micro-nutrient accumulation in effluent irrigated soils of the Korangi Industrial Area, Karachi–Sindh (Pakistan). It was concluded that effluent irrigation had made fair micronutrient accumulation in soil, which could be considered adequate for crop growth. However, the long-term application of industrial and domestic wastewater via irrigation water may cause the buildup of these elements in soils to undesirable and phytotoxic levels as the soil samples were found alkaline in reaction, non-saline, moderately to highly calcareous and low to adequate in organic matter content [53]. Characteristics of soils and crop uptake of metals in municipal waste dumpsites in Nigeria were investigated [54]. It was found that crops growing in the dumpsite's bio-accumulate considerably higher metal contents than those in typical agricultural soils. It was also observed that crops differ in their ability to uptake metals. The result showed that grounds in municipal waste dump sites are higher in heavy metals like Zn, Co, Cu, Pb, and Cd, and It was also observed that crops differ in their ability to up-take metals [53].

A combination of mechanical processes and biological processes of MSW management is known as Mechanical Biological Treatment (MBT). MBT was applied as a pre-treatment technology for reducing the mass, volume toxicity, and biological reactivity of the residues before landfill to minimize the environmental impact of landfills, such as greenhouse gases and toxic leachate emission. Recovery of waste components for industrial reuse is an integral part of the development of MBT, especially in the production of Reuse Derived Fuels (RDF). In the last decade, Germany, Austria, and Switzerland accepted MSW's mechanical Biological Treatment (MBT) on a technical and pilot plant scale for some developing countries. In Germany, 1.8 million tons of MSW are treated in 29 Mechanical Biological Treatment plants.

It was reported that the mechanical process is fixed in the MBT, which aims to extract the organic fraction from mixed waste, but the biological stage is optional [55]. Two natural alternatives to process organic-rich materials are aerobic composting and anaerobic fermentation. Anaerobic digestion is flexible for easily degradable kitchen waste and slaughterhouse waste. It has been deeply researched and developed by the U.S. and several European Countries, unlike in developing countries such as Nigeria. In [56] it is emphasized that waste incineration always goes with complex discharge and highly environmental flue gas, e.g., CO_2, NOx, and fly ash, which may lead to environmental and social consequences such as global warming and a toxic regional atmosphere. High cost, as well as inadequate technical support, may influence the further development of MSW incineration. It has been established that the primary function of incineration is mass reduction and waste minimization. It has been observed that most waste in developing countries continues to be disposed of in landfills, which is the least desirable option in the waste management hierarchy. Initially, the conventional landfill methods just disposed of the MSW without recovering materials, producing environmental and social problems, such as landscape. During the last few decades, municipal governments have advanced from non-standard waste disposal to a more controlled environment.

The main focus of this evolution has been to close uncontrolled landfill plants and shift to more environmentally solid land disposal facilities [57]. An in-depth investigation of solid waste management in Nigeria was conducted by quantifying sustainable development to develop an assessment tool. Sustainable development concerning solid waste management was broken down into its aspects and factors that influence those aspects in a hierarchy of three levels according to the procedure of the analytic hierarchy process. In [58] authors stated rules and regulations for investigating and remedying hazardous material release, emphasizing some socio-economic factors affecting solid waste generation and disposal in some of our urban areas [59]. Some of these factors have been explained in terms of spatial variation in solid waste composition and municipal waste management strategy implementation plan.

Solid Waste Management

Spatial variation in solid waste composition and management with Primary and secondary data collection methods were used to meet the objectives examined [60]. The results revealed disparities and

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similarities between the management and composition of waste within the study area. Recommendations were made on improving environmental problems, and waste disposal management [60] evaluated solid waste management practices in Japan and found that 20.3% of total solid waste generated in Japan is landfilled, including ash from incineration. Approximately 75% of the Municipal Solid Waste Japan generates annually is incinerated, generating an estimated 2.5 million Kilowatts of electricity. According to Moqsud and Hayashi, the "waste management hierarchy" (minimization, recovery, transformation, and disposal) has been adopted by Japan in recent times as the menu for developing solid waste management strategies. It was reported that Municipal Solid Waste (MSW) recycling targets had been set nationally in many states. It found that MSW recycling is costly for most municipalities compared to landfill disposal and concluded that the cost to the community and society should more generally determine the MSW recycling policy. In [61] it was reported reviewing and analyzing the solid waste management situation in urban areas of Pakistan. They identified poor solid waste management as one of Pakistan's major causes of environmental degradation. According to [1], Municipal Solid Waste generation showed a different trend and a positive correlation with economic development in terms of kg/capita/day solid waste generation at a world scale. The reported waste generation varied from 200-600 kg/capita/day, with collection efficiency ranging from 50-90 % in India.

Solid waste management in Mysore city was conducted in [63], and the studies on Detailed investigation regarding the methods and practices associated with sources, quantity generated, collection, transportation, storage, treatment, and disposal of municipal solids were conducted. In [62] it was investigated the economic values of private sector characterization of Municipal Solid Waste compost and use for groundwater remediation of petroleum hydrocarbons. Strict implementation of legislation required to minimize the potential human and environmental risks was observed in [64]. The EU15 members DEFRA 2004 generated an average of 580 kg MSW per person per year, with 242 kg of these wastes disposed of by landfill, corresponding to 41.7% [64]. Modern incineration and anaerobic fermentation have attracted the attention of MSW decision-makers because of their efficient reduction of mass value toxicity and biological reactivity at MSW before the final disposal on landfill. Developed and several developing countries have already accepted both, and further improvements are now under research and development to optimize environmental, social, and economic performance. However, some negative impacts are congenital; for example, an incineration process is inefficient for low-caloric materials, while anaerobic fermentation has a low treatment capacity. Thus, optimizing the MSW management efficiency and minimizing the negative impacts depending on the decision maker's choice and the local condition. Three fundamental aspects of sustainable waste management have been identified. These are the Protection of man and the Environment and economic and social compatibility. It was reported that the technical implementation of the performance at these three levels is critical to the willingness of local governments and decision-makers [65].

Waste Management in Nigeria

Nigeria generates an estimated 32 million tonnes of solid waste yearly, one of the highest in Africa; from that figure, plastic constitutes 2.5 million tonnes. Nigeria is among the top 20 nations contributing 83 percent of the total land-based plastic waste in the oceans. An estimate of over 200,000 metric tonnes of plastic waste from land-based sources in Nigeria is Solid waste management remains one of the most daunting environmental sanitation challenges facing Nigeria today, and it has continually remained at its lowest ebb despite considerable investments in the sector.

The management of solid waste needs to be more satisfactory in Nigeria. Many parts of cities and towns do not benefit from organized waste management services; therefore, wastes are unattended to, buried, burnt, or disposed of haphazardly. It is often irregular and sporadic in areas where the authorities do the collection. When left alone for a long time, waste constitutes a severe health hazard, causes offensive odor, pollutes underground water sources, and decreases environmental aesthetics and quality. Plastics, notably single-use plastics pollution, is visible in all cities of Nigeria due to the inefficiency of the waste management system. Marine litter causes environmental, economic, health, and aesthetic problems. Solutions to these endemic problems include reduction, reuse, increased recycling, strict litter abatement laws, and well-run municipal waste management systems.

Conversion of Waste to Resources

Proper characterization of Municipal Solid Waste was reported as fundamental for planning municipal waste management services through the characterization of domestic and market solid wastes at source in Lagos metropolis, Lagos, Nigeria [66]. Mixtures of solid waste and cassava peels have been investigated as potential raw materials for biogas generation [67]. Biogas generation from domestic solid waste in mesophilic anaerobic digestion has been reported using the analytical approach for predicting biogas generation in a Municipal Solid Waste anaerobic digester as innovative [67]. Mixtures of solid waste and cassava peels have been investigated as potential raw materials for Biogas generation in cross-river states [67]. reported that more than 125 digestion plants were operating worldwide, and a further 35 were under construction using Municipal Solid Waste as feedstock, with a combined capacity of more than five million tons annually. Department for Environment Food and Rural Affairs has pointed out that organic and mineral materials are recycled and transferred into high-quality fertilizer through stabilization. Anaerobic fermentation as a renewable energy source was reported by them in 2004, another processing feature. This biological process by anaerobic fermentation produces 100-200 m^3 of biogas with a methane content of about 65%, 34% carbon dioxide, and 1% trace gases. Due to the strict requirement of operating conditions (such as temperature and pH), high-quality equipment is required, which raises the cost. MSW incineration is popular in some developing and developed countries with high waste treatment efficiency. Burning of MSW can generate energy and reduce the amount of waste by up to 75% percentage in volume and 75 percent in weight. Studies have shown that over 70 % of the heat generated from incineration has been used for electricity generation. The potential of organic waste for biogas and biofertilizer production in Nigeria was reported in [68]. Anaerobic composting of municipal wastes and bio drying for mechanical biological treatment of debris have been reported [69].

Extraction Procedure Toxicity Test (EPTT) [70]

It consists of five steps that are summarized in the flow chart Illustrated in Figure 2.

Step 1: Separation Procedures: A waste containing unbanned liquid is filtered, and if the solid phase is less than 0.5 % of the trash, the solid phase is discarded, and the filtrate is analyzed for trace elements, pesticides, and herbicides. If the waste contains more than 0.5% solid, the solid phase is extracted, and the liquid phase is stored for later use.

Step 2: Structural Integrity Procedure Particle Size Reduction: Before extraction, the solid material must pass through a 9.5 mm standard sieve, have a surface area per gram of waste at 3.1 cm^2, or if it consists of a single piece, should be subjected to the structural integrity procedure. If the waste does not meet one of these conditions, it must be ground to pass through a 9.5 mm sieve. This procedure is used to demonstrate the ability of the waste to remain intact after disposal.

Step 3: The solid material from step 2 is extracted for 24 hours in an aqueous medium whose pH is maintained at or below 5.0), with no more than 4.0ml of acid solution with a concentration of 0.5N acetic acid. The pH is maintained either automatically or manually.

Step 4: After extraction, the liquid-solid ratio is adjusted to 20:1, and the mixed solid and extraction liquid is separated by filtration. The solid is discarded, and the liquid is combined with any filtrate obtained in Step 1.

Step 5: Inorganic and organic species are identified and quantified using the appropriate 7000 and 8000 series analysis method. These methods are listed in USEPA Manual Test methods, and the Extraction Procedure Toxicity Test is illustrated in Figure 4 below, reporting evaluation of solid waste analysis using (S.W. – 846 USEPA 1982– 1986) Standard Several procedures to obtain samples from Municipal Solid Waste have been reported in [71]. These methods are as follows:

Assembling a composite sample: In an engineering sense, a composite is any material physically assembled to form one single bulk without physical blending to form a homogeneous material. The resulting material would still have components identifiable as the constituent of the different materials. One of the advantages of composite is that two or more materials can be combined to take advantage of the good characteristics of each of the materials [71].

Random truck sampling: This procedure was applied for collecting the representative municipal solid waste in the waste stream. Based on the American Society for Testing and Materials (ASTM), The first step in the random sampling method was a random pick up of the garbage bag from arrival waste loads (trucks) which is usually an amount of 15 or 20 kg per unit (MSW trucks) [72].

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Cornering and quartering: The cornering and quartering technique was adopted to reduce and select the representative samples [71].

Collecting a grab sample from a randomly selected point using front–end loader: In this part, only MSW trucks were considered to take the pieces. Next, the waste was separated according to the selected classification, such as wood, paper, glass, and green waste, each category was weighed using a weight balance, and the materials were discarded after recording the data. To obtain an accurate measure of waste characterization, the original plan called for sorting 200 kg of MSW, which can be considered as a representative of the total MSW composition in the study region following established standards protocol.

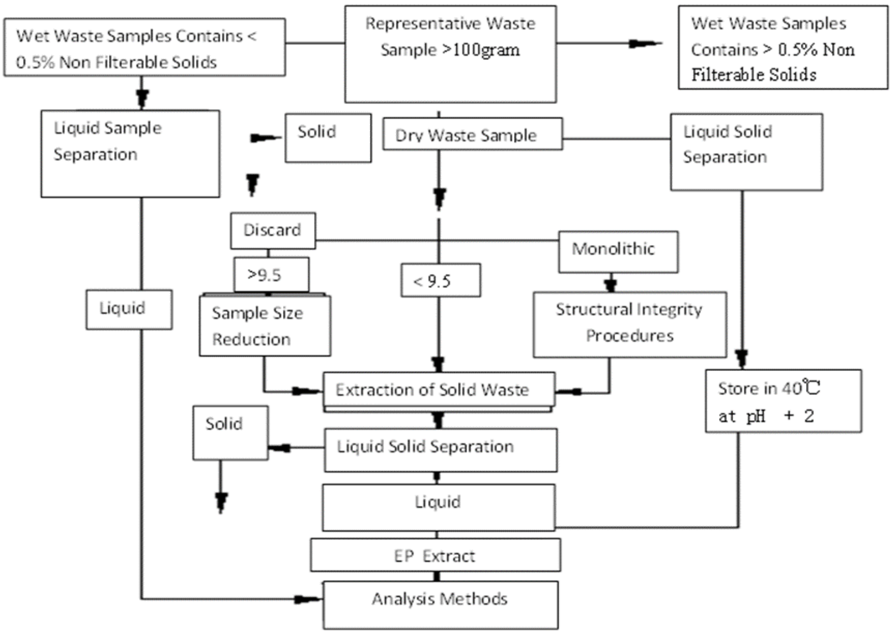

Figure 4 – Extraction Procedure Toxicity Test scheme adapted from technical report of the Department of army waterways experiment station (1992) [70]
Рисунок 4 – Схема испытания токсичности процедуры экстракции (адаптировано из Технического отчета экспериментальной станции водных путей Департамента армии (1992) [70])

Risk Assessment Framework

The risk assessment was defined as a process engendered by the need to make risk management decisions out of uncertainty, simulated scenarios, and statistical analysis in [73] and United States Environmental Protection Agency (USEPA). The risk assessment strategies require understanding the distribution of exposure over time and some understanding of the outcomes from different types of hazards, the formal risk assessment of MSW composting and its product by appropriate mathematical models, and various risk assessment strategies. Environmental pollution has been one of the fields where more efforts have been aimed to control. Due to a lack of ecological consciousness and technical capacity, many industries have released toxic substances into the air, water, and soil for several years. As a first consequence, levels of pollution in areas surrounding industrial sites became much higher than in background (unpolluted) zones. The concern resulting from the potential exposure to contaminants was the starting point for developing methodologies to evaluate the consequences that those might have on the environment and human health. Risk assessment has been one of the most widely used among these methods. Risk assessment is a formalized process for estimating the magnitude, likelihood, and uncertainty of environmentally induced health effects [74, 75]. In 1983, the US National Research Council (NRC), in the so-called RED BOOK, defined a series of principles to be considered for human health risk assessment and described it as a process in which information is analyzed to determine if an environmental hazard might cause harm to exposed persons and ecosystems [75]. In addition to the definition, NRC proposed a human health risk assessment framework involving four basic steps [75]. The six steps of the process are Hazard identification, Receptor Identification, Exposure or Dose-response assessment, Toxicity assessment, Risk characterization, and Risk Management.

Hazard Identification

This step can be defined as the qualitative determination of whether or not a particular hazardous agent is associated with health effects of sufficient importance to warrant further scientific investigations. Different kinds of tools, such as the Quantitative Structure-Activity Relationship (QSAR) for short–term toxicity tests, etc.), are used to estimate the chemical damage of a single substance. When establishing the hazards from industrial sources, the chemicals are also identified according to the measurement of the amount and typology of emissions.

Receptor Identification

This component is focused on examining quantitative relationships between the magnitude of the exposure (or dose) and the probability of occurrence of adverse effects in the population. Usually, dose-response assessment is based on extrapolation from data about laboratory animals that have been given high doses of toxicants.

Exposure Assessment

Exposure assessment may be defined as the quantitative determination of the extent of exposure of the population to the hazardous agent in question. Since they provide fundamental knowledge of the state of pollution in an area, data obtained in environmental monitoring are commonly used as a starting point. Factors that need to be considered include frequency and duration of exposure, uptake or contact rates, and absorption rate [75]. Other factors in assessing exposure include release patterns, cumulative versus non-cumulative exposure, persistence, failure of exposure controls, data quality, and model quality. It was reported that exposure models have evolved from models used primarily in the environmental sciences by incorporating human activity patterns to determine contact with environmental toxicants [76]. They have also been expanded to include pharmacokinetic models whose framework was developed for the pharmaceutical industry to estimate internal exposure and a biologically effective dose. Exposure models have been developed to define population exposures and individual personal exposures [75].

Toxicity Assessment

The toxicity of substances can be observed by (a) studying the accidental exposures to a substance, (b) *in vitro* studies using cells / cell lines (c) *in vivo* exposure on experimental animals. This review mainly focuses on the various experimental animal models and methods used for toxicity testing substances [33]: It was also reported that the pre-clinical toxicity testing helps calculate the “No Observed Adverse Effect Level” needed to initiate the clinical evaluation of investigational products.

Risk Characterization

This fourth component can be defined as the description of the nature and magnitude of the risk, expressed in terms that are understandable to decision-makers and the public. Information acquired in the previous three steps is integrated to communicate the overall meaning of, and confidence in, hazard, exposure, and risk conclusions. Risk is the probability of suffering harm from a threat to a specified population group. Moreover, qualitative and quantitative uncertainty related to risk must also be supplied. It was reported that Risk characterization is the final step of the risk assessment process as laid out in the classic National Research Council report: Risk Assessment in the Federal Government: Managing the Process [75]. This step evaluates the risk from a specific agent (chemical or physical) or group of agents in a particular setting. This evaluation is based on comparing the results of the dose-response assessment for these agents with the outcome of the exposure assessment for these agents in the situation of interest [33]: Risk assessment has been marked as a procedure to link scientific information about potentially hazardous substances to the decision-making process through which human exposures to these substances are regulated. Clear differentiation between the role of scientists (Risk Assessors, Decision Makers, and Risk Managers) in the evaluation process must be carried out [33]: Risk assessment is a part of risk analysis, comprising two steps: risk communication and risk management. Risk management is the subsequent stage where social, cultural, economic, and political issues are considered and integrated into the risk evaluation process. Finally, risk communication is the interactive exchange of information and opinions among individual groups [77].

Risk Management

Risk Management is a distinctly different process from risk assessment. Risk assessment establishes whether a risk is present and, if so, the range or magnitude of that risk. In the risk management process, the risk assessment results are integrated with other considerations, such as economic or legal concerns, to decide the need for and practicability of implementing various risk reduction activities. Risk managers also use risk assessment results to communicate risks to interested parties and the general public. Risk managers may also employ consensus-based approaches, such as the Risk-based decision-making (RBDM) process, in which decisions about contaminated sites according to the risk each site poses to human health and the environment using general protocols underground storage tank (UST). Implementing agencies often use (RBDM) to determine the extent and urgency of convective action needed and the scope and intensity of their oversight of convective movement and activities by UST owners and operators. The estimation of human exposure and significant roles are shown in Figure 5.

Sources and Movement of Metals in the Environment

Trace metals are the most common environmental pollutants, and their occurrence in water and biota indicates the effect of natural or anthropogenic activities. Trace metals in the environment may originate naturally, e.g., the original trace metal contents of rocks and parent materials, processes of soil formation, and produced through human activities. Source identification of trace metals in the environment is essential to environmental chemists. Once metals originate from the source and they release into the environment. Different metals may be produced from various sources, and a similar source can result in more than one trace metal. It has been stated that specific local authorities such as discharge from smelters [78], metal-based industries (e.g., Zn, Cr, and Cd from electroplating), paint and dye formulators, petroleum refineries (AS, Pb), as well as effluents from chemical manufacturing plants, may lead to metal input to the Environment [78].

Anthropogenic activities such as applying chemical or synthetic fertilizers, uncontrolled disposal of plastics and abrasions, etc., have been implicated in the higher levels of Cd and Pb in soils compared to background levels [78]. Human activities such as industrial and energy production, vehicle exhaust, waste disposal, coal, fuel combustion, etc., are the potential sources of trace metals in agricultural soils [79].

Trace metal contamination resulted mainly from the dumping of waste, although motor vehicle emissions and debris likely contributed to soil contamination with Pb and Zn [80]. Industrial activities and atmospheric emissions significantly contribute to Cd content in the environment. The primary sources of Cd in most water bodies include mining through acid mine drainage and battery manufacturing industries. Other probable sources of Cd include leachates from discarded Ni-Cd batteries and Cd-plated items [81]. Among trace metals, Pb is one of the metals of great concern due to its harmful activity. Lead is considered a good indicator of pollution by urban runoff water.

Leaded gasoline has been mainly responsible for the Pb pollution load during the 20th century in urban areas [82]. In Japan, from the 1980s, adding Pb to gasoline was forbidden, but in developing countries, the primary source of Pb is considered fuel even if other origins are considered [82]. The activities of paint and tannery industries and municipal sewage are pervasive processes in the industrial area of Bangladesh, whereas the contribution from pesticides (used for tanning and disinfecting hides) has localized effects. The effluents discharged from the tannery, auxiliary industries, and urban sewage systems are the primary sources of trace metal pollution in the lagoon and canal water systems in the Hazaribagh area of southwestern Dhaka, Bangladesh [82, 83]. Identifying toxic metals is very important for pollution prevention and human health protection. So, locating the sources of trace metals' sources in urban areas' environmental media is essential. This is why more attention is needed to identify the industry or sources for contributing trace metals to the Environment.

Trace metals in soil

Trace metals may increase in the agricultural soil due to the continuous application of chemicals for crop production. From the contaminated soil, trace metals eventually enter to human body through different exposure pathways. This is why metal pollution in agricultural soil has become essential in developed and developing countries [83]. In Bangladesh, trace metal monitoring in the soil is crucial because of the high risks for humans. There is increasing concern that the lack of suitable land for agriculture is prompting urban farmers to use contaminated lands, such as waste disposal sites, burning sites, metal workshop sites, and other commercial areas, which are exacerbated by rapid population growth, urbanization, and industrialization [80]. In Bangladesh, agricultural land is decreasing continuously due to rapid urbanization, industrialization, population growth, etc. In the 1980s, there was a dramatic change in agricultural land use to other purposes due to the following reasons: (1) low profit in farming, (2) the government posed a positive non-intervention attitude towards the agricultural industry without direct subsidization for farmers and (3) more importantly, rapid urbanization and industrial development render many rural areas in the new region, leaving many nonconforming land uses [80].

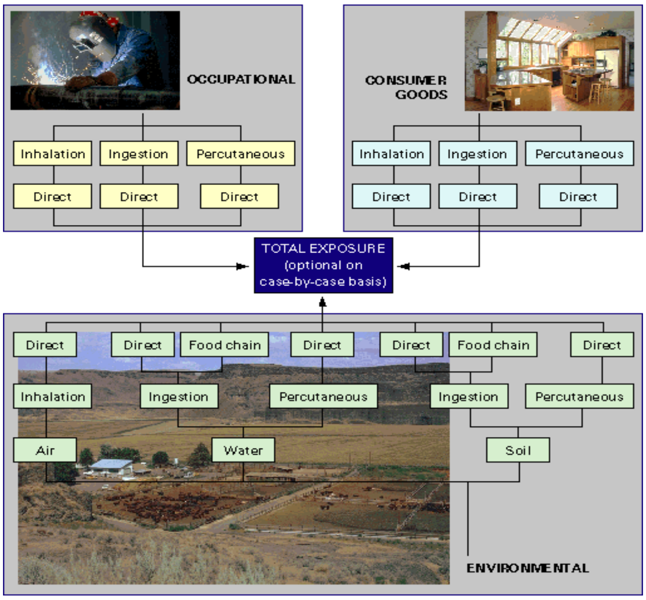

Figure 5 – Estimation of Human Exposure and Major Routes (source: UK Government and Industry Working Group, 1993)
Рисунок 5 – Оценка воздействия на человека и основные маршруты (источник: Рабочая группа правительства и промышленности Великобритании, 1993)

Consequently, many farmers or owners of agricultural land are prone to changing their land for more profitable uses, such as open storage sites, car dismantling workshops, other commercial activities, etc. The nonconforming land uses are potentially dangerous to the surrounding environment and may jeopardize human health [80]. This is especially true for agricultural land, which has been used for storing or recycling 15 electronic wastes containing high levels of trace metals and persistent organic pollutants (POPs) associated with the wastes [84]. Wastewater irrigation is a common practice in most parts of the world due to the shortage of surface water and the presence of nutrients [85]. Therefore, the long-term application of wastewater results in a substantial build-up of trace metals in the receiving soil. Due to the repeated application of wastewater as irrigation, soil's retention capacity decreases, eventually increasing the leaching of trace metals into groundwater and plant uptake [85].

Concentrations of metals in soil, atmospheric deposition, climatic conditions, the nature of the ground, and the degree of maturity of plants are the major factors that affect the uptake and bioaccumulation of metals in crop plants [86]. Crops and vegetables have absorbed trace metals from contaminated soils or atmospheric deposition from polluted air. Therefore, trace metal pollution in agricultural soil severely negatively influences human health [86]. The increasing reliance on agrochemicals for higher yields, especially in developing countries, is another important source of trace metals in soils [87].

Trace metals in sediments

In recent years, the accumulation of trace metals in aquatic systems has been of great concern worldwide. In the water body, toxic metals may accumulate and cause a severe impact on the aquatic organisms without any visible sign. In sediment, different types of toxic chemicals have been taken up by the benthic organisms in bioaccumulation, which may kill benthic microorganisms and reduce the food availability for larger animals like fish. When larger animals feed on these contaminated organisms, the toxins are taken into their bodies, moving up the food chain and increasing the concentrations in the process of Biomagnification.

As a result, fish and shellfish, waterfowl, and freshwater mammals may accumulate hazardous concentrations of toxic chemicals. Contaminated sediments do not always remain at the bottom of a water body and resuspend due to the effect of dredging. As a result, bottom-dwelling organisms will be directly exposed to toxic contaminants. Knowing the metal's chemical forms in sediments determines their transport and mobility in the aquatic media. The metals can also contaminate when changes in pH, redox potential, salinity, particulate matter, or microbial activity occur in the environment. These changes can increase the mobility and transport of the metals in the aquatic media and make them bioavailable [88]. Pollutants have contaminated many sediments in rivers, lakes, and oceans. Industrial and municipal sewage treatment plants, urban runoff, and agricultural activities directly discharge these pollutants. It was reported that sediment containing metals ingested by the suspended filter feeder p. Viridis became bioavailable as a metal source for mussels. Sediment pollution by trace metals has been regarded as a critical problem in the marine environment because of their toxicity and bioaccumulation [89]. Fourteen Suspended sediments adsorb pollutants from water, thus, lowering their concentration in the water column.

Trace metals are inert in the sediment environment and are often considered conservative pollutants [90], although they may be released into the water column in response to certain disturbances, causing a potential threat to ecosystems [90]. Trace metals may be mobilized through mineralization and solubility reactions to obtain metals that are soluble in water, ion Exchange through adsorption and desorption to get exchangeable metals, Aqueous Complexation to bring reducible metals, biological immobilization, and mobilization to obtain Oxidizable metals and plant uptake through translocation [5]. Research has shown that sediments undergo sequential extraction to get speciated metals through adsorption, co-precipitation, and complex formation. The mobility factor is determined to predict the level of bioaccumulation and Biomagnification [91]. Contaminated sediment can decrease aquatic biodiversity and affect the food chain. The organisms of the food chain have been used as biomarkers in assessing the level of contaminants in sediment [91].

Trace metals in surface water

Trace amounts of metals are always present in freshwater from terrigenous sources such as weathering of rocks resulting in geochemical recycling of trace metals in the ecosystems. In the aquatic environment, the organisms may uptake trace metals through different activities such as bioaccumulation, Biomagnification, and bioconcentration and cause a long-term detrimental effect. The existence of trace metals in the aquatic environment has led to serious concern about their influence on plant and animal life [92]. It has been emphasized that the most significant portion of trace elements, such as As, Cr, Ni, Zn, etc., dissolved in natural water systems is usually tied up primarily in two forms- as weathered solids of precipitates and adsorbed on the surfaces of particulate material such as organic debris or clay [92]. The behavior of metals in natural water is a function of the substrate sediment composition, the suspended sediment composition, and the water chemistry. Pollutants accumulated in sediments can return to waters in suspended or dissolved form and pose a potential risk to the aquatic biota [93]. Sediment can accumulate many metals released into the body of natural water.

The favorable Physicochemical conditions of sediment can remobilize and release the metals into the water column. The behavior of metals in natural water is a function of the substrate sediment composition, suspended sediment composition, and water chemistry [94]. Trace metals in surface water were investigated, and heavy metal levels were reported across the Ndawuse River near the dumpsite at Phase 1 District of the Federal Capital Territory (FCT), Abuja, Nigeria (Ibironke Titilayo Enitan *et.al*, 2018).

The results indicated that oxygen demand, turbidity, and heavy metals were above the standard limits set for drinking water. Multivariate analysis using principal component analysis and hierarchical cluster analysis revealed natural and anthropogenic activities linked to the dumpsite in the neighborhood as sources of heavy metal contamination. The estimated non-carcinogenic effects using hazard quotient toxicity potential, cumulative hazard index, and daily human exposure dose of surface water through ingestion pathway were less than unity. The estimated carcinogenic risks (CRing) exceeded the suggested potential risk limits, with lead (Pb) having the highest CRing value for all age groups. The concentration of heavy metals in the investigated river could pose an adverse health risk to several communities that rely on these receiving water bodies for domestic purposes [95].

Basic Soil Chemistry and Potential Risks of Heavy Metals

In order of abundance, the most common heavy metals found at contaminated sites are Pb, Cr, As, Zn, Cd, Cu, and Hg [5]. Those metals are essential since they can decrease crop production due to the risk of bioaccumulation and Biomagnification in the food chain. There is also the risk of superficial and groundwater contamination. Knowledge of these heavy metals' introductory chemistry, Environment, and associated health effects is necessary for understanding their Speciation, bioavailability, and remedial options. The fate and transport of heavy metal in soil depend significantly on the chemical form and Speciation of the metal. Once in the ground, heavy metals are adsorbed by initial fast reactions (minutes, hours), followed by slow adsorb on responses (days, years), and are, therefore, redistributed into different chemical forms with varying bioavailability, mobility, and toxicity.

This distribution is believed to be controlled by reactions of heavy metals in soils, such as:

(i) Mineral precipitation and dissolution
(ii) ion exchange adsorption and desorption
(iii) aqueous complexation
(iv) biological immobilization and mobilization and
(v) plant uptake.

Assessment of Heavy Metals in surface water within the Ilorin Metropolis

The mean concentrations of heavy metals [96] in Oyun River sediment collected at eight locations were determined. This was undertaken to assess the environmental fate of these heavy metals. The Tessier sequential extraction method was used. The proportion of mean metal concentration of the bio-available metals follows the order Cr > Zn > Cu > Fe > Pb. Generally, Mn has the highest level in the the-available fraction, which could be attributed to the geogenic input from the underlying bedrock of the river.

The non-bioavailability proportion of the metals follows the order Pb >Fe > Cu > Zn > Cr. Apart from iron, all other metals were within the USEPA recommended limit for dredged sediment disposal and quality guidelines. Hence Oyun River appeared not to have suffered adverse impacts from human and industrial activities.

Similarly, it was reported [96] that some physical and chemical analysis was carried out on samples collected at various distances from the effluent discharge from a soft drink plant in Ilorin into the Asa River. The pH ranged between 7.2-7.8 with a mean temperature of 25.25 °C. Experimental results obtained on replicate samples showed that the standard deviation was generally below 10%. The total organic matter ranged between 21-22.9% while the nitrate concentration ranged between 5.81-15.41 mg/l; these were high and could lead to eutrophication of the water body into which it empties.

The cation and anion concentrations all fall within safe limits except for zinc and, in some cases, NO_3^- concentrations higher than the standard set by regulatory bodies. A Pearson's correlation study showed correlations between different parameters at 1% and 5% probability levels [96]. Potable water is becoming progressively scarce due to anthropogenic pollution, and it has necessitated monitoring of the water quality of rivers and dams as a subject of ongoing concern and research. Using standard procedures, further studies were conducted to assess the quality of water collected from four different dams (Omu-Aran) in Kwara State, Nigeria. Water and sediment samples were collected from three other spatial locations on the dams. The average values of most physicochemical parameters like pH, temperature, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Total Dissolved Solids (TDS), Total Hardness (TH), Alkalinity, and some nutrients such as chloride (Cl^-), sulphate (SO_4^{2-}), phosphate (PO_4^{3-}), nitrate (NO_3^-) and some heavy metals such as Cu, Zn have values that were within World Health Organization (WHO) guidelines for drinking water for each of the dams. At the same time, Cd and Fe concentrations were observed to be much higher than WHO guidelines for drinking water. This could be a result of anthropogenic input. The dams' sediments analyzed for heavy metals showed that Cr, Zn, and Cd were high in the dams, which can be easily washed into the water body through leaching, thereby causing a detrimental effect on the consumers [23]. Further studies determined

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the mean concentrations of heavy metals [96]; in Oyun River sediment collected at eight locations. This was undertaken to assess the environmental fate of these heavy metals. The Tessier sequential extraction method was used. The proportion of mean metal concentration of the bio-available metals follows the order Cr > Zn > Cu > Fe > Pb. Generally, Mn has the highest level in the bio-available fraction, which could be attributed to the geogenic input from the underlying bedrock of the river. The non-bioavailability proportion of the metals follows the order Pb > Fe > Cu > Zn > Cr. Apart from iron, all other metals were within the USEPA recommended limit for dredged sediment disposal and quality guidelines. Hence Oyun River appeared not to have suffered adverse impacts from human and industrial activities [96].

Exposure to metals due to food consumption

Trace metals may enter the human body by inhaling dust, consuming water, or ingesting soil or crops grown on contaminated land [19]. Foods with toxic metals could present a toxic hazard for the consumer dependent on the metal concentration in the food and the amount consumed. For most people, the main route of exposure to trace metals is through diet, accounting for > 90% compared to other ways of exposure, such as inhalation and dermal contact. It must be noted that although metals can change their chemical form, they cannot be degraded or destroyed.

Therefore, the risk assessment of these elements via dietary intake is essential [19]. The accumulation of metals in the edible parts of vegetables could directly impact nearby inhabitants' health because vegetables produced from fields are mostly consumed locally. Therefore, the concentration of metals in vegetables could be a health concern for the residents. Trace metals are known to cause deleterious effects on 20 human health [97], which can accumulate in human bodies producing toxic, neurotoxic, carcinogenic, mutagenic, or teratogenic illnesses [98].

It has been noted that an exposure pathway is not simply an environmental medium (e.g., air, soil, water) or a route of exposure. Instead, an exposure pathway includes all the elements that link a contaminant source to a receptor population. However, intensity, frequency, and duration of contact with the polluted media are essential for estimating metal exposure. For most people, dietary intake is the main route of exposure to toxic elements [99]. Dietary intake of trace metals also risks animal and human health. It has been reported that exposure to two or more pollutants may result in additive and interactive effects. Excess amounts of trace metals from anthropogenic sources may pollute the environment and ultimately risk human health [100]. A primary concern in urban agriculture is the transfer of trace metals from the food chain to humans. Trace metals uptake by plants can cause serious health problems for consumers. Human health exposure to metals occurs due to consuming contaminated foods and inhaling contaminated dust particles [97].

The daily intake of trace metals from food consumption for adult inhabitants has been estimated. The estimated daily intakes (EDIs) of trace metals have been compared with the provisional tolerable daily intakes (PTDIs) suggested by the Joint FAO/WHO Expert Committee on Food Additives (JECFA) or an oral reference dose (RfD) to assess the potential health risks. The 'tolerable intake' is widely used to describe 'safe' intake levels. It can be expressed on either a daily basis (tolerable daily intake) or a weekly basis (modest weekly information).

The tolerable intake of trace metals, as PTWI [98] is set by the Food and Agriculture Organization/World Health Organization (FAO/WHO) Joint Expert Committee on Food Additives (JECFA). PTWI is the maximum amount of a contaminant to which a person can be exposed per week over a lifetime without unacceptable risk. Oral reference doses (RfD) for Ni, Cu, Pb, Cr, As, and Cd are 0.02, 0.04, 0.004, 1.5, 0.0003, and 0.001 (mg/kg/day), respectively. The RfD estimates daily exposure to the human population, likely without an appreciable risk of deleterious effects during a lifetime. To assess the health risk of trace metals in foods, it is essential to estimate the level of exposure by quantifying the routes of exposure of 21 trace metals to the target organisms.

The food chain through food consumption is one of the humans' essential exposure pathways to trace metals [97]. Environmental exposure to trace metals is a well-known risk factor for cancer. Among different pathways, the food chain is one of the most important routes for human exposure. In the study area, food crops are contaminated with trace metals, and consumption of these contaminated food crops can cause risks to a human. The association of metal concentrations in foods to that in soils and waters may indicate the extent of metal contamination and reveal the potential health risk to consumers. The health risks associated with trace metals ingested through food consumption are often assessed using hazard quotients (HQs). The HQ can be defined as the ratio of the determined dose of a pollutant to the reference dose (RfD) (mg/kg/day) and the ingestion toxicity reference dose (Mg/Kg/day). The values for the selected heavy metals were obtained from [101]: C is the concentration in foods, BW is the average body weight, and 10^{-3} is the unit conversion factor Hazard quotients (HQs) are the ratio between the exposure and the reference doses (RfD), which are used to express the risk of non-carcinogenic risks. If HQ is less than 1, there is no apparent risk from the substance, while if HQ is higher than 1, the toxicant may produce an adverse effect. Combined HQ values are sometimes described as Hazard Indices.

However, their application is controversial as their value and significance depend on the number of contaminants involved and the extent to which toxic responses are truly additive. Excess consumption of non-essential trace elements such as As and Cd can result in skin lesions, bone and cardiovascular diseases, renal dysfunction, and cancers, even at relatively low levels. The consumption of trace metal contaminated food can seriously deplete some essential nutrients in the body that are further responsible for decreasing immunological defenses, intrauterine growth retardation, impaired psycho-social faculties, disabilities associated with malnutrition, and high prevalence of upper gastrointestinal cancer rates. It has been found that the high concentrations of metals: in vegetables in the Van region of Eastern Turkey are related to the high prevalence of upper gastrointestinal (GI) cancer rates [101].

To assess the health risks, it is necessary to identify the potential of a source to introduce risk agents into the environment, estimate the number of risk agents that come into contact with the human-environment boundaries, and quantify the health consequence of the exposure.

Risk Assessment of vegetable uptake grown near dumpsites Ghana and Nigeria

It was reported that the concentration levels of heavy metals in vegetables grown on urban waste dumpsites. The research was carried out on three waste dumpsites in Kumasi where vegetable cultivation (cabbage, lettuce, and spring onions) practices. Experimental plots of cabbage, lettuce, and spring onions were set up at these sites and harvested at the complete maturity stage. Crops and soil samples were collected and analyzed for the presence of four heavy metals: cadmium, lead, copper, and zinc. Cadmium levels recorded were in the range of 0.68-1.78 mg/kg as against the WHO/FAO recommended level of 0.20 mg/kg; lead had values in the range of 2.42-13.50 mg/ kg as against the WHO/FAO recommended guideline value of 0.30 mg/ kg; copper levels were in the range of 16.17-90.33 mg/kg as against the WHO/FAO recommended guideline value of 73.3 mg/kg and zinc had values between 26.77-106.83 mg/kg compared to the WHO/FAO recommended guideline value of 99.40 mg/kg. The levels of the two most toxic heavy metals, cadmium, and lead, were far higher in the vegetables than the WHO/FAO recommended values. The transfer factors of these two metals were also the most elevated, suggesting that consuming vegetables grown in such sites could be dangerous to human health. Similarly, another experimental study was conducted on dumpsite soil to assess the potential of *Ricinus communis* to accumulate heavy metals from the ground using bioconcentration (BCF) and translocation factors (TF). Heavy metals concentration (mg/kg) in dumpsite and control soil before planting were Mn (50.68-220.08); Zn (29.01-135.56) (Cu (8.92-86.88), Pb (5.88-48.86), Ni (3.01-7.99) and Co (1.78-6.88) while the concentration in soils after planting were Mn (29.89-135.21); Zn (15.11-88.21); Cu (3.89-50.22), Pb (3.68-31.56), Ni (1.22-3.56) and Co (0.67-2.68) in Mg/kg. *Ricinus communis* showed BCF greater than 1 for Ni and Co and less than 1 for Mn, Cu, Zn, and Pb, while TF is greater than 1 for all the determined heavy metals. The dumpsite soils have a higher heavy metal concentration than the control soil. The levels of heavy metals concentration in soils and plants are in the order of Mn> Zn> Cu> Pb> Ni. Significant reduction ($P<0.05$) was observed in the heavy metal concentrations in the soils before and after planting, indicating their plant accumulation. Results of this study indicate the accumulation of heavy metals in Ricinus *communis* plants and its potential for effective removal of Cu, Zn, Pb, Ni, Co, and Mn from the dumpsite soils [101].

Persistent Organic Pollutants (POPs)

In the 2001 Stockholm Convention on Persistent Organic Pollutants (POPs), a global treaty for the regulation of these pollutants was signed by member countries. POPs are hazardous compounds characterized by a high persistence in the environment, bioaccumulation in the body burden, toxicity, and capacity to travel long distances from where they are released (long-range transport). The Stockholm

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Treaty aims to promote the reduction and prohibition of a list of 12 POPs, commonly identified as the "dirty dozen". PCDD/Fs, Phthalate Esters, and PCBs were included. New compounds, such as polychlorinated naphthylenes (PCNs), were proposed for further revisions. Most POPs are Endocrine Disrupting Chemicals, while other chemicals that are included in the list of EDCs include:

Polychlorinated Biphenyls in the Aquatic Environment

Phthalates in the Aquatic Environment

Phthalic acid esters (PAEs) or phthalates are ubiquitous in the environment due to their widespread application. Their presence has attracted considerable attention due to their potential impacts on ecosystem functioning and public health, so their quantification has become necessary. A detailed account of the environmental fate of phthalate esters was recently reviewed in [102]. In brief, biodegradation is considered the primary loss mechanism of phthalate loss in surface water and sediments. Primary degradation half-lives in surface and marine waters range from 1000, indicating a high capacity for the species to accumulate or concentrate the pollutant. Fishes have been reported to focus PAEs at a significant level with total BCF of 57, 117, 45-663, 11-900, 207-, and 2668-2125 mL/g/wet, respectively, for DMP, DEP, BBP, DEHP, DOP, and DDP. Few phthalates like DEHP can reduce sperm production and velocity in goldfish following monthly exposure. Significant decreases in 11-ketotestosterone and luteinizing hormone levels were observed following 15-30 d of exposure. An earlier study also suggests that DEHP-reduced sperm quality is due to DEHP's effects on testicular and pituitary hormonal functions. These compounds are classified as priority pollutants and endocrine-disrupting compounds by the US Environmental Protection Agency (EPA) and other governmental agencies. High priority has been posed on understanding their fate in aquatic ecosystems such as coastal areas. Various extraction procedures, gas/liquid chromatography, and mass spectrometry detection techniques are suitable for reliable 56 detections of such compounds. However, PAEs are ubiquitous in the laboratory environment, including ambient air, reagents, sampling equipment, and various analytical devices, which induces complex analysis of actual samples with a low PAE background. Therefore, accurate PAE analysis in environmental matrices is a challenging task. A comprehensive review on sampling, sample extraction/pretreatment, and detection for quantifying PAEs in different environmental matrices (air, water, sludge, sediment, and soil) has been reviewed in [102]. An overview of mass spectrometric methods used to determine endocrine-disrupting compounds (EDCs), including phthalates in environmental samples, was reviewed in [103]. Various aspects of current LC-MS, FID with dichlorination, and GC–MS methodology, including sample preparation, are also discussed in the literature [103]. It was also investigated, and the Concentrations of 8 PEs were determined in sediment samples collected from upstream and downstream of Covenant University Oxidation Pond (COP) between March and June 2013. Samples were extracted using the mechanical shaking method with double-distilled dichloromethane.

The prepared extracts were cleaned using activated silica gel-packed column chromatography and analyzed with high capillary gas chromatography equipped with a flame ionization detector (GC-FID). The mean concentrations over the study period for the PEs, monoethyl phthalate (MMP), dimethyl phthalate (DMP), diallyl phthalate (DAP), diethyl phthalate (DEP), diisobutyl- (DIBP), di-n-butyl phthalate (DBP), butyl benzyl phthalate (BBP), and di-(2-ethyl) hexyl phthalate (DEHP) are 23.1 mg kg-1, 273 mg / kg, 28.9 mg/ kg, 150 mg/kg, 26.5 mg/kg, 264.5 mg/kg, 41.7 mg /kg, and 20.9 mg/ kg for upstream samples. Mean concentrations for the downstream samples are 24.2 mg/ kg, 280 mg /kg, 33.4 mg /kg, 176 mg/kg, 26.9 mg /kg, 264 mg/ kg, 41.8 mg/kg, and 18.2 mg/kg, respectively. Generally, the PEs' concentration in downstream samples was significantly higher (p>0.05) than upstream, except for DIBP, BBP, and DBP, whose DEHP concentrations were significantly higher (p>0.05) upstream than downstream.

The distribution pattern of PEs in the sediment is in the order DMP> DBP> DEP> BBP> DAP> DiBP> MMP> DEHP. The occurrence of PEs in the samples analyzed further supports their ubiquity in the Environment [104]. Similarly, Phthalate esters were investigated in rivers and dams of the Venda region, South Africa. Liquid-liquid extraction, column chromatographic clean-up, and capillary gas chromatography were used for the quantitative analyses. Levels of phthalates in water samples from the rivers and dams ranged from 0.16 mg/l to 10.17 mg/l and varied between 0.02 mg/kg and 0.89 mg/kg in sediments. Generally, the highest concentrations of phthalates were found as DBP and DEHP, consistent with their everyday use in plastic materials and other industrial chemicals. The phthalate levels found in the water samples were much higher than the criterion of 3 µg/l phthalates recommended by the United States Environmental Protection Agency (USEPA) for the protection of fish and other aquatic life and higher than the Suggested No-Adverse Effect Levels (SNAEL) of 7.5 to 38.5 µg/l for drinking water.

The health risk-assessment studies on the phthalates found in the water systems suggested potential carcinogenic and other toxic effects they may pose to communities downstream, which might be exposed either through drinking untreated water from the rivers, through dermal absorption or by using the freshwater sources to water their vegetable gardens. DEHP posed the highest risk potential of all the phthalates, and the water use or exposure pathway that appeared to pose the highest potential health risk for carcinogenic and toxic effects was vegetable watering

The results for phthalates in the water samples cause environmental concern as people's health downstream is at stake if rural populations use this water. Further studies are ongoing on identifying and quantifying Phthalate esters in Asa River, Ilorin Kwara state Nigeria [104]. The distribution of phthalate esters (PAEs) in the water and sediments in the Ori stream, Iwo, Nigeria, was also reported. Using hexane, the liquid-liquid extraction method was then cleaned up in an alumina column. Chromatographic separation and quantification were done using Zorbax Eclipse AAA C18 analytical column. The concentrations of DMP, DBP, DEP, and DPP in water (µg/L) ranged from 1.29±1.3 in DBP to 938±780 in DMP, while in sediment (µg/kg) ranged from 12.7±15 in DEP to 152±140 µg/kg in DBP.

These concentrations were above the USEPA limits of 3 µg/L as recommended for phthalates in water [104]. Consequent upon their widespread use as plasticizers and high volume of production, phthalates constantly diffuse and release into the various environmental components (air, water, soil) has become noticeable. In the report [105], phthalate esters levels and presence were analyzed in newly purchased plastic toys and polyethylene terephthalate (PET) bottled drinking water samples. The samples' phthalate esters (PEs) were liquid-liquid extracted, pre-concentrated, and analyzed for detection and quantification using HPLC. From the data obtained, the DMP, DEP, and DBP levels in the PET drinking water samples did not exceed the stipulated threshold levels, while the level of DEHP was dominant and exceeded the safe limit. PEs were detected in all the ten plastic toy samples analyzed, including mountable ones (teethers) used by children, imported into the country from China, Taiwan, etc. The values obtained revealed that the concentrations of PEs in the plastic toys ranged between 0.96-532 (µg/l). Also, the percentage (w/w) values obtained were significantly higher and ranged between 1.96-79.88% than the European Union (EU) recommended limits for all phthalate esters in toys; this portends risk to children who innocently put these toys in their mouth or chew them, as the toxic chemicals could leach into their bloodstream. These results can be used as reference levels for future monitoring programs for pollution studies [105].

Principle of Instrumentation and Analytical Techniques Used in the Research

Atomic Absorption Spectrophotometer (AAS)

Atomic absorption spectroscopy (AAS) and atomic emission spectroscopy (AES) are electroanalytical procedures for the quantitative determination of chemical elements using the absorption of optical radiation (light) by free atoms in the gaseous state. The standard AAS instrument consists of four components: the sample introduction area, the light (radiation) source, the monochromator or polychromator, and the detector, the principle of absorption spectroscopy refers to the quantity of light absorbed by a solution or free atoms at a specific wavelength, using an atomic absorption spectrometer, you can determine the concentration of many different elements in a sample within a short period. The spectrometer identifies the amount of metal in liquids and measures the metal quality in a sample based on Lamber's law. The AAS can be performed with both flame and electrothermal atomization, and the samples are measured in the form of solutions in water or organic phase (methanol, ethanol). The main advantages of AAS are that it is relatively inexpensive and easy to use while still offering high throughput and quantitative analysis of the metal content of solids or liquids. This makes it suitable for use in a wide range of applications but with a lower detection limit of Part Per

Million (ppm), which is a disadvantage to other high-precision analytical types of equipment for the determination of heavy metals in inorganic or organic matrices [106].

Gas Chromatography (GC) with Flame-Ionization Detection (FID)

Gas Chromatography is a popular high-precision analytical equipment for environmental monitoring and industrial applications because it is reliable and can run continuously. It is typically used in applications where small, volatile molecules are detected with non-aqueous solutions. Liquid chromatography is more famous for measurements in aqueous samples and can be used to study larger molecules because the molecules do not need to vaporize. GC is favored for nonpolar molecules, while LC is more common for separating polar analytes. Since the carrier gas is not solvent, the column's temperature range is critical in optimizing operations. The mobile phase for gas chromatography is a carrier gas, typically helium because it is chemically inert and has low molecular weight. Pressure is applied, and the mobile phase moves the analyte through the column. The separation is accomplished using a column coated with a stationary phase. Open tubular capillary columns are the most popular, with the stationary phase painted on the capillary walls. Stationary phases are often derivatives of polydimethylsiloxane, with 5-10% of the groups functionalized to tune the separation. Typical functional groups are phenyl, cyanopropyl, or trifluoropropyl groups. Capillary columns are usually 5-50 m long. Narrower columns have higher resolution but require higher pressures. Packed columns or stainless steel can also be used where the stationary phase is coated onto beads packed in the column. Packed columns are shorter, 1-5 m.

Open tubular capillaries are generally preferred. Alternatively, the stationary phase can be coated with one of many high boiling liquids (e.g., SE 30), Carbowax – Gas Liquid Chromatography; separation depends on the different fractions of time they are dissolved in the stationary liquid phases best for the detection of volatile compounds Non-volatile compounds need to be derivatized to make them volatile before determination by GC (e.g., by esterification or by use of diazomethane, CH_2N_2) Compounds eluted are detected by use of detectors because they allow higher efficiencies, faster analyses, and higher capacities. Flame-ionization detection (FID) is an excellent general detector for organic compounds in GC that detects the amount of carbon in a sample. After the dichlorination of oregano, chlorine samples and the column are burned in a hot, hydrogen-air flame. Carbon ions are produced by combustion. While the overall efficiency of the process is low (only 1 in 105 carbon ions have an ion in the flame), the total amount of ions is directly proportional to the amount of carbon in the sample. Electrodes are used to measure the current from the ions. FID is a destructive detector, as the entire piece is pyrolyzed. FID is unaffected by non-combustible gases and water., sensitive to hydrocarbons, phthalates, and other compounds liable up to a low ug/l range. The schematic diagram of GC – FID is shown in Figure 6.

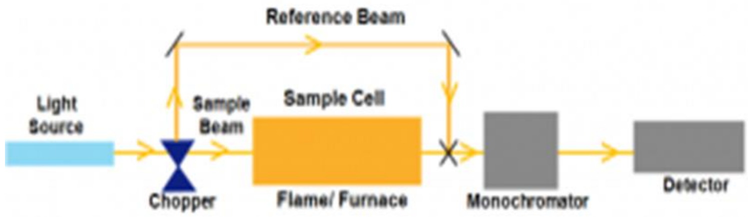

Figure 6 – Gas Chromatography (GC) with Flame-Ionization Detection (FID)
Рисунок 6 – Газовая хроматография (ГХ) с пламенно-ионизационным детектированием (ПИД)

Summary of the Literature Search and the Research Gap

In Ilorin, the capital of Kwara state, little or no studies were conducted on organic and inorganic pollutants emanating from dumpsites to the surface or groundwater, soil, and sediment, which the plant consumes through translocation (Plant Uptake) and animals by Inhalation injection, or by thermal adsorption. Hence urgent step is, therefore, necessary to mitigate soil and water pollution as well as find an everlasting solution to the environmental pollution as a result of leachate leaching from nearby dumpsites into ground and surface water, and it is upon this background that these studies were conducted to assess and quantify the level of organic and inorganic pollutants in water, soil, and sediment and carried out the risk assessment, provide possible and best remediation techniques [108].

Conflicts of Interest
The authors declare no conflict of interest.

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ЭКОЛОГИЧЕСКАЯ ОЦЕНКА СОДЕРЖАНИЯ ТЯЖЕЛЫХ МЕТАЛЛОВ, ФТАЛАТНЫХ ЭФИРОВ И ПОЛИХЛОРИРОВАННЫХ БИФЕНИЛОВ НА ПОЛИГОНАХ ОТХОДОВ

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Abstract.
По данным Министерства охраны окружающей среды, продовольствия и сельского хозяйства Нигерии твердые бытовые отходы являются основным источником стойких органических загрязнителей и тяжелых металлов, представляя собой серьезную экологическую, социальную и экономическую проблему во всем мире. Отходы можно определить как любой материал, не имеющий прямой ценности для производителя и поэтому подлежащий утилизации, или любой материал, который выбрасывается как ненужный. Аналогичным образом можно рассматривать все, что люди выбрасывают на помойку или утилизируют любым способом. Отходы состоят из органических веществ, таких как бумага, тряпки, выброшенные упаковки, продукты питания, твердые отходы, садовый мусор; неорганических материалов – изношенные приборы, неработающие автомобили, мебель, промышленные отходы, строительный мусор, а также смешанные отходы, например, электронные и медицинские отходы. Эти отходы поступают из различных источников, включая муниципальные, промышленные, сельскохозяйственные, очистные сооружения и институциональные учреждения – школы, больницы, рынки и жилые комплексы.

Количество твердых отходов значительно увеличилось, а их характер изменился в связи с ускоренной урбанизацией, индустриализацией и ростом населения в большинстве городов развивающихся стран. Сбор и утилизация твердых бытовых отходов представляют особую проблему в городах развивающихся стран, в отличие от развитых стран, где существуют более совершенные системы управления. Образование твердых отходов связано с экономическим ростом, но в большей степени коррелирует с индустриализацией и численностью населения. В данной статье выполнен подробный обзор научно-технической периодической литературы, посвященной загрязнению городских свалок.

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