Deanship of Graduate Studies

Al-Quds University

Sewage Sludge Conversion to Agricultural Compost
Case Study: Jericho WWTP

Maram Jadallah Mohammad Nassar

M.Sc. Thesis

Jerusalem-Palestine

2024/1446

Sewage Sludge Conversion to Agricultural Compost

Case Study: Jericho WWTP

Prepared By:

Maram Jadallah Mohammad Nassar

B.Sc: Material Engineering - Al-Quds University-Palestine

Supervisor: Prof. Jawad Hasan Shoqeir

A Thesis Submitted in Partial Fulfillment of Requirements for the Degree of Master of Water Science Innovation, Department of Applied Earth & Environmental Studies, Faculty of Graduated Studies - Al-Quds University.

2024-1446

Al-Quds University
Deanship of Graduate Studies
Water Science Innovation

Thesis Approval

Sewage sludge conversion to agricultural compost Case Study: Jericho WWTP.

Prepared by: Maram Jadallah Mohammad Nassar

Registration NO: 22011948

Supervisor: Prof. Jawad Hasan Shoqeir

Master thesis submitted and accepted date: 27 /8/2024

The names and signatures of examining committee members are as follows:

1. Head of committee: Prof. Jawad Hasan Shoqeir Signature: ....
2. Internal Examiner: Dr. Omar Ayyad Signature: ....
3. External Examiner: Dr. Subhi Samhan Signature: Subhi Samhan

Jerusalem-Palestine

2024/1446

Dedication

First, thanks God and peace be upon His messenger Mohamad, for blessing and giving me.

To my beloved parents, brothers, and sisters, thank you for all the love, guidance, support, and encouragement you have given. Your prayers and continuous support mean everything to me.

Thanks to my husband and my daughters for being such important parts of my life.

In conclusion, I am grateful for the support and love of my extended family and true friends. They believed in me during a time when I was on the verge of losing my self-confidence. Without their unwavering assistance over the past few years, it would not have been possible for me to complete my studies.

I dedicate this research study.

Declaration

I, the undersigned, declare that I submitted the thesis entitled:

Sewage sludge conversion to agricultural compost

Case Study: Jericho WWTP.

I declare that the work provided in this thesis, unless otherwise referenced, is the researcher's work, and has not been submitted elsewhere for any other degree or qualification.

Maram Jadallah Mohammad Nassar

Signature: ....

Date: 27/ 8 /2024

Acknowledgment

First and foremost, I want to express my gratitude to God for all the blessings I have received, whether I am aware of them or not, and for guiding me through all the challenges I have encountered in my life, including completing this degree. I shall continue to put my complete trust in Him. With the support and patience of many individuals, this goal has become a reality. My sincere gratitude is extended to Prof. Jawad Hasan for his invaluable advice, continuous support, and patience throughout my master's program, and thank you for being such an important part of my story and helping me grow. His immense knowledge and wealth of experience have motivated me during my entire academic study period. To all my teachers, who taught me, To my colleagues, and thanks are extended to especially Derar and Sameh.

I would like to express my gratitude to the Faculty of Graduate Studies in the Environmental Science Department at Al-Quds University for providing me with the necessary tools to pursue advanced studies in the Department of Water Science Innovation.

I also like to express my sincere thanks to Dr. Sobhi Samhan, the key person in the Palestinian Water Authority, for his assistance and guidance during my research. And MEDRC organization for her financial support for my research.

I also like to express my sincere thanks to Jericho Municipality, for their assistance during my research.

Abstract:

There is a rapid increase in sewage sludge products, where approximately 6468 tons of sludge is produced annually in Palestine. Sludge can cause environmental and health problems if not managed properly, including surface and groundwater pollution, emission of foul odors, transmission of diseases and harmful microbes, impacts on ecological systems, and economic repercussions. as well as the absence of a long-term solution to the serious situation in Palestine. The primary objectives of this study were to assess the composting potential of sewage sludge with various bulking agents and to identify the most effective combination.

Four trials of composting (Exp. 1, Exp. 2, Exp. 3, and Exp. 4) were carried out using sewage sludge, soil, Azolla, and palm leaves mixtures in all experiments. Palm leaves were proposed as a solution to another environmental issue because of the ecological harm they caused to Jericho City and the difficulty in getting rid of them. Additionally, Azolla was added because it contains important nutritional elements that help plants grow and flourish, such as proteins, vitamins, and minerals. In Exp. 4, Opuntia was added to the previous mixture instead of Azolla. Varying proportions of sewage sludge, Palm leaf, Opuntia (dry basis to moisture content 14–5%), and Azolla (wet basis to moisture content 88–8%) were used. The nutritional significance of Opuntia that lies in its ability to improve soil quality and support plant growth, which includes benefits like improving soil structure, providing nutrients, improving aeration, protecting against oxidation, and increasing water use efficiency in turned-windrows and open-air conditions.

This research utilizes a rigorous analytical methodology that systematically examines all necessary elements. The composting process was monitored for temperature and moisture content (MC), while organic matter (OM), pH, electrical conductivity (EC), and C/N ratio were evaluated post-composting. The assessment of operational parameters revealed that the highest levels of organic matter degradation (32.5%), pH (7.18), C/N ratio (1/25.8), temperature (44°C), and composting duration (3 months) was achieved with the Exp. 2 mixture. Additionally, the Exp. 1 and Exp. 4 mixtures also demonstrated success in terms of these operational parameters following Palestinian specifications (OM>35%, pH 5-85, C/N ratio (1/25).

Using sewage sludge in composting procedures is important for agricultural waste management, cost-effectiveness, and process efficiency. This is especially true for palm leaves too, which were previously underutilized composting but showed encouraging results in this study. We found that the mixture Exp. 2 was the most successful in increasing growth, germination, stem length, and root density. The fourth Experiment was the next most effective. Then the first experiment. These results reflect the impact of different fertilizer components on plant growth and development. It is important to note that results in this study are solely derived from practical experiments, thereby enhancing the credibility of the findings.

Contents

List of Abbreviations

C:N : A Carbon-to-Nitrogen Ratio

DS: Dried Sludge

EC: Electrical Conductivity

GR: Germination Rate

HS : Humic Substances

MC: Moisture Content

MLSS : Mixed Liquor Suspended Solids

NPK: Nitrogen, Phosphorous, Potassium

OM: Organic Matter.

pH: Acidity or Basicity

PSI: Palestine Standards Institution

SAR: Sodium Adsorption Ratio

SOM: Soil Organic Matter

Temp: Temperature

TKN: Total Kjeldahl Nitrogen

TOC: Total Organic Carbon.

WWTP: WasteWater Treatment Plant

List of Tables

List of Figures

Chapter One:

Introduction

The content of this chapter covers the problem statement, the studies justification, and a summary of the current state of the environment. Furthermore, mentioned were the studies aims and research questions.

1.1 Current Conditions and Justification of the Study:

The global production of Sewage Sludge is estimated to be 45 million metric tons of dry matter, and it continues to escalate annually due to urbanization and population growth (Gray, 2010). Consequently, the environmental ramifications of sewage sludge, whether through landfill disposal, agricultural utilization, or other applications, are of paramount importance. Recently, there has been a focus on studying the contribution of various processes of sewage sludge treatment for agricultural use (S. Zhang, 2017).

Energy consumption during sewage sludge treatment predominantly contributes to global warming (over 50%) (Muter, 2022), while the transportation of sewage sludge to agricultural areas impacts terrestrial and freshwater ecotoxicity, as well as ozone formation in terrestrial ecosystems. Disposing of sludge in agricultural areas primarily contributes to human toxicity, terrestrial acidification, and freshwater ecotoxicity (K. G. C. d. Amaral, 2021). The primary impacts of sewage sludge on soil are associated with the presence of Zinc (Zn), which affects freshwater ecotoxicity and human toxicity(Amaral et al., 2021). These findings underscore the necessity for comprehensive evaluation and management strategies regarding the utilization and disposal of sewage sludge to mitigate its environmental impacts (Muter, 2022).

The enormous volumes of solid sludge waste in the sewage sludge treatment plants in the Palestinian territories are estimated at 6468 tons according to the sludge strategy of the Palestinian Water Authority (Palestinian Water Authority, 2024). Along with the limited space accessible to hold the vast volumes of sludge formed by the stations, which are harming the environment, have contributed to the sludge reuse. Furthermore, promoted the use of sewage sludge to help foster the growth of a recycling-focused culture. However, direct utilization of waste from municipal streams may lead to both short- and long-term environmental problems involving pathogenic microorganisms, heavy metals, offensive odors, or organic compounds that are phytotoxic (B. Díez, 2001).

Composting the organic content obtained from such wastes might mitigate the risks (C. Tognetti, 2007). It is important to remember that organic material can be used as fertilizer for agricultural land and to remediate ruined soil.

Thus, it is essential to carry out this research to safely dispose of a greater quantity of sludge. In this research, samples were taken at predetermined intervals and analyzed for the assessment of physical, chemical, and biological parameters to evaluate the effectiveness of solid output for a pilot-scale wastewater treatment facility (Jericho plant), which is comprised of extended Aeration System /gravel bed filter, toward domestic wastewater treatment over the period (2022-2023). The purpose of this treatment facility is to handle the wastewater resulting from the city of Jericho.

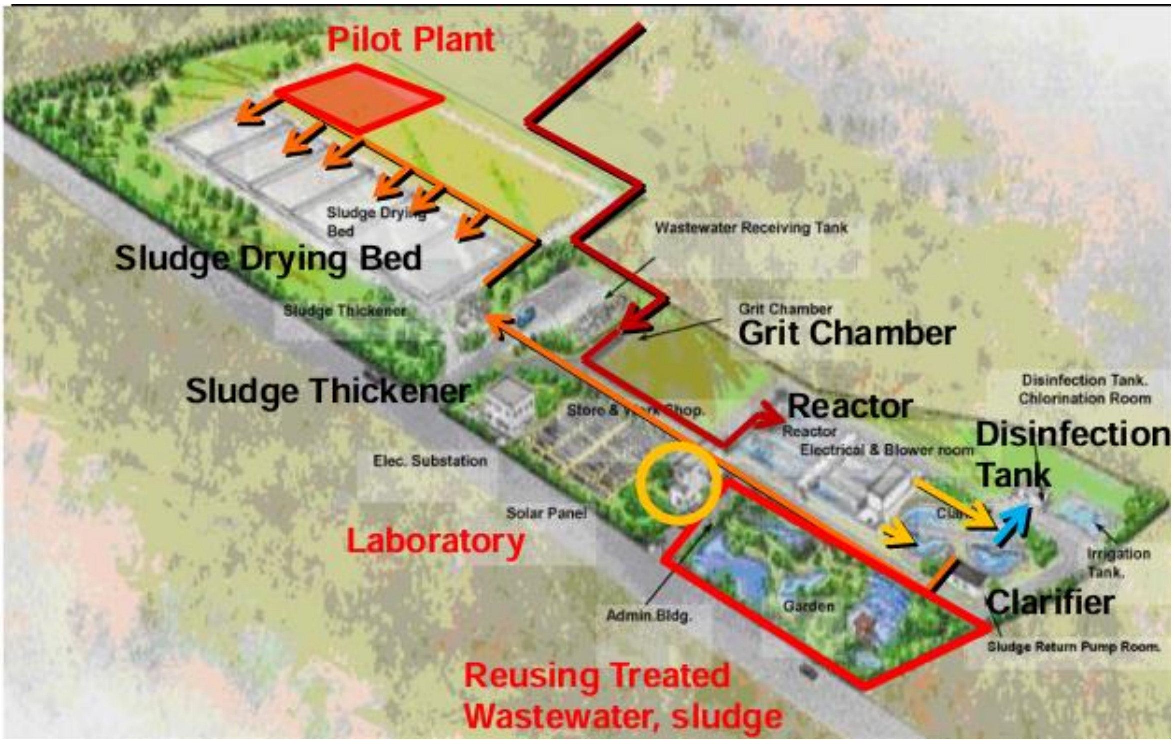


Figure 1.1: Stages of wastewater treatment in Jericho WWTP (Toshiya, 2024)

Due to the high organic content of palm leaves' solid waste reaching up to 19800 tons, according to Palm Farmers Cooperative Association in Jericho and Jordan Valley (Farmers, 2024), composting remains an interesting treatment option in Jericho City. See (Figure 1.2)

Figure 1.2: A picture of palm waste in Jericho and the Jordan Valley

Composting is an environmentally friendly waste management technology for municipal solid waste. The finished compost can enhance the quality of soil organic fertilizers, thereby helping to protect the environment. However, to obtain high-quality compost, composting techniques need to be improved efficiently. Therefore, manipulating the nutrient elements used in the composting process is an important approach to enhance the agricultural value of the compost (T.-J. Hu, 2007).

1.2 Research Questions

In order to achieve the best possible outcomes for this research, the following inquiries have been developed to assess the efficacy of sludge treatment:

- Is there an optimal solution to Palestine's problems of Sewage Sludge it uses safety?

- Which operational parameter will influence compost duration and finished product quality?
- Which optimal mixture produces the highest quality of finished product?
- Will sewage sludge have an impact on the composting process and finished product?
- How will diverse C/N ratios impact the composting process and finished product?

1.3 Research Objectives

The aim of this study is to establish an effective technique that satisfies the requirements and expectations of decision-makers over the conversion of enormous quantities of the sludge produced from treatment plants. To attain the primary goal of this study, the following particular goals have been granted:

- Analysis of Sewage Sludge
- Formulate a designed ratio of sewage sludge/additives for composting
- Monitor the composting process by measuring physical, chemical, and biological parameter
- Examine the quality of the compost at its various phases and compare it with Palestinian composting standards.

Chapter Two:

Literature Review

This chapter comprises four sections. The initial section presents a general overview of the Characteristics of sludge used in compost; the second segment delves into an overview of thermophilic composting. Subsequently, the third segment delves into detailed thermophilic composting systems lastly, the fourth segment centers on the effect of sludge-derived fertilizers on plant growth.

Background

Over the last decade, researchers have directed significant attention toward the generation and application of compost across various domains, encompassing agricultural, industrial, and municipal waste management, soil enrichment, nutrient circulation, carbon capture, remediation, erosion mitigation, and environmental enhancement. Although the body of compost related literature addressing these topics is extensive, this literature review focuses solely on providing a broad summary of aerobic and thermophilic composting methods, and convert of sludge to compost.

2.1 Characteristics of sludge used in compost:

The process of adding treated sludge should be homogeneous within the specifications and guidelines outlined in this standard “sludge use of treated sludge, and sludge disposal” (PSI, sludge use of treated sludge and sludge disposal, 2010). The following considerations should be taken into account during the addition process:

1. Treated sludge should be added in irrigated areas along planting lines and mixed with the topsoil layer (10 cm – 20 cm) one week before planting, with no specific timing for addition.
   - In rainfed areas, sludge should be added before the rainy season, mixed with the topsoil surface, ensuring that the land slope does not exceed 5%.

- In non-arable lands, sludge should be added before the rainy season, ensuring contouring and mixing with the topsoil surface.

When treating and packaging sludge for sale, approval from relevant regulatory authorities is required. In this case, guidelines from the U.S. Environmental Protection Agency, European Union, and World Health Organization may be consulted.

Sludge must be treated before use according to the methods specified in this standard and any other approved method. Sludge is classified into three classes: first, second, and third, for this specification.

First-class sludge may be used as organic fertilizer for agricultural land and soil improvement purposes (PSI, sludge use of treated sludge and sludge disposal, 2010).

Sludge treatment levels:

Treatment level for first-class sludge:

- Fermentation: Sludge is fermented using a ventilated container or by placing it in piles, keeping the temperature above 40°C for 5 days or at ambient temperature for 60 days.
- Air drying: Liquid is removed from the sludge using hot gases to reduce moisture content to 10% or less, and the sludge temperature reaches 80°C at the end of the heating process.
- Aerobic drying: Liquid sludge is allowed to filter and/or dry in sand beds, ensuring sludge thickness does not exceed 25 cm, and it remains in these beds for at least 45 days.
- Aerobic land digestion: Stirring the sludge in the presence of oxygen while maintaining aerobic conditions for 10 days at a temperature of 55°C to 60°C, reducing at least 38% of volatile solids (PSI, sludge use of treated sludge and sludge disposal, 2010).

Any other method capable of meeting the technical requirements outlined in this standard (PS-898-2010) is acceptable.

Table2.1: Maximum permissible limits in sludge (PSI, sludge use of treated sludge and sludge disposal, 2010)

Element code	**Concentration - First class (mg/Kg)**
As	41
Cd	40
Cr	900
Cu	1500
Hg	17
Mo	75
Ni	300
Se	100
Pb	300
Zn	2800
FC	1000*
Salmonella	3**
*unit /g ** bacillus/ g	

2.2 An overview of thermophilic composting

2.2.1. General mechanisms of composting

The decomposition of organic matter during the composting process relies on the interaction of several factors. These factors include moisture content, microbial communities, oxygen availability, and a proper balance of carbon and nitrogen ratios (C: N) (see Figure 2.1). Microorganisms present in the organic matter consume the easily accessible carbon compounds. As these compounds are metabolized, temperatures within the compost pile rise and carbon dioxide (CO2) is generated as a byproduct (McClintock, 2004). Consequently, various types of microorganisms exhibit activity at different stages within the composting pile (Geesing, 2009).

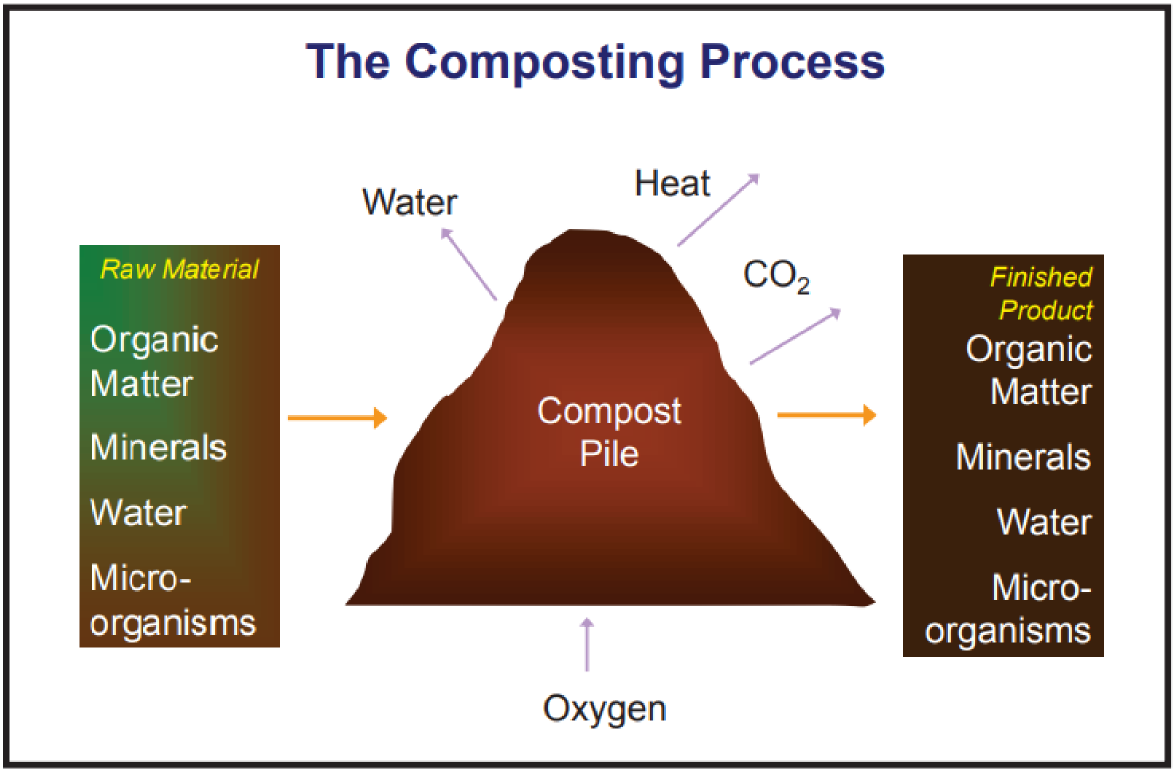


Figure 2.1: Schematic diagram of the mechanism of thermophilic composting (Epstein, 1997, and NRAES, 1999)

At first, bacteria dominate by utilizing easily degradable carbon sources. As microbial activity decreases, temperatures drop, allowing fungi to take over and gradually break down the more resistant carbon forms, including lignins and cellulose (McClintock, 2004). Furthermore, a compost pile represents a complex ecosystem harboring a diverse array of organisms. These organisms play a vital role in the composting process and can be categorized in various ways (Geesing, 2009). Furthermore, the final product of composting, which is crumbly, earthy humus, is significantly more stable than raw manure. This stability decreases the chances of nutrient loss due to leaching or volatilization into the atmosphere. As compost matures, its nitrogen undergoes mineralization, transitioning from its organic form to ammonium and subsequently to nitrate, which is the preferred form for plant absorption (McClintock, 2004).

2.2.2 Aeration, moisture, and temperature

In certain scenarios, employing forced aeration and turning techniques may serve as a more efficient composting strategy, enabling composting at elevated moisture levels and consequently reducing the size of composting facilities. During the initial mixing phase, liquids can be incorporated if the feedstock mix falls below 45% moisture content. Additionally, liquid wastes can be introduced throughout the composting process if there is a risk of the material becoming excessively dry. Concurrently with turning, water is applied in a sprayed form, aiming to achieve approximately 65% moisture content in the material, which can be confirmed by conducting a fist test. The continuation of microbial metabolism relies on adequate aeration. Typically, the average oxygen (O2) concentration within the compost mixture ranges from 15 to 20%, while carbon dioxide (CO2) levels typically range from 0.5 to 5%. When the oxygen content drops below these thresholds, anaerobic microbial populations can outcompete aerobic species. Consequently, this can lead to an increase in the production of malodorous fatty acids and methane. Since oxygen consumption is directly correlated with microbial activity, oxygen levels are also influenced by substrate temperatures (P. Roman, 2015). Temperature plays a pivotal role in regulating microbial activity, thereby influencing the rate of degradation and moisture evaporation. The heat generated during composting arises from microbial metabolism and the retention of thermal energy within the composting mass. Consequently, the composting process typically undergoes an initial phase of temperature elevation, followed by a subsequent decline and stabilization as microbial activity diminishes due to decreased availability of organic matter. The temperature dynamics within the composting medium are influenced by factors such as compost composition, aeration, and the specific composting methods employed (R. Verma, 2014).

2.2.3 Carbon and nitrogen dynamics

During the initial one to two days of aerobic composting, easily degradable organic matter (OM) carbon is broken down by bacterial enzymes found in mesophilic microflora thriving at temperatures ranging from 90 to 110°F (50 to 61.2°C). As a result, the resultant products exhibit a lower C/N ratio compared to the initial value. This decline in C/N ratios indicates the breakdown and stabilization of organic matter achieved during composting. Microorganisms drive the decomposition of organic matter, utilizing carbon for energy and nitrogen for cellular component synthesis. When the compost's C/N ratio is elevated, the excess carbon tends to utilize nitrogen from the soil for cellular structure formation, resulting in nitrogen loss from the soil, a phenomenon known as nitrogen robbing. Conversely, if the C/N ratio is too low, the compost may not effectively enhance soil texture. To adjust the C/N ratio, various ingredient combinations can be utilized (V. K. Vishwakarma), calculated using an online calculator available on the Cornell University website (Calculate C/N Ratio, 1996).

2.2.4 Indices Stability and Maturity of Compost

Among the various characteristics influencing the quality of compost, particularly for agricultural use, two key aspects are "stability" and "maturity." Throughout the different phases of composting, the extent of organic matter decomposition and humification significantly influences the quality of the final product. Research indicates that mature composts enhance Soil Organic Matter (SOM) more effectively than fresh and immature composts, primarily due to their higher levels of stable carbon (C). However, incomplete decomposition and humification of organic matter may lead to the accumulation of harmful substances in the soil, potentially resulting in toxic effects on plants (T. Sayara, 2020).

To mitigate potential side effects and ensure compost quality, it is advisable to evaluate both its maturity and stability. Maturity assessment is crucial for determining the compost's suitability for agricultural use, taking into account its impact on plant growth and potential phytotoxicity. On the other hand, stability refers to the resistance of organic matter against extensive biodegradation or microbial activity. It's essential to consider both characteristics together when assessing compost quality, as phytotoxic compounds can result from the microbial activity of unstable organic matter (T. Sayara, 2020).

Various tests have been employed in the literature to evaluate the stability and maturity of compost. In this context, respiration techniques, which measure oxygen consumption by microbial activity, are considered among the most valuable methods for assessing compost stability and maturity. Additionally, germination tests are widely utilized for determining compost maturity. The respiration index, which quantifies the degradation rate of various materials, is correlated with the organic matter content and biochemical reactions driven by microbial activities. For example, materials exhibiting a respiration index ranging from 0.5 to 1.5 mg O_2 g^{-1} OM h^{-1} are deemed stable, while values exceeding 1.5 mg O_2 g^{-1} OM h^{-1} indicate unstable materials (T. Sayara, 2020).

2.3 Thermophilic composting systems

As observed by Sir Albert Howard in the early 20th century, farmers have historically utilized decomposed animal manure to enhance soil fertility over centuries. However, while manure piles naturally decompose over a period of a year or more, much of this decomposition is likely anaerobic, resulting in the loss of nitrogen as ammonia and the emission of foul-smelling methane and hydrogen sulfide gases. In cases where bedding is incorporated into the manure or if the manure is relatively dry, conditions may be conducive to aerobic decomposition.

As previously mentioned, the presence of sufficient oxygen is essential in the substrate to facilitate the colonization of aerobic thermophilic bacteria. Successful thermophilic composting of the substrate can occur if adequate aeration and carbonaceous materials are available to mitigate significant ammonification. This process is known as passive composting. However, such ideal conditions are uncommon.

The original Indore method, proposed by Howard in 1943, involved layering carbonaceous and nitrogenous residues to promote aeration and homogenize feedstock mixtures. Additionally, "pit composting" was described as a technique that involves placing organic wastes in a subterranean depression or pit to minimize moisture loss. Howard recommended this method for semi-arid regions with limited water resources. The pit is typically lined with cement or cement blocks and measures at least 2 to 3 meters in length, 1 to 1.5 meters in width, and 1 to 1.5 meters in depth.

In areas where water availability is ample, Howard suggested composting in aboveground piles, as this method is less labor-intensive and does not necessitate the construction of pits. Small compost piles can be manually turned with a pitchfork for aeration, while in industrialized countries, farms may employ tractors with front-end or bucket loaders for this purpose. Larger on-farm and commercial composting facilities typically utilize turned windrow systems, passively aerated windrows, or aerated static piles (McClintock, 2004).

2.4 Effect of sludge-derived fertilizers on plant growth

Amending soil with Sewage Sludge proves beneficial in augmenting crop production, alongside fostering the accumulation of nutrients and organic matter within the soil. Nonetheless, it's imperative to regularly monitor the accumulation of humic substances (HS) in both soil and plant tissues when sewage sludge is continuously utilized. Additionally, Sewage Sludge can be employed as fertilizers post-pyrolysis. Both the exclusive application of sewage sludge and its corresponding biochars furnish adequate phosphorus (P) to plants, enabling them to achieve biomass surpassing conventional levels.

The impact of sewage sludge on plant growth varies depending on the method of application, whether it's applied to the soil surface as mulch or mixed uniformly with the soil. Surface application of Sewage Sludge offers certain advantages, such as limiting water evaporation by creating a physical barrier that helps retain soil moisture for longer periods. Consequently, this intensifies the biological and chemical processes involved in the transformation of organic matter. For instance, the highest yield of wheat (Triticum durum Desf.) was observed when dried sewage sludge was applied to the surface of clayey-silty soil as mulch, compared to when it was mixed uniformly with the soil. It's crucial to note that a direct application of sewage sludge onto agricultural soils is not recommended.

Experiments indicate that the utilization of sewage sludge impacts the germination and growth of seedlings. Concentrations surpassing 7 g kg^{-1} inhibited the germination of cucumber seeds and led to necrosis in primary roots.

Soil microbiological activity is influenced when Sewage Sludge is applied alongside mineral fertilizers. Further experiments were conducted with cucumbers and leaf mustard. Sole application of Sewage Sludge preparation did not supply plants with mineral nutrients at adequate levels. However, when combined with nitrogen-containing fertilizers, the Sewage Sludge preparation significantly enhanced plant growth and facilitated plant development. This combination may yield long-term benefits for plant mineral nutrition. Additionally, findings revealed that different plant species respond divergently to Sewage Sludge. This species-specific effect can be attributed to (i) varying sensitivity of plants to compounds in Sewage Sludge preparations, (ii) the requirement for mineral elements during early stages of ontogenesis due to slow nutrient release from Sewage Sludge, and (iii) inadequate maturation and presence of growth inhibitors in Sewage Sludge (McClintock, 2004).

Chapter Three:

Materials and Methods

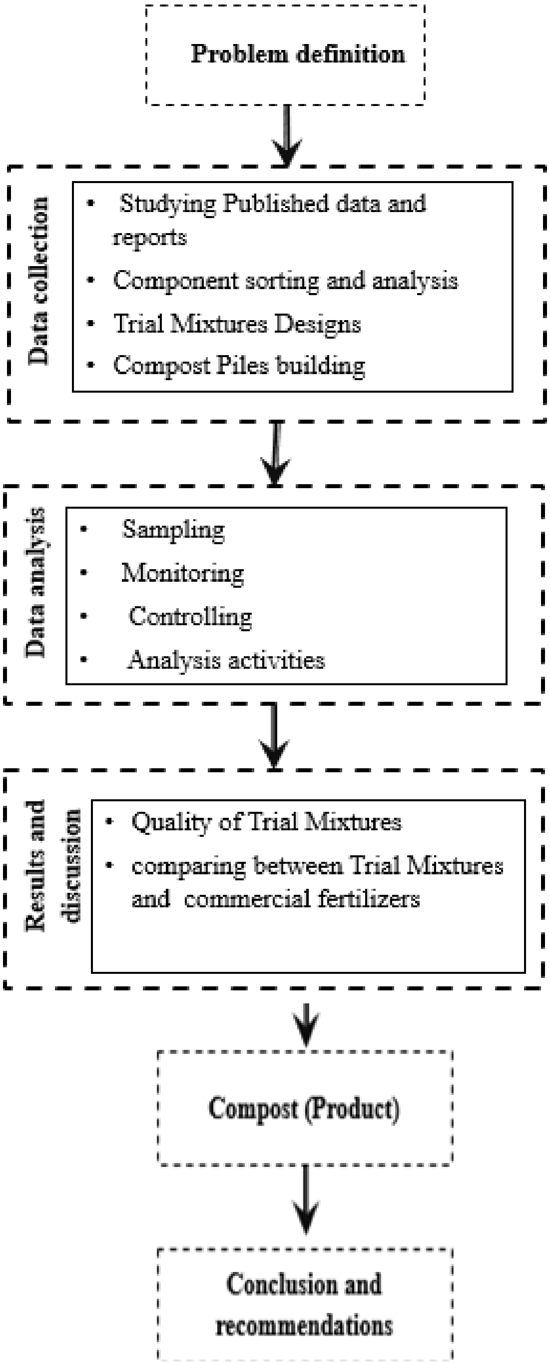
3.1 Data Collection

This chapter provides an extensive description of the creation of compost sludge as well as its sludge rid and reuse, together with all associated field and lab work conducted during the study's duration, as well as monitoring, sampling, and analysis procedures. Also, a presentation of the mathematical formulas and equations has been added.

This study employs a meticulous analytical methodology built on the analysis of every element required. It should be mentioned that the conclusions of this study are exclusively based on actual experiments, which lends the findings more credibility. This work may serve as a foundation for numerous future research projects on converting sludge into a useful commodity, particularly compost, which is rich in nutrients that plants require. This study will provide relevant details on the composting method used in our experiments of utilizing various bulking agents, demonstrating the capacity of sewage sludge to turn into organic compost rich in valuable ingredients. The raw materials for this research were gathered and analyzed qualitatively and quantitatively. One conversation with Jericho WWTP official is part of the qualitative method; he gave us the details we needed to understand the vast amounts of sewage sludge for which there is no feasible means to dispose properly, see (Figure 3.1). Achieving the objective entails an in-depth search to identify the ideal compost properties. The quantitative method will involve testing and evaluating numerical data regarding the quantity of sludge generated by the Jericho sewage treatment plant.

Figure 3.1: The waste sludge in the vicinity of WWTP Jericho

Flowchart 1 highlights the Methodology of the research



Flowchart 1: Methodology of the research.

3.2 Materials

3.2.1 Sludge Source

The source of the sludge was the Jericho wastewater treatment plant, which is situated 8.7 km north of the Dead Sea in Jericho city (31°50′23 N 35°30′01 E), The sludge was processed to reach appropriate quality, such as drying in sunlight, (Figure 3.2) & (Figure 3.3) show JWWTP and the drying beds of sludge at JWWTP, and (Table 3.1) Details about the sludge region.

Figure 3.2: The Jericho Wastewater Treatment Plant (Google Earth, 2022)

Figure 3.3: The drying beds of the sludge at JWWTP

Table 3.1: Details about the sludge region, such as location, altitude, average annual rainfall, average annual temperature, and humidity (Jericho Municipality, 2021)

Study area	Jericho
Location	8.7 km North Dead Sea
Altitude	260 m sea level
Mean annual rainfall	166 mm
Average annual temperature	39.6^{o} C
Average annual humidity	55%

3.2.2 Technical Aspect of Jericho WWTP

The surplus sludge at the Jericho WWTP is transferred to the drying bed where it undergoes a once-monthly sludge thickening stage. When it thickens six or seven times in the thickener, it is released to a sludge drying bed and removed from surrounding drying beds when the water content has decreased to 30 – 40 % (Toshiya, 2024).

The range of Mixed Liquor Suspended Solids (MLSS) in wastewater treatment plants (WWTPs) may vary due to factors such as the treatment process type, plant design, and specific treatment goals. Typically, MLSS concentrations are regulated within specific limits to optimize treatment efficiency and mitigate operational challenges (Municipality, 2024).

Typically, in the activated sludge process, a prevalent biological treatment method in wastewater treatment plants, Mixed Liquor Suspended Solids (MLSS) concentrations range from approximately 1.5 to 5 g/L (Eslamian, 2016). At the Jericho WWTP, MLSS is maintained below 3000 mg/L by primarily treating the sludge once a month (Toshiya, 2024). This concentration range facilitates sufficient biomass for efficient decomposition of organic matter and the removal of nutrients like nitrogen and phosphorus from wastewater (G. Tchobanoglus, 2003).

Average daily wastewater flow quantities at the Jericho Treatment Plant 6600 m^3\day (Municipality, 2024).

The daily return sludge flow has been operated manually and is in good condition with 1,700m^3/day of volume on the current inflow condition.

A single sludge treatment process is applied to around 1,000 m^3 of sludge with 3,000 mg/L of density removed from the clarifier; it is estimated that 90% of the suspended solid (SS) will be recovered at the sludge thickener (Toshiya, 2024).

3.3 Methods

3.3.1 Sampling and Analysis

Two samples were collected from each raw material mixture and finished compost at various locations and depths within each composting experiment (Exp.). The samples were thoroughly mixed to ensure homogeneity, then placed in labeled plastic containers and transported to the laboratory on the day of sampling.

All collected samples were analyzed at Al-Quds University testing labs Soil & Hydrology Research Lab (SHR), and examined using (SOP) methods, according to official methods, and the parameters analyzed included pH, moisture, EC, total nitrogen, and Total Organic Carbon. organic matter (P, K, Na, Ca, Mg) which were measured according to (APHA, 2005), Total and fecal coliforms were measured by filtration of 100 ml sample through a 0.45 µm Millipore membrane filters and the filters were incubated for 24 h at 37o C for TC and 44.5o C for 24 h for FC. The quality of the finished compost was verified using (PSI, Organic Fertilizer (Humus) Compost, 2019).

Heavy metals and minerals values (Pb, Zn, Cd, Cu, Ni) for composting mixtures were analyzed using an Atomic Absorption Spectrometer (PinAAcle 500) according to the Standard Method, by using Agilent Technologies 700 series (ICP/OES) and the standard method of (PSI, Organic Fertilizer (Humus) Compost, 2019).

Total nitrogen was determined by analyzing using the Kjeldahl method. Total coliform and Fecal coliform were analyzed according to the standard method of (PSI, sludge use of treated sludge and sludge disposal, 2010).

3.3.2 Chemicals and Instrumentation

The following chemicals were utilized in this study:

- ferric sulfate solution (FeSO4)
- digesting solution (K2Cr2O7, H2SO4)
- sulfuric acid reagent (H2SO4)
- potassium nitrate (KNO3)
- Hydrochloric acid solution HCl (1N)
- sodium hydroxide (NaOH 50%)

- Pure Humic Acid.
- (HCL)
- HNO3

The selected sample was subjected to numerous tests, including the following:

- Measure pH with a model HQ 11 d pH meter.
- EC test with the HQ 14 d model of E.C. meters.
- TOC was measured using the Walkley-Black chromic acid wet oxidation method.
- TN test using the Kjeldahl method to analyze organic and ammonia nitrogen.
- K+ and Na+ tests using flame photometric.
- The determination of humic acid in certain materials using a modified method of UV-Vis spectroscopy.

3.3.3 C: N Ratio calculation

Calculating the optimal C: N ratio is crucial to the amount of materials present within the experiment mixtures, the formula for calculating the C: N ratio is as follows: (Calculate C/N Ratio, 1996)

Equation 1:

$$R=Q1(C1*(100-M1) + Q2(C2*(100-M2) + Q3(C3*(100-M3) / Q1(N1*(100-M1) + Q2(N2*(100-M2) + Q3(N3*(100-M3)$$

In which:

R = C/N ratio

Qn = mass of material n

Cn = Carbon (%)

Nn = Nitrogen (%)

Mn = Moisture content (%) of material n.

3.3.4 Compost procedure

Sampling Strategy and Raw Materials

This study was performed at Al-Quds University in collaboration with the Jericho municipality and WWTP Jericho, which processes raw materials from the west of Palestine, including Sewage Sludge.

Four different types of materials were chosen: Azolla, Palm leaves, Opuntia, and Sewage Sludge. The main treatment characteristics of every composting process in the piles, along with the duration of the process, are displayed in (Figure 3.4), and (Table 3.2)**.**

Figure 3.4: Components of Experiments

Table 3.2: The main treatment characteristics of each composting process in the experiments, and the time of the composting process.

Experiments	**Waste Mixture (Kg)**	**Method of composting**	**Time of Composting Process (Months)**
Exp. 1	Sewage sludge + palm leaves+ Azolla 1:2:1	Open air turned wind rows	3.3
Exp. 2	Sewage sludge + palm leaves+ Azolla 1:1:0.5	Open air turned wind rows	3
Exp. 3	Sewage sludge + palm leaves+ Azolla 0.5:1:1	Open air turned wind rows	6.3
Exp. 4	Sewage sludge + palm leaves+ Opuntia 1:3:2	Open air turned wind rows	3

The composting piles were set up outside in a row with dimensions of 0.4–0.50 meters in width and 1-1.2 meters in length. each pile was filled to a specified weight of mix that was calculated based on the C: N ratio. Every few days, the temperatures of the composting matter were recorded using a thermometer. The thermometer is set up at several points throughout the pile, and an approximate temperature according to the composting phase is detected. This temperature is then compared to each phase's recommended temperature, which is 40-65 max, as shown in the table below.

A pitchfork or shovel is employed to aerate the compost to turn the pile initially each pile was turned twice a week for 2 weeks using a fork, then once a week for the remaining duration to aerate the mixture. Stirring the contents from time to time will help to prevent anaerobic pockets and accelerate the composting process (E. Bazrafshan, 2006).

The moisture content value obtained in this study will be presented in (Table 3.3).According to a compost facility operator, the range of an ideal moisture content that must be possessed by compost medium was within 40-60% (K. G. C. d. Amaral, 2021).

Table 3.3: Spreadsheet to track the various parameters

	experiments	Week1	Week2	Week3	Week4	Week5	Week6	Week7	Week8	Week9	Week10	Week11	Week12	Week13	Week14	Week15	Week 16
Temperature	Exp. 1																
	Exp. 2																
	Exp. 3																
	Exp. 4																
Ref Temp		15°-40°		40°-65°			15°-40°					Ambient temperature					
Humidity	Exp. 1																
	Exp. 2																
	Exp. 3																
	Exp. 4																
Ref humidity		Variable depended on the humidity of input material (30%-60%)															

Two samples were randomly extracted from various locations within each pile. To achieve this, samples obtained from distinct points were meticulously blended to create a comprehensive sample, resulting in a final mass of 2 kg. This composite sample was subsequently partitioned into three sub-samples, each approximately 650 g. Following this division, the sub-samples were meticulously placed into vacuum-sealed bags, ensuring optimal preservation for subsequent scientific analysis, as shown in Figure (3.5).

Figure 3.5: Stages of Composting

Figure 3.6: Final Products.

3.3.5 Germination tests

Simple tests can be done comparing germination rates of a given seed type in all compost products.

Garden (Armenian CUCUMBER) is considered a very suitable plant to do this (Figure 3.7).

We conducted a viability test by selecting the Armenian cucumber, the growth of cucumbers in pots (with a diameter of 1 cm, and height of 5 cm) filled with compost products (Exp.1, Exp.2, Exp.3, Exp.4) was compared to their growth in two samples of commercial fertilizer for comparison, 12 Armenian cucumber seeds were used in each type of soil.

The germination rate was studied based on the following equation:

Germination rate (GR) = $\sum G/t$, where G is the percentage of germinated seeds per day and t is the total germination period (J. Lin, 2017).

The plant length, germination density, leaf density, and length of the roots in compost and potting commercial fertilizer were then compared.

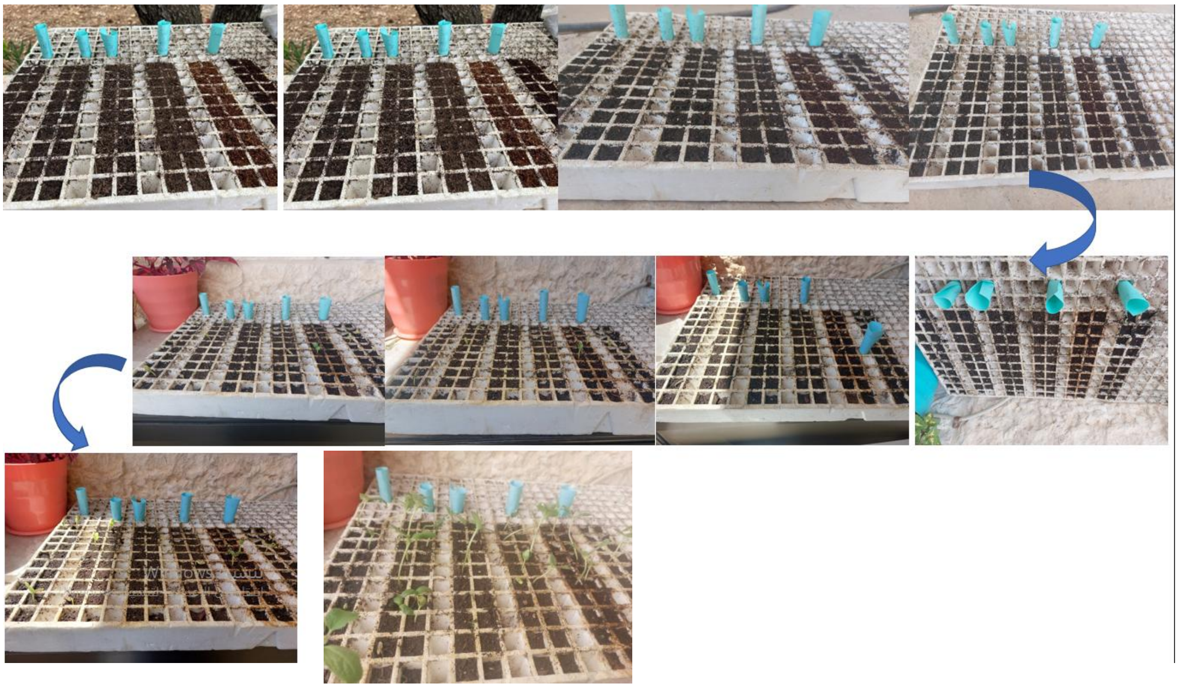


Figure 3.7: A picture showing the germination stages of some seeds in samples of the produced compost, in addition to two commercial compost samples from the market

Chapter Four:

Results and Discussion

The results and discussion within this chapter encompass four distinct sections: chemical and physical measurements, performance efficiencies, evaluation of composted quality, and germination experiment.

4.1 The Characteristics of Raw Materials (Chemical and Physical Parameters)

All the methods used for measuring and collecting the relevant physical and chemical parameters during the study period are detailed in the attached Appendix, as outlined below:

- Physical parameters (Appendix A).
- Chemical parameters (Appendix B).

4.1.1 Physical parameters

The evaluation of compost quality has mainly been based on physicochemical properties. The most relevant physical parameters of raw material in compost mix are analyzed in the present study.

4.1.1.1 pH, EC, and Moisture Content Measurements

In the study, some Physical parameters were measured, such as the EC, moisture content, and acidity (pH) tested time before the research for the raw materials. The following section shows the results, see (Table 4.1).

Table 4.1: The Physical Measurements of Raw Material.

Parameter	Sewage sludge	Azolla (wet)	Palm leave (Dry)	Opuntia (Dry)	Compost (standard)	added soil
EC (μS/cm)	1192	147	369	2.59ms	1137	101.97
pH	6.60	7.05	6.05	5.90	5.65	8.21
MOISTURE %	16.53	88	14.4	12.95	11.11	10.3

4.1.2 Chemical parameters

The evaluation of compost quality has mainly been based on physicochemical properties. The most relevant chemical parameters of raw material in compost mix are analyzed in the present study.

4.1.2.1 The determination of Na+ , K+, Mg+, Ca+, and P.

In the study, some initial Chemical parameters in each pile before composting, such as the Na+, K+, Mg+, Ca+, and P. (Figure 4.1) shows the results.

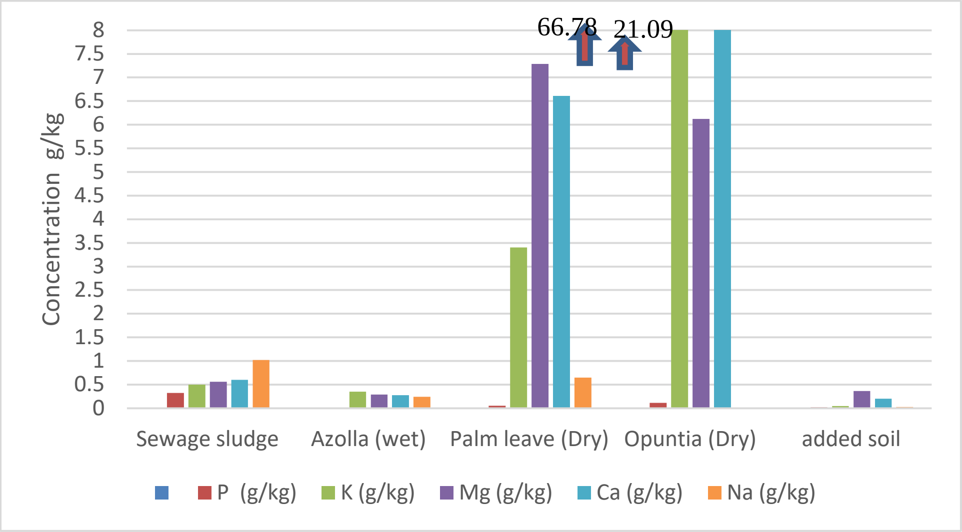


Figure 4.1: The Concentration of Na+, K+, Mg+, Ca+, and P. (g/kg) for the raw materials.

Calcium, potassium, and magnesium are essential nutrients for agricultural plants and play a significant role in soil fertility. These elements are abundant in palm and Opuntia leaves. Conversely, sodium is not a primary nutrient for plants like the previous elements, and high concentrations of sodium are not preferred because they can adversely affect plant growth and development, Plants tolerate low concentrations of sodium, which is seen mostly in us raw materials most elevated in the sludge followed by palm leaves.

As for phosphorus, it interacts with many other elements in the soil and contributes to improving soil structure and enhancing its ability to absorb water and other nutrients. Organic matter, represented in sludge, plays a crucial role in providing the phosphorus we need.

4.1.2.2 Total Nitrogen Determination

In the study, some initial chemical parameters in each pile before composting, such as the TN. (Figure 4.2) shows the results

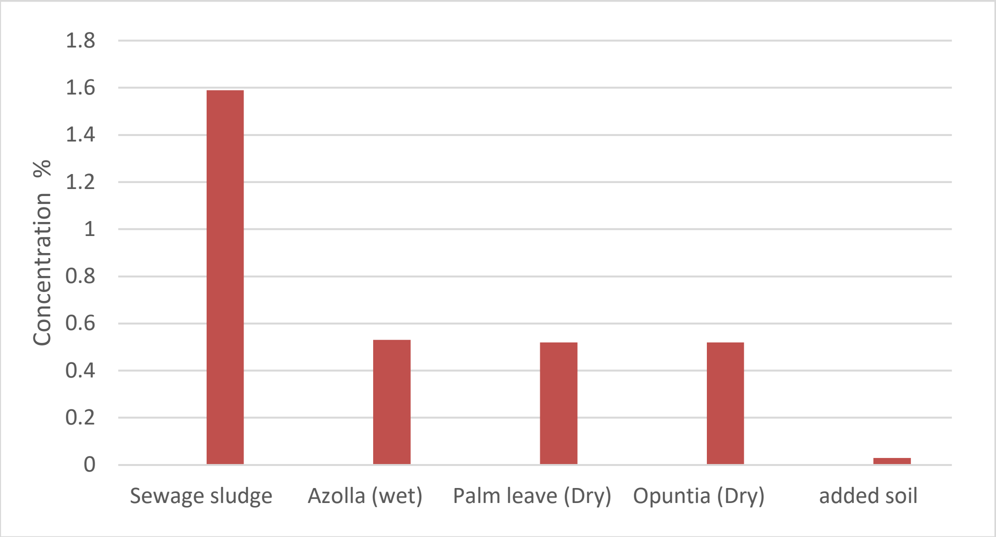


Figure 4.2: The Concentration of TN (%) for the raw materials.

Nitrogen is one of the key elements added to compost to enhance its quality and provide optimal conditions for organic decomposition, resulting in nutrient-rich compost essential for plants. As seen in the image above, we have materials rich in nitrogen available.

4.1.2.3 Organic Carbon Determination

In the study, some Chemical parameters were measured, such as the TOC% tested time before the research for the raw materials. The following section shows the results.

Organic Matter (OM) and Total Organic Carbon (TOC) are important indicators of compost quality, contributing to improving soil properties such as structure and aeration and enhancing biological activity including microorganisms, worms, and other microbes that aid in organic matter decomposition and nutrient release.

The following image reflects the raw materials' organic matter content and total organic carbon, where Palm leaves contain the highest levels of organic matter and organic carbon, followed by sludge, see (Figure 4.3).

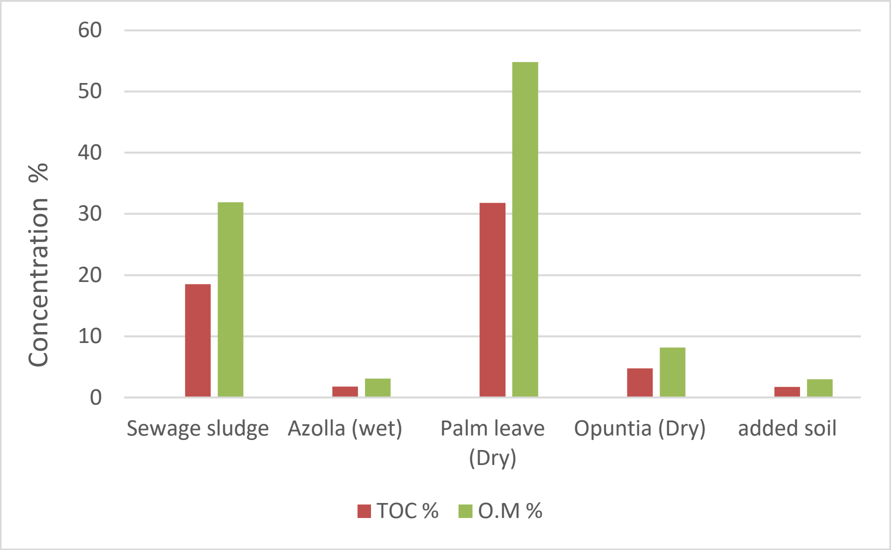


Figure 4.3: Concentration of TOC and OM (%) for the raw materials

4.1.2.4 Humic Acid Determination:

Humic acid enhances compost structure by promoting bonding between organic matter particles. This improves soil structure and increases its capacity to retain water and nutrients. It also boosts microbial activity in the soil, enhancing organic decomposition and nutrient release essential for plant growth. Moreover, it improves plant resistance to environmental stressors such as drought and salinity, promoting plant health and productivity. Humic acid is available from the sludge material we use in compost production. Shows the (figure 4.4)

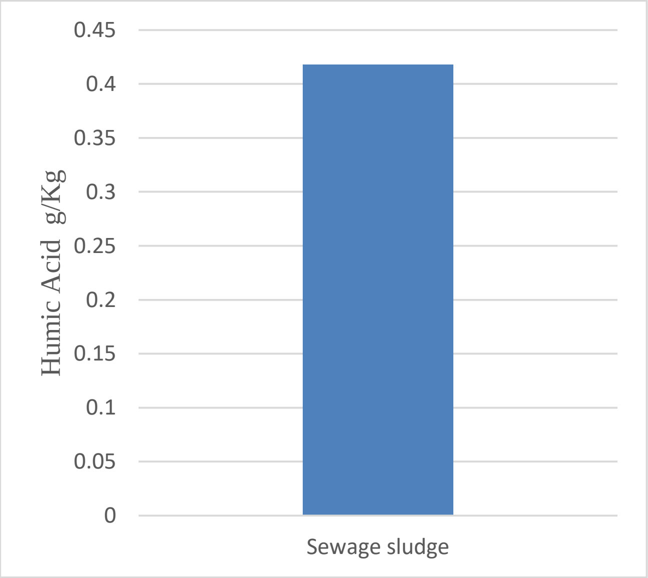


Figure 4.4: The concentration of humic acid (g/kg) for sewage sludge from Jericho WWTP

4.1.2.5 SAR :

Equation 2: $SAR = Na^{+} / \sqrt{(Mg^{+2} + Ca^{+2} / 2)}$ (Suarez, 2009)

Table 4.2: SAR Calculation of Raw Materials

Materials	Sewage sludge	Azolla (Dry)	Azolla (wet)	Wood chips	Palm leave (Dry)	Opuntia (Dry)	Compost (standard)	added soil
SAR	**13.465**	**14.029**	**0.449**	**0.400**	**0.246**	**0.005**	**2.213**	**0.066**

Only a limited number of plant species can withstand high sodium concentrations, and in general, sodium levels exceeding 1% saturation in the growth medium are toxic to root systems. Excessive sodium competes with the uptake of calcium and potassium, leading to damage to root tissues. When sodium saturation exceeds 1% in the cation exchange complex, it can cause issues with germination and emergence in several plant species.

This early indication of sodium availability can signal potential harm to plant growth well before an elevated Sodium Adsorption Ratio (SAR) might identify a problem (affiliates).

4.2 C: N Ratio calculation for materials

Calculating the optimal C: N ratio is crucial to the amount of materials present within the experiment mixtures. The formula C: N ratio calculation was used to compute the known weight of the Exp., as shown in (Table 4.3).

Table 4.3: known weight of the Exp. according to C: N ratio

Materials	Sewage sludge	Azolla (wet)	Palm leave (Dry)	Opuntia (Dry)	
Moisture content %	16.53	88	14.4	12.95	
TN %	1.59	0.53	0.52	0.52	
TOC %	18.51	1.79	31.78	4.75	
C: N	11.64	3.37	61.11	9.13	
					C: N Ratio
Exp. 1 **(%)**	**1**	**1**	**2**	**--**	**30.38**
Exp. **2 (%)**	**2**	**1**	**2**	**--**	**23.37**
Exp. 3**(%)**	**1**	**2**	**2**	**--**	**29.97**
Exp. 4**(%)**	**1**	**--**	**3**	**2**	**29.52**

4.3 In-Situ Field Measurements

This section includes all the field measurements that were carried out during the study period, which include the following: water content measurement, Temp, decomposition time, and water consumption.

4.3.1 Performance Efficiencies

The performance of the product was determined in terms of organic decomposition which occurred through the predominant aerobic and physical processes during the treatment process, see (Table 4.4).

Table 4.4: A spreadsheet to track the various parameters

	Experiments	Week1	Week2	Week3	Week4	Week5	Week6	Week7	Week8	Week9	Week10	Week11	Week12	Week13	Week14	Week15	Week*16-27
Temperature	Exp. 1	25.2	27.5	29.1	32.6	39	43	40.9	37.1	36.7	29.5	25.7	26.7	26.4	26.9	25.2	mature
	Exp. 2	26.7	27.6	27.3	31.1	33.1	35.6	40.6	43.4	40.1	36.4	33.7	30.5	26	25.4	25	mature
	Exp. 3	25.5	28.5	28	36.2	42.3	43.8	40.5	38.1	35.9	33.8	30.8	29	27.1	26.2	26.3	26.6-19.5
	Exp. 4	30.2	32.9	38.8	42	41.3	42.3	38.3	36.8	35.7	34.4	31.9	29.6	22.3	19.2	17.9	mature
	Ref Temp C°	15°-40°		40°-65°			15°-40°					Ambient temperature					
Humidity	Exp. 1	34.8	32.4	29.1	38.5	39.8	39.2	33.3	35.5	42.5	40.5	37.4	31.5	29.9	33.3	32.9	mature
	Exp. 2	36.8	36.1	40.9	35	36.9	34	32.5	31.7	31.5	30.1	36.2	33.5	33.2	36.9	30.6	mature
	Exp. 3	31.2	40.2	37	31.9	30.8	34.7	32.2	38.8	36.9	32	34.7	40.2	32.9	36	32.8	33.3-29.9
	Exp. 4	29.7	34.5	31	32.4	31.5	32.5	31	32.7	33.7	34.4	34.8	35.7	32.7	35	29.6	mature
	Ref humidity	Variable depended on the humidity of input material (30%-60%)															

The thermometer was several points throughout the pile, and an approximate temperature according to the composting phase was detected. This temperature was then compared to each phase's recommended temperature, which is 40-65 max, the samples reached 45 degrees Celsius at their highest value, as shown in the table above.

The moisture content value obtained in this study is shown in (Table 4.4). This study's moisture content range was between (30 % to 40%). According to a compost facility operator, the range of an ideal moisture content that must be possessed by compost medium was within 40-60% (K. G. C. d. Amaral, 2021).

The overall decomposition for Exp. 1 during the study period is indicated in (Figure 4.5) below.

In the first Experiment, a maximum temperature of 44 degrees Celsius was reached, and the decomposition process lasted for 100 days.

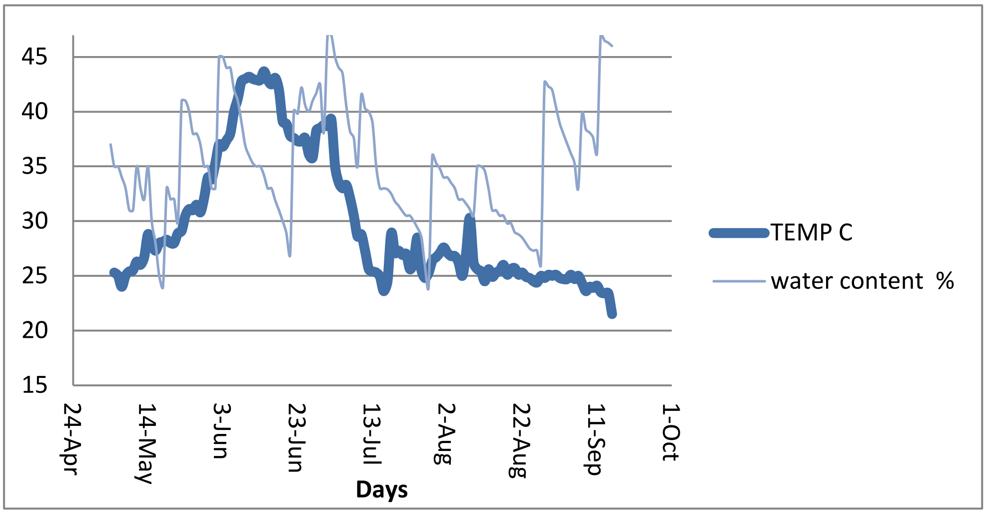


Figure 4.5: The Temp (expressed in C) and water content (expressed in %) inside the Exp. 1 at the period of the study.

In the second Experiment, a maximum temperature of 45 degrees Celsius was reached, and the decomposition process lasted for 90 days. The fastest mixture to be produced among the four mixtures was observed, see (Figure 4.6).

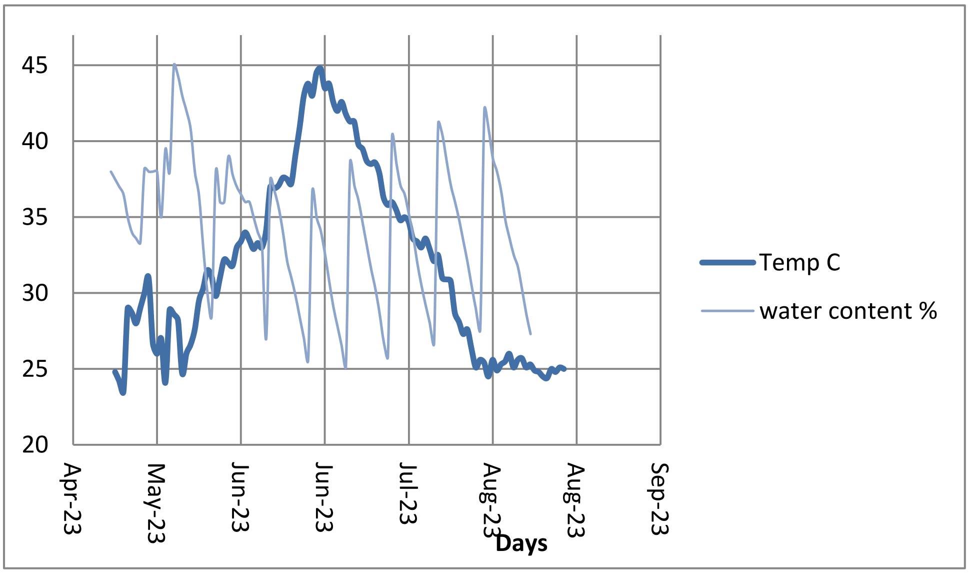


Figure 4.6: The Temp (expressed in C) and water content (expressed in %) inside the Exp.2 at different periods of the study.

In the third Experiment, a maximum temperature of 41 degrees Celsius was recorded, and the decomposition process lasted for over 195 days, see (Figure 4.7).

While, high nitrogen source ratio can negatively impact the production process in several ways, including the generated heat and production time. Here are some potential reasons:

Loss of organic matter: In some cases, a high nitrogen ratio can lead to the rapid loss of organic matter due to accelerated decomposition. This can adversely affect the quality of the resulting compost.

Effect on production time: A high nitrogen ratio may accelerate the composting process, leading to faster production. While this might be beneficial if rapid fertilizer production is desired, it could result in lower quality if the compost cannot fully decompose.

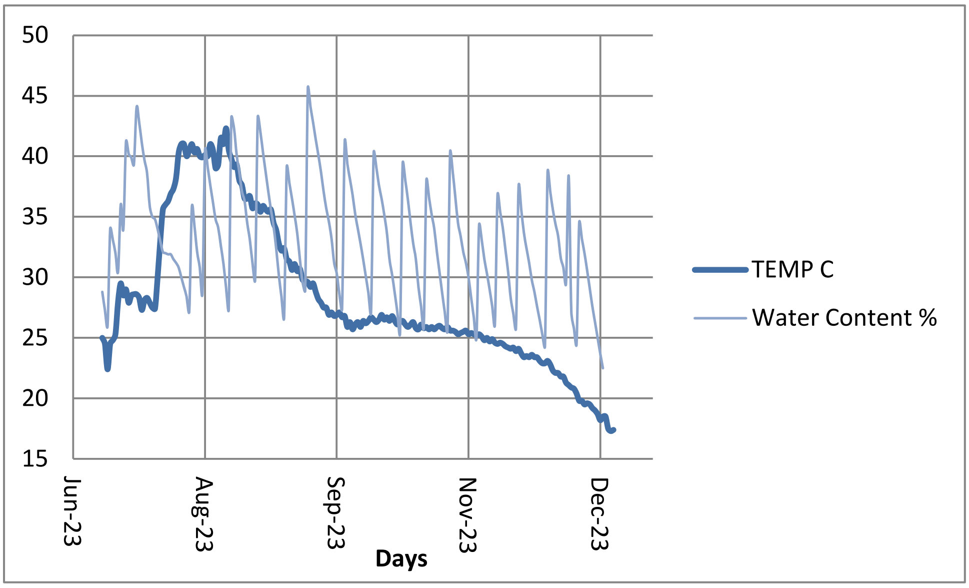


Figure 3.7: The Temp (expressed in C) and water content (expressed in %) inside the Exp.3 at different periods of the study

In the fourth mixture, the temperature reached 45 degrees Celsius, and the decomposition process lasted for 100 days. Additionally, the decomposition temperature exceeded 33 degrees Celsius for more than 60 days, see (Figure 4.8).

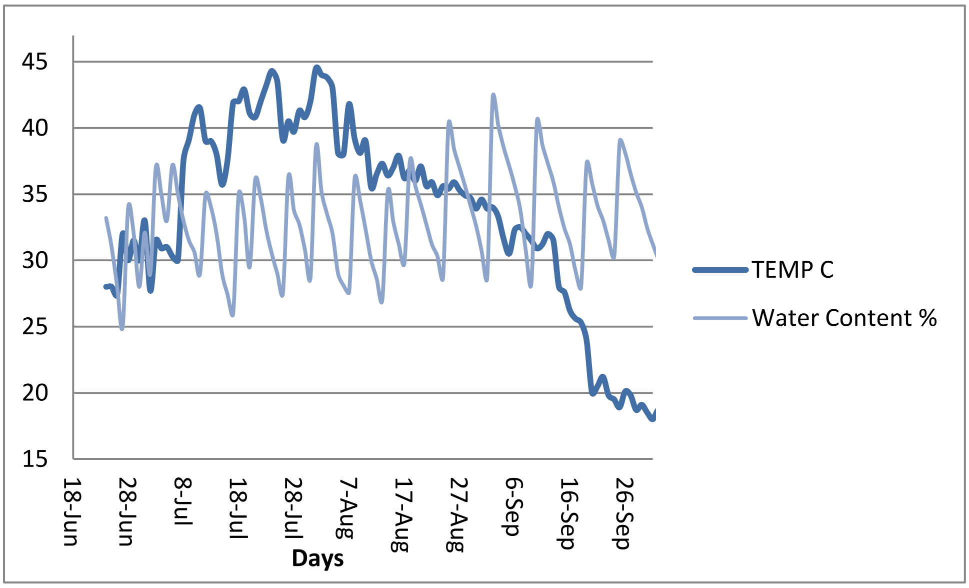


Figure 4.8: The Temp (expressed in C) and water content (expressed in %) inside the Exp.4 at different periods of the study.

4.3.2 Water Quantity Measurements

The water quantity was measured frequently through the addition of the water and measured to the water content of the mix. The results of monitoring during the period of the study showed that the water content was around 30-45% in volume in the mix. The approximate rate of water requirement per kilogram of the mixture can vary significantly depending on the quality and composition of the mixture. However, the general water consumption rate per kilogram of the mixture is considered to be around 6 liters in many cases. It should be noted that this figure may vary depending on the production conditions and the precise composition of the mixture.

4.3.3 Water Quantity Estimation

The Water Quantity test was performed through Measurements of all pans in each corner and at the center. The test was conducted within all months under the climatic conditions that have been identified in (Table 4.5).

Table 4.5: Temperature in ºC, water content in %, and Water quantity in liter (according to the measurements).

	Experiments	Month1	Month2	Month3	Month4	Month 5-7
Temperature	Exp. 1	28.6	40	29.65	26.1	mature
	Exp. 2	28.2	38.2	35.2	25.5	mature
	Exp. 3	29.5	41.1	32.4	26.5	25-21
	Exp. 4	36	39.7	32.9	19.8	mature
Ref Temp C°		15°-40°	40°-65°	15°-40°	Ambient temperature	
Humidity	Exp. 1	33.7	37	38	32	mature
	Exp. 2	37.2	33.8	32.8	33.6	mature
	Exp. 3	35.1	34.1	36	33.8	32.6-31.2
	Exp. 4	31.9	31.9	34.7	32.4	mature
Ref humidity		Variable depended on the humidity of input material (30%-60%)				
Water quantity	Exp. 1	12	6	7.5	6.5	mature
	Exp. 2	12	5	7.5	7	mature
	Exp. 3	14	6.5	5.5	5.5	+13
	Exp. 4	13	6.75	4.5	6	mature

For each pan, the initial weight and the remaining weight were recorded as shown in (Table 4.6). The Decompose percentage by weight for each pan was calculated by applying the next formula:

Equation 3: Decompose % = (Average final weight / Average initial weight) *100%

Table 4.6: % Decomposition of the four Exp.’s. The table shows the initial weight, remaining weight, and Decomposed weight all expressed in kg units.

Pan No.	Initial Weight	Remaining weight	Decomposed weight	% Decomposition
Exp. 1	4.44	2.84	1.6	36%
Exp. 2	5.55	3.02	2.53	45.5%
Exp. 3	5.55	4.5	1.05	18.9%
Exp. 4	3.33	1.68	1.35	40.5%

4.4 Evaluation of Composite Quality

The following parameters were measured for the final product of the two composting experiments, after maturity since the start of each experiment. These parameters were compared against the PSI standards to make sure that the final product is an environment-friendly product for land application.

In addition to the regular measurements (Temperature, Moisture Content) which are controlled to keep the finished product quality compliant with local and international standards, which were mentioned earlier.

Physical and chemical quality parameters were monitored and recorded before and after the two composting experiments to evaluate the final produced compost quality, adding to bacteriological quality parameters after the composting experiments.

- Physical parameters (Appendix A).
- Chemical parameters (Appendix B).

4.4.1 Physical parameters.

The evaluation of compost quality has mainly been based on physicochemical properties. The resulting compost's most relevant physical parameters are analyzed in the present study.

4.4.1.1 pH, EC, and Moisture Content Measurements

In the study, some Physical parameters were measured, such as the EC, moisture content, and acidity (pH) tested time after the composting for the product. The following section shows the results compared to the requirements specified in the PSI and the compost Facility Operator's Manual.

Table 4.7: The physical measurements of samples compared to the requirements specified in the PSI and the compost Facility Operator Manual

Parameter	Exp. 1	Exp. 2	Exp. 3	Exp.4	ACCORDING TO (PSI, sludge use of treated sludge and sludge disposal, 2010)	Compost Facility Operator Manual (Geesing, 2009)
EC (µs/cm)	337	260.3	343.3	344.6		
PH	7.24	7.18	7.5	8.44	5-8.5	4.5-8.5
MOISTURE %	34.5	27.5	22.0	32.5	25-40	30-40

4.4.2 Chemical parameters

The evaluation of compost quality has mainly been based on physicochemical properties. The resulting compost's most relevant chemical parameters are analyzed in the present study.

4.4.2.1 The determination of Na+ , K+, Mg+, Ca+, and P

The Concentrations of P, K+, Mg+, Ca+, and P were analyzed and recorded in (Figure 18). The recorded measurements of salts showed low proportions in the samples, according to the Compost Facility Operator Manual (Geesing, 2009), attributed to the scarcity of materials containing these minerals in these blends. However, they can be adjusted as required adding enhancers to these salts in the compost blends, see (Figure 4.9).

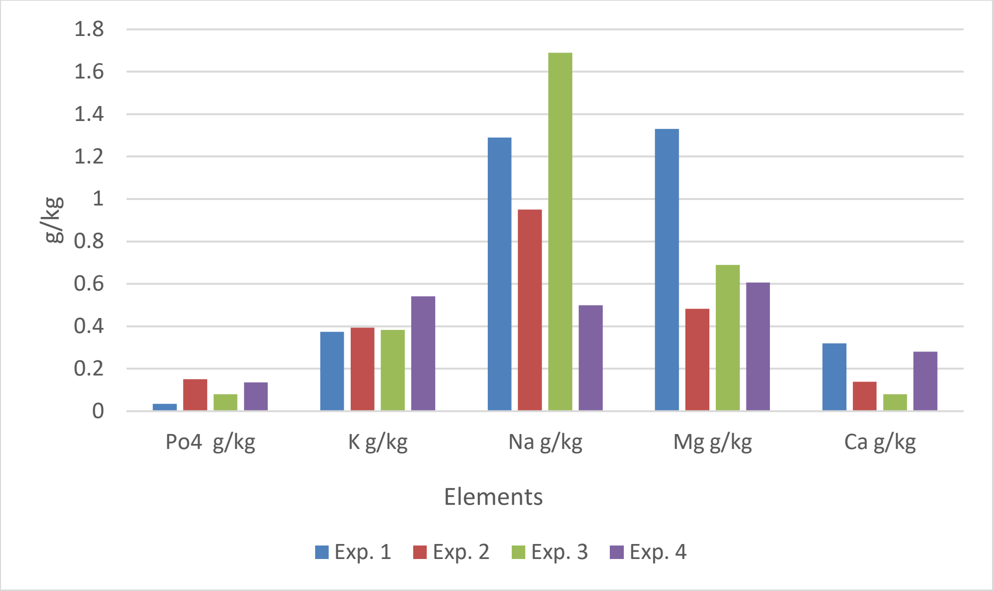


Figure 4.9: The Concentration of P, K+, Mg+, Ca+, and P. (g/kg) for the sampling including Exp.1, Exp.2, Exp.3 and Exp.4.

4.4.2.2 Total nitrogen was determined by analyzing the organic and ammonia nitrogen using the Kjeldahl method.

The total nitrogen yield achieved the required percentage as specified in the compost Facility Operator Manual (0.3-1.5) %, which was crucial in achieving an acceptable C: N ratio. Also, it results in a good reaction, as shown in (Figure 4.10).

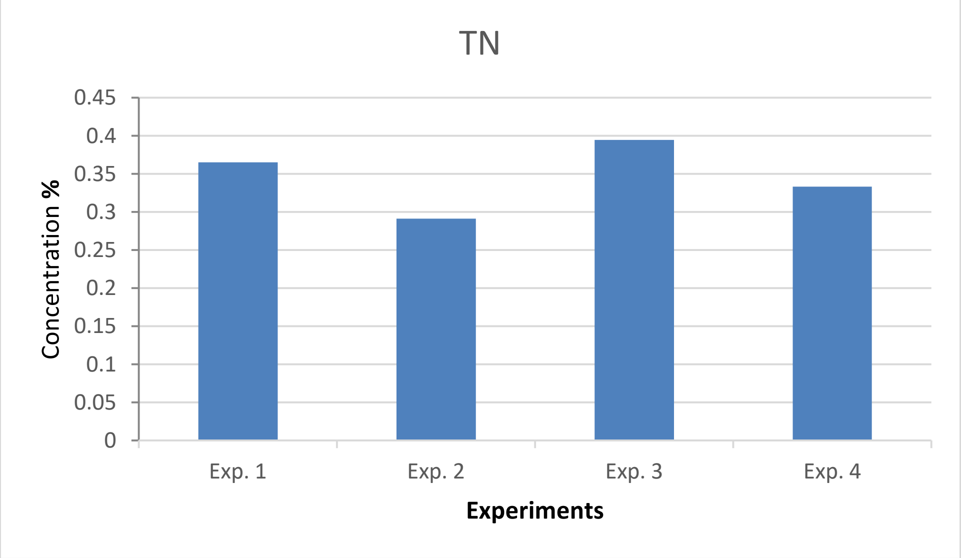


Figure 4.10: Concentration of TN (%) for the sampling including Exp.1, Exp.2, Exp.3 and Exp.4.

4.4.2.3 Total Organic Carbon and Organic Matter

The mean values of total organic carbon (TOC) and organic matter (OM) are shown in (Figure 4.11). As it was observed the TOC concentration in the produce compost was between 13.5-19% and the OM concentration was between 23-32.5 %. The results showed a reduction in the TOC concentration during the treatment process with an average of 3.5% to 24% for the products Exp.1, Exp.3, and Exp.4, while increasing TOC for the product Exp.2 an average of 39%.

Results of C/N analysis for the first stage raw mixtures ranged from 23% to 30% as listed in (Table 4.8), and results of C/N for finished compost of mix No. (Exp.1, Exp.3, and Exp.4) between 1:18 and 1:13.9. and where C/N for finished compost from mix Exp.2 was 1:25.9 which is considered an indication of good cure compost where the preferred range of finished compost is more than 1:25. Less ratio for finished compost explained by the microorganisms multiply rapidly and consume carbon as a food source and nutrients to metabolize and build proteins. The analysis presented that compost Exp. 2 had high organic-matter content this is considered an indicator of high-quality compost.

Table 4.8: TOC measurements of samples compared to the requirements specified in the PSI and the compost Facility Operator Manual

Parameter	Exp. 1	Exp. 2	Exp. 3	Exp. 4	ACCORDING TO (PSI, sludge use of treated sludge and sludge disposal, 2010)	Compost Facility Operator Manual (Geesing, 2009)
OM%	28.9	32.46	25.15	23.04	MIN 35 MIN25	>20%
TOC%	16.76	18.83	14.59	13.36		
C: N	1/18	1/25.8	1/13.9	1/16.3	1/25	1/30

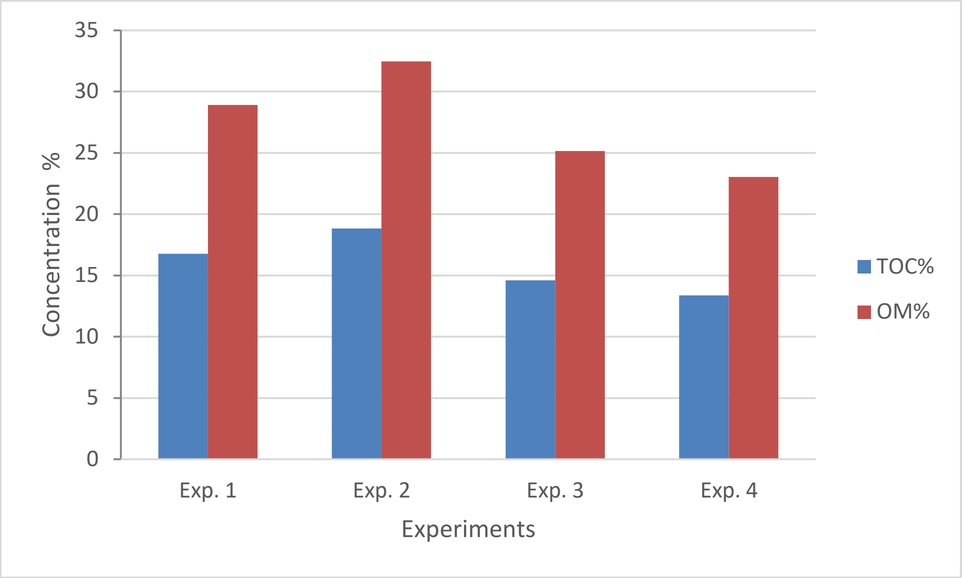


Figure 4.11: Concentration of TOC and OM (%) for the sampling including Exp.1, Exp.2, Exp.3 and Exp.4.

4.4.2.5 Humic Acid Determination in some materials:

The term "maturation degree" can describe the extent of completion of the biological decomposition process in organic compost. The maturation degree is determined when the biological breakdown of organic materials in the compost is completed. The maturation degree depends on several factors such as the ratio of carbon to nitrogen, temperature, and the content of advanced organic materials. Compost is considered mature when it has reached a sufficient level of maturation to provide multiple benefits to plants and soil, such as increased nutrition, improved soil structure, and reduced risk of absorbing toxic substances. Regarding humic acid, the maturity level in the compost is below 5 and above 1, indeed, this means that the compost in this experiment has reached the required and permissible maturity level according to Palestinian standards.

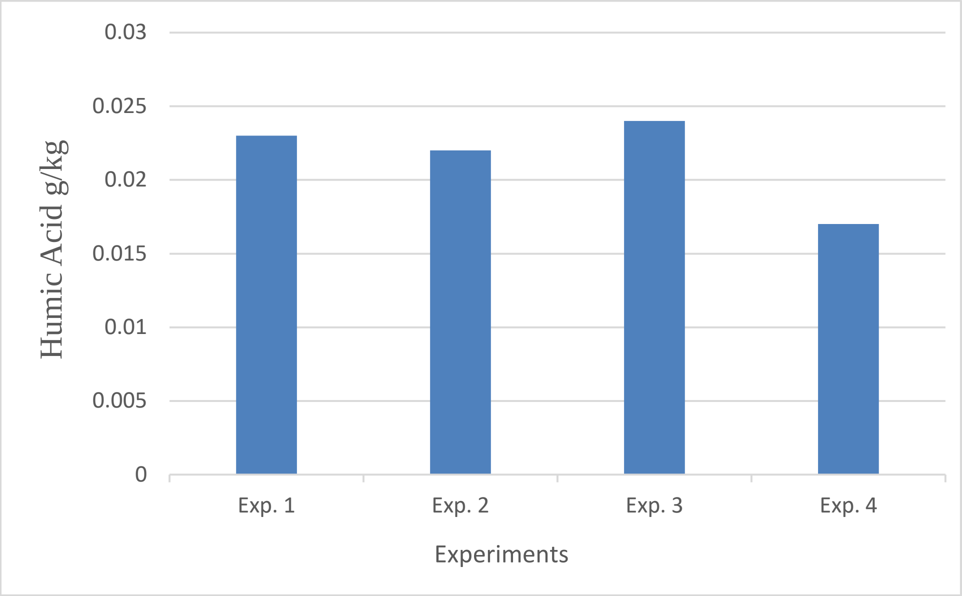


Figure 4.12: Concentration of Humic acid (g/kg) for the sampling including Exp.1, Exp.2, Exp.3 and Exp.4.

4.4.2.6 SAR :

The SAR (Sodium Adsorption Ratio) equation determines the ratio of dissolved sodium in water compared to other cations such as calcium and magnesium in the soil.

The SAR (Sodium Adsorption Ratio) value is used as an indicator of soil salinity and the impact of sodium on soil structure, water retention, and nutrient availability for plants. SAR values below 10 are considered suitable for agriculture, while higher values may indicate soil salinity issues and sodium's negative effects on plant growth. The values were calculated based on the following equations:

Equation 4: SAR= $Na^{+}/\sqrt{(Mg^{+2} + Ca^{+2}/2)}$ (Suarez, 2009)

Table 4.9: SAR Calculation of Experiments

Parameters	Exp. 1	Exp. 2	Exp. 3	Exp. 4
SAR	**1.580**	**1.910**	**2.967**	**0.857**

Based on the results above, it was found that all compost mixtures do not contain soil salinity problems and are suitable for agriculture.

4.4.2.7 Heavy Metals testing

For the compost stage, all of the heavy metals were analyzed (Cd, Pb, Zn Cu, Cr) as listed in (Table 4.10).

Table 4.10: Heavy Metals measurements of sewage sludge and compost samples compared to the requirements specified in the PSI (PSI, 2010)

Lime	units	Result				Limits of sludge (PSI, 2010)	Limits of compost(PSI, 2019)
		Sludge	Exp.1	Exp.2	Exp.4		
Copper Cu	**mg/kg**	27.3	16.33	11.9	7.66	Max 1500	Max 600
Lead Pb	**mg/kg**	65.93	58.2	54.5	53.26	Max 300	Max 300
Cadmium Cd	**mg/kg**	0.00	0.00	0.00	0.00	Max 40	Max 10
Zinc Zn	**mg/kg**	63.33	22.66	30.2	11.4	Max 2800	Max 2500
Chromium	**mg/kg**	5.2	3.86	3.86	5.0	Max 900	Max 200

Heavy metals refer to a group of chemical elements that are problematic due to their inability to decompose, as they typically only undergo changes in oxidation state. These metals pose significant risks to human health and can disrupt the food chain at both terrestrial and aquatic levels. While they naturally occur in the environment, their accumulation becomes a concern when concentrations surpass defined thresholds. This accumulation can occur in plant tissues (such as fruits and roots) or in vital organs (including the liver, brain, and adipose tissue), often leading to long-term, chronic health effects (P. Roman, 2015).

Heavy metals, together with the presence of pathogens, are considered to determine the quality of compost. All heavy metals were tested, and the analysis results were within the limits and found to comply with the required Palestinian standards of (PSI, Organic Fertilizer (Humus) Compost, 2019). Accordingly, the heavy metal content in finished compost qualifies it to be used on land without toxic impacts.

4.5 Biological parameters

Fecal coliform, and total coliform, are considered indicators of compost pathogenicity. fecal coliforms can stay present under aerobic and anaerobic conditions and are usually found in all starting compost piles (Haug, 2018). Since fecal coliform is responsible for some human diseases was analyzed to evaluate if the used method for pathogenic reduction (Heat from compost) is efficient in fecal reduction and qualifies the compost to match with international standards. The pathogens will be considered eliminated when the fecal coliform becomes less than 1000 CFU/ gram dry wt (J. Bonhotal, 2008).

Pathogenic analysis for the composting experiments presented in (Table 4.11) shows that fecal coliform, content in finished compost of experiments No. (1,2,3,4) is 0 so <1000 CFU/g these results comply with the PSI, where the temperature which is considered the main factor for pathogens removal kept within the mesophilic range although the pathogens content complies with the international standard, which could result in the consumption of required nutrients for pathogens growth.

Table 4.11: The bacterial parameters after a composting period using an open pile with an aeration

Materials	Exp. 1	Exp. 2	Exp. 3	Exp. 4	Compost standard
Total coliform	49*100	60*1000	2*100	46*1000	100*3
fecal coliform	0	0	0	0	0

The bacteriological results are in (Figure 4.13), from which it is clear that fecal coliforms were completely not found after completion of composting.

Figure 4.13: The biological results for samples compared with commercial compost sample

4.6 Germination Experiment.

The results describe the sequential emergence of germination and its effect concerning the density of growth and plant characteristics in various fertilizer samples.

1. Germination Emergence:

Germination first appeared in the first fertilizer sample, followed by its emergence in a sample of commercial fertilizer.

Subsequently, germination occurred in the second and fourth samples, and finally in the other sample of commercial fertilizer.

2. Germination Density:

Germination density began to manifest clearly in the second sample, It was the highest, then increased in the fourth sample, The first sample with commercial fertilizer followed them.

3. Leaf Density and Size:

Higher leaf density and larger leaf size were observed in the second and fourth samples compared to the first and commercial fertilizer samples.

Exp.1	Exp.2	Exp.3	Exp.4
			

Figure 4.14: Leaf Density and Size in Exp.s

4. Stem Length:

Stem length was better in the second, and fourth, compared to commercial fertilizer samples and first samples.

5. Root Density:

The sample with the highest root density is preferable for plants, as high root density indicates a strong and healthy root system. However, other factors such as root distribution and depth must be considered. In this study, root density in the second sample was found to be the best compared to the other samples, followed by the fourth sample, the commercial fertilizer samples, and the first sample.

Figure 4.15: Root Density in Exp.s

From the results, it can be inferred that the second fertilizer sample was the most effective in enhancing growth and germination, followed by the fourth sample, and then the first with commercial fertilizer. These results reflect the impact of different fertilizer components on plant growth and development.

Figure 4.16: Plant Growth and Development in Exp.s

Mixtures 1, 2, and 4 exhibited production at a time lower compared to mixture 3 due to their high Azolla content. This high Azolla content led to problems such as loss of organic matter, longer production time, and difficulties in moisture control, resulting in issues like rot or irregular fermentation.

The second mixture offers the potential for faster production compared to the other mixtures mentioned. This could be advantageous when the objective is to quickly obtain large quantities of fertilizer. Moreover, it guarantees high quality by fully decomposing the materials under proper process conditions. Therefore, it is important to balance productivity and quality when deciding on the appropriate mixture for the production process.

In the fourth batch, we added Opuntia instead of Azolla to the mixture, and it turned out to be a beneficial addition to the compost. This led to improved decomposition time and helped us achieve the desired compost quality.

Chapter Five:

Conclusions and Recommendations

5.1 Conclusions

This research demonstrates the method that aided in the design, operation, and control of diverse composting piles which is achieved for the recycling of sewage sludge, which can further be converted into fertilizers, such as:

- Exp. 1: (1Sludge:1Azolla:2Palm:10%soil)
- Exp. 2: (2Sludge:1Azolla:2Palm:10% soil)
- Exp. 3: (1Sludge:2Azolla:2Palm:10% soil)
- Exp. 4: (1Sludge:3Palm:2 Opuntia:10% soil)

Exp.'s 1, 2 and 4 showed lower time production potential than Exp. 3

In the fourth Exp., Opuntia was added instead of Azolla to the mixture, which in turn proved to be a beneficial addition to the compost. This resulted in good outcomes in terms of decomposition time and achieving the desired compost quality.

The recorded measurements of salts showed low proportions in the mixes, attributed to the scarcity of materials containing these minerals in these blends. However, they can be adjusted as required by adding enhancers to these salts in the compost blends.

The total nitrogen yield achieved the required percentage as specified in the compost Facility Operator Manual, which played a crucial role in achieving an acceptable C: N ratio. Also, it results in a good reaction.

All heavy metals were tested and found to comply with the required Palestinian standards

Regarding humic acid, the compost in this experiment has reached the required and permissible maturity level according to Palestinian standards.

The second Exp. was the most effective in enhancing growth and germination, followed by the fourth, and then the first with commercial fertilizer.

5.2 Recommendations:

Further large-scale pilot studies are justified to explore the viability of composting sludge and biosolids generated from wastewater treatment plants (WWTPs) in Palestine, following successful outcomes observed in this study. Composting effectively reduces substantial quantities of sludge from WWTPs.

Sustainable sewage sludge disposal is of utmost importance and requires immediate attention. This issue has garnered sufficient focus from responsible governmental officials in the municipality of Jericho City, Public awareness and community outreach should be integral components of any solid waste management program to promote acceptance and cooperation.

The use of simulation programs in blending management processes sludge in future studies encourages technological advancement and innovation, thereby enhancing resource efficiency and providing innovative and sustainable solutions in agriculture and the environment. Additionally, this reduces costs associated with materials and equipment needed for real-field experiments.

Lastly, the Ministry of Agriculture should promote the adoption of composting among farmers to enhance soil properties and explain the impacts of using fresh manure or excessive amounts of chemical fertilizers.

References:

A&L Canada Laboratories. (2004), *Compost Management : Compost Analysis for Available Nutrients and Soil Suitability Criteria and Evaluation.*

APHA. (2005). *Standard Methods for examination of water and wastewater.* Washington D. C: APHA.

B. Díez, C. P.-A. (2001). Application of denaturing gradient gel electrophoresis (DGGE) to study the diversity of marine picoeukaryotic assemblages and comparison of DGGE with other molecular techniques. In *Applied and environmental microbiology* (pp. 2942-2951).

C. Tognetti, M. M. (2007). Cocomposting biosolids and municipal organic waste: effects of process management on stabilization and quality. In *Biology and Fertility of Soils* (pp. 387-397).

Calculate C/N Ratio. (1996). Retrieved May 2024, from Cornell University website: https://compost.css.cornell.edu/calc/2.html

E. Bazrafshan, M. Z. (2006). Evaluation of microbiological and chemical parameters during wastewater Sludge and Sawdust Co-composting. *Journal of Applied Sciences and Environmental Management.*

Eslamian, S. (2016). Urban Water Reuse. *Nova Yorque: CRC Press Taylor & Francis Group* .

Farmers, P. (2024). *Palm Farmers Cooperative Association In Jericho And Jordan Valley* . Retrieved from http://www.pfca-pal.org/

G. Tchobanoglus, F. B. (2003). Wastewater engineering: treatment and reuse. *American Water Works Association*, 201.

Geesing, J. P. (2009). *Compost facility operator manual.*

Google Earth. (2022). Retrieved Jun 2024, from https://www.google.com/earth/about/

Gray, N. (2010). Water technology: an introduction for environmental scientists and engineers.

Haug, R. (2018). The practical handbook of compost engineering. Routledge.

J. Bonhotal, M. S. (2008). Compost quality assessment for use in horticulture: Impact of the composting process.

J. Lin, Y. S. (2017). Seed-germination response of Leymus chinensis to cold stratification in a range of temperatures, light and low water potentials under salt and drought stresses.

Jericho Municipality. (2021). Retrieved Aug 2023, from service Jericho city org: service@jericho-city.org

K. G. C. d. Amaral, J. C. (2021). In *Evaluation of the environmental life cycle of an STP that employs a low-rate trickling filter as post-treatment of a UASB reactor and different sludge-management alternatives* (p. e2648). Revista Ambiente & Água.

McClintock, N. C. (2004). Production and use of compost and vermicompost in sustainable farming systems.

Municipality, J. (2024). Retrieved from service@jericho-city.org

Muter, O. D. (2022). Soil fertility, technoeconomic, and life-cycle assessment. In *Application of the sewage sludge in agriculture.*

P. Roman, M. M. (2015). *Farmer´ s Compost Handbook.*

Palestinian Water Authority(2024): https://www.pwa.ps/english.aspx

PSI. (2010). sludge use of treated sludge and sludge disposal. *PS:898-2010.*

PSI. (2019). Organic Fertilizer (Humus) Compost. *PS:2652-2019* .

R. Verma, B. M. (2014). *Studies on temperature fluctuation and moisture changes in different methods of composting.*

S. Zhang, Z. Y. (2017). Novel electro-dewatering system for activated sludge biosolids in bench-scale, pilot-scale and industrial-scale applications. In *Chemical Engineering Research and Design* (pp. 44-56).

Suarez, S. L. (2009). A short note on calculating the adjusted SAR index. In *Transactions of the ASABE* (pp. 493-496).

T. Sayara, R. B.-S. (2020). Recycling of organic wastes through composting: Process performance and compost application in agriculture. Agronomy.

T.-J. Hu, G.-M. Z.-L.-Y.-Y. (2007). Use of potassium dihydrogen phosphate and sawdust as adsorbents of ammoniacal nitrogen in aerobic composting process. *Journal of Hazardous Materials,* 736-744.

Toshiya, A. (2024). *History of JICA's Development Assistance to Palestine—Jericho Agro-Industrial Park—.*

V. K. Vishwakarma, P. K. (n.d.). Comparative study on assessment of compost stability through C/N ratio by different composting techniques.

Appendices:

Appendix A: Results of physical parameters

The methods used for measuring and collecting the relevant physical parameters during the study period

1. **pH, EC Measurements**

pH, EC Measurements for Raw Materials

Materials	Sewage sludge	Azolla (wet)	Palm leave (Dry)	Opuntia (Dry)	Compost (standard)	Azolla water	added soil
pH	6.60	7.05	6.05	5.90	5.65	7.60	8.21
EC (µs/cm)	1192	147	369	2.59ms	1137	2.21ms	101.97

pH, EC Measurements for Samples

Materials	Exp.1 (1sludge:1Azolla :2Palm:10%soil)	Exp.2 (2sludge:1Azolla: 2Palm:10% soil)	Exp.3 (1sludge:2Azolla: 2Palm:10% soil)	Exp.4 (1sludge:3Palm:2 Opuntia:10% soil)
pH	7.24	7.18	7.5	8.44
EC (µs/cm)	337	260.3	343.3	344.6

2. Measure Moisture content

step1: weight

Find the initial weight of the sample by weighing the sample before drying

step2: Dry

using furnace, Set parameters (temperature 40C, time 24hr) and dry sample

step 3: calculate LOD

Weigh the sample after drying and compare it to the initial weight to calculate the Loss on Drying.

or using Precisa's Moisture Analyser devise for measuring moisture content

$$M\% = ((m_1 - m_2)/m_1) * 100\%$$

Moisture content Measurements for Raw Materials

Materials	Sewage sludge	Azolla (wet)	Palm leave (Dry)	Opuntia (Dry)	Compost (standard)	added soil
Moisture content %	16.53	88	14.4	12.95	11.11	10.3

Moisture content Measurements for Samples

Materials	Exp.1 (1sludge:1Azolla: 2Palm:10%soil)	Exp.2 (2sludge:1Azolla: 2Palm:10% soil)	Exp.3 (1sludge:2Azolla: 2Palm:10% soil)	Exp.4 (1sludge:3Palm :2 Opuntia:10% soil)
Moisture content %	34.5	27.5	21.2	22.5

Appendix B: Results of chemical parameters

The methods used for measuring and collecting the relevant chemical parameters during the study period

1. The determination of Na+ and K+ by Flame photometric.

Sample preparation

The sample should be liquid, if it solid it is undergoes a digestion to convert it to liquid. Also, it

should be pure, if not filtrate it by using 0.25 or 0.45µm Millipore filter. Finally, if it has a high

concentration, it should be diluted.

Stock Solution Preparation

- If we don’t have a 1000ppm Na or K standards, we can prepare it from nay salt.

Ex. Prepare 1000ppm Na stock solution from NaCl:

ppm = 1mg/ L, 1000ppm = 1 g/L

1g Na * 1mole Na * 1mol NaCl * 58.5g NaCl = 2.54g NaCl,

23g Na 1mol Na 1 mole NaCl

So, weight 2.54g NaCl and dissolve in 100 ml D.W, and transfer it to 1000ml V.F and complete

With D.W to the mark.

Standard Preparation

- Prepare 100ppm from stock solution in 100ml V.F for both sodium and potassium:

$M_1 V_1 = M_2 V_2$

$1000ppm * V_1 = 100ppm * 100ml$

$V_1 = 10ml$

Dilute 10ml of the 1000ppm stock solution to 100ml with D.W

- Prepare 1, 5, 10, 20 and 40ppm standard in 25ml V.F for both sodium and potassium as in above eq.

Procedure

1) Turn on the flame photometer instrument

2) Turn on the fuel

3) Ignite the flame by pressing on the ignition button on the front and let it stabilized for few min.

4) Select the appropriation filter by switching to the alkali element (Na or K)

5) Aspirate a blank and zero the instrument

6) Aspirate the standards and set the display reading accordingly using the fine and course sensitivity controls

7) Aspiration the pre-diluted samples, where it sucked up through a tube and mixed with air and a fuel. As it burns light is emitted the light is focused by a lens and then passes through a filter to be detected and then note the reading.

8) Shut down: aspirate distilled water for (10min), turn off the fuel supplies then turn off the power switch.

1.1 Na+

Na+ Measurements for Raw Materials

Materials	Sewage sludge	Azolla (Dry)	Azolla (wet)	Wood chips	Palm leave (Dry)	Opuntia (Dry)	Compost (standard)	added soil
EC (µs/cm)	**1192**	**6.68ms**	**147**	**462**	**369**	**2.59ms**	**1137**	101.97
Wt. Sample (g)	5.01	2.00	5.03	5.00	5.00	4.94	5.01	5.01
V ml	50	50	50	50	50	50	50	50
nm	48.7	37.3	11.4	10.8	30.8	8.8	57.3	16.7
Mg/l	10.26	7.85	2.40	2.27	6.49	1.75	12.07	3.03
Mg/l * D:F	102.6*	785.49**	24.01*	22.74*	64.86*	1.75	120.67*	3.03
Na g/Kg	1.02	19.64	0.24	0.23	0.65	0.02	1.20	0.03

Na+ Measurements for Samples

Materials	Exp.1 (1sludge:1Azolla:2Palm:10%soil)	Exp.2 (2sludge:1Azolla:2Palm:10% soil)	Exp.3 (1sludge:2Azolla:2Palm:10% soil)	Exp.4 (1sludge:3Palm:2 Opuntia:10% soil)
EC (µs/cm)	**337**	**260.3**	**343.3**	**344.6**
Wt. Sample (g)	5.01	5.2	5.00	5.01
V ml	50	50	50	50
nm	71.1	52.5	93	27.5
Mg/l	12.89	9.52	16.86	4.99
Mg/l * D:F	128.9*	95.18*	168.61*	49.86*
Na g/Kg	1.29	0.95	1.69	0.50

1.2 K+:

K+ Measurements for Raw Materials

Materials	Sewage sludge	Azolla (Dry)	Azolla (wet)	Wood chips	Palm leave (Dry)	Opuntia (Dry)	Compost (standard)	added soil
Wt. Sample (g)	5.01	2.00	5.03	5.00	5.00	4.94	5.01	5.01
V ml	50	50	50	50	50	50	50	50
nm	68.4	139.1	48.1	76.2	46.9	91.1	69.75	13.2
Mg/l	4.95	10.07	3.48	5.52	3.40	6.60	5.05	0.55
Mg/l * D:F	49.54*	1007.39**	34.83*	55.19*	339.66**	6597.62***	505.14**	5.49*
K+ g/Kg	0.50	25.18	0.35	0.55	3.40	66.78	5.05	0.05

K+ Measurements for Samples

Materials	Exp.1 (1sludge:1Azolla:2Palm:10%soil)	Exp.2 (2sludge:1Azolla:2Palm:10% soil)	Exp.3 (1sludge:2Azolla:2Palm:10% soil)	Exp.4 (1sludge:3Palm:2 Opuntia:10% soil)
Wt. Sample (g)	5.01	5.03	5.00	5.00
V ml	50	50	50	50
nm	68.4	139.1	48.1	76.2
Mg/l	4.95	10.07	3.48	5.52
Mg/l * D:F	49.54*	1007.39**	34.83*	55.19*
K+ g/Kg	0.50	25.18	0.35	0.55

2. Total nitrogen was determined by analyzing the organic and ammonia nitrogen using the Kjeldahl method.

DIGESTION

1- Weigh approx. 0.5 g of the homogenized sample. for (sludge, Azolla, Palm leaves, cactus, wood chips)

2- Place the sample into a digestion flask.

3- Add 2 Kjeldahl tablets of 5 g of the Missouri catalyst, 20 mL Sulfuric Acid 98%, and homogenize gently

4- Place the mixture into the digestion/heating block.

5- Heat the mixture (350 – 380 o C) until white fumes and continue heating approx. 3 h.

6- The vapors of water and sulfuric acid are bubbled through a solution of sodium hydroxide (scrubber) to neutralize them.

7- The digestion is finished when the sample turns clear with a slightly blue color.

8- Allow to cool and carefully add about 100 mL of water.

9- Transfer the sample to the distillation unit.

DISTILLATION

1. Sample already digested with sulfuric acid 98%

2. 50 mL of NaOH 50% are added in excess to neutralize the acidic digestion mixture and to convert NH4+ into NH3 (alkaline solution).

3. A stream of water vapor is bubbled into the sample to entrain the NH3 formed.

4. NH3 is condensed.

5. NH3 is captured in 50 mL of boric acid solution 4% with Tashiro’s indicator. The solution will turn from red-violet to green (pH 4.4-5.8). Around 150 mL of condensate is collected in the boric acid solution.

TITRATION

1- Titrate with HCl 0.25 mol/L until the solution becomes slightly violet.

2- Use the volume and concentration of HCl consumed to calculate the nitrogen content and then the % of protein in the sample.

TN Measurements for Raw Materials

Materials	Sewage sludge	Azolla (Dry)	Azolla (wet)	Wood chips	Palm leave (Dry)	Opuntia (Dry)	Compost (standard)*	added soil
Wt. Sample (g)	0.501	0.501	0.500	0.503	0.500	0.501	0.500	0.50
abs	0.637	0.606	0.169	0.500	0.167	0.166	0.193	0.111
Abs after D.F	0.101*	0.103*	0.169	0.068*	0.167	0.166	0.193	0.111
Mg/l	26.58	27.11	44.47	21.58	43.95	43.68	50.79	2.466
mg/l*D.F	132.89	135.53	44.47	107.89	43.95	43.68	50.79	2.466
TN(g/kg)	15.95	16.26	5.34	12.95	5.27	5.24	6.09	0.296
TN %	1.59	1.62	0.53	1.29	0.52	0.52	0.60	0.0296

TN Measurements for Samples

Materials	Exp.1 (1sludge:1Azolla:2Palm:10%soil)	Exp.2 (2sludge:1Azolla:2Palm:10% soil)	Exp.3 (1sludge:2Azolla:2Palm:10% soil)	Exp.4 (1sludge:3Palm:2 Opuntia:10% soil)
Wt. Sample (g)	0.501	0.501	0.500	0.503
abs	1.37	1.092	1.48	1.25
Mg/l	30.44	24.26	32.88	27.77
TN(g/kg)	3.65	2.91	3.94	3.33
TN %	0.93	0.73	1.05	0.82

TN (g/kg) = (N-ppm * V *D.F) / (Wt * 1000)

3. Organic carbon

Walkley-Black chromic acid wet oxidation method

1. Determine the moisture content of the air-dry soil which has been ground to pass a 0.42 mm sieve.

Weigh accurately enough soil to contain between 10 mg and 20 mg of carbon into a dry-tared 250 mL conical flask (between 0.5 g and 1 g for material).

2. Accurately add 10 mL 1 N K2Cr2O7 and swirl the flask gently to disperse the soil in the solution. Add 20 mL concentrated H2SO4, directing the stream into the suspension.

Immediately swirl the flask until the soil and the reagent are mixed. Insert a 200 °C thermometer and heat while swirling the flask and the contents on a hot plate or over a gas burner and gauze until the temperature reaches 135 °C (approximately ½ minute). (. heat must be removed when the digesting solution reaches 135° C as the dichromate thermally decomposes at 150 °C causing significant errors.)

3. Set aside to cool slowly on an asbestos sheet in a fume cupboard. Two blanks must be run in the same way to standardize the FeSO4 solution.

4. When cool (20–30 minutes), dilute to 200 mL with deionized water and proceed with the FeSO4 titration using either the "ferroin" indicator

5- "Ferroin" Titration: Add 10 or 15 drops of Ferroin indicator and titrate with 0.5 N FeSO4. As the end point is approached, the solution takes on a greenish color and then changes to a dark green. At this point, add the ferrous sulfate drop-by-drop until the color changes sharply from blue-green to reddish-grey. (Some matrials adsorb the "Ferroin" indicator and it might be necessary to filter using a rapid filter paper.). If the end point is overshot, add 0.5 or 1.0 mL of 1 N K2Cr2O7 and reapproach the end point drop-by-drop. Correct for the extra volume added. If over 8 mL of the 10 mL dichromate has been consumed, the determination must be repeated with a smaller soil sample.

$M=10/ V_{blank}$

$O.O.C\ \% = ((V_{blank}-V_{sample})*0.3*M)/Wt$

$TOC\% = 1.334 * OOC\%$

$OM\% = 1.724 * TOC\%$

TOC Measurements for Raw Materials

Materials	Sewage sludge	Azolla (Dry)	Azolla (wet)	Wood chips	Palm leave (Dry)	Opuntia (Dry)	Compost (standard)	added soil
Wt. Sample (g)	0.11	0.106	1.02	0.5	0.055	0.501	0.103	0.58
V blank ml	20.9	20.9	20.9	20.9	20.9	20.9	20.9	20.5
V sample ml	10.3	7.5	11.4	5.3	11.8	8.5	9.9	15.4
O.O.C %	13.87	18.20	1.34	4.49	23.82	3.56	15.37	1.292
TOC %	**18.51**	**24.28**	**1.79**	**5.99**	**31.78**	**4.75**	**20.51**	**1.724**
O.M %	31.91	41.86	3.08	10.33	54.79	8.19	35.36	2.972

TOC Measurements for Samples

Materials	Exp.1 (1sludge:1Azolla:2Palm:10%soil)	Exp.2 (2sludge:1 Azolla:2Palm:10% soil)	Exp.3 (1sludge:2Azolla:2Palm:10% soil)	Exp.4 (1sludge:3Palm:2 Opuntia:10% soil)
Wt. Sample (g)	0.145	0.126	0.168	0.113
V blank ml	20.5	20.5	20.5	20.5
V sample ml	8.1	8.4	80	12.8
O.O.C %	12.57	14.11	10.93	10.01
TOC %	**16.76**	**18.83**	**14.59**	**13.36**
O.M %	28.91	32.46	25.15	23.03

*****Temp Room 23c

4. Determination of phosphorus

Samples must be prepared according to (SOP-W-003), (SOP-P-002) AND(SOP-5-002)

1-Pipet aliquots containing 1 to 20mg of orthophosphate into a 25-ml volumetric flask (usually 5mI),

2. Add distilled water to make the volume to 20 mI.

3. Add 4 ml of reagent B.

4. Make to volume with distilled water and mix. The color is stable for 24 hours, the maximum intensity is obtained in 10 min.

5- Prepare a blank with distilled H_2O and 4 mI of reagent B.

6-Calibrate the method using standard P solution in the same manner as above

7- Leave samples to stand for 1.5 hours in summer. 2 hours in winter

8-Measure the absorbance at 882nm.

9-Prepare standard curve for phosphorus from KH2PO4 (cat #P0662) from 1, 2.3.4.5.10, ppm.

For mass analysis into a 2-ml cuvette:

1- 0.4 ml of the sample, 0.32 mi reagent B. 1.28 ml D.H2O into the Cuvette

2- Shake it well, and leave it for 1.5 2 hours

3- Measure the absorbance at 882 nm.

4- Apply a standard curve for 1. 2. 3. 4. 5, 10, 20 ppm.

PO4 Measurements for Raw Materials

Materials	Sewage sludge	Azolla (Dry)	Azolla (wet)	Wood chips	Palm leave (Dry)	Opuntia (Dry)	Compost (standard)	added soil
Wt. Sample (g) – /50ml D.W	5.02	2.99	5.02	5.06	1.2	5.00	5.01	0.5
Abs at(882nm)	0.247	1.9	0.038	0.605	0.103	0.089	0.316	0.004
P mg/l	3.259	25.07	0.50	7.98	1.36	1.174	4.17	0.201
P mg/l * D.F	*32.59	25.07	0.50	7.98	1.36	*11.74	4.17	0.201
P g/Kg	0.324	0.419	0.005	0.078	0.056	0.117	0.041	0.0201

*D.F (1:10)

PO4 Measurements for Samples

Materials	Exp.1 (1sludge:1Azolla:2Palm: 10%soil)	Exp.2 (2sludge:1Azolla:2Palm:10% soil)	Exp.3 (1sludge:2Azolla:2Palm: 10% soil)	Exp.4 (1sludge:3Palm:2 Opuntia:10% soil)
Wt. Sample (g) – /50ml D.W	0.5	0.5	0.5	0.5
Abs at(882nm)	0.007	0.03	0.016	0.027
P mg/l	0.351	1.50	0.80	1.35
P g/Kg	0.035	0.15	0.080	0.135

5. Humic Acid Determination in some materials by UV-Vis Spectroscopy Modified Method:

1- The Humic Acid pure sample was taken as reference material.

2- 3.6 g of Humic Acid pure was weighed for calibration curve construction.

3- Diluted into 50 ml of 0.5M NaOH solution.

4- The solution was transferred in two falcon tubes and shaken for 1.5 hrs.

5- Centrifuged at 2000 rpm for 20 min.

6- Each solution was decanted in another tube, and 5 ml of 1% NaOH solution was pipetted on the residue in the original tube and centrifuged.

7- The first supernatant was decanted on the original one for each tube.

8- (0, 0.1, 0.2, 0.4, 0.6, 0.8) % W/V solutions from the above solution in a 50ml volumetric flask (sample dilution was by distilled water).

9- A dilution of 1:100 was prepared for each of the above solutions.

10- The absorbance was measured at 450 nm. using UV-Vis Spectroscopy device.

11- This procedure was repeated for the material test in the same method.

(Ilham Shamia et al, 2017)

Humic Acid Measurements for Raw Materials

Materials	Sewage sludge	Compost (standard)
Wt. Sample (g) /50ml NaOH 0.5	5	5
Abs at(450nm)	0.62	0.057
Humic Acid mg/l	0.418	0.0381
Humic Acid mg/l * D.F	**41.87	**3.816
Humic Acid **g/Kg**	0.418	0.0384

**D.F (1:100)

Humic Acid Measurements for Samples

Materials	Exp.1 (1sludge:1Azolla:2Palm:10%soil)	Exp.2 (2sludge:1Azolla:2 Palm:10% soil)	Exp.3 (1sludge:2Azolla:2 Palm:10% soil)	Exp.4 (1sludge:3 Palm:2 Opuntia:10 % soil)
Wt. Sample (g) /50ml NaOH 0.5	10	10	10	10
Abs at(450nm)	0.1676	0.1607	0.171	0.1202
Humic Acid mg/l	0.235	0.226	0.240	0.169
Humic Acid mg/l * D.F	2.358	2.261	2.406	1.691
Humic Acid g/Kg	0.0235	0.0226	0.0240	0.0169
Abs at(465nm) E4	0.1342	0.1323	0.1382	0.0968
Humic Acid mg/l	0.2124	0.2094	0.2188	0.1532
Humic Acid mg/l * D.F	2.1247	2.0946	2.1880	1.5326
Humic Acid g/Kg	0.0212	0.0209	0.0218	0.0153
Abs at(665nm) E6	0.0137	0.0138	0.0147	0.0099
Humic Acid mg/l	0.1298	0.1308	0.1393	0.0938
Humic Acid mg/l * D.F	1.2985	1.3080	1.3933	0.9383
Humic Acid g/Kg	0.0129	0.013	0.013	0.009
E4/E6 Maturation Degree	1.63	1.60	1.57	1.63

*D.F (1:10)

6. Mg+ And Ca+:

6.1 Mg+:

Procedure:

- 25 ml sample
- 25 ml D.W
- 2 ml of Ammonium buffer
- 1-2 drops of Erichrome blake T indicator
- Titrate with 0.01N EDTA
- Shake continuously and keep titration slowly when you are reaching the end
- point as color will change slowly from purple to blue.

Calculations:

V Mg = V TH - V Ca

Where:

V TH : volume of EDTA required for total titration

V Ca: volume of EDTA required for Ca titration

Mg mg/L= (A*N*1000*C)/B

A: volume of EDTA required for Mg titration

N: Normality of EDTA

C: Equivalent weight of Mg= 12.15

B: Volume of sample

Mg+ Measurements for Raw Materials

Materials	Sewage sludge	Azolla (Dry)	Azolla (wet)	Wood chips	Palm leave (Dry)	Opuntia (Dry)	Compost (standard)	added soil
Wt. Sample (g)	5.01	2.00	5.03	5.00	5.00	4.94	5.01	5.01
A: $V_{Titration}$ ml	2.3	5.2	1.2	0.7	30	25.2	1.6	0.3
B: V sample ml	5	5	5	2.5	5	5	5	10
N of EDTA	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.1
Mg+ mg/L	**55.89**	**126.36**	**29.16**	**34.02**	**729**	**612.36**	**38.88**	**36.45**
Mg+ g/Kg	**0.558**	**3.159**	**0.291**	**0.340**	**7.29**	**6.123**	**0.388**	**0.364**

Mg+ Measurements for Samples

Materials	Exp.1 (1sludge:1Azolla:2Palm:10%soil)	Exp.2 (2sludge:1Azolla:2Palm:10% soil)	Exp.3 (1sludge:2Azolla:2Palm:10% soil)	Exp.4 (1sludge:3Palm:2 Opuntia:10% soil)
Wt. Sample (g)	5.01	5.03	5.03	5.01
A: $V_{Titration}$ ml	1.1	0.4	0.4	0.5
B: V sample ml	10	10	7	10
N of EDTA	0.1	0.1	0.1	0.1
Mg+ mg/L	**133.65**	**48.6**	**69.4286**	**60.75**
Mg+ g/Kg	**1.334**	**0.483**	**0.690**	**0.606**

6.2 Ca+:

Procedure:

- 25 ml sample
- 25 ml D.W
- 2 ml of 2N NaOH
- 2-3 drops of Murexide Pink indicator.
- Titrate with 0.01N EDTA
- Shake continuously and keep titration slowly when you are reaching the end
- point as color will change slowly from purple to blue.

Calculations:

Ca mg/L= (A*N*1000*C)/B

A: volume of EDTA required for Ca titration

N: Normality of EDTA

C: Equivalent weight of Ca = 20.04

B: Volume of sample

Ca+ Measurements for Raw Materials

Materials	**Sewage sludge**	**Azolla (Dry)**	**Azolla (wet)**	**Wood chips**	**Palm leave (Dry)**	**Opuntia (Dry)**	**Compost (standard)**	**added soil**
Wt. Sample (g)	5.01	2.00	5.03	5.00	5.00	4.94	5.01	5.01
A: $V_{Titration}$ ml	1.5	1.9	0.7	0.4	16.5	52	0.5	1
B: V sample ml	5	5	5	2.5	5	5	5	10
N of EDTA	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Ca+ mg/L	**60.12**	**76.152**	**28.056**	**32.064**	**661.32**	**2084.16**	**20.04**	**20.04**
Ca+ g/Kg	**0.600**	**1.904**	**0.279**	**0.321**	**6.613**	**21.095**	**0.200**	**0.200**

Ca+ Measurements for Samples

Materials	Exp.1 (1sludge:1Azolla:2Palm: 10%soil)	Exp.2 (2sludge:1Azolla:2Palm:10% soil)	Exp.3 (1sludge:2Azolla:2 Palm:10% soil)	Exp.4 (1sludge:3Palm:2 Opuntia:10% soil)
Wt. Sample (g)	5.01	5.03	5.03	5.01
A: $V_{\text{Titration}}$ ml	1.6	0.7	0.4	1.4
B: V sample ml	10	10	10	10
N of EDTA	0.01	0.01	0.01	0.01
Ca+ mg/L	**32.064**	**14.028**	**8.016**	**28.056**
Ca+ g/Kg	**0.320**	**0.139**	**0.080**	**0.280**

7. SAR :

$SAR= Na^{+}/ \surd(Mg^{+2} + Ca^{+2} /2)$

SAR Calculate for Raw Materials

	Sewage sludge	Azolla (Dry)	Azolla (wet)	Wood chips	Palm leave (Dry)	Opuntia (Dry)	Compost
Materials							(standard)
EC (µs/cm)	**1192**	**6.68ms**	**147**	**462**	**369**	**2.59ms**	**1137**
Na+ mg/l	10.25	19.64	0.24	0.23	0.65	0.02	1.2
Na+ mequ/l	0.4458	0.8542	0.0104	0.01	0.0282	0.0008	0.0522
Ca+2 mg/l	0.601	0.761	0.28	0.32	6.62	21.09	0.2
Ca+2 mequ/l	0.0599	0.0759	0.0279	0.0319	0.6606	2.1047	0.0199
Mg+2 mg/l	0.558	3.159	0.291	0.34	7.29	6.123	0.388
Mg+2 mequ/l	0.0917	0.5195	0.0478	0.0559	1.1990	1.0070	0.0638
SAR	**1.619**	**1.566**	**0.054**	**0.048**	**0.029**	**0.001**	**0.255**

SAR Calculation of samples

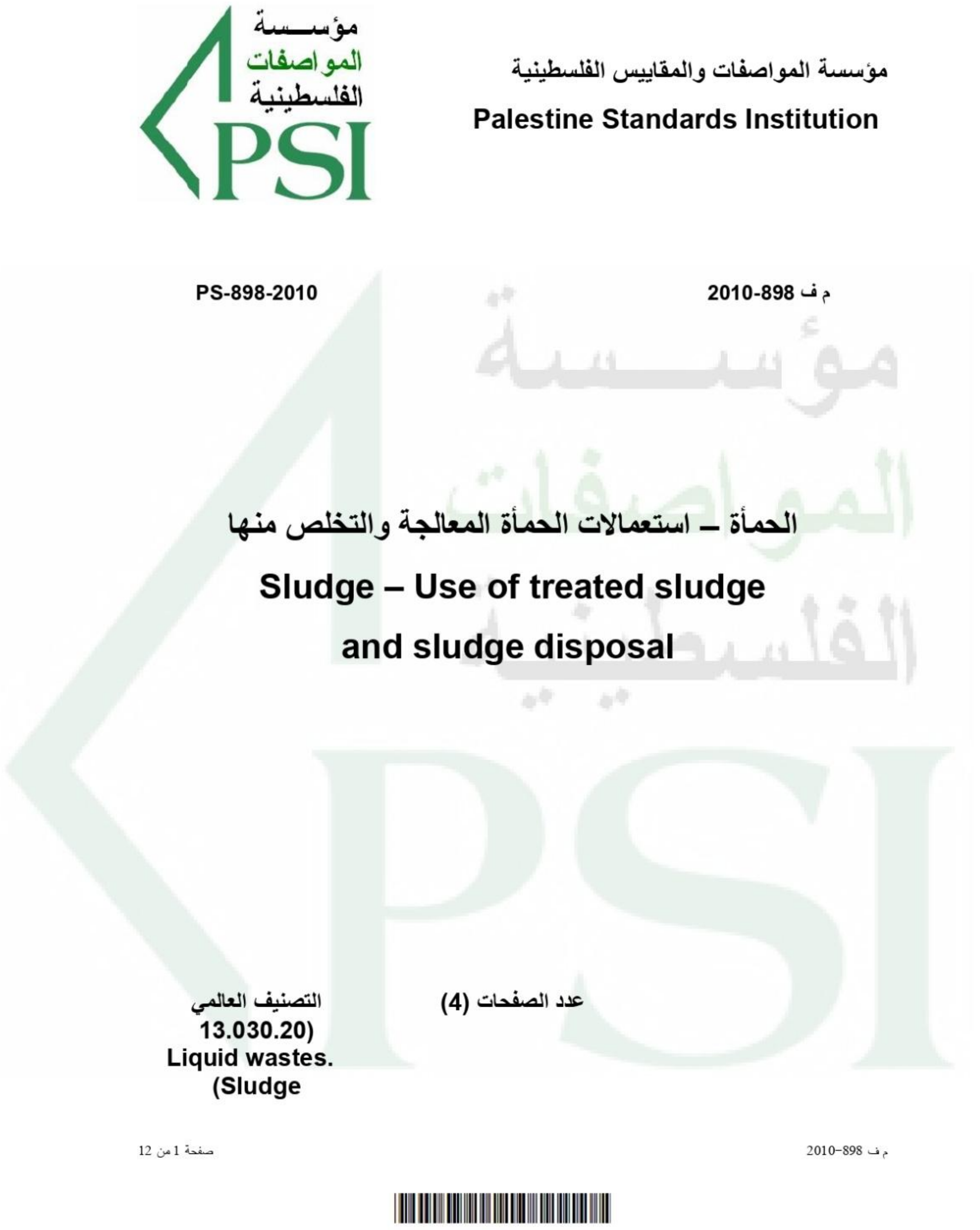
Materials	Mix1 (1sludge:1Azolla:2Palm:10%soil)	Mix2 (2sludge:1Azolla:2Palm:10% soil)	Mix3 (1sludge:2Azolla:2Palm:10% soil)	Mix4 (1sludge:3Palm:2 Opuntia:10% soil)
EC (µs/cm)	337	260.3	343.3	344.6
Na mg/l	128.9	95.18	168.6	49.85
Na mequ/l	5.606785559	4.140060896	7.333623314	2.168334058
Ca+2 mg/l	32.064	14.028	8.016	28.056
Ca+2 mequ/l	3.2	1.4	0.8	2.8
Mg+2 mg/l	133.65	48.6	69.42857143	60.75
Mg+2 mequ/l	21.98190789	7.993421053	11.41917293	9.991776316
SAR	**1.580**	**1.910**	**2.967**	**0.857**

8. Heavy Metals

Heavy Metals Calculation of samples

samples	zink	cadmium	silver	lead	copper	chromium
Sludge(mg/l)	0.950	0	0.399	0.989	0.410	0.078
mg/kg	63.330	0	26.600	65.93	27.33	5.200
S1(mg/l)	0.340	0	0.355	0.873	0.245	0.058
mg/kg	22.666	0	23.666	58.200	16.333	3.866
S2(mg/l)	0.453	0	0.351	0.818	0.179	0.058
mg/kg	30.200	0	23.400	54.533	11.933	3.866
S4(mg/l)	0.171	0	0.399	0.799	0.115	0.075
mg/kg	11.400	0	26.600	53.266	7.666	5.000

AppendixC:



مؤسسة المواصفات الفلسطينية

PSI

مؤسسة المواصفات والمقاييس الفلسطينية

Palestine Standards Institution

PS-898-2010 **م ف 898-2010**

الحمأة – استعمالات الحمأة المعالجة والتخلص منها

Sludge – Use of treated sludge and sludge disposal

التصنيف العالمي
13.030.20)
Liquid wastes.
(Sludge

عدد الصفحات (4)

صفحة 1 من 12 م ف 898-2010

مواصفة فلسطينية الطبعة الأولى

م ف 898-2010

الحمأة- استعمالات الحمأة المعالجة والتخلص منها

Sludge – Use of treated sludge and sludge disposal

المحتويات

الفصل الأول: عام

1-1 المجال

تختص هذه المواصفة بالاشتراطات الواجب توفرها في الحمأة الناتجة عن محطات معالجة مياه الصرف الصحي المنزلية والمراد إعادة استخدامها في تحسين خواص التربة أو كسماد عضوي للأغراض الزراعية، أو المراد طرحها في مكبات النفايات وحسب الأشتراطات المبينة في هذه المواصفة.

1-2 المراجع التكميلية

- مواصفات فلسطينية

المياه العادمة المعالجة م ف 742 – 2003

- مراجع أجنبية

كتاب الطرق القياسية لفحص المياه والمياه العادمة الصادر عن الجمعية الأمريكية للصحة العامة والجمعية الفدرالية الأمريكية لأبحاث المياه ورقابة تلوثها، 2001.

1-3 المصطلحات

لأغراض هذه المواصفة تستخدم المصطلحات والتعريفات الواردة أدناه:

1-3-1 الحمأة:

المواد الصلبة ذات القوام الرطب أو الجاف الناتجة عن عمليات معالجة مياه الصرف الصحي المنزلي قبل معالجتها.

1-3-2 الحمأة الرطبة:

المواد ذات القوام الرطب الناتجة عن عمليات معالجة مياه الصرف الصحي المنزلية والتي يتراوح محتوى المواد الصلبة فيها من 50 % الى 89%.

1-3-3 الحمأة الجافة:

المواد ذات القوام الجاف الناتجة عن عمليات معالجة مياه الصرف الصحي المنزلية والتي لا يزيد محتوى الرطوبة فيها على 10%.

4-3-1 الحمأة المعالجة:

الحمأة التي تعرضت لإحدى طرق المعالجة والقادرة على تحقيق اشتراطات هذه المواصفة.

5-3-1 المياه العادمة:

هي المياه الملوثة بفعل مواد صلبة أو سائلة أو غازية أو كائنات دقيقه نتجت أو تخلفت عن المنازل أو المباني أو المنشآت المختلفة.

6-3-1 وزن الحمأة الجافة:

وزن المواد الصلبة الكلية بعد تجفيف الحمأة عند درجة حرارة (103م° إلى 105م°) للوصول إلى وزن ثابت.

7-3-1 المنتج:

الجهة المسؤولة عن معالجة مياه الصرف الصحي وإنتاج الحمأة.

8-3-1 الموزع:

الجهة المسؤولة عن توزيع ونقل الحمأة إلى المستخدم.

9-3-1 المستخدم:

الجهات أو الأفراد الذين يستخدمون الحمأة.

10-3-1 التجميع:

عمليات جمع الحمأة بعد معالجتها وقبل استخدامها.

11-3-1إضافة الحمأة للتربة:

عملية نثر الحمأة على سطح التربة أو حقن الحمأة تحت سطح التربة أو خلط الحمأة بالتربة.

12-3-1 الأشجار المثمرة:

الأشجار التي تنتج ثماراً للاستهلاك البشري

13-3-1 المحاصيل الحقلية:

محاصيل الحبوب والأعلاف التي تحصد مرة واحدة أو أكثر في العام.

14-3-1 جهة الترخيص:

الجهات المعنية التي تمنح الترخيص باستخدام الحمأة.

15-3-1 الجهات الرقابية:

الوزارات والمؤسسات الرسمية التي تراقب عناصر البيئة و الصحة والسلامة العامة بموجب الأنظمة والقوانين والتعليمات السارية المفعول.

16-3-1 مكبات النفايات:

المواقع المحددة من قبل الجهات المختصة لطرح النفايات الصلبة والسائلة.

17-3-1 الصنف الأول من الحمأة:

الحمأة التي يسمح باستخدامها في كافة المجالات المتعلقة بتطبيق هذه المواصفة والتي تطابق نوعيتها ومحتواها الفيزيائي والكيميائي والجرثومي الاشتراطات والتراكيز المبينة في الجدول (2) من هذه المواصفة.

18-3-1 الصنف الثاني من الحمأة:

الحمأة التي يسمح باستخدامها في تحسين خصائص التربة ويسمح بطرحها في مكبات النفايات والتي تطابق نوعيتها ومحتواها الفيزيائي والكيميائي والجرثومي والتراكيز المبينة في الجدول (2) من هذه المواصفة.

19-3-1 الصنف الثالث من الحمأة:

الحمأة التي يسمح بطرحها في مكبات النفايات فقط والتي تطابق نوعيتها ومحتواها الفيزيائي والكيميائي والجرثومي الاشتراطات والتركيز المبينة في الجدول (2) من هذه المواصفة.

20-3-1 أراضي المراعي:

الأرض المخصصة لزراعة المحاصيل العلفية و/ أو الشجيرات الرعوية.

4-1 الرموز والمصطلحات المختصرة

لأغراض هذه المواصفة تحمل المصطلحات المختصرة المذكورة في الجدول (1) الرموز التالية:

الجدول (1) الرموز والمصطلحات المستخدمة في المواصفة

الرمز	المصطلح المختصر
As	Arsenic
Cd	Cadmium
Cr	Chromium
Cu	Copper
Hg	Mercury
Mo	Molybdenum
Ni	Nickel
Pb	Lead
Se	Selenium
FC	Fecal Coliform
Zn	Zinc

الفصل الثاني: المتطلبات الفنية

1-2 الأشتراطات العامة

1-1-2 يمنع إستخدام الحمأة غير المعالجة منعاً باتاً.

2-1-2 لا يسمح لأية جهة أو شخص باستخدام الحمأة المعالجة ما لم تتحقق الاشتراطات المنصوص عليها بهذه المواصفة.

2-1-3 يقدم المنتج لجهة الترخيص وللمستخدم وللجهات الرقابية وثائق تبين نتائج تحاليل الحمأة المعالجة من جهة معتمدة وفق حيثيات هذه المواصفة.

2-1-4 على المستخدم الحصول على التراخيص اللازمة من خلال جهات التراخيص وتوفير كافة البيانات اللازمة بما فيها تحديد موقع إنتاج وإستخدام الحمأة المعالجة ومصادر المياه القريبة ونوعية التربة في موقع الإستخدام والمحاصيل التي سيتم زراعتها. كما ويجب تجديد هذه التراخيص مره كل سنتين وللجهات الرقابية حق إلغاء أو تعديل التراخيص في حال وجود مخالفات.

2-1-5 على المنتج الاحتفاظ بسجلات خاصة ولمدة لا تقل عن خمس سنوات تبين كميات ونوعية الحمأة المنتجة وطرق معالجتها وتداولها لإبرازها عند الطلب وبحسب حيثيات هذه المواصفة.

2-1-6 على المنتج والمستخدم وضع إشارات إرشادية في مواقع تجميع و/أو إستخدام الحمأة.

2-1-7 إذا تطلب الأمر تجميع الحمأة المعالجة قبل الاستخدام، فيجب أن يتم ذلك في مواقع مغطاة وذات ارضية وجوانب غير نفاذة و/ أو مبطنة وبطريقة لا تؤثر سلباً على خواصها وعلى عناصر البيئة المحيطة وبحيث لا تتجاوز مدة تجميعها ثلاث سنوات.

2-1-8 يمنع تجميع الحمأة المعالجة بالقرب من الأودية والمواقع المعرضة للفيضانات وقنوات الري والمسطحات المائية والمواقع التي تؤثر سلباً على المياه الجوفية والسطحية.

2-1-9 في حالة استخدام الحمأة المعالجة للأغراض الزراعية تضاف للأرض خلال شهري كانون الأول وكانون الثاني في حالة الأشجار المثمرة، وخلال شهري أيلول وتشرين الأول للمحاصيل الحقلية والمراعي، وقبل عملية الزراعة بأسبوع في المناطق المروية.

2-1-10 لا يسمح باستخدام الحمأة المعالجة لتسميد الأراضي المزروعة بالخضروات، وكذلك المنتزهات والحدائق المنزلية والمسطحات الخضراء القريبة من التجمعات السكانية والمواقع التي قد يرتادها العامة. كما ولا يسمح باستخدامها في تسميد أراضي مزروعة بمحاصيل جذرية مثل الفجل والجزر والبطاطا وغيرها سواء أكانت تؤكل نيئة أو مطبوخة.

2-1-11 على الموزع التقيد بمتطلبات السلامة الصحية والبيئية المعمول بها أثناء نقل الحمأة وهي:

2-1-11-1 وضع علامات على وسائط نقل الحمأة المعالجة بكتابات واضحة.

2-1-11-2 منع التسرب وتدفق السوائل من وسائط النقل أو تطاير الحمأة من السطح.

2-1-11-3 حفظ وسائط النقل في حالة نظافة تامة.

2-1-11-4 تغطية جميع الأحمال عند النقل بحيث لا يكون هناك أي أثر للحمأة المعالجة على جوانب وسائط النقل.

2-1-12 يجب أن تكون عملية إضافة الحمأة المعالجة متجانسة وضمن محددات هذه المواصفة ويراعى في عملية الإضافة ما يلي:

1-12-1-2 تضاف الحمأة المعالجة في المناطق المروية على خطوط الزراعة وتخلط مع الطبقة السطحية من التربة من (10 سم – 20 سم) وقبل أسبوع من الزراعة ولا يوجد وقت محدد للإضافة.

2-12-1-2 تضاف الحمأة المعالجة في المناطق المطرية قبل موسم الأمطار (بدءاً من تشرين أول) وتخلط بالتربة السطحية ويراعى أن لا يزيد إنحدار الأرض على 5%.

3-12-1-2 تضاف الحمأة المعالجة في أراضي المراعي قبل موسم الأمطار (بدءاً من تشرين أول) وتخلط بالتربة السطحية ويراعى أن تكون الحراثة كنتورية وتخلط مع الطبقة السطحية من التربة.

13-1-2 يعتمد معدل إضافة الحمأة المعالجة للتربة على تراكيز العناصر المغذية وغيرها من العناصر والخصائص الواردة بهذه المواصفة.

1-13-1-2 يراعى الحد الأعلى المسموح فيه لتراكم العناصر المغذية وغيرها من العناصر والخصائص الواردة في هذه المواصفة.

2-13-1-2 على مستخدم الحمأة المعالجة التحقق من محتوى التربة من المغذيات والحاجة الفعلية منها للمحصول.

14-1-2 للجهات الرقابية الحق في إجراء الفحوصات اللازمة للمنتجات والمحاصيل المزروعة في الأماكن التي استخدمت فيها الحمأة المعالجة وذلك للتأكد من سلامة المنتجات المزروعة في الأماكن التي استخدمت فيها الحمأة المعالجة وذلك للتأكد من سلامة المنتج وبما لا يؤثر على الصحة والسلامة العامة والبيئة بشكل عام.

15-1-2 على المنتج إعداد خطة لإدارة الحمأة وتقديمها للجهات الرقابية.

16-1-2 ا يسمح بطرح الحمأة بجميع أنواعها في المسطحات المائية والسيول والأودية ومناطق تغذية المياه الجوفية وشبكات الصرف الصحي ويستثنى من ذلك محطات التنقية العامة التي تستقبل محتويات الحفر الامتصاصية المنزلية.

17-1-2 في حال معالجة الحمأة وتعبئتها لغايات البيع يشترط موافقة الجهات الرقابية المختصة. وفي هذه الحالة يمكن الاسترشاد باشتراطات وكالة حماية البيئة الأمريكية والاتحاد الأوروبي و منظمة الصحة العالمية.

18-1-2 في حال الرغبة باستخدام الحمأة المعالجة لأغراض غير واردة في هذه المواصفة (مثل إعادة تأهيل مواقع المقالع والمناجم وغيرها) يشترط قبل الاستخدام إجراء دراسات فنية متكاملة وتقديمها للجهات الرقابية و لجهة الترخيص للموافقة عليها.

2-2 الاشتراطات الصحية والبيئية

1-2-2 يمنع إستخدام الحمأة المعالجة في الحالات التي تؤثر سلباً على نوعية المياه الجوفية والسطحية بما في ذلك الأودية ومشاريع الحصاد المائي والمناطق المعرضة للفيضانات.

2-2-2 يحق للجهات الرقابية في بعض الحالات الخاصة فرض قيود إضافية عن تلك القيود المذكورة في هذه المواصفة إذا ارتأت أن ذلك ضرورياً للحفاظ على الصحة والبيئة والسلامة العامة.

2-2-3 يجب على المنتج والمستخدم توفير الظروف الصحية واتخاذ تدابير السلامة العامة والصحة المهنية للمتعاملين مع الحمأة.

2-2-4 على المنتج و المستخدم الالتزام بمتطلبات الرعاية الصحية الأولية والتطعيم الأولي والدوري للعاملين ضد الأمراض والأوبئة وإبراز ذلك للجهات الرقابية عند الطلب.

2-2-5 يراعى في عمليات تجميع واستخدام الحمأة المعالجة الالتزام بتوفير ظروف ملائمة لمنع تكاثر الحشرات الناقلة للأمراض.

2-2-6 يجب خلط الحمأة المعالجة بالتربة خلال مدة لا تتجاوز يومين من موعد الإضافة.

2-2-7 يمنع إستخدام الحمأة المعالجة لغايات استصلاح الأراضي في المناطق التي تزيد معدلات إنحدارها على 15%.

2-2-8 في حالة إضافة الحمأة المعالجة في مناطق قريبة من التجمعات السكانية يجب أن لا تقل المسافة بين موقع الإضافة والتجمعات السكانية عن 250 م.

2-2-9 لا يسمح باستهلاك الثمار التي تسقط أو تلامس الأرض التي تمت إضافة الحمأة المعالجة لها.

2-2-10 لا يسمح برعي الماشية قبل مرور فترة شهرين على إضافة الحمأة المعالجة.

2-2-11 يجب الالتزام بوضع لافتات إرشادية عامة على الأرض التي تمت إضافة الحمأة المعالجة لها بهدف تحسين نوعية التربة لبيان خطورة الدخول إليها.

2-2-12 يراعى استخدام الطرق الميكانيكية قدر الإمكان عند إضافة الحمأة المعالجة للتربة.

2-3 الإشتراطات الفنية

2-3-1 يجب معالجة الحمأة قبل إستخدامها بحسب طرق المعالجة المذكورة بهذه المواصفة وأية طريقة معتمدة أخرى.

2-3-2 يجب أن تحقق الحمأة التي يتم التخلص منها في مكبات النفايات شروط هذه المواصفة.

2-3-3 يجب فحص خصائص التربة قبل إضافة الحمأة المعالجة للمرة الأولى.

2-3-4 تصنف الحمأة إلى ثلاثة أصناف : صنف أول وصنف ثاني وصنف ثالث، لغايات تطبيق هذه لمواصفة.

2-3-4-1 يسمح باستخدام الحمأة ذات الصنف الأول كسماد عضوي للأغراض الزراعية وكذلك لأغراض تحسين التربة.

2-3-4-2 يسمح باستخدام الحمأة ذات الصنف الثاني لأغراض تحسين خواص التربة فقط.

2-3-4-3 يسمح بطرح الحمأة التي تحقق متطلبات الصنف الأول والثاني والثالث في مواقع مكبات النفايات.

2-3-5 يمنع إضافة الحمأة المعالجة والتي مواصفاتها محددة في الجدول (2) بمعدلات تتجاوز (6 طن متري / هكتار سنوياً).

6-3-2 الجدول (2) والجدول (3) يبينان على التوالي الحدود القصوى لتراكيز العناصر والمعالم الأخرى الواجب توافرها في الحمأة المعالجة بالإضافة للمعدلات القصوى السنوية والحدود التراكمية لإضافة العناصر الموجودة فيها.

الجدول (2) الحدود القصوى المسموح بها في الحمأة

العنصر والمعالم الأخري	الرمز	التركيز / صنف الحمأة ملغم/كغم وزن جاف (باستثناءالمشار إليها)		
		الصنف الأول	الصنف الثاني	الصنف الثالث
الزرنيخ	As	41	75	75
الكادميوم	Cd	40	40	85
الكروم	Cr	900	900	3000
النحاس	Cu	1500	3000	4300
الزئبق	Hg	17	57	57
الموليبدنوم	Mo	75	75	75
النيكل	Ni	300	400	420
السلينيوم	Se	100	100	100
الرصاص	Pb	300	840	840
الخارصين	Zn	2800	4000	7500
مستوي الرطوبة	---	*10	*50	---
بكتيريا القلون البرازية	FC	**1000	**2000000	---
السالمونيلا	--	***3	--	---
بيوض الديدان المعوية الحية	---	***1	---	---
الفيروسات العوية	---	****1	---	----

ملاحظات على الجدول (2)

*نسبة مئوية.

** العدد الأكثر إحتمالاً / غرام أو وحدة تكوين المستعمرة / غرام.

*** عصية / غرام جاف.

**** وحدة / 4 غرام جاف.

الجدول (3) المعدلات القصوى السنوية والحدود التراكمية لإضافة العناصر الموجودة في الحمأة المعالجة

العنصر	الرمز	معدل الإضافة السنوي للعنصر	الحدود التراكمية القصوى في التربة

		كيلوغرام / هكتار / 365 يوم	كيلوغرام/ هكتار
الزرنيخ	As	1	20
الكادميوم	Cd	1	20
الكروم	Cr	25	500
النحاس	Cu	35	700
الزئبق	Hg	0,85	17
الموليبدنوم	Mo	0,90	18
النيكل	Ni	5	100
السلينيوم	Se	2	40
الرصاص	Pb	11	220
الخارصين	Zn	50	1000

2–4 مستويات معالجة الحمأة

2–5 مستوى معالجة الحمأة للصنف الأول

تتم معالجة الحمأة بإحدى الطرق التالية:

2–5–1 التخمير :

تتم هذه العملية باستخدام وعاء فيه عمود تهوية أو بوضع الحمأة في أكوام تبقي الكتلة الصلبة فيها عند درجة حرارة لا تقل عن (40م°) لمدة (5 أيام) أو بدرجة حرارة الجو لمدة (60 يوم).

2–5–2 التجفيف الحراري:

يتم تجفيف الحمأة بإزالة السوائل منها باستخدام الغازات الساخنة بحيث تنخفض نسبة الرطوبة إلى (10%) أو أقل وأن تصل درجة حرارة الحمأة إلى (80 م°) في نهاية عملية التسخين.

2–5–3 التجفبف الهوائي:

يسمح للحمأة السائلة بأن ترشح و/أو تجفف في أحواض رملية وبحيث لا يزيد سمك الحمأة عن (25 سم) ، ويجب أن تبقي الحمأة في هذه الأحواض لمدة لا تقل عن (45 يوم).

2–5–4 الهضم الهوائي الحراري:

تحريك الحمأة بوجود الأكسجين مع المحافظة على بقاء الظروف الهوائية لمدة(10 أيام) عند درجة حرارة من (55 م° إلى 60 م°) مع خفض ما لا يقل عن (38%) من المواد الصلبة المتطايرة.

2–5–5 أية طريقة أخرى قادرة على تحقيق الاشتراطات الفنية الواردة في هذه المواصفة.

2–6 مستوى معالجة الحمأة من الصنف الثاني

تتم معالجة الحمأة بإحدى الطرق التالية:

2–6–1 هضم الهوائي:

تتم هذه العملية بتحريك الحمأة بوجود الهواء مع المحافظة على الظروف الهوائية لمدة (40 يوم) عند درجة حرارة الجو مع خفض ما لا يقل عن (38%) للمواد الصلبة المتطايرة.

2–6–2 التجفيف الهوائي:

يسمح للحمأة بأن ترشح و/أو تجفف في أحواض رملية وبحيث لا يزيد سمك الحمأة (25سم) ويجب أن تبقي الحمأة في هذه الأحواض لمدة لا تقل عن (30 يوم).

2–6–3 الهضم اللاهوائي:

تتم هذه العملية بعدم وجود الهواء بشرط بقاء الحمأة لمدة لا تقل عن (15 يوم) عند درجة حرارة لا تقل عن (37 م°) أو لمدة لا تقل عن (24 يوم) عند درجة حرارة لا تقل عن (24 م°) مع خفض ما لا يقل عن (38%) من المواد الصلبة المتطايرة.

2–6–4 أية طريقة أخرى قادرة على تحقيق الاشتراطات الفنية الواردة في هذه المواصفة.

2–7 مستوى معالجة الحمأة للصنف الثالث

2–7–1 تكثيف الحمأة بحيث لا يقل تركيز المواد الصلبة فيهاعن (3%).

2–7–2 أية طريقة أخرى قادرة على تحقيق الاشتراطات الفنية الواردة بهذه المواصفة.

الفصل الثالث: الفحوصات

3–1 مراقبة النوعية

3–1–1 يجب أن تكون عينات الحمأة المعالجة التي يتم جمعها لأغراض الفحص المخبري ممثلة (تجميعية) ومن آخر مرحلة من مراحل المعالجة.

3–1–2 يجب أن تكون معدات جمع العينات نظيفة وجافة. وفيما يتعلق بالفحوصات البيولوجية والجرثومية فيجب أن تكون معدات جمع العينات وأواني الحفظ معقمة قبل الاستخدام.

3–1–3 يتم جمع عينات الحمأة المعالجة وحفظها ونقلها وتحليلها خلال مدة زمنية محددة حسب ما هو وارد في كتاب الطرق القياسية لتحليل المياه العادمة الصادر عن الجمعية الأمريكية للصحة العامة والجمعية الفدرالية الأمريكية لأبحاث المياه ورقابة تلوثها، وأي طرق تحليل أخرى معتمدة إذا لم تتوفر في المرجع المشار إليه (مثلاً الدليل الخاص بجمع وتحليل الحمأة الصادر عن الوكالة الأمريكية لحماية البيئة).

3–1–4 يتم إجراء الفحوصات المخبرية اللازمة على عينات الحمأة المعالجة لدى مختبرات فنية معتمدة ومؤهلة من قبل مؤسسة المواصفات الفلسطينية.

3–1–5 يحق للجهات الرقابية تحليل عينات من الحمأة المعالجة والتربة والمحاصيل الزراعية وفق الدورية التي تراها مناسبة.

3–1–6 تكون تكرارية جمع العينات وإجراء الفحوصات الكيميائية والبيولوجية والجرثومية الواردة في الجدول (2) من هذه المواصفة كما هو مبين في الجدول (4).

الجدول (4) كميات الحمأة المنتجة ودورية إجراء الفحوصات

كمية الحمأة التي يتم إنتاجها طن متري/ عام	دورية إجراء الفحوصات من قبل الجهات الرقابية
أقل من 300	مره واحده سنوياً
300 إلى 1500	مره واحده كل ثلاث شهور
1500 إلى 15000	مره واحده كل شهرين
أكثر من 150000	مرة واحده شهرياً

3–2 ضبط جودة الحمأة المعالجة

يقوم المستخدم من خلال مختبرات فنية معتمده ومؤهلة بجمع ثلاث عينات من الحمأة المعالجة وتحليلها للتأكد من نوعيتها ومدى اندراجها مع محددات هذه المواصفة للاستعمال المنشود. ويعتمد المتوسط الحسابي لنتائج تحاليل العينات لأغراض التصنيف وأخذ قرار بالاستخدام.

4 – المراجع

المواصفات عربيه

المواصفة الأردنية 2006/1145 المياه – الحمأة– استعمالات الحمأة المعالجة والتخلص منها.

Appendix D:

مؤسسة المواصفات الفلسطينية
PSI

مؤسسة المواصفات والمقاييس الفلسطينية
Palestine Standards Institution

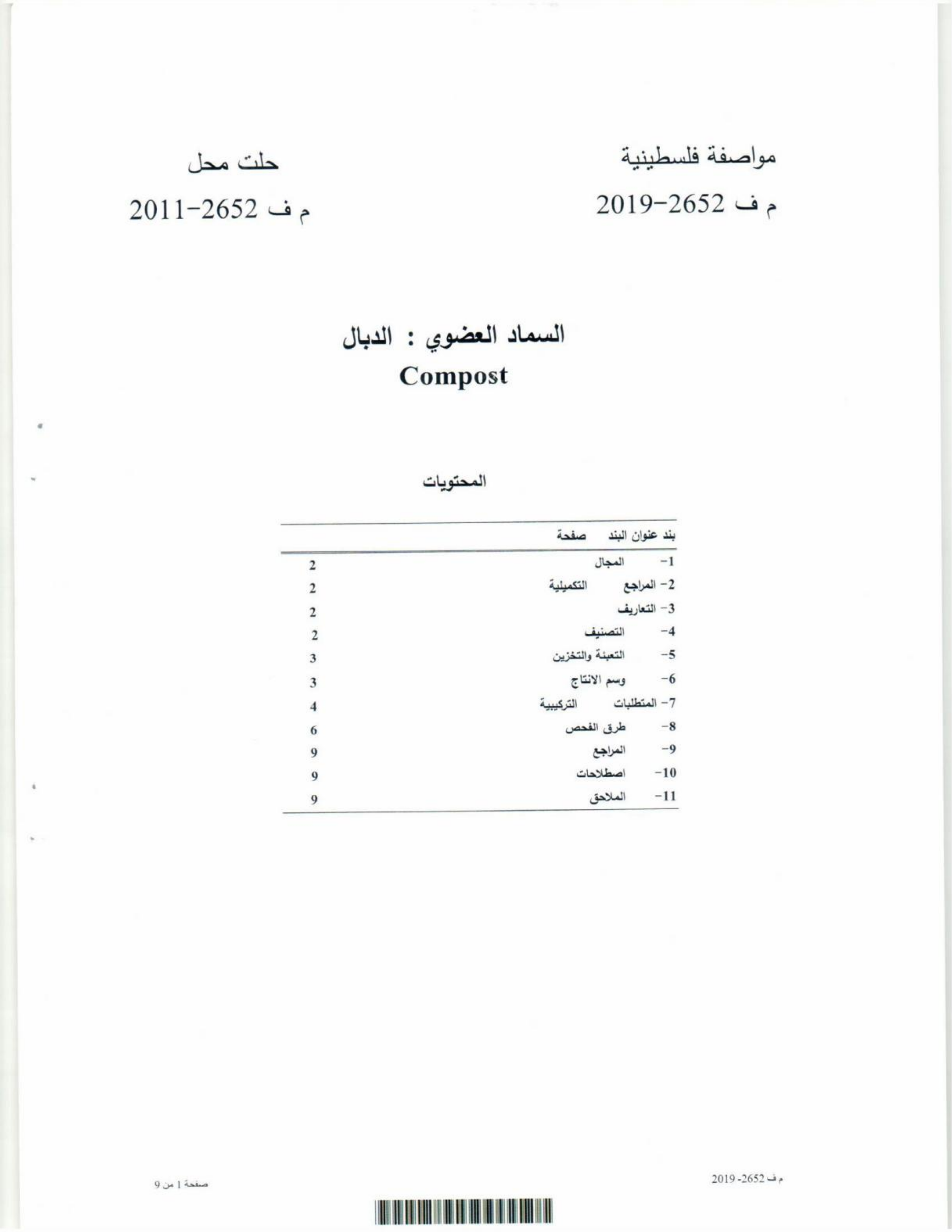
PS-2652-2019

م ف 2652-2019

السماد العضوي الدبال
Compost

التصنيف العالمي
(65.080 الأسمدة)

عدد الصفحات (9)



مواصفة فلسطينية
م ف 2652-2019

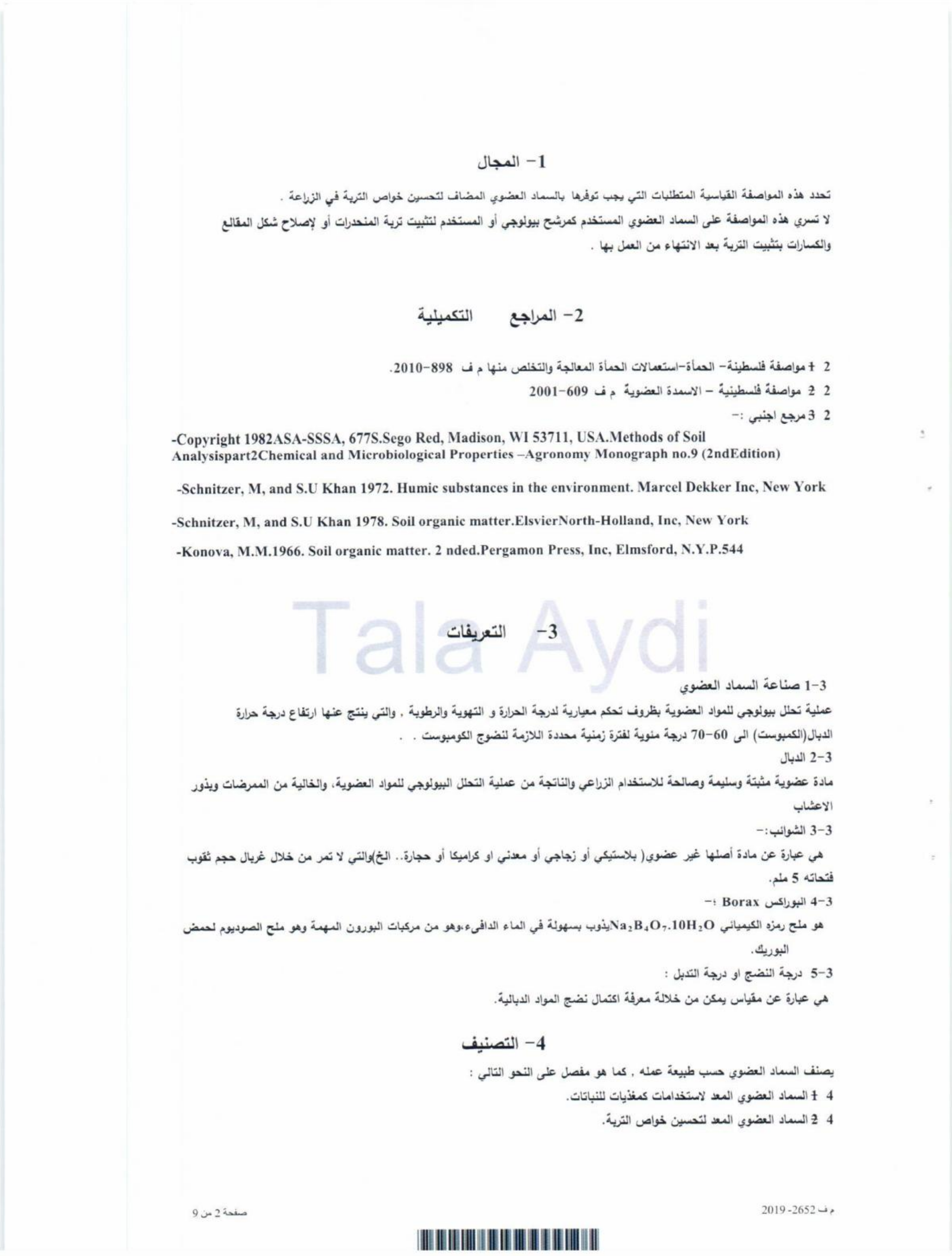
حلت محل
م ف 2652-2011

السماد العضوي : الدبال
Compost

المحتويات

م ف 2652-2019

صفحة 1 من 9



1- المجال

تحدد هذه المواصفة القياسية المتطلبات التي يجب توفرها بالسماد العضوي المضاف لتحسين خواص التربة في الزراعة .

لا تسري هذه المواصفة على السماد العضوي المستخدم كمرشح بيولوجي أو المستخدم لتثبيت تربة المنحدرات أو لإصلاح شكل المقالع والكسارات بتثبيت التربة بعد الانتهاء من العمل بها .

2- المراجع التكميلية

2 ~~1~~ مواصفة فلسطينة- الحمأة-استعمالات الحمأة المعالجة والتخلص منها م ف 898-2010.

2 ~~2~~ مواصفة فلسطينية - الاسمدة العضوية م ف 609-2001

2 ~~3~~ مرجع اجنبي :-

-Copyright 1982ASA-SSSA, 677S.Sego Red, Madison, WI 53711, USA.Methods of Soil Analysispart2Chemical and Microbiological Properties –Agronomy Monograph no.9 (2ndEdition)

-Schnitzer, M, and S.U Khan 1972. Humic substances in the environment. Marcel Dekker Inc, New York

-Schnitzer, M, and S.U Khan 1978. Soil organic matter.ElsvierNorth-Holland, Inc, New York

-Konova, M.M.1966. Soil organic matter. 2 nded.Pergamon Press, Inc, Elmsford, N.Y.P.544

3- التعريفات

3-1 صناعة السماد العضوي

عملية تحلل بيولوجي للمواد العضوية بظروف تحكم معيارية لدرجة الحرارة و التهوية والرطوبة . والتي ينتج عنها ارتفاع درجة حرارة الدبال(الكمبوست) الى 60-70 درجة مئوية لفترة زمنية محددة اللازمة لنضوج الكومبوست . .

3-2 الدبال

مادة عضوية مثبتة وسليمة وصالحة للاستخدام الزراعي والناتجة من عملية التحلل البيولوجي للمواد العضوية، والخالية من الممرضات وبذور الاعشاب

3-3 الشوائب:-

هي عبارة عن مادة أصلها غير عضوي(بلاستيكي أو زجاجي أو معدني او كراميكا أو حجارة.. الخ)والتي لا تمر من خلال غربال حجم ثقوب فتحاته 5 ملم.

3-4 البوراكس Borax :-

هو ملح رمزه الكيميائي $Na_2B_4O_7.10H_2O$يذوب بسهولة في الماء الدافىء،وهو من مركبات البورون المهمة وهو ملح الصوديوم لحمض البوريك.

3-5 درجة النضج او درجة التدبل :

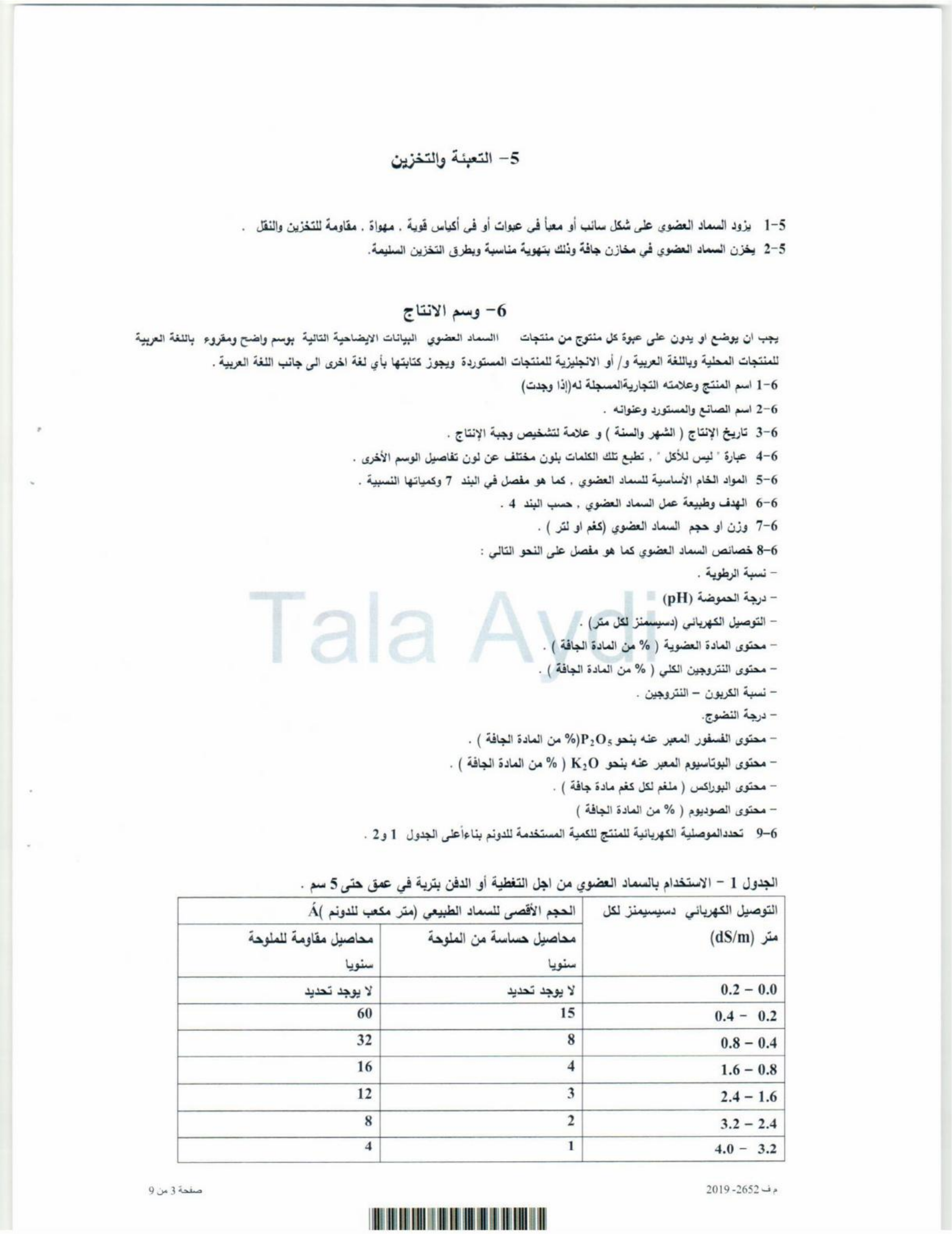
هي عبارة عن مقياس يمكن من خلالة معرفة اكتمال نضج المواد الدبالية.

4- التصنيف

يصنف السماد العضوي حسب طبيعة عمله . كما هو مفصل على النحو التالي :

4 ~~1~~ السماد العضوي المعد لاستخدامات كمغذيات للنباتات.

4 ~~2~~ السماد العضوي المعد لتحسين خواص التربة.



5- التعبئة والتخزين

5-1 يزود السماد العضوي على شكل سائب أو معبأ فى عبوات أو فى أكياس قوية . مهواة . مقاومة للتخزين والنقل .

5-2 يخزن السماد العضوي في مخازن جافة وذلك بتهوية مناسبة وبطرق التخزين السليمة.

6- وسم الانتاج

يجب ان يوضع او يدون على عبوة كل منتوج من منتجات السماد العضوي البيانات الايضاحية التالية بوسم واضح ومقروء باللغة العربية للمنتجات المحلية وباللغة العربية و/ أو الانجليزية للمنتجات المستوردة ويجوز كتابتها بأي لغة اخرى الى جانب اللغة العربية .

6-1 اسم المنتج وعلامته التجاريةالمسجلة له(إذا وجدت)

6-2 اسم الصانع والمستورد وعنوانه .

6-3 تاريخ الإنتاج (الشهر والسنة) و علامة لتشخيص وجبة الإنتاج .

6-4 عبارة " ليس للأكل " , تطبع تلك الكلمات بلون مختلف عن لون تفاصيل الوسم الأخرى .

6-5 المواد الخام الأساسية للسماد العضوي , كما هو مفصل في البند 7 وكمياتها النسبية .

6-6 الهدف وطبيعة عمل السماد العضوي , حسب البند 4 .

6-7 وزن او حجم السماد العضوي (كغم او لتر) .

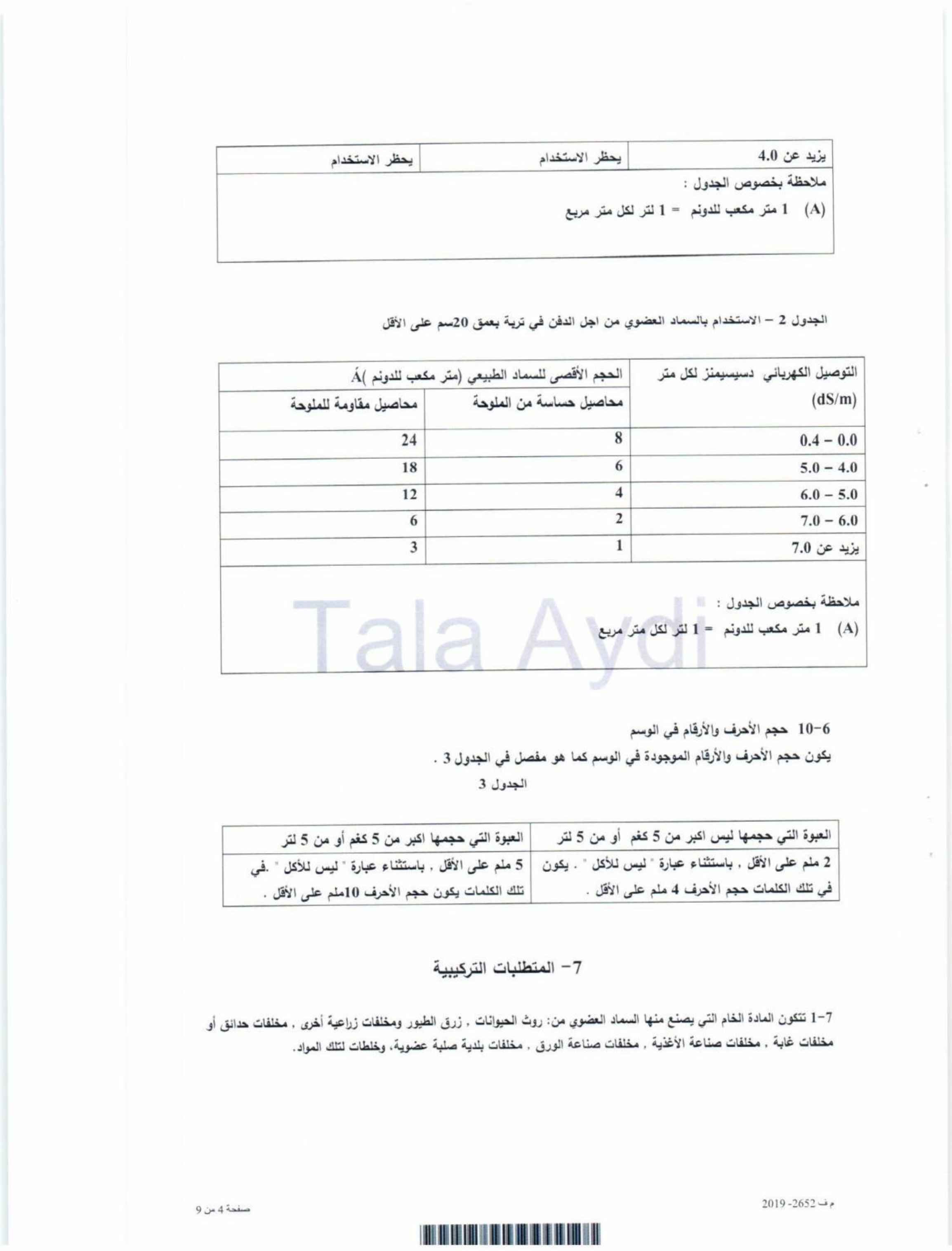
6-8 خصائص السماد العضوي كما هو مفصل على النحو التالي :

- نسبة الرطوبة .
- درجة الحموضة (pH)
- التوصيل الكهربائي (دسيسمنز لكل متر) .
- محتوى المادة العضوية (% من المادة الجافة) .
- محتوى النتروجين الكلي (% من المادة الجافة) .
- نسبة الكربون – النتروجين .
- درجة النضوج.
- محتوى الفسفور المعبر عنه بنحو P_2O_5(% من المادة الجافة) .
- محتوى البوتاسيوم المعبر عنه بنحو K_2O (% من المادة الجافة) .
- محتوى البوراكس (ملغم لكل كغم مادة جافة) .
- محتوى الصوديوم (% من المادة الجافة)

6-9 تحددالموصلية الكهربائية للمنتج للكمية المستخدمة للدونم بناءأعلى الجدول 1 و2 .

الجدول 1 – الاستخدام بالسماد العضوي من اجل التغطية أو الدفن بتربة في عمق حتى 5 سم .

التوصيل الكهربائي دسيسيمنز لكل متر (dS/m)	الحجم الأقصى للسماد الطبيعي (متر مكعب للدونم)Á	
	محاصيل حساسة من الملوحة سنويا	محاصيل مقاومة للملوحة سنويا
0.2 – 0.0	لا يوجد تحديد	لا يوجد تحديد
0.4 – 0.2	15	60
0.8 – 0.4	8	32
1.6 – 0.8	4	16
2.4 – 1.6	3	12
3.2 – 2.4	2	8
4.0 – 3.2	1	4



يزيد عن 4.0	يحظر الاستخدام	يحظر الاستخدام
ملاحظة بخصوص الجدول : (A) 1 متر مكعب للدونم = 1 لتر لكل متر مربع		

الجدول 2 – الاستخدام بالسماد العضوي من اجل الدفن في تربة بعمق 20سم على الأقل

التوصيل الكهربائي دسيسيمنز لكل متر (dS/m)	الحجم الأقصى للسماد الطبيعي (متر مكعب للدونم)Á	
	محاصيل حساسة من الملوحة	محاصيل مقاومة للملوحة
0.4 – 0.0	8	24
5.0 – 4.0	6	18
6.0 – 5.0	4	12
7.0 – 6.0	2	6
يزيد عن 7.0	1	3
ملاحظة بخصوص الجدول : (A) 1 متر مكعب للدونم = 1 لتر لكل متر مربع		

10-6 حجم الأحرف والأرقام في الوسم

يكون حجم الأحرف والأرقام الموجودة في الوسم كما هو مفصل في الجدول 3 .

الجدول 3

العبوة التي حجمها ليس اكبر من 5 كغم أو من 5 لتر	العبوة التي حجمها اكبر من 5 كغم أو من 5 لتر
2 ملم على الأقل ، باستثناء عبارة " ليس للأكل " . يكون في تلك الكلمات حجم الأحرف 4 ملم على الأقل .	5 ملم على الأقل ، باستثناء عبارة " ليس للأكل " .في تلك الكلمات يكون حجم الأحرف 10ملم على الأقل .

7– المتطلبات التركيبية

1–7 تتكون المادة الخام التي يصنع منها السماد العضوي من: روث الحيوانات ، زرق الطيور ومخلفات زراعية أخرى ، مخلفات حدائق أو مخلفات غابة ، مخلفات صناعة الأغذية ، مخلفات صناعة الورق ، مخلفات بلدية صلبة عضوية، وخلطات لتلك المواد.

7-2 تكون خصائص السماد العضوي . كما هو مفصل في الجدول 4 .

الجدول 4

البند	الخاصية المفحوصة	متطلبات		الفحص حسب البند
		الصنف 4-1	الصنف4-2	
7-3-1	حجم الجزيئات	20 ملم . حد أقصى .علاوة على ما ذكر أعلاه يسمح بان يكون حجم الجزيئات كبير جدا بشرط أن لايزيد عن 10%من وزن السماد العضوي	لا يوجد تحديد	8-2
7-3-2	محتوى الشوائب (انظر التعريف 3-3) والتي يزيد حجمها عن 5 ملم (%من المادة الجافة)	5 ملم حد أقصى نسبة سماح 5%	10ملم حد أقصى نسبة سماح 5%	8-3
7-3-3	نسبة الرطوبة (% من المادة الرطبة)	25- 40	25 - 40	8-4
7-3-4	درجة الحموضة(pH)	كما هو معلن عنه في الوسم . ولكن ليس اقل من 5 وليس أكبرمن 8.5	كما هو معلن عنه في الوسم . ولكن ليس اقل من 5 وليس اكبر من 8.5	8-5
7-3-5	التوصيل الكهربائي دسيسيمنزلكل متر (dS/m)	كما هو معلن عنه في الوسم	كما هو معلن عنه في الوسم	8-6
7-3-6	محتوى المادة العضوية (%من المادة الجافة)	35 حد ادني	25 حد أدنى	8-7
7.3.7	محتوى النتروجين الكلي (%من المادة الجافة)	كما هو معلن عنه من خلال المنتج ±25%	كما هو معلن عنه من خلال المنتج±25%	8-8
7-3-8	نسبة الكربون – النتروجين	25-1	25-1	8-9
7-3-9	درجة النضوج (A)	كما هو معلن عنه من خلال المنتج ولكن ليس اقل من 4 (B)	كما هو معلن عنه من خلال المنتج ولكن ليس اقل من 2	8-10
7-3-10	محتوى الفسفور (P) (% من المادة الجافة)	كما هو معلن عنه من خلال المنتج ±25%	كما هو معلن عنه من خلال المنتج ±25%	8-11
7-3-11	محتوى البوتاسيوم (K)(%من المادة الجافة)	كما هو معلن عنه من خلال المنتج ±25%	كما هو معلن عنه من خلال المنتج ±25%	8-11
7-3-12	محتوى البور الكس (ملغم لكل كغم مادة جافة)	200 حد أقصى	200 حد أقصى	8-11
7-3-13	محتوى الصوديوم (% من المادة الجافة)	كما هو معلن عنه من خلال المنتج ±25%	كما هو معلن عنه من خلال المنتج ±25%	8-11
7-3-14	محتوى المعادن الفضة	5 حد أقصى	5 حد اقصى	8-11

	الثقيلة (ملغم لكل كغم مادة جافة)	الكروم	200 حد اقصى	200 حد اقصى	
		النيكل	90 حد أقصى	90 حد أقصى	
		الكادميوم	10 حد أقصى	10 حد أقصى	
		الرصاص	300 حد أقصى	300 حد أقصى	
		النحاس	600 حد أقصى	600 حد أقصى	
		الزنك	2500 حد أقصى	2500 حد أقصى	
15-3-7	التركيز الميكروبي		كما هو مفصل بخصوص راسب من الصنف الثاني في مواصفات الماء(الحمأة-استعمالات الحمأة المعالجة والتخلص منها(Sludge)	كماهو هو مفصل بخصوص راسب من الصنف الثاني في مواصفات الماء(الحمأة- استعمالات الحمأة المعالجة والتخلص منها	12-8

ملاحظات بخصوص الجدول :

(A) درجة النضوج 1 تبين بان السماد العضوي طازج ودرجة النضوج 5 تبين بان السماد العضوي قدنضج جيدا .

(B) ينصح بدرجة نضوج 5 للطبقات المفصولة .

8- طرق الفحص

8-1تعليمات الفحص العامة:-

8-1-1من كل وجبة إنتاج. يتم فحص 5 عينات (أيضا انظر الملحق أ) في كل واحدة من الفحوصات المفصلة الآتية.ومن ثم حساب النتائج التي تم الحصول عليها.

8-1-2 من اجل الفحوصات امفصلة التالية , باستثناء فحص الرطوبة , يجفف السماد العضوي في فرن ذو تهوية بدرجة حرارة (5 ± 65) ° درجة مئوية لفترة 48 ساعة على الأقل ومن ثم إجراء التبريد من خلال جهاز الدسيكيتور وبعد ذلك إجراء التوزين .يتم الاستمرار في التجفيف في فرن حتى لا يكون الفرق بين توزينين متواليين اكبر من 0.1 غرام .

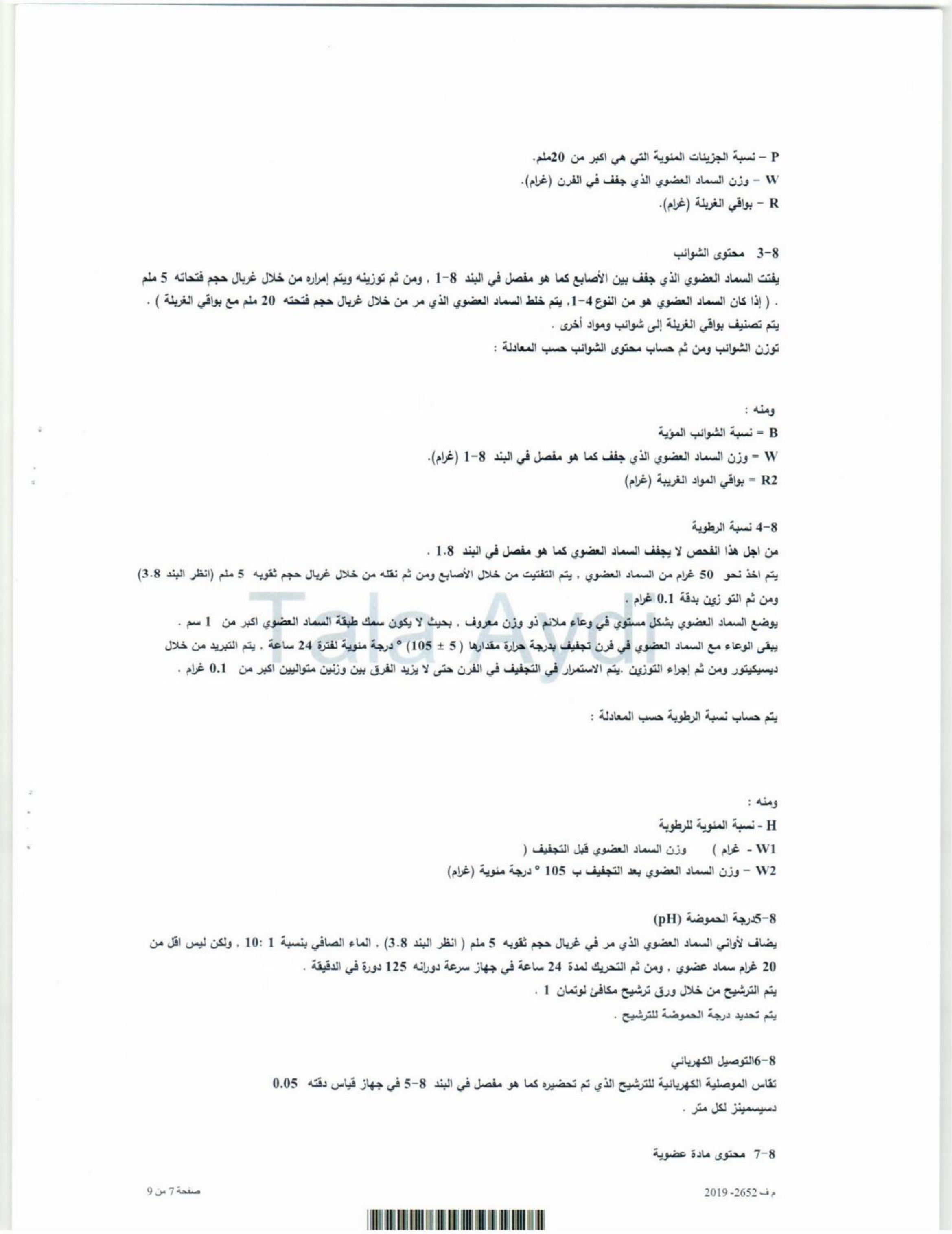
8-2 حجم الجزيئات

بهذا الفحص يتم فحص السماد العضوي من نوع 1.4 فقط .

يوزن السماد العضوي الذي جفف , كما هو مفصل في البند 8-1 , ويغربل من خلال غربال حجم فتحاته 20 ملم , دون العمل على تفتيته .

يتم توزين السماد العضوي الذي مر من خلال غربال وحساب نسبة البواقي حسب المعادلة :

ومنه :



P – نسبة الجزيئات المئوية التي هي اكبر من 20ملم.
W – وزن السماد العضوي الذي جفف في الفرن (غرام).
R – بواقي الغربلة (غرام).

8-3 محتوى الشوائب

يفتت السماد العضوي الذي جفف بين الأصابع كما هو مفصل في البند 8-1 ، ومن ثم توزينه ويتم إمراره من خلال غربال حجم فتحاته 5 ملم . (إذا كان السماد العضوي هو من النوع 4-1، يتم خلط السماد العضوي الذي مر من خلال غربال حجم فتحته 20 ملم مع بواقي الغربلة) .
يتم تصنيف بواقي الغربلة إلى شوائب ومواد أخرى .
توزن الشوائب ومن ثم حساب محتوى الشوائب حسب المعادلة :

ومنه :
B = نسبة الشوائب المؤية
W = وزن السماد العضوي الذي جفف كما هو مفصل في البند 8-1 (غرام).
R2 = بواقي المواد الغريبة (غرام)

8-4 نسبة الرطوبة

من اجل هذا الفحص لا يجفف السماد العضوي كما هو مفصل في البند 1.8 .
يتم اخذ نحو 50 غرام من السماد العضوي ، يتم التفتيت من خلال الأصابع ومن ثم نقله من خلال غربال حجم ثقوبه 5 ملم (انظر البند 3.8) ومن ثم التو زين بدقة 0.1 غرام .
يوضع السماد العضوي بشكل مستوي في وعاء ملائم ذو وزن معروف ، بحيث لا يكون سمك طبقة السماد العضوي اكبر من 1 سم .
يبقى الوعاء مع السماد العضوي في فرن تجفيف بدرجة حرارة مقدارها (5 ± 105) ° درجة مئوية لفترة 24 ساعة ، يتم التبريد من خلال ديسيكيتور ومن ثم إجراء التوزين .يتم الاستمرار في التجفيف في الفرن حتى لا يزيد الفرق بين وزنين متواليين اكبر من 0.1 غرام .

يتم حساب نسبة الرطوبة حسب المعادلة :

ومنه :
H - نسبة المئوية للرطوبة
W1 - غرام) وزن السماد العضوي قبل التجفيف (
W2 – وزن السماد العضوي بعد التجفيف ب 105 ° درجة مئوية (غرام)

8-5درجة الحموضة (pH)

يضاف لأواني السماد العضوي الذي مر في غربال حجم ثقوبه 5 ملم (انظر البند 3.8) ، الماء الصافي بنسبة 1 :10 ، ولكن ليس اقل من 20 غرام سماد عضوي ، ومن ثم التحريك لمدة 24 ساعة في جهاز سرعة دورانه 125 دورة في الدقيقة .
يتم الترشيح من خلال ورق ترشيح مكافئ لوتمان 1 .
يتم تحديد درجة الحموضة للترشيح .

8-6التوصيل الكهربائي

تقاس الموصلية الكهربائية للترشيح الذي تم تحضيره كما هو مفصل في البند 8-5 في جهاز قياس دقته 0.05 دسيسمينز لكل متر .

8-7 محتوى مادة عضوية

يتم اخذ نحو 20 غرام من السماد العضوي الذي مر من خلال غربال حجم فتحاته 5 ملم (انظر البند 3.8) وجفف كما هو مفصل في البند 8-1-2يتم التو زين بدقة 0.1 غرام . يفتت السماد العضوي حتى لسمك أقصى 1 سم . على قاعدة قدر ذات وزن معروف .يبقى القدر مع السماد العضوي في فرن بدرجة حرارة (5 ±550) ° درجة مئوية لفترة 6 ساعات على الأقل .يتم التبريد من خلال جهاز الديسيكتور ومن ثم يتم التو زين.يتم حساب محتوى المادة العضوية حسب المعادلة :

ومنه :

F = النسبة المؤية للمادة العضوية .

O1 – وزن السماد العضوي بعد التجفيف ب 105 ° درجة مئوية (غرام) .

O2 - وزن السماد العضوي بعد التجفيف ب 550° درجة مئوية (غرام) .

8-8 محتوى النتروجين الكلي

يتم اخذ نحو 1 غرام من السماد العضوي الذي مر من خلال غربال حجم فتحته 5 ملم (انظر البند 8-3) ويتم تحديد محتوى النتروجين الكلي حسب طريقة كيلدهال أو من خلال طريقة أخرى مكافئة . في حالة الاختلاف في الآراء فان طريقة كيلدهال هي الطريقة التي تحدد .

8-9- نسبة الكربون – النتروجين

تحسب النسبة بين محتوى الكربون وبين محتوى النتروجين الكلي حسب المعادلة :

$$C / N$$

ومنه :

N – محتوى النتروجين الكلي (انظر البند 8-8).

F - محتوى المادة العضوية .

C - محتوى الكربون المحسوب من محتوى المادة العضوية (انظر البند 8-7) حسب المعادلة :

$$C = 0.58F$$

درجة النضوج-8-10

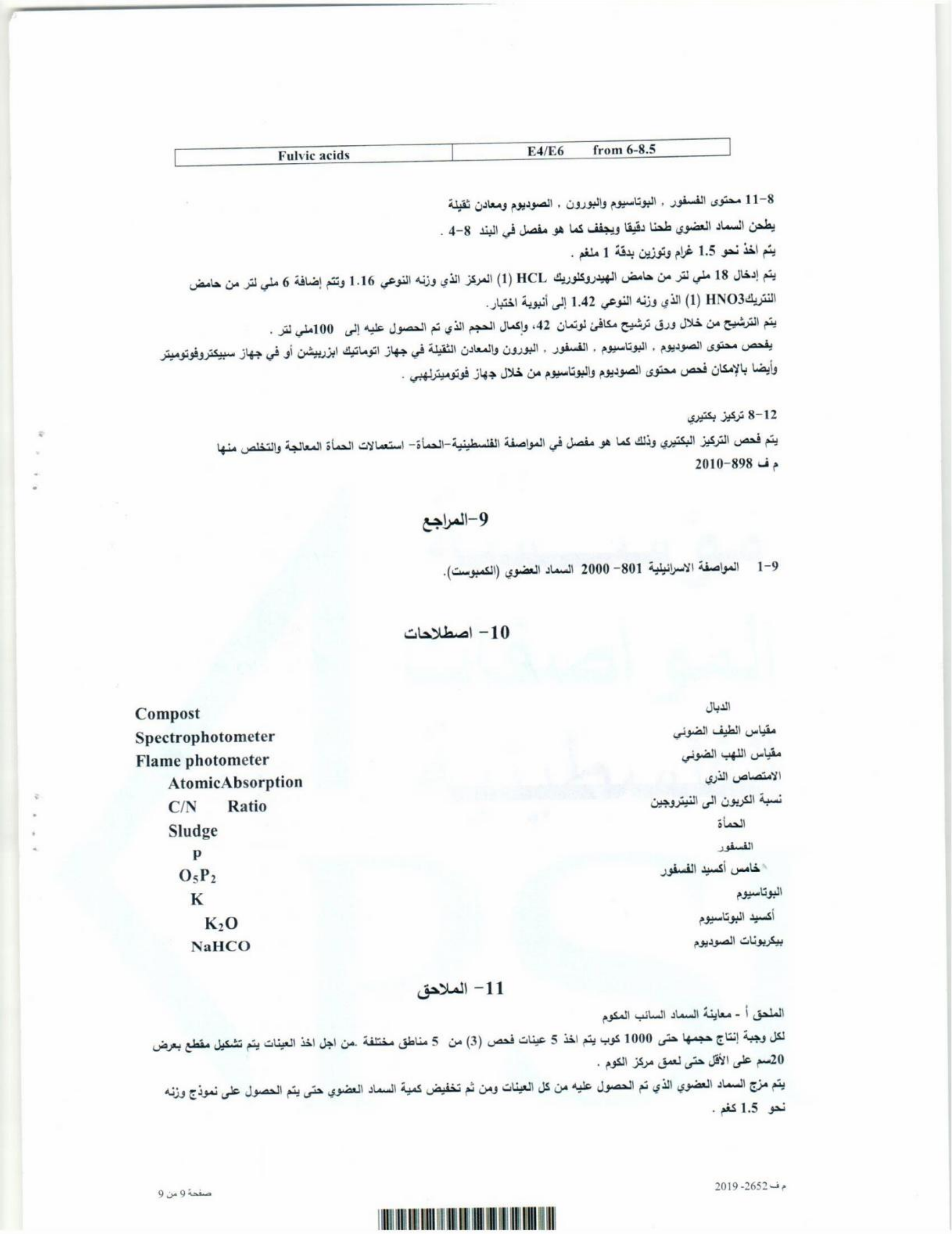
تحدد درجة النضوج حسب الطريقة التالية:-

استخدام Visible Spectrum حيث تستخدم نسبة الامتصاص الطيفي للمادة الدبالية عند طول موجة 465 نانوميتر الى الامتصاص الطيفي عند طول موجة 665 نانوميتر والتي تعرف باسم E4/E6

- يتم اذابة من 2-4 ملغم من الهيومك اسيد في محلول من مادة $NaHCO_3$ بتركيز 0.05 N ويراعى ان تكون pH قريبة من 8 ثم يقاس الامتصاص الطيفي عن 465nm و665nm حيث ان نسبة E4/E6 يجب ان تكون اقل من 5 في حامض الهيومك اسيد وفي الفلفيك اسيد من 6-8.5
- ان نسبة الامتصاص الطيفي عند طول موجة 465 نانوميتر الى تلك عند طول موجة 665 نانوميتر يتم التعبير عنها بنسبة E4/E6 : وهي صفة تشخيصية لاحماض الهيومك والفالفيك حيث تقل هذه النسبة عن 5 بالنسبة لحمض الهيومك وتتراوح بين 6 – 8.5 لحمض الفالفيك حيث ان :
- E4 : الامتصاص عند طول موجة 465 نانوميتر
- E6 : الامتصاص عند طول موجة 665 نانوميتر
- E4/E6 تكون اكبر من 1 صحيح دائماً
-

E4/E6 Ratio of Humic and Fulvic acids:

Acids	E4/E6 Ratio
Humic acids	E4/E6< 5



Fulvic acids	E4/E6 from 6-8.5

8-11 محتوى الفسفور ، البوتاسيوم والبورون ، الصوديوم ومعادن ثقيلة

يطحن السماد العضوي طحنا دقيقا ويجفف كما هو مفصل في البند 8-4 .

يتم اخذ نحو 1.5 غرام وتوزين بدقة 1 ملغم .

يتم إدخال 18 ملي لتر من حامض الهيدروكلوريك HCL (1) المركز الذي وزنه النوعي 1.16 وتتم إضافة 6 ملي لتر من حامض النتريكHNO_3 (1) الذي وزنه النوعي 1.42 إلى أنبوبة اختبار.

يتم الترشيح من خلال ورق ترشيح مكافئ لوتمان 42، وإكمال الحجم الذي تم الحصول عليه إلى 100ملي لتر .

يفحص محتوى الصوديوم ، البوتاسيوم ، الفسفور ، البورون والمعادن الثقيلة في جهاز اتوماتيك ابزربيشن أو في جهاز سبيكتروفوتوميتر وأيضا بالإمكان فحص محتوى الصوديوم والبوتاسيوم من خلال جهاز فوتوميترلهبي .

8-12 تركيز بكتيري

يتم فحص التركيز البكتيري وذلك كما هو مفصل في المواصفة الفلسطينية-الحمأة- استعمالات الحمأة المعالجة والتخلص منها م ف 898-2010

9-المراجع

9-1 المواصفة الاسرائيلية 801- 2000 السماد العضوي (الكمبوست).

10- اصطلاحات

الدبال	Compost
مقياس الطيف الضوئي	Spectrophotometer
مقياس اللهب الضوئي	Flame photometer
الامتصاص الذري	AtomicAbsorption
نسبة الكربون الى النيتروجين	C/N Ratio
الحمأة	Sludge
الفسفور	p
خامس أكسيد الفسفور	O_5P_2
البوتاسيوم	K
أكسيد البوتاسيوم	K_2O
بيكربونات الصوديوم	NaHCO

11- الملاحق

الملحق أ - معاينة السماد السائب المكوم

لكل وجبة إنتاج حجمها حتى 1000 كوب يتم اخذ 5 عينات فحص (3) من 5 مناطق مختلفة .من اجل اخذ العينات يتم تشكيل مقطع بعرض 20سم على الأقل حتى لعمق مركز الكوم .

يتم مزج السماد العضوي الذي تم الحصول عليه من كل العينات ومن ثم تخفيض كمية السماد العضوي حتى يتم الحصول على نموذج وزنه نحو 1.5 كغم .

تحويل حمأة الصرف الصحي إلى سماد زراعي

الحالة الدراسية: محطة معالجة مياه الصرف الصحي في أريحا

اعداد: مرام جادالله نصار

اشراف: د. جواد حسن شقير

الملخص:

هناك زيادة سريعة في منتجات الحمأة، حيث يتم إنتاج حوالي 6468 طنًا من الحمأة سنويًا في فلسطين. يمكن أن تسبب الحمأة مشاكل بيئية وصحية إذا لم تتم إدارتها بشكل صحيح، بما في ذلك تلوث المياه السطحية والجوفية، وانبعاث الروائح الكريهة، وانتقال الأمراض والميكروبات الضارة، وتأثيرات على النظم البيئية، بالإضافة إلى التداعيات الاقتصادية. وبسبب غياب الحلول طويلة المدى للوضع الخطير في فلسطين، كانت الأهداف الرئيسية لهذه الدراسة تقييم إمكانية تحضير السماد العضوي من الحمأة باستخدام عوامل مختلفة وتحديد أفضل تركيبة فعالة.

تم إجراء أربع تجارب للسماد (التجربة 1، التجربة 2، التجربة 3، التجربة 4) باستخدام خليط من حمأة الصرف الصحي والتربة والأزولا وأوراق النخيل في جميع التجارب. حيث تم اقتراح أوراق النخيل كحل لمشكلة بيئية أخرى بسبب الضرر البيئي الذي تسببه لمدينة أريحا وصعوبة التخلص منها. بالإضافة إلى ذلك، تمت إضافة الأزولا لأنها تحتوي على عناصر غذائية مهمة تساعد النباتات على النمو، مثل البروتينات والفيتامينات والمعادن. في التجربة 4، تمت إضافة الصبار إلى الخليط السابق بدلاً من الأزولا. وقد تم استخدام نسب متفاوتة من حمأة الصرف الصحي وأوراق النخيل والصبار (على أساس جاف إلى محتوى رطوبة 14-5٪) والأزولا (على أساس رطب بمحتوى رطوبة 88-8٪). حيث تكمن الأهمية الغذائية لنبات الصبار في قدرته على تحسين جودة التربة ودعم نمو النبات، والذي يتضمن فوائد مثل تحسين بنية التربة، وتوفير العناصر الغذائية، وتحسين التهوية، والحماية من الأكسدة، وزيادة كفاءة استخدام المياه في ظروف الرياح المفتوحة والهواء الطلق.

يعتمد هذا البحث على منهجية تحليلية صارمة تدرس جميع العناصر اللازمة بشكل منهجي. تم مراقبة عملية التحضير للسماد من حيث درجة الحرارة ومحتوى الرطوبة، في حين تم تقييم المادة العضوية، والـpH ، والموصلية الكهربائية، ونسبة C/N بعد عملية التحضير. وأظهرت نتائج تقييم المعايير التشغيلية أن أعلى مستويات تحلل المادة العضوية (32.5%)، و(7.18) pH ، ونسبة(1/25.8) C/N ، ودرجة الحرارة (44 درجة مئوية)، وفترة التحضير (3 أشهر) تم تحقيقها باستخدام الخليط في التجربة 2. بالإضافة إلى ذلك، أظهرت خلطات التجربة 1 والتجربة 4 أيضًا نجاحًا من حيث هذه المعايير التشغيلية وفقًا للمواصفات الفلسطينية (المادة العضوية 35% <، pH 5-8.5، ونسبةC/N (1/25) .

يعد استخدام حمأة الصرف الصحي في إجراءات التسميد أمرًا مهمًا لإدارة النفايات الزراعية وفعالية التكلفة وكفاءة العملية. وينطبق هذا بشكل خاص على أوراق النخيل أيضًا، والتي لم يتم استغلالها بشكل كافٍ في السابق كسماد ولكنها أظهرت نتائج مشجعة في هذه الدراسة.

وكانت النتيجة أن الخليط في التجربة 2 كان الأكثر نجاحاً في زيادة النمو والإنبات وطول الساق وكثافة الجذور. وكانت التجربة الرابعة هي التالية من حيث الفعالية. ثم التجربة الأولى. تعكس هذه النتائج تأثير المكونات المختلفة للسماد على نمو النباتات وتطورها. ومن المهم ملاحظة أن النتائج في هذه الدراسة مستمدة من التجارب العملية، مما يعزز من مصداقية النتائج.