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Feasibility of a Windrow Composting Pilot for Domestic Organic Waste Recycling in Beit Liqia Village-Palestine

By

Mahmoud Ahmad Mafarjeh

(1055114)

Supervisor

Dr. Rashed Al-Sa'ed

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Examination Committee

Dr. Rashed Al-Sa'ed ....

Chairman

Dr. Maher Abu-Madi ....

Member

Dr. Jamil Harb ....

Member

Birzeit, April, 2011

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بسم الله الرحمن الرحيم

ظهر الفساد في البر والبحر بما كسبت أيدي الناس ليذيقهم بعض الذي عملوا لعلهم يرجعون. (الروم ،41)

صدق الله العظيم

Corruption doth appear on land and sea because of (the evil) which men’s hands have done, that he may make them taste a part of that which they have done, in order that they may return.

(Al-Rum, 41)

DEDICATION

To whom I would never have to see light without her heart, mercy, fear and love, my mother.

To the ghost of my father Al-Haj Ahmad Abed Hussein, who in his lifetime toiled to make me educated.

To my life participant, whom she brings gladness and welfare to my heart, my lovely wife.

To my liver slice Ahmad and my eight lovely daughters.

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I am solely responsible for any errors remaining.

ABSTRACT

This study has been carried out to investigate the feasibility of a windrow composting pilot for domestic organic waste recycling in Beit Liqia village – Palestine. In order to overcome the problems related to waste collection and disposal and their negative impacts on human and environment health. The study aimed to reduce the amount of waste to be landfilled, promote recycling, protect human and environment from pollution risks, restrict the excessive use of fertilizers and to find new job opportunities. Composting is a basic element of ISWM strategy which means the aerobic biological degradation of organic materials to produce carbon-dioxide, water, minerals and stabilized organic matter. The end product called compost. The study area was Beit Liqia village in the south western of Ramallah city, the village has a total area of 14000 dunoms. About 12920 dunoms are agricultural land, planted with crops, vegetables and olive trees. This village has been selected because it is suffering from SWM problems, like scattered garbage in the streets, odors, smog air and pollution of soil and water. Also this village has a large area of agricultural land, so large quantities of compost are expected to be consumed. Many tools were used for data collection included meeting with municipality leader and municipal waste management stuff, and weighing domestic organic waste, and community survey using questionnaire. A pilot-scale compost pile of 400 kg of organic waste was erected. After six months samples of end product (compost) were analyzed at The Water and Wastewater Lab of Birzeit University. The quality of compost was checked through physical, chemical and biological parameters (pH, EC, C/N, OM, TN, TC, TP, and HM). Results analysis revealed that domestic organic waste generation equal to 0.55 kg/cap.day which can result of 4.3 ton.day -1 for Beit Liqia village. The percentage of yield was 46.5%. Compost characteristics were compared with international standards. The compost content of heavy metals was within the acceptable range. A decentralized composting facility was proposed after a feasibility study through cost / benefit analysis. NPV= 310131 NIS, BCR = 1.32. The study concludes that initiating a national windrow composting program for domestic organic waste is a feasible waste management alternative, and this program will reduce environmental pollution, and improve soil properties and increase the farm productivity.

الخلاصة

جاءت هذه الدراسة للكشف عن جدوى إنشاء نظام دبال ريادي لتدوير النفايات العضوية المنزلية بتحويلها إلى سماد عضوي (كمبوست)، وذلك في محاولة لحل المشاكل المتعلقة بجمع النفايات وطرق التخلص منها وما تسببه من تأثيرات سلبية على سلامة الإنسان والبيئة. تهدف هذه الدراسة إلى اختزال كمية النفايات الداخلة إلى مكب النفايات، وتشجيع التدوير، وحماية الإنسان والبيئة من خطر التلوث والحد من الاستخدام المفرط للأسمدة الكيماوية، إضافة إلى توفير فرص جديدة للعمل. تعتبر عملية تدوير النفايات العضوية المنزلية لإنتاج الدبال (الكمبوست) عنصراً أساسياً في الإدارة المتكاملة للنفايات الصلبة، والتي تعرّف على أنها عملية تحلل هوائي يمكن التحكم بها، تقوم من خلالها الكائنات الحية الدقيقة بتفكيك المواد العضوية إلى ماء وثاني أكسيد الكربون وعناصر أولية ومواد عضوية ثابتة. تطبق هذه العملية بشكل واسع في الدول المتقدمة وفي الدول النامية على مستويات عدة. أجريت هذه الدراسة في قرية بيت لقيا جنوب غرب مدينة رام الله، مساحتها حوالي 14000 دونم، منها 1080 دونم مباني سكنية، والباقي 12920 دونم أرض زراعية، تزرع بالخضار والحبوب وأشجار الزيتون وغيرها، وقد تم اختيار هذه القرية لكونها تعاني من مشاكل التخلص من النفايات الصلبة و ما تخلفه من تلوث للتربة و المياه و الهواء، ولكونها تمتلك مساحات واسعة من الأراضي الزراعية يتوقع لها أن تستهلك كميات كبيرة من الكمبوست الناتج. استخدمت في الدراسة عدة وسائل لتجميع المعلومات مثل المقابلات الشخصية مع رئيس البلدية وطاقم جمع النفايات، و توزين النفايات العضوية المنزلية، وتوزيع استبيانات على عينة تتكون من 90 منزل اختيرت عشوائياً، ثم صممت تجربة عملية لتحليل 400 كغ من النفايات العضوية وأرسلت عينات من الناتج النهائي للتحليل في مختبرات المياه والبيئة في جامعة بيرزيت. أظهرت النتائج أنه ينتج 0.55 كغ/فرد.يوم من النفايات العضوية أي ما يعادل 4.3 طن/يوم، وكانت نسبة الناتج النهائي 46.5 %، وعند مقارنة مواصفات الكمبوست الناتج بالمواصفات العالمية كانت النتائج مقبولة ومحتواه من المعادن الثقيلة منخفض. عرضت الدراسة مقترحا لإنشاء برنامج لتحليل النفايات العضوية في القرية تعتمد على تشغيل عمال بأدوات يدوية بسيطة، وتمت دراسة جدوى اقتصادية للمشروع من خلال تقدير التكاليف والعائدات المتوقعة. حيث كانت قيمة NPV= 310131 شيكل و قيمة BCR= 1.32. خلصت الدراسة إلى أن إنشاء برنامج لتحليل النفايات العضوية المنزلية هوائياً بطريقة الخنادق (windrows) هو مشروع ذو جدوى اقتصادية و يتوقع له أن يدر أرباحاً، ويسهم في حل مشاكل التلوث، ويحسن من خصائص التربة، ويرفع إنتاجية الأراضي الزراعية في منطقة الدراسة.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ARIJ: Applied Research Institute, Jerusalem.

BCR: Benefit / Cost Ratio.

BZU: Birzeit University.

C/N: Carbon, Nitrogen Ratio.

EC: Electrical Conductivity.

EPA: Environmental Protection Agency.

ISWM: Integrated Solid Waste Management.

JCSPD: Joint Councils for Services, Planning and Development.

MSW: Municipal Solid Waste.

MSWM: Municipal Solid Waste Management.

NGOs: Non Governmental Organizations.

NPK: Nitrogen, Phosphorous, Potassium.

NPV: Net Present Value.

NRC: National Recycling Coalition.

OM: Organic Matter.

OPT: Occupied Palestinian Territory.

PCBs: Palestinian Central Bureau of statistics.

pH: Acidity or Alkalinity scale.

SWM: Solid Waste Management.

WB: West Bank.

WM: Waste Management.

WTE: Waste To Energy.

Chapter One

INTRODUCTION

1.1 Background

Solid waste is a byproduct of human activities that is unavoidable, and a noticeable increase in waste quantity and complexity is continuously observed as a result of economic development, urbanization and improving living standards (Rathi, 2005; AIT, 2004). A troubling problem of waste management in developing countries is rapidly growing, as there is a significant increase in the quantity of solid waste generated as a result of rapid growth of population and change in the people's lifestyle due to accelerated urbanization (Sida, 2006; AIT, 2004).

The rapid growth in population and industrialization has led also to environmental deterioration and pulled down sustainable development in the developing world (Rathi, 2005). Accordingly, developing countries raise the level of concern to improve municipal solid waste management (MSWM) practices in order to protect public and environmental health (AIT, 2004). However, municipalities of the developing countries are not able to handle the increasing quantities of waste, which cause waste accumulation in roads and public places. So that there is an urgent need to build a sustainable waste management system which requires sustainability in social, economical, financial, institutional and environmental aspects (Rathi, 2005).

But the low income in developing countries restrict the capacity to collect, process, dispose or reuse solid waste in a cost effective way. There are many factors affecting solid waste generation and the association problems in developing countries, these factors including geographic location, industry, infrastructure, environmental regulations and socio-economic conditions (AIT, 2004).

Table 1.1: MSW generation in some developing countries(AIT, 2004).

Country	China	India	Srilanka	Thailand
Amount (kg/cap. day)	0.6-0.9	0.3-0.6	0.4-0.8	0.5-1.0

Almost there are similarity conditions among developing countries and their issues in MSWM, the lack to institutional capability with technical expertise, financial resources, and legal provisions and role designation (AIT, 2004).

To develop MSWM strategies, most industrialization nations adopted waste management hierarchy (prevention/minimization, materials recovery, incineration and landfill) (Saki et al., 1996).

Many factors determine the option that a given country use, including topography, population density, transportation infrastructure, socioeconomics and environmental regulations (Sakai et al., 1996).

1.2 MSWM Options

EPA propose the integrated solid waste management to solve the growing MSW problem. EPA's hierarchy of integrated solid waste management includes: Source reduction, Recycling/composting, Waste combustion and landfilling. Source reduction and recycling are likely to be more attractive options to most communities. Reduction, Reuse, Recycling and Recovery (4Rs) are main principles of integrated solid waste management (ISWM) (Yaghmaein et al., 2005).

1.2.1 Source Reduction

Source reduction means reducing waste at its original source, thus minimize the negative environmental impacts. usEPA defines source reduction as: The design, manufacture, purchase or use of materials to reduce their quantity or toxicity before they reach the waste stream (EPA, 1995).

The National Recycling Coalition (NRC) defines source reduction as: Any action that avoids the creation of waste by reducing waste at the source, including redesigning of products or packaging so that less material is used, making voluntary or imposed behavioral changes in the use of materials, or increasing durability or re-usability of materials (EPA, 1995).

There are many differences in the source reduction definitions, but the national policy denotes that SR in the highest priority waste management technique. Waste reduction, waste prevention, waste minimization, pollution prevention, and pre-cycling are all terms often used to mean source reduction.

Waste preventions may achieved by adopting more efficient manufacturing methods , and by changing the public attitudes towards consumption with emphasis on production quality, durability and environmental friendliness (Sakai et al., 1996).

1.2.2 Recycling

Instead of disposal to some waste materials they are collected; processed, and remanufactured or reused. Many communities adopt recycling as a method of managing municipal solid waste. Recycling programs can generate revenues as a result of saling the recyclable materials. Public participation and support are essential for successful recycling program in MSWM. Environmental impacts resulting from a well-operated recycling program should be at the minimal levels (EPA, 1995).

Recycling is a good manner for a large fraction of MSW, like paper, glass, plastic, metals, tires, and organic waste. Thus recycling can achieve waste reduction as it prevent materials from entering the waste stream and minimizing the environmental impacts (Sakai et al., 1996).

Recycling emphasize the concept of " resource not waste", in which that the waste materials are used as a raw materials to produce a new similar type of product (Sakai et al., 1996).

Developing a market for recyclables and recycled products is essential to adopt recycling as an option in MSW. Market development involves balancing between the supply of recyclable materials and the demand of products made from them (EPA, 1996).

Composting is an environment friendly recycling method, and simple solution for organic waste. It can significantly reduce the waste stream volume, particularly that a large portion of the waste is often organic (Sida, 2006; EPA, 1996; Colon et al., 2010).

Also the compost produced from organic waste can positively impact soil productivity and house hold income, and can achieve food security by improving soil fertility and water holding capacity (Sida, 2006; Weber et al., 2007; Achiba et al., 2009). But composting is still not wide spread in developing countries (Zurbrugg et al., 2005).

1.2.3 Combustion (Inciniration)

Combustion is the process in which combustible MSW is fully incinerated to produce heat energy as steam used to derive turbines in order to produce electricity. This process described as waste - to - energy system (WTE) (EPA, 1995).

Developing a WTE project is a complex process, it needs long time, heavy investments, high operation costs, and specialized skills. Therefore this option to MSWM couldn’t be adopted by developing countries (Rand et al., 2000).

Incineration can reduce waste volume by 90% (Sakai et al., 1996). Energy can be recovered for heat or power consumption. Elimination CH_4 emissions can be achieved (Rand et al., 2000).

20-30% of the original waste weight is left as ash, which needs further management. The ash has potential to pollute air and water due to its content of fly particles and trace metals like (Cd, Hg, Pb, Zn) (Sakai et al., 1996).

Coordination with other Waste Managment practices is required to increase WTE efficiency, these practices include: source reduction, recycling, composting and landfilling (EPA, 1995).

1.2.4 Land Disposal

MSW landfill is the basis of a good solid waste management. A sanitary landfill is needed to dispose residues from other processing facilities, like recycling, composting, combustion, or others, and can be used in the case of breakdown of the alternative facilities (EPA, 1995).

Landfilling is the easiest and cheapest method of waste disposal. However modern MSW landfills are designed to control leachate and gas emissions and minimize the negative impacts on the environment and maximize benefits. These improvements require additional costs. Otherwise, emissions and leachate from the landfill have potential pollution to air and groundwater (Sida, 2006; EPA, 1995).

In general, the best solution for improving waste management is often waste prevention, then reuse, recycling, and finally controlled sanitary landfilling if the first options are not feasible (Sida, 2006; Muhle et al., 2010).

Sustainable good community relations are crucial. MSW managers must maintain a continuous dialog with residents, municipal leader, community activities, and state governmental representatives.

1.3 Status of MSWM in the West Bank

Municipalities, village councils, village communities or UNRWA in refugee camps are responsible for MSWM. 25% of lack to SWM programs (ARIJ, 2006).

MSW in the WB is mostly dumped in open and uncontrolled dumping sites. There are more than 400 dumping site in the WB(ARIJ, 2006). 70% of the household generated waste in the Palestinian territories is constituted of organic waste (ARI, 2006), which means high potential for utilizing organic waste to produce compost.

The Palestinian territories are currently suffering from inefficient MSW strategy due to shortage in the available dumping sites and inaccessibility to open spaces.

Small area of the WB, location of groundwater aquifer, lack of sanitary landfills, and lack of recycling programs are all make the problem of MSW disposal (Al-Khatib et al., 2007).

Other problems faced MSWM, like increasing population growth, changes in habits, lack of awareness and poorly coverage of local municipalities to solid waste services (El-Hamouz, 2008).

The main factor inhibiting the improvements in the sanitary disposal of MSW is the political situation (Al-Khatib et al., 2007).

Gradually deterioration of MSWM quality in the Palestinian districts since the year of 2000 was observed as a result to instability in the political situation and high ratio of residents don’t pay fees for MSW collection (Al-Khatib et al., 2007).

Inadequate solid waste management system in the occupied Palestinian territory (OPT) threatens public health, damages the environment. Many institutions have made attempts over the years to improve infrastructure to coordinate planning, and to educate the public. These efforts faced with the realities of the Israeli occupation, so there is no significant improvement in SWM. Palestinian authorities with help from local and external NGOs continued to work towards greater effectiveness in serving the residents needs for solid waste collection and disposal . But satisfactory results are most likely not achieved .

The common method of waste management in the WB is dumping in unmonitored open sites there are 161 sites in the WB (PCBs, 2006), and 166 localities have not any solid waste collection services at all which represent 27.8 % of all localities (PCBs, 2006).

In Dura (Hebron) and Jericho two dumping sites were rehabilitated in 2003 and 2007 respectively, and transformed to sanitary landfills by JCspd, which bring out positive environmental results (ARIJ , 2005).

Most solid waste in OPT composed of organic materials ,paper , cardboard, plastic, metals, and glass. Organic materials make up nearly 60% of all household solid waste in the POT (ARIJ, 2006). In Nblus district, organic waste consist the majority of solid waste (65.1%) by weight (Al-Katib et al., 2010).

The average production of solid waste from Palestinian household equal to 4.6 kg /day (PCBs, 2006).

Table 1.2: Individual production in various regions in Palestine(ARIJ, 2006).

Region	Production (kg .cap $^{-1}$ .day^{-1})
Rural areas	0.4 – 0.6
Refugee camps	0.5 – 0.8
Villages &towns	0.6 – 0.8
Cities	0.9 – 1.2

As the highest fraction of solid waste is organic, composting programs might be a highly effective method to reduce waste volume (ARIJ, 2006).

The following table show the composition of total solid waste stream in four countries by volume :

Table 1.3: Composition of total solid waste stream in four countries by volume (ARIJ, 2006)

Type / Country	Organic Matter	Paper cardboard	Plastic	Glass	Metals	Others
OPT	59	15	12	4	4	6
Jordan	50-68	5-10	4-6	2-5	3-6	>5
Israel	43	22	14	3	3	15
USA	24	35	11	5	8	17

Recycling and composting have not been implemented to any significant degree at the national level in the OPT (ARIJ, 2005). These two strategies reduce waste volume and conserve natural resources, in addition to saving energy used in manufacturing new goods. pilot composting programs were started in Gaza strip and Bethlehem, but they have been suspended due to damage caused by Israeli aggression, in addition to residents unwillingness to allow composting plants to be built near them.

Palestinian authorities faced with many challenges to improve waste management to be environmentally sound. These challenges include:

- Rapid population growth and increased waste production.
- Persistent public ignorance on waste management.
- Israeli restrictions.
- Israeli military of civil services.

The recent trends of decentralization is a positive one, whereby the joint councils for services, planning, and development have achieved success in Hebron and Jericho towards regional management of collection and disposal of solid waste, in addition to similar projects are ongoing in Jenin, Bethlehem, and most other regions of the OPT.

1.4 Study Area

Beit Liqia village was selected for this empirical study of windrow composting for domestic organic waste recycling, the village was selected because it is suffering from solid waste collection and disposal problems scattered garbage all along streets, odors, and potential pollution to the local environment.

MSW is collected, disposed and burned in an old and filled up open dumping site, the location of this site is in the west of the village exactly, so the wind carry the smut released “as a result of burning waste“ to the houses of residents causing odors problems and overthrow plants in the neighbor. Furthermore, an overdone to compactor truck which used to collect MSW from three villages in the region (Beit Liqia, Beit Sire, and Kharbatha Al-Mesbah). The truck is broken down frequently, resulting in accumulation of waste and additional cost is needed to repair the truck.

Beit Liqia village is the focus of this study. Therefore, it is important to understand the nature of this village; geographical location, land area, population, socio-economic characteristics, households, institutions and environment.

Table 1.4: Basic information about the village (B.L. Municipality, 2008).

Population	7800
Household	1350
Total area (donum)	14000
Built-up area (donum)	1080
Agricultural local area (donum)	12920
Schools	5
Clinics	6
Business firms	142
Animal farms	20
Green house	8
Graduates	120

Beit Liqia is the largest village in the south western villages of Ramallah city. It far 20 km from Ramallah, it lied near the three demolished villages of Yalo, Imwas and Beit Nuba. It bounded from the north by Kharbatha Al-Mesbah/Beit Sira, and from the east by Beit Anan, and from the south by Beit Nuba, and from the west by the Green line. Part of the village agricultural land was taken over by the Israeli authorities in 1967, and another part was taken in 2004 by the segregation wall.

The village has many local establishments and associations overseen by many adepts persons from the village, most of the families profess agricultural activities.

1.5 Research Problem

Beit Liqia village is suffering from continuously problems of solid waste collection and disposal, weak concern to MSWM leads to misshaped landscape, as a result of accumulation of garbage in the streets.

Garbage is collected and disposed in a wild unsanitary dump site, odors and smoke are seen all year around. The wind carry pollutants over the households creating health problems for human, animals, and plants. Leachate from the dumpsite forms one major pollution source for soil and ground water.

This study is based on the hypothesis that applying organic waste recycling through a pilot scale windrow composting will reduce solid waste production at source and pick up financial and environmental benefits within solid waste management rural areas.

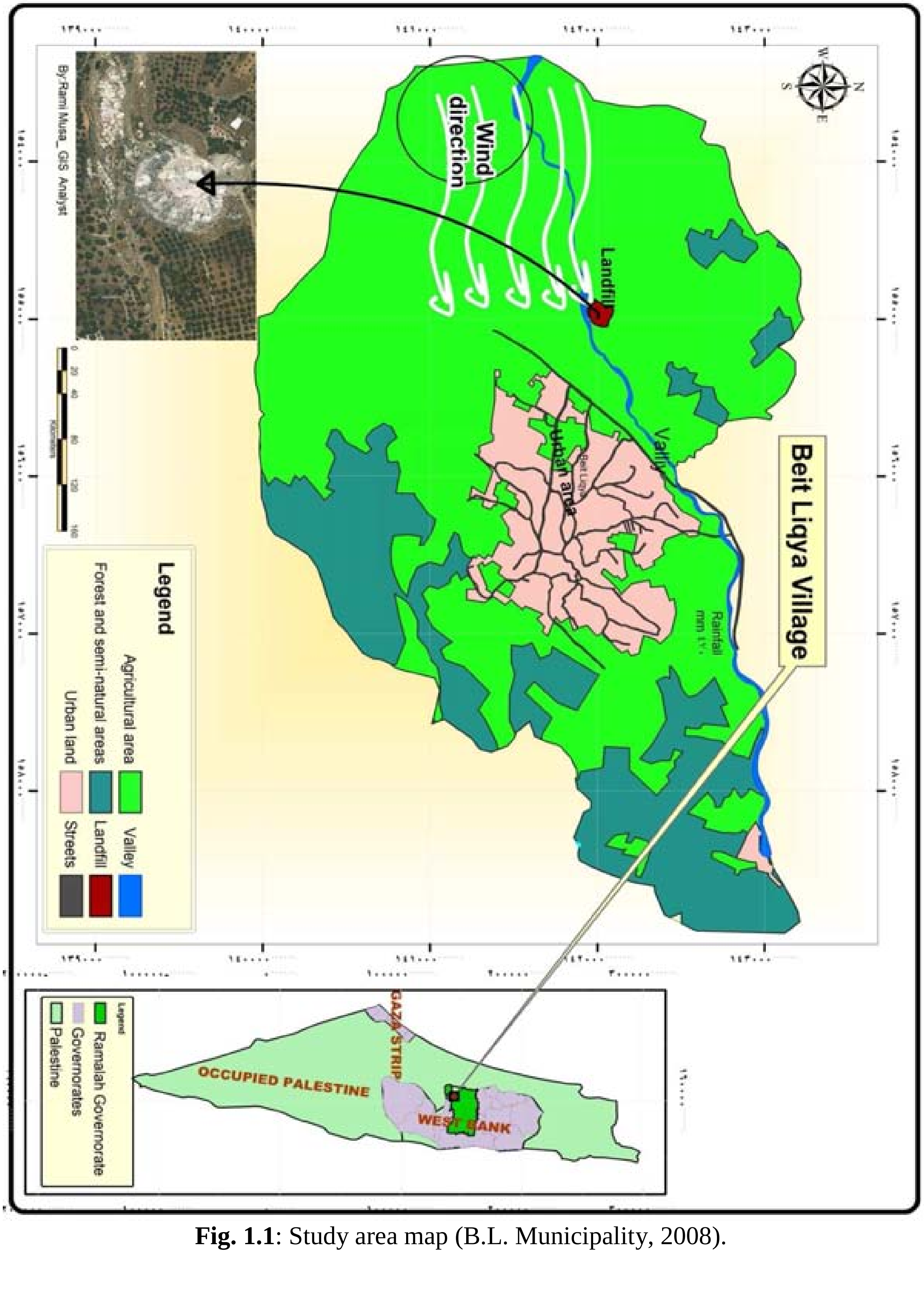

Fig. 1.1: Study area map (B.L. Municipality, 2008).

1.6 Research Goals and Objectives

The goal of this study is to improve the efficiency of MSWM practices in Beit Liqia village and other rural areas, such as reduction, reuse, recycling and recovery in order to protect human and environment health. The study seeks specifically to:

1- Estimate individual household organic waste in Beit Liqia.

2- Assess the quality of the compost prepared from household organic waste degradation.

3- Investigate residents ideas about the actual situation of SWM, and acceptance for initiating a windrow composting facility to produce compost from organic waste.

4- Assess the financial viability of building a composting plant using Benefit – Cost analysis.

1.7 Research Questions

1- What is the current practice of SWM in Beit Liqia? Is that sufficient? Are there any adverse effects?

2- How much SW generated from household in Beit Liqia? How much is the organic ratio?

3- Is windrow composting feasible to apply in Beit Liqia?

4- What is the opinion of residents to initiate a composting facility for organic waste?

1.8 Thesis Outline

Chapter one introduce to the study including MSWM options, status of MSWM in the WB, study area and research objectives and goals. Chapter two includes composting definition, compost biology, chemistry, physics and the optimal conditions for composting process, in addition to the final product quality parameters and potential uses. Chapter three presents the research methodology which includes a pilot design and management, temperature and pH records, lab analysis methods and questionnaire construction. Chapter four expose the results including individual production of organic waste, lab analysis results, questionnaire analysis and simple Cost – Benefit calculations, and propose a composting program in the study area. Chapter five includes the main conclusions of the study and the researcher recommendations.

Chapter Two

Literature Review

2.1 What is Composting?

Composting is a basic element of ISWM strategy which can be applied to source separation of MSW. It defined as “a controlled aerobic process carried out by successive microbial populations combining both mesophilic and theremophilic activities and leading to the production of carbon dioxide, water, minerals and stabilized organic matter’’ (Yaghmaein et al., 2005).

Composting is the aerobic biological degradation of organic materials to produce a stable humus-like product (EPA, 1995). Naturally biodegradation is an ongoing biological process. Food scraps rotting in a trash can is an example of natural and slow uncontrolled decomposition.

Controlling the environmental conditions during the composting process can significantly increase the rate of degradation and derive the most benefit from this natural process to obtain a high quality compost (Illmer et al., 1997).

The end product of the compositing process is compost, in addition to water and carbon dioxide as by-products. Weed seeds and pathogens should be absent in the good compost. Temperature needed to reduce pathogens is 55º or over for 15 d at least, according to usEPA’s recommendations (Yaghmaein et al., 2005).

“ It is important to view compostable materials as usable resource, not as waste requiring disposal, and managers should stress that the composting process is an environmentally sound and beneficial means of recycling organic materials, not a means of waste disposal’’ (EPA, 1995).

2.2 Why Composting?

Composting can generate many benefits to human and environment. It present a partial solution to the solid waste crisis, as it reduce waste stream volume significantly (Trautmann et al., 1997; EPA, 1995).

Economical advantages can be achieved because the cost of using other options are higher specially that the equipment and materials used in composting are inexpensive and readily available (Trautmann et al., 1997).

Also compost is a valuable soil amendment improves the soil's conditions, promotes proper balance between air and water, prevents soil erosion and release nutrients for plants causing increase in plant yield (EPA, 1995; Farrell et al., 2009).

Composting of organic portion of waste , recycling and reuse nonbiodegradable portion of waste are the main cost effective and environment friendly waste disposal methods that are in practices now (Pattnaik et al., 2010).

2.3 Compost Biology

Biological organisms in compost process include microorganisms like bacteria, fungi and actinomycetes, in addition to larger organisms like insects and earthworms. Microorganisms are the most vital biological organisms in composting (Trautmann et al., 1997). Whereas larger organisms have a less significant role. Different bacterial communities dominate the process of windrow composting. Other microorganisms like fungi are also have a role in the process. Actinomycetes activity is slower than bacteria or fungi (Adams et al., 2008).

Complex interactions take place between organic matter and organisms in compost food web. Microorganisms need optimal conditions to give peak performance, they need sufficient nutrients and Oxygen and optimal moisture, temperature and pH.

Microorganisms obtain carbon from decomposed organic materials, and convert it to by-products like carbon dioxide (CO_2) and water (H_2O) and end product. Some carbon consumed to build new cells and heat is released during this process.

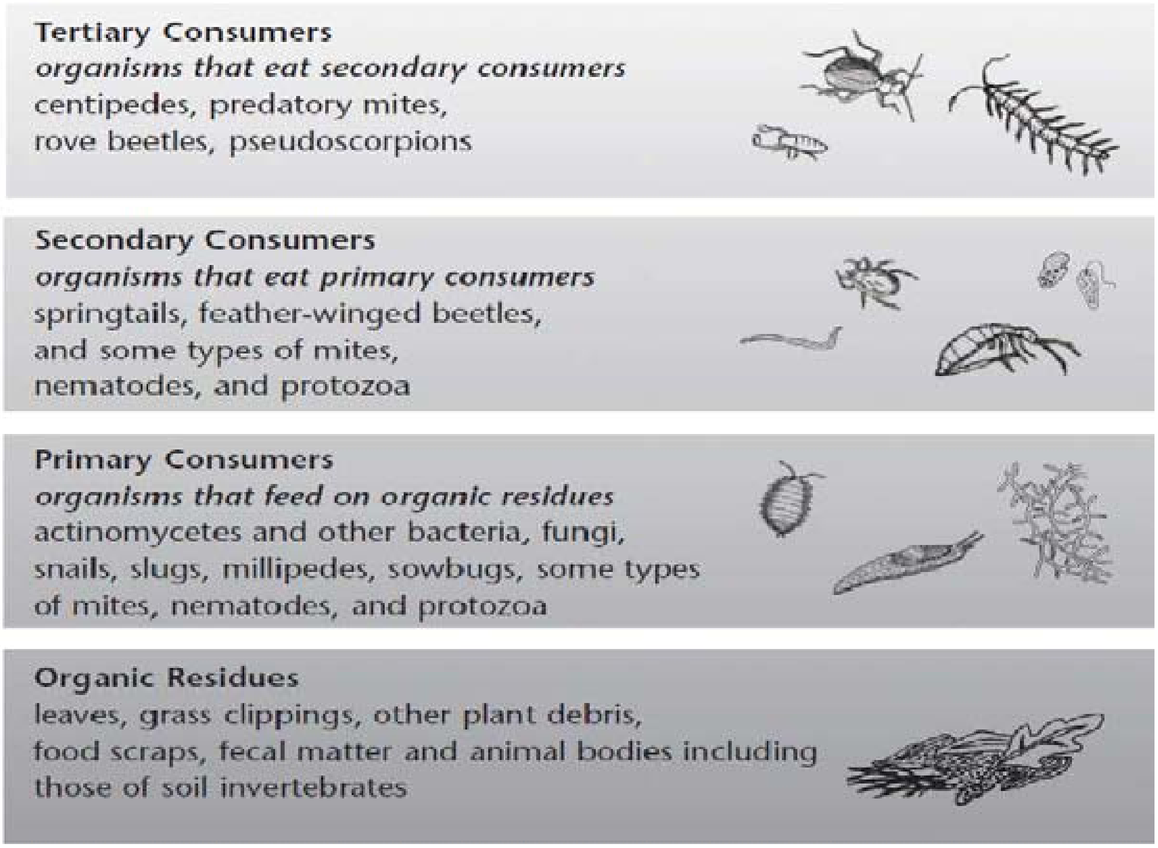

Fig. 2.1: Functional groups of organisms in compost food web (Trautmann et al., 1997).

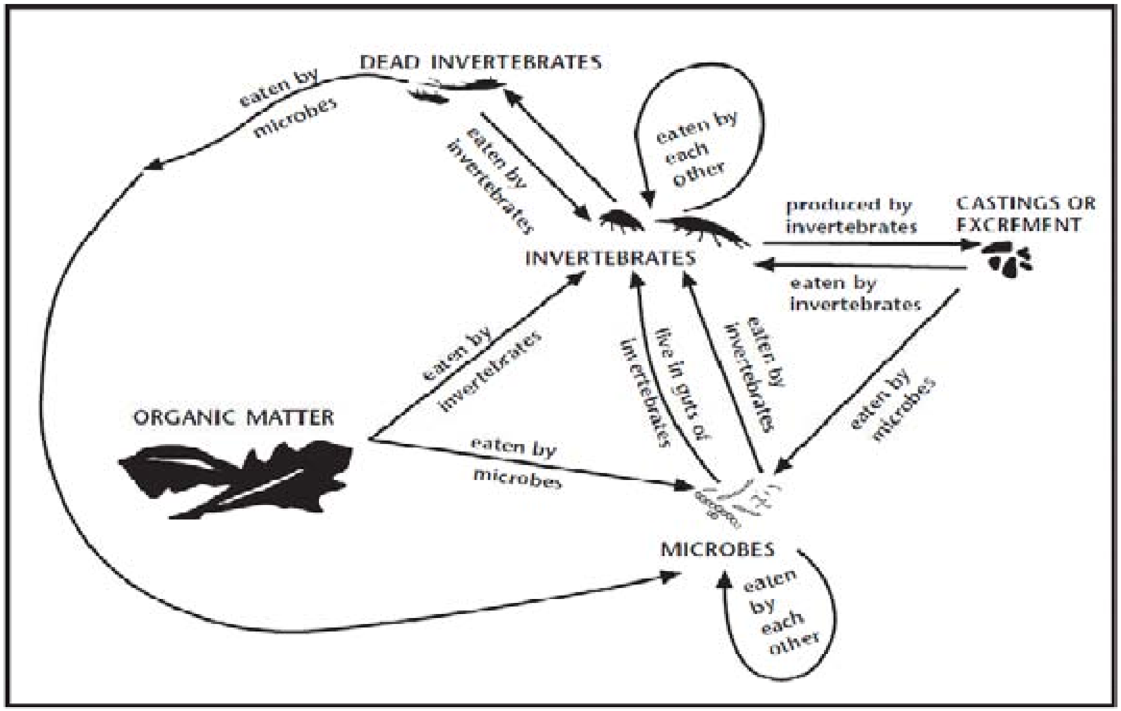

Fig. 2.2: Feeding interaction among organisms in compost (Trautmann et al., 1997).

Composting process need different types of microorganisms to achieve complete decomposition, because end products from one type may be used as a food by another type in a continuous chain of microorganisms. Remaining organic materials is named compost. It consists of microbial cells, microbial skeletons, and by-products of microbial decomposition, and non decomposed particles of organic and inorganic origin. As microbial population increase the decomposition process proceed faster (EPA, 1995).

MSW usually contain sufficient diversity of microorganisms if it toxins free. In the case of lacks microorganisms diversity, inoculums of specially selected microorganisms may be added in order to accelerate the compost maturation process (Wei et al., 2007).

Generally, mature compost is added as inoculums to speed the composting process (EPA, 1995; Trautmann, 1997).

Microorganisms are the key in the compositing process, decomposition will occur rapidly under ideal conditions for microbial populations, and that will lead to rapid stabilization to the organic materials. Some microbes are potential pathogens to humans, plants, or animals. These pathogens must be killed during the composting process by controlling the temperature. usEPA recommends maintaining the compost piles at above 55ºc for at least 5 days (EPA, 1995).

Total elimination of all phytopathogens achieved between 48 and 120 hours from the beginning of the composting process as a result of heat generation during thermophilic phase (Estrella et al., 2007).

Bacteria have a greater persistence than fungi during composting (Estrella et al., 2007).

2.4 Compost Chemistry

Organic matters consist mainly of carbohydrates (sugar, starches, cellulose, lignin), proteins and lipids. Microorganisms secrete specialized enzymes to break down complex organic compounds; then they absorb simple compounds, like glucose and amino acids into their cells.

Ultimately organic compounds are oxidized producing carbon dioxide (CO_2), water (H_2O), energy (ATP), and compounds resistant to further decomposition. Some complex organic compounds are decompose slowly like lignin (large polymers that cement cellulose fiber together in wood). Simple inorganic ions like nitrate (NO_3^-), sulfate (SO_4^{-2}), and ammonium ($NH4^+$) are yield as a result of amino acids decomposition, that become available for uptake by microorganisms and plants.

Composition of feed stocks determine the chemical environment. Also several modification can be made to create an ideal chemical environment during the composting process to accelerate decomposition of organic materials. Chemical environment for composting determined by many factors; presence of sufficient amounts of carbon and nitrogen with optimal C/N ratio, sufficient amount of oxygen, suitable pH, and absence of toxic materials which may be lead to inhibition in microbial activity (EPA, 1995).

2.4.1 Carbon / Energy Source

Microorganisms need nutritional materials (N, P, K, and trace elements) as plants. The main difference is that plants use carbon dioxide (CO_2) and sunlight as a carbon / energy source, while microorganisms use organic materials as their carbon /energy source (EPA, 1995).

Organic carbon may or may not be biodegradable, this process depends on the genome of microorganism and the makeup of organic molecules. Large types of microorganisms can decompose the carbon in sugars, but fewer types can do that in lignin. Some organic carbon may not be biodegradable by any microorganisms.

However, MSW contain sufficient amount of biodegradable forms of carbon(EPA, 1995), so the carbon is not a limiting factor in the composting process.

Small fraction of degraded carbon converted to microbial cells, and the large fraction converted to carbon dioxide and lost to the atmosphere, which explain the decrease in the weight and volume of feedstocks.

The reduction of dry organic mass and volume is up to 50% (Yaghmaein et al., 2005).

2.4.2 Nutrients

Some materials in MSW are lack to nitrogen, so the nitrogen is a limiting factor in the composting process. The other nutrient usually are not limiting factors. The carbon to nitrogen ratio is considered critical in decomposition rate. The initial should be (30:1) carbon: nitrogen (EPA, 1995; Trautmann et al., 1997; Yaghmaeian et al., 2005).

With attention just to this ratio on the basis of available carbon rather than total carbon (EPA, 1995).

Higher ratios restrict the process because higher ratios do not provide sufficient nitrogen for optimal growth of the microbial populations. While lower ratios generate noxious odors (Trautmann et al., 1997).

Microorganisms need carbon to build cells as it represents the basic building block making up about 50% of the mass of microbial cells (Trautmann et al., 1997), and need nitrogen to build proteins, amino acids, enzymes, and DNA.

Microorganisms need, in addition to C and N, some elements that necessary to microbial metabolism like phosphorous, sulfur, calcium, and potassium, and it need to some trace elements such as iron, magnesium, and copper. Feedstocks normally provide sufficient quantities of these elements for microbial growth.

2.4.3 Moisture

there is no life without water, microorganisms within the compost pile need water. the ideal water content in the compost pile 50-60 % by weight (Fabrizio, et al., 2008; Trautmann et al., 1997; EPA, 1995).

Water content must not be proceed this ratio to prevent leachate which creates potential water pollution and odor problems, in addition to anaerobic conditions because excess moisture decrease the porosity required for air flow.

Since the amount of water produced from the decomposition process is less than that evaporated, water must be added to keep moisture at ideal levels (EPA, 1995). Minimizing evaporation should be managed by controlling the piles size, larger volume has less evaporating surface per unit volume than smaller volume (EPA, 1995).

Adjusting the moisture within the optimal range can be achieved using squeeze test, by taking a handful of the pile mixture and squeeze it very hard. One or two drops of free liquid indicate 60% moisture level, more than 3 or 4 drops indicate too much moisture.

2.4.4 Oxygen

Decomposition may occur under both aerobic and anaerobic conditions, but aerobic decomposition is faster than anaerobic which go slowly and produce offensive odors (EPA, 1995). Microorganisms in aerobic composting require oxygen for respiration to produce energy needed to microbial activities. The compost pile must have enough space for air movement so that oxygen enter the pile and carbon dioxide and other gases leave. To keep pile aerated, it must be turned frequently to create more air spaces.

For successful compositing proper balance is needed between oxygen and moisture, too much moisture make pores between compost particles filled with water, then oxygen diffusion is impeded, and less moisture lead to dry out the films of water surrounding compost particles dry out also can be occurred as a result of excess aeration. However, increased aeration rates at the initial stages of composting process resulted in higher microbial activity, increase in pH, and more stable compost product (Sundberg et al., 2007).

Also increased aeration caused severe drying of the compost but addition of water was adequate to prevent drying. Thus aeration and watering could shorten the time needed to produce a stable compost product.

Improving the oxygen supply by forced ventilation proved to be unnecessary, thus greatly reducing production costs as forced ventilation equipment involves high capital investments and operating costs (Cegarra et al., 2006).

So that most suitable aeration technology for composting is mechanical turning (Cegarra et al., 2006).

Adequate concentration of oxygen is 10 – 15% (EPA 1995; Trautmann et al., 1997). Higher concentrations haven't negative effects, but excess air circulation removes heat and promotes evaporation leading to cooling and dry out the pile.

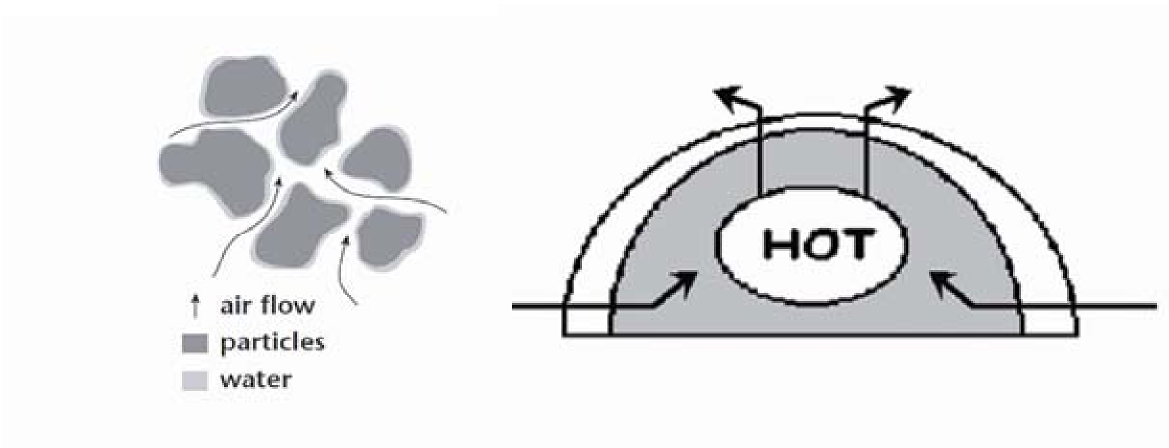

Fig.2.3: Air circulation in a compost pile (Schneider et al., 2001).

2.4.5 pH

pH is an indicator for compost acidity or alkalinity, it is measured on a scale from 0 to 14.

pH SCALE

Acid(H^+) Neutral (OH^-)Base

0==========================7==========================14

Red Litmus Paper Blue

Fig. 2.4: pH Scale (Schneider et al., 2001).

During the composting process, the pH values vary between 5.5 and 8.5. The ideal range of pH for most efficient compositing is between 6 and 8 (EPA, 1995; Schneider et al., 2001).

The pH affects the activity of enzymes that controlling the overall metabolic activity, and affects the availability of nutrients for microorganisms (EPA, 1995).

In the initial stages of composting, accumulation of organic acid is formed as a result of organic matter digestion by bacteria and fungi (Trautmann et al., 1997; Schneider et al.,2001). Decrease in pH encourages fungi's growth, which are active in lignin and cellulose decomposition (Trautmann et al., 1997). Sufficient oxygen availability encourages to consume these organic acids. While without sufficient amounts of oxygen organic acids will not be converted to usable form by microbes. Thus, excess acidity may lower the pH below 6, and slow down the process of decomposition (Schneider et al., 2001). Two processes during the thermophilic phase rise the pH: break down and volatilization of organic acid, and lose of ammonia produced as a result of break down proteins and other organic nitrogen sources (Trautmann et al., 1997).

The problem of excess acidity is likely to happen when easily composed organic compounds are present in larger amounts, these compounds include undiluted animal manure, some green wastes, etc.

Good aeration usually solve the problem (Schneider et al., 2001).

Lime and sulfur can be used to adjust the pH, lime increases the pH value, while sulfur decreases it. But usually such additives are not necessary, because organic materials are naturally well- buffered with respect to pH changes (EPA, 1995).

Final pH of finished compost is a main factor in compost marketing. pH more than 8 may be unfavorable to use for acid – loving plants such as a azaleas, rhododendrons, pine, or blueberries. It may kill plants when it used in large quantities (Schneider et al., 2001).

2.5 Compost Physics

Efficient composting can be achieved by adjusting many physical factors, such as temperature, particle size, mixing, and pile size.

2.5.1 Particle Size

The surface of the organic particles is the site that most microbial activity occurs on it. so large surface area means higher microbial activity and faster decomposition rate. Decreasing particle size increases the surface area and the availability of carbon and nitrogen needed to microorganisms for successful efficient composting (Trautmann et al., 1997; Schneider et al., 2001). Creating smaller particles which expose larger surface area to microbial activity can be achieved by shredding, chopping, and grinding the feedstocks for composting. Shredding lead to more stable and mature compost rich in organic matter(Tognetti et al., 2007).

However, too small and compact particles will inhibit air circulation through the pile. Thus, the oxygen available to microorganisms will decrease (Trautmann et al., 1997).

Enough void spaces must be available to achieve air circulation for microbial respiration. Balancing between these two important factors (particle size, void spaces) must be taken in consideration.

Frequently turning and addition of large particles such as branches to piles to enhance aeration. Bulking agents that have not decomposed can be sieved out and reused (Trautmann et al., 1997).

2.5.2 Temperature

The biological systems activity is temperature sensitive (Schneider et al., 2001). Thus, temperature inside the windrow determines the rate of composting.

Microorganisms involved in the composting process are need optimum temperature range between 32 C^o and 60 C^o, or 90 F^o and 140 F^o (EPA 1995; Schneider et al., 2001).

Higher temperature denaturate microbial enzymes, and increase ammonia and VOCs emission (Comilis et al., 2004; Pagans et al., 2006). Lower temperature inhibit microbial enzymes activity. Consequently, composting rates will decrease in both higher and lower temperatures (Schneider et al., 2001).

Thermophilic composting can be divided according to the temperature of the pile, into three phases: a mesophilic phase (up to 40 Cº) which lasts for 2-3 days, thermophilic phase (over 40 Cº) which lasts form few days to several months, and mesophilic maturation phase which lasts for several months.

Thermophilic phase is preferred in order to promote rapid decomposition and to kill pathogens and weed seeds. Temperature of 55 Cº for 15 days destroys pathogens. The pile during this period must be turned many times (5) to achieve uniform pathogens destruction (EPA, 1995).

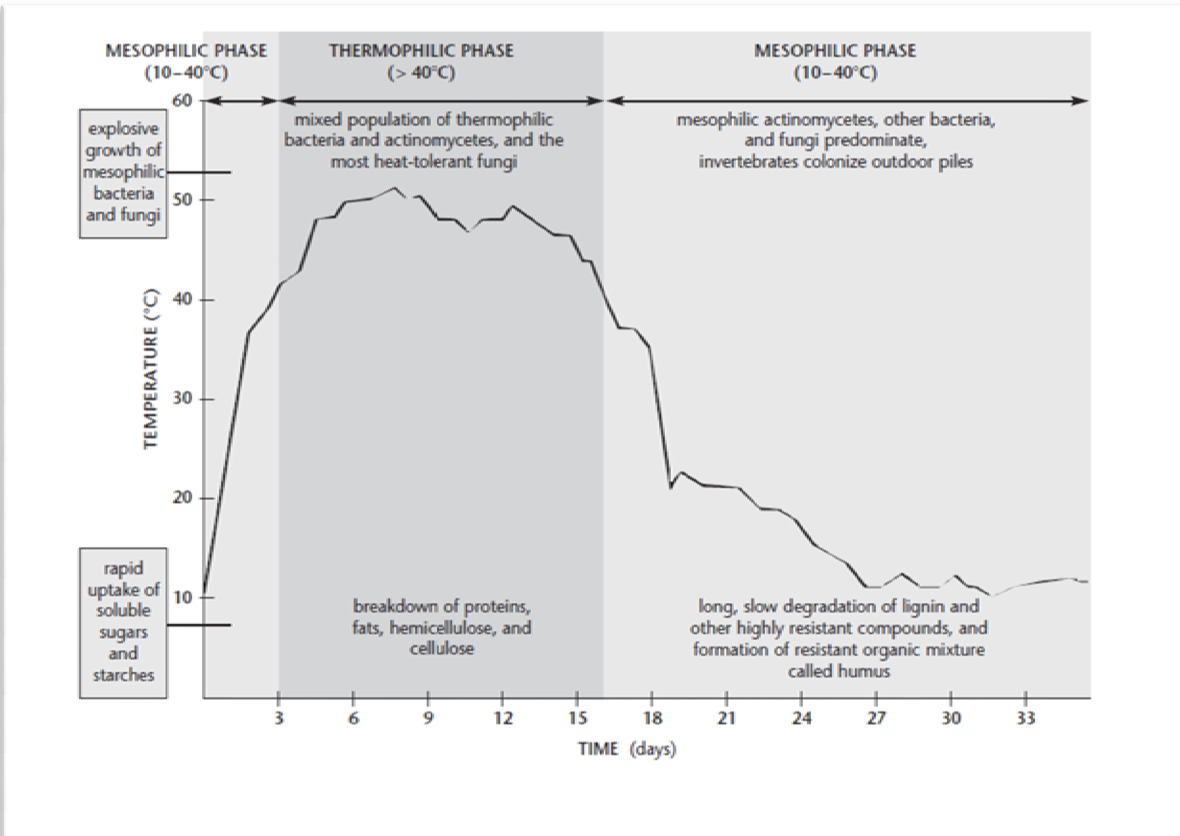

Fig. 2.5: Phases of thermophilic composting (Trautmann et al., 1997).

Compost temperature is rapidly increased as a result of heat produced from metabolic activity to microbes. controlling the temperature during composting can be achieved by mixing or turning the pile, because turning can release heat from the core of the pile (Trautmann et al., 1997).

Stabilization of windrow temperature has occurred when providing favorable environmental factors, such as ambient temperature, wind, shadow, and Humidity.

Heat that being produced by microorganisms must be balanced by heat that being lost to the atmosphere. There are three mechanisms of heat loss from a thermophilic compost pile: conduction, convection, and radiation.

- Conduction, refer to energy that is transferred from atom to atom by direct contact. This mechanism causes heat loss to surrounding air molecules. Small compost pile has a high surface area / volume ratio, therefore lost heat quickly by conduction. Insulation reduce this loss.
- Convection, refers to the transfer of heat by movement of upward air and vapor slowly and release the heat out the top. Most of the heat lost as latent heat (the heat needed to evaporate water).
- Radiation, refers to electromagnetic waves like the sunlight radiation. Heat radiation from the compost pile depend on the difference between pile temperature and ambient temperature, usually radiation of heat is negligible (Trautmann et al., 1997).

2.5.3 Mixing

Mixing of feedstocks that used to build a compost pile is very important in the initial stages of composting. It make the pile homogenized, and create equal distribution of moisture and air within the pile, therefore, promote decomposition (EPA, 1995).

Good mixing spead up degradation and lead to produce high quality homogenous compost, which often more important to establish a good marketing (Schneider et al., 2001; Illmer et al., 1997).

2.5.4 Size of Compost System

The size of a compost pile must be balanced to achieve good circulation of air, and to prevent rapid dissipation of moisture and heat. Thus, pile size must be large enough to ensure retention of heat and moisture, and small enough to allow good air circulation.

commonly the size of a pile for thermophilic composition should be at least $1m^3$(Trautmann et al., 1997).

2.6 Composting Methods

There are four general systems of composting; windrow composting, aerated static pile, in-vessel composting, and anaerobic composting. These system vary in aeration method, temperature control, mixing / turning, and the time required to obtain a finished compost. they may vary in their capital and operating costs. Generally, the lower the level of technology, the tower the cost per ton of finished product. Turned windrows method is a widely used for MSW composting (EPA, 1995; Schneider et al., 2001).

2.6.1 Windrow Composting

The windrow is a longitudinal pile, has a triangular cross section, and its height equal half the width, pile's height and width must be build to make the size of piles large enough to maintain temperature, and allow air circulation within the pile. Ideal height is between 4 and 8 feet (1.2 – 2.4 m), and ideal width between 14 to 16 feet (4.2 – 4.8 m) (EPA, 1995).

To prepare a homogeneous mixture for windrow, feedstocks must be shredded or grinded. This process also increase the active surface area for decomposition.

Air diffuse passively through the pile upward as a result of heat generated from microorganisms (connective currents).

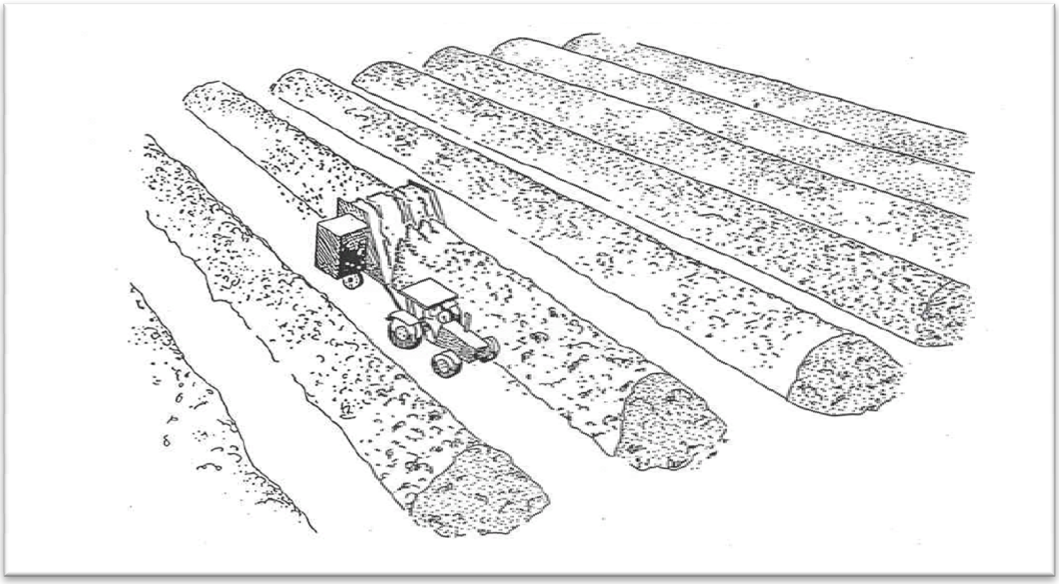

Fig. 2.6: Windrow composting(Schneider et al., 2001).

Front–end loader or commercial windrow turners can be used to turn the windrows, in addition to simple equipment like paddles and tines which may be used manually according to feedstocks volume. Using front-end loader is more cost effective than other specialized turning equipment (EPA, 1995).

Many municipalities have found the windrow compositing process very acceptable as it frequently requires very little additional capital investment when using front-end loader to turn the windrows (Schneider et al., 2001).

For easily turning and working the windrows must be placed on a firm surface and turned once a week.

Windrows may be placed under a roof or outdoor according to the environmental conditions; like: sunlight, wind, or precipitation. winter precipitation can result in runoff or leachate, which must be collected and can be reused in watering windrows. Therefore, to prevent problems related to leachate or runoff, piles must be covered or placed under a roof. Precipitation over the roof can be collected, and used for watering and other purposes in the facility, so that minimize costs of operation. Covering the piles also prevent the direct sunlight to reach and rise the pile temperature.

During the windrow turning process, slight odors may be developed, which can be minimized through frequent turning and good management such as C:N ratio adjustment, and keep optimal moisture (Schneider et al., 2001).

The time needed to produce stable compost is various according to feedstocks, however, finished compost can be produced within 4 to 5 months (Schneider et al., 2001).

2.6.2 Static Pile Composting

Feedstocks in this way are placed over a network of pipes connected to a blower or fan. Air is blowed or forced through pipes within the pile. Blower or fan usually controlled by timers or thermostat (Schneider et al., 2001). Movement of air inside the pile result in replacement of oxygen used by the microorganisms, and remove the excess heat produced from the microorganisms.

There is a possibility to retain optimum conditions in the pile at all times, therefore, increasing the rate of compositing process. usually the process takes 6 to 12 weeks to produce finished compost (EPA, 1995). Static piles can be placed very close together, thus, they need less land area which is advantage over windrow composting.

Static pile composting need daily monitoring and high level of management, also it is electricity dependent. Electricity or another power source is required to operate air blowers and fans.

Static pile system used under a roof or outside. Some projects ingather between static pile system and windrow system. Firstly, for few weeks static pile system used, then windrow system and mechanical aeration.

The greatest demand of oxygen occur in the beginning. Thus speed up the decomposition rate, after that material is moved and placed in windrow system (Schneider et al., 2001).

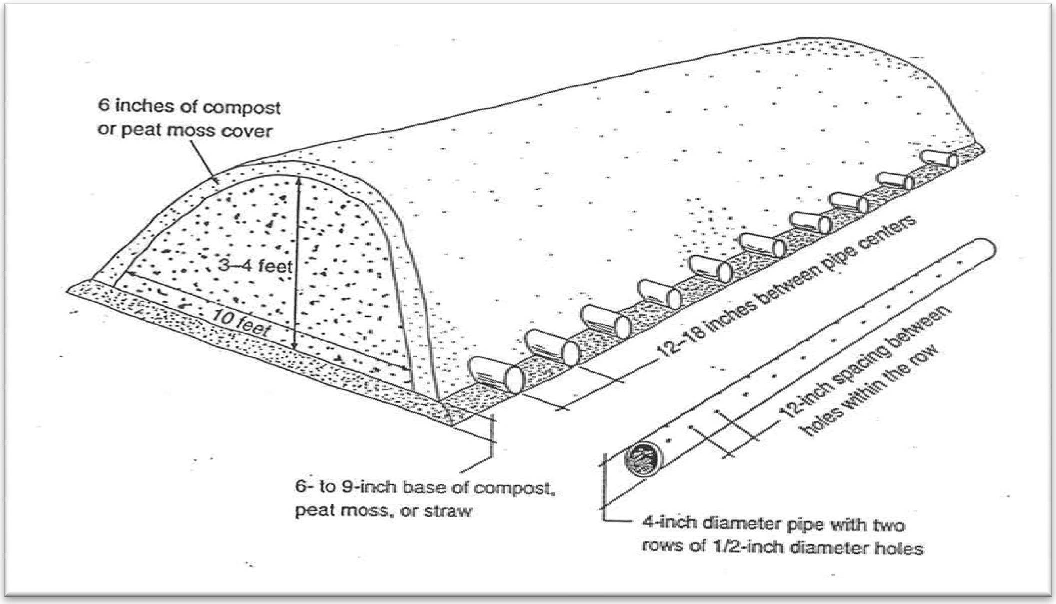

Fig. 2.7: Passively aerated windrow (Schneider et al., 2001).

2.6.3 In Vessel Composting

Feedstocks are enclosed in a chamber or vessel, there are a various types of system require high levels of technology and management, they need forced aeration mixing and moisture. Most of these systems are continuous feed systems, some are batches.

These systems include drums, silos, digester bins and tunnels. Some of these vessels rotate, others are stationary vessels and the material move around. In all in-vessel systems, curing is needed after discharging the material from the vessel.

All environmental conditions can be controlled in the vessel, allowing faster processes. retention time needed is range less than one week to as long as four weeks.

In-vessel systems have many advantages; they need less time, achieve homogenization, and produce minimal odors and leachate (EPA, 1995; Schneider et al., 2001).

In – vessel systems may not be economically sound for yard waste or separated MSW, but may be appropriate for sewage slug composting (Schneider et al., 2001).

2.6.4 Anaerobic Processing

This way has been used extensively to stabilize bio-solids from municipal sewage treatment plants for many years. Many scientists demonstrate that anaerobic processing can be used to stabilize MSW (EPA, 1995).

Organic materials are digested in the absence of oxygen by facultative bacteria to produce methane and carbon dioxide, methane can be converted to electricity.
Feedstocks are shredded, water and other nutrients are added, then the mixture is placed in a container. Liquefied materials are continuously stirred

.

2.7.1 Screening

Screening means to separate compost from non compostable fraction, and to reduce compost's particle size. Compost is screened before or after curing. The moisture content of the compost being screened should be less than 40 percent.

2.7.2 Curing

Curing is the process in which compost becomes biologically stable, this stage needs longer time than the first stage; in which rapid decomposition takes place resulting in significant lost in compostable materials weight, The microbial activity continued in the curing phase slowly to complete maturation. Curing stage usually takes several weeks to six months, typical period for curing is 3 to 4 months to obtain a fine texture and stable product (EPA, 1995).

2.7.3 Marketing

High quality compost which meets the needs of the markets is necessary to distribute all compost produced. for land application of MSW compost regulating standards considered. An important consideration is the metals content of the applied compost.
Many factors determine the quality and composition required for compost product to meet the needs of the market, those factors include: intended use, local climate conditions, and social and cultural factors. Marketing plan should incorporate criteria to fit a specific market needs; such as metal contaminants, foreign matters, nutrient contents, maturity, soluble salts, particle size and water holding capacity.
Marketing efforts should be continues; before, during, and after the compost production. To guide marketing plans, two objectives should be in concern: the first is to sell or distribute all of the compost produced, the second is to minimize costs and optimize revenues.

Potential large- scale users of composts include: farms, landscape contractors, high way departments, sports facilities, parks, golf courses, office parks, home buildings, cemeteries nurseries, green houses, topsoil, and land reclamation contractors as composts are rich sources of xenobiotic-degrading microorganisms, which can degrade pollutants and reduce its potential bioavailability (EPA, 1995; Semple et al., 2001; Smith, 2009). Compost must be viewed as a usable product, not as a waste needing disposal.

2.8 Compost Quality

The quality of compost directly impacts its marketability, several characteristics and parameters determine the quality of compost, include: particle size, pH, soluble salts, stability, and presence of undesirable components such as heavy metals, weed seeds, phytotoxines, glass, and plastic. According to the end uses of compost many countries suggest compost quality guidelines.

Common sources of chemical contaminants in MSW include: batteries, consumer electronics, motor oil, solvents, cleaning products, automotive products, paints, and cosmetics (EPA, 1994). Compost quality has significant differences in relation to collection systems. Source separation showed higher quality than mechanical sorting (Lopez et al., 2010; Achiba et al., 2009).

Age and storage conditions also affect compost quality. In curing phase most of available nitrogen converts from ammonium-nitrogen to nitrate – nitrogen. End compost must be stored as small piles in an aerated dry location, to allow aerobic respiration to continue, and to prevent anaerobic respiration which produce odors , alcohol, and organic acids that are damaging to plants.

Table 2.1: Heavy metals limits for compost standards (mg/kg dm)
(Hogg et al., 2002).

country	Cd	Cu	Ni	Pb	Zn
Austria	0.7	70	25	45	200
France	3	-	200	800	-
Germany	1.5	100	50	150	400
Greece	10	500	200	500	2000
Italy	10	600	200	500	2500
Spain	40	1750	400	1200	4000
Uk	0.7	70	25	45	200
Canada	3	100	62	150	500
Newzealand	15	1000	200	600	2000
USA	39	1500	420	300	2800

Table 2.2: Nutrients contents in conventional compost of waste concern (Rothenberger et al., 2006).

Nutrient	Concentration (%)
Organic matter (OM)	35-40
Nitrogen (N)	1.0 – 2.0
Phosphorus (P)	0.4 – 4.0
Potassium (K)	0.5 – 2.6
pH	7.8

2.9 Potential Compost Uses

There are many different potential compost applications. In agriculture compost can be used as a soil conditioner, fertilizer, erosion control, land remediation and for suppress some planet diseases. Also compost can be used as a potting soil and soil amendments. Compost as a soil conditioner can improve the soil characteristics (Farrell et al., 2010; Hargreaves et al., 2008; Mylavarapu et al., 2009; Semple et al., 2001; Weber et al., 2007). These improvements include:

- Improve water draining.
- Increase water holding capacity.
- Improve nutrient holding capacity.
- Buffer the pH of the soil. (Optimal pH for plant growth is 5 – 6).
- Regulate the temperature of the soil.
- Control soil erosion.
- Increase void space, that activate air circulation.
- Improve soil content of organic matter.
- Aid in disease suppression.
- Provide the soil with trace elements, and retard its leaching (Kaschl et al., 2002
- Reduce bulk density.
- Increase cation exchange capacity of sandy soil.

Composts may have several advantages over fertilizers, such as:

- Compost’s slowly release nutrient among long period of time.
- Composts provide the soil with micronutrients that lacked in fertilizers.
- Stable compost can suppress some soil-borne diseases.
- Fewer impacts if the avoided loads are considered (Blanco et al., 2009).

2.10 Developing A Composting Program

Developing a composting program is the business of residents, planners, and decision makers. According to the principles of integrated waste management, there is no single solid waste management option can solve all waste problems in any community. Often there is disagreement among all stakeholders about the best alternative. On the base of the community goals and evaluation criteria that adopted in the planning phase, the best option must be selected. There are two main types of composting programs with respect to MSW collecting manner; source separated organic composting programs, and mixed MSW composting; It minimizes handling time, tipping space and equipment needed in mixed MSW compositing. Moreover source – separation compositing produces a high quality compost, because the feedstocks are relatively free of heavy metals, chemical contaminants, and foreign materials.

Organic materials that used for source-separation composting include some of the following materials: yard trimmings, food scraps, shredded paper and wood scraps.

The number of source – separated composting programs and facilities is steadily increasing in the USA. EPA places the mixed MSW composting at the bottom of the compositing hierarchy.

2.10.1 Planning

If composting is available and desirable option, well planning must be the first step in order to minimize operational difficulties, keep costs, produce a high – quality compost, keep markets, and maintain community support.

EPA suggests the following steps for developing and implementing a successful composting program:

1- Identify the scope of the project.
2- Gather Identify the goals of composting project.
3- political support.
4- Identify potential sites and environmental factors.
5- Identify potential compost uses and markets.
6- Initiate public information programs.
7- Inventory materials available for composting.
8- Visit successful compost program.
9- Evaluate alternative composting and collection techniques.
10- Finalize arrangements for compost use.
11- Obtain necessary governmental approvals.
12- Prepare funding.
13- Facility construction.
14- Operation and monitoring.

2.10.2 Identify Compost Project Goals

In order to save time and efforts, identifying the goals clearly, must be the first step in planning compositing project. Usually the basic goals include: reducing the amount of waste to be landfilled, reducing the costs of collection, encourage recycling, using compost as a landfill cover, and using compost for erosion control, and recovering revenues by producing a marketable compost. Selling compost needs high quality compost that meet high standards.

Chosen goals should be compatible with the community's overall solid waste management plan, including collection and landfilling. The clear identified goals facilitate the governmental approval and political support to the project. Open dialogue with the concerned members of the public must be conducted in order to gain community support.

2.10.3 Identify Potential Compost Uses and Markets

To obtain revenues from compost, useful purposes must be developed .General uses of compost include: agricultural applications, greenhouses, mine reclamation, forestry application, topsoil, landscaping, soil remediation, roadside, landscaping, and landfills cover.

2.10.4 Source of Feedstocks

Good planning must accurately assess the quantities of waste, and the composition and the sources. This assessment is required to estimate feedstocks quantities for compost, and helps to choose the type and size of equipment needed and the area required for initiating a composting project. Such data can help in determining the labor needs and the economics of the operation. Data must be collected for one year at least, such data should be representative for second fluctuations in waste quantities and composition. Household hazardous waste must be collected separately, so that, eliminate contaminants from compositing feedstock and produce a high quality compost.

2.10.5 Public Participation

Local residents have a critical role to successful any project deal with MSW management. Therefore residents concern with composting projects to protect themselves from waste-borne diseases. Public involvement must begin in the planning stages, compost approach should be questioned by residents before it is fully established, and education programs are required to gain public support, and to avoid any objections from residents. Also source – separation of compostable materials require public willingness to participate and change the way that residents sort discarded waste.

Chapter Three

Research Methodology

3.1 Introduction

This chapter reviews the approach used to investigate the research objectives, and discusses the methods of data collection, pilot scale, lab. analysis, questionnaire design, and the materials used through that.

3.2 Data Collection

Detailed literature survey was conducted on solid waste management practices and composting methods in Palestine and other developed countries. There are appreciable variation in MSWM and compositing organic waste. Composting methods vary in the degree of technology, monitoring, space needed, time, and feedstock.

The windrow composting is one of the most economical methods, thus, it has been chosen as a method to recycle household organic waste in this study. The amounts of household organic waste generated were measured with the contribution of pupils of Beit liqia boy's secondary school. Every pupil weighed the food scraps that generated from his household. Daily data were recorded for a week, household generation was equal to 0.55 ($kg.\ cap^{-1}.day^{-1}$).

Total amount of MSW generated from the village was estimated through the number of moves of overall MSW, and the volume and weight of compactor truck load.

3.3 Pilot Design

At the end of April 2008, 400 kg of compostable organic waste (food scraps) were collected after source separation. Food scraps were shredded manually to small pieces using kitchen cutting equipments. Chopped wheat straw had been chosen to used as a bulking agent because it found to offer the best properties with a high water absorption, capacity of over 500% and neutral pH (Adhikari et al., 2009).

Fig. 3.1: Compost pile.

As the ratio 1:1 v:v is more suitable than others (Banegas et al., 2006), equal volumes of shredded food scraps and bulking agent, which was chopped wheat straw mixed with sheep manure (bedding) were loosely spreaded in layers of 15 cm alternatively in a pit with 1.0 m, 2.0 m, 0.2 m dimensions prepared for this purpose. The pile was covered with a thin layer of soil mixed with manure.

Initially the pile was turned twice a week for 2 weeks using a fork, then once a week for 40 days. Turning is required to supply the microorganisms with sufficient oxygen. Temperature was measured daily using alcohol thermometer at 40 cm depth within the pile. Temperature was monitored and recorded until the pile temperature stopped decreasing and was nearby the ambient temperature.

Optimum moisture content generally ranges of 50-60 % (Yaghmaein et al., 2005). Moisture content was tested using squeeze test, in which a handful of compost squeezed very hard. One to three drops indicate ideal level, no drops indicate dry, many drops indicate too wet. Wear protective gloves were used in squeeze test, little water was added during turning when needed in the case of dry.

The pH was measured once a week .After two months the produced compost was cured for 5 months, finished compost was screened using a manual sieve of 0.4 cm pores.

3.4 Lab. Analysis

Finished and screened compost was mixed. Random ten sub-samples were taken and mixed again, then two samples were taken and analyzed at the water and waste water lab. of Birzeit university according to the standard methods of soil and plant analysis laboratory manual (Ryan et al, 2001).

The parameters that tested include pH, EC, nutrient content (N, P, K), moisture, dry mater, organic carbon, ash, and heavy metals concentrations. Results were compared to the national standards in order to verify the quality of finished compost.

3.5 Questionnaire

A structured survey using a questionnaire has been conducted in order to make inquiries about the satisfaction with the current MSW management system and the willingness to pay for a new compositing system. The survey was covered a randomly sample of households selected from the community. The number of households for the survey was (88 – 93) according to an already calculated sample size allowing a 95 % confidence level.

Calculations of sample size (n) is based on the equation below

$$n = \frac{tp2 * p * (1 - p) * N}{tp2 * p * (1 - p) + \ (N - 1) * y2}$$

Where N stands for population size.

y for sampling error.

p for the true proportion set as 0.5.

t_p equals to 1.96 for 95 % confidence level.

Table 3.1: Calculations of sample sizes for household surveys (Rothenberger et al.,2006)

Required sample size allowing a 95% confidence level			
Total number of house-Hold in the community	±5% sampling Error	±7% sampling Error	±10% sampling Error
100	50	50	49
250	152	110	70
500	217	141	81
750	254	156	85
1,000	278	164	88
2,500	333	182	93
5,000	357	189	94
10,000	370	192	95
25,000	378	194	96
50,000	381	195	96
100,000	383	196	96
1,000,000	384	196	96
100,000,000	384	196	96

Many relevant questions were included in the questionnaire for the household survey, about satisfaction with current solid waste management system, municipal administration, pollution of the local environment, waste collection system, and the willingness to pay monthly for the compositing system. Completed questionnaires were analyzed manually, the given answers were counted and expressed as a percentage of the total number of answers for each question. Survey axes include:

1- The degree of satisfaction with the current solid waste management system in the community.
2- The degree of solid waste management services from municipal administration in the study area.

3- The degree of public awareness that the current waste management system pollutes the local environment.
4- The degree of willingness to pay a fee for developing a composition system.
5- Basic information about the local environment of study area, family size, educational level, agricultural activities.

Chapter Four
Results and Discussion

Experimental results: including temperature and pH measurement all along the experiment.

4.1.1 Temperature Measurement

A rapid increase in temperature was recorded during the initial days of composting. Temperature reached the thermophilic phase in the third day, water vapor volatilization was observed during turning of the compost pile.

Daily measurements of temperature 40-50 cm inside the compost pile, the ambient temperature, pH, and times of turning the pile were recorded as shown in table 4:1.

Initially, the temperature of the composting pile gradually increased to reach 62 C^o in the end of the first week, then ranged from 62 to 68 C^o in the second and third two weeks, then it began to decrease gradually in the beginning of the fourth week to become near or close to the ambient temperature at the end of the second month. Fig. 4.1 shows temperature variations in 40 cm depth of the composting pile and the ambient temperatures.

Table 4.1: Measurements of temperature and pH inside the compost pile.

Day	*pile Temp.*	*Amb. Temp.*	*PH*	*Turning*
1	24	24	7.3	
2	27	25		
3	30	24		
4	35	24		
5	58	23		
6	62	25		
7	62	24		
8	63	21	6.3	***
9	63	24		
10	68	32		
11	68	28	8.2	
12	65	29		
13	65	28		***
14	63	23		
15	65	25		
16	65	25		
17	65	28	8.1	***
18	66	28		
19	65	27		
20	65	26		
21	64	25		***
22	62	27		
23	60	26		
24	60	27		***
25	58	26	8.1	
26	58	26		
27	57	26		
28	56	27		***
29	55	27		
30	53	28		
31	50	29		
32	48	28		
33	47	29		

34	46	33		
35	45	29	8.2	***
36	45	28		
37	43	27		
38	43	28		
39	42	27		
40	42	28		
41	40	28		
42	38	29		
43	35	28		
44	34	27	8.3	
45	34	27		
46	34	28		
47	34	29		
48	34	30		
49	34	30		
50	34	29		
51	34	30		
52	34	30		
53	34	31		
54	34	32		
55	34	32		
56	36	33		
57	36	32		
58	37	30		

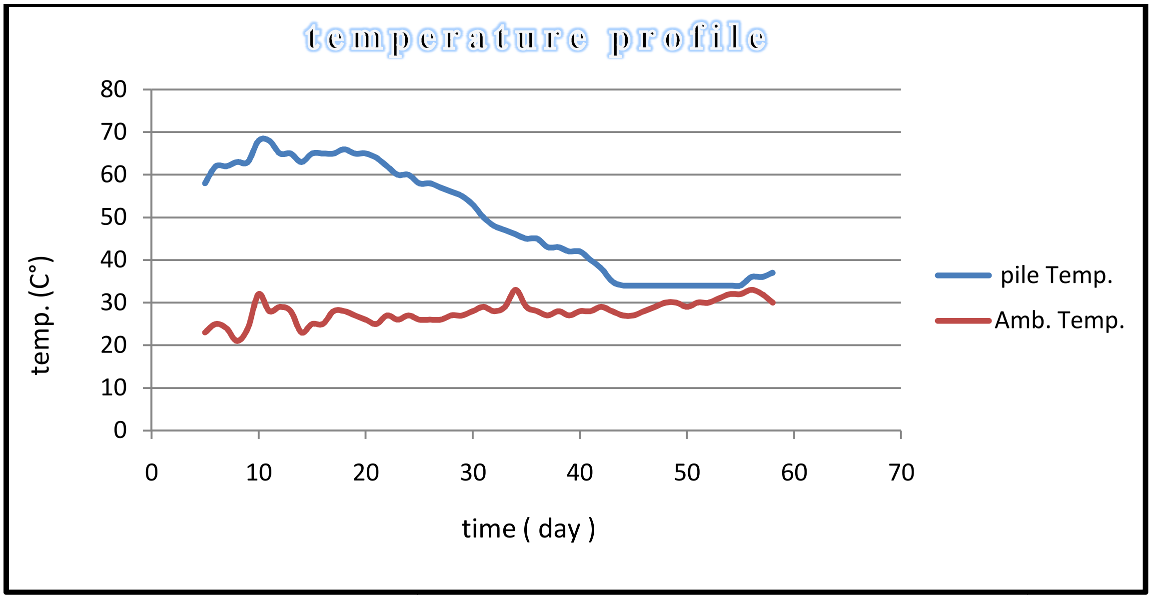

Fig. 4.1: Temperature variations in 40 cm depth of the pile compared to ambient temperature variations.

4.1.2 pH Measurements

The pH values were recorded weekly, as shown in table 4.1, a rapid decrease was observed in the first week, it reached 6.3 in the 8th day, then it began to increase during the second week, pH= 8.2 was recorded in the 15th day, after that the pH values began slowly to decrease, pH = 7.9 in the day number 57.

Figure 4.2 shows the pH variations all along the composting process.

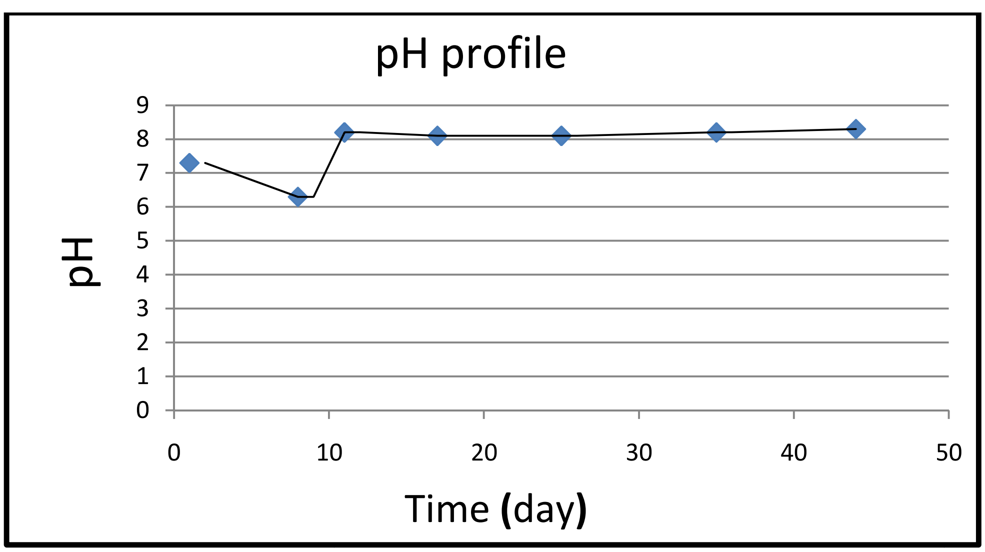

Fig. 4.2: pH variations during the composting process.

4.1.3 Weight of End Product

About 400 kg of raw food scraps and straw mixed with animal manure had been decomposed and cured then screened manually.

The weight of end product(compost) was 186 kg, (percentage yield = 46.5 %).

4.2 Lab. Analysis Results

The characteristic of the end product are shown in table 4.2.

Table 4.2: Main characteristics of the produced compost.

Parameter	Unit	Result
Moisture	%	34.31 ± 0.18
pH		7.65 ± 0.02
EC	ms/cm	9.13 ± 0.06
Organic matter	%	55.57 ± 0.39
Ash @550 Cº	%	44.43 ± 0.39
C/N ratio		48.00 ± 1.78
Total nitrogen (N)	%	0.64 ± 0.02
Total phosphorous (P)	%	1.70 ± 0.12
Total potassium (K)	$mg.kg^{-1}$	9880 ± 30
Total calcium (Ca)	$mg.kg^{-1}$	88900 ± 300
Total magnesium (Mg)	$mg.kg^{-1}$	6350 ± 20
Total boron (B)	$mg.kg^{-1}$	35.65 ± 2.75
Total copper (Cu)	$mg.kg^{-1}$	23.95 ± 0.05
Total manganese (Mn)	$mg.kg^{-1}$	190.5 ± 0.5
Total cadmium (Cd)	$mg.kg^{-1}$	1.3 ± 0.00
Total lead (Pb)	$mg.kg^{-1}$	5.15 ± 5.05
Total iron (Fe)	$mg.kg^{-1}$	11200 ± 0.00
Total zinc (Zn)	$mg.kg^{-1}$	280.5 ± 0.5
Total nickel (Ni)	$mg.kg^{-1}$	17.95 ± 0.95

4.3 Questionnaire Analysis

Completed questionnaires were analyzed by counting the given answers. Total number of answers expressed as percentages in table 4.3 below:

Table 4.3: questionnaires answers.

Average family size		8.3
Husband job	a-employees	25.55%
	b-worker	61.11%
	c- farmers	3.30%
	d- without job	4.44%
Wife job	a-worker women	7.77%
	B- without job	90%
Educational level for husband	illiterate	2.20%
	elementary	10.00%
	high elementary	20.00%
	secondary	30.00%
	institute	10.00%
	university	20.00%
Educational level for wife	illiterate	3.30%
	elementary	21.11%
	high elementary	36.70%
	secondary	14.40%
	institute	5.00%
	university	5.60%
Family income	< 2000 NIS	22.20%
	2000-3000 NIS	36.70%
	3000-4000 NIS	22.20%
	> 4000 NIS	16.70%
Current system of household waste	small container for single household	65.60%
	large container for many households	10.00%

storage	bags to put on the edge of the street	23.30%
Average area of the household		153m2
Household included in MSWM service		88.90%
Household not included in MSWM service		11.10%
Residents satisfaction on MSWM	very good	11.70%
	good	26.70%
	weak	31.10%
	not satisfied	25.60%
Weekly number of collection times	once a week	17.80%
	twice a week	35.60%
	three times	4.40%
	unstable program	36.70%
Problems faced residents	absence of container	40.00%
	container misplace	20.00%
	container not extent to waste	46.70%
	container is too far- reaching	23.30%
	container surrounding is dirty	16.70%
	workers don’t return the container to its place	41.10%
Current system for SWM pollutes environment	yes	95.60%
	no	3.30%
Pollution reasons	a-absence of containers	30.00%
	b-scattering garbage in the street and agricultural land	36.70%
	c-waste collector come late	57.8%
	d-leave scattered garbage around the container	42.20%

	e-throw garbage in rainwater flow	25.60%
	f-waste incineration in the dump site	73.30%
Household fee for MSWM		15.00NIS
Who disposes household waste	a-husband	5.60%
	b-wife	18.90%
	c-one of child	81.10%
	d-others	2.20%
Current time for waste collection	a-morning	23.30%
	b-noon & afternoon	14.40%
	c-evening	13.30%
	d-night	5.90%
	e-undetermined times	54.40%
Is this time good	a-yes	28.90%
	b-no	68.90%
At what time you prefer waste collection	morning	32.20%
	noon	14.40%
	evening	13.30%
	night	23.30%
Preferable way to remove waste from the house	a-put waste in a small container	54.40%
	b-put waste in a large container at the roadside	45.60%
	c-send waste to the dumping site by your self	1.10%
Beit liqia need to develop a new system for SWM	yes	95.60%
	no	3.30%
Which steps you agree	a-source separation	61.10%

to develop a new system for SWM	b-set a time table for waste collection	25.60%
	c-waste recycling	44.40%
	d-rehabilitate the current dumping site	18.90%
	e-initiate a new sanitary landfill site	52.20%
	f-Initiate a public awareness program .	42.20%
Willingness to initiate a composting program	yes	97.80%
	no	2.20 %
Agricultural activities by residents	yes	64.40%
	no	33.30%
Using compost is better than chemical fertilizer	yes	93.30%
	no	1.10%
Willingness to purchase compost	yes	87.80%
	no	7.80%
Compost advantages over chemical fertilizers	a-less price	50.00%
	b-improve soil properties and increase fertility	58.90%
	c-leads to healthy food out of chemicals	63.30%
	d-release nutrient in the soil for a long time	37.80%

Many suggestions from residents interviewed were looked out, the included:

- want to give out session and lectures in environmental awareness, and the importance of compost uses in agriculture.
- availability of institutions that present help to farmers to fertilize plants correctly with compost and fertilizers.
- stop burning waste in the dumping site, and found an alternative.
- BZU should takes these researches seriously, and work for applying them to be realistic.
- Increase the number of containers, and systematize waste collection and disposal.

The results revealed an accelerated increase in the temperature of compositing pile in the beginning few days of the process. This can be explained as the microbial community in the pile produced heat as a by- product because of the intensive metabolic activity.

This raise is required to kill pathogens in order to obtain compost out of pathogens and weed seeds that causing diseases to human and plant, but the manager must be careful from excess raise of temperature because if temperature goes above 60-65 Cº, the beneficial microorganisms are also killed (Trautmann et al., 1997).

It is known that the study area has a warm climate relatively, which make the temperature rising above the allowable value is bearable. Therefore, composting process must be takes place in the shadow and far-off the direct sun shine. The pH value was decreased in the beginning of decomposition process as a result of accumulation of organic acids that produced as a by-product of bacterial digestion to organic matter. This drop in pH may be beneficial as it encourages growth of fungi, which are active in degradation of cellulose and lignin. Organic acids also decomposed or volatilize creating a rise in the pH. Percentage yield of end product compost was 46.5% of the raw waste materials. The loss of weight is due to the loss of water and carbon dioxide that released as a result of microbial respiration, and volatilization of ammonia produced from proteins.

Lab. analysis results present many indicators for compost quality, most of the quality parameters were nearby the quality standards presented in EU, North America and Australasia, except the EC value which was 9.3 ms/cm, and this is a common problem with all the biowaste composts (>4.0 ms/cm). This parameter (EC) is correlated mainly with salts concentration (Manios, 2004). Heavy metals concentrations were below standard limits which means a safe end product for plants. Maturity indicators like pH, organic matter and dry matter were within the ranges of maturation parameters.

High C/N ratio was recorded which may be due to excess amount of straw as a bulking agent and source of carbon. This problem can be solved by reusing the end product as a bulking agent in a new compost pile. Nutrients content of compost recorded low concentration of NPK nutrients, that are needed in large quantities for plants. This problem can be solved by adding some additives of certain nutrients. Fertilization with mineral N follows compost application is recommended (Weber et al., 2007).

Questionnaire analysis results present important indicators about the current system of MSWM and local community opinions and willingness toward developing composting program. High percentages indicate a burning desire to transships MSWM in the study area, which means expected community advocacy to proposed project in this study.

Many obstacles may be faced in the future, as too much optimism may lead to failure, so solutions for such expected obstacles must be solved. These difficulties include SW fee payment, fluctuation of SW amount among seasons, permissions and marketing of the end product. Planners must seek for alternatives.

4.4 Constructions of Composting Facility

There are many different models for solid waste management, four models for decentralized compositing proved to be applicable in many countries (Rothenberger et al.,2006). The usefulness of each model is strongly dependent on local conditions and cultural backgrounds. The factor models are:

1- Municipally owned – municipally operated.
2- Municipally owned – community operated.
3- Municipally owned – privately operated.
4- Privately owned – privately operated.

The first model (Municipally owned – municipally operated) was chosen for two factors; land is available, and already existing waste collection system.

4.4.1 Composting Plant Layout

This section describes a windrow composting plant. Components able to process three to five tons per day, figure 4.3 shows a layout plan for windrow – composting plant.

Table 4.4 shows the required spaces for each part of the composting plant. These requirement areas can be scaled up to fit the local conditions, the composting area can be extended to five tons of waste per day. These schemes are suitable for manual work, more waste need more mechanization, leading to higher operational costs. However, higher capacities are unnecessary, as the decentralized composting sites seldom cover more than 3000 households (Rothenberger et al., 2006).

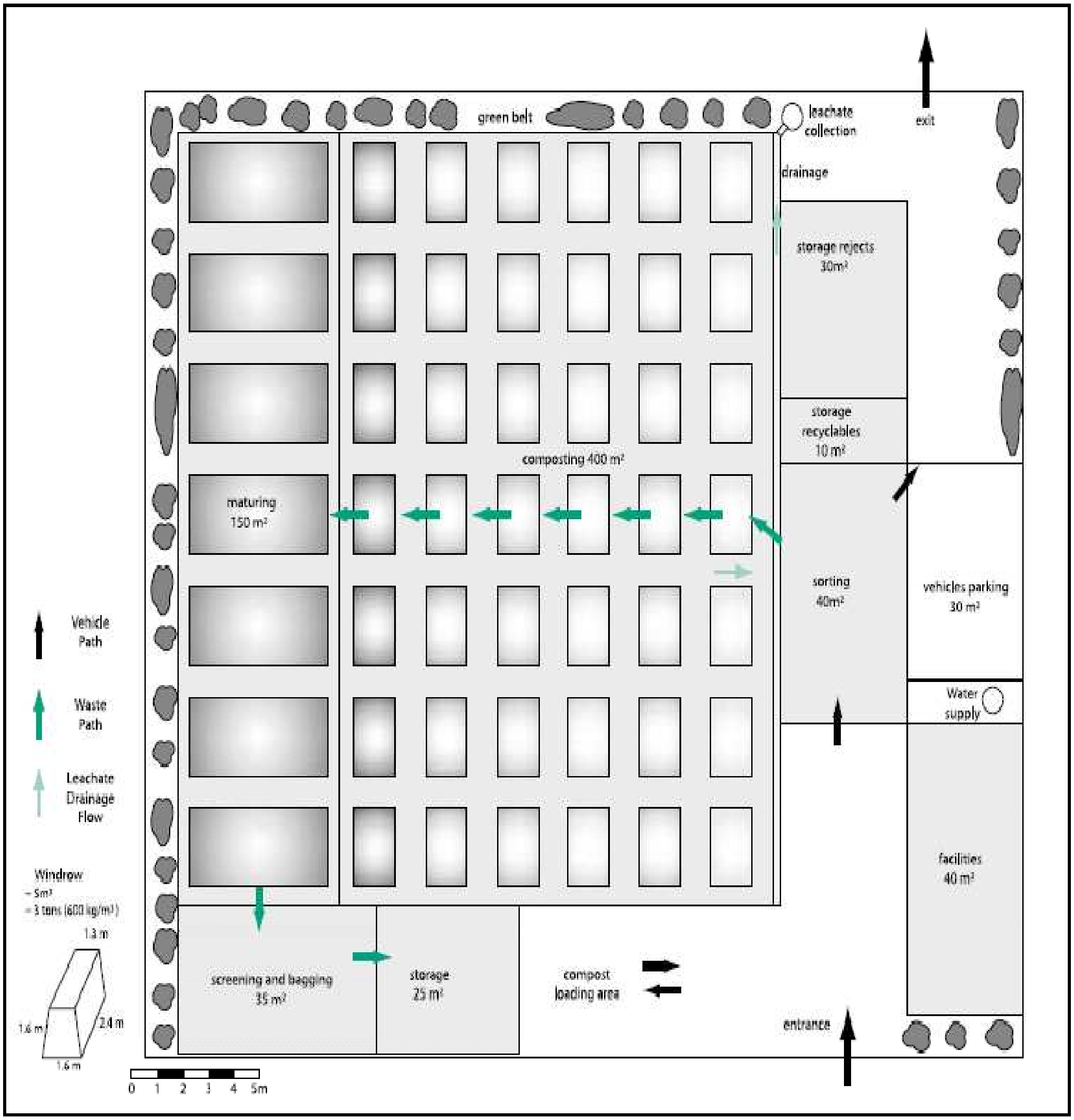

Fig. 4.3: Windrow-composting system layout plan (Rothenberger et al., 2006).

Table 4.4: Required space for windrow – composting plant.

Type	Required area (m^2)	Roof
Sorting area	40	Yes
Storage of rejects	30	Yes
Storage of recyclable	10	Yes
Composting pad	400	Yes
Maturation area	150	Yes
Screening and bagging area	35	Yes
Compost storage area	25	Yes
Sub-total composting area	690	
Facilities		
Office	16	Yes
Sanitary facilities	10	Yes
Tool shed	10	Yes
Water supply point	4	No
Vehicles parking area	30	No
Green buffer zone (trees /bushes)	50	No
Total area	810	

4.4.2 On – site water supply

Water is needed for hygienic purpose in addition to watering the compost piles. The plant must contain a stand pipe and additional water storage tank because water supply is not continuous. Also there is a possibility to design a rainwater harvesting system. water can be collected during winter in tanks or well to solve water shortages during summer. The average rainfall in the study area reach to 400mm (Beit liqia – metrology station), which means that if the roof area equal to 1000 m^2, the catchment amount of rainwater equal to 400 m3, which means more saving of operational costs as a result of less consumption of water from the network.

4.4.3 Roofed Area

Roof protects the compost piles from sunshine and excessive rainwater, as direct expose to sunshine heats the compost piles more than allowable temperature (65 C^o) leading to death of microorganisms and composting failure. Excessive rainwater causes leachate to minerals and nutrient leading to poorly end product which is plant nutrients. Mild steel pipes and corrugated iron sheets can be used to build the roofed area.

The distance between the pillars must be more than three meters to allow easier movement of workers and vehicles during composting.

Foundation construction must be carefully designed by engineers to avoid settlement and cracks in the structure. As study area found in semi-aired region it is advisable to cover the compost piles with a permeable cover made of just to prevent excessive evaporation.

4.4.4 Sorting Area

The floor consist of smooth concrete surface which slightly sloped (1%) to prevent ponding of leachate that may squeezed from fresh waste.

Incoming waste spread on the surface, then inorganic recyclable and rejects removed. Leachate and cleaning water collected and reused for watering compost piles. Racks and shovels can be used to remove impurities from organic waste.

4.4.5 Storage Area for rejects and recyclables

This area must be roofed and possibly enclosed to prevent roaming animals from entering the site. Rejects should be collected in covered container and frequently replaced.

4.4.6 Office and Sanitary Facilities

On-site office provided with essential equipment and furniture is needed to facilitate monitoring and accounting records. Also workers need to rest in a comfortable place during the break time. Sanitary area comprises toilets, bathroom and clothes room, workers need to wash and change clothes after handling waste and before leaving the work place. Workers protection from bioaerosols and volatile compounds exposures is needed (Persoons et al., 2010).

4.4.7 Tool Shed

This facility is required for storing small equipment, such as sieves, shovels and rakes. Approximately 40 m^2 roofed area is needed.

4.4.8 Composting Area

This area should be roofed, and the floor is preferably to be concreted, and slightly sloped (1%) to allow leachate to flow down into a drain towards to a collected pond to reuse in watering composting piles. This area of the plant can be designed to be expanded in the future according to the amount of waste, an area of 360 m^2 is sufficient to hold seven parallel windrows.

4.4.9 Additional Composting plant features

A small shop can be set up within the composting plant to sale compost products and potted plants, this can promote organic forming and use compost in agriculture. A nursery for pot plants can be established if land and staff are available, this keep the environment near the composting plant clean and green, and attractable for visitors, creating an additional source of income. Waste water reuse system also can be designed to benefit from waste water generated from cleaning the plant to be reused for new compost piles. Wastewater can be collected in a small covered storage tank under the ground level then reused by mixing with pipes or rainwater.

4.4.10 Staffing Requirements

Composting plant needs persons have to be willing to work with waste. local habits and values such as culture, religion, gender and perceptions are strongly affect the staff selection. The work in the composting plant is more convenience for poor people than others as they have the willing to work with the waste, but some of the workers should be literate to be able to monitor and record daily measurements like temperature, pH, and moisture. Table 4.5 shows staff needed and basic skills required.

Table 4.5: Staff required for three tons / day composting plant.

Item	Number	Requirement
Manager / Engineer	1	-Graduate with management skills , willing to work with waste
Collection workers (part time)	4	-basic mechanical skills
Composting worker (full time)	6	One of the literate monitoring and recording

4.4.11 Equipment Requirement

For efficient performance of composting plant, many expendables and manual equipments must be available. Table 4.6 shows the needed equipment and expendables.

Table 4.6: Equipment and expendables.

Item	Number
Buckets	6
Shovels	6
Rakes (long and short handle)	6
Watering pots	2
Thermometer	2
Sieves	2
Bags (size depend on market)	as requirement
Brooms	6
Baskets	6
Uniforms gloves boots and face masks	20 sets

4.5 Financial Projection

In order to assess the financial viability of the composting plant a benefit – cost analysis is needed. As all projects have many risks, using too favorable assumptions can lead to a failure. Immediate returns from the investments made on composting plant are usually unexpected, because the returns are generated over a number of years. So that net present value (NPV) and benefit / cost ratio (BCR) calculations are needed to evaluate future costs and revenues.

The following steps were conducted to calculate NPV and BCR:

a- The time frame for the composting plant was assumed to be 5 years.
b- Determination of annual revenues.
c- Determination of annual costs.
d- Calculation of annual net benefits.
e- Determination of appropriate discount rate.
f- Calculation of the financial net present value (NPV).
g- Calculation of the benefits / cost ratio(BCR).

4.5.1 Annual Project Revenues

Usually in decentralized composting projects, there are two types of revenues; revenues from sale of compost, and revenues from fees for waste collection.

In addition to future expected revenues from sale of recyclables and potted plants. Revenues were assumed to be constant over the calculated period (5 years). In the future the collection fees might increase over years, in addition to the increase in the number of households. Also compost prices might increase over years. Table 4.7 shows the expected annual revenues from the project.

Table 4.7: Annual revenues.

Item	NIS	US $
Sale of compost 2tons/ day @ NIS .200/ton (365days/year)	146000	36500
Monthly fees for house-to-house waste collection service from 1350 households @ NIS 15 / household	243000	60750
Total revenues / year	389000	97250

4.5.2 Project Costs

There are two main types of costs; investment costs which usually occur at the beginning of the project, and annual operation costs that continually all along with the daily activities. Operation costs are divided into fixed and variable costs. Tables 4.8 and 4.9 show investment and operational costs.

Table 4.8: Investment costs.

Item	NIS	US $
Site preparation	5000	1250
Construction of roofed compositing plant Of 1000 m^2 × NIS 200 / m^2	150000	37500
Construction of office , bathroom and toilet	10000	2500
Water and electricity connection	30000	7500
Shovels , buckets , balance , protection gear , Overalls workers , …. etc.	2000	500
Purchase of front end loader	40000	10000
Purchase of shredder .	11000	2750
Total investment cost	248000	62000

Table 4.9: Annual operational cost.

Item	NIS	US $
Salary of 3 workers @ NIS 4500/month×12 months	40950	10237.5
Salary of guardsman @ NIS 750 / month × 12 months	9100	2275
Salary of driver @ NIS 2000 / month ×12 months	22999	5749.75
Salary of 3 waste collector @ NIS 4500/month ×12	40950	10237.5
Salary of plant manager @ NIS 2500 / month ×12months	30000	7500
Electricity and water consumption	5000	1250
Fuel consumption (annual)	57369	14342.25
Maintenance costs for equipment (annual)	43849	10962.25
Additives for compositing process (annual)	2000	500
Transportation (NIS 10/ton)	7300	1825
Total operational costs	174718	43680

4.5.3 Annual Project net Benefits

Subtraction costs from revenues for each year is equal the annual net benefits. Annual net benefits were calculated for each year of the five year . Table 4.10 shows the annual net benefits for the compositing plant in NIS, as it a circulating currency. the annual net benefits in the year 0 is negative as a result of the high costs at year 0 which equal to the total investment costs of the project, and there are no revenues in that year.

Table 4.10: Calculations of annual net benefits (NIS).

Year	Annual revenues	Annual costs	Annual net benefits
0	0	248000	-248000
1	389000	174718	214282
2	389000	174718	214282
3	389000	174718	214282
4	389000	174718	214282
5	389000	174718	214282

4.5.4 Discount Rate Determination

Discounting means the process used to convert the future cash flows(costs and revenues) to present value. The value of money decreases with time; the longer you have to wait the lower is the present value for you Therefore future costs and revenues of the composting plant were discounted. Present value (PV) is calculated using the formula

$$PV = A / (1+r)^{n}$$

Where A: Is the annual revenues / cost , and r: is the discount rate (local interest rate) and n is the year when the revenues / cost occur. PV calculation for a whole project is a complex process, therefore, discount factor tables were developed by practitioners to be easily used. Table 4.11 shows a selection of discount factors of different discount rates for periods up to seven years. The interest rate of the local market is determinative factor for discount rate selection.

Table 4.11: Discount factors for selected discount rates.

Year	6%	8%	10%	12%	14%	16%	18%	20%
1	0.9434	0.9259	0.9091	0.8929	0.8722	0.8621	0.8475	0.8333
2	0.89	0.8573	0.8264	0.7972	0.7695	0.7432	0.7182	0.6944
3	0.8396	0.7938	0.7513	0.7118	0.6750	0.6407	0.6086	0.5787
4	0.7921	0.7350	0.6830	0.6355	0.5921	0.5523	0.5158	0.4823
5	0.7473	0.6806	0.6209	0.5674	0.5194	0.4761	0.4371	0.4019
6	0.7050	0.6302	0.5645	0.5066	0.4556	0.4104	0.3704	0.3349
7	0.6651	0.5835	0.5132	0.4523	0.3996	0.3558	0.3139	0.2791

4.5.5 Net Present Value (NPV) Calculations

The NPV is the sum of the discounted revenues minus the discounted costs. The project will be viable when the NPV is positive, which achieved when the sum of discounted revenues exceeds the investments. The higher the NPV the more the profit that can be generated. Seek for additional subsidies and cost reduction is advisable to increase profit and keep the project financially viable. A negative NPV means that the project is not financially feasible. Table 4.12 shows NPV calculations with 16 % assumed discount rate.

Table 4.12: NPV calculation (NIS) (discount rate 16 %).

Year	Annual revenues	Annual cost	Annual net benefit	Discount factor	NPV
0	0	248000	-248000	1	-248000
1	389000	174718	214282	0.8621	184733
2	389000	174718	214282	0.7432	159254
3	389000	174718	214282	0.6407	137290
4	389000	174718	214282	0.5523	118348
5	389000	174718	214282	0.4761	102020
Sum of NPV					453645

4.5.6 Benefit –Cost Ratio (BCR) calculation

BCR = sum of discounted revenues / sum of discounted cost

Similarly to the NPV, if the BCR >1 then the project is viable, and if the BCR <1 then the project is not financially feasible. Table 4.13 shows BCR calculation.

Table 4.13: BCR calculation (NIS) (discount rate 16 %).

Year	Annual revenues	Annual cost	Discount factor	Annual discounted revenues	Annual discounted costs
0	0	248000	1	0	248000
1	389000	174718	0.8621	335357	150624
2	389000	174718	0.7432	289105	129850
3	389000	174718	0.6407	249232	111942
4	389000	174718	0.5523	214845	96497
5	389000	174718	0.4761	185203	83183
sum				1273742	820096
BCR = discounted revenues / discounted costs				1.553	

As the value of BCR is greater than one, the project is viable. The value of BCR equal to 1.553 means that investing 1 US$ today, you will get 1.553 US$ in return after five years. In private investments it is favorable to rise BCR value to increase the profits, but in community services there are other considerations more important than money, like environmental and social consideration, which means that a composting project still viable even if the BCR value is less than one, because of the several benefits which can be generated from composting.

4.5.7 Cash-flow Analysis

The annual cash flow is the net benefits for each year of the project. It consists of the incremental benefits minus the incremental costs. The total cash flow is the sum of the annual cash flows over the life of the project. It is the undiscounted measure of the aggregate change expected from the project. Cash flow graphing gives a preconception about the future of the project and help in determining the payback period and break-even point, which occurs when total revenues (TR) equal to total costs (TC), or total cash flow (CF) equal to zero.

Table 4.14: TR, TC and CF calculations (NIS).

year	TC	TR(Priv.)	TR(Pub.)	CF(Priv.)	CF(Pub.)
0	24800	0	0	-24800	-24800
1	422718	389000	227000	-33718	-195718
2	597436	778000	454000	180564	-143436
3	772154	1167000	681000	394846	-91154
4	946872	1556000	908000	609128	-38872
5	1121590	1945000	1135000	823410	13410

Break-even point or payback period (x) is calculated, it equal the time when TR = TC (Fig. 4.4), or equal the time when total cash flow equal to zero (Fig. 4.5).

$TC = 248000 + 174718\,(x) \;=\; TR = 389000\,(x)$

$x = 248000 / 214282 \;=\; 1.16$ years

This value means that the project will recover the costs after 1.16 years as seen in figure 4.4. This value can be decreased or increased according to the type of the project whether it is private or public. In private projects it is generally desirable to have a low break-even value, and this can be achieved by increasing the price of compost to be sailed and the fees for MSWM. But in public projects a high break-even value can be acceptable, as public projects are concern with community services and environment protection more than generating profits. Figure 4.5 shows two different break-even points in both the project still viable.

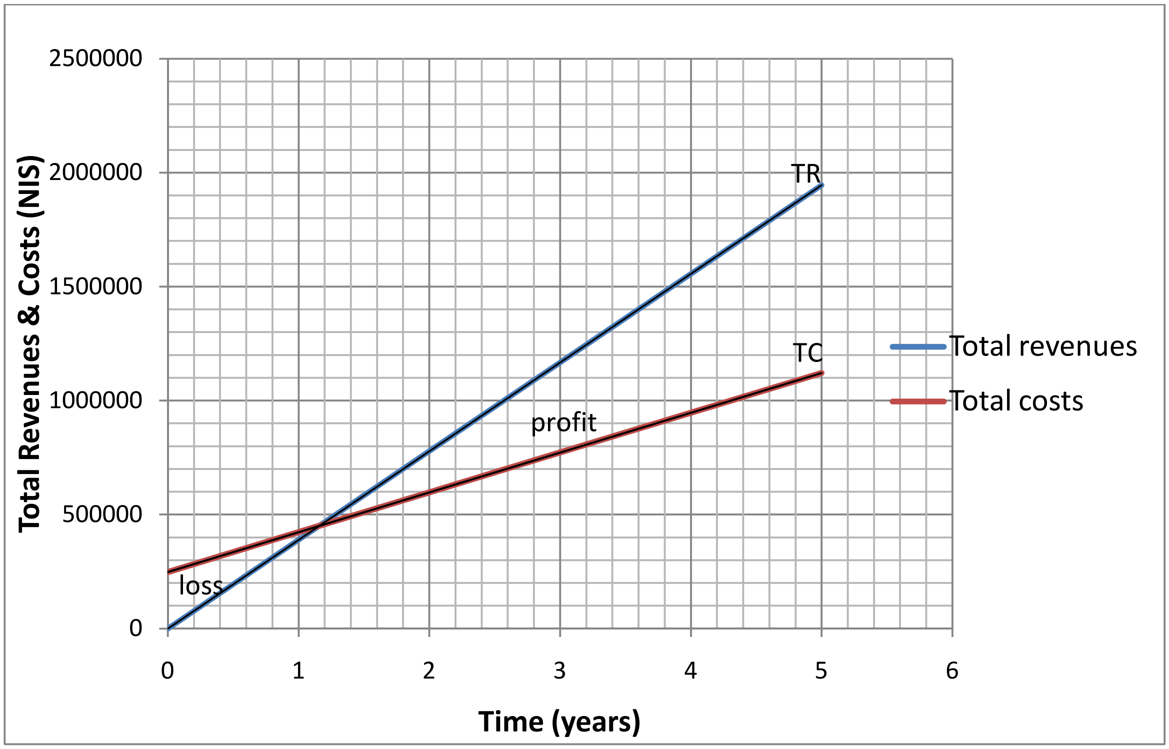

Fig. 4.4: Total revenues & costs.

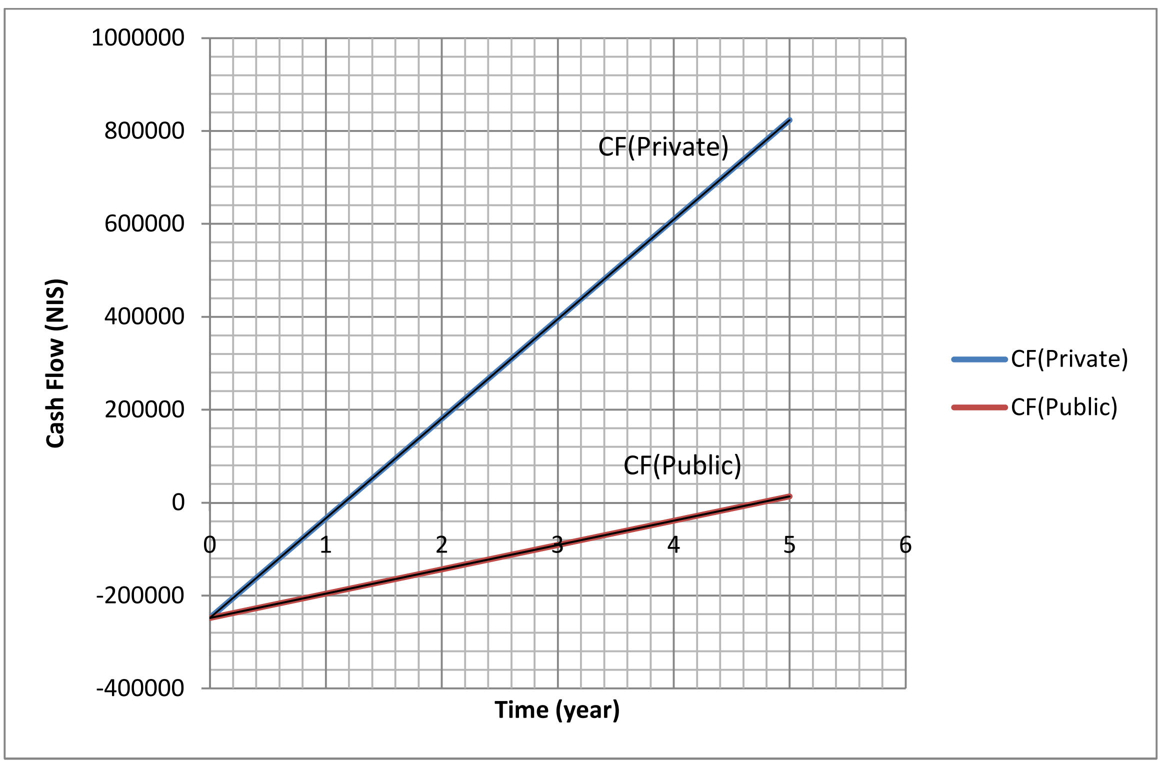

Fig. 4.5: Cash- flow.

Chapter Five

Conclusions and Recommendations

5.1 Conclusions

Solid waste management in Beit liqia village is a serious problem that threat the human and environmental health, and has inadequate concern from responsible authorities. This problem requires immediate and urgent attention with sufficient and high priority consideration.

The questionnaire conducted in this study spotlights people feelings toward MSW management in Beit liqia village; more than 50% of people have low degree of satisfaction with the current solid waste management system. All of the households surveyed suffering from one or more problems in waste disposal, 97% of people surveyed believed that the current system of waste disposal pollute the environment, 96% of people surveyed believed that the village need to develop a new system for solid waste management. 53% of people accede source separation of waste. 97% of people accede developing a composting plant for household organic waste recycling. 97% of people believed that using compost is better than chemical fertilizers in agriculture.

Waste minimization at source, recycling, recovery and reuse options can offer practical solutions to solid waste problems (WHO,1997). Therefore, there are a good opportunity to initiate a composting program in the study area of this study in order to recycle the organic fraction of household waste, and it can pose a good option to prevent the adverse impact of solid waste on the environment and public health. At the same time composting minimizes the waste amount to be landfilled.

The pilot conducted in this study assure that composting can be applied successfully as a good option to solid waste management in Beit liqia, it can produce a benefit final product with a suitable quality when compared with international standards, and has the potential for many useful uses in agriculture as a soil amendment.

As success of composting program depends mainly on the degree of the public participation (WHO, 1997), and municipal support (Zurbrugg et al., 2002), and as the community in the study area reveals the willing to change the current system of waste management, community education programs should be holded to strength the environmental awareness with support from the municipality and local institutions.

The current system of solid waste management is a fully consumption project, with zero revenues and huge costs including vehicles and operational costs reach to 50000 US $ per year, in addition to environmental cost which considered to be more important than money.

This study presents a composting plant to the organic fraction of household waste as an alternative to be available producing project. Benefit – cost analysis to the alternative project shows a positive values to NPV and BCR, which means that a composting plant is a feasible project.

Decentralized composting system is strongly favorable over centralized in low and middle income countries, as decentralized systems are less technology dependent, low cost, labour-intensive, locally available materials and simple technology can be used, contrary to centralized composting systems that require technical machinery of high capital cost, high maintenance costs and mandatory need to specialized skills. Therefore, centralized systems have a higher risk of failure than de- centralized.

5.2 Recommendations

1- As wide-spread public participation is required to success any waste management program, effective public education programs must be holded from the beginning and continue even after the program being in use. A continual plan of public education, discussion, implementation and evaluation is recommended.

2- Government and local authorities should support and hold education and public awareness programs.

3- Ministry of education should prepare simple teaching materials in the curriculums, and school children should be encouraged to participate in public awareness in composting and compost advantages over chemical fertilizers.

4-Mass media (TV, radio stations, press, … etc) should be employed to stimulate public participation in the efforts related to solid waste management, like collection, storage, and its impact for health and economics.

5-Ministry of agriculture should encourage farmers to use compost in order to improve the soil properties, and explain the impacts of using fresh manure of animals and poultry or excessive amounts of chemical fertilizers.

6-Environmental health institutions, academic institutions and NGOs should be encouraged to promote and support pilot projects to increase community participation to develop compost facilities.

7-The municipality should give consideration to involve the private sector in solid waste management, especially composting the organic waste.

8-Training efforts should be undertaken to prepare a good team of engineers, managers and workers in order to achieve healthy and safety requirements for composting. The municipality with UN agencies should provide support for preparation of an appropriate guide lines and training courses to design and operate composting facilities.

9-Current open burning site should be closed and replaced by a proper sanitary landfill.

10- Source separation of municipal solid waste components should be promoted, also reuse and recycling of some materials by industry should be encouraged.

11- Clinical and medical wastes should be disposed in a properly designed and secure sanitary landfill or using a small specialized incinerators under specialists supervisors from the ministry of health.

12- storage containers should be selected with suitable sizes and colors to overcome problems of handling waste.

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Annex 1

بسم الله الرحمن الرحيم

استبيان

الأخوة الأفاضل : إن الهدف الأساسي من إدارة البيئة هو حمايتها و حفظ مواردها سعيا لتحقيق التنمية المستدامة ، وتوفير بيئة صحية مناسبة لحياة الإنسان حاضرا ومستقبلا في ظل التزايد السكاني المطرد ، والنزعة القوية للتحضر والتي قادت العالم إلى مشاكل التلوث الهائل والتدهور البيئي الجسيم .

لقد بدأ العالم اليوم يهتم كثيرا بإدارة البيئة من خلال المنظمات الدولية والمؤسسات المحلية ، ولتحقيق النجاح في هذا الإطار لا بد من إشراك أفراد المجتمع المحلي في تخطيط و تنفيذ الخطط البيئية ، وأن يستشعر جميع أفراد المجتمع المسؤولية الملقاة على عاتقهم في خلق بيئة نظيفة و أمنة و جميلة .

عزيزي المواطن : بين يديك استبانة لدراسة علمية في مجال تدوير النفايات العضوية المنزلية و تحويلها إلى سماد عضوي (كومبست) في بلدة بيت لقيا بهدف الحد من التلوث الناتج عن انتشار النفايات الصلبة في بيئة البلدة ، وإنتاج سماد عضوي طبيعي لتحسين وضعية الأراضي الزراعية في البلدة ، والحصول على غذاء خالي من الملوثات الكيماوية التي باتت تهدد صحة المواطنين نتيجة الإفراط في استخدام الأسمدة الكيماوية .

عزيزي المشارك : أرجو أن تشارك بالإدلاء برأيك بصراحة تامة دون الحاجة لذكر اسمك أو ما يوضح هويتك . (تذكر أن دقة نتائج هذا البحث تعتمد على دقة الإجابات على الأسئلة)

مع جزيل شكري و تقديري لكم على تعاونكم .

القسم الأول : معلومات عن الأسرة

1) عدد أفراد الأسرة :

2) الوظيفة : للزوج : ------------------ للزوجة :---------

3) المستوى التعليمي : للزوج : ------------------ للزوجة : --- -----

4) الدخل الشهري للأسرة :
- □ أقل من (2000) شيكل
- □ من (2000) إلى (3000) شيكل
- □ من(3000) إلى (4000) شيكل
- □ أكثر من (4000) شيكل

5) تجمع النفايات المنزلية في :
- □ حاوية صغيرة خاصة بالمنزل
- □ حاوية كبيرة على جانب الطريق تكفي لعدد من المنازل
- □ أكياس توضع على حافة الطريق

6) مساحة البيت ------------

القسم الثاني : تقييم الوضع الحالي لخدمة جمع النفايات في البلدة

7) هل بيتكم مشمول في الخدمة التي تقدمها البلدية لإدارة النفايات الصلبة ؟
□ نعم □ لا

8) إذا نعم ، ما هي درجة رضاك عن النظام الحالي للتخلص من النفايات ؟
□ جيدة جدا □ جيدة □ مقبولة □ غير راض

9) كم مرة في الأسبوع يقوم عمال البلدية بجمع النفايات الصلبة من منزلكم ؟
□ مرة □ مرتان □ ثلاث مرات □ لا يوجد برنامج ثابت

10) هل تواجهون أية مشاكل للتخلص من النفايات الصلبة الصادرة عن منزلكم ؟
□ لا يوجد حاوية نفايات □ الحاوية بعيدة عن المنزل
□ مكان الحاوية غير مناسب □ المنطقة المحيطة بالحاوية متسخة
□ الحاوية لا تتسع للنفايات □ العمال لا يعيدون الحاوية الى مكانها
مشاكل أخرى ---

11) هل تعتقد إن النظام الحالي للتخلص من النفايات يلوث البيئة المحلية ؟
□ نعم □ لا

12) إذا نعم ، ما هي الأسباب ؟
□ لا يوجد حاوية قريبة ، النفايات تلقى هنا وهناك في أماكن كثيرة
□ النفايات تلقى في الشوارع وفي الأراضي الزراعية
□ التأخر في جمع النفايات فتمتلئ الحاويات وتفيض بالنفايات
□ عدم جمع النفايات المبعثرة حول الحاوية
□ النفايات تلقى في مجاري مياه الأمطار
□ حرق النفايات في المكب

13) ما هو المبلغ الذي تدفعونه مقابل خدمة جمع النفايات كل شهر ؟ (------) شيكل

14) من ينقل النفايات من داخل المنزل إلى الحاوية ؟
□ الزوج □ الزوجة □ أحد الأبناء □ غير ذلك ------------

15) في أي وقت يأتي عمال النفايات لجمعها ؟
□ في الصباح □ في الظهيرة □ في المساء □ في الليل □ توقيت متغير

16) هل تعتقد أن هذا التوقيت مناسب ؟ □ نعم □ لا

17) إذا لا ، في أي وقت تفضل أن يأتي عمال النفايات لجمعها ؟
□ في الصباح □ في الظهيرة □ في المساء □ في الليل

18) أي نظام فيما يلي تفضل لإزالة النفايات الصلبة من منزلكم ؟
□ وضع النفايات في حاوية صغيرة إمام المنزل ويأتي عامل النفايات لأخذها
□ وضع النفايات في حاوية كبيرة توضع على جانب الشارع
□ ترسل النفايات بنفسك إلى المكب

19) هل تعتقد أن البلدة بحاجة إلى تطوير نظام جديد لإدارة النفايات ؟
□ نعم □ لا

20) إذا نعم ، أي الخطوات التالية تؤيد لتطوير نظام جديد لإدارة النفايات الصلبة ؟
□ فصل النفايات في المصدر بحيث يوضع كل نوع في حاوية خاصة
(بقايا الطعام ، المعادن ، الزجاج ، البلاستيك ، الورق)
□ تحديد أوقات محددة في برنامج زمني يأتي فيه عمال النفايات لجمعها

□ تدوير النفايات وإعادة تصنيعها
□ إعادة تأهيل مكب النفايات الحالي
□ إنشاء مكب نفايات صحي جديد
□ عقد دورات تثقيفية من قبل المؤسسات الأهلية لخلق وعي بيئي لدى المواطنين

21) هل تؤيد إنشاء مشروع لتدوير النفايات العضوية المنزلية وتحويلها إلى سماد عضوي (كمبوست) ؟ □ نعم □ لا

22) هل تمارس الأسرة أية أعمال زراعية ؟ □ نعم □ لا

23) إذا نعم ، املأ البيانات التالية :
= مساحة الأرض المزروعة بالدنم --
= أنواع المزروعات --
= عدد الأشجار ---
= كمية السماد الكيماوي المستخدم في العام ---
= كمية السماد البلدي المستخدم في العام ونوعه---
= كمية الكمبوست المستخدم في العام ---

24) هل تعتقد أن استخدام الكمبوست أفضل من استخدام السماد الكيماوي ؟
□ نعم □ لا

25) إذا نعم ، فما هو السبب ؟ --
----

26) اذا لا ، فما هو السبب ؟ --
----

27) بم يمتاز الكمبوست عن السماد الكيماوي ؟
□ أقل ثمنا من السماد الكيماوي
□ يحسن من خصائص التربة مثل خصوبتها وقدرتها على الاحتفاظ بالماء ومقاومة الآفات
□ يؤدي إلى إنتاج غذاء صحي وخالي من الملوثات الكيماوية
□ يدوم تأثيره في التربة لفترة زمنية طويلة (عدة أعوام)

28) هل أنت مستعد لشراء كمبوست ناتج عن تدوير النفايات العضوية إذا احتجت إليه ؟
□ نعم □ لا

30) هل هناك مقترحات تود إضافتها ؟ --

شكرا لحسن تعاونكم

الباحث : محمود مفارجة

Annex 2

بسم الله الرحمن الرحيم

حضرة السيد رئيس بلدية بيت لقيا المحترم ،

الموضوع : النفايات الصلبة

تحية طيبة وبعد ،

الرجاء تزويدنا بالمعلومات المطلوبة حول إدارة النفايات العضوية في القرية ، وذلك بهدف استخدامها ضمن رسالة ماجستير حول جدوى مشروع نظام دبال ريادي لتدوير النفايات العضوية المنزلية في قرية بيت لقيا .

ولكم جزيل الشكر

الباحث : محمود مفارجة

1) كم يبلغ عدد منازل القرية ؟ --
2) كم نسبة المنازل المستفيدة من خدمة جمع النفايات الصلبة المنزلية ؟ -----------------------
3) إذا كان هناك منازل غير مشمولة بخدمة جمع النفايات الصلبة ، فما هو السبب ؟ -----------
----
4) ماذا يحدث للنفايات التي لا يتم جمعها ؟ --
5) ما كمية النفايات التي تجمعونها ؟ ---
6) كيف يتم التخلص منها ؟ ---
7) هل توزع البلدية حاويات لتجميع النفايات المنزلية ؟ ما أعدادها و أحجامها ؟ -------------
----
8) هل يتم عمل صيانة لهذه الحاويات ؟ ---
9) ما هي قيمة الرسوم المفروضة من قبل البلدية مقابل خدمة جمع النفايات ؟ ----------------
10) ما هي معايير تحديد هذه الرسوم ؟ (هل لعدد أفراد الأسرة علاقة ؟) -----------------------
----
11) كيف يتم جمع هذه الرسوم ؟ ---
12) ما هي نسبة التزام الأهالي بالدفع ؟ ---
13) ما هو إجمالي المبلغ المفترض جمعه من الأهالي ؟ ------------------------------
14) ما هو إجمالي المبلغ المجموع فعلا ؟ ---
15) ما هي المعدات المستخدمة في جمع النفايات والتخلص منها ؟------------------------------
----

----
16) ما هي تكاليف إدارة النفايات الصلبة ؟ --

----
17) كم عدد أفراد الطاقم المكلف بجمع النفايات والتخلص منها ؟ -----------------------------
----
----
18) هل تقوم البلدية بالإشراف والمراقبة على المكب ؟ --------------------------------------
----
19) هل هناك نظام مراقبة لدراسة تأثير المكب على البيئة (تلوث الهواء والمياه والتربة) ؟ ----
----
----
20) هل يتم رفع شكاوى من المواطنين بخصوص المكب ؟ ما طبيعتها ؟ وكم عددها ؟ ---------
----
----

21) هل يستقبل المكب نفايات من مصادر أخرى غير البلدية ؟ ما هي هذه المصادر ؟ ----------
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----

22) ما هي الأسس التي تم بناء عليها اختيار موقع المكب ؟ ------------------------------------
----
----

23) هل هناك من يبحث في المكب عن بعض المواد لبيعها ؟ ------------------------------------
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24) هل هناك خطط مستقبلية لتطوير برنامج إدارة النفايات الصلبة ؟ (الرجاء إيضاحها) -----
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25) الرجاء تزويدنا بالمعلومات التالية ما أمكن :

- مساحة أرض القرية : --
- المساحة المقام عليها البناء :---
- مساحة الأرض الزراعية : --
- عدد السكان :--
- عدد المساكن :--
- عدد المراكز الصحية : --
- العيادات الخاصة :---
- إعداد المدارس والطلاب : --
- عدد الخريجين : --
- عدد المحال التجارية : --
- المنشات الصناعية : ---
- عدد المزارع الحيوانية :--
- عدد الدفيئات : --