SOLID WASTE MANAGEMENT ON THAPAR UNIVERSITY CAMPUS

A Thesis
submitted towards the partial fulfillment of requirements for the award of the degree of

M.TECH. (ENVIRONMENTAL SCIENCE & TECHNOLOGY)

Submitted by

AMIT KUMAR TIWARI
Roll No. 60601001

Under the Supervision of

PROF. SUSHEEL MITTAL
Dean (Research & Sponsored Project)
(Professor and Head, School of Chemistry & Biochemistry)

ER. RAJEEV GARG
Env. Engineer
Punjab Pollution Control Board,
Patiala

DEPARTMENT OF BIOTECHNOLOGY AND ENVIRONMENTAL SCIENCES
THAPAR UNIVERSITY
PATIALA- 147001 (INDIA)

Dedicated to My Father

Who taught me how to face difficulties of life , made me worthy of the present day and who is not here to see this day………………

CANDIDATE'S DECLARATION

I hereby declare that the work which is being presented in the dissertation entitled I hereby certify that the work which is being presented in thesis entitled, **"Solid Waste Management on Thapar University Campus",** in partial fulfillment of the requirements for the award of degree of **Master of Technology in Environmental Science & Technology**, Department of Biotechnology and Environmental Sciences (DBTES), Thapar University, Patiala, is an authentic record of my own work carried out during a period of twelve months from July 2007 to July 2008, under the supervision of **Prof. Susheel Mittal Dean (Research & Sponsored Project), and Head, School of Chemistry & Biochemistry, Thapar University- Patiala,** and **Er. Rajeev Garg (Environmental Engineer, PPCB)-Patiala.** I have not submitted the matter embodied in this dissertation for the award of any other degree or diploma.

AMIT KUMAR TIWARI

Patiala
Date:

This is to certify that the above statement made by the candidate is correct and true to the best of our knowledge.

THAPAR UNIVERSITY

CERTIFICATE

I hereby certify that the work which is being presented in thesis entitled, **"Solid Waste Management on Thapar University Campus",** in partial fulfillment of the requirements for the award of degree of **Master Of Technology In Environmental Science & Technolohy,** Thapar University, Patiala, is an authentic record of my own work carried out under the supervision of **Prof. Susheel Mittal Dean (Research & Sponsored Project), and Head, School of Chemistry & Biochemistry, Thapar University- Patiala,** and **Er. Rajeev Garg (Environmental Engineer, PPCB)-Patiala.** The matter presented in this thesis has not been submitted for the award of any other degree of this or any other university.

This is certified that the above statement made by the candidate is correct and true to the best of my knowledge.

Dr. Susheel Mittal
Supervisor,
Professor & Head
School of Chemistry & Biochemistry
Thapar University
Patiala

Mr Rajeev Garg
Supervisor
Environmental Engineer
Pb Pollution Control Board
Nabha Road
Patiala

Dr. N. Das
Head, Department of Biotechnology & Env Sci.
Thapar University
Patiala

Dr R K Sharma
Dean, Academic Affairs
Thapar University
Patiala

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Amit Kumar Tiwari

Contents

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1. Introduction

Municipal solid waste (MSW) refers to the materials discarded in the urban areas for which municipalities are usually held responsible for collection, transport and final disposal. MSW encompasses household refuse, institutional wastes, street sweepings, commercial wastes, as well as construction and demolition debris. In developing countries, MSW also contains varying amounts of industrial wastes from small industries, as well as dead animals, and fecal matter.

Municipal solid waste management (MSWM) encompasses planning, engineering, organization, administration, financial and legal aspects of activities associated with generation, storage, collection, transfer and transport, processing and disposal of municipal solid wastes (household garbage and rubbish, street sweepings, construction debris, sanitation residues etc.) in an environmentally compatible manner adopting principles of economy, aesthetics, energy and conservation (Tchobanoglous et al, 1993). The explosion in urban population is changing the nature of solid waste management in developing countries from mainly a low priority, localized issue to an internationally pervasive social problem. India, the world's second highest populated country with population exceeding a billion and one of the fastest urbanizing countries, is a land of physical, climatic, geographic, ecological, social, cultural and linguistic diversity. The annual rate of growth of urban population in India is 3.09%. The proportion of population living in urban areas has increased from 17.35% in 1951 to 26.15% in 1991(CPCB, 1999). It is interesting to note that as much as 65.2% of the urban population is living in these Class I cities. India has achieved multifaceted socio economic progress during the last 55 years of its independence. However, in spite of heavy expenditure by the Civic bodies, the present level of service in many urban areas is so low that there is a threat to the public health in particular and the environmental quality in general (Supreme Court Committee Report, 1999). Management of Municipal Solid Wastes (MSW) continues to remain one of the most neglected areas of urban development in India. The 23 metro cities in India generates about 30,000 tones of such wastes per day while about 50,000 tones are generated daily from the Class I cities. Piles of Garbage and wastes of all kinds littered everywhere have become common sight in our urban life.

1.1 Solid Waste (SW)

Solid Wastes are unwanted materials disposed of by man, which can neither flow into streams nor escape immediately into the atmosphere. These non-gaseous and non-liquid residues result from various human activities. These cause pollution in water, soil and air (Misra and Mani, 1993).

Waste is an unavoidable consequence of satisfying man's needs for food, water, air, space, shelter and mobility. In any material process, by product recovery or recycling can substantially alter waste quantity and quality, but all processes eventually produce some waste (Swarup *et al*, 1992).

Though generation of SW is not a new phenomenon, it has acquired a danger status of being "third pollution" after air pollution and water pollution with progress in industrialization and population explosion. Earlier the major constituents of SW were domestic wastes and agricultural residues which are both biodegradable. Since there was much fallow land, SW could be conveniently disposed of on ground or in pits covered with layers of earth. However, since 1960s, not only has the quantity of SW increased but its quality has also changed. Though rural wastes continue to be mainly made of domestic and agricultural wastes, wastes from urban areas and the industrial units contain diverse types of materials which include toxic and hazardous materials.

SW is generated because of human activities. Depending upon their origin, the wastes could be grouped under four heads namely agricultural wastes, domestic wastes, municipal wastes and industrial wastes.

A. Agricultural Wastes

In India, the main sources of agricultural wastes are wheat straw, paddy straw, maize straw, sugarcane trash, rice and wheat bran, maize cobs, left over from pulses etc. There has been a great increase in the generation of crop residues and allied wastes. The total production of agro-residues and by products during 1985 was estimated to be 320 million tones.

B. Industrial Wastes

Huge amount of industrial SW are usually produced by different industries. The estimated SW of industrial origin contribute only 10% of the total wastes generated, the bulk is liquid

C. Domestic and Municipal Wastes

There are different sources of the Municipal Solid Wastes (MSW): domestic, market community facilities etc. The amount of MSW generated is dependent on the public- habits which can vary from country to country and even among towns e.g. the per capita production of MSW is much greater in the USA in comparison to other Western countries as well as Asian countries. In India, per capita MSW production in metropolitan cities is significantly high in comparison to the towns and villages. Average MSW production is about 0.33 kg/capita/day in India.

Solid Wastes Produced by Human Activities

Human Activities	Example of wastes liberated
Agricultural	Plant remains, processing wastes, animal wastes
Domestic	Garbage, rubbish, wastes produced at home from cooking etc
Municipal	Street sweepings, wastes from schools, offices and other institutions
Industrial	Wastes produced by mining operations, manufacturing and construction works

(Source: Misra and Mani 1993)

1.2 Solid Waste Characteristics

The waste characteristics in developing nations vary considerably from that in developed countries. The United States, with only 4.6% of the world's population, produces about 33% of the world's SW (Miller, 2004). About 1/5 of India's total population lives in urban agglomerations and generates approximately 15 million tonnes of SW every year (Misra and Mani, 1993).

The density of SW in India is very high (300- 560 kg/ cubic m.). The metal content is less than 1%. The average calorific value of urban SW is low (1500 kcal/ kg). The per capita generation of SW in Indian cities ranges from 0.15 to 0.25 kg/day (Bhide and Sundaresan, 1983).

1.3 Classification of Solid Wastes (SW)

SW can be classified into various heads as given here under:

a) Garbage: Putrescible (decomposable) wastes from food, slaughterhouses, canning, and freezing industries etc.

b) Rubbish: Non-putrescible wastes, either combustible or non-combustible. Combustible wastes would include paper, wood, cloth, rubber, leather, and garden wastes. Non-combustibles would include metals, glass, ceramics, stones, dirt, masonry and some chemicals.

c) Ashes : Residues (such as cinders and fly ash) of the combustion of solid fuels for heating and cooking or the incineration of SW by municipal, industrial and apartment house incinerators.

d) Large Wastes: Demolition and construction rubble (pipes, plumber, masonry, brick, plastic, roofing and insulating material), automobiles, furniture, refrigerators and other home appliances, trees, tyres etc.

e) Dead animals: Household pets, birds, rodents, zoo animals, etc. there are also anatomical and pathological wastes from hospitals.

f) Sewage Treatment Process Solids: screening, settled solids, sludge.

g) Industrial Solid Wastes: Chemicals, paints, sand, explosives etc.

h) Mining Wastes: ‘Tailings’, slag heaps, culm piles at coal mines etc.

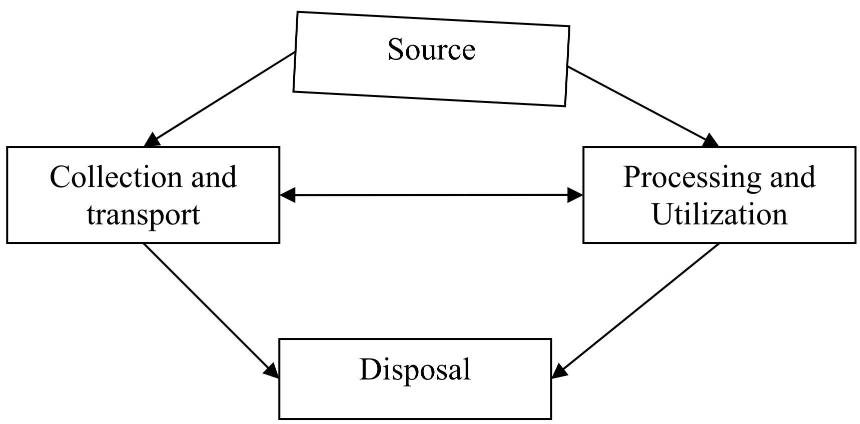
i) Agricultural Wastes: Farm animal manure, crop residues etc.

1.4 Solid Waste Management (SWM)

Rotting organic refuse is not only aesthetically unpleasant but attracts predators, and carried by these, bacteria thrive in warm, moist, rotting garbage spreading malaria, viral fever (dengue), plague etc. (Coverstory, Sunday, 1994). The incident of plague in Oct, 1994 in Surat city pressed everyone to think over SW problem. If this problem is not tackled within preventive time, it may create other dreadful, hazardous and incurable problems.

The proper disposal of SW derived from any source is dependent on management practices. A management system must be developed and described that incorporates many diverse factors. Those factors considered may include economics, engineering, land use ordinances, environmental regulations, geography and sociology. A Solid Waste Management (SWM) system that could optimize these parameters would be designed based on Figure 1 (Shukla and Srivastava, 1992).

A Solid Waste management System



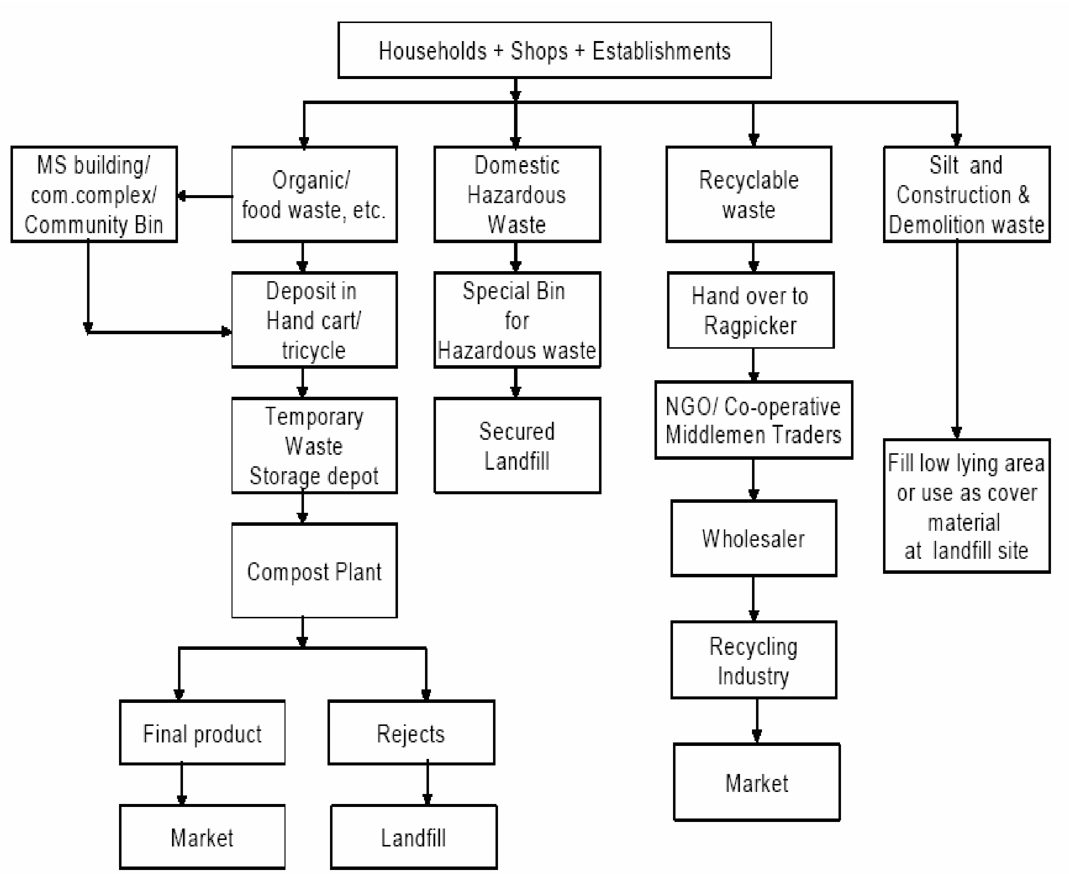
SWM involves interplay of six functional elements- generation of wastes, storage, collection, transfer and transport, processing, recovery and disposal in a manner that is in accord with the best principles of public health, economics, engineering, conservation, aesthetics and other environment considerations and that also is responsive to public attitude (Bhide and Sundaresan, 1983).

Over 90% of SW is disposed of in landfill sites. Sanitary landfilling is the main method used in the West but crude dumping is very common in developing countries (Ambrose, 1983). Landfilling leads to contamination of ground water eventually because of leachates. Many countries will have to suffer from existing landfillling practice in the near future. By 2010, almost all of England will be suffering from a landfill shortage (Read *et al*., 1996). Another widely used method of disposal is incineration but it often results in air pollution and thus loses out preference. The commonest method adopted in India is dumping- either in ponds or on land. A practice of Collection, Transport and Disposal (CTD) is followed by municipalities.

SW is stored till a sizable amount accumulates which may be transported using vehicle of suitable size. When the quantity of SW to be managed is relatively small then collection, handling and short distance transport is done manually. However, mechanical devices like bulldozers and cranes may be used when quantity is large. To transport solid Waste over a short distance, wheel barrow may be used. Vehicles commonly employed are open body trucks and flat bed trucks. Nearly 75-80% of all collected residential and commercial SW are sent to open dumps, less than 10% is buried in sanitary landfills, a small amount is dumped into the sea and the remaining is converted to obtain energy and recover metals (Mishra and Mani, 1993).

NATIONAL PLAN FOR MUNICIPAL SOLID WASTE MANAGEMENT (MSWM)

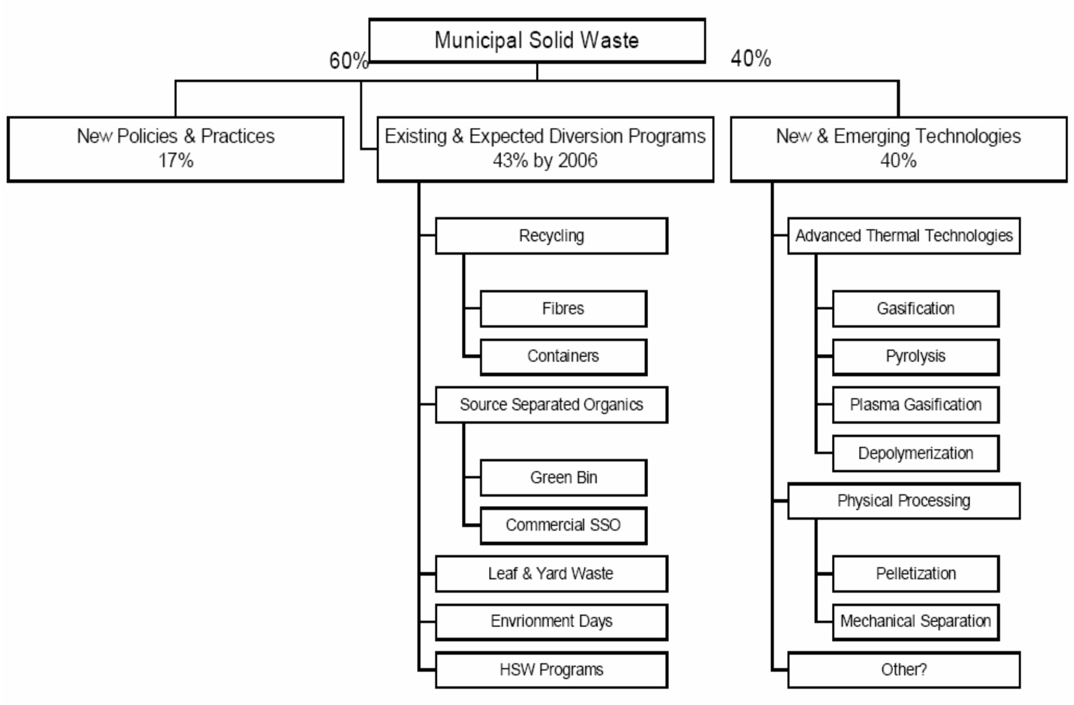
Consider the present status of MSWM in the country, the committee constituted by the Honb'le Supreme Court of India has summarized the elements of MSWM for India in the flowchart



RECOMMENDED FLOW CHART OF MUNICIPAL SOLID WASTE IN INDIA (Source: Supreme Court Committee Report, 1999)

TECHNOLOGIES AVAILABLE FOR PROCESSING, TREATMENT, AND DISPOSAL OF SOLID WASTE

Application of new emerging technologies for solid waste management services



Objectives

The study has following main **objectives:**

1) To study the present status of Solid Waste Management in Campus
2) Processing of house hold solid waste by Vermicomposting
3) Experimental setup for removal of heavy metals (Ni and Cu) with the help of Earth-worm (Eisenia fetida)
4) Characterization and quantification of solid waste on Thapar University campus.

Work Elements

1) Characterization of solid waste
2) Physico-chemical analysis of biodegradable fraction of HSW
3) Quantitative measurement of total solid waste generation.
4) Processing of house hold solid waste management by Vermicomposting
5) Analysis of solid waste samples with artificially added heavy metals before processing and after processing of waste

2. Review of Literature

The Solid Waste Committee of the National Research Council in its report stated in 1970- " Much of the problem of Solid Waste Management derives from the continued reluctance of those concerned to come to grips with it and apply existing technology systems and organizational know-how to its solution and above all to pay for these services." Forster (1973) warned that "increasing numbers and densities of visitors and increasing pressures for more accommodation of tourism are threatening some of the most meaningful natural and historic resources of the world's national parks and equivalent resources."

A detailed report on utilization and recycling of waste (research, development and extension requirement) was submitted in 1975 by the National Committee on Science and Technology of the Government of India. Although over three decades old, this report along with some research papers constitutes the only available information on the extent and nature of wastes available and the R&D efforts in progress as also possible on the subject. The basic rational on which the report has been based is "what is waste to one industry may be raw material for another."

A health survey carried out in Patancheru industrial estate near Hyderabad in 1989 showed that in a sample of 942 persons examined in four villages in the area, 196 had respiratory diseases, 115 had digestive disorders and 111 suffered from skin diseases due to ill effects of wastes dumped openly.

Composting yard waste would reduce the amount of solid waste in America by nearly 18%. Presently, less than 1% of American waste is composted (Miller, 1990). Even college students, for whom this process can be challenging and very inconvenient, can take part. A tightly sealed bucket in a refrigerator can work very well as a temporary composter. When full, it can be dumped into an appropriate compost-friendly site on campus.

Cole and Mwanza (1991) declared that when plastic is thrown out to sea, it causes the deaths of up to two million sea birds each year and as many as 1,00,000 marine species.

Swarup *et al.* (1992) postulated the growing use of packing materials as the major source of household waste. The use of paperboard has been growing at an annual rate of 4.5 %. Ishwaran (1994) found that international tourism and global environmental awareness have both grown significantly during the last three decades. Between 1970 and 1990, tourism grew by nearly 300 % and the industry now employs about 7 % of the workers of the world. Environment's role in sustaining the growth of tourism is better appreciated now than any time in the past.

Jain and Kuniyal (1994) studied the SW problem in the Himalayan regions and found that both religious and recreational tourist resorts are going to be extensively and intensively polluted by SW due to inadequate and poor infrastructural carrying capacity. They assessed the environment in and around the Valley of Flowers National Park in 1995 and found "urban slum like" conditions due to indiscriminate waste disposal.

Hockett et al.(1995) in their determination of per capita MSW generation in south eastern US found that US currently generates and disposes of almost 200 million tones per year of paper, plastics, yard waste, glass an other materials which are primarily produced by residential, institutional and commercial sources. The quantity of Municipal solid waste depends on the population, geographical of location, season of the year and standard of living etc. (Bhoyer et.al., 1996). The quantity of municipal solid waste usually expressed on a per capita basis.

Renkaw and Keeler (1996) while working on various SWM options, concluded that in the foreseeable future, no community will be able to do without access to landfill spaces (either located within the community or in some other area). Several attempts have been made to establish a general methodology to solve hazardous waste problems; Wei and Weber (1996) list a sequence of steps for selection of treatment process for a given waste stream.

Herat (1999) while studying the alternate use of SW as a supplementary fuel in cement kilns found that high temperature (>1500˚ C), long residence times (6-10s) and high turbulence result in complete destruction of a variety of wastes including waste oil, organic solvents, chlorofloro carbons, used tyres, Municipal Solid Waste and sewage sludge and simultaneous recovery of energy and material values.

Field experiments were conducted during 2002-2003 on clay loam, sandy loam and red loam soil at Sivapuri, Chidambaram, Tamil Nadu, to evaluate the efficacy of vermicompost on the physico-chemical and biological characteristics of the soils and on the yield and nutrient content of blackgram - Vigna mungo, in comparison to inorganic fertilizers nitrogen, phosphorous, potassium. Vermicompost had increased the pore space, reduced particle and bulk density, increased water holding capacity, cation exchange capacity, reduced pH and electrical conductivity, increased organic carbon content, available nitrogen, phosphorous, potassium and microbial population and activity in all the soil types, particularly clay loam. The yield and quality (protein and sugar content in seed) of blackgram was enhanced in soils, particularly clay loam soil. On the contrary, the application of inorganic fertilizers has resulted in reduced porosity, compaction of soil, reduced carbon and reduced microbial activity.(K. Parthasarathi, M. Balamurugan, L. S. Ranganathan,)

Mani and Kaur (2004) reported that the quantity of biomedical waste (BMW) produced and its inherent nature to contaminate other wastes has made it imperative to effectively handle and treat this waste. They reported that 90% of BMW in India is either dumped along with MSW, dumped into lakes and ponds or is burnt in the open. Small Grants programme funded by Global Environment Facility and the Country Co- operation Framework-1 Environment Programme Support, seeks to support activities that demonstrate community-based approaches that could reduce threats to the global environment. According to their report (2004) the programme is rooted in the belief that global environmental problems can be addressed adequately only if local people are involved, and that, with small amount of funding local communities can undertake activities that will make a significant difference in their lives.

Vermicomposting of organic waste has an important part to play in an integrated waste management strategy. In this study, the possibility of heavy metals accumulation with two groups of Iranian and Australian earthworms in sewage sludge vermicompost was investigated. Eisenia fetida was the species of earthworms used in the vermicomposting process. The bioaccumulation of Cr, Cd, Pb, Cu, and Zn as heavy metals by Iranian and Australian earthworms was studied. The results indicated that heavy metals concentration decreased with increasing vermicomposting time. Comparison of the two groups of earthworms showed that the Iranian earthworms consumed higher quantities of micronutrients such as Cu and Zn comparing with the Australian earthworms, while the bioaccumulation of non-essential elements such as Cr, Cd, and Pb by the Australian group was higher. The significant decrease in heavy metal concentrations in the final vermicompost indicated the capability of both Iranian and Australian E.fetida species in accumulating heavy metals in their body tissues. (M R Shahmansouri, H Pourghadas, AR Parvaresh, H Alidadi,)

A comparative study was conducted between exotic and local (epigeic, Eisenia fetida and anaecic-Lempito mauritii, respectively) species of earthworms for the evaluation of their efficacy in vermicomposting of municipal solid waste (MSW). Vermicomposting of MSW for 42 days resulted in significant difference between the two species in their performance measured as loss in total organic carbon, carbon-nitrogen ratio (C:N) and increase in total Kjeldahl nitrogen, electrical conductivity and total potassium and weight loss of MSW. The change in pH and increase in number of earthworms and cocoons and weight of earthworms were non-significant (Kaviraj , Satyawati Sharma).

Due to rapid urbanization and uncontrolled growth rate of population, municipal solid waste management (MSWM) has become acute in India. MSWM, though an essential service, is given low priority. Lacks of financial resources, institutional weaknesses, improper choice of technology and public apathy towards MSW have made this service far from satisfaction. The current practices of the uncontrolled dumping of waste on the outskirts of towns/cities have created a serious environmental and public health problem

The decomposition efficiency of Perionyx sansibaricus (Perrier) for vermicomposting was evaluated by using a variety of wastes such as agriculture waste, farm yard manure and urban solid waste. Vermicomposting resulted in significant increase in total nitrogen

(80.8–142.3%), phosphorous (33.1–114.6%) and potassium (26.3–125.2%), whereas decrease in organic C (14.0–37.0%) as well as C:N ratio (52.4–69.8%) in different experimental beddings. P. sansibaricus showed maximum biomass production, growth rate (mg day^{-1}), mean cocoon numbers, and reproduction rate (cocoon $worm^{-1}$) in VLL (vegetable waste + leaf litter) as compared to other substrate materials. There was a consistent trend for earthworms' growth and reproduction rate, related to initial N-content of the substrate ($P < 0.05$), but there was no clear effect of C:N ratio of the composted material on earthworm cocoon numbers and weight gain. Earthworm showed minimum total population mortality in VLL and maximum in HHCD (household waste + cow dung), after 150 days of experimentation. The increased level of plant metabolites in end product (vermicompost) and growth patterns of P. sansibaricus in different organic waste resources demonstrated the candidature of this species for wastes recycle operations at low-input basis. (Surendra Suthar, S.Singh).

The effect of vermicomposting on kinetic behavior of the products is not well recognized.An incubation study was conducted to investigate C mineralization kinetics of cow manure, sugarcane filter cake and their vermicomposts. Two different soils were treated with the four solid wastes at a rate of 0.5 g solid waste C per kg soil with three replications. Soils were incubated for 56 d. The CO_2-C respired was monitored periodically and a first-order kinetic model was used to calculate the kinetic parameters of C mineralization. Results indicated that the percentage of C mineralized during the incubation period ranged from 31.9% to 41.8% and 55.9% to 73.4% in the calcareous and acidic soils, respectively. The potentially mineralizable C (C_0) of the treated soils was lower in the solid waste composts compared to their starting materials. Overall, it can be concluded that decomposable fraction of solid wastes has decreased due to vermicomposting.(Farshid Nourbakhsh).

The composting potential of two epigeic earthworms (P. excavatus and P. sansibaricus) was studied in 2002 to breakdown the domestic waste under laboratory conditions. The experimental container with P. sansibaricus showed maximum mineralization and decomposition rate than that of P. excavatus. Except for exchangeable K , the domestic waste processed by P. sansibaricus showed about 6% more total nitrogen and about 7% more available P at the end than by P. excavatus. As compared with the initial level organic C content as well as C:N ratio showed a considerable reduction that was noted higher in substrate with P. sansibaricus than those by P. excavatus. The growth (biomass increase) and reproduction parameters such as mean individual live weight, maximum individual growth rate (mg wt./worm/day), number of cocoons and reproduction rate (cocoon/worm/day) were higher in bedding with P. sansibaricus. The maximum earthworm mortality was in vermibed having P. sansibaricus (50% higher than by P. excavatus), since both species did not show a drastic difference in waste mineralization rate, but comparatively, P. excavatus exhibited better growth and reproduction performance, which further support the suitability of the species for large scale vermiculture operations. (1*S. Suthar; 2S. Singh)

Vermitechnology was investigated as a means of reducing organic waste materials. Vermicomposting conditions were optimized to convert the biowastes to nutritious composts for amending agricultural soil. Studies were undertaken to select the most suitable earthworm species for vermicomposting, to enrich vermicompost by inoculation with beneficial microbes, to standardize an economically feasible method of vermicomposting, to achieve nutrient economy through vermicompost application in acid soils (pH 4.5), and to assess the performance of vermicompost as a bioinoculant in cow-pea, banana, and cassava. Earthworm species Eudrillus eugineae, Eisenia foetida, Perionyx sansibaricus, Pontoscolex corethrurus and Megascolex chinensis were compared for their efficiencies in biodegrading organic wastes. E. eugineae was found to be a superb agent. As a bioinoculant, vermicompost increased nitrogen and phosphorous availability by enhancing biological nitrogen fixation and phosphorous solubilisation. Vermicompost-amended acid-agriculture-soil significantly improved the yield, biometric character and quality of banana, cassava and cow-pea. Vermicompost application stimulated root growth, facilitating nutrient absorption and thereby favouring higher yield**. (**Padmavathiamma, P.K.; Kumari, U.R.)

In view of the environmental problems generated by large-scale production of fly ash, increasing attention is now being paid to the recycling of fly ash as a good source of nutrients. Because availability of many nutrients is very low in fly ash, available ranges of such nutrients must be improved to increase the effectiveness of fly ash as a soil amendment. In our experiment, we assessed the possibility of increasing total nitrogen, total phosphorus, total potassium and micronutrients in fly ash through vermicomposting. Fly ash was mixed with cow dung at 1:3, 1:1, and 3:1 ratios and incubated with Eudrilus eugeniae for 60 days. The concentration of above said macro and micronutrient was found to increase in the earthworm-treated series of fly ash and cow dung combinations compared with the fly ash alone. This helped to transform considerable amounts of total nitrogen, total phosphorus, total potassium and micronutrients from fly ash into more soluble forms and thus resulted in increased bioavailability of the nutrients in the vermicomposted series. Among different combinations of fly ash and cow dung, nutrient availability was significantly higher in the 1:3 fly ash to cow dung treatment compared with the other treatments. (R.M.Venkatesh, T.Eevera)

The problem of solid waste management has manifested itself as a threat to the cities with increasing urbanization and change in lifestyle. The problem of solid waste has been increasing rapidly with increase in population, changes in lifestyle and consumption patterns in Guwahati. Presently, the total amount of Municipal Solid Waste (MSW) generated varies between 350 to 500 metric tons per day in Guwahati. The performance of MSW disposal system in the city has been observed to be miserably poor. Moreover, the Guwahati Municipal Corporation (GMC) does not provide door-to-door waste collection service in the city. If these wastes can be collected at the source in a segregated form for further treatment, these wastes can be converted to wealth. Hence, a survey on the willingness to pay has been conducted to elicit the people's preference for such waste collection services. (Daisy Das , Ratul Mahanta)

3. Solid Waste Management on Thapar University Campus

3.1 Present Status

Total population in T.U. campus is 4000. Total waste generated in T.U. campus on an average **2700 kg/day**. Three workers and a driver load the waste on trolley. Waste is not collected on Sunday and public holidays and a backlog is created on the next working day. This waste (other than grasses) is finally dumped at Sanauri Adda (outer of the city). This open dumping site does not follow any criteria or specification provided by CPCB or SPCB for Solid Waste (Management and Handling rule) 2000. Total amount of news paper supplied by the supplier is about 1020 copies. These news papers after reading become a waste and are sold to market. The news papers after reading independently collect and get back for recycling. The quality and quantity of the paper waste depend on the living style (higher income group to lower income group). The waste generated in the campus includes vegetable wastes, fruit peels, plastics and other packaging materials. The process of grass cutting takes place in campus. In the campus grasses is cut by lawn mover. These grass waste is (purely biodegradable) collected, loaded on tricycles and trolley and finally goes to NEEM plant near sports ground where it is allowed for composting along with yard wastes (plants and trees leaves) in pits and after composting it is sold to formers). The process of transportation of wastes takes place by tractors. There are two restaurants, two fruit corners, one coffee shop, one shop for Photostat; one of gift shop and last one is of general store. They dump their packaging material into bins which is transferred daily to collection site for dumping. No hazardous waste was found anywhere during survey or analysis. Although there are eight hostels (5 boys + 3 girls) but the waste generation rate is minimum as compared to colonies due this fact that students produce only packaging materials and paper wastes. The wastes produced from hostels mainly include food wastes and vegetable cuts from their respective mess. We found a large amount of paper waste in the each hostel after every six months at the end of semester examination because students do not keep the papers and copies.

The process of collecting, loading and dumping of wastes mentioned in picture.


These are mixed wastes temporary stored in well like structure up to 4 meters depth in the campus. These wastes are from the hostel's mess and residential colonies.

Mixed wastes collection and loading on trolley in the campus.

These wastes are finally dumped to Sanauri Adda, outer of Patiala city. Here open dumping takes place which do not follow any standards or specification provided SPCB or CPCB.

We can see here the site where open dumping of Solid wastes takes place, such type of solid waste management practice (as mentioned in above figure) create, Air pollution, Soil contamination, Global warming, Ground water pollution by leachate (various type of organic chemicals) production, Littering of wastes by animals, bad smell and human health problems.

The process of grass cut loading and dumping to NEEM plant near sport ground for composting along with yard wastes. Here a worker (in figure) using the red colour bin for biodegradable wastes (grasses), it means workers are not aware about colour coding systems for wastes and also not aware about Municipal Solid Waste Management Handling Rule 2000, provided by Central Pollution Control Board (CPCB).

Residences on T.U. Campus

Type of Houses	Number of Houses
Type II Colony (d type)	12
Type III Colony (new)	40
Type III Colony (old)	08
Type IV Colony (new)	20
Type IV Colony (old)	08
A Type residence	03
B Type residence	03
C Type residence	10
E Type staff colony	46
Houses at backsides of hostels	16
Houses at Building center	04
Houses at Backside of dispensary	03
Houses near Guest house	04
R & D.Centre Colony (A Type)	24
R & D.Centre Colony (B Type)	32
R & D.Centre Colony (CType)	16
Grand Total of Residences	**249**
Hostels	**8** (5 boys hostels and 3 girls hostel)

3.2 Drawbacks in the Present System

No Storage of Waste at Source in segregated way

There is no practice of storing the waste at source in a scientifically segregated way. Residents store their house hold waste in plastic bags or in plastic tub and they dump to waste in mixed form into well made of concrete and bricks up to 4 meter depth which is nearer to every type of colonies e.g. lecturer's colony, Professors Colony, and subordinate class Colony.

Irregular Street Sweeping

Even street sweeping is not carried out on a day-to-day in T.U.Campus. Generally important roads are prioritized and rest of the streets is swept occasionally. Generally, no sweeping is done on Sundays and public holidays.

Waste Storage Depots

As waste is collected through tractors/tricycles that can carry only a small quantity of waste at a time, there is a practice to set up depots for temporary storage of waste to facilitate transportation through motorized vehicles. Generally, open sites or round cement concrete bins, masonry bins or concrete structures are used for temporary bulk storage, which necessitates multiple handling of waste. Waste often spills over, which is both unsightly as well as unhygienic.

Transportation of Waste

Transportation of waste from the waste storage depots to the disposal site is done through tractors. They are usually loaded manually. There are no provisions for safety of workers.

Disposal of Waste

The waste loaded on tractor and finally dumped to Sanauri Adda disposal point on outskirts of the city. Here open dumping takes place which does not follow any rules or Standards provided by CPCB. Disposal of waste is the most neglected area of SWM services and the current practices are grossly unscientific. Almost all municipal authorities deposit solid waste at a dump-yard situated within or outside the city haphazardly and do not bother to spread and cover the waste with inert material. These sites emanate foul smell and become breeding grounds for flies, rodent, and pests. Liquid seeping through the rotting organic waste called leachate pollutes underground water and poses a serious threat to health and environment. Landfill sites also release landfill gas with 50 to 60 per cent methane by volume. Methane is 21 times more potent than carbon dioxide aggravating problems related to global warming.

Lack of Awareness: Although there are bins at every place e.g., in institutional, residential and commercial areas (shops on the campus) to store the waste and also colour coded as prescribed by Central Pollution Control Board, for example, green bin for biodegradable wastes, white for recyclable wastes, yellow bin for mixed wastes and red for hazardous wastes but these are not indicated on bins and generally peoples are unaware about it so wastes do not segregate at source of generation. Hazardous waste is not produced on the campus.

4. Waste management by Vermicomposting

Vermiculture or vermicomposting is derived from the Latin term vermis, meaning worms. Vermicompsting is essentially the consumption of organic material by earthworms. This speeds up the process of decomposition and provides a nutrient rich end product, called vermicompost, in the form of 'worm castings'. Vermicomposting is a simple biotechnological process of composting, in which certain species of earthworms are used to enhance the process of waste conversion and produce a better end product. Vermicomposting differs from composting in several ways (Gandhi et al. 1997). It is a mesophilic process, utilizing microorganisms and earthworms that are active at 10–32°C (not ambient temperature but temperature within the pile of moist organic material). The process is faster than composting; because the material passes through the earthworm gut, a significant but not yet fully understood transformation takes place, whereby the resulting earthworm castings (worm manure) are rich in microbial activity and plant growth regulators, and fortified with pest repellence attributes as well! In short, earthworms, through a type of biological alchemy, are capable of transforming garbage into 'gold' (Vermi Co 2001, Tara Crescent 2003).

Vermicomposting involves the stabilization of organic solid waste through earthworm consumption which converts the material into worm castings. Vermicomposting is the result of combined activity of microorganisms and earthworms. Microbial decomposition of biodegradable organic matter occurs through extra cellular enzymatic activities (primary decomposition) whereas decomposition in earthworm occurs in alimentary tract by microorganisms inhabiting the gut (secondary decomposition). Microbes such as fungi, actinomycetes, protozoa etc. are reported to inhabit the gut of earthworms.

Ingested feed substrates are subjected to grinding in the anterior part of the worms (gizzard) resulting in particle size reduction. Vermitechnology, a tripartite system which involves biomass, microbes and earthworms is influenced by the abiotic factors such as temperature, moisture, aeration etc. Microbial ecology changes according to change of abiotic factors in the biomass but decomposition never ceases.

A condition unfavourable to aerobic decomposition result in mortality of earthworms and gut subsequently no vermicomposting occurs. Hence, preprocessing of the waste as well as providing favorable environmental condition is necessary for vermicomposting. The vermicompost is relatively more stabilized and harmonises with soil system without any ill effects. Unfavourable conditions such as particle size of biomass and extent of its decomposition, very large temperature increase, anaerobic condition, toxicity of decomposition products etc. influence activity of worms. This technology has been used for agricultural waste and its adoption to municipal solid waste is of recent origin. The worm species that are commonly considered are Pheretima sp, Eisenia sp & Perionyx excavatus sp**.** These worms are known to survive in the moisture range of 20-80% and the temperature range of 20-40^{o}C. The worms do not survive in pure organic substrates containing more that 40% fermentable organic substances. Hence, fresh waste is commonly mixed with partially or fully stabilised waste before it is subjected to vermicomposting. The worms are also known to be adversely affected by high concentrations of such heavy metals, as Cd, Cr, Pb & Zn. Due to the constraints of the temperature and moisture, Fermentable Organic Substances (FOS) and heavy metals use in vermicomposting on municipal scale has not been successful. However, use of this method for wastes from individual houses, housing colonies etc., where the waste is mainly organic in nature and where the quantities are less and can be manually handled is common.

4.1 Equipment and Supplies

Materials needed to start a vermicomposting system are simple and inexpensive. All we will need are a worm bin, bedding, water, worms and food scraps.

Worm Bin

A suitable bin can be constructed of untreated, non aromatic wood, or plastic container to be purchased. A wooden box is better if we will keep the worms outdoors, because it will keep the worms cooler in the summer and warmer in the winter. An outdoor wooden bin can even serve double-duty as a bench. If a plastic container is used, it should be thoroughly washed and rinsed before the worms and bedding are added. The bin size depends on the amount of food produced by household. The general rule of thumb is one square foot of surface area for each pound of garbage generated per week.

For two people (producing approximately 31/2 pounds of food scraps per week), a box 2 feet wide, 2 feet long, and 8 inches deep should be adequate. A 2-foot-by-3- foot box is suitable for four to six people (about 6 pounds of waste per week). Redworms (the type used for vermicomposting) thrive in moist bedding in a bin with air holes on all sides. For aeration and drainage, drill nine l/2-inch holes in the bottom of the 2-foot-by-2- foot bin or 12 holes in the 2-foot-by-3-foot bin. Place a plastic tray under the worm bin to collect any moisture that may seep out. Drilling holes on the upper sides of wer bin will also help wer worms get needed oxygen and prevent odors in wer worm bin. Keep a lid on the bin, as worms like to work in the dark. Store the worm bin where the temperature remains between 55° and 77°F.

Bedding

The worms need bedding material in which to burrow and to bury the garbage. It should be a non toxic, fluffy material that holds moisture and allows air to circulate. Suitable materials include shredded paper (such as black-and-white newspapers, paper bags, computer paper, or cardboard); composted animal manure (cow, horse, or rabbit); shredded, decaying leaves; peat moss (which increases moisture retention); or any combination of these. Do not use glossy paper or magazines. Add two handfuls of soil to supply roughage for the worms. Adding crushed eggshells provides not only roughage but also calcium for the worms, and it lowers acidity in the bin. About 4 to 6 pounds of bedding is needed for a 2- foot-by-2-foot bin (for two people), and 9 to 14 pounds of bedding should be used in a 2- foot-by-3-foot bin (for four to six people). Worms will eat the bedding, so we will need to add more within a few months.

Water

The bedding must be kept moist to enable the worms to breathe. To keep bedding moist, add 3 pints of water for each pound 7 of bedding. We will need about 1 1/2 to 2 1/4 gallons of water for 4 to 6 pounds of bedding. If the bedding dries out, use a plant mister to spray some water on it.

Worms

It is important to get the type of worms that will thrive in a worm bin. Only redworms or "wigglers" which are "composting worms" should be used (do not use night crawlers or other types of worms).

Food Scraps

Feed allowed to worms any non-meat organic waste such as vegetables, fruits, eggshells, tea bags, coffee grounds, paper coffee filters, and shredded garden waste. Worms especially like cantaloupe, watermelon, and pumpkin. Limit the amount of citrus fruits that we add to the bin to prevent it from becoming too acidic. Break or cut food scraps into small pieces so they break down easier. Do not add meat scraps or bones, fish, greasy or oily foods, fat, tobacco, or pet or human manure. Be sure to cover the food scraps completely with the bedding to discourage fruit flies and molds. One pound of worms will eat about four pounds of food scraps a week. If we add more food than capacity of worms can cause, anaerobic conditions will set in and cause odor. This should dissipate shortly if we stop adding food for a while.

Temperature

Redworms will tolerate temperatures from 50° to 84°F, but 55° to 77°F is ideal. They are also grown outdoors in the coldest areas of the country. Information regarding this method is available from us.

Starting the Process

To start vermicomposting system, first selected a location for worm bin in the open tubs of plastic kept at suitable place in the lab making sure that air circulated around the bin. Next, prepared the bedding, news papers soaked in water. Spread the bedding evenly until it filled about three-quarters of the bin. Sprinkled a couple of handfuls of cow dung into the bedding to introduce beneficial microorganisms and aid the worms' digestive process. The bedding was fluffed up about once a week so the worms could get plenty of air and freedom of movement. Worms were gently placed on top of the bedding and left the bin lid off for a while so the worms burrowed into the bedding, away from the light. The worms would not try to crawl out of the bin due to the light overhead. Once the worms have settled into their new home, added food scraps that we have been collecting in a leak-proof container. Dug a hole in the bedding, placed the food scraps in the hole, and covered it with at least an inch of bedding. After this first feeding, waited a week before adding more food. Left worms alone during this time to allow them to get used to their new surroundings. Burried food scraps in a different area of the bin each time and fed the worms once in a week.

4.2 Harvesting the Worms and Compost

After about six weeks, began to see worm casting (soil-like material that has moved through the worms' digestive tracts). The castings could be used to boost plant growth.. This is called Vermicompost. We may harvest the vermicompost by one of two methods:

Method 1: Place food scraps on only one side of worm bin for several weeks, and most of the worms will migrate to that side of the bin. Then we can remove the vermicompost from the other side of the bin where we have not been adding food scraps, and add fresh bedding. Repeat this process on the other side of the bin. After both sides are harvested, we can begin adding food scraps to both sides of the bin again.

Method 2: Empty the contents of worm bin onto a plastic sheet or used shower curtain where there is strong sunlight or artificial light. Wait 20-30 minutes, and then scrape off the top layer of vermicompost. The worms will keep moving away from the light, so we can scrape more compost off every 20 minutes or so. After several scrapings, we will find worms in clusters; just pick up the worms and gently return them to the bin in fresh bedding.

4.3 Using Worm Compost

We either use vermicompost immediately or store it and use it later. The material can be mulched or mixed into the soil in garden and around trees and yard plants. We also use it as a top dressing on outdoor plants or sprinkle it on lawn as a conditioner. For indoor plants, we mix vermicompost with potting soil. For top dressing indoor plants, we want to remove decaying bedding and food scraps from the castings. Make sure there are no worms or eggs in the castings, because conditions in a plant pot will not allow them to survive.

4.4 EARTHWORMS - The Benefits

a) Improve the physical structure of the soil : improve water filtration rates and absorption rates helping the soil to drain better. Less runoff equals less watering and less erosion. The tunneling activity improves soil aeration, porosity, and permeability. It increase moisture absorption and moisture available to plants. Castings absorb water faster than soil, castings hold more water than equivalent amounts of soil . Castings have the ability to absorb moisture from the air and hold it in a manner that plants can use. (Bhawalker Earthworm Research Institute).

b) Improve soil fertility: removes litter from soil surface - earthworms eat the litter and leave the nutrients in their castings for plants to use as a natural fertilizer that is non-polluting. Make plant nutrients more available, worms concentrate minerals in their castings in a form that is easy for plants to absorb. Worms stimulate microbial populations; nitrogen fixing bacteria are more numerous near earthworm burrows and in their castings. One study on bacteria and actinomycetes found densities from 10-1,000 times greater. Earthworm Ecology and Biogeography in North America, 1995. Plant growth stimulants such as Auxins are produced in the castings; these hormones stimulate roots to grow faster and deeper. Analysis of earthworm castings reveal that they are richer in nutrients than surrounding soil, often 3 times more calcium, several times more nitrogen, phosphorus, and potassium. (K.P. Barley, Advances In Agronomy, Vol. 13, 1961)

c) Worms often help clean up dangerous chemicals in the environment: Researchers have found that bacteria living in the guts of worms breakdown (detoxify) many hazardous chemicals such as hexachlorocyclohexane (HCH), organic gardening may/June 1993 Microbes living in worms have the ability to breakdown complex organic molecules like cellulose and lignin.

d) Improve water absorption and prevent erosion: - increase the water stability of the soil, earthworm castings can take a direct hit by a raindrop and maintain their shape, this reduces erosion and runoff hence helps the soil absorb water .A research study conducted in Minnesota, showed that earthworms added to cornfields increased water absorption rates 35 times over control fields without the earthworms, within a 6 week period. Acres USA, March 1994. The most important aspects of SWM in developing countries are related to the problem of (1) effective shortage in generating premises, (2) collection, (3) efficient transportation of the waste to disposal sites, (4) lack of proper disposal sites except river beds or valleys, (5) lack of co-ordination between related research institutions and administration and (6) inadequate SWM funding (Kuniyal *et al.*, 1998).

5. MATERIAL AND METHODS

Present investigation was conducted from September 2007 to May, 2008 with the solid waste sample collected from different zone of Thapar University campus-Patiala. The samples were analyzed for physical and chemical characteristics.

Sample collection and analysis

i) Identification of houses (sites) for the collection of samples.

ii) Waste samples were collected from house to house at interval of 24 hours in plastic bags.

iii) Waste samples were collected from selected sites (houses) and the sites were changed after 5 continuous samplings.

iv) Waste samples were segregated in laboratory to know the physical composition of wastes e.g. biodegradable, plastics, papers, metals, etc. (% by weight)

v) Analysis of physico-chemical properties of biodegradable portion of solid waste samples.

Physicochemical Analysis

1) Moisture Content Determination: A known amount of the sample was weighed in a petri plate. It was dried in an oven at 100° C for 8 hours.

$$\textbf{Moisture Content (\%)} = \frac{\textbf{Initial wt. of sample - Final wt. of sample}}{\textbf{Initial wt. of sample}} \times 100$$

2) pH Measurement: 5g of compost material was dissolved in 100 mL of distilled water and stirred for half an hour on a magnetic stirrer. pH was measured after settling of biomass.

3) Organic Carbon: It was measure by Walkeky and Black (1934) method by rapid dichromate oxidation technique.

$$\textbf{Organic Carbon \%} = \frac{10\,(B-T)}{B} \times 0.003 \times \frac{100}{S}$$

Where, B = Volume of ferrous ammonium sulfate required for blank titration in mL
T = Volume of ferrous ammonium sulfate required for sample titration in mL
S = Weight of sample in g

4) Organic matter = Organic carbon (%) X 1.724
(1.724 is a factor for conversion of organic carbon to organic matter)

5) Total Nitrogen: (By Kjeldahl method)

5.0g of dry sample along with 20 g of digestion catalyst mixture was poured into a 500 ml digester flask. After adding 35 ml conc. H_2SO_4, it was heated between 360-410C in a fuming chamber for one hour. The digestion of the sample was continued till it turns light green. Added 100 ml of NaOH (40%) and few granules of Zn in the Kjeldahl flask took 50 ml of boric acid cum indicator solution (pink colour solution) in 250 ml flask and placed it below the condenser of the distillation assembly so that the lower open end of the condenser is dipped in solution. Heated the distillation flask on hot plate or heating mentle and collect about 150 ml of distillate in flask, pink solution turns to green due to absorption of ammonia. Titrated the distillate with 0.01HCl to its original colour (i.e. green to pink colour indicates the end point of titration) Run a distilled water blank in same manner.

$$\text{Kjeldahl Nitrogen \%} = \frac{(T_1 - T_2)\, N \times 1.4}{W}$$

Where, T_1 = Volume of titrant used against sample (ml)
T_2 = Volume of titrant used against distilled water (blank) (ml)
N = Normality of titrant (0.01N HCl)
W = Weight of sample (g)

6) Total Phosphorus: (digestion method)

Mixed 2 g of fine sample with 30 ml of 60% $HClO_4$ in 250 ml volumetric flask, digested the mixture at a temperature a few degree below the boiling point on hot plate in a fume hood until the dark colour due to organic matter disappears. Then continue heating at the boiling temperature 20 minute longer. At this stage heavy fumes of $HClO_4$ appear, and the insoluble material becomes like white sand, if necessary add 1s ml of $HClO_4$ to move down black particles that sticks to the sides of flask. If sample is high in organic matter, add 20 ml of HNO_3 and heat to oxidize the sample. Then add the $HClO_4$. The total digestion with $HClO_4$, usually Requires about 40 minutes. Cool the mixtures. Added distilled water to obtain the volume of 250 ml, and mix the content.

Colour Development: Pipette an aliquot that contains 0.05 to 1.0 mg of P of the solution into a 50 ml volumetric flask, added 10 ml of the vanamolybdate reagent and diluted the solution to 50 ml with distilled water. Measure the optical density after 10 minutes at wavelengths from 400 to 490 nm. Prepare a reagent blank, and substract its optical density from the optical density of sample. Value is obtained by standard graph. The P content of fertilizer is expressed as the oxide of P_2O_5 instead of elemental P.

% P = % P_2O_5 X 0.436 % P_2O_5 = % P X 2.29

The conversion factors are derived from the ratio of molecular weights of P and P_2O_5

$$2 \times \frac{\text{Molecular weight of P}}{\text{Molecular weight of } P_2O_5} = \frac{2 \times 31}{142} = 0.436$$

7) Available Potassium by Flame Photometer

Weight out 5 g of soil in a 150 ml conical flask and add to it 25 ml of the neutral ammonium acetate solution, shake the flask on electrical shaker for 5 minute and filter it. Feed the filtrate into the atomizer of the flame photometer, which is already adjusted with standard solution. For standard curve dissolved 0.91 g of KCl in distilled water and made the volume 1 litre and prepared the different concentration from it by dilution. Flame photometer reading is noted at different concentration for K solution (10 ppm to 100 ppm) for standardization. It gives direct value of Potassium in ppm.

8) Heavy Metal Analysis

The heavy metal contents of the vermicompost were measured by Maboeta method (2003). About one gram of vermicompost was obtained to prepare the required samples. These samples were subjected to digestion by adding 25 ml of nitric acid and then were placed on a hot plate and heated for 4 h at 90 to 950C. During digestion, care was taken to ensure that the samples did not dry out. After digestion, the samples were poured into 100-ml flasks through filter paper and injected into the Flame Atomic Absorption, Perkins Elmer 2380 to determine heavy metal concentration.

Results and Discussions

Results of physicochemical analysis of solid wastes (house hold, institutional, hostels, and shops) collected from different zones of Thapar University campus are presented in this chapter. The physical investigations indicate about individual components of the waste and their proportions, where as the chemical investigations such as organic carbon, nitrogen , phosphorus and potassium tells us about composition and nutritive value of the waste.

Selection of various sampling sites

The sampling sites selected are Professors Colony, Lecturers Colony, Type II Colony, Type E Colony and Class IV colony on Thapar University Campus. Wastes were collected from selected sites and site was changed after 5 continuous samplings at one site. Wastes were segregated in laboratory to know the physical composition of wastes (% by weight) e.g. biodegradable, plastics, papers, metals, etc.

Investigation of different components of sampled solid waste

The Results of physical investigation of solid waste obtained by individual collections are shown in Table 6.1. The variations in physical characteristics were observed and average characteristics of solid waste. Result from Table 6.2 show physicochemical analysis of biodegradable fraction of the solid waste in Thapar Campus obtained during the study period, Table 6.3 and 6.4 shows the results of Vermicompost of littered leaves as well as vegetable cut and fruit peels.

Biodegradable matter

It can be seen from Table 6.1 that the samples contain high proportion of biodegradable matter of the extent 60% to 85%. The reason behind this is that samples were collected from house to house and these were generally kitchen wastes (vegetable cuts, fruit peels and yard waste). Compostable matter in the solid waste results from preparation, handling, cooking of food from and plant or animal origin. Due to its putrescibility, it results in the unpleasant odours. Although the quantity of waste generated in Professors Colony and lecturers colony is less than the Type ecolony and Class 4th Colony, but slightly variation in quantity of biodegradable fraction. These fractions have moisture contents up to 60% to 80 % So the best option for these waste utilization is vermicomposting which can do nutrients recovery (macronutrients NPK, as well as micronutrients) in the form of compost and can get back to the soil. Biodegradable waste is a type of waste, typically originating from plant or animal sources, which may be broken down by other living organisms. It can be commonly found in municipal solid waste (sometimes called biodegradable municipal waste [BMW]) as:

* Green waste * Food waste * Paper waste * Biodegradable plastics

Other biodegradable waste

* Human waste * Manure * Sewage * Slaughter house waste

Uses of biodegradable waste

Biodegradable waste is a little recognized resource. Through correct waste management, often using the two key processes of anaerobic digestion and composting, it can be converted into valuable product. Anaerobic digestion converts biodegradable waste into several products, including biogas, which can be used to generate renewable energy or eat for local heating, and soil amendment. Composting converts biodegradable waste into compost.

Paper Wastes

As shown in Table from 6.1, paper waste generated 4% to15%. These are packaging material in addition to 1020 copies of news papers circulated daily on campus. News papers after reading sold in the market for recycling. The quality and quantity of the paper waste depend on the living style (higher income group to lower income group). The paper waste in institutional area is dumped into bin alongwith mixed wastes. Paper is responsible for creation of nuisances when it becomes scattered by the wind and careless handling. The proportion of paper waste except news papers are found maximum in lower income group (E-type colony and Fourth class colony) as comparison to higher income group(Professors colony and Lecturers colony). It takes 17 trees and 1500 litres of oil to make one tonne of paper. In Hong Kong, over 12,000 tones of municipal solid wastes are disposed of daily, or 4.4 million tones a year. About 20% of the domestic solid waste collected is paper. A pilot scheme in Tuen Mun indicated that an average household throws away 1 kg of newspaper every week. That's one tree a year. Recycling of paper creates 74% less air pollution and 35% less water pollution than producing paper from virgin fibres. It is a very simple operation.

Plastics

The plastic content found in the sample varies from 2% to 33%. This variation in plastic content is due to living style of people. Table 6.1 shows that the plastic content is maximum in samples of E-type colony and Class 4^{th} colony as compared to Professors Colony and Lecturers Colony. In most of samples, plastics are present in the form of broken plastic toys. Plastics are non biodegradable component of solid waste, although biodegradable plastics may be in practice but it is much expensive. It is seen during survey that the rag pickers gather at the dump sites and pick up the waste material i.e., papers, plastics and metals. Hence, activities of rag pickers might have influenced the above results. The finding of Central Pollution Control Board (CPCB) on rag pickers is described by Parivesh News letter (Biswass, 1997).

Reusing

Plastic is preferable to recycling as it uses less energy and fewer resources. Long life, multi-trip plastics packaging has become more widespread in recent years, replacing less durable and single-trip alternatives, so reducing waste. For example, major supermarkets have increased their use of returnable plastic crates for transport and display purposes four-fold from 8.5 million in 1992 to an estimated 35.8 million in 2002. They usually last up to 20 years and can be recycled at the end of their useful life. According to a 2001 Environment Agency report, 80% of post-consumer plastic waste is sent to landfill, 8% is incinerated and only 7% is recycled.

Wood

Table 6.1 shows that wood content in the samples are 3% to 10%. Wood waste generation is not regular on the campus. So there are fluctuation in quantity in the sample. In most of the sample woods is not found. In one of the sample of Class 4^{th} colony 16% wood of total waste are found but its not regular. Here is not a proper source of wood in house hold waste sample. Wood waste generated by householders comes mainly from old furniture, fencing, and very little comes from wood packaging. alternatives to disposal. These alternative uses represent a significant potential saving in disposal costs. http://www. ciwmb.ca.gov/conDemo/Wood

Metals

Metals in the sample are 2% to 27%. This is in the form of iron and aluminum coils from waste electricity cables. In some samples its content is found up to 27% while in most of the samples it is absent. The metal content is found maximum in the sample collected from 4th Class and E-type of colony (Table no.6.1) but one sample collected from Professors Colony had highest metal content 27% (Table no.6.1**).**

Clothes

Clothes were absent in the sample.

<u>Vermicomposting</u>

This study was conducted during the period from April 30 to July 5, 2008. The vermicompost experiments were performed in three plastic worm-bins of 0.8X0.9X0.7 m3 (length·width·depth). These plastic bins provided 1m2 of exposed top surface. The waste used in this study was biodegradable fraction segregated from the House hold waste sample. The ratio of waste and worms used was 1:4 with 28 percent moisture on dry basis content mixed with 1 kg of cow dung of 70% percent moisture content to provide a suitable C/N ratio. These wastes were spiked with heavy metals (Cu, and Ni,) at different ratio. 0.75 g (Cu, and Ni), 0.25 g (Cu, and Ni) and 1.0 g (Cu, and Ni) are added according to their elemental concentration in heavy metal compounds to per kg of wastes in different experimental bin used vermicomposting. The species of worm E.fetida used for this purpose. After 60 days vermicompost was analysed for pH , Moisture content, organic carbon, organic matter and macronutrient (NPK).

Table 6.2 Nutritive value parameters of household biodegradable waste before composting (average of 4 days)

	Colony			
	PROFESSORS	LECTURERS	TYPE II	CLASS IV
M.C. % (Wt.basis)	84	84	69	73
pH	6.5	6.1	6.4	6.2
O.C.%	0.1	0.21	0.12	0.09
O.M.%	0.1724	0.36	0.206	0.155
TKN %	0.74	0.60	0.52	0.65
TOTAL P %	0.013	0.012	0.014	0.012
K (ppm)	nil	nil	3ppm	Nil

Table 6.3
Nutritive value of vermicompost of Yard waste (littered leaves) mixed with Cow dung, Waste and Earthworm (4:1) after 60 days.

M.C. % (dry basis)	62	65
pH	7.3	7.2
O.C.%	25	24
O.M.%	43.1	41.37
TKN %	0.83	0.74
P as P_2O_5 %	0.76	0.64
K (ppm)	45	50

Table 6.4
Nutritive value of household biodegradable waste (vegetable cuts and fruit peels) mixed with Cow dung, Waste and Earthworm (4:1) after 60 days.

Moisture Content %	62
pH	7.4
O.C.%	21
O.M.%	36.20
TKN %	1.9
P as P_2O_5 %	1.2
K ppm	60

pH of Vermicompost

pH values of vermicompost of different samples of leaf litter waste and vegetable cuts are 7.3, 7.2 and 7.4 respectively (Table 6.3 and Table 6.4) which show good condition of vermicompost.

Organic Carbon and Organic matter in Vermicompost

Average organic carbon content in samples vary from 0.09% to 0.21% (Table 6.2), which is better value then normal values. When it is mixed with Cow dung for vermicompost experiments it yields good composition for earthworms. Correspondingly higher organic content was also observed.The nutrient content of the vermicompost depends upon the quality of the organic waste which is fed to earthworms. Total organic carbon decreased with time in all treatments. The organic carbon is lost as carbon dioxide and total Nitrogen increase as a result of carbon loss. Microorganism and Earthworms uses the carbon, as a source of energy and nitrogen for building cell structure brings about decomposition of organic matter. (Crawford, 1983). Initially the organic carbon of cow dung was 27 % while after 60 days it reduces to 25 %, 24 % and 21 % (table 6.3 and 6.4). But the reduction was greater in vermicomposting compared to the ordinary composting; this may be due to the fact that earthworms have higher assimilating capacity for the food. Typical soil generally contains at least 45% inorganic components, 5% organic components, 25% air and 25% water on average basis. Organic carbon plays major role in biological activity and fertility of the soil. In different parts of the world positive correlation between the amounts of organic carbon and soil fertility has been proved. Indian soil ecosystems are very dynamic due to its sub-tropical climate, resulting rapid degradation of organic matter in these soils.

Soil organic matter (SOM)

Soil organic matter contributes to soil fertility in several quite distinct ways. It helps to give a soil a good stable structure which is particularly important in the surface soil. By its oxidation in soil, plant nutrients such as nitrogen, phosphorus and sulphur are released in a form available for uptake by crop roots. In sandy soil it helps to increase cation exchange capacity, so increasing the ability of soil to hold cations against leaching but in a form available to the crop. (Mercer & Richmond 1970, 1971, 1972).

Total nitrogen in vermicompost: Total nitrogen in the sample vary from 0.54% to 0.74% which is an indicator good quality of organic waste. Earthworms also had a great impact on Nitrogen transformation in the compost. The increase in the Nitrogen value is as result of carbon loss Nitrogen is an important macronutrient in soil. The TKN content increased in vermicompost of vegetable cuts and fruit peels (Table 6.4) as compared to vermicompost of littered leaves (Table 6.3). Crop production is often enhanced by the application of this element. Nitrogen is a part of all living matter and is essential for plant growth. Nitrogen stimulates above-ground plant growth and is required to maintain high yields. Most soil nitrogen is associated with organic compounds such as proteins or fertilizer inputs. The final Nitrogen content of compost is dependent on the initial N present in the waste and the extent of decomposition (Crawford, 1983).

Total phosphorus in Vermicompost

Phosphorus (P) is essential for plant growth. It stimulates growth of young plants, giving them a good and vigorous start. Phosphorus management and nutrition has both economic and environmental implications. The total phosphorus in biodegradable content of solid waste is 0.012 to 0.014 % (Table 6.2) while after 60 days vermicomposting it is increased to 0.64% (Table 6.3) to 1.2 % (Table 6.4) as P_2O_5 respectively.

Potassium in Vermicompost

Potassium content in the sample of biodegradable fraction was 3ppm and some time absent (Table 6.2). Potassium content in the vermicompost of littered leaf was found 40 ppm to 45 ppm (Table 6.3), while in case of vermicompost of vegetable cuts and fruit peels the K content was found 65ppm. Potassium is an essential element for healthy plant and animal growth. In plants, one of its most important functions is regulation of stomata opening. This controls the rate of assimilation of carbon dioxide and the rate of transpiration.

Heavy metal uptake by earthworms during composting

Experiments were conducted

Sr No.	Amount of Cu added (ppm)	Amount of Cu found in waste (ppm)	Amount of Cu retained by earthworm (ppm)
1	2.5		
2	5.0		
3	10.0		

Sr No.	Amount of Ni added (ppm)	Amount of Cu found in waste (ppm)	Amount of Cu retained by earthworm (ppm)
1	2.5		
2	5.0		
3	10.0		

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