Solid Waste Management Utilizing Microbial Consortia and its Comparative effectiveness study with VermiComposting

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Abstract

The paper focuses on the treatment of Municipal Solid Wastes by methods of aerobic composting with a bio consortium used for waste water treatment and vermicomposting. An analysis of physical, chemical and biological characteristics from samples collected at different stages of decomposition of the wastes during the treatment processes will be analyzed and their variations will be compared to obtain an idea on the efficiency of treatment using the two methods. The fertilizer value of the compost obtained from the two methods would be compared to get an insight into the efficiency and usefulness of the new technique as vermicomposting is used and well studied method of solid waste treatment.

1. INTRODUCTION

One of the biggest challenges in front of the modern society is the proper handling and management of the solid waste being produced indiscriminately. India, a developing country in Asia produces 52,000 tonnes of MSW per day with a per capita generation ranging from 0.1 to 0.6 kg/day. Almost all of the collected wastes are disposed in open dumps. This requires the acquiring of more land as dump sites and landfill sites which is likely to dwindle in the future due to the increase in population which has touched the 7 billion mark worldwide due to the requirements for residential, agriculture and industry purposes. The projected cumulative land requirement for India to dispose MSW in 2047 would be about 1,400 km^2 against the present land requirement of 100 km^2. In this scenario, it is important to look for alternative technologies which could be utilized for easy and faster management of the solid waste in the available space. The Non biodegradable fraction of solid wastes could be sent for recycling while the biodegradable fraction could be converted into useful organic manures or compost or recovery of wastes in the form of energy could be done through incineration or by conversion into RDFs or by pelletization . Some of the technologies already in use for conversion into composts are aerobic and anaerobic composting, vermicomposting, windrow composting etc. But all these processes take about 90 -360 days to yield results. So, faster technologies are required to be adopted having better organic values for compost than those utilized presently. For the project purpose, a microbial consortia presently utilized for waste water treatment is

inoculated into the solid wastes for aerobic composting and its characteristics is compared with that of vermicomposting a commonly utilized technique these days for organic composting.

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Indentations and Equations

1.INTRODUCTION

1.1 GENERAL

One of the biggest challenges in front of the modern society is the proper handling and management of the solid waste being produced indiscriminately. India, a developing country in Asia produces 52,000 tonnes of MSW per day with a per capita generation ranging from 0.1 to 0.6 kg/day. Almost all of the collected wastes are disposed in open dumps. This requires the acquiring of more land as dump sites and landfill sites which is likely to dwindle in the future due to the increase in population which has touched the 7 billion mark worldwide due to the requirements for residential, agriculture and industry purposes. The projected cumulative land requirement for India to dispose MSW in 2047 would be about 1,400 km^2 against the present land requirement of 100 km^2. In this scenario, it is important to look for alternative technologies which could be utilized for easy and faster management of the solid waste in the available space. The Non biodegradable fraction of solid wastes could be sent for recycling while the biodegradable fraction could be converted into useful organic manures or compost or recovery of wastes in the form of energy could be done through incineration or by conversion into RDFs or by pelletization . Some of the technologies already in use for conversion into composts are aerobic and anaerobic composting, vermicomposting, windrow composting etc. But all these processes take about 90 -360 days to yield results. So, faster technologies are required to be adopted having better organic values for compost than those utilized presently. For the project purpose, a microbial consortia presently utilized for *waste water treatment* is inoculated into the solid wastes for aerobic composting and its characteristics is compared with that of vermicomposting a commonly utilized technique these days for organic composting.

1.2 NEED AND SCOPE OF THE STUDY

Population growth, irregular development of cities, unsuited consumption pattern and other factors cause has been a problem for human society especially in developing countries like India. One of most obvious problems is generation of solid waste in large quantities. The lack of proper implementation of the three R's in solid waste management in developing countries like its effects on health of human beings, environment and other members of the ecosystem in a bad way. One of the important kinds of waste is Municipal Solid waste. Due to the improper management of Solid waste, it has become a major issue of the modern day society resulting in the outbreak of epidemics, change in characteristics of the soil, loss of soil fertility etc.

In any solid waste management system, the functional elements are to be taken care in a proper way. Usually, the six main functional elements from the point of generation to final disposal are: (1) waste generation; (2) waste handling and separation; (3) collection; (4) separation and processing and transformation of solid wastes; (5) transfer and transport and (6) disposal.

Waste generation usually includes activities in which materials are identified as no longer useful or of being of value and are either thrown away or gathered together for disposal. Main problem about waste generation is that it is uncontrollable, however different countries are bringing in laws to control the generation of wastes. Waste handling and separation includes activities associated with management of wastes until they are placed in storage containers to the point of collection. Separation of waste components is also an important step in the handling and storage of waste at source. On site storage is of great importance due to public health concerns and aesthetic considerations. Unsightly makeshift containers and methods such as open ground storage is undesirable and are often seen at many residential and commercial sites. Here comes the importance of collection which includes not only the gathering of solid wastes and recyclable materials, but also the transport of these materials after collection, to the location where the collection vehicle would be emptied. The location may either be a materials processing facility, a transfer station, or a land fill disposal site. The recovery of separated materials, the separation and processing of solid waste components, and transfornaton of solid waste that occurs primarily in locations away from the source of waste generation is the next important functional element. The final functional element in the solid waste management system is disposal. It is usually done by land filling or landspreading thereby making it the ultimate fate of all solid wastes, whether they are residential wastes collected directly or residual materials from materials recovery facilities or MRF's, residue from the combustion of solid waste, compost or othere substances from other forms of solid waste processing facilities. A modern day landfill is not justa a dump but an engineered facility for disposal of solid wastes on land or within the earth's mantle without creating nuisances or hazards to public health or safety, such as the breeding of rats and insects and also contamination to ground water.

Hence, a modern method other than land filling and open dumping is to be adopted as both utilizes a huge area as well as has disadvantages like formation of leachate as well as landfill gases which is harmful in many ways to human beings. Also, modern technique adopted should be in line with the thinking that management or treatment of solid wastes would have the capacity for recovery and transformation of materials into composts, energy in the form of heat etc. which thus becomes a part of Integrated Solid Waste Management (1SWM).

ISWM could be defined as the selection and application of suitable techniques, technologies, and management programs to achieve specific waste management objectives and goals.

A hierarchy of waste management activities has also been established in the

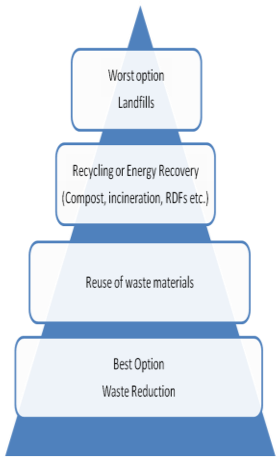


Fig 1.1 Hierarchy of ISWM

recent years which can be classified as waste reduction, recycling, waste transformation which may be through physical, chemical and biological transformations of MSW and utilized for improvement of solid waste management efficiency, recovery of reusable and recyclable materials and also for recovery of conversion products like composts or energy in the form of heat and combustible gas. In the hierarchy, landfilling or landspreading is stated as the worst options as it represents the least desirable means of dealing with society's waste.

The project basically focuses on treating the Municipal Solid Wastes by method of recycling of biodegradable fraction of MSW called composting. Here, aerobic composting is done by inoculating it with a microbial consortium used for *waste water treatment* and by vermicomposting which is a common method of recycling the wastes. The expected time required for recycling aided by microbial consortia is much faster when compared to vermicomposting. The advantages of the new methodology with respect to an age old proven technique would be analysed by comparing their fertilizer values, time required for treatment and the controls that are to exercised over the entire process. Usually earthworms are employed for vermicomposting even though other organisms too aid in the process. Most common types in use are *Eudrilus eugenae and Esienia foetida*. During vermicomposting, the important plant nutrients such as N, P, K, and Ca, present in the organic waste are released and converted into forms that are more soluble and available to plants. Vermicompost also contains biologically active substances such as plant growth regulators. Hence, a comparison with respect these aspects could also be brought under comparison.

2. LITREATURE SURVEY

For a getting a better and clear picture regarding the methodologies utilized, processes taking place and various precautions to be adopted in my area of study for the project, a detailed literature review of similar works were conducted.

2.1.Heckman, J. 2006. A history of organic farming: transitions from Sir Albert Howard's War in the Soil to USDA National Organic Program. Renew. Agric. Food Syst. 21:143–150 states that **Compost** is organic matter that has been decomposed and recycled as a fertilizer and soil amendment. Compost is a key ingredient in organic farming. At its most essential, the process of **composting** requires simply piling up waste outdoors and waiting a year or more. Modern, methodical composting is a multi – step , closely monitored process with measured inputs of water, air and carbon – and nitrogen-rich materials

2.2Dougherty, Mark. (1999). "Field Guide to On-Farm Composting" Ithaca, New York: Natural Resource, Agriculture, and Engineering Service explains **Composting** as nature's way of recycling, it is the biological process of breaking up of organic waste such as food waste, manure, leaves, grass trimmings, paper, worms, and coffee grounds, etc., into an extremely useful humus-like substance by various microorganisms including bacteria, fungi and actinomycetes in the presence of oxygen.

2.3.Edwards, C.A., et. al. 2004. Earthworm ecology, 2nd ed. CRC Press, Boca Raton, Florida explains Vermiculture or Vermicomposting is derived from the Latin term vermis, meaning worms. Vermicomposting 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'.

2.4.Payel Sarkar, Mukesh Meghvanshi and Rajni Singh Microbial Consortium (2011): "A New Approach in Effective Degradation of Organic Kitchen Wastes", ***International Journal of Environmental Science and Development ,Vol. 2,No. 3,*** took up to prepare efficient microbial consortia with concomitant enzymatic activity for the effective degradation of organic kitchen waste. Eleven different consortia were prepared and the compatibility of the bacterial strains within the consortia was checked. Seven successful microbial consortia were selected in which all the bacterial strains concomitantly produced all these enzymes (amylase, protease, lipase, cellulose) in a specialized media that are responsible for the degradation of kitchen wastes.

2.5.Afshin Asadi, Nader Shariatmadari, Hossein Moayedi and Bujang B.K. Huat (2011) "Effect of

MSW Leachate on Soil Consistency under influence of Electrochemical Forces Induced by Soil Particles", International Journal of Electrochemical Science, Vol6: 2344 – 2351 had done investigations on the effect of leachate from municipal solid waste on the soils in landfill sites and focused on the effect of leachate compounds on the engineering properties of the soil. The chemical composition of leachate produced and its effect on the consistency of soil are important factors for designing liner systems. Soil samples from the bottom of the Esfahan, Iran landfill were collected. Leachate samples were collected within the landfill and from a composting factory leachate lagoon and its effects on cation exchange capacity, electrical conductivity, pH, and consistency of the soil samples were investigated.

The chemical properties of the leachate showed that compost factory leachate was contaminated by higher concentrations of heavy metals (Cu, Zn, Pb, Cd, Ni, and Hg) and of Na^{+},Ca^{2+}, Mg^{2+}, and K^{+} ions and had a higher EC and were more acidic than the landfill leachate. Also the liquid limits and plastic limits of the soil were higher in the compost factory leachate in comparison with the values for landfill leachate.

2.6.Frederick C. Michel Jr., John Quensen, C.A.Reddy (2001)"Bioremediation of a PCB – Contaminated Soil via Composting", Compost Science and Utilization, Vol9(4):274-283 found out that Polychlorinated biphenyls (PCBs) were widely used in the past and now contaminate many industrial and natural areas. In this study, a PCB-contaminated soil from a former paper mill was mixed with a yard trimmings amendment and composted in field scale piles to determine the effect of soil to amendment ratio on PCB degradation. Temperature, oxygen concentrations, and a number of other environmental parameters that influence microbial activity during composting were monitored. PCB loss observed during the composting of the PCB -contaminated soil appeared to be largely due to biodegradation and not volatilization. Effective bioremediation of aged PCB-contaminated soils may require coupling of composting with additional remediation technologies to reduce levels of PCB congeners with greater than 4 chlorines.

2.7.Ayesha Parveen, C.K. Padmaja (2010),"Bioconversion of Municipal Solid Waste(MSW) and Water Hyacinth(WH) into Organic Manure by Fungal Consortium"*Journal of Sustainable Development* Vol. 3, No. 1 carried out the study to assess the degrading efficiency of the fungal consortium (Cellulolytic fungi –*Paecilomyces variotti and Chaetomium globosum, lignolytic fungi – Pleurotus florida and Tramates versicolor and* actinomycetes – *Streptomyces lavendulae* and *Thermobifida fusca)* in converting the Municipal solid waste (MSW) and Water hyacinth (WH) mixture into an eco-friendly value added organic manure. The results revealed that the bio - manure obtained by inoculation of fungal consortium into the municipal solid waste (MSW) and water hyacinth (WH) mixture was found to be efficient in enhancing the rate of decomposition within as they showed a drastic reduction in the biochemical parameters like organic carbon(21.09%),cellulose (20.56%), phenolic content (0.46 mg g-1) and reducing sugars (0.67 mg g-1).C: N ratio was narrowed down from 92:1 to 15:1, while Nitrogen content increased from 0.37 percent to 1.39 per cent compared to uninoculated MSW-WH compost. β-glucosidase and urease enzyme activities were much pronounced up to 75 days from 0.05to2.82 Ul-1 enzyme protein (β-glucosidase) and from 0.93 to2.39 μ mol of ammonia formed mg-1 enzyme protein (urease) in fungal consortium inoculated MSW-WH over the un - inoculated MSW-WH compost.

2.8.S.P. Gautam, P.S. Bundela, A.K. Pandey,M.K. Awasthi and S. Sarsaiya (2010), "Evolution of Composting as a Strategy for Managing Organic Municipal Solid Wastes in Central India", Australian Journal of Basic and Applied Sciences, 4(10): 5451-5455 studied the quality of municipal and agricultural waste under aerobic and anaerobic composting. Composting methods with enrichment techniques were adopted with two methods (Aerobic and Anaerobic) and seven treatments in each method. The samples of the aerobic were drawn after 0, 10, 20, 30 and 40 days after composting and in anaerobic compost samples were drawn after 50 days of compost. Effect of bio-inorganic carbonulum (Fungal Consortium), chemical amendments (2% P2O5 and 1% N) and method of composting on organic carbon, C/N ratio, pH, EC and total nutrient status during composting was determined in aerobic and anaerobic composts.

2.9.Piper Selden, Michael DuPonte, Brent Sipes, and Kelly Dinges "Small-ScaleVermicomposting",Aug. 2005 for Cooperative Extension Centre, College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa stated on how to perform Vermicomposting in urban environment in a smaller scale without no negative impacts. The paper emphasized on the selection of the type of worms to be selected and how to prepare the vermicompost bin so that optimum and fast results are obtained. Also it lists out the precautionary measures to be taken against the factors that may affect the efficiency of the composting process.

2.10.S. Esakku, J. Kurian and R. Nagendran (2005) "Methodological constraints and challenges in sampling and characterization for dumpsite rehabilitation", Tenth International Waste Management and Landfill Symposium, Sardinia gave light to the difficulties encountered during sampling and physico-chemical analyses of MSW, leachates, methane measurements in dumps and on site studies on phytoremediation and vermicomposting. An approach to overcome the constraints is also been discussed.

2.11.Sewerage and Solid Waste Project Unit. (2000). "The solid waste management programme", Barbados gave an insight into the number of processes involved into the effective management of solid waste for a municipality including its monitoring, collection, transport, processing, recycling and disposal. Different methods for waste reduction, reuse and recycling were enlisted. Also the methods for efficient collection and transport of wastes were also enlisted in the paper. Also sustainable methods of treatment and disposal were discussed. An efficient mode of Integrated Solid waste Management was also discussed in the paper.

2.12.Michael G. Pace, Bruce E. Miller, Kathryn L. Farrell-Poe (1995). "The Composting Process", The Utah State Univesity Extension Programme, Utah, USA gave ideas about the composting process, how it is taking place and processes involved. It also gave valuable information regarding the various factors affecting composting process such as Oxygen and aeration, C:N ratio, Moisture content, particle size etc. and also the importance of activity called curing has in the process of composting in whichever method or way it is being done.

2.13.J. Palsania, R. Sharma, J.K.Srivastava, D. Sharma (2008). "Effect of Moisture Content Variation Over Kinetic Reaction Rate During Vermicomposting Process", Applied Ecology and Environmental Research 6(2): 49-61,Penkala Bt., Budapest, Hungary stated that even though vermicomposting is an age old process, due to rapid changes in technology in present scenario it is essential to change such process with application of advanced technique available.The same attempt was made by authors during series of their experiments of bioconversion over solid waste containing substrates cellulose into useful biofertilizer. In the present study the substrate sugarcane bagasse taken as carbon source is bio-converted with species of earthworm *Eudrilus eugeniae*. The role of moisture content in the process is studied by varying moisture content from 45 ± 5%, 55 ± 5%, 65 ± 5%,75 ± 5% to 85 ± 5%. It is observed that the moisture content 75 ± 5% is the optimal at which the vermicomposting is fastest. Other relative parameters observed varied with maximum changes in range of 75 ± 5% of moisture content. The maximum kinetic reaction rate is recorded at the same level of moisture content.

2.14.Leslie Cooperband (2004). "Biology of Composting", University of Winconsin, Department of Soil Science gave an idea about the various processes taking place in compost pile and how the microbes actively break down the materials. Also the various phases in the aerobic composting were stated and the type of microbial communities that could take part during the composting process was also stated. The microbial classes depending upon oxygen consumption, temperature range in which they function and the food quality which they preferred were also cited in the study material.

2.15.V.Gawaikar, Dr. V.P Deshpande(2004), "Source Specific Quantification and Characterization of Municipal Solid Waste – A Review", International Journal of Environmental and Energy Engineering , Vol:86 gave an idea about the estimation of resource requirement for collection, transportation, processing and disposal requires correct assessment of quantity of waste generated per day from different sources and their characteristics. However, it is done arbitrarily merely on number of trips of vehiclesbasis and without knowing characteristics. As a result, the solid waste management system is not operated satisfactorily. In view of this, sourcespecific quantification and characterization of municipal solid waste assumes great significance which will enable accurate assessment of waste load and it would be easier for proper planning of solid waste management system. This would help in achieving the objectives of proper utilization of available resources and protection of environment and public health. The present paper highlights the importance of source specific quantification and characterization of municipal solid waste.

3.PROJECT STUDY AREA

The study area selected was the Kalamassery Municipality, Ernakulam District, Kerala. The Municipality belongs to the heart of Kerala as well as to Ernakulam district and is just 8 km away from Kochi, one of the fastest growing cities in South India. Size of the municipality is 27 square kilometers and the population of the municipality is 75656. Kalamassery is home to public sector industries such as Hindustan Machine Tools, Carborandum India etc. It also has a number of educational institutions ranging from primary schools, a university in the form of Cochin University of Science and Technology, the Cooperative Medical College and a half a dozen Engineering Colleges within its boundaries. The all important National Highways NH-47 and NH-17 passes through this municipality. These make the municipality a hotspot in the district and thus attract a lot of attention as a great residential area. This also resulted in an increase of waste generation for which the authorities were ill equipped as most of the development in the municipality came over a decade. The waste handling, seperation, its transfer and final disposal are on its worst best thus creating nuisance as well as health issues.

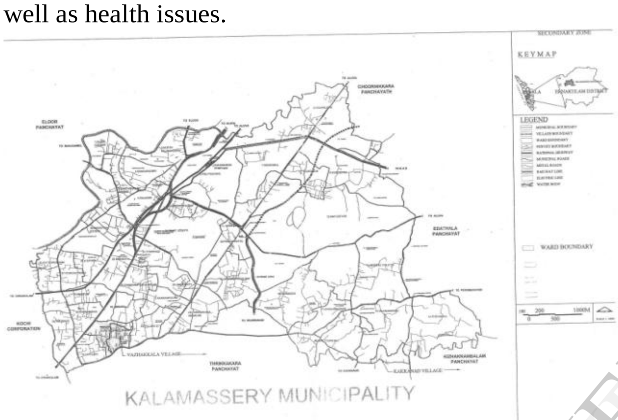


Fig 3.1 Kalamassery Municipality Site Map

3.2 SOLID WASTE GENERATED IN KALAMASSERY MUNICIPALITY

Since, the municipal boundaries span over 27 square kilometers and the type of residential, industrial and commercial units vary from one area to other, the type of waste generated varies and is usually very high. Approximately 0.50 - 1 tonnes of solid waste is generated daily in the municipality. A vast majority of the waste collected and transported to the Municipal Dump yard every 2 days if a single point is being considered. This results in problems like insects and rodents, air pollution, reduced land values and nuisance to the public. Still the local authorities have done enough to make sure that the collection is being done systematically. But the processing and disposal of the wastes is not being carried out properly. The land spreading is done without segregating the whole biodegradable and non biodegradable fraction of MSW as shown in Fig.1.3

Fig 3.2 Open dumping practiced at site

Since, only wastes from the residential and commercial units are collected, no hospital wastes or hazardous wastes are expected into the dumpyard. Hence, the wastes coming in could be segregated into biodegradable and non – biodegradable.

Biodegradable wastes include organic waste like kitchen wastes, vegetables, fruits, flowers and leaves coming from houses as well as markets. Solid waste management is important and could be easily adopted. Different methods include aerobic composting, vermicomposting, incineration, pelletization etc.

The non – biodegradable fraction may include plastic, leather, glass, metals, paints, tin cans, batteries etc. They could be sent for recycling or for final disposal in a proper way.

For the purpose of getting an idea of the type of waste coming into the dumpyard, a sample of waste was procured of weight 100 kg and the biodegradable and non biodegradable fraction was so that an idea about how sampling for the project is to done.

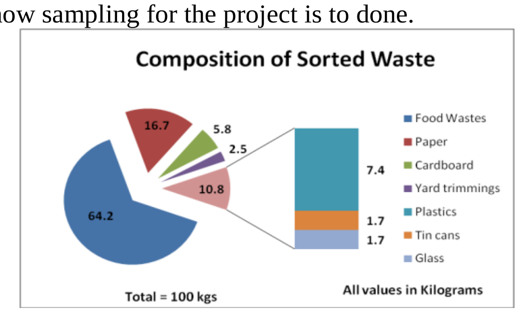


Fig 3.3Composition of the waste after characterization of wastes

Here, from the random sampling done for the day, we can see that 89.2 kg was biodegradable fraction while only 10.8 kg was non – biodegradable fraction. Composition and characteristics of wastes changes with the area and day of collection.

4. PAPER STUDY AREA AND METHODS

4.1 GENERAL

For efficient composting in lab scale, the wastes collected was sorted and only the organic fractions, namely food and kitchen wastes, paper wastes, yard trimmings including leaves and small branches chipped and shredded into size of not greater than 5cm was placed in plastic containers of size 0.66m X 0.45m X 0.31m with rectangular cross section..

The aim of the project was basically a relative analysis of efficiencies of composting methods using a microbial consortium and vermicomposting. The recycling or treatment of wastes was performed using the consortia and earthworms and samples from the treated wastes was collected and analysis from time to time to get an idea of how the process was moving forward.

The fertilizer value of the compost produced from both the processes were compared and the efficiency and usefulness of treatment using the new technique could be identified so that it could be utilized by local municipalities and private agencies for treatment and management of their waste by production of useful compost which could be marketed as an alternative soil amendment.

4.2 OBJECTIVES

The basic objectives of the performing the project included the following:

i. Collection and characterization of MSW from a nearby municipal dump yard.
ii. Treatment of the MSW by aerobic composting aided by bioconsortia and vermicomposting
iii. Analysis of parameters such as Moisture Content, pH, COD, Cl^-, TDS, Fe, Ca and Mg from the samples of decomposing wastes collected at different stages of the composting process and their variations as the process proceed forward and their relative comparisons.
iv. Analysis of Total Nitrogen, Total Phosphorus, Potassium and C/N ratio of the waste collected at different stages of the composting process and their variations so that the value of the product for reuse as a soil amendment or fertilizer could be known.

4.3 MATERIALS REQUIRED

Materials required for the project would include

1. Two plastic tanks of standard sizes 0.66m X 0.45m X 0.31m
2.The mother culture of the bio consortium
3.Sugar or jaggery with high glucose content to make the organic solution for the aerobic composting from the mother culture
4.Red wigglers or *Esienia foetida,* worms to be used for vermicomposting
5.Glass ware like Beakers, Burettes, Pipettes, Measuring jars, graduated tubes etc for analytical purposes of various parameters.
6.Chemicals for the various analytical purposes.
7.High temperature furnace, Hot air ovens, BOD Incubator, COD reflux setup, pH meter, TDS meter, Electrical conductivity meter etc. for analysis of the various physical, chemical and biological parameters as referred to from the objectives of the project.

4.4 METHODOLOGY

For conducting the project at a lab scale, MSW was collected from the Kalamassery Municipal solid waste dump yard . The experimental setup would consist of two plastic tanks of standard sizes of 0.66m X 0.45m X 0.31m at a pilot scale. For the project purpose, 100 Kg of MSW was collected utilizing the method of random sampling from the Kalamassery Municipal dump yard of which 50 Kg was selected for the experimental purposes. 25kg of MSW was treated using the microbial consortium utilized for the treatment of waste water by method of aerobic composting. A common composting method, vermicomposting was also initiated using the other 25 kg of MSW having similar characteristics. As the treatment moved forward samples were collected and analyzed at different stages and values were compared.8 to 12 holes of size varying from 0.65cm – 1.25cm are drilled in the sides and bottom for aeration and drainage. The bins were then raised on bricks or wooden blocks, and a tray was kept underneath to capture excess liquid or leachate which was disposed off from time to time.

4.4.1 COMPOSTING USING BIO CONSORTIUM

The Microbial consortium OS -1 manufactured by M/s JMS Biotech, Mysore was utilized as it is cheap and is presently used for *waste water treatment*. Requirement of the consortia was estimated at 1 liter per 1000kg of waste along with 1 kg of finely powdered and divided jaggery as growth media.. The solution was selected as its efficiency for MSW treatment could be estimated as presently it is used for waste water treatment. The microbial solution to be sprayed over was prepared at the rate of 50 liters per 1000 kilo gram of waste. So, by calculation, 100 ml of the mother culture was taken and it was mixed with a glucose rich nutrient solution made up of sugar or jiggery. Usually, for 1 tonne of solid waste, 50 liters of this solution is to be used. So, by calculation, 100 ml of mother culture of the consortia was mixed in 5 liter of this solution. For efficient startup process during which the microbes in the mother culture would utilize the nutrients and multiply and become active so that they could be utilized directly for treatment purpose, the whole mixture is kept in an air tight container for a period of 7 days or more after which it could be used up to a time period of 20 – 30 days. Start up process was done prior to the collection of the sample.

Composting using bio consortia will be done by adding MSW in layers and consortia solution prepared applied over each layer. The segregated MSW consisting of food and kitchen wastes, shredded cardboard, paper and garden and yard trimmings are added into the two bins to reach a height of 18cm from the bottom. The waste was rolled over neatly every 3-5 days and required amount of solution was added so that the moisture content was maintained throughout the period of treatment. The solution would be sprayed over the solid waste to be treated by placing one layer over the other with no requirement for any bedding materials. During the initial phases of treatment, ie; from days 5-8, temperature would increase to 43^{o}C - 45^{o}C during the period of initial microbial activity after which the temperature dropped down to 35^{o}C - 28^{o}C showing that the microbes have acclimatized to the conditions and they have started their treatment of the food or waste provided to them. Aeration was also provided so that the oxygen content within the waste did not go down. Also, it ensured that chances for anaerobic conditions within the setup would reduce further.

Final product was in the form of sludge as in sludge drying beds, they are to be added with water, mulched and powdered before utilization as a soil amendment. The treated compost had an odor similar to that of ether making the treatment process as well as the final product easy to handle.

4.4.2 VERMICOMPOSTING

Vermicomposting was done by providing a bedding of shredded cardboard, paper, soil and poultry wastes and some kitchen waste as the bedding layer. The bedding layer was prepared two weeks prior to collection of MSW and worms were added after making sure that the initial heat of biodegradation has come down so that the worms utilized were safe as temperature sore to nearly 49^{o}C during this period. The MSW was then placed over the bedding layer so that the earthworms which were introduced into the system would decompose the wastes. Given suitable conditions, vermicomposting provide a relatively straightforward solution to the management of compostable organic wastes. For increased efficiency, care would be taken to ensure that organic feedstock and conditions allow worms to reproduce successfully and withstand moisture and climatic fluctuations. For the project purpose the high yielding *Esienia foetida* – The Red Wiggler is used along with *Eudrilus eugenae* species which would have a faster reproduction rate and a high conversion capacity of the solid wastes into manure. Vermicompost pit was made using a bedding of shredded cardboard, paper, clean soil or sand for the worms to grow over which the MSW would be placed where it will be eaten by the worms and converted into castings utilized as the compost. In order to separate and retain worms as well as casts, the wire mesh screen method was utilized.

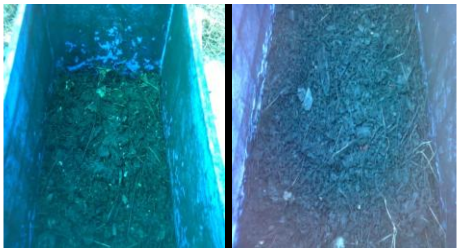


Fig:4.1 Inside view of the aerobic compost and vermi compost set ups on 35th and 90th days respectively

Figures and Tables

5.Results and graphs

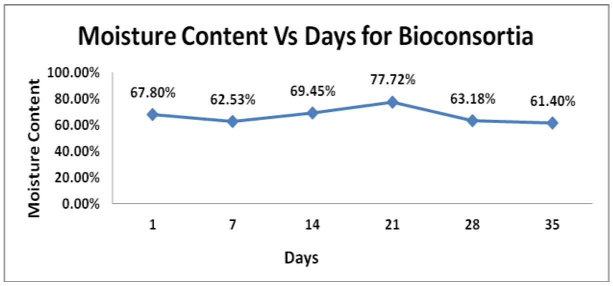
GRAPHICAL REPRESENTATION OF PARAMETERS FOR COMPOST AIDED BY BIOCONSORTIA OF DIFFERENT PARAMETERS FOR GIVEN BELOW FROM FIG. 5.1 TO 5.9

5.1 Moisture Content

The protocol of analysis utilized for finding out Moisture content was AOAC.

Moisture is necessary to support the metabolic processes of the microbes. Composting materials should be maintained within a range of 40% to 65% moisture.

Experience has shown that the composting process becomes inhibited when the moisture content is below 40%. Water displaces much of the air in the pore spaces of the composting materials when the moisture content is above 65%. This limits air movement and leads to anaerobic conditions. Moisture content generally decreases as composting proceeds; therefore, you may need to add additional water to the compost. As a rule of thumb, the materials are too wet if water can be squeezed out of a handful and too dry if the handful does not feel moist to the touch.



Moisture content Vs Days for compost using Bioconsortia

In this case, we can see that initially the moisture content is high, it is basically due to the presence of high amount of kitchen and food waste in the sample collected for the composting process. Here, we can see that the moisture content increases above the desirable limit of moisture but it causes no effect on the reactions taking place other than bringing in swings in temperature thereby reducing the availability of Oxygen. But temperature has not shown any varying tendencies. So, the moisture content has not affected the microbial activities during these days and after that period, the moisture content has come down well within the desirable limit of 40 -65%. The result indicates that the composting process is moving along well along the expected manner.

4.1.2 pH

The protocol of analysis utilized for finding out pH is IS 3025(pt-11)-1983.

Any matter breaking down will have an initial drop in the pH followed by an increase in the pH levels to alkaline pH ranges. As the treatment process move forward, due to reduced production and increased evaporation of NH_3 followed by a subsequent release of Hydrogen ions, the pH values drops again at the end of the treatment phase. The desired limit of pH in compost is usually in a range of 6.5 – 8.5.

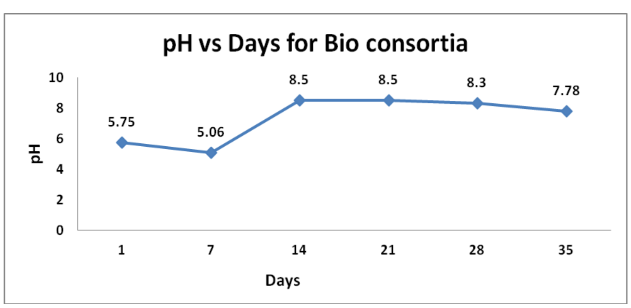


Fig. 4.4 pH Vs Days for compost using Bioconsortia

Here, the initial drop and late rise of the compost pH is shown in the above figure, it may be due to the initial microbial degradation of food waste leading to the production of organic acids thereby causing the pH to decrease, this would have been followed by the oxic microbes utilizing a lot of Oxygen available in the system thereby resulting in insufficient oxygen presence causing anoxic fermentation causing a drop in the pH. This is also followed by the decomposition of Nitrogen containing organic matter leading to the accumulation of NH_3 that dissolves in the moisture present to form alkaline NH^{4+}. Later, the reaction causing the intermediate organic acids formed to breakdown to give gaseous Carbon Dioxide and water. This followed by decomposition off fatty acids to fat and further into smaller molecular acids which evaporate. All the above phenomenon helps increase compost pH.

Here, pH reaches a maximum of 8.5 from the acidic pH value of 5.75 which again drops to 5.06 and then decreases to reach a value of 7.78. This may be due to the reduced production and increased evaporation of NH_3 at the end of the composting period. A slightly alkaline to neutral pH indicates that the end product is mature compost.

4.1.3 Chemical Oxygen Demand

The protocol of analysis utilized for finding out COD is IS 3025(Pt-58)-2006.

Determination of Chemical Oxygen Demand is the method designed to determine the amount of decomposable, i.e., oxidizable, material in a representative sample of solid wastes. The measure of decomposability can also be determined from the concentration of oxidizable matter in the sample.

The rationale for the test is that the difference between the concentrations of decomposable material in the raw waste and that in the sample to be tested is indicative of the degree of stability of the latter. The basic procedure involved in the test is the determination of amount of oxidizing reagent used in the analysis. Because stability in composting is a matter of extent of oxidation, the amount of oxidizable material in a product is a measure of its degree of stability.

The basis for oxidation-reduction potential as a test for maturity of the compost is the apparent rise in oxidation-reduction potential that accompanies increase in mineralization of the organic matter. The increase is brought about by microbial activity made possible by the presence of decomposable material. The presence of decomposable material results in an intensification of microbial activity and, hence, an accompanying increase in oxygen uptake; which, in turn, leads to a drop in the oxidation-reduction potential. An important shortcoming of the oxidation-reduction potential is the test's lack of accuracy and its vulnerability to interfering factors. COD is often preferred for daily analysis since it is inherently more reproducible, accounts for changing conditions and takes a short time to complete.

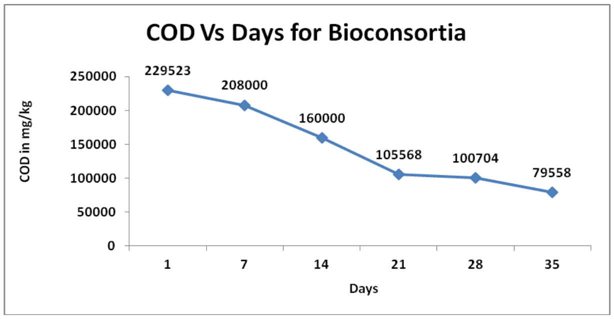


Fig. 4.5 COD Vs Days for compost using Bioconsortia

Here, COD, has reduced from 229523 mg/kg to 79523mg/kg after a slow oxidation period from 21 to 28 days which may indicate the reduced microbial activity and the compost achieving maturity during the period from 28 to 35 days. The aerobic composting using the microbial consortia has shown excellent oxidizing effects for the decomposable materials with a reduction in COD by 65.38%.

4.1.4 Total Nitrogen

The protocol of analysis utilized for finding out N is IS 3025(Pt-34)-1988.

Variations of the Total Nitrogen for the aerobic compost inoculated with the microbial consortium is listed in the figure. The initial content is 11218 mg/kg which has gradually increased to 13555.46 mg/kg after 35 days which is shows an increase of Total Nitrogen by 21%, so the compost could be utilized as a soil amendment.

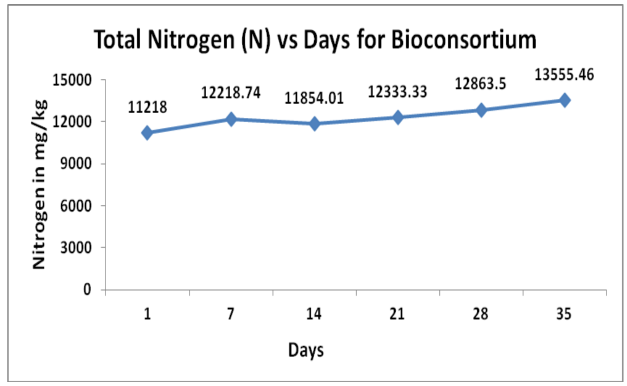


Fig. 4.6 Total Nitrogen Vs Days for compost using Bioconsortia

The increase may be caused by the concentration effect on N due to higher losing rate of carbon. When the organic carbon in the compost is decomposed into CH_4 or CO_2 , an inference could be made out that carbon has a higher losing rate when compared to N thereby resulting in an increase of Nitrogen in the compost. This is also a governing reason for reduction of C/N ratio as it gains maturity.

4.1.5 Total Phosphorus

The protocol of analysis utilized for finding out P is APHA 4500 –D

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Variations of Total Phosphorus for the aerobic compost inoculated with the microbial consortium is listed in the figure below.

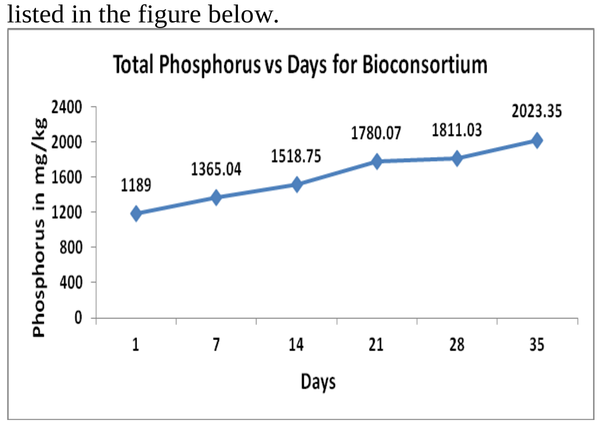


Fig. 4.7 Total phosphorus Vs Days for compost using Bioconsortia

The value of Phosphorus in the form of phosphate has increased from 1189 mg/kg to 2023.35mg/kg showing an increase by 70.17% after a period of 35 days which shows that the compost would be good enough as a soil amendment.

4.1.6 Potassium

The protocol of analysis utilized for finding out K is IS 3025 (Pt-45) – 1993

Variations of Potassium for the aerobic compost inoculated with the microbial consortium is listed in the figure 4.8.

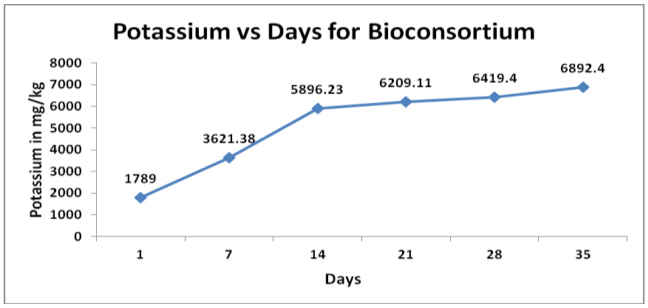


Fig. 4.7 Potassium Vs Days for compost using Bioconsortia

The value of Potassium has shown marked improvement from 1789 mg/kg to 6892.4 mg/kg after 35 days making sure that the compost produced would be a good enough soil amendment or fertilizer.

4.1.7 C/N ratio

Carbon (C), nitrogen (N), phosphorous (P), and potassium(K) are the primary nutrients required by the microorganisms involved in composting. Microorganisms use carbon for both energy and growth, while nitrogen is essential for protein production and reproduction. The ratio of carbon to nitrogen is referred to as the C:N ratio. An appropriate C:N ratio usually ensures that the other required nutrients are present in adequate amounts.

Raw materials blended to provide a C:N ratio of 25:1 to 30:1are ideal for active composting, although initial C:N ratios from 20:1 up to 40:1 consistently give good composting results. For C:N ratios below 20:1, the available carbon is fully utilized without stabilizing all of the nitrogen which can lead to the production of excess ammonia and unpleasant odors. For C:N ratios above 40:1, not enough N is available for the growth of microorganisms and the composting process slows dramatically.

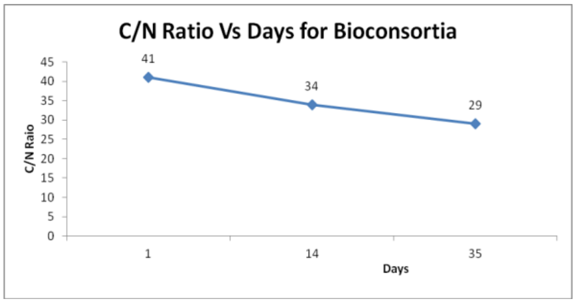
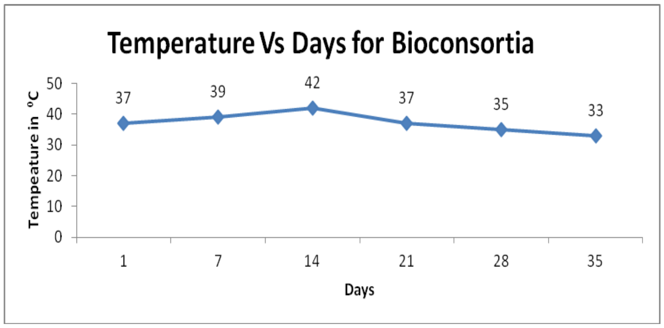


Fig. 4.8 C:N ratio Vs Days for compost using Bioconsortia

Here, we can see that the C/N ratio initially is 41 which get reduced to 29 at the end of 35 days. The preferred range of C/N ratio for a good compost is 25 - 30. Hence, the final product could be utilized as a good compost.

4.1.8 Temperature

Composting will essentially take place within two temperature ranges known as mesophilic (10 – 40 ^{0}C) and thermophilic (over 40 ^{0}C). Although mesophilic temperatures allow effective composting, experts suggest maintaining temperatures between 43^{0}C and 65^{0}C . The thermophilic temperatures are desirable because they destroy more pathogens, weed seeds and fly larvae in the composting materials. If the temperature of your compost pile is in the mesophilic range, try mixing the pile. If the temperature still does not reach the thermophilic range, review the factors described above to determine whether one or more of the factors is limiting the composting process. If you are still unable to increase the compost's temperature, the active stage of composting maybe complete.



Here , the temperature goes to the thermophilic range around the 14th day, but slowly gets back to the mesophilic range and stays that way especially towards the 28th and 35th days. Hence, the active stage of composting may be complete for the composting.

Fig. 4.9 Temperature Vs Days for compost using Bioconsortia

5.1 Moisture Content

The most important requirement of earthworms is perhaps adequate moisture. The feed stock should not be too wet ,otherwise it may create anaerobic conditions which may be fatal to earthworms, the bedding used must be able to hold sufficient moisture if the worms are to have a livable environment. They breathe through their skins and moisture content in the bedding of less than 50% is dangerous. With the exception of extreme heat or cold, nothing will kill worms faster than a lack of adequate moisture. The ideal moisture content range for materials in conventional composting systems is 45-60%. In contrast, the ideal moisture-content range for vermicomposting or vermiculture processes is 60-70% range.

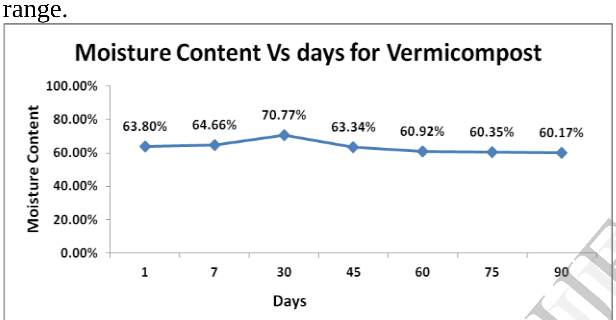


Fig. 4.1 Moisture Content Vs Days for compost using vermicomposting

Here, the moisture content mostly varies between the ideal range of 60 -70%, only a slight increase been seen on the 30^{th} day which may not be fatal enough to the activity of the worms as the earthworms utilized are Eisenia foetida which can acclimatize fast enough against variations in the environment around them. Since, the moisture content remains in the desirable limit, temperature would not have any effect and from the graph, we can also infer that the process is moving forward in the proper range of moisture content.

4.2 pH.

Worms can survive in a pH range of 5 to 9, but a range of 7.5 to 8.0 is considered to bethe optimum. In general, the pH of worm beds tends to drop over time due to the fragmentation of organic matter under series of chemical reactions. Thus, if the food sources are alkaline, the effect is a moderating one, tending to neutral or slightly acidic, and if acidic pH of the beds can drop well below 7. In such acidic conditions, pests like mites may become abundant.

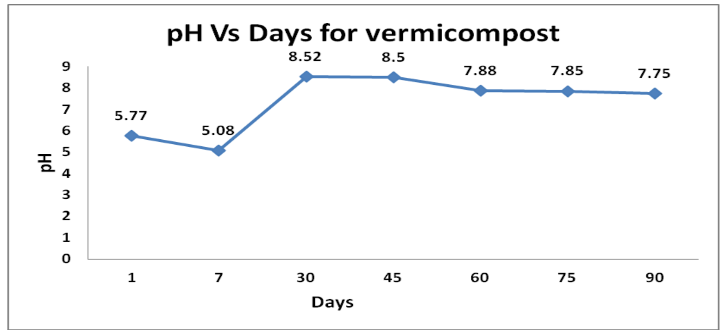


Fig. 5.2 pH Vs Days for compost using vermicomposting

The vermicompost shows a swing in pH from the acidic range at 5.77 to further drop to 5.08 and then increase upto 8.52 from where it slowly got reduced to 7.75 which is neutral to slightly alkaline pH. Hence, we can tell that the worms can clearly withstand the pH variation and the process is proceeding in the proper pH range to give a good matured compost

5.3 Chemical Oxygen Demand

Determination of Chemical Oxygen Demand is the method designed to determine the amount of decomposable, i.e., oxidizable, material in a representative sample of solid wastes. The measure of decomposability can also be determined from the concentration of oxidizable matter in the sample available to the worms to act upon break it down using various enzymatic activities.

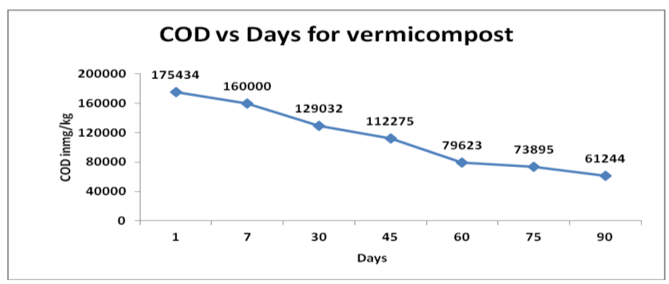


Fig. 4.12 COD Vs Days for compost using vermicomposting

Here, COD, has reduced from 175434 mg/kg to 61244 mg/kg after a slow oxidation period from 60 to 75 days which may indicate a reduction in activity of the worms or the compost achieving maturity during the period of 75 to 90 days. The vermicompost has shown excellent reducing capabilities of the decomposable materials with a reduction in COD by 65.1%.

4.2.4 Total Nitrogen

Variations of the Total Nitrogen for the vermicompost is listed in the figure. The initial content is 11511mg/kg which has gradually increased to 15114.78 mg/kg after 90 days which is shows an increase of Total Nitrogen by 31%, so the compost could be utilized as a soil amendment.

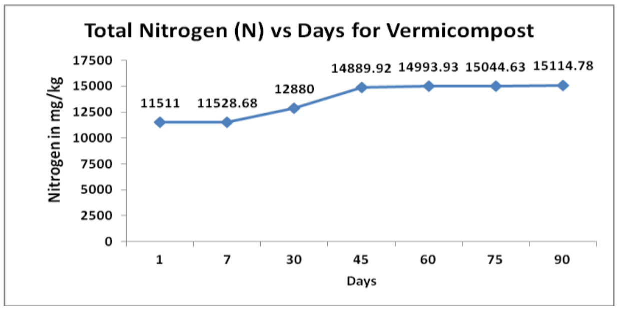


Fig. 4.13 Nitorgen Vs Days for compost using vermicomposting

Nitrogen is an important constituent of any fertilizer or organic manure as plants abasorbs nitrogen mainly in the form of nitrate (NO_3) or (NH^{4+}). The raw material would contain large amounts of nitrogenous compounds but they may not be in the available form. The earthworms convert the nitrogenous compounds into the absorbable form. As the days of activity increases, the quantity of nitrogen increases slowly but steadily. The earthworms would secrete a variety of digestive enzymes from there gut such as amylase, chitinase, cellulose, protease etc that would help in the digestion of complex form into simpler form thereby making it available to the plants when used as a soil amendment.

4.2.5 Total Phosphorus

The value of Phosphorus in the form of phosphate has increased from 1298 mg/kg to 2341.92 mg/kg showing an increase by 80.43% after a period of 90 days so that the final compost produced would be a good enough soil amendment or fertilizer.

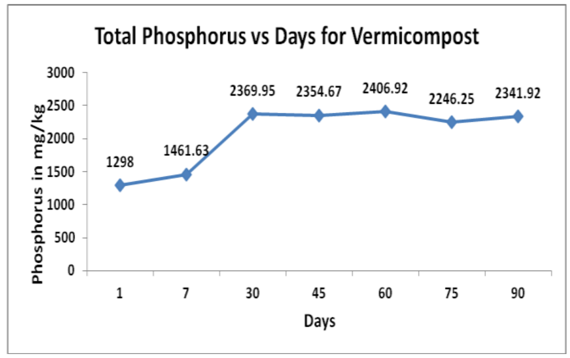


Fig. 4.14 Phosphorus Vs Days for compost using vermicomposting

Phosphorus is present in all living cells and is a constituent of cell nucleus. It is essential for cell division and for development various tissues during the growth phase. Phosphorus helps the root system of plants and encourages the formation of lateral and fibrous root which increase the absorbing effect of nutrients. The growth of plants would be affected if the soil has poor phosphorus content. Availability at root zone is high when the compost is slightly basic in nature. Here, the pH range is slightly basic and hence, it would not be a problem.

4.2.6 Potassium

Variations of values are as shown in figure below. The value of Potassium has shown marked improvement from 1780 mg/kg to 6897.88 mg/kg after 90 days making sure that the compost produced would be a good enough soil amendment or fertilizer.

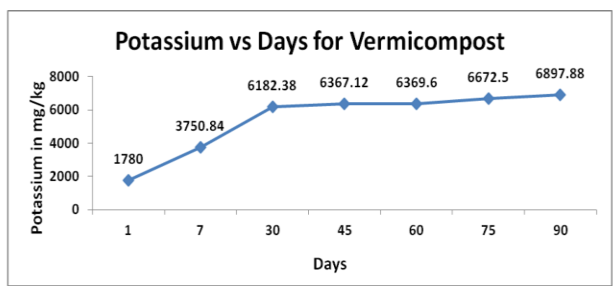


Fig. 4.15 Potassium Vs Days for compost using vermicomposting

Potassium is an essential element for both plants and animals and as a result occurs in the form of mineral dissolution from decomposing plant material, agricultural runoff. As the number of treatment period increases, the dissolution of potassium also increases and as a result, the quantity of Potassium too.
Potassium helps in storage of carbohydrates and proteinds, increases mobility of ions of Ca,, Mg, Fe etc

and also activates the number of amino acid activating enzymes and thus helps in synthesis of amino acid and several other enzymes concerned with carbohydrate and nucleic acid metabolism.

4.2.7 C/N ratio

When the material with higher carbon content is used with C: N ratio exceeding 40: 1, it is advisable to add nitrogen supplements to ensure effective decomposition. The food should be added only as a limited layer as an excess of the waste many generate heat. From the waste ingested by the worms, 5-10% are being assimilated in their body and the rest are being excreted in the form of vermicast.

Raw materials blended to provide a C:N ratio of 25:1 to 30:1are ideal for active vermicomposting, although initial C:N ratios from 20:1 up to 40:1 consistently give good composting results. For C:N ratios below 20:1, the available carbon is fully utilized without stabilizing all of the nitrogen which can lead to the production of excess ammonia and unpleasant odors. For C:N ratios above 40:1, not enough N is available for the growth of microorganisms and the composting process slows dramatically.

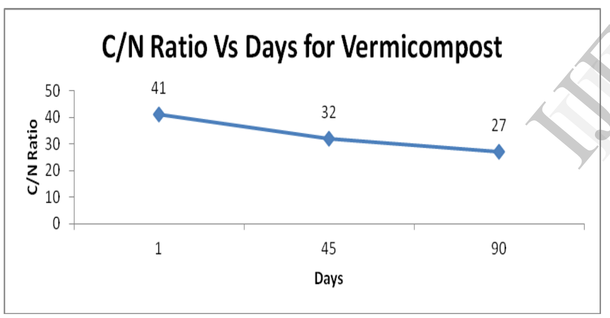


Fig. 4.16 C/N Ratio Vs Days for compost using vermicomposting

Here, we can see that the C/N ratio initially is 41 which get reduced to 27 at the end of 90 days. The preferred range of C/N ratio for a good compost is 25 - 30. Hence, the final product could be utilized as a good compost.

4.2.8 Temperature

The activity, metabolism, growth, respiration and reproduction of earthworms are greatly influenced by temperature. Most earthworm species used in vermicomposting require moderate temperatures from 10 – 35^{0} C. While tolerances and preferences vary from species to species. Earthworms can tolerate cold and moist conditions far better than hot and dry conditions. For *Eisenia foetida* temperatures above 10^{0}C (minimum) and preferably 15^{0}C be maintained for maximizing vermicomposting efficiency and above 15^{0}C (minimum) and preferably 20^{0}C for vermiculture. Higher temperatures (> 35^{0} C) may result in high mortality. Worms will redistribute themselves within piles, beds or windrows such that they get favorable temperatures in the bed.

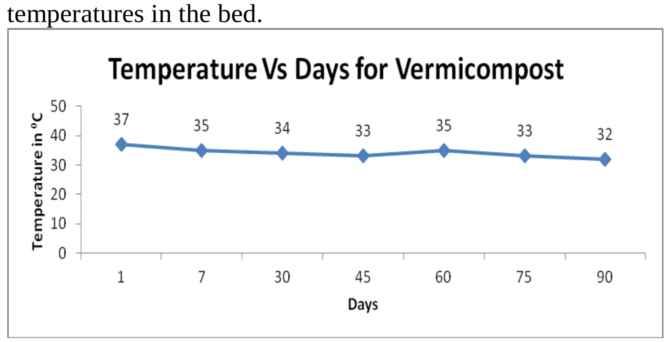


Fig. 4.17 Temperature Vs Days for compost using vermicomposting

Here, we can see that the temperature range is higher only during the initial period when the initial heat of degradation was higher and is in the process of moving in a downward trend. The temperature mostly hovers in the upper range of the desirable temperature range. Even though the temperature is higher, the species of earthworm used are actually good at acclimatizing with the climatic conditions. The mortality rate was less and so were the reactions taking place as was evident from the values of other parameters.

5.CONCLUSIONS

Main objective of the project included the characterization and study of the wastes generated in the study area. From, the random samplings done, we could get an idea that the main constituent in the waste was the biodegradable fraction which included the kitchen and market wastes like raw fruits, vegetables, leaves etc. , paper, card board etc. The non – biodegradable fraction included the glass, tin cans, plastics etc. thereby making it ideal for utilizing for composting or vermicomposting rather than the land spreading utilized in the dumpyard as of now.

The comparison of results showed that the microbial consortium offered a faster medium of treatment or recycling when compared to vermicomposting where results were obtained in a span of 35 days while vermicomposting took 90 days for the process to complete. The other highlight of the utilization of bio consortium was the volume reduction, while the consortia offered a volume reduction of 91% as opposed to 85% offered by vermicomposting. The weight reduction offered by the utilization of the the consortium was 88% as opposed to 68% offered by the method of vermicomposting.

The Nitrogen available was 0.41% for the aerobic composting aided by microbial consortia when compared to 1.2% offered by vermicomposting, as the minimum standards by Council of Agriculture for a good compost put Nitrogen content in a compost as 0.6%. The Phosphate available for the aerobic composting aided by microbial consortia was 0.61% as opposed to 1.8% offered by vermicomposting as the minimum standards by Council of Agriculture puts Phosphate content as 0.3%. The Potassium content available was 0.22% for the composting aided by microbial consortia as opposed to 0.51% obtained by vermicomposting, as the minimum standards by Council of Agriculture puts Potassium content as 0.3%. The C/N ratio of the final product after treatment using microbial consortia was obtained as 29 as opposed to 27 obtained from vermicomposting. The Council of Agriculture puts the standards for C/N ratio as 25 – 30.

Eventhough the values for N, P, K and C/N ratio obtained using bioconsortia is lower when compared to vermicomposting, it could be still used as a good soil amendment considering that, the consortium is utilized for waste water treatment.

Other advantage of the bioconsortia is that the variations in control parameters like pH, temperature, moisture content could be compromised as the consortia might have different types of bacteria, fungi or other microbes which could acclimatize and take the process forward without any big variations in the result. This is in opposition to that of vermicomposting where the variations in pH, temperature and moisture content may be harmful or inhibitory to the worms utilized for the vermi composting process.

Other advantage of the microbial solution is that it is not necessary to take extra precautions against pest, insects and rodent control at site as the microbes are not affected by any of these problems while in vermicomposting we have to be extra careful ants, pests and insects such as soldier flies, rodents etc could result in the mortality of the worms used thereby making the process a failure which is always present when the vermicomposting is done on a large scale for MSW.

Microbial solution needs to be sprayed over the layers of the MSW without any preparation of bedding. The rolling over of the waste for effective oxygenation and prevention of anaerobic conditions could be done manually or mechanically, while for vermicomposting, bedding layer is to prepared before laying the waste over and for the reduction of initial heat of decomposition from the bedding materials, wastes could not be added for 15 -20 days. But , wastes could then be added continuously taking care of the parameters and health of the earthworms added for composting.

Cost of utilization of microbial solution may be compared to vermicomposting as 100 earthworms cost 70 rupees while it requires nearly 500 – 600 earthworms for efficient treatment along with the manual labour, masonry or trench preperations for composting, monitoring equipments considering per tonne of MSW in a large scale. Microbial solution required cost 35 rupees per litre and one litre is estimated to be enough to treat 1 tonne of MSW. But while doing large scale treatment, the utilization of manual labour, monitoring equipments, spraying nozzles and other equipment such as front end loader in case mechanical turning being used.

Other advantage is the marketability of the product as the final product from the treatment process could be sold as garden manure at a rate of 5 – 6 Rs./kg when compared to the 7 – 8 Rs./kg gained from vermicomposting.

These make the microbial solution a viable, speedy and advantageous option when compared to vermicomposting and could be utilized for large scale operations by municipalities, private agencies who go for open dumping, land filling or any other mode of final disposal.

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