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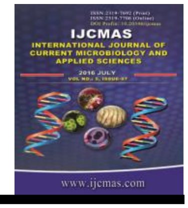

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Solid Waste Management using Effective Microorganism (EM) Technology

Smitha Mathews* and R. Gowrilekshmi

Department of Zoology, Assumption College, Chanaganacherry, Kottayam, Kerala, India
**Corresponding author*

A B S T R A C T

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EM or Effective Microorganisms is a microbial inoculant containing many kinds of naturally occurring beneficial microbes. Maple EM-1(Expired and Non-Expired) is activated using ricewater and jaggery separately. Fruit and vegetable wastes were collected and inoculated with Activated Non expired Jaggery EM, Activated Non expired Rice water EM, Activated Expired Jaggery EM and Activated Expired Rice water EM respectively. The physical (Odour, Appearance and Colour) chemical (pH, Salinity, Conductivity, TDS, DO, BOD and Temperature) and biological (Population of Coliforms including *E.coli*, Lactobacillus population, Yeast population and Actinomyces population) parameters of leachate from each sample are examined at an interval of 7 days. There was a generation of alcohol and vinegar like smell in the due process other than non offensive smell. Chemical parameters such as pH, TDS (Total Dissolved Solids) and BOD shows a declining trend. An increase in Salinity, conductivity and Dissolved Oxygen (DO) was also observed. While analysing the biological parameters a steady decrease in Non EM organisms are seen. Lactobacillus, Actinomyces and yeast populations almost doubled within 14 days compared to control .It can be concluded that jaggery is the best activator of Maple EM-compost a method of waste disposal at a low cost.

Introduction

The reduction and recycling of solid wastes has become a main problem in the present day life of each and every one. Improper waste management facilities and treatments leads to acute environmental problems, serious health issues, visual discomfort, putrefying odour etc and these waste piles becomes a breeding site for vectors. Solid wastes also result in Air pollution, Water pollution and Soil pollution. The current composting techniques were initially employed as a contingency plan to alleviate the problems associated with waste reduction at the sources and land filling. It is, therefore, necessary to establish and develop an efficient collection and composting system for the fruit and vegetable wastes that allows solution of problems coped with collection (offensive smell and sanitation) and production of quality composts.

Effective Microorganism

EM technology for production of good quality compost. Developed by Dr.

TeuroHiga, Professor of Horticulture in Okinawa , Japan in 1968. EM is regarded as mixed liquid culture of microorganisms that "work together with the beneficial in the area to which it is added, creating a synergy among microorganisms and larger forms of life". Main species of EM microorganisms : Lactic acid bacteria - *Lactobacillus plantarum, L. Casei, Streptococcus lactis,* Photosynthetic bacteria, *Rhodopseudomonas palustrus, Rhodobacters paeroides,* Yeasts - *Saccharomyces cervisiae, Candida utilis,* Actinomyces - *Streptomyces albur, S. griseus,* Fermenting fungi – *Aspergillus oryzae, Mucor hiemalis*

EM prevents putrefaction, decrease pH, suppress *Fusarium* propagation, inhibits soil-borne pathogens, fix and utilize CO_2 and H_2S generated, promotes active cell and root division etc. EM enhance anti-oxidation capability in soil, widely used in organic farming which increases yield and quality of crops without large investment of money and labour. Recycling of municipal liquid waste using EM Technology for domestic use is found effective. EM treatments @ 0.1% were given to 5 samples, one municipal liquid waste, 4 different local industries for four days. The treated samples were analysed for odour, turbidity, pH, EC, BOD, COD heavy metals concentrations, TDS & TSS. These parameters were reduced with EM treatment. It is reported that EM has the potential to deoxidize the heavy metals and convert it into organo-metallic compounds, which are not harmful for human animal health (Hussain, 2001).

Effective microorganism were used in treating food wastes by fermentation and subsequent production of compost from them. It reveals that the use of EM reduced the offensive odour of fermenting garbage within 4 days. The development of esters and alcohol in the process of fermentation was evident in two days. The development of Lactic acid bacteria observed, along with the increase in acidity of the leachate. These parameters were used as indicators of fermentation. In addition to this the pH, salinity and microbial populations in the compost were monitored Thus addition of the compost increased soil properties which could promote crop growth (Sung Cheol Koh, Young-ChaeSong, In-Soo Kim, 2010).

Materials and Methods

Effective Microorganisms

Effective microorganism (EM) used in this study was supplied by Consolidated Agri Tech CO. (Calicut) as Maple EM 1 (Environment – Solid waste Management). EM solution is a brownish liquid with a pleasant odour and sweet sour taste with a pH of 3 and stored in cool place without refrigeration before activation.

Activating the Effective Microorganisms

EM is available in a dormant state and requires activation before application. Activation involves either the use of Jaggery or rice water. Here, both Jaggery and rice water is being used to activate expired and non-expired EM in order to take a comparison among them.

Fruit and vegetable wastes decomposition by AEM

Sample collection - Fruit and vegetable wastes (Banana, orange, apple, cauliflower, carrot, brinjal etc.) were collected from retail fruit and vegetable outlets and brought to home immediately before indigenous decomposition.

Setting up the system – It starts by labelling 5 bucket as Control, NJC, NRC, EJC and

ERC. Little AEM is sprinkled to the bottom of each bucket except control. The layering process starts initially with soil, saw dust, decayed leaves followed by fruits and vegetable wastes respectively in all the buckets. Coat each bucket with AEM on top except in control. The lid was closed for further examination. If the material is still moist, it must be turned over. During each subsequent turning, an additional AEM must be injected to each compost in order to avoid smell pollution and to "reboot" the anaerobic fermentation. Drain the liquid frequently from each buckets.

Location of Buckets – The buckets should be keep out of direct sunlight and warm situation is the best.

Decomposition studies – Every 7 days interval the samples from each buckets were analysed for microbial population of respective EM and Non EM members through serial dilution, MPN for detecting coliforms and *E.coli*. Also physical and chemical indicators for monitoring fermentation such as smell, colour, temperature, pH, mV, Salinity, Conductivity, TDS and DO were tested using Systronics Water Analyzer 371.

Analysis of decomposition process

Initial microbial count were taken before application of EM. The physical and chemical parameters were detected before the application of AEM. The same procedures were repeated during every 7 seven days of interval.

Measurement of physical parameters

Smell

Two categories such as non-offensive smell (esters, alcohol etc) and offensive smell (ammonia, H_2S etc) and detected using olfactory judgement.

Colour change and Appearance: Detected through visual observation.

Measurement of chemical parameters

Temperature, pH, Salinity, mV, Dissolved oxygen (DO), Conductivity and TDS (Total Dissolved Solids) is measured by taking each samples in separate beakers (60-70 ml each) and analysed using Systronics Water Analyser 371.

Measurement of biological parameters

Detection of coliforms and *E.coli:* Analysed using Multiple Tube Fermentation technique.

The positive tubes are then streaked on EMB plates to confirm the presence of coliforms.

Detection and Analysis of Lactobacillus: It is analysed through spread/pour plate method in MRS medium.

Detection of EM and Non EM members : It is done by carrying out serial dilutions and subsequent plating onNutrient Agar (NA) and Potato Dextrose Agar (PDA).

Results and Discussions

Evaluation of physical properties

During the first 28 days of decomposition process each of the sample contained in 5 different buckets are analysed for determining the physical properties.

a.Odour : The results based on olfactory judgement showed that the C sample within 7 days developed strong offensive smell (ammonia and hydrogen sulphide) which were consistently detected throughout the decomposition process. This may be due to the presence of less number of Lactic acid bacteria in the Control(C) sample. At the same time a little of non-offensive smells (esters and alcohol) were detected in the EM treated samples throughout the process except in NRC (Non expired Rice Compost) sample which started to produce an offensive smell after 14 days of decomposition and continued throughout. This appeared to result from a reduced number of Lactic acid bacteria in the sample leading to putrefaction producing hydrogen sulphide

b.Appearance : A white cotton like fungi growth (Actinomyces) is observed on the surface of EM treated sample within 7 days of process while no such growth is observed on C sample. Actinomyces growth indicates that good fermentation process has taken place. Later occurrence of black fungi on top of NRC sample is observed after 14 days of process. It indicates that contamination has occurred and process has followed a putrefaction pathway rather than fermentation pathway.

C sample also holds black fungi on the surface after 7 days of process indicating decomposition follows putrification pathway rather than fermentation process. Also bubbles are observed on the surface of C sample after 7 days indicating production of hydrogen sulphide. In course of time after 14 days of process in NRC, bubbles are observed indicating H2S production - shift from fermentation to putrification pathway.

c. Colours: The colour of EM treated samples gradually changes to pale green then to light brown as the process continues while the C sample shows black colour in course of time. After 14 days of process the NRC sample showed a change in colour from pale green to light black colour indicating a change in fermentation pathway.

Evaluation of Chemical parameters

During the first 28 days of decomposition, each of the 5 samples are analysed to determine its chemical parameters.

Changes in pH and salinity of samples

pH of NJC,EJC and ERC shows a shift from initial condition towards more acidic condition by producing organic acids and which enhances the fertility of the soil by bringing the pH down. Also lactic acid produced by Lactobacillus contributed to the acidic pH. The initial drop in pH reflects the synthesis of organic acids, which serve as substrates for succeeding microbial populations. The subsequent rise reflects the utilization of the organic acids by microorganisms. An exception is seen in NRC Sample where there is a fluctuation in pH values are observed which indicates the succession of putrification pathway rather than fermentation.

Salinity increase in the EM treated samples than control appeared to be related to the effective production of leachate by EM organism. The destruction of tissues in waste was obviously observed in the EM treated samples while little structural changes were observed in Control. The destruction of tissues might be ascribed to the functions of EM organism (particularly, filamentous fungi and yeast) in the wastes whose major component were fruits and vegetables.

EM compost can be used in areas were constant salt removal takes place. All samples including control shows a favourable salinity within 5ds/m except in NJC which shows an increasing trend. So sample treated with Jaggery Activated EM as per salinity norms are not suitable for application on plants after 14th day of decomposition process. On the other hand the sample treated with Rice water Activated EM decreases the salinity of leachate making it suitable for application on plants after 21st Day of decomposition process.

Sample	Zeroth Day	7th Day	14th Day	21st Day	28th Day
Control	- No specific smell - No colour change	• Offensive smell • Presence of bubbles and black fungi on surface • Light brown colour	• Offensive smell • Increased presence of bubbles and black fungi on surface • Brown colour	• Offensive smell continues • Bubbles and black fungi on surface • Black colour • Rotting appearance	• Offensive smell continues • Appears in rotten form which looks sticky and black in colour
NJC	- No specific smell - No colour change	• Non offensive smell • Actinomyces growth on surface • Pale green colour • Leachate formed	• Non offensive smell • Actinomyces growth on surface • Brown colour with rotting appearance	• Non offensive smell • Rotting continues • Brown leachate	• Non offensive smell • Black leachate formed • White coloured spots in sample
NRC	- No specific smell - No colour change	• Non offensive smell • Actinomyces growth on surface • Pale green colour • Leachate formed	• Offensive smell • Presence of bubbles and black fungi on surface • Brown colour	• Offensive smell • Bubbles and black fungi continues on surface • Sticky black paste like appearance	• Offensive smell • Black leachate formed • Mycelial growth appears
EJC	- No specific smell - No colour change	• Non offensive smell • Actinomyces growth on surface • Pale green colour • Leachate formed	• Non offensive smell • Actinomyces growth on surface • Brown colour with rotting appearance	• Non offensive smell • Rotting continues • Occurrence of white spots • Dark brown leachate	• Non offensive smell • White mycelial growth • Turbid • Light black leachate
ERC	- No specific smell - No colour change	• Non offensive smell • Actinomyces growth • Pale green colour	• Non offensive smell • Actinomyces growth • Brown colour with rotting appearance	• Non offensive smell • White mycelial growth • Dark brown leachate • Rotting continues	• Non offensive smell • Light black leachate • White mycelial growth • Turbid

Change in conductivity and TDS among samples within 28 days

EC of specific composting treatments was found to be increasing because of EM inoculation which releases mineral salts such as phosphates and ammonium ions through the decomposition of wastes. A huge increase of conductivity was found in NJC, EJC and NRC applied samples. It indicates high concentration of better nutrients in those samples. As conductivity increases turbidity decreases, indicating better degradation of organic matter and release of better nutrients. Jaggery AEM attains the higher conductivity than other samples.

TDS represents the Total Dissolved Solids, which dissolves easily in the early stages of decomposition process. The initial rise maybe due to slow decomposition of organic matter by available microorganism and the subsequent decrease may be due to fast breakdown of organic matter by the organisms present releasing the nutrients.

High rate of nutrients in compost indicate that it belongs to good quality class. It is clear from the graph that EM inoculated samples reduce TDS at a faster rate than in control sample. Rice water AEM shows a decline in TDS on 14^{th} Day of application but after that a steady increase in TDS is seen in NRC while Jaggery AEM shows a steady ongoing decline in TDS from 14^{th} Day onwards.

Change in Dissolved Oxygen (DO).

DO increases as the time goes and at the end of 28^{th} day a minimum of 1.8 ppm increase is seen in each sample. Dissolved oxygen is necessary to minimize odour pollution and provide a much better indication of living conditions for microbes within actively composting materials. Oxygen produced by photosynthetic bacteria as a by-product of decomposition contributes to an increase in amount of DO at a faster rate in EM inoculated samples compared to the Control. Here NJC, EJC and ERC sample shows high amount of DO compared to other two samples. DO is higher in sample inoculated with Jaggery AEM than sample inoculated with Rice water AEM, indicating that the process occurs at a faster rate in sample inoculated by Jaggery AEM.

A subsequent decrease in BOD is seen within the samples in 28 days. As the biological organic content is diminished, BOD is decreased, resulting in decreased emission of carbon dioxide, ultimately indicating stabilization of the compost. Here, BOD decreases at a faster rate in EM inoculated samples indicating more degradation of organic matter. It can be observed that sample inoculated with Jaggery AEM shows a steady reduction in BOD on 14^{th} day of process than sample with Ricewater AEM.

Evaluation of Biological parameters

During the first 28 days of decomposition each of the EM inoculated samples and control were analysed for its biological parameters.

It is clear from the table that as the number of composting days increases a reduction in number of coliforms and *E.coli*were observed. This may be due a decrease in pH indicating acidic condition and reduction in BOD which causing deficiency in organic matter. Acceptable levels of Faecal coliform (includes *E. coli)* in finished compost is less than 1,000 Most Probable Number per gram of total solids on dry weight basis(Food waste Composting Regulations White paper California Integrated Waste Management Board October 2009).So it can be concluded that treating samples with EM reduces the number of coliforms at a faster rate than without EM.There was a decrease from initial $4.6x10^{6}$ cells/100 ml to $9x10^{2}$ cells/100ml within 7 days and from $9x10^{2}$ cells/100ml to less than 3 cells/100ml was observed within the next 7 days.So it is clear that almost 90% of coliforms (including *E.coli*) are removed by treating the samples with AEM.

Population dynamics of Lactobacillus and Non EM organisms

Population dynamics of Lactobacillus shows a great increase on EM treated samples than control . Lactobacillus by production of lactic acid decreases the offensive smell produced during fermentation process. Population of Lactobacillus almost doubled in the sample inoculated with Jaggery AEM compared to Rice water AEM at 21^{st} day and after that not a huge variation in population of Lactobacillus is seen indicating the initiation of death phase.

Population dynamics of Yeast and Actinomycets

There was an initial decrease and subsequent increase in microbial population in the EM inoculated sample than control. The sudden decrease in Non EM members may be due to the active growth of lactobacillus in the compost which uses most of the nutrients available producing lactic acid giving acidic nature to compost attributed as the killing of Non EM organisms by EM organisms. Also the organic acids produced by the fungus maybe harmful for the Non EM micro flora leading to the decrease in their population. It is clear that the population of Non-EM micro flora shows a declining trendupto 14^{th} Day of process. Also both Jaggery and Rice water AEM shows almost same effect in decreasing the number of Non EM micro flora.

Yeast (*Saccharomyces* spp) synthesizes anti-microbial and other useful bioactive substances such as hormones and enzymes, which are useful substrates for effective microorganisms. upto 14^{th} Day ,yeast population shows almost same growth in Rice water and Jaggery AEM but on approaching the 21^{st}Day,Ricewater AEM compost shows a declining trend and after that almost the rate of yeast growth becomes stable. Population dynamics of Actinomyces showed a profund increase in their numbers. This result seems reasonable since actinomycetes are common in EM sample and able to utilize a wider range of carbon sources and to sporulate prolifically due to their ubiquity. They prefer a mesophilic range of temperature which is maintained in the composting process. They slowly increase their number because of their capacity to degrade complex organic polymers.

In conclusion, the results regarding physical parameters indicated that, there was a generation of alcohol and vinegar like smell in the due process other than non offensive smell. This is due to the fermentation process by yeast cells and production of Lactic acids by Lactobacillus.

Also growth of Actinomyces on the surface of wastes were seen within 7 days, also a colour change from green to light black/brown are observed in the process. The chemical parameters such as pH, TDS (Total Dissolved Solids) and BOD shows a declining trend.

Fig.1 Changes in pH and salinity of samples within 28 Days

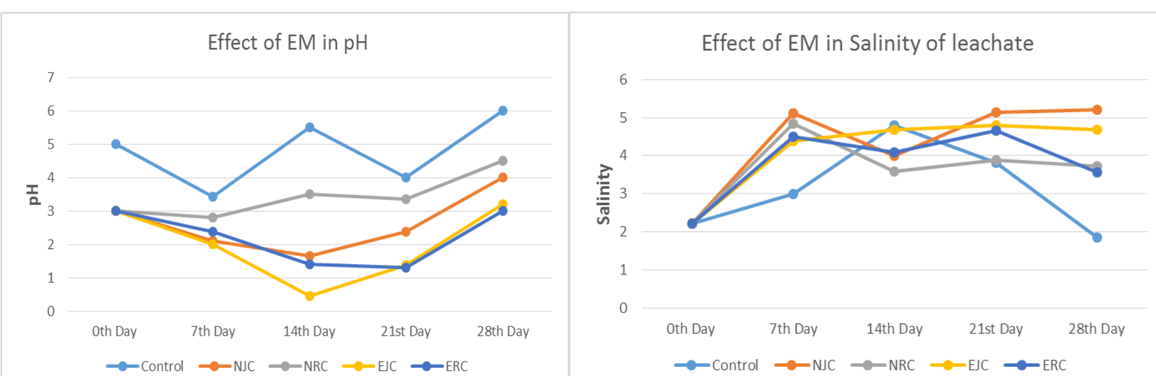


Fig.2 Changes in conductivity and TDS among samples within 28 day

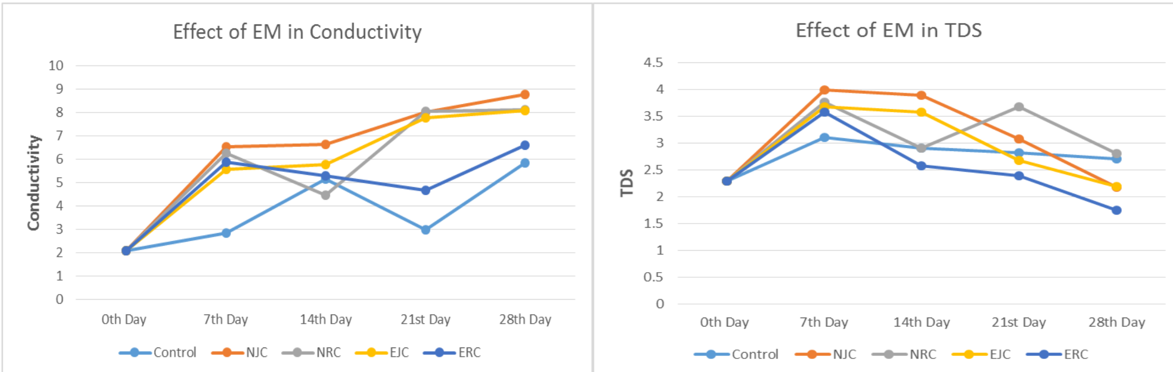


Fig.3 Changes in Dissolved Oxygen (DO) among samples within 28 days.

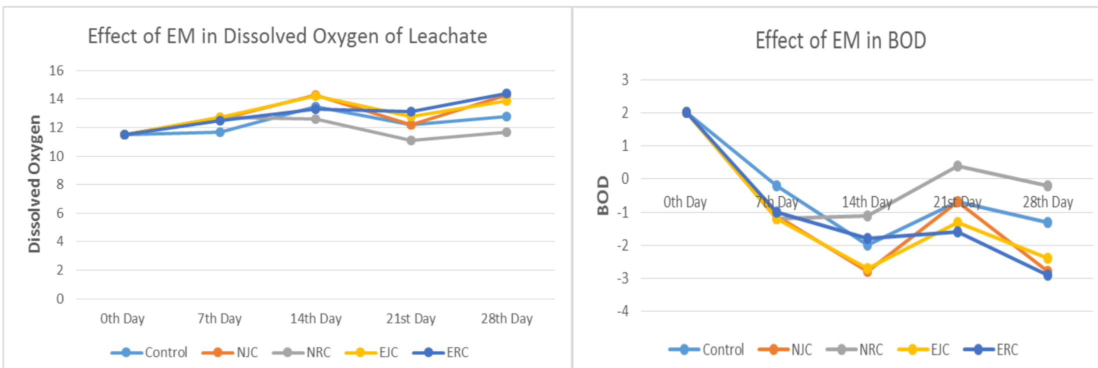


Fig.4 MPN result of Control on Zeroth Day – 4.6x106cells / 100ml

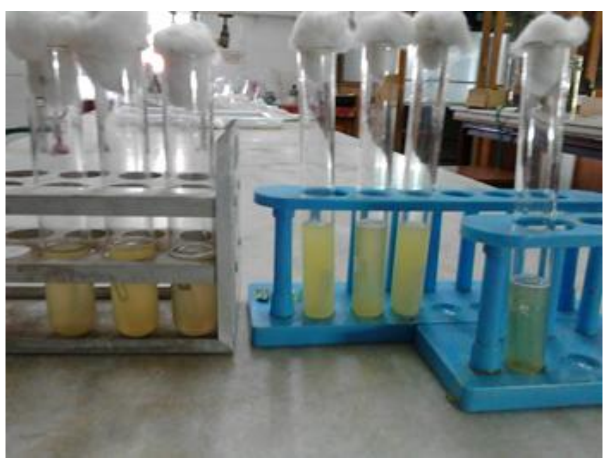


Fig.5 MPN result of Control on 7th Day -1.1x105cells/100 mlMPN result of EM inoculated sample on 7th Day -9x102cells/100ml

MPN/100 ml

Sample	0^{th} Day (Before application of EM)	7^{th} Day	14^{th} Day	21^{st} Day
Control	4.6×10^{6} cells/100ml E.coli + Coliforms present	1.1×10^{5} cells/ 100ml E.coli + coliforms present	1.1×10^{5} cells/100ml E.coli + coliforms present and Turbidity observed	Less than 3 cells/ 100ml
NJC		9×10^{2} cells/100ml Coliforms only No E.coli present	Less than 3 cells/ 100ml	Less than 3 cells/ 100ml
NRC		1.5×10^{4} cells/100ml E.coli + coliforms present	Less than 3 cells/ 100ml	Less than 3 cells/ 100ml
EJC		9×10^{2}cells/100ml Coliforms only No E.coli present	Less than 3 cells/ 100ml	Less than 3 cells/ 100ml
ERC		9×10^{2}cells/100ml Coliforms only No E.coli present	Less than 3 cells/ 100ml	Less than 3 cells/ 100ml

Fig.6 Population dynamics of Lactobacillus and Non EM organisms

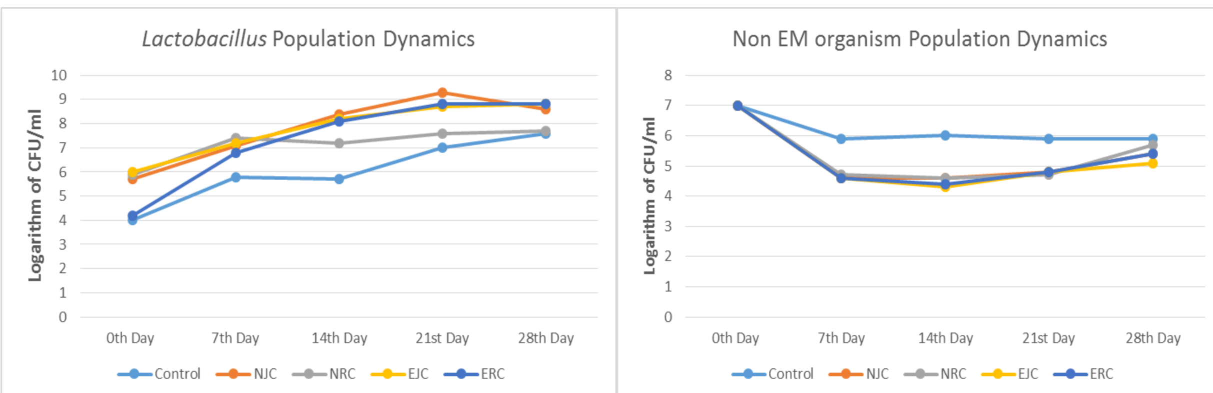
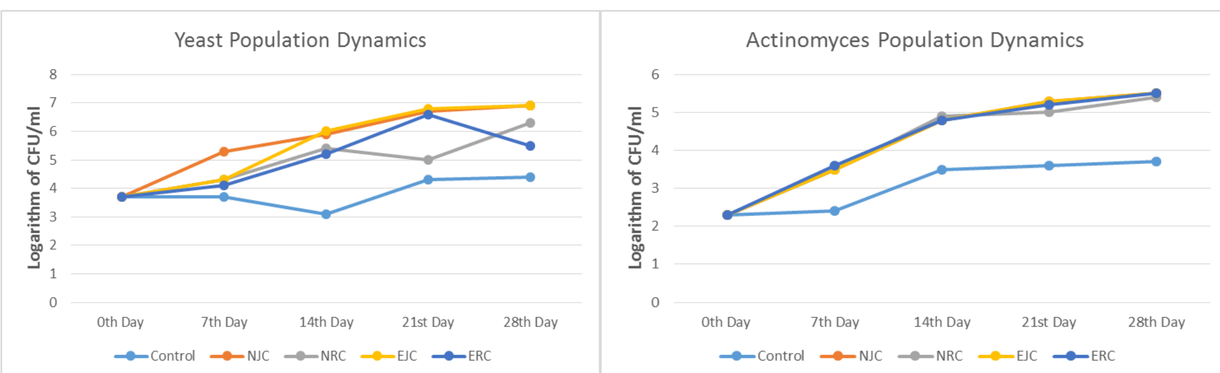
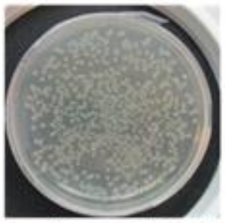


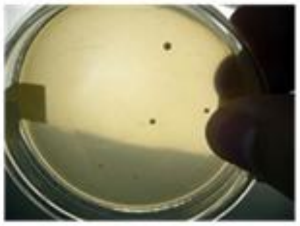
Fig.7 Population dynamics of Yeast and Actinomycets





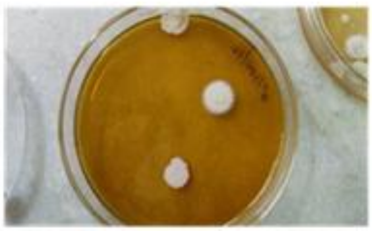
Non EM organism growth on Zeroth Day

Non EM organism growth on 14th Day



Yeast population on Zeroth Day

Yeast population on 28th Day



Actinomyces population on Zeroth Day

Zeroth Day

Control – 7th Day

EM inoculated – 7th day

Bokashi leachate

Control- 28th Day

EM inoculated – 28th Day

The reduction in pH is attributed to the production of organic acids which increases the fertility of compost while TDS and BOD reduction is due to decomposition of organic matter. Here an increasing trend in salinity of leachate is seen in Jaggery activated EM, but considerable decrease in salinity, suitable for application on plants is seen in samples inoculated with Rice water Activated EM. Conductivity (due to decrease in turbidity) and Dissolved Oxygen (due to the presence of photosynthetic bacteria) also shows an increasing trend .Increse in conductivity enhances the release of mineral salts and high DO gives minimum odour pollution and good living conditions for EM organisms.

A steady decrease in Non EM organisms are seen due to the killing effect of Non EM microflora by EM organisms. Lactobacillus, Actinomyces and yeast populations almost doubled within 14 days compared to control indicating the well growth of EM organisms leading to the formation of compost in due process. The results from MPN suggested that after inoculation of sample with AEM, the number of coliforms decreased to less than 3 cells/100ml which is proved beneficial. Almost all the parameters attained its peak value on 14th Day of decomposition process by samples inoculated with jaggery AEM. It can be concluded that jaggery is the best activator of EM-compost which is easy to prepare and with enhanced bacteria population, increases soil fertility but also gives good quality of soil and also a method of waste disposal at a low cost.

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