# Assessment of different types of in-vessel composters and its effect on stabilization of MSW compost.

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**Abstract** - *This study was conducted to determine the physico -chemical characteristics of organic matters separated from Municipal solid waste ( MSW ) using a rotary drum reactor ( RDR ) process and static mechanically air blown reactor (ABR). The aeration method of the compost had great influence on the physico-chemical characteristics ( temperature, moisture content, pH, organic content ) of the compost. In the ABR the temperature was observed to be higher than the RDR which may be due to the daily rotation of the rotary drum as it dissipates the heat generated and interrupt the temperature rise. On analyzing results by ANOVA showed that decrease in the temperature varied significantly between the two reactor ( p<0.05 ), but in both the process the temperature did not attain the thermophilic phase as it was below 50°C. The temperature control methods can be implemented to attain the required thermopilic phase. The present study helps to prove that the pH is not a key factor in the deciding the stability of the compost as it is same in both the cases throughout the experiment. The fertilizing index for TOC was calculated for the MSW compost taking the relative importance of the parameter into consideration. ADR and RDR which showed 4.43 and 5 for TOC. The results indicated that ADR had more advantage over the RDR. After composting the material for duration of 20 days the end product need further curing, hence these methods can be used for preliminary stabilization of compost.*

*Key Words: Municipal solid waste, temperature, moisture content, Stabilization.*

## 1. INTRODUCTION

Municipal solid waste is a good and easily available raw material for the compost production at low cost. In a developing country like India, MSW has been always considered as a very rich source of organic compost having rich nutrient required for agriculture based country [ Kalamdhad et al., 2009 ] [ 1 ] .The quantity of MSW has also increased tremendously with improved life style and social status of the populations in urban centers [ Sharholy et al., 2007 ] [ 2 ]. The annual waste generation has been observed to increase in proportion to the rise in population and urbanization, and issues related to disposal have become challenging as more land is needed for the ultimate disposal of these solid wastes [ Idris et al., 2004 ] [3]. The physico-chemical characteristics of the MSW of the cities in the north-eastern India having population < 0.1 million and between 0.11-0.5 million, the C/N ratio was 18-37, the compostable fraction was 29-63%, and total recyclable were observed to be 13.68-36.64%. High calorific value on dry weight basis was observed to vary from 591to 3766 kcal/kg [Sunil Kumar et al, 2009] [4]. Unscientific disposal causes an adverse impact on all the components of the environment and humane health [Rather. 2006] [5]. In the hilly region cities like in Itanager, disposal of waste is carried out along the valleys ridges, polluting the land and underground water [ Shin et al., 2001][6] through leachating that carries both organic and inorganic contaminants [ Bou-Zeid and El-Fadel., 2004 ][ 7 ]. The estimated waste produced in Itanagar per capita per day is 0.456 kg thus the total waste generate per day according to the population of 2011 census is 317 tones which is much more than the expected municipal solid waste to be generated from a small town of 50000 population [Arunachal Pradesh Development Report, 2009] [8]. According to the studies and the survey carried it show [ Department of Housing and Urban Development, Government of Arunachal Pradesh, Itanagar ] [ 9 ] that the MSW of the region have high degradable components value up to 65%,which is very high and can be positively tapped to convert it into compost using the aerobic method of composting. Aerobic composting is the decomposition of organic substrates in the presence of oxygen [ Haug, 1993 ] [10]. But the quality of compost is important from maturity and stability viewpoint [ Tiquia, SM., 2005 ] [ 11 ] which unfortunately in most of compost factories, proper attention is not paid [ Heydarzadeh et al., 2009 ] [ 12 ]. The application of unstable and immature compost would fix nitrogen in the soil and restrict plant growth by competing for oxygen in the rhizosphere and releasing toxic substances [ Bernal et al., 2009 ] [13].

 

Stability is not only an important compost quality characteristic but it can also be used for process performance monitoring and comparative evaluation of different composting systems [ Gomez, R.B., et al., 2006 ] [14]. The most common waste management strategy today is land filling [ Hogg, D.H., et al., 2008 ] [15 ] and it is expected to increase due to developing countries moving away from open dumping to engineered land fillings. But in recent years, there has been a movement to divert waste from landfills in order to reduce the negative environmental impact of landfills, such as leachate contamination posing a risk of groundwater contamination [ Shin et al., 2001 ] [7], GHG emissions and space limitation [ Norbu et al., 2005 ] [ 16 ]. The in-vessel composter ( Rotary drum type ) has been considered as the suitable reactor for composting of MSW with different ratio of bulking agents [ Daekeun Kim et al., 2008 [17], M. Nikaeen et al., 2011[ 18 ], Ka-Man Lai et al., 2011[ 19 ] Kalamdhad et al., 2009 ] [ 20 ]. The performance of each compost formula is evaluated from its ability to reach optimum TOC, to maintain a pH between 6 and 8 during the active composting stage, to lose the most dry and wet mass during the maturation phase, to decompose to the extent that no substrate particles are visible and, once matured, to offer a final moisture content under 50%. The in-vessel method can be considered as solution ad alternate to the waste disposal and management system catering to the increasing waste generated in the hilly region as the centralized system have failed. But very less work has been done on the use of such vessel in the tropical region which needs to be investigated thoroughly.

The aim of this study was the characterization of different quality control parameters (Temperature, pH, moisture, TOC) of compost produced from MSW and also to work out the most appropriate methods of in-vessel composting from ABR & RDR which can be adopted for the region.

## 2. MATERIAL AND METHODS

### 2.1 Experimental set-up and Design

The MSW is the raw material for the experiment which was collected from the NERIST campus. The waste collection routine of the campus was after every three days so the MSW collected was three days old. Since the waste was mixture of all types of waste segregation was done manually two times before loading. The segregated material was shredded manually to smaller pieces less than 2 cm. The pure form of organic waste from MSW is used in the study with no addition of bulking agent or bio-inoculums.

In the ADR method of composting consist of a plastic cylindrical drum of 1m height and 0.5 cm diameter fitted with a leachate out let near the bottom of the drum. For the aeration perforated PVC pipes of diameter of 10cm are laid on the bottom of the drum .the perforated pipes was covered with a plastic mash to control the entry of the particles into the tiny holes. The air was blown into the system by air blower on a daily basis.

The RDR composter used in this study is an especially designed aerobic type in-vessel composter. The main unit of the reactor i.e. diameter of 0.5m, length 1.20 m, the height is 1m above the ground level, made of 3mm thick sheet. The aeration of the reactor can be done manual by rotating and also mechanically by aeration which is done with the help of an air compressor. The reactor is supported on stand in both the ends attached with bearing to help rotation of the drum. There is an opening for the leachate collection. The axially running pipe in the drum not only supports the system but can be used in the leachate recirculation process and also for the aeration of the compost through it as it consist of small holes. The axial pipe again helps in the mixing of the compost as it is fitted with blade which helps in the further mixing of the compost. The surface of the composter is made water and rust proof by painting it with water resistant paints.

### 2.2 sample collection.

The reactors were placed in the environmental lab I at NERIST. The MSW is collected and grinded to achieve the required particles size ( 2-4cm ) for composting. The net initial weight of the MSW taken is 86 kg. 75% of the total volume of the in-vessel composter was filled for better and easy circulation of air and compost rotation. Five-hundred gram grab samples were collected manually from four different sources without disturbing the adjacent materials. Finally the entire grab samples were mixed thoroughly to make a homogenized sample. Triplicate homogenized samples were collected on the initial day and afterwards every third day for 27 days.

Table I: The initial characteristics of the MSW.

| Characteristics | MSW |
|---|---|
| pH | 5.5 |
| Size in cm or mm | 2-4 cm |
| Mass (kg) | 86 |
| Moisture content (%) | 74 |
| Total carbon content (%) | 47.49 |
| Total phosphorus | 4.27 |
| C/N | 37.4 |
| Total Nitrogen (%) | 1.27 |

## 2.3 The analytical method

The Temperature was daily measured by using digital thermometer before turning the compost material. Triplicate samples were collected and dried at 105°C in hot air oven for 24 hours and moisture content was calculated, dried samples were ground to pass 0.2 mm sieves and stored for further analysis. pH of the compost (1:10, w/v waste: water extract) were analyzed as described by [Kalamdhad et al., 2009][1]. Volatile solids (VS) were determined by the ignition method (550 °C for 2 h in muffle furnace) [BIS 1982] [21]. The total carbon content was determined by dividing the volatile fraction by 1.83 [Barrington et al., 2002] [22]

$$C(\%) = (100 - \%ash)/1.83 \quad (1)$$

The bulk density of the compost is determined by inserting the matter in 5 cm diameter, 5cm height cylinder made of thin-sheet metal of weight [ $W_1$] and volume [ V ] .[Anderson, J.M and Ingram, J.S.I, 1993] [23]. The material in the tube is dried at 105°C for two days and weighed [$W2_{]}$:

$$\text{Bulk density} = [W_2 - W_{1]} / V \ g/cm^3 \quad (2)$$

## 2.4 Assigning grade for the quality of the MSW compost of the reactors.

The quality compost (QC) guideline restricts the marketing of MSW composts that are beyond the certain level of different QC parameters and ensures the safety of the environment. However it fails to indicate their overall quality resulting from the use of certain type of input material and adopting a definite type of composting process. So indexing methods like fertilizing index for each analytical data affecting to fertilizing value (responsible for improving soil productivity) of compost like total C, N, P, K contents and C:N ratio and respiration activity are assigned to a score value as per the category given in table II. The minimum values of above fertilizing parameters obtained for a composts are placed under 3 higher value of any fertilizing parameter are assigned higher score value [ J.K. Sasha et al., 2010 ] [ 24 ]. Based on the scientific knowledge on their role in improving soil productivity each of these fertility parameters is assigned a weighing 'factor'. Organic carbon control several soil productivity parameters like water holding capacity, nature of porosity, soil structure, plant nutrient reserve pool as well as promotes ,soil biological activity and hence, its addition through compost results higher biomass production from land area. Hence the TOC content in the compost was assigned maximum weighing factor. The fertilizing index of MSW compost is computed using the formula

$$\text{Fertilizing index} = \frac{\sum_{n}^{i=1} S_i W_i}{\sum_{n}^{i=1} W_i} \quad (3)$$

Where $S_i$ is score value of analytical data and $W_i$ is weighing factor of the 'i'th fertility parameter.

Table II : Criteria for assigning 'weighing factor ' to fertility parameter and 'score value ' to analytical data.

| | Score value (Si) | | | | | Weighing factor(Wi) |
|---|---|---|---|---|---|---|
| | 5 | 4 | 3 | 2 | 1 | |
| Total organic carbon | >20.0 | 15.1-20 | 12.1-15 | 9.1-12 | <9.1 | 5 |

Source: J.K. Saha et al./Management 30(2010) 192-201[ 24 ]

All the results reported are the means of three replicates of a sample taken. Repeated measures treated with ANOVA and the graphs are plotted using origin software. The objective of statistical analysis is to determine any significant differences among the parameters analyzed for different mixtures during the composting process.

# 3. RESULT AND DISCUSSION

## 3.1 The effect of ABR and RDR on the moisture content of the compost

The moisture content between 40% to 60 % is considered optimum [Gajalakhshmi and Abbasi., 2008 ] [ 24 ] .The moisture content if exceed 60% it inhibit the aerobic process and leads to anaerobic process [ Das and Keener, 1997 ] [ 25]. Fig. 1 shows initial decrease of moisture content in the RDR process within 3 days which may be due excess evaporation of water content due to the daily turning of compost. The rewetting of the RDR compost was done to maintain the water content in the optimum range. Another reason for the sudden decrease of water content in RDR could be due to the draining out of the water through the leachate exit in the bottom of the in-vessel under the action of gravity. On the second week of composting the water content in ABR steadily decreased from 60% to 56 % which had inhibits the degradation process by clogging the voids [ Das and Keener., 1997 ] [ 25 ] causing change in the pH of the compost as it decreases from 8.1 to 7.25 on the 9th day. Analyzing the results by ANOVA, the decrease in moisture content varied significantly between the 20 days of composting ( $P < 0.05$, $F= 40.43$ ) for both the process. The composting period of the compost in ABR process was in the month of May which is rainy season so the moisture content may have been very much effected by the weather condition and also by the type of reactor used, as in the case of RDR which lead to the greater loss of moisture due to the daily rotation of the compost. So the moisture content of ABR was found to be more optimum for further curing of the compost.

 

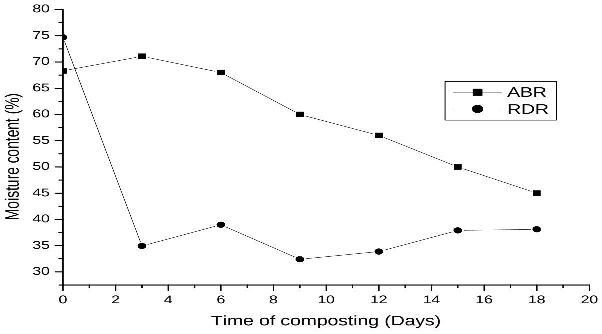


Fig.1 Moisture content of composting material over time.

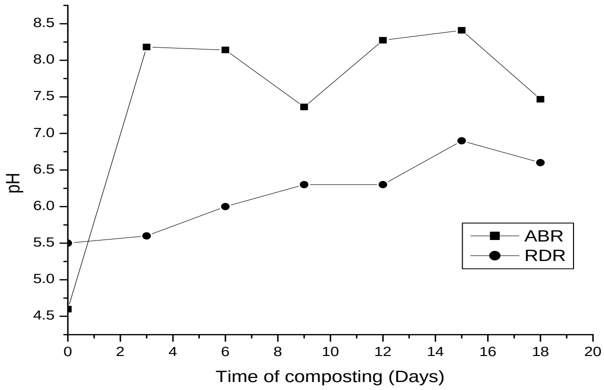


Fig. 2 pH of composting material over time.

## 3.2 The effect of ABR and RDR on the pH of the compost

A pH of 6.7-9 supports good microbial activity during composting. Optimum values range from 5.5 to 8 [ Miller., 1992 ] [ 26 ]. However this factor it is not considered as the key factor for composting since most of the material are within this pH range. The initial pH in ADR and RDR process are 4.6 and 5.5 respectively which is acidic in nature. This acidity is due to the formation of organic acids produced by acid forming bacteria which are anaerobic in nature. It happens due to lack of aeration which gives anaerobic bacteria an opportunity to develop. The initial acidity of the compost in the experiment (i.e. In-vessel aerobic decomposition) was due the un-aerated period during the grinding and shifting of organic waste from field to the laboratory. This gave anaerobic bacteria the chance to develop and form acids which decreases pH value. After this period, the pH tends to move towards neutral, when these acids are converted to carbon dioxide by microbial action. The drop in pH value is observed during the early days of loading due to addition of biodegradable organic matter, then during maturation phase, the pH value increases due to the formation of ammonia .The similar trend is followed by pH in both the process Figure 2. The statistical analysis of both the process by ANOVA showed no significant difference hence proving the point why it is not always considered as standard for measuring the stability of compost. Figure 2 show that the ABD process has more of neutral or optimum range for the better degradation of the MSW compost.

## 3.3 The effect of ABR and RDR on TOC of the compost

The decrease in the TOC content during the composting period is given in Figure 3. The organic contents tends to decrease as the decommpostion progresses. The major decrease in TOC is observed in ABR process which show more active microbial activity [Fig. 3 ]. The RDR showed poor rate of degradation of TOC . The slow rate of degradation can be correalted with the moisture content and the temperature of the compost [ Liao et al., 1996 ] [ 27 ] as the temperature was very low and the moisture content was relativly high ultimately leading to lowering of degradation rate. On analysisng with ANOVA the TOC of both the process showed significantly different ( $p < 0.05$, $F=27.68$ ). Thus it can be concluded that the rate of degradation is much higher in the ABR type which means it is a better decomposting mechanism in thses case. Considering the significant role of TOC in the composting process and the maximum score value of 5 has been conferred. The 'fertilizating index' values of the analyzed MSW compost for ADB and RDR are 4.43 & 5 respectively.

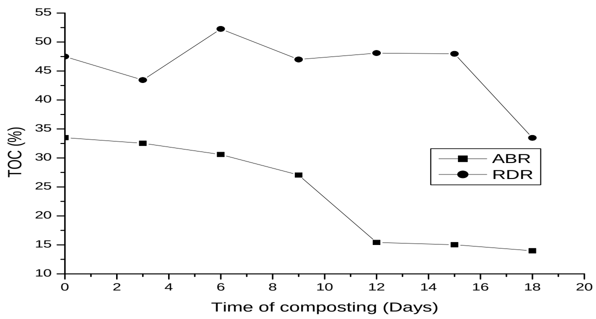


Fig. 3 TOC of composting material over time.

## 3.4 The effect of ABR and RDR on Temperature of the compost

The temperature has been widely recognized as one of the most important parameters in the composting process [ Bernal et al., 2009 ] [ 12 ]. The rise and fall in the compost can be strongly correlated with the rate of microbial activities [ Tiquia et al., 1996 ] [ 28 ]. The optimum temperature is 40-65°C for composting [ Bernal et al., 2009 ] [ 13 ]. The temperature is higher in ABR to RDR process. But both the cases could not attain the thermophilic phase which is above 50°C.The compost in RDR showed the lowest point of temperature i.e 23°C [ Fig. 1 ]. The seasonal effect on the compost can be considered as one of the causes for the falling temperature, as composting was done in winter in the month of February. Another reason could be the material used in construction of the rotary drum reactor which is metal and a good conductor .The rise in the temperature of the compost in ABR caused greater decrease of TOC of the compost in the ABR process, as the micro organisms were active which also help in the stabilization of the compost. On analyzing the results with ANOVA the temperature in both the process showed significant difference ( $F = 81.87$, $P < 0.05$ ). Thus it can be concluded that the two methods have varying effect on the temperature of compost and the ADR process was found to be better of the two to attain the required optimum.

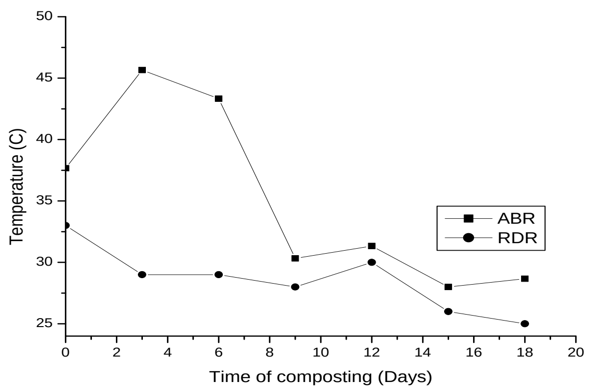


Fig. 4 Temperature of composting material over time.

## 4. CONCLUSION

According to the experiment the ABR composting process is more efficient than the RDR for composting of MSW for duration of 20 days. The moisture content is well maintained in the ABR process as the final Moisture Content is 45% which is within the optimum range for composting. Hence it has been proved from the study that pH is not a key factor for deciding the stability status of compost as it is not significantly different in both the case. But the TOC has greater significance in the composting process .the main factor which can directly be related to decomposing is temperature and ABR showed better control over the temperature changes but the material used for the construction of the reactor should be investigated more as it may have some role in the change of temperature.

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