FORM-E

Council of Scientific and Industrial Research Human Resource Development Group, CSIR Complex, Library Avenue, Pusa, New Delhi - 110 012	
1. Title of the Scheme: **“**Sustainable Utilization of solid Waste as a Source of Plant Nutrient in Rice Based Agroecosystem of North-East India”	Financial year for which Renewals requested:2014-15 Scheme number: **38(2275)/11/EMR-II**
2. Name & Address of PI: Dr. S. S. Bhattacharya Asstt. Professor, Dept. of Env. Sc., Tezpur University, Tezpur,Assam	Date of Commencement: 20/02/2012
3. Name of Sponsoring CSIR Laboratory (if applicable): N/A	

4. JRF/SRF/RA associated with the project

Name & Designation	Date of joining	Date of relieving
Md. Imran Ullah Farooqui	23/04/2012	30/11/2012
Linee Goswami, Senior Research Fellow(SRF)	01/01/2013	31/08/2015

5. Details of Equipment Purchased:

Name of Equipment	Cost	Supplier	Date of placing order for each item of equipment
1:UV-VIS spectrophotometer	Rs 3, 17,800/- only	M/S R.S. Traders Kolkata	20/06/2012
2 : Incubator	Rs 18,160/- only	M/S R.S. Traders	20/06/2012
3 : Flame Photometer,	Rs 54,423/-only	M/S Assam Chemicals	20/06/2012
4 : Rotary Shaker	Rs 30,645/- only	M/S Assam chemicals & instruments corporation.	20/06/2012
5: Horizontal Laminar Air flow,	Rs 71,857/-only	M/S Instrumentation India kolkata	20/06/2012
6. 1 mL quratz cuvette, Vortex multi tube, UV lamp 15 W	Rs 1,17,130/- only	Patel Chem-De-Drugs, Kolkata.	31/07/2012

6. Grants received, and expenditure made in Rupees.

	1st Year 20th February 2012 to 31st March 2012 **(1 month 8 days)**	1st Year 1st April 2012 to 31st March 2013	2nd Year 1st April 2013_ to 31st March 2014	3rd Year 1st April 2014_ to 31st March 2015	Extension period 1st March to 31st August 2015**(6 months)**
JRF/SRF/RA	SRF	SRF	SRF	SRF	SRF
Sanctioned	Rs 88,000.00	Rs: 2,64,000/-	Rs. 2,64,000/-	Rs. 2,42,000/-	Rs. 1,80,000/-
Received	Rs 88,000.00	Rs: 1,85,620/-	Rs. 1,68,000/-	Rs. 1,54,000/-	Rs. 84,000/-
Expenditure	NIL	Rs: 1,24,506/-	Rs. 1,68,000/-	Rs. 1,54,000/-	Rs. 84,000/-
CONTINGENCY					
Sanctioned	Rs 36,667/-	Rs: 110,000/-	Rs: 110,000/-	Rs. 1,00,834/-	Rs. 45,834/-
Received	Rs 36,667/-	Rs: 110,000/-	Rs: 110,000/-	Rs. 1,00,834/-	Rs. 45,834/-
Expenditure	Rs 36,667/-	Rs: 115,659/-	Rs: 110,000/-	Rs. 1,00,834/-	Rs. 45,834/-
EQUIPMENT					
Sanctioned	Rs: 6 Lakh	-------	Nil	Nil	Nil
Received	Rs: 6 Lakh	Rs: 6 Lakh **(carried over fund)**	Nil	Nil	Nil
Expenditure	NIL	Rs: 6 Lakh	Nil	Nil	Nil

7. Amount saved (if any) from the last year's grant: Nil

Staff	Contingency	Equipment

8. Date on which scheme will complete its normal tenure of 12/24/36 months. 20.02.2015
Whether extension beyond normal tenure has been requested Y/N. Y
If yes, give One year (20/02/2016) justification (justifications are given in a separate page as Annexure II)
(Extension beyond normal tenure should be requested at the PMW/one year before end of normal tenure.)

Note: If yes, justification for extension and programme of work to be completed. Also mention as to why the work could not be completed the original plan.

9. Constraints (if any) faced in the progress of work and suggestions to overcome them.
N/A

10. Any deviation from original plan with its nature and cause: N/A

11. List of publication giving full bibliographic details (copies of the paper(s) should be enclosed):

a) Bhattacharya, S.S., Barman, S., Ghosh, R., Duary, R. K., Goswami, L., Mandal, N.C.2013. **Phosphate solubilizing ability of *Emericella nidulans* strain V1 isolated from vermicompost.** Ind. J. of Exp. Biol. Vol 51 (10) 840-848.

b) Sahariah, B., Goswami , L., Kim, K.H., Bhattacharyya, P., Bhattacharya, S.S., 2015. ***Metal remediation and biodegradation potential of earthworm species on municipal solid waste: A parallel analysis between Metaphire posthuma and Eisenia fetida***, **Bioresource Technology**, 180, 230–236

c) Sahariah, B., Farooqui, I. U., Goswami, L., Raul, P., Bhattacharyya, P., Bhattacharya, S.S., 2014. ***Solubility, hydrogeochemical impact and health assessment of heavy metals in municipal solid wastes of two different cities.*** **Journal of Geochemical Exploration**, 157, 100-109.

12. Summary of work done (200 words): So far, the following activities were undertaken.

a) Renovation of vermicomposting unit and setting up waste segregation methodology has been completed.

b) Purchasing of equipments and preparation for setting up microbiological study are done.

c) Collection of earthworm species and multiplication of the same is done. In the original project it was proposed that two earthworm species viz. *Eisenia fetida* & *Eudrillus euginae* will be used for the study. However, due to unavailability of authentic *Eudrillus euginae* species in Assam, we are using ***Metaphire postheuma*** species instead of *E. euginae*. This species have been collected from Assam soil and it is equally efficient in degrading wide range of waste materials.

d) Detailed characterization of municipal solid waste collected from Guwahati and Tezpur city is completed and reported earlier. A paper is published in Journal of Geochemical Exploration (I.F.2.74).

e) Vermicomposting experiment with municipal solid waste collected from Tezpur town has been completed and reported earlier as well as in the current report. A paper has been published in Bioresource technology (I.F. 4.49).

f) First and second season crop experiment with vermicomposted solid waste is completed and reported in Annexure I.

j) Microbiological analysis of the vermicomposted samples was completed and reported earlier.

k) Metal accumulation ability of earthworms was studied using fluorescence tagged ligands. The study showed some promising results regarding presence of high molecular weight protein other than metallothionein like proteins which can help in bioaccumulation of metals. However, a much detailed study is needed for characterization of the protein.

k) The detail final technical report has been given in Annexure I.

3. Proposed program of work for the next 6 months (Extended period) Detail is reported in Annexure I.

14. Detailed Annual Progress Report (up to five pages maximum): The project completed three years and six months. As the project is terminated, so, final technical report was submitted as Annexure I.

Bhattacharya

Signature of PI:
Date: 31/8/15

Assistant Professor
Dept. of Environmental Science
Tezpur University

FORM-F

COUNCIL OF SCIENTIFIC AND INDUSTRIAL RESEARCH

Human Resource Development Group

(Extra Mural Research Division)

CSIR Complex, Library Avenue, Pusa, New Delhi – 110012

PROFORMA FOR PREPARING FINAL TECHNICAL REPORT

(Ten copies of the report must be submitted immediately after completion of the research scheme)

1. Title of the Scheme: **"**Sustainable Utilization of solid Waste as a Source of Plant Nutrient in Rice Based Agro ecosystem of	Scheme number: 38(1307)/11/EMR-II Dated 20/02/2012
2. Name & Address of Principal Investigator: Dr. Satya Sundar Bhattacharya, Asst. Professor, Department of Environmental Science, Tezpur University-784028, Assam, India	Date of Commencement: 20/02/2012 Date of termination : 31/08/2015
3. Name of Host Institution: Tezpur University	

4. Total grant sanctioned and expenditure during the entire tenure

	Amount Sanctioned	Expenditure
Staff	Rs. 10,38,000/-	Rs. 5,30,506/-
Contingency	Rs. 4,03,335/-	Rs. 4,08,994/-
Equipment	Rs. 6,00,000/-	Rs. 6,00,000/-
Total	Rs. 20,41,335/-	Rs. 15,39,500/-

5. Equipment(s) purchased out of CSIR grant

Name	Cost
1:UV-VIS spectrophotometer	Rs. 3, 17,800/- only
2 : Incubator	Rs. 18,160/- only
3 : Flame Photometer	Rs. 54,423/-only
4 : Rotary Shaker	Rs. 30,645/- only
5: Horizontal Laminar Air flow	Rs. 71,857/-only
6. 1 mL quratz cuvette, Vortex multi tube, UV lamp 15 W	Rs. 1,17,130/- only

6. Research fellows associated with scheme

Name& Designation	Date of Joining	Date of leaving
Md. Imran Ullah Farooqui	23/04/2012	30/11/2012
Linee Goswami, Senior Research Fellow(SRF)	01/01/2013	31/08/2015

7. Name(s) of the fellow(s) who received Ph.D. by working in the scheme, along with the Title(s) of thesis:

Name: Ms Linee Goswami

Title of the thesis: **Vermistabilization of coal ash produced in Tea factories of Assam by using *Eisenia fetida (Savigny)* and *Lampito mauritii (Kinberg)***

Status: Thesis Submitted

8. List of research papers published/communicated, based on the research work done under the scheme (Name(s) of author(s), Title, Journal, Volume number, Year and Pages should be given for each paper published and a copy of each of them should be enclosed; reprints/copies of papers appearing after submission of FTR should also be sent to CSIR):

a) Bhattacharya, S.S., Barman, S., Ghosh, R., Duary, R. K., Goswami, L., Mandal, N.C.2013. **Phosphate solubilizing ability of *Emericella nidulans* strain V1 isolated from vermicompost.** Ind. J. of Exp. Biol. Vol 51 (10) 840-848.

b) Sahariah, B., Goswami , L., Kim, K.H., Bhattacharyya, P., Bhattacharya, S.S., 2015. ***Metal remediation and biodegradation potential of earthworm species on municipal solid waste: A parallel analysis between Metaphire posthuma and Eisenia fetida***, **Bioresource Technology**, 180, 230–236

c) Sahariah, B., Farooqui, I. U., Goswami, L., Raul, P., Bhattacharyya, P., Bhattacharya, S.S., 2014. ***Solubility, hydrogeochemical impact and health assessment of heavy metals in municipal solid wastes of two different cities.*** **Journal of Geochemical Exploration**, 157, 100-109.

9. Details of new apparatus or equipment designed or constructed during the investigation: N/A

10. The likely impact of the completed work on the scientific/technological potential of the country (this may be attached as Enclosure-I):

See **Enclosure I**.

11. Is the research work done of some industrial or agricultural importance and whether patent(s) should be taken? Yes/No; if yes, what action has been/should be taken:

Yes.

This research has rendered valuable information and knowledge for conversion of MSW solid waste into formidable organic manure for agricultural application in the North East India. The optimized vermitechnology may be recommended for the framers of the country.

12. How has the research work complemented the work of CSIR Laboratory that sponsored your scheme?

Not applicable.

13. Detailed account of the work carried out in terms of the objective(s) of the project and how far they have been achieved; results and discussion should be presented in the manner of a scientific paper/project report in about 5000 words; and this should be submitted as Enclosure-II to this report:

Detail report is attached in **Enclosure II i.e., Annexure I** .

14. An abstract of research achievements in about 200-500 words, suitable for publication.

Detail characterization of Municipal solid waste (MSW) generated in two rapidly growing cities of North East India (Guwahati and Tezpur) was done. In addition, assessments of human health and environmental impacts have been done through solubility study and metal dissolution dynamics analysis with the help of Visual MINTEQ geochemical model. Vermicomposting technology for converting these MSWs into ecologically sound and agriculturally viable high valued organic manure has been optimized through a parallel performance analysis employing two earthworm species (*Metaphire posthuma* and *Eisenia fetida*). High vermicomposting efficiency of a new earthworm species viz. *Metaphire posthuma* was recorded as compared to *Eisenia fetida* with respect to increment in bioavailability of N, P, K and Fe. The earthworm was also highly competitive with *E. fetida* in regard to enzyme activation, microbial diversity and activity, and organic C sequestration capacity. Moreover, significantly high metal (Cu, Mn, Zn, and Pb) accumulation ability from MSW and CD mixed vermibeds was shown by both *M. posthuma* and *E. fetida*. However, among different feed mixtures MSW + CD (4:1) was found to be a suitable substrate for vermicomposting. In this research, we have addressed the metal accumulation capacity of *E. fetida* through a mechanistic approach by employing fluorescent tagging technique. The outcome of this study indicates occurrence of some unknown metal binding proteins in earthworm gut and thus offers the scientific community a new domain of investigation. Furthermore, vermicomposted MSW could be used as a formidable organic manure for rice grown under alluvial soil of Assam.

15. Mention here whether or not the unspent grant has been refunded to CSIR:

There is no unspent grant amount.

Date: 31/8/13

Signature of the Principal investigator

Assistant Professor
Dept. of Environmental Science
Tezpur University

Note: Final Technical Report is expected to be self-contained complete report of the work done. Please do not leave any column unanswered.

Enclosure I

The likely impact of the completed work on the scientific/technological potential of the country

This project has come up with few significant findings, which are given in detail as below:

- Municipal solid waste (MSW) generated in two rapidly growing cities (Guwahati and Tezpur) of North East India have been characterized in detail. The probable human health and environmental impacts have also been estimated and through various experimentations. Hence, the information and this publications of this research will facilitate the municipal managers to set a holistic strategy for sustainable of management of solid waste generated in their localities.
- The project has also accomplished to optimize the vermicomposting technology for converting these MSWs into ecologically sound and agriculturally viable high valued organic manure. Detail estimation of various nutrient elements and humification rates of on temporal basis provided valuable information on vermicompost quality and maturity. Moreover, high vermicomposting efficiency of a new earthworm species viz. *Metaphire posthuma* was recorded as compared to *Eisenia fetida* with respect to increment in bioavailability of N, P, K and Fe. The earthworm was also highly competitive with *E. fetida* in regard to enzyme activation, microbial diversity and activity, organic C sequestration capacity, and metal (Cu, Mn, Zn, and Pb) accumulation ability from MSW and CD mixed vermibeds.
- In this research, we have addressed the metal accumulation capacity of *E. fetida* through a mechanistic approach by employing fluorescent tagging technique. The outcome of this study indicates occurrence of some unknown metal binding proteins in earthworm gut and thus offers the scientific community a new domain of investigation.
- Finally, in this project we have demonstrated that vermicomposted MSW could be used as a formidable organic manure for rice grown under alluvial soil of Assam. We also rendered valuable information on soil quality improvement with reduced synthetic fertilizer use, supplemented by vermicomposted MSW, without compromising the crop yield. In addition, thorough this work a balanced nutrient management scheme has been recommended for rice cultivation in alluvial soils of Assam.

Assistant Professor
Dept. of Environmental Science
Tezpur University

[signature] 31/8/15

Enlo. II/Annexure I: Final Technical Report

1.1 Introduction

Environmental impacts of increasing waste generation are gaining attention nowadays in India (Mor et al., 2006). Exponential increase in population and unplanned expansion resulted in rapid increase in solid waste generation in Indian cities.Literatures also clearly indicate that the amount of MSW is expected to increase significantly in the near future as the country strives to attain an industrialized nation status by the year 2020 (Sharma and Shah, 2005; CPCB, 2004).On promulgation of the municipal solid waste (Management and Handling) Rule, 2000, it is mandatory for the cities to have a viable solid waste management plan (MoEF, 2000).However, the characteristics of municipal solid waste (MSW) are highly heterogeneous; vary widely among cities depending on the level of industrialization and living standard of the inhabitants (Zhang et al., 2008). Therefore, the generalized plans do not suffice the actual need in many cases. Sharholy et al. (2008) had suggested that the composition and quantity of MSW generated be the basis of planning, designing and operating waste management system. Thus, authentic information on waste composition is extremely important to formulate case specific management strategies.

Many Indian workers reviewed MSW generation, composition, disposal and management avenues generally applicable for Indian cities (Karak et al., 2012). The major findings of these studies are the wide variation in characteristics of MSWs, which mostly depends upon the factors discussed earlier. However, comparative analyses of waste characteristics in regard to human health and environmental risks are yet to be addressed adequately for Indian cities. In this investigation, we have characterized the MSWs generated in Tezpur municipality area; as well as the associated risks of environmental degradation has been assessed through studying the solubility dynamics of pollutants.

Bioprocessing of MSW can be an effective proposition because of organic constituents in the waste. Among various bioprocessing technologies, vermicomposting has been recommended as a preferable option to stabilize various kinds of solid wastes (Suthar et al., 2012). The application of earthworms for bioconversion of different types of industrial solid wastes has been discussed and reviewed (Hickman and Reid, 2008; Ravindran et al., 2008; Subramanian et al., 2010; Goswami et al., 2014). Earthworms grind waste materials into finer substances by their gizzards. Subsequently, their gut microflora mineralizes organically bound nutrient elements into bioavailable forms and releases the mineralized materials through their excreta. As such, these earthworms can remediate heavy metal species in the processed product by accumulating metals in their intestines as metal bound protein metallothioneins (Goswami et al., 2014). The metallothioneins fix the metal ions by forming organometallic complexes. When the earthworms die, these protein-bound metals are exposed to soil environment and retained in the humic substances of soil in immobilized forms (Nannoni et al., 2011).

Previously, Bisht et al. (2007) observed the reproductive potential of endogeic*Metaphireposthuma* in cow dung manure. It has also been reported that *Metaphire posthuma*can significantly modify soil aggregation and porosity (Bottinelli et al., 2010). However, vermicomposting efficacy of *Metaphire posthuma*has not yet been explored as bioagent for vermicomposting. To the best of our knowledge, this study presents in detail for the first time the potent role of a new endogeic earthworm, *Metaphire posthuma*in future vermicomposting applications.

1.2 Objective of the study:

1. To convert the solid waste into organic manure for better nutrition to crop plant through vermicomposting technology.
2. To study the changes in soil health due to application of vermicomposted product from solid wastes.
3. To demonstrate the efficiency of vermicompost in reducing the use of inorganic fertilizer in agricultural fields of Assam (surrounding areas of Tezpur).
4. To establish vermicomposting technology as a tool for sustainable use of solid waste in rice based cropping system of this part of North-East India.

2. Materials and Method

2.1. Sample collection and segregation

Sample collection was carried out in Tezpur town, India. Apart from adopting random sampling procedure in collecting the MSW samples, variety in selection of locations was also maintained. MSW samples were collected in waste disposal bags by taking standard precautions using gloves, masks etc. and the collection was done following the methods as per the municipal solid waste (Management and Handling) Rule, 2000 (MoEF, 2000). The bags were then properly sealed and transported safely to the experimental site.

Collected MSW samples were primarily segregated into biodegradable and non-biodegradable fractions.All the representative samples are mixed together to form two composite samples one each from Tezpur. The composite samples were then subsequently air dried and used for the study taking three replicas.

2.2 Procurement of cow dung (CD) and earthworm species

Urine free cow dung (CD), collected from a nearby dairy farm was used as the organic source to subsidize and facilitate the biological conversion process. Non-clitellated juvenile *Eisenia fetida* specimens were collected from the vermiculture unit managed by the Department of Environmental Science, Tezpur University, Assam, India. Indigenous endogeic earthworm,*Metaphire posthuma* specimens were primarily isolated from alluvial soil near Tezpur and their species verified by the Zoological Survey of India under the Ministry of Environment and Forests, Government of India. Subsequently, the collected specimens were bred in our vermiculture unit in a 50:50 mixture of soil and cow dung for two months and subsequently used for the study.

2.3 Physicochemical characterization: Proximate analysis for moisture content, ash content, volatile matter and fixed Carbon were done by following Kalanatarifard and Yang (2012). Physico-chemical properties of the MSW samples were analyzed by employing established methodologies (Page et al., 1982). Heavy metals (Fe, Cu, Mn, Zn, Pb, Ni, Cd and Cr) were analyzed according to Lindsay and Norvell (1978) by Atomic Absorption Spectrophotometer. Moreover, the human health risk analysis was carried out by computing the hazard quotients of various metals according Chabukdhara and Nema (2013).

2.3.1 Study of the solubility patterns of ions using geochemical modeling: We determined water-soluble concentration of different elements in the MSW samples following Bhattacharyya *et al.* (2011) and Goswami *et al.* (2014). The samples were mixed with distilled deionized water (1:10 (w/v)) in conical flasks. Data collected from 7-, 14-, and 21-day solubility studies were put into the Visual MINTEQ for speciation, saturation indices (SI), and ionic strength determination. Saturation index (SI) for each solid is defined as log IAP −log Ks (IAP, ion activity product; Ks being the temperature-corrected solubility constant). When SI>0, it indicates that the solution is oversaturated; when SI<0, the solution is under-saturated; and when SI=0, there is an apparent equilibrium with respect to the solid.

2.4 Experimental design for bioprocessing techniques: Three bioprocessing systems, viz., aerobic composting and vermicomposting (with *Eisenia fetida* or *Metaphire posthuma*) were employed in these experiments. Round shaped, perforated earthen vessels (0.60 m diameter and 0.45 m height) were used for the study. Prior to incubation, various ratios of MSW and CD were thoroughly mixed. Four kg of each mixture was poured into the vessels and incubated separately with *E. fetida* or *M. posthuma*(10 worms kg^{-1} substrate). Moisture content was maintained uniformly at 50-60% for all three bioconversion systems by supplying water at 2-3 day intervals. Moreover, adequate aeration was provided by churning for 30 minutes twice a day throughout the incubation period (60 days). Experiments were done in triplicate for each combination. Changes in elemental composition were monitored by removing samples at 0, 30, and 60 d during the incubation period from each replicate.

The following combinations of MSW and CD were used for the study:

E1- Only MSW$_{E.fetida}$	M1- Only MSW$_{M. posthuma}$	C1- Only MSW$_{composting}$
E2- MSW + CD (2:1)$_{E. fetida}$	M2- MSW + CD (2:1)$_{M. posthuma}$	C2- MSW + CD
E3- MSW + CD (4:1)$_{E. fetida}$	M3-MSW + CD (4:1)$_{M. posthuma}$	(2:1)$_{composting}$ C3- MSW +
E4- CD$_{E. fetida}$	M4- CD$_{M. posthuma}$	CD (4:1)$_{composting}$
		C4- CD$_{composting}$

2.4.1 Analysis of physicochemical properties, carbon fractions, and microbial compositions

The procured MSW and temporal changes in bioprocessed materials were analyzed for easily mineralizable N, available P, available K, degree of humification (DOH), fulvic acid C (FAC) and humic acid C (HAC) following the analytical procedures of Page et al. (1982). In addition, the diethylenetriaminepentaceticacid (DTPA) extractable metals (Fe, Mn, Cu, Zn, and Pb) were assayed following the procedure of Lindsay and Norvell (1978) with the help of an Atomic Absorption Spectrophotometer (AAS). The total bacterial count was obtained using nutrient agar media (Parmer and Schmidt, 1964). All elemental analyses were performed following the general quality control (QC) guidelines published by Tezpur University.

2.5 Fluorescence probes of Zn and Cd: Chemistry and utility

Synthesis of Ligand (L1): Using a 250 ml round bottom flask, 2-amino 6-methyl pyridine-2-amine (30 mmol) and 2-hydroxy benzaldehyde (30 mmol) was added in 150 ml toluene. To this, 50 g molecular sieves (4 Å) and 300 mg Ambertlite IR-120 resin were added and stirred for 10 minutes at room temperature. Subsequently, the reaction mixture was refluxed at 150 °C for 24 h using a Dean Stark apparatus. During the course of the reaction, thecalculated amount of water was collected. After the completion of the reaction, the remaining amount of toluene was evaporated in reduced pressure. Then, a yellow condensed product was obtained and dried under reduced pressure and used for further analysis. Yield = 5.6 g (88%). IR (KBr, cm^{-1}): ν = 3058, 2969 (C–H), 1620 (C=N). $_{H}$(400 MHz; $CDCl_3$): 2.58 (s, 3H, CH_3), 6.96 (t, 1H, $J = 7.5$ *Hz*), 7.03

(d, 1H,J = 8.0 Hz), 7.12 (d, 1H,J= 7.8 Hz), 7.15 (d, 1H, J = 7.8Hz), 7.40 (d, 1H, J= 7.8 Hz,), 7.52 (d, 1H, J = 7.6 Hz,), 7.70 (t, 1H, J = 7.8), 9.47 (s, 1H, HC=N), 13.52 (s, 1H, OH).

2.6 Metal accumulation in Eisenia fetida

Non-clitellated juvenile *Eisenia fetida* specimens were collected from the vermiculture unit of the Department of Environmental Science, Tezpur University and reared in urine free cow dung for two weeks. Fluorescent-labeled Cd (CdL1)and Zn (ZnL1) (Conc.: 5 mg ml^{-1})wereadded individually in the feed stock and then incubated for 2 months. After incubation, earthworms were collected and kept overnight in PBS for gut cleaning. Gut cleaned, freeze killed earthworms were sonicated, and the homogenate sample was centrifuged for 10,000 rpm for 15 min. Supernatants were collected and subjected to amicon YM-50 and YM-100 filter devices (Millipore, Bedford, MA) for separating the proteins based on their molecular weight. The filtrate and retentate from these filter devices were collected, and the fluorescence in the separated protein samples was analyzedby using fluorescence spectrophotometer.

2.7 Crop trial:

We are conducting the crop trial with Rice (*Oryza sativa* L.) in a typical alluvial soil of Assam in Tezpur (26^{0}41’31.8”N 92^{0}50’02.4”E). Rice was grown consecutively two seasons i.e. *boro* (winter) and *kharif* (summer) in the same field. Vermiconverted mixtures of TSW were applied to experimental soil (typic endoaquepts) under Rice. The experiment was conducted in a randomized block design with three replicates during both and *Boro* (Summer Rice) and *Kharif* (Autumn Rice) on the same field. We have selected *Boro*-1 and Ranjit cultivars for *Boro* and *Kharif* season consecutively. Various combinations of vermicomposted TSW were applied to all the plots keeping other management practices identical. We have collected exhaustive data but only few important indicative parameters that are highly relevant to our objectives are presently reported. The treatment combinations used for the study is given as below:

T1 - NPK100 = 100% recommended NPK

T2- NPK100+FYM = 100% recommended NPK & Farmyard manure @ 10 t ha^{-1}

T3 - NPK100+VCei = 100% recommended NPK &*Eisenia* vermicomposted TSW (4:1) @ 10 t ha^{-1}

T4 - NPK100+VCmp = 100% recommended NPK &*Metaphire* vermicomposted TSW (4:1) @ 10 t ha^{-1}

T5 - NPK80+VCei = 80% recommended NPK &*Eisenia* vermicomposted TSW (4:1) @ 10 t ha^{-1}

T6 - NPK80+VCmp = 80% recommended NPK &*Metaphire* vermicomposted TSW (4:1) @ 10 t ha^{-1}

T7 - NPK60+VCei = 60% recommended NPK &*Eisenia* vermicomposted TSW (4:1) @ 10 t ha^{-1}

T8 - NPK60+VCmp = 60% recommended NPK &*Metaphire* vermicomposted TSW (4:1) @ 10 t ha^{-1}

T9 - NPK80+FYM = 80% recommended NPK & Farmyard manure @ 10 t ha^{-1}

T10 - NPK60+FYM = 60% recommended NPK & Farmyard manure @ 10 t ha^{-1}

T11 -VCei = *Eisenia* vermicomposted TSW (4:1) @ 10 t ha^{-1}

T12 - VCmp = *Metaphire* vermicomposted TSW (4:1) @ 10 t ha^{-1}

2.8 Statistical analysis

We performed one-way ANOVA followed by Least Significant Difference (LSD) tests to analyze the real temporal variations in dissolution/precipitation dynamics in TMSW.The temporal data on various parameters (pH, CEC, TOC, TKN, CEC, HAC, FAC, DOH, available K, P and metals) were analyzed using a two-way ANOVA with three observations per cell in order to accommodate the temporal variations. However, one-way ANOVA was performed for bacterial count. To identify the efficacy of different combinations of feed mixture, the least significant difference (LSD) test was utilized.For crop trial, two-way ANOVA was performed by following standard method for randomized Block Design. Finally for identifying optimum treatment combinations, Least Significant Difference (LSD) test have been implemented.

3.0 Result and Discussion

3.1Characterization of TSW

The samples are alkaline in nature with the presence of organic matter in municipal solid waste (table 1). High EC of the samples reveals the lower level of salinity in the TSW, which is an essential character for bio-composting. Moreover, water holding capacity, porosity, cation exchange capacity were considerably high. Status of availability of all the three major nutrients in TSW viz., N, P and K were also found to be on higher side.However, total concentration of metals viz. Fe, Cu, Mn, Zn, Cr and Ni, were noticeably high and thus is a matter of serious concern which warrants further intensive study focusing on stabilization of these elements within permissible limits.

Visual MINTEQ is a useful speciation model for measuring the equilibrium composition of dilute aqueous solutions in the laboratory or in natural ecosystems (Zhang et al., 2008). This model was run to predict pH dependent solubility behavior and stabilization process of chemical agents in absence of surface complexation reactions (Zhang et al., 2008). The main products of stabilization process as simulated by visual MINTEQ with dissolution/precipitation mechanism are shown in table 2. In TSW saturation index (SI) value of Aragonite, Calcite and Vaterite gradually decreased from 7 to 14 d, indicating considerable dissolution of these Ca bearing minerals (table 2).

Table 1: Physicochemical characterization of Tezpur solid waste (TSW) (mean ± standard deviation)

Parameters	TSW
pH	8.2±0.86
Conductivity(µS cm $^{-1}$)	37±1.89
Bulk density(g ml $^{-1}$)	0.754±0.08
Water Holding Capacity (%)	72.74±6.75
Porosity (%)	32.76±3.1
Particle density(g cc $^{-1}$)	1.09±0.14
Cation Exchange Capacity (meq 100g $^{-1}$)	30.69±2.7
TOC (%)	17.84±1.4
Total N (%)	4.57±0.56
Available P (mg kg $^{-1}$)	119.67±9.88
Available K (mg kg $^{-1}$)	117.5±10.6
*** Total and exchangeable metals in TSW in ppm**	
Total Fe	1506.5±0.52
Exch. Fe	11.84±0.01
Total Cu	119.44±0.04
Exch. Cu	2.48±0.04
Total Mn	-------
Exch. Mn	5.6±0.26
Total Zn	284.6±0.02
Exch. Zn	14.8±0.26
Total Pb	131±0.5
Exch. Pb	0.36±0.002
Total Cr	20.14±0.02
Exch. Cr	-------
Total Ni	15.4±0.1
Exch. Ni	-------

The precipitation of $Ca_4H(PO_4)_3{:}3H_2O$ increased from 14 to 21 d (table 2). Therefore, the majority of the Ca solubilized during the study though a small part as $Ca_4H(PO_4)_3{:}3H_2O$ precipitated at later stage. Interestingly, precipitation of some Cu based minerals (Antherite and Azurite) increased during the study period. On the other hand, CO_3 and SO_4 containing minerals (Malachite and Langite) showed substantial dissolution. This indicates considerable amount of

Cu solubilized during the study period. Similarly, considerable amount of Zn solubilized from Zincite and $ZnCO_3$.

Table 2: Saturation index values of minerals having precipitation potential in the MSW samples

	TMSW		
Mineral	7 Days	14 Days	21 Days
Antlerite(Cu)	1.109	1.761	1.791
Aragonite(Ca)	2.107	1.617	0.907
Azurite(Cu)	6.605	6.789	6.139
$Ca_4H(PO_4)_3$:$3H_2O$(soil)	4.58	2.078	2.443
Calcite(Ca)	2.251	1.76	1.051
$CuCO_3$(soil)	1.042	1.129	1.14
Langite (Cu)	2.53	3.191	2.549
Magnesite ($MgCO_3$)	1.378	0.865	0.155
Malachite($CuCO_3$)	5.132	5.229	4.567
$MnHPO_4$(soil)	4.353	4.128	4.964
Tenorite (Cu)	2.481	2.491	1.818
Vaterite(Ca)	1.685	1.194	0.484
$Zn_3(PO_4)$2:$4H_2O$(soil)	5.988	5.408	5.956
$ZnCO_3$(soil)	2.804	2.739	2.285
Zincite	1.353	1.21	0.073

Vermitechnology and lab scale study

3.2. Conversion of TSW through vermitechnology: Table 3 depicts the availability of exchangeable NPK in various treatments under vermicomposting with two different earthworm species viz. *Eisenia fetida* and *Metaphire postheuma* during the period of incubation. Interestingly, vermicomposting with both the species showed significant increment in N mineralization. This may be due to increased microbiological activity in the vermicomposted product. Earthworms actually enhance microbial activity (Fracchia*et al.*, 2006; Lazcano*et al.*, 2008).

P solubility also increased significantly over time under vermicomposting (Table 2).This corroborates the findings of other workers who observed stimulating effect of earthworms on phosphorous availability in soil (Kaviraj and Sharma,2003; Tognetti*et al.*, 2005).

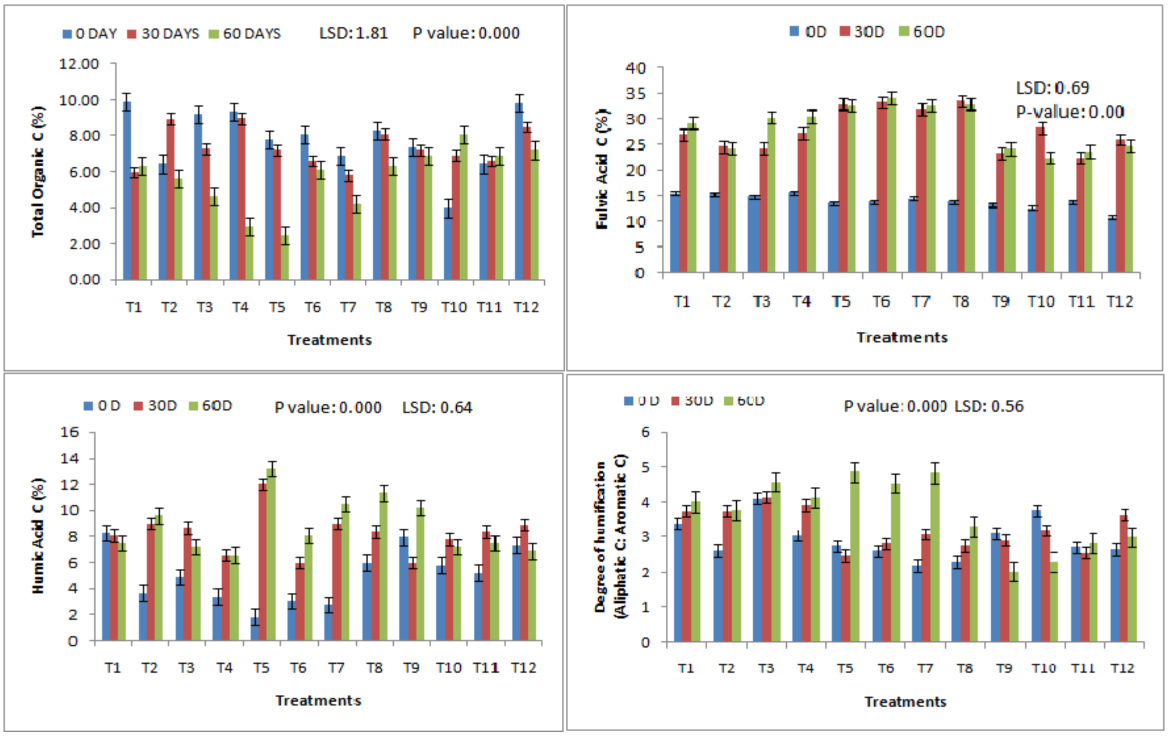
The highest increase in K status has been found in vermicomposting of *Eisenia fetida* with MSW only (469.06 mg kg^{-1}). Kaviraj and Sharma (2003) have reported that enhanced number of microflora in the gut of earthworm might have played an important role in increasing the potassium content during the vermicomposting process.

Table 3: Nutrient availability in vermicomposted and composted TSW

Eisenia fetida	**N(mg/kg)**	**P(mg/kg)**	**K(mg/kg)**
MSW	324.8±28	125.13±3.15	469.06±18.09
MSW+CD,2:1	1131.2±5.6	192.86±8.48	435.46±53.07
MSW+CD,4:1	1148±14	190.83±15.30	440.26±8.92
CD	938±28	638.42±27.31	403.93±8.20
Metaphire posthuma	**N(mg/kg)**	**P(mg/kg)**	**K(mg/kg)**
MSW	1064±28	162.94±31.94	403.6±24.75
MSW+CD,2:1	1106±42	190.23±33.73	464.66±22.78
MSW+CD,4:1	1260±70	226.41±26.27	456.26±22.98
CD	1274±24.24	265.03±19.29	407.46±10.32
Composting	**N(mg/kg)**	**P(mg/kg)**	**K(mg/kg)**
MSW	851.2±5.6	122.03±13.25	495.53±52.75
MSW+CD,2:1	980±14	173.45±21.71	489.06±36.70
MSW+CD,4:1	1134±14	175.34±14.14	486.13±2.19
CD	910±14	310.78±34.23	505.6±36.24

Fig 1 represents the changes in TOC, FAC, HAC and degree of humification during the vermicomposting process. Significant reduction in pH was observed under all treatments. However, maximum reduction in pH was observed under T3 followed by T2, T7, and T6 (LSD= 0.027). Such reduction in pH could be due to production of CO_2, ammonia, NO_3^- and organic acids during vermicomposting process (Deka et al., 2011). Humified OC i.e. fulvic acid, humic acids and humin in particular, represents the most persistent pool of OC with mean residence times of several hundreds of years. Significant reduction in TOC was observed with gradual increase in FAC and HAC during vermicomposting process. Maximum FAC was recorded under T5 followed by T6, T7 and T8 (LSD = 0.69). Whereas, highest HAC was recorded under T5 followed by T8 and T7 (LSD = 0.64). Degree of humification is represented by a ratio of aliphatic and aromatic C content. Interestingly, substantial reduction in degree of humification was observed under T7 followed by T9, T6 and T5. Therefore, the study depicts that although *Eisenia fetida* is a prolific decomposer but *Metaphire posthuma* is a better C sequester.

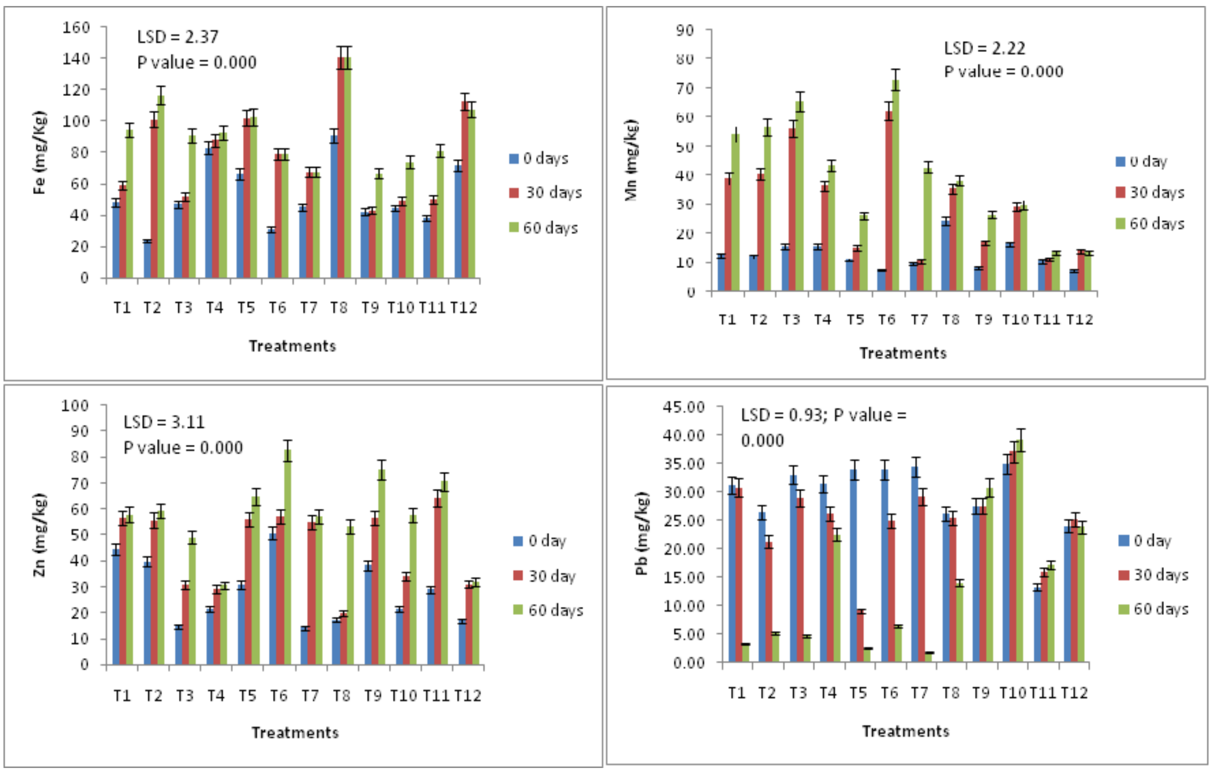
Fig 1: Periodic changes in TOC, FAC, HAC and degree of humification during the vermicomposting process



3.3 Changes in heavy metals during vermicomposting

Concentration of different trace elements under few selected treatment combinations under bioconversion was analyzed (Fig. 3). Three of these elements viz. Fe, Mn and Zn are essential micronutrients for plants and Pb is known as a pollutant. Fascinatingly, we have found that extent of bioavailability of both essential (Fe, Mn and Zn) and non-essential (Pb) heavy metals substantially differed on a temporal scale under aerobic composting and vermiconversion systems. This may be due to inter-specific differences in the dietary intake of elements, in physiological and morphological characteristics, chemical species requirements, excretion and detoxification (Nannoni et al., 2011). Moreover, exposure to heavy metals induces synthesis of metallothionein isoform in earthworm intestines (Dai et al., 2004). This metal binding protein in earthworm gut can detoxify metal ions (As, Cd, Hg, Si, Al, Fe etc.) to a considerable extent (Maity et al., 2009).

Fig 2: Changes in heavy metal concentrations during the process of vermicomposting



The total bacterial count in TSW mixtures (table 3) vindicated the nutrient enhancement and C mineralization under bio-composting processes. Increase in microorganisms probably contributed towards accelerated nutrient availability under vermicomposting. TSW + CD (4:1) found to be a good substrate for microbial growth.

Table 3: Impact of vermicomposting on bacterial growth in TSW mixtures (mean± standard deviation)

Treatment	**No. of bacteria/ml ($x10^5$)**
*VC: TSW + CD (4:1) (*Metaphire posthuma)*	82±4.21
VC : TSW + CD (4:1) (*Eisenia fetida)*	75±5.8
Compost : TSW + CD (2:1)	67±3.7
P value (0.05)	0.002

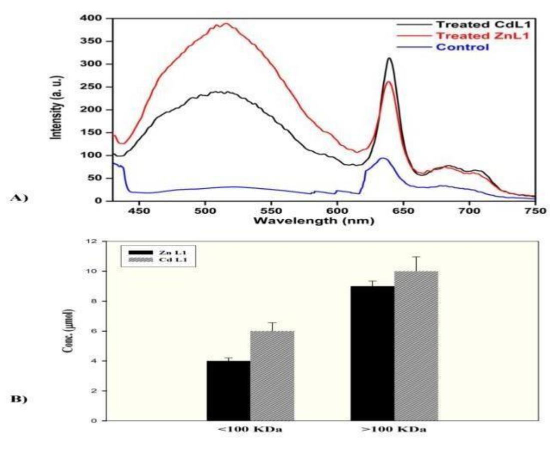
* VC: Vermicompost

3.4 Metal accumulation in earthworm intestine: A fluorescence probe based study

The emission peaks for the treated samples clearly confirmed the signature of the fluorescence tagged metal compounds bound with proteins of higher than 100 KDa molecular mass (Fig 3a). Interestingly, no similar peaks were observed in control samples between 450 to 550 nm wavelengths of the fluorescence spectrum. However, the emission peaks at 640, 680, and 710 nm should probably be ascribed to some other fluorescent biomolecules that should also occur in the earthworm guts. Therefore, similar peaks were also detected in the control samples. Moreover, high concentration of Zn and Cd complexes were detected in >100 KDa as compared to the <100 KDa proteins (Fig 3b). All These results indicate that one or more efficient metal binding proteins with high molecular mass should also play a significant role in binding a wide range of toxic along with the well-known metallothioneins.

Fig 3: (a) The fluorescence emission peaks of Cd and Zn-ligand complex treated (Treated CdL1 and Treated ZnL1)and untreated (control) earthworm gut protein (above 100 KDa).

(b) The accumulation concentration (µM) of CdL1 and ZnL1 in <100KDa and >100 KDa protein complexes in the earthworm intestines.



3.5 Field experiment

The two year long field experiment has been completed. As discussed in the earlier section, different combinations of vermicomposted MSW were used as nutritional source in rice. Both *boro* and *sali* (*Kharif*) rice cultivation was undertaken on the same experimental field in consecutive manner starting with *boro* rice during November 2013. The soil under study is acidic in reaction with moderate bulk density (BD), high nitrogen (N), phosphorus (P) and iron (Fe) but low in potassium (K)(Table 1). TOC content of the soil was on higher side as found in most of the North East soil.

Table 4: Basic physicochemical properties of the soil under study

Paramaters	Result
pH	5.3±0.08
Bulk density(g/cc)	1.31±0.02
N(mg/kg)	476±74.08
P(mg/kg)	16.73±0.37
K(mg/kg)	5.3±0.13
Soil organic C (SOC) (%)	2.02±0.10
Fulvic acid C (FAC) (%)	1.65±0.20
Humic acid C (HAC) (%)	2.18±0.13

The data on changes in pH and BD was presented in table 2. Interestingly, substantial reduction in bulk density was recorded under vermicomposted treatments. BD reduced by 20-30% after the first *boro* season which went on reducing till the end of the study irrespective of treatment combinations. This implies increase in soil porosity that must facilitate improvement in water holding capacity of soil. Significantly, low BD was recorded in T3 followed by T4, T5, T6, T8, T9, T10, T11 and T12 (LSD 0.002).

Gradual decrease in pH was recorded after the first *boro* season as compared to the initial value and reduced further after the first *sali* season (2013). Afterwards, in the *boro* season pH was raised sharply under all the treatments and reduced in subsequent *sali* season. This may be due to accelerated mineralization of applied vermicomposts leading to release of several organic acids, NH_3 and CO_2 etc. (Saikia et al., 2015, Goswami et al., 2013). However, such reduction was highly prominent in soils treated with only chemical fertilizer (T_1) and NPK100+FYM (T_2).

Table5. Changes in soil pH and Bulk density (BD) under various treatments

Treatments	pH				BD(g cc^{-1})			
	BORO1	SALI1	BORO2	SALI2	BORO1	SALI1	BORO2	SALI2
T1	5.8±0.1	5.2±0.1	6.2±0.1	5.3±0.1	1.0±0.1	1.0±0.1	0.9±0.1	1.0±0.1
T2	5.4±0.1	5.2±0.1	6.1 ±0.1	5.3±0.1	1.0±0.1	0.9±0.1	0.8 ±0.1	0.1±0.1
T3	5.9±0.2	5.6±0.1	6.2±0.1	5.7±0.1	1.0±0.2	1.0±0.1	0.8±0.1	0.7±0.1

T4	5.3±0.1	5.3±0.1	6.3±0.2	5.3±0.2	1.0±0.1	1.0±0.1	0.8±0.2	0.9±0.2
T5	5.8±0.1	5.8±0.3	6.3±0.1	5.6±0.2	1.1±0.1	0.9±0.3	0.9±0.1	0.9±0.2
T6	5.2±0.2	5.1±0.1	6.3±0.2	5.6±0.1	1.1±0.2	0.9±0.1	0.9±0.2	0.9±0.1
T7	6.4±0.1	5.7±0.1	6.4 ±0.1	5.5±0.1	1.2±0.1	1.0±0.1	0.8 ±0.1	1.0±0.1
T8	5.7±0.2	5.6±0.2	6.2±0.1	5.5±0.1	1.1±0.2	0.9±0.2	1.0±0.1	0.9±0.1
T9	5.6±0.1	5.2±0.1	6.0±0.1	5.3±0.1	1.0±0.1	0.9±0.1	0.9±0.1	0.9±0.1
T10	5.7±0.3	5.5±0.2	6.2±0.1	5.7±0.2	1.1±0.3	1.0±0.2	0.8±0.1	0.9±0.2
T11	6.2±0.3	6.1±0.2	6.3±0.1	5.7±0.1	1.0±0.3	0.9±0.2	0.8±0.1	0.9±0.1
T12	5.7±0.1	5.5±0.1	6.3±0.2	5.5±0.1	1.1±0.1	0.9±0.1	0.9±0.2	0.9±0.1
P-value	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00
LSD	0.02	0.06	0.04	0.03	0.06	0.001	0.02	0.002

Table 3 presents the data on changes in major soil nutrients (N, P &K). Interestingly, N mineralization improved gradually after each season of cultivation. Significant increase in mineralizable N was recorded under T3 followed by T4, T5, T2 and T6 (P 0.000, LSD 60.24) after two years of cultivation. Addition of vermicompost may increase N-fixing microorganism in soil by many fold and thus have a long term beneficial effect on soil N mineralization (Masciandaro et al., 2000). P availability in soil gradually increased over seasons till the second *boro* season under all the treatments as compared to the initial value and reduced slightly afterwards (Table 6). This may be due to enhancement in plant uptake of the nutrient. Similar fluctuation in K availability was also evidenced from the study. Significant enhancement in K availability was recorded under T4 followed by T7. Vermicomposting promotes release of several exogenous and endogenous enzymes as well as improvement in CEC of soils (Sahariah et al., 2015).

The impacts of various treatments on soil organic carbon (SOC) and its humified fractions are presented in table 4. The SOC status of the soil has naturally high (table1). The nature of temporal variation in SOC greatly varied between treatments. Overall, SOC reduced or did not change under most of the treatments at the end of the first *boro* season which significantly enhanced in the subsequent *kharif* and *boro* season (P value for year = 0.000). However, based on LSD test, the final SOC stock after two years of continuous cultivation was in the order T2=T7> T3=T8=T9=T12. Our result is in good agreement with recent findings (Sahariah et al., 2015).

Humic acid carbon and fulvic acid carbon is the most vital indicator of the status of intensified humification of soil organic matter. Interestingly, we recorded considerable rise in soil HAC under all treatments (Table 7). Significantly, high HAC was recorded under T7 followed T2, T3, T8, T9 and T12. Similarly, highest FAC was recorded in soils under T7 followed by T8. Therefore, vermicomposted MSW significantly contributed in regard to organic carbon stabilization in soil.

Data on crop growth rate (CGR) and relative growth rate (RGR) during the second year cultivation (*boro* and *kharif*) respectively is presented in the table 8. CGR indicates at what rate the crop is growing as compared to normal, whereas, RGR indicates the rate of growth per unit dry matter. A steady and increasing CGR was recorded under T3, T8 and T9 during *boro* season, whereas, T2, T3, T6, T7 showed similar trend during *sali* (*kharif*) season along with T8 and T9. Therefore plants under T8 and T9 treatments showed above normal growth rate during both the season. However, highest CGR was recorded under T8 in *boro* rice (LSD= 0.33). Similar trend was also observed for RGR.

The benefit of addition of vermicomposted MSW and FYM in soil was convincingly prominent with respect to grain yield of rice. Interestingly, rice production during the first *boro* season (2012-13) was very low under all treatments which enhanced 3-4 folds in the 2nd*boro* season irrespective of applied treatment combinations (table 9). As the first year s*ali* rice was cultivated after the *boro* season, therefore we recorded similar range of grain yield in both the s*ali* crops under all the treatments. In regard to *boro* rice, significantly high grain yield was achieved under T3 and T4 during both seasons (LSD= 0.21) whereas T3, T6, T7 and T8 showed promising impact on s*ali* rice production during both the season (table 9).

Table 6: Changes in available N, P and K in soil under various treatments during the two year rice cultivation

Treatments	Avail N (mg/kg)				Avail P (mg/kg)				Avail K (mg/kg)			
	BORO1	SALI1	BORO2	SALI2	BORO1	SALI1	BORO2	SALI2	BORO1	SALI1	BORO2	SALI2
T1	774.7± 85.5	933.3±427.7	1054.7±42.8	1316±28	8.1±6.8	8.5±1.4	30.9±0.7	19.9±0.7	99.0±31.8	61.8±0.2	71.3±1.5	96.9±56.8
T2	1036± 56	1400±280	1278.7±113.2	1614.7±70.5	17.1±7.3	19.1±0.7	31.5±2.4	24.8±2.3	82.9±34.6	47.8±32.8	50.3±0.6	68.4±17.8
T3	1054.7± 98.3	1166.7±291.4	1353.3±42.8	1773.3±90	20.3±8.6	41.4±1.2	31.4±1.3	32.7±1.1	96.9±56.8	61.3±0.6	73.0±2.0	88.0±26.0
T4	933.3±98.3	1456±56	1092±28	1624±48.5	16.8±8.7	23.8±1.5	32.3±1.2	26.0±0.7	74.8±25.6	52.6±0.3	82.3±2.5	122.9±36.8
T5	980±84	1316.5±315.5	1278.7±126.3	1614.7±42.8	14.6±8.6	31.3±16.1	33.6±2.7	30.0±1.3	93.3±19.3	53.5±0.4	51.5±0.7	74.8±25.6
T6	840±140	1306.7±575.4	1306.7±98.3	1605.3±42.8	26.0±6.9	37.3±1.2	30.8±5.5	24.7±0.6	68.4±17.8	58.6±0.1	91.0±1.0	82.9±34.6
T7	1064±56	1362.7±226.3	1101.3±58.3	1586.7±42.8	36.0±9.4	22.4±0.4	44.0±3.5	27.0±1.0	88.0±26.0	85.8± 0.3	55.0±0.3	113.3±19.3
T8	998.7±132.3	1260±364	1082.7±16.2	1540±28	10.8±7.3	31.9±0.6	18.2±1.7	26.0±1.2	73.6±13.4	59.3±0.3	53.9±1.8	74.1±19.7
T9	1194.7±42.8	1213.3±42.8	1092±28	1530.7±58.3	22.8±8.7	24.0±0.8	23.7±0.4	25.6±0.5	92.9±36.8	61.5±0.3	80.0±1.0	74.2±22.0
T10	1176±112	1054.7±286	1222.7±58.3	1549.3±16.2	9.6±6.3	35.6±1.3	18.9±1.3	26.5±0.8	66.3±20.4	54.4±0.6	61.1±0.7	73.6±13.4
T11	1138.7± 85.5	1540±196	1353.3±42.8	1502.7± 42.8	23.2±11	25.5±0.6	32.7±3.2	25.7±0.6	74.1±19.7	49.2±2.6	71.0±1.0	98.1±33.4
T12	1054.7± 85.5	1409.3±254.1	1297.3±113.2	1484 ± 56	19.6±9.3	32.8±0.8	25.2±2.0	25.4±0.5	74.2±22.0	55.0±11.6	57.2±0.1	69.2±18.3
P-Value	0.00	0.52	0.00	0.00	0.02	0.00	0.00	0.00	0.35	0.01	0.00	0.00
LSD	76.77	252.80	60.24	41.56	6.80	3.88	2.08	0.86	23.89	8.22	1.05	23.91

(mean ± standard deviation) (LSD = least significant difference)

Table 7: Changes in total organic C (TOC), humic acid C (HAC), fulvic acid C (FAC) under different treatment combinations

Treatments	TOC (%)				Humic Acid C (%)				Fulvic Acid C (%)			
	BORO1	SALI1	BORO2	SALI2	BORO1	SALI1	BORO2	SALI2	BORO1	SALI1	BORO2	SALI2
T1	2.5±0.1	2.6±0.3	2.2±0.2	2.6±0.1	1.6±0.1	2.4±0.1	2.2±0.2	2.6± 0.1	2.4±0.1	1.8±0.1	3.0±0.1	2.6±0.2
T2	2.2±0.1	3.1±0.1	2.6 ±0.2	3.1±0.1	1.7±0.1	2.2±0.2	2.6±0.2	3.1± 0.1	1.6±0.1	2.5±0.1	2.5±0.2	3.1±0.1
T3	2.0±0.1	3.4±0.1	4.5±0.3	3.1±0.1	1.8±0.2	2.7±0.1	4.5±0.3	3.1±0.1	2.1±0.2	3.8±0.1	2.8±0.2	3.4±0.2
T4	1.9±0.1	3.5±0.1	2.5±0.2	2.5±0.1	2.2±0.1	2.3±0.2	2.5±0.2	2.5±0.1	1.7±0.1	2.5±0.1	2.6±0.2	2.6±0.1
T5	1.9±0.1	2.7±0.1	2.3±0.2	2.9±0.1	4.2±0.8	1.9±0.2	2.3±0.2	2.9±0.1	1.7±0.2	2.3±0.2	2.3±0.1	3.1±0.1
T6	1.6±0.1	3.9±0.2	2.6±0.3	2.6±0.1	2.3±0.1	2.9±0.1	2.6±0.3	2.6±0.1	1.7±0.1	3.0±0.2	2.5±0.2	2.9±0.1
T7	2.4±0.1	4.0±0.2	3.4 ±0.1	3.3±0.2	2.5±0.1	2.5±0.1	3.4±0.1	3.3±0.2	1.8±0.1	2.7±0.1	2.8±0.2	4.6±0.1
T8	1.8±0.2	3.1±0.2	2.3±0.2	3.1±0.1	2.8±0.2	2.6±0.2	2.3±0.2	3.1±0.1	3.3±0.1	1.9±0.1	3.8±0.2	3.9±0.3
T9	2.2±0.1	4.1±0.2	2.9±0.1	3.1±0.1	4.7±0.2	2.4±0.2	2.9±0.1	3.1±0.1	2.3±0.1	2.6±0.2	3.2±0.3	3.2±0.3
T10	2.1±0.2	2.5±0.1	2.2±0.2	2.6±0.2	2.4±0.3	2.4±0.1	2.2±0.2	2.6±0.2	2.2±0.3	1.8±0.1	2.9±0.2	2.6±0.3
T11	2.3±0.4	3.3±0.2	2.9±0.3	2.9±0.1	2.1±0.4	2.3±0.1	2.9±0.3	2.9±0.1	2.4±0.1	2.3±0.2	3.4±0.3	2.9±0.1
T12	2.4±0.1	2.9±0.2	2.8±0.1	3.0±0.2	1.7±0.2	2.5±0.2	2.8±0.1	3.0±0.2	2.3±0.1	2.0±0.2	3.3± 0.3	3.1±0.1
Treatment (T)	0.000				0.000					0.000		
Year (Y)	0.000				0.000					0.000		
T x Y	0.000				0.000					0.000		
LSD for T	0.100				0.187					0.176		

(Mean ± standard deviation) (LSD = least significant difference)

Table8: Impact of various treatments on Crop Growth Rate (CGR) and Relative Growth Rate (RGR) of both boro and Sali (kharif) rice

	CGR				**RGR**			
Treatments	BORO2		SALI2		BORO2		SALI2	
	Panicle stage	Harvesting stage	Panicle stage	Harvesting stage	Panicle stage	Harvesting stage	Panicle stage	Harvesting stage
T1	0.9±0.1	1.1±0.5	1.0±0.1	0.6± 0.6	0.1±0.1	0.1±0.1	0.1±0.1	0.1±0.1
T2	0.8±0.3	0.6±0.3	1.0±0.2	1.1± 1.2	0.1±0.1	0.1±0.1	0.1±0.1	0.2±0.1
T3	0.7±0.1	1.2±0.2	0.7±0.2	1.0±0.4	0.1±0.1	0.1±0.1	0.1±0.1	0.2±0.1
T4	0.6±0.3	0.6±0.4	1.7±0.5	0.4±0.2	0.1±0.1	0.1±0.1	0.1±0.1	0.1±0.1
T5	1.0±0.3	0.7±0.4	0.8±0.6	1.1±0.7	0.1±0.1	0.1±0.1	0.1±0.1	0.2±0.1
T6	1.0±0.2	0.9±0.8	0.8±0.4	1.4±0.8	0.1±0.1	0.1±0.1	0.1±0.1	0.2±0.1
T7	1.1±0.2	0.7±0.3	0.7±0.3	2.0±1.5	0.1±0.1	0.1±0.1	0.1±0.1	0.2±0.1
T8	1.0±0.2	1.4±0.5	1.0±0.1	1.2±0.4	0.1±0.1	0.1±0.1	0.1±0.1	0.2±0.1
T9	1.1±0.1	1.1±0.8	1.2±0.4	1.4±0.8	0.1±0.1	0.1±0.1	0.1±0.1	0.2±0.1
T10	1.0±0.4	0.8±0.6	1.4±0.8	1.1±0.6	0.1±0.1	0.1±0.1	0.1±0.1	0.2±0.1
T11	1.2±0.1	0.4±0.2	1.4±0.2	1.1±0.1	0.1±0.1	0.1±0.1	0.1±0.1	0.2±0.1
T12	1.0±0.1	0.8±0.1	0.9±0.5	1.9±0.8	0.1±0.1	0.1±0.1	0.1±0.1	0.2±0.1
LSD	0.007	0.393	0.333	0.634	0.007	0.021	0.010	0.027

(Mean ± standard deviation) (LSD = least significant difference)

Table 9: Yield of rice under various treatments (t ha^{-1})

Treatments	Yield			
	BORO1	BORO2	SALI1	SALI2
T1	2.5±0.1	12.2±0.1	6.6±0.5	5.9±0.8
T2	2.8±0.2	12.1 ±0.3	6.6±0.3	6.2±0.8
T3	3.1±0.1	12.3±0.1	6.7±0.4	6.2±0.9
T4	3.9±0.4	12.1±0.1	6.5±0.3	5.9±0.6
T5	2.5±0.1	12.1±0.1	6.2±0.5	5.5±0.1
T6	2.9±0.2	12.0±0.2	6.7±0.2	5.5±0.4
T7	2.6±0.1	12.2±0.1	6.7±0.5	6.0±0.8
T8	2.3±0.2	11.9±0.1	6.9±0.4	6.5±0.1
T9	2.3±0.4	12.1±0.3	6.6±0.1	5.6±0.4
T10	2.1±0.2	12.1±0.1	6.6±0.2	5.4±0.2
T11	2.3±0.3	12.0±0.2	6.2±0.5	5.8±0.5
T12	2.8±0.3	12.0±0.3	6.4±0.2	5.3±0.1
P- value	0.000	0.009	0.005	0.000
LSD	0.213	0.145	0.892	0.453

(Mean ± standard deviation) (LSD = least significant difference)

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Submitted:

3/8/13

Assistant Professor
Dept. of Environmental Science
Tezpur University

SURAJIT CHAKRABORTY & CO.
CHARTERED ACCOUNTANTS
C/o-Akashganga Bldg, Ist floor, M.C. Road, Near Jonaki Cinema,
Tezpur (784001), Tel-8011631406, E-mail :- surajitc2011@yahoo.com

AUDITOR'S REPORT

I have compiled and audited the attached Receipts and Payments account for the period 20.02.2015 to 31.08.2015 of **Dr Satya Sundar Bhattacharya for the scheme 'Sustainable Utilization of Solid Waste as a source of Plant Nutrient in Rice based Agro Ecosystem of North East India'** of Department of **Environmental Science :: Tezpur University** and I report that :-

(A) I have obtained all the information and explanations which to the best of my knowledge and belief, were necessary for the purposes of the audit.

(B) In my opinion, proper books of account have been kept by the head office and branches of the assessee so far as it appears from my examination of the books.

(C) In my opinion and to the best of my information and according to explanations given to me the said accounts,read with notes thereon, if any, give a true and fair view :

(i) In the case of the Receipt & Payment account of the balance of the assessee for the year ended on that date.

Place :- Tezpur
Date :- 04-02-2016

SURAJIT CHAKRABORTY & Co
MRN- 305054
TEZPUR
CHARTERED ACCOUNTANT

For Surajit Chakraborty & Co.
Chartered Accountants

CA Surajit Chakraborty
(Propreitor)
M. No. - 305054

SURAJIT CHAKRABORTY & CO.
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C/o-Akashganga Bldg, Ist floor, M.C. Road, Near Jonaki Cinema,
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Dr Satya Sundar Bhattacharya

Title of the Scheme- Sustainable Utilization of Solid Waste as a source of Plant Nutrient in Rice based Agro Ecosystem of North East India

Department of Environmental Science :: Tezpur University

Reciept & Payment Account for the period from 20.02.2012 to 31.08.2015

	Reciept	Amount(Rs.)		Payment	Amount(Rs.)
To	Opening Balance	-	By	Staff	5,30,506.00
"	Grant received from CSIR HRDG, New Delhi Sch No-38(1307)/11/EMR-11	15,39,500.00	"	Contingency	4,08,994.00
			"	Equipment	6,00,000.00
			"	Closing Balance	-
		15,39,500.00		-	**15,39,500.00**

In terms of my report of even date attached.

Place :- Tezpur
Date :- 04-02-2016

For Surajit Chakraborty & Co.
Chartered Accountants

SURAJIT CHAKRABORTY & Co. MRN- 305054 TEZPUR CHARTERED ACCOUNTANTS

CA Surajit Chakraborty
(Propreitor)
M. No. - 305054

(From the date of commencement : 1st April 2012 , till 31st March : 2013)

Scheme Number: 38(2275)/11/EMR / -II date 05/11/2011

Title of the Research Scheme : "**Sustainable Utilization of solid Waste as a Source of Plant Nutrient in Rice Based Agroecosystem of North-East Ind**

Name of the Investigator-in-Charge : Dr. S.S. Bhattacharya

Date of Commencement : 20th February 2012 Date of Termination : 20th February 2015

Receipts (Particulars of grants received)								Payments (Particulars of grants spent)						
Period (ending 31March)	Cheque No., date & Amount (Rs)	Stipend period ending 31 March (Rs)	Contingency (Rs)	Scientist Allowance (for Emeritus Scientist Scheme only)	Equipment Grant (Rs)	HRA + MA	Total (Rs)	Stipend (Rs)	Contingency (Rs)	Scientist Allowance (for Emeritus Scientist Scheme only)	Equipment Grant (Rs)	HRA + MA	**Total (Rs)**	**Balance (Rs)**
1st April 2012 to 31st March 2013	Opening Balance: 724667/-(014021 Dt.16/01/2012) +Rs 1,70,953/- TOTAL= **8,95,620/-**	1,85,620/-	110000/-	Nil	6 Lakh	Nil	895620/	124,506/-	115,659/-	Nil	600,000/-	Nil	**840165/-**	**554**

The balance amount of Rs. 55455.00 (fifty five thousand four hundred and fifty five) only is under the 'Staff/Stipend' head of service.

Signature of Registrar with Stamp

Signature of Finance Officer with Stamp

Signature of PI with Stamp

Bhattacharya

P.I.
&
Assistant Professor
Dept. of Environmental Science
Tezpur University

o/c

Consolidated Statement of Accounts

(From the date of commencement : 1st April 2013 , till 31st March : 2014)

Scheme Number: 38(2275)/11/EMR / -II date 05/11/2011

Title of the Research Scheme : "**Sustainable Utilization of solid Waste as a Source of Plant Nutrient in Rice Based Agroecosystem of North-East In**

Name of the Investigator-in-Charge : Dr. S.S. Bhattacharya

Date of Commencement : 20th February 2012 Date of Termination : 20th February 2015

	Receipts (Particulars of grants received)							Payments (Particulars of grants spent)						
Period (ending 31March)	Cheque No., date & Amount (Rs)	Stipend period ending 31 March (Rs)	Contingency (Rs)	Scientist Allowance (for Emeritus Scientist Scheme only)	Equipment Grant (Rs)	HRA + MA	Total (Rs)	Stipend (Rs)	Contingency (Rs)	Scientist Allowance (for Emeritus Scientist Scheme only)	Equipment Grant (Rs)	HRA + MA	**Total (Rs)**	Balance (Rs)
1st April 2013 to 31st March 2014	Opening Balance: **55,455/-**	1,68,000/-	110000/-	Nil	Nil	Nil	278000/	1,68,000/-	1,10,000/-	Nil	Nil	Nil	**2,78,000/-**	N

B 19/7/14

Signature of Registrar with Stamp

Registrar Tezpur University

Signature of 19.7.14 Finance Officer with Stamp

Finance Officer Tezpur University

Signature of PI with Stamp

P. I. & Assistant Professor Dept. of Environmental Science Tezpur University

Consolidated Statement of Accounts

(From the date of commencement : <u>1st April 2014</u> , till 28th February, <u>2015</u>)

Scheme Number: 38(2275)/11/EMR / -II date 05/11/2011

Title of the Research Scheme : **"Sustainable Utilization of solid Waste as a Source of Plant Nutrient in Rice Based Agroecosystem of North-East India"**
Name of the Investigator-in-Charge : Dr. S.S. Bhattacharya
Date of Commencement : 20th February 2012

Date of Termination : 20th February 2015

Receipts (Particulars of grants received)							Payments (Particulars of grants spent)							
Period (ending 31March)	Cheque No., date & Amount (Rs)	Stipend period ending 31 March (Rs)	Contingency (Rs)	Scientist Allowance (for Emeritus Scientist Scheme only)	Equipment Grant (Rs)	HRA + MA	Total (Rs)	Stipend (Rs)	Contingency (Rs)	Scientist Allowance (for Emeritus Scientist Scheme only)	Equipment Grant (Rs)	HRA + MA	**Total (Rs)**	**Balance (Rs)**
1st April 2014 to 28th February 2015	Opening Balance: **2,54,834/- (through bank transfer)**	1,54,000/-	1,00,834/ -	Nil	Nil	Nil	2,54,834/-	1,54,000/-	1,00,834/-	Nil	Nil	Nil	**2,54,834/-**	Nil

Signature of Registrar with Stamp

Registrar
Tezpur University

Signature of Finance Officer with Stamp 10/3/15

Finance Officer
Tezpur University

Signature of PI with Stamp

&
Assistant Professor
Dept. of Environmental Science
Tezpur University

Consolidated Statement of Accounts

(From the date of commencement : 1st March 2015 till 31st August, 2015)

Scheme Number: 38(2275)/11/EMR / II date 05/11/2011

Title of the Research Scheme : **"Sustainable Utilization of solid Waste as a Source of Plant Nutrient in Rice Based Agro ecosystem of North-East India"**

Name of the Investigator-in-Charge : Dr. S.S. Bhattacharya

Date of Commencement : 20th February 2012

Date of Termination : 31st August 2015

	Receipts (Particulars of grants received)							Payments (Particulars of grants spent)						
Period (ending 31March)	Cheque No., date & Amount (Rs)	Stipend period ending 31 March (Rs)	Contingency (Rs)	Scientist Allowance (for Emeritus Scientist Scheme only)	Equipment Grant (Rs)	HRA + MA	Total (Rs)	Stipend (Rs)	Contingency (Rs)	Scientist Allowance (for Emeritus Scientist Scheme only)	Equipment Grant (Rs)	HRA + MA	**Total (Rs)**	**Balance (Rs)**
1st March 2015 to 31st August 2015	Opening Balance: **1,29,834/- (through bank transfer)**	84,000/-	45,834/-	Nil	Nil	Nil	1,29,834/-	84,000/-	45,834/-	Nil	Nil	Nil	**1,29,834/-**	Nil

Signature of Registrar with Stamp

Registrar
Tezpur University

Signature of Finance Officer with Stamp
16.11.15

Finance Officer
Tezpur University

Signature of PI with Stamp

P. I.
&
Assistant Professor
Dept. of Environmental Scie
Tezpur University