Indian Journal of Chemical Technology
Vol. 13, January 2006, pp. 24-29

# Bioprocessing and resource recovery of solid waste by low-income citizens

S Gajalakshmi, P Sankar Ganesh & S A Abbasi*

Centre for Pollution Control & Energy Technology, Pondicherry University, Pondicherry 605 014, India

E-mail: prof_abbasi@vsnl.com

*Received 17 December 2004; revised received 18 October 2005; accepted 28 November 2005*

The know-how developed earlier by the authors for resource recovery from household wastes, crop wastes, and weeds was extended to subsistence farmers and householders in rural Pondicherry, India, with an objective of identifying technological, operational, and sociological problems which may be faced when transferring this know-how to similar rural populations in the developing countries. The aim of the study was also to refine the know-how for eliminating the problems. In this paper the results of solid waste management by composting-vermicomposting at 53 sites in four villages of Pondicherry are presented. At all sites the pH, temperature, and C/N ratio were systematically measured for process monitoring and control. The results establish the suitability of the know-how for easy adoption by low-income householders and its propensity to achieve pollution control with income generation.

**Keywords**: Composting, Vermicomposting, Resource recovery, Water hyacinth, Earthworms
**IPC Code**: Int. Cl.$^7$ C05F9/00

In a series of recent publications[1-4] studies on the design and optimization of vermireactors have been described. Efforts have simultaneously been made to draw farmers and other householders in the rural and suburban Pondicherry towards utilizing the know-how for composting/vermicomposting. These initiatives were taken with the hope that popularization of composting/vermicomposting among the rural population would encourage it to drive benefits from biodegradable solid wastes. As of now, such waste is a major source of land and water pollution. It also, indirectly, harms public health by its inadvertent role in supporting insects and rodents.

Studies on extending the composting/vermicomposting know-how to villages were conducted at three locations.

i) *Kalapet and Pillaichavady*: This location, close to the north-eastern extremity of Pondicherry involves two adjacent villages. Both villages lie on the coast and the majority of the population in both comprises of fisherfolk.
ii) *Abishegapakkam*: This location is about 8 km south of downtown Pondicherry and involves people engaged in subsistence agriculture. Paddy, millets, groundnuts, sugarcane, and casuarina are the major crops. Due to the agricultural activities the village generates large quantities of agrowaste.

   About 9 water bodies, comprising of ponds and small lakes, in this village form another source of income for the villagers by way of inland fisheries. Unfortunately, the water-bodies are infested by water hyacinth and other weeds. As these weeds make fishing difficult, they are harvested and left along the embankment to decompose. This creates bad odour and breeding of mosquitoes.
iii) *Seliamedu*: This location is about 12 km south of downtown Pondicherry. As in case of Abishegapakkam, the majority of populace in Seliamedu is also engaged in farming.

## Experimental Procedure

In each village, the householders were supplied with discarded cardboard boxes of approximate size 30×30×60 cm. Each household was also provided with a thermometer (0-100°C) for monitoring the temperature.

Prior to initiation of the work, group training was given regarding as per the system developed and how to put the compost for the laying of material for compost, operation of the compost reactors vermicomposting[1,2]. As per the process monitoring involved, a mere reading of temperature, and the process control was easily achieved by simple precautions such as daily sprinkling of certain quantity of water, and the timely covering or overturning of the reactor contents, which was easily mastered by the generally illiterate but naturally skillful housewives.

## Results and Discussion

### Observations at different locations

The different types of wastes used by the villagers of Kalapet and Pillaichavady are depicted in Fig. 1.

When work was started at Abishegapakkam it was learnt that in the village 'composting' has been traditionally done by piling up household refuse and cowdung in large heaps, topped with soil. The heaps are left unattended for about an year and the resulting 'compost' is then used as a fertilizer supplement. This practice is clearly sub-optimal.

Trials were made to encourage the householders to do composting round the year in used packing boxes so that larger quantities of different substrates can be composted and utilized round the year.

Initially, composting was started in about 5-6 households. Later about 17 households joined in the initiative.

The various wastes used for the study at different sites in this village are depicted in Fig. 2.

At the beginning vermicomposting was done in pits 1×0.5×0.5m dug underground. Vermibeds were prepared by filling the pits from below to the top with a layer of broken bricks, followed by 20 cm of sand and 30 cm of garden soil. After the vermibeds were moistened, 200-250 locally collected earthworms – *Lampito mauritii* and *Perionyx excavatus* – were introduced. On top of the vermibed, the compost earlier obtained from one or the other substrate was applied as feed for the earthworms. The vermibed was kept moist by sprinkling water when required. The vermicast generated was harvested once in 10 days.

The problems encountered, and solved, are summarized below.

i) Once a composting process is set in motion, the contents of the substrate undergoing composting should get heated up due to the exothermic nature of the aerobic fermentation process. If the composting occurs efficiently, the temperature of the contents rises significantly. Such rise in temperature helps in killing most pathogens and may also inactivate seeds of harmful plants such as weeds. But when the composting units were set-up at Abishegapakkam, adequate rise in temperature didn't occur. Householders were then advised to cover the compost boxes with plastic sheets to assist insulation. This move significantly helped in attaining higher temperatures during composting than were occurring in uncovered boxes. The temperature was hovering around 35-40ºC in uncovered boxes, whereas the temperature in the covered boxes reached upto ~55ºC.

ii) At one of the sites where water hyacinth compost had been applied to fertilize tomato plants already grown to a fair height, the plants wilted and died. This led to great apprehension in the minds of the farmers that compost/vermicompost generated from water hyacinth and other weeds might be toxic to plants.

In order to check whether it was indeed so, systematic studies were conducted on the impact of water hyacinth compost/vermicompost on different species of plants as described earlier in Gajalakshmi and Abbasi[5]. The studies confirmed that water hyacinth compost as well as vermicompost are actually beneficial to plant

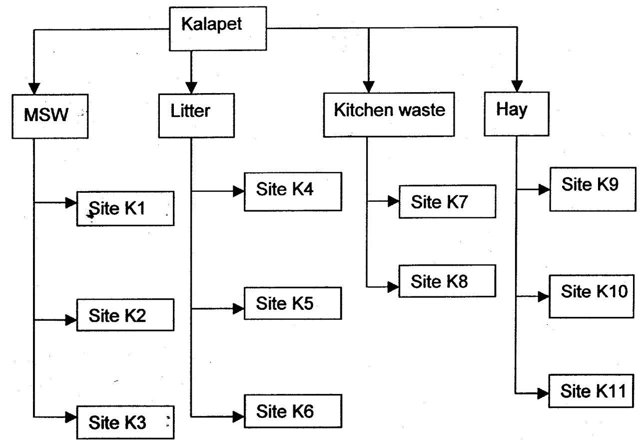


Fig. 1—Various substrates studied at different sites (K=Kalapet)

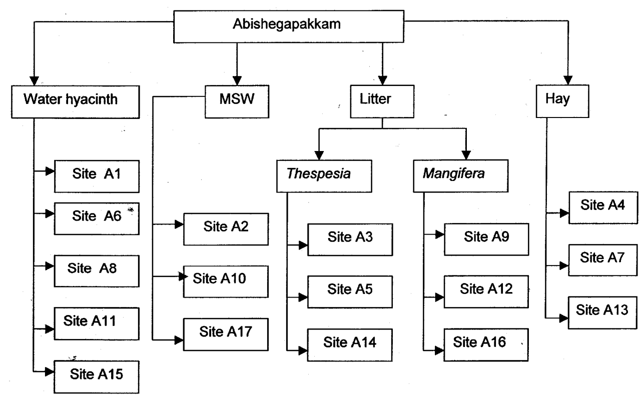


Fig. 2—Various sites with different wastes as substrates for composting in Abishegapakkam

growth. Further investigations on the case of wilting of the tomato plants revealed that the phytotoxicity had occurred due to a toxic run-off from a small-scale dyeing unit.

iii) When vermicomposting was done in pits dug underground the earthworms tended to migrate away from the pits. To prevent this, cloth nylon mesh was put just above the dug surface. Over the mesh, the vermibed was prepared and the earthworms were released there.

iv) Another problem faced was the flooding of water into the vermipit during rains. Hence, small bunds made of bricks were built around the vermipits. Thereafter, it was advocated that vermi-composting be preferably done in wooden cases.

The substrates being composted at different sites at Seliamedu are depicted in Fig. 3.

**Influence of temperature, pH, and C:N ratio on composting**

***Temperature***

The normal pattern after a composting unit is set-up is that aerobic fermentation causes gradual degradation of the biodegradable portion of the carbonaceous organic compounds contained in the substrate. The process is exothermic and lifts the temperature of the contents to above ambient. In efficiently occurring composting process, the reactors may reach upto 55ºC from ambient mesophilic range ~ 35ºC. Then, as the oxygen entrained in the substrate is significantly depleted, and becomes limiting, the rate of composting slows down which causes a fall in temperature from its peak value. At that stage the covers of the reactors are removed, the contents stirred, and covered again. This triggers the second cycle of composting as the reactants get warmed up again and the reactor temperature gradually rises to another peak. After about 3 weeks of these cycles occurring again and again, usually at 3-5 day intervals, the composting is complete and further stirring and covering does not lead to further rise in temperature.

Similar pattern of 'temperature waves' were observed in all the composting efforts at the three locations, though the peak temperatures differed from substrate to substrate; the pattern is exemplified in three of the curves presented in Fig. 4. It was felt, that, minor adjustments in process control such as better covering of reactors (to prevent heat loss), a little higher concentration of the inoculum (cowdung), and with moisture maintained at optimum levels, timely addition of water would easily improve the efficiency of the composting in these reactors. Such modifications were within the grasp of the villagers, and now the aim is to implement these during the extension work planned for future.

***pH***

The average *p*H value of the compost obtained at the end of the process with water hyacinth as substrate from different sites was 7.1 at Abishegapakkam and 7.3 at Seliamedu. The compost of the other weed, *Ipomoea* had *p*H 7.4. In the systems with mango (*Mangifera indica*) leaf litter as substrate, the *p*H value was 7.4 and 7.5 at Abishegapakkam and Seliamedu respectively. The corresponding *p*H values for Thespesia (*Thespesia populnea)* leaf litter were

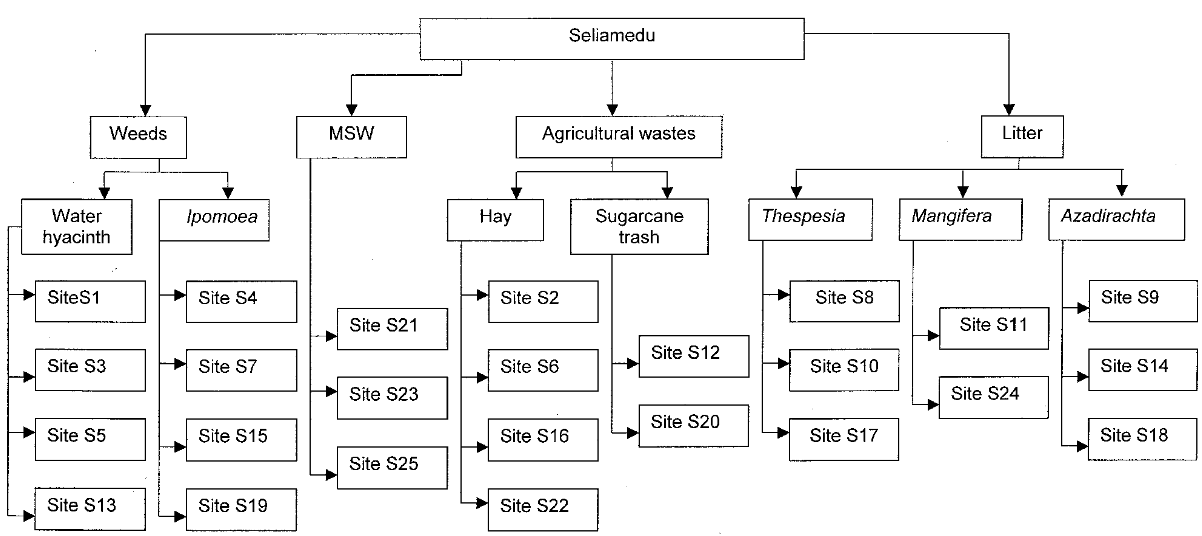


Fig. 3—Various sites with different wastes as substrates for composting in Seliamedu

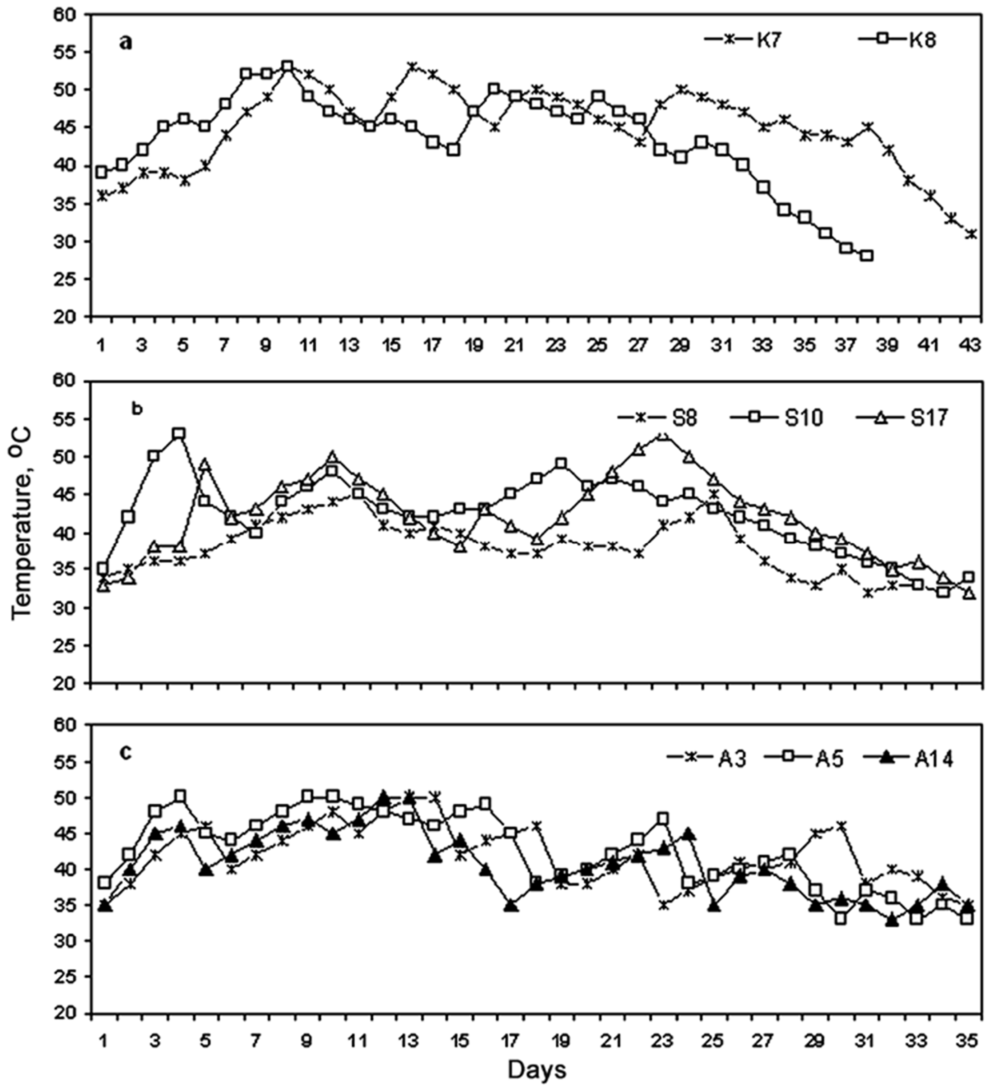


Fig. 4—Illustrative figures of temperature waves encountered during the composting of different substrates at different sites

7.4 and 7.6 in Abishegapakkam. The compost obtained with municipal solid waste (MSW) as substrate had average *p*H 7.2 and 7.6. The hay compost had an average *p*H of 6.8 and 7.5 in Abishegapakkam and Seliamedu respectively; whereas it was 8.0 in the case of sugarcane trash in Seliamedu.

According to Jimenez & Garcia[6], mature compost generally has a *p*H value between 7 and 8; it was within this range that the *p*H of all the compost obtained in the three locations eventually laid. Further, throughout the process, the *p*H of no composting units was less than 5.9 indicating that the contents had not undergone putrefaction at any stage and no appreciable amounts of troublesome organic acids were apparently produced.

***C/N ratio***

C/N ratio is important because plants cannot assimilate mineral nitrogen unless the ratio is 20:1 or less[7]. Loquet[8] reported more rapid degradation of substrate during vermicomposting than composting[9]. Composting and vermicomposting both result in loss of carbon because of mineralization. Composting is essentially an aerobic fermentation process in which biodegradable organic compounds are metabolized by aerobes. In the process, some of the carbon is lost to the atmosphere as carbon dioxide which is generated by microbial respiration. On the other hand, the nitrogen present in the substrate remains bound as the substrate is composted. Due to these factors, the C/N ratio of a substrate goes down during composting. The change in the C/N ratio as the composting proceeds from start to finish can even be used as an indicator of the efficacy of the composting.

What should be the C/N ratio of an ideal compost? Opinions vary; different workers have deemed different C/N ratio as ideal, as summarized below:

| Recommendation on the C/N ratio of a compost | Author(s) |
|---|---|
| Should be in the range 15-25 | Mathur *et al.*[10] |
| | Canet and Pomares[11] |
| Should be less than 22 | Zucconi and Bertoldi[12] |
| Should be lower than 20 | Clarion *et al.*[13] |
| Should be close to 15 | Juste[14] |

It can be said that C/N ratio of a compost should not be too high, as an application of such composts can result in immobilization of available nitrogen, causing an N-deficiency in plants[15,16]. Conversely, C/N values of composts must not be too low, as N-mobilization and subsequent N-toxification and efflux to groundwater may occur[17,18].

Extended composting periods will reduce long-term N-availability, primarily since as composting proceeds a higher proportion of N will be converted to available, organic forms, either within the microbial biomass or incorporated into developing humic acid substances[19]. In the former case, release of N is dependent upon microbial death or predation by grazing protozoa and nematodes. In the latter, humic substances are relatively recalcitrant, having a high half-life within the soil, thus requiring longer to release nitrogen[20].

In Abishegapakkam (Fig. 5) the water hyacinth compost had an average C/N ratio of 19.3 whereas it was 19.6 in Seliamedu (Fig. 6). The compost of the other weed *Ipomoea* had an average C/N ratio of 22.7 in Seliamedu. The MSW compost had higher C/N ratio of 22.9 and 23.6 in Abishegapakkam and Seliamedu respectively. As for the leaf litter composts, the one from *Mangifera* had a ratio of 22.5 and 22.7; whereas *Thespesia* compost had C/N ratio of 22.5 and 22.7 at Abishegapakkam at the composting locations. The hay compost had a C/N ratio of 24.6 at Abishegapakkam and 22.3 in Seliamedu. The sugarcane trash compost had C/N 22.1.

The values of C/N ratio obtained in these studies, fall within the range of 19.3-24.6: in most of the cases these are between 22 and 23. It is by and large in conformity with the recommendations of Zucconi and Bertoldi[12]; Mathur *et al.*[10] and Canet and Pomares[11].

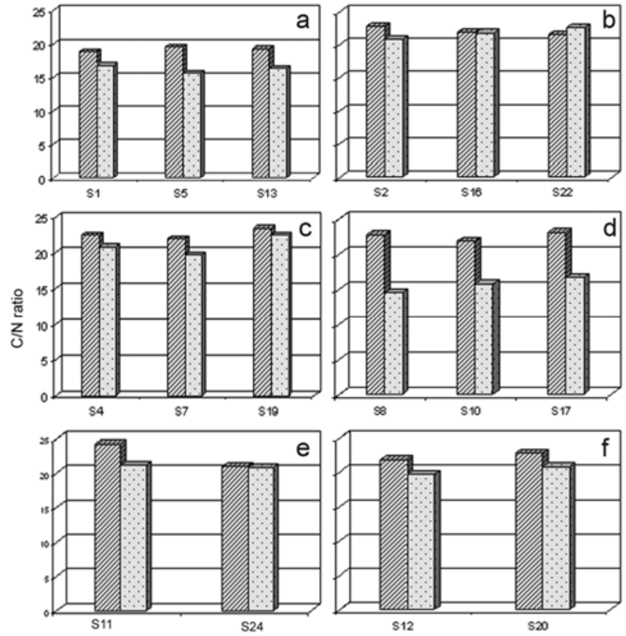


Fig. 5—C/N ratio of the compost/vermicompost obtained from different site at Kalapet and Abishegapakkam

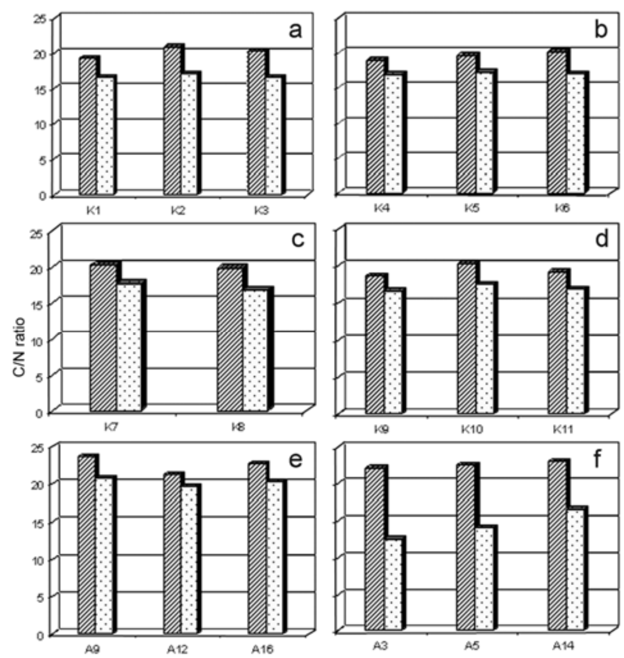


Fig. 6—C/N ratio of the compost/vermicompost obtained from different site at Seliamendu

During vermicomposting, earthworms accelerate the decrease in C/N ratio significantly, demonstrating rapid decomposition and rates of mineralization of the organic matter[21-26]. The release of part of the carbon as carbon dioxide in the process of respiration, production of mucus and nitrogen excrements, increases level of nitrogen and lowers the C/N ratio[27].

According to Senesi[28], a decline of C/N ratio to less than 20 indicates an advanced degree of organic matter stabilization and reflects a satisfactory degree of maturity of organic waste. In our experiments, the C/N ratio of the various substrates from different sites was ~ 20 except for few sites where the maximum value was 21.8.

**Acknowledgement**

The authors thank Department of Biotechnology, Govt of India, New Delhi for financial support. SG thanks the Council of Scientific and Industrial Research (CSIR), New Delhi, for the Research Associateship.

## References

1 Gajalakshmi S, *PhD thesis*, Pondicherry University, Pondicherry, (2002) 187.
2 Gajalakshmi S & Abbasi S A, *Indian J Biotechnol*, 2 (2003) 613
3 Gajalakshmi S & Abbasi S A, *Biores Technol*, 92 (2004) 291.
4 Gajalakshmi S, Sankar Ganesh P & Abbasi S A, *Biochem Eng J*, 22 (2004) 111.
5 Gajalakshmi S & Abbasi S A, *Biores Technol*, 85 (2002) 197.
6 Jimenez E I & Garcia V P, *Biol Wastes*, 27 (1989) 115.
7 Tripathi G & Bhardwaj P, *Biores Technol*, 92 (2004) 215.
8 Vinceslas-Akpa Loquet, *Soil Biol Biochem*, 29 (1997) 751.
9 Chaoui H I, Zibilske L M & Ohno T, *Soil BiolBiochem*, 35 (2003) 295.
10 Mathur S P, Owen G, Dinel H & Schitzer M, *Biol Agric Hortic*, 10 (1993) 65.
11 Canet R & Pomares F, *Biores Technol*, 51 (1995) 259.
12 Zucconi F & Bertoldi M, *In Compost: Production, Quality and Use* (Elsevier Applied Science London), 1987, 30.
13 Clarion M, Zinsou C & Nagoud D, *Agronomie*, 2 (1982) 295.
14 Juste C, Paper presented at the Jornadas Internacionales sobre el compost conference, Madrid, (1980).
15 Kostov O, Rankov V, Atanacova G & Lynch J M, *Biol Fert Soils*, 11, (1991) 105.
16 Bannick C G & Joergensen R G, *Biol Fert Soils*, 16 (1993) 369.
17 Jimenez E I & Alvarez C E, *Biol Fert Soils*, 16 (1993) 313.
18 Brink N, *Soil Plant Sci*, 45 (1995) 118.
19 Keeling A A, Mullett J A J & Paton I K, *Soil Biol Biochem*, 26 (1994) 773.
20 Keeling A A, Griffiths B S, Ritz K & Myers M, *Biores Technol*, 54 (1995) 279.
21 Kale R D, Bano K & Krishnamoorthy R V, *Pedobiologia*, 23 (1982) 419.
22 Singh K & Sharma S, *Biores Technol*, 85 (2002) 107.
23 Atiyeh R M, Dominguez J, Subler S & Edwards C A, *Pedobiologia*, 44 (2000) 709.
24 Bansal S & Kapoor K K, *Biores Technol*, 73 (2000) 95.
25 Kaushik P & Garg V K, *Biores Technol*, 90 (2003) 311.
26 Kaushik P & Garg V K, *Biores Technol*, 94 (2004) 203.
27 Senapati K K, Dash M C, Rane A K & Panda B K, *Comp Phys Ecol*, 5 (1980) 140.
28 Senesi N, *The Science of Total Environment*, 81/82 (1989) 521.