Study on septic sludge utilization to coordinate with agricultural wastes to produce compost fertilizer

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Abstract. In Vietnam, little attention is being paid to the management and treatment of septic tank sludge to take advantage of the number of nutrients in this available resource. This paper presents the potentials and performance of the compost production on the mixing of septic tank sludge and agricultural residues as coffee husk, coconut husk, peat. It added supplementary by 5% bioproducts of Trichoderma sp and 30 ml of molasses in 45 days. The results showed the highest quality compost, being mixes of septic tank sludge and coffee husks with total N = 4.01%, total P = 0.41%, total K2O = 3.68% and accepting for the Vietnam standards of fertilizer regulations, resulted also illustrated that E.coli concentration in septic tank sludge sample decreased 2.5 - 3.3 times compared to the previous sample. The second one, the composting efficiency was surveyed on the growth of green mustard plant during 31 days by basal fertilizing and top dressing of this compost at 10 days. The growth of the green mustard plant showed the high compost efficiency septic tank sludge and coffee husk based on 28.21 cm of height and 62.5 g/plant weight. Especially, NT4 combining from septic tank waste, coffee husk with chemical fertilizers was a good formula by getting the best result in all treatment by combined of compost and chemical fertilizer was at the top dressing period, seems the high compost efficiency in helping Brassica juncea grow well by growing green mustard, being 31.25 cm of height and 95.83 g/plant weight.

1. Introduction
Vietnam now is the 14th largest population in the world, with an estimated 92 million people. It has a rapid increase in population, economic growth, urbanization in Vietnam, and waste generated as a result of urban daily life activities with an increase of 10% per year. The practical difficulties facing urban waste management, as raw sludge from septic tanks of the domestic waste treatment system. For example, Cau Dien composting facility received and treat the solid waste treatment 10% in total waste/day in Ha Noi Capital [1]. Ho Chi Minh city generated about 5,000-6000 tons/day [2], this organic in Ho Chi Minh City (HCMC) waste was sent to landfills at Da Phuoc Solid Waste Treatment Complexes. Sludge contains water, sand, organic matter, and even pathogenic bacteria, pathogenic microorganisms, as environmental impact associated with sewage sludge, is likely to influence on the urban area. Nitrogen and phosphorus are the most valuable nutrients in sewage sludge, communities have not yet taken full advantage of this available resource for reusability.
On other hand, the increase in crop yields is positively correlated with the amount of chemical fertilizer used and the overuse of chemical fertilizers and pesticides makes the environment increasingly polluted and farmers are affected [3]. Therefore, the number of studies on biological fertilizers to replace chemical fertilizers is increasing nowadays. Chemical fertilizer will bring immediate effect, but in the long run, the soil will become barren, difficult to renovate, which does not bring benefits in the long term. Instead, using organic fertilizer for the first time may not bring about the effect of "eating right" but gradually will improve the fertility of the soil, grow vegetables better, have fewer diseases, the yield is always stable. and the pests and diseases situation is greatly reduced without using too much toxic insecticide [4]. Fertilizers from septic tanks have good nutrition but have some disadvantages. First, physical and chemical components often change according to their origin and instability. Second, the cost is usually expensive due to the need to collect special conditions. Therefore, with these disadvantages, microorganisms disintegrating and dissolving indigestible substances will have difficulty in growth and development. To address these disadvantages, other materials are used to replace peat such as coal, vermiculite [5] or coconut husk [6], coffee husks, bentonite, kaolinite, straw, compost, corn stover .... [7, 8] or one can mix these materials to create the best carrier for bacterial survival.

The objective of this study is to evaluate a good formula combining agricultural residues and septic tank sludge to form organic fertilizer for green agriculture to generate great economic compost and minimize environmental pollution.

2. Materials and methods

2.1. Research materials

Septic Sludge is collected at Hoa Binh Environment Service companies in Binh Chanh District. Sludge collected at septic tanks and the agricultural residues were dried and analyzed for physical and chemical as humidity, pH, Electro-conductivity (EC), C, N. And then, confirmation the optimal C/N ratio is suitable for composting process.

Auxiliary materials: coffee husk, coconut husk, peat, Tri-Bio Eco Probiotic, Azotobacter (Nitrogen-fixing bacteria), seeds of a green mustard plant (purchased from Dia Dia Trading Co., organic fertilizer, chemical fertilizer).

2.2. Evaluation of the sludge quality before and after incubation

Experimental model

This is a 10-15 kg container in a rectangular shape. The experiment was arranged by completely random and divided into 3 plots. It consisted of 4 experiments and conducted with 3 replicates, carried out until unchanged temperature in incubation process:

- Experiment 1 (NT1): Sludge mixed with coffee husk
- Experiment 2 (NT2): Sludge mixed with peat
- Experiment 3 (NT3): Sludge mixed with coconut husk
- Control experiment (Control): Septic sludge.

Monitoring the temperature every 3 days per time during the incubation process
Experimental procedures

![Flowchart diagram]

**Figure 1.** The production of bio-organic fertilizer from septic tank sludge and some agricultural residues (coffee husk, coconut husk, and peat)

Gather the agricultural residues, sludge, and other materials was well prepared for the composting process. Conduction of incubation took ferment by adding the 5% Tri-Bio Eco Probiotic following the product's instruction. Mixing more 30 ml of molasses into each compost to speed up the breakdown of cellulose. All treatment is covered by tarpaulin to retain moisture and temperature, stir once per week, checking the temperature every 3 days per time during the incubation process. We waited for the temperature of the compost until stabilizing at 35 °C, and then we added 5 ml of supplementation Azotobacter with a density of 7 x 107 CFU/g into this compost with stirring periodically 7 days/time, incubating until the unchanged temperature, after that, we harvested the compost products.

*Experimental elements:*
- Analysis of physical and chemical indicators: EC & pH (HI98129), Humidity (TCVN 9297:2012), total N (10TCN 304-97), total P (TCVN 5815-94), and total K2O (IS 6092-1971) after composting process, to evaluate the quality of compost.
- Bacterial identification:
  - Isolated bacterial strains that were capable of decoloration were sent to sequencing for the 16SrDNA (Institute of Tropical Biology, Ho Chi Minh City, Vietnam).
  - Then, the obtained sequencing was BLAST from NCBI using the default mode for the bacterial identification.

2.3. Evaluation of compost efficiency on the growth performance of Brassica juncea

An experiment was arranged in a completely random, including 7 treatments with 3 replicates. This experiment was carried out for 31 days.

- Treatment 1 (NT1): Using the compost product of sludge - coffee husk.
Treatment 2 (NT2): Using the compost product of sludge - peat.
Treatment 3 (NT3): Using the compost product of sludge - coconut husk.
Treatment 4 (NT4): Using the compost product of sludge - coffee husk and adding chemical fertilizer (Commercial NPK).
Treatment 5 (NT5): Using the commercially available bio-fertilizer.
Treatment 6 (NT6): Using the compost product from the control experiment (sludge).
Control treatment: Do not use fertilizers.

Experimental procedures

Figure 2. Planting procedure of Brassica juncea by compost

| Treatment                          | Compost (g) | Bio-fertilizer (g) | Commercial NPK (g/l) |
|-----------------------------------|-------------|--------------------|----------------------|
| NT1 (Sludge – coffee husk)        | 80          | 0                  | 0                    |
| NT2 (Sludge – peat)               | 80          | 0                  | 0                    |
| NT3 (Sludge – coconut husk)       | 80          | 0                  | 0                    |
| NT4 (Sludge – coffee husk + chemical fertilizer) | 0           | 0                  | 20/10                |
| NT5 (bio-fertilizer)              | 0           | 20                 | 0                    |
| NT6 (Sludge)                      | 80          | 0                  | 0                    |
| Control                           | 0           | 0                  | 0                    |

Monitoring elements:
- Tracking of green growth and indicators: Height, number of leaves, total weight.
Stage monitoring: 10 days after basal fertilizing, and 10 days after top dressing.
3. Results and discussions

3.1. Physical and Chemical Properties of a mixture

Results showed that the physical and chemical properties of septic tank sludge and some agricultural residues were analyzed to overview their properties in Table 2.

| Elements          | Samples       |
|-------------------|---------------|
|                   | Sludge        | Coffee Husk | Peat      | Coconut Husk |
| Organic matter (%)| 60.68 ± 1.15  | 86.91 ± 0.81| 14.32 ± 0.82| 96.44 ± 0.21|
| N (%)             | 4.03 ± 0.12   | 1.61        | 0.298     | 0.56         |
| C (%)             | 33.71 ± 0.64  | 48.28 ± 0.45| 7.95 ± 0.46| 53.58 ± 0.12|
| pH                | 6.95 ± 0.01   | 5.44 ± 0.06 | 4.26 ± 0.11| 5.79 ± 0.06 |
| Humidity (%)      | 85.07 ± 0.09  | 9.87 ± 0.16 | 8.96 ± 0.09| 69.27 ± 0.41|
| EC (ms)           | 1.75 ± 0.18   | 5.28 ± 0.03 | 0.84 ± 0.003| 1.89 ± 0.08 |
| C/N               | 8.38          | 30.01       | 26.68     | 95.68        |

Table 2 showed the highest content of organic matter in samples was 96.44% of coconut husk, 86.91% of coffee husk. Organic matter in coffee husks and coconut husk seems the hard-soluble organic substances, mainly lignin and lingo - cellulose, leading to the ability to decompose very slowly. Therefore, it is necessary to mix this material for the decomposition of organic substances, being more effective.

Total N content of septic tank sludge has the highest value with 4.03%, higher 2,421 - 3,732% than the other samples.

The pH in septic tank sludge had the highest value in the analysis samples with pH = 6.95. The second one was pH = 5.79 of coconut husk. The pH value of this septic tank sludge and coconut husk ranged from 5.79 to 6.95, which is the appropriate pH range for the composting process (pH = 5.5 - 8.5). This samples of coffee husk and peat husk was a lower pH value, which affects the tempering process, it is essential to combine the incubation materials of higher pH value.

This sludge sample had the highest humidity of 85.07%, followed by coconut husk with 69.27%. The humidity was lower or higher, don't create favorable conditions for microorganisms to mineralized organic compounds [9]. Therefore, it is necessary to mix the incubated materials to catch the optimum moisture (50 - 70%) in the incubation process.

Table 3 presented that the ratio C/N of coffee husk and peat was 30.01 and 26.68, being suitable for composting (20 - 30). The ratio C/N of coconut husk was very high C/N = 95.68, but the C/N ratio of septic tank sludge was relatively lower C/N = 8.38. Therefore, creating the ratio C/N of sludge and coconut husk was suitable for the composting process by mixing them or mixing other incubated materials. Samples of NT1 and NT3 had the ratio C/N ranging from 24.86 - 27.74, being most suitable for the composting process (20-30) [10].
Table 3. Mixing ratio of septic tank sludge and agricultural residues

| Treatment                          | Mixing ratio (kg)       | Total (kg) | Ratio C/N |
|-----------------------------------|-------------------------|------------|-----------|
|                                   | Sludge | Coffee Husk | Peat | Coconut Husk |           |
| Control                           | 14     | 0           | 0    | 0            | 14        |
| NT1 (Sludge – Coffee Husk)        | 6      | 8           | 0    | 0            | 14        |
| NT2 (Sludge – Peat)               | 5      | 0           | 7.5  | 0            | 12.5      |
| NT3 (Sludge – Coconut Husk)       | 3      | 0           | 0    | 3            | 6         |

Adding 5% of Trichoderma and 5% of molasses for each treatment.
When the incubation temperature was caught at 35°C, adding 5ml of Azotobacter with a density of $7 \times 10^7$ CFU/g to each incubated treatment.

3.2. Changing the incubation temperature

The composting process is usually divided into 4 stages depending on the Temperature profile of composting: warm, hot, cool, and stable period. There are different active microorganisms. In this experiment for each period. The temperature of mixing formula between this sludge and agricultural residues was monitored every 3 days per time. And then, the result is presented in Figure 3.

![Figure 3. Changing the incubation temperature](image)

In general, the temperature of the incubation process reached the maximum value on the 3rd day and then gradually decreased over the next days. This temperature trend stabilized from the 39th day of incubation. The highest temperature of NT1 was 55°C, indicating a strong activity of anaerobic microorganisms in thermophilic conditions, the lowest temperature was 30°C in the control treatment. The high temperatures maintained up to the second week in NT1, in the opposite of other treatments, had a decreasing temperature over the days of incubation. The prolonged high-temperature range help killing pathogenic microorganisms: *Salmonella, E.coli, Coliform, Shigella*, and even helping to decompose organic matter faster [11]. The maximum decomposition was 45 - 60°C of temperature, this
study occurred that this high-temperature range may have a negative effect of the decomposition process, basing on [12]. Temperature is a keyword, being considered as an important parameter to evaluate the ripeness (maturity) of compost [13].

Table 3 and Figure 3 showed that the relationship between the ratio of C/N and incubation temperature are closely related. The control result was 8.38 of the ratio C/N, very low compared to the optimal ration C/N ratio for the composting process, and unchanged this temperature during the composting process. The ratio C/N of peat was lower than the optimal ratio C/N, the amount of organic matter, and total C of peat were low, it led the microorganism growing so lower in this compost because the carbon is the main energy source. Moreover, the temperature of NT2 has a slight increase of about 1 - 3°C, compared to the room's temperature. The ratio C/N of both treatments NT1 and NT3 were 24.86 and 27.74 respectively. This is considered the optimal C/N ratio for the composting process, and the temperature of both treatments varies over the incubation days.

### 3.3. Compost Quality

The compost was collected after 45 days of the incubation process, being dark brown or black (depending on the compost material). Products of sludge-coffee husk was black and more porous, this compost characteristic is smaller and smoother before an incubation.

Products sludge-coconut husk was dark brown, smooth, and porous. The control treatment did not mix with agricultural residues, the product quality of control after incubation had lumpy, with lower moisture than the first period of the incubated process. What is needed to consider this compost to become organic fertilizer, evaluating three major elements N, P, and K, be sufficient to provide for the plant growth.

| Samples | Analytical criteria | Total (%) | Total P (%) | Total K₂O (%) | EC (ms) | pH       | Humidity (%) |
|---------|---------------------|-----------|-------------|---------------|---------|----------|--------------|
| DC      | 3.62 ± 0.18b        | 0.92 ± 0.06c | 0.24 ± 0.02d | 1.34 ± 0.17   | 6.88 ± 0.17 | 62.84 ± 0.55 |
| NT1     | **4.01 ± 0.17a**    | **0.41 ± 0.02b** | **3.69 ± 0.12a** | **2.24 ± 0.29** | **7.54 ± 0.11** | **50.2 ± 3.88** |
| NT2     | 0.94 ± 0.12d        | 0.17 ± 0.02c | 0.54 ± 0.04c | 1.37 ± 0.15   | 5.37 ± 0.03 | 21.14 ± 0.2 |
| NT3     | 1.96 ± 0.03c        | 0.42 ± 0.02b | 1.33 ± 0.05b | 2.23 ± 0.44   | 5.81 ± 0.37 | 57.74 ± 1.92 |
| CV (%)  | 5.23                | 6.84       | 4.81        |

The mean had the same column with the same influencing factor, the mean values were statistically significant differences (P <0.01). Control, NT1 (Sludge-coffee husk), NT2 (Sludge-peat), NT3 (Sludge-coconut husk).

Results in Table 4 showed total N in sample NT1 had the highest value with 4.01%. In general, N amount of four compost samples met the fertilizer standard (Nts amount ≥ 0.6%) by the Vietnam Standards on fertilizers (Circular 36/2010 / TT-BNNPTNT). Content of total P in all samples ranged from 0.17 to 0.92%, the control sample had the highest P amount around 0.92%. The samples of not only control and NT1 but NT3 also had the P amount, meeting the fertilizer standard (Pts content ≥ 0.3%) according to the Vietnam Standards on fertilizers. Particularly, the NT2 sample had a total P content of 0.17%, did not meet the fertilizer standard.
The NT1 sample had the highest amount of total K\(_2\)O around 3.69%. In general, the majority of all samples illustrated total K\(_2\)O content in meeting the demand for fertilizer standards (total K\(_2\)O content \(\geq 0.3\%\)) according to the Vietnam Standards on fertilizers. Particularly, the control sample was 0.06% of the total K\(_2\)O content, being lower than the fertilizer standard.

The moisture content in all compost products was still higher than the fertilizer standard (humidity \(\leq 25\%\)). This may be because during the moisture feeding of the compost pile, the amount of water added should be controlled more carefully. Reducing the moisture content of compost products of control let NT1 and NT3 samples were conducted by drying these products.

Value of pH in Control, NT1, NT3 reached neutral values after incubated compost process (a range 5.81 - 7.54), it seems the pH environment where Azotobacter can well grow and fix nitrogen. Therefore, this treatment had the available N sources in the fertilizer product, the plants also provided an additional amount of N molecules from the atmosphere.

### 3.4. Evaluation basing on microbiological criteria

\[\textbf{Table 5. Analyzed results of pathogenic microorganisms (Unit: CFU/g)}\]

| Sample                  | Input (Sludge) | Output (Compost) |
|-------------------------|----------------|------------------|
|                         | \(E. \text{coli}\) | \(\text{Coliforms}\) | \(E. \text{coli}\) | \(\text{Coliforms}\) |
| Control                 | \(5 \times 10^4\) | \(10^5\)         | \(1.5 \times 10^4\) | \(2.6 \times 10^5\) |
| Sludge – Coffee Husk    | -               | -                | \(2 \times 10^4\)  | \(1.1 \times 10^5\)  |
| Sludge – Coconut Husk   | -               | -                | \(10^3\)          | \(2.6 \times 10^5\)  |
| Sludge – Peat           | -               | -                | \(10^3\)          | \(5.5 \times 10^4\)  |

(-) Samples without the input analysis E. coli and coliforms.

Results in Table 5 showed that E. Coli in the compost samples have decreased compared to the original sludge, this can be explained by the fact that during composting, the increase in the pile temperature limits the activity and reduces the number of harmful microorganisms such as E. Coli. Samples in the control treatment and sludge - coffee husk decreased from 2.5 to 3.3 times. Samples of sludge - peat and sludge - coconut husk had E. Coli decreasing significantly, a density of the input sludge sample 104 CFU/g decreased to 103 CFU/g in the output composting product.

The density of Coliforms in the sludge - peat samples had a slightly decreased compared to the input samples. The samples of control and sludge - coconut husk samples increased by 2.6 times, the samples of sludge - coffee husk increased 1.1 times. Thus, it is possible that the agricultural waste samples presented coliforms adulterated from the environment into the composting process. In general, a density of \(7 \times 10^7\) CFU/g samples of sludge - coconut husk after incubation showed the presence of Azotobacter with a density of \(2 \times 10^4\) CFU/g samples, other compost samples without Azotobacter at the tested concentration \(104\) CFU/g. Results proved that the incubated environment was not a suitable environment for the growth and development of Azotobacter bacteria or the limit amount of Azotobacter not enough for an addition to the compost.

### 3.5. Evaluation based on microbiological criteria

Basing on Figure 4, all treatments had height growth after 10-day cultivation, ranged from 3.81 to 5.5 cm, being larger than the NT6 treatment. In the stage between 10 days and 17 days, a plant adapted to the new environment, keeping growth, means the strongest growth of cultivation. In 17-24 days, the treatments tended to grow slowly, the growth stage of plant concentrated the number of leaf growth nutrients, the exception of NT5 cultivated by organic fertilizer from the market with a high growth rate. The sample of NT6 tended to decrease gradually from 14.61 to 17.43 cm. In the period of 24 - 31 days
(harvest period), most treatments showed very fast growth, and NT4 had the strongest growth of 31.25 cm in a height in this period.

![Figure 4](image1.png)

**Figure 4.** Effect of compost on plant's height growth (A: height over time, B: average height after timelines)

![Figure 5](image2.png)

**Figure 5:** Effect of compost on the leaflet's speed-up of Brassica juncea (A: Average number of the leaf of samples, B: The leaf growth rate of samples).

The compost quality proved by contributing to plant height growth. The compost contained the higher the nutrient content, leading to the high growth performance of the plant. According to Figure 4 in the period of 24 - 31 days, plants in NT4 had the fastest height growth (8.18 cm / 7 days) compared to other treatments. Control treatments without fertilizers have already shown the lowest height growth (1.43 cm/7 days).

Figure 5 showed plants poorly absorbed nutrients from start time to the 10 days, the plant's ability was relatively equal in the nutrients absorption rate and presented in all treatments. The leaf number fluctuations significantly unchanged in this period just about 0.16 - 0.91 leaves. After that plant had matured and absorbed maximum nutrients from 17 days period, the number of leaves varied from 0.33 to 1.75 leaves. In 31 days after planting, plant growth's result presented a range of 2 - 3.58 leaves, and plant in NT6 had the highest number of leaves (12.83 leaves/plant head), this could be reason because of the parse render was used at NT6 with the support effect of other sample, in the convince of the compost quality in NT6, enhancing the development performance of Brassica Juncea’s leaves.

The leaflet's speed-up rate, NT6 presented 1.42 leaves in 10 days period (from 0-10days), and then the highest leaf rate with 1.83 leaves in the period 7 days (from 11-17days). In this case, NT2 and NT5 had the highest leaf rate of 1.42 leaves/7 days compared to the other treatments. Trees in NT6 had the
highest leaf rate (1.96 leaves/7 days). Therefore, it showed that the compost quality affects the leaflet's speed-up rate of Brassica juncea.

3.6. Assessment of the compost's impact on the growth performance of Brassica juncea.

Figure 6 presented that the plant weight increased by using compost and fertilizer relating to scientific data such as specific nutrient content N (%) and C (%) in Table 2, the exception of the plant weight in control treatments. The average weight of *Brassica juncea* of NT1, NT2, NT3, NT5, NT6 was 62.50g, 62.08g, 45.83g, 58.33g, and 55g respectively without significant difference. Especially, the average weight of plant was calculated in NT4 use compost mixed between septic tank sludge and coffee husk, combined with chemical fertilizer, NT4 (Sludge – Coffee Husk + chemical fertilizer) showed the highest weight of 95.83g / plant head. The above results proved a combination of compost and chemical fertilizer was at the top dressing period, helping *Brassica juncea* grow well.

![Figure 6. Effect of compost on Brassica Juncea's productivity](image)

4. Conclusions

Results showed the efficiency of sludge mixed with agricultural waste products such as coffee husk, peat, and coconut husk to become bio-organic fertilizer by recycling septic tank sludge and waste products of agriculture, other advantages as reducing an amount of this waste directly discharged into the environment. Moreover, results showed this compost from sludge and coffee husk, providing the highest quality with N, P, K components after incubation with 4.01% total N; 0.41% of total P; 3.69% of total K2O respectively, meeting the standard of organic fertilizer QCVN 01-189 2019/BNNPTNT. The moisture content was 50.2% in high value. If this compost is used as a commercial fertilizer in field, it needs drying at the appropriate temperature. Results convinced the composting efficiency of NT4 on *Brassica juncea* by the plant growth and development, NT4 (sludge – coffee husk + chemical fertilizer) was a good formula by getting the best result in all treatment by combined of compost and chemical fertilizer was at the top dressing period, helping *Brassica juncea* grow well. The results also showed some conditions for good experiment results, for instance, the plant height 6.21 cm/plant head and with the number of leaves reached 12.83 leaves/plant head. Leaflet's speed-up rate reached 1.42 leaf/plant head and overall harvest yield is reached 0.64 kg / 0.15 m2.

References

[1] Anh N V 2011 *Env. J.* 1 20-5

[2] Tran T M D, Thanh N K, Duong D T, Tam L M, Linh V T, Diem T M, Hang T T L, De L M and Trang T T T 2013 *J. Env. Prot.,* 4 (12) 1329-1335

[3] Saha S, Prakash V, Kundu S, Kumar N and Mina B L 2008 *Eur. J. Soil. Biol.* 44 309-15
[4] Paau A S 1998 *Formulation of microbial biopesticides*: Springer) pp 235-54
[5] Paau A 1989 Bacterial agricultural inoculants. Google Patents)
[6] Faizah A, Broughton W and John C 1980 *Soil Biol. Biochem.* 12 219-27
[7] Kremer R J and Peterson H L 1982 *Appl. Env. Microb.* 43 636-42
[8] Sparrow Jr S and Ham G 1983 *Agron. J.* 75 181-4
[9] Miller F and Finstein M 1985 *J. (Wat. Poll. Control. Fed.)* 122-7
[10] Pace M G, Miller B E and Farrell-Poe K L 1995 The composting process
[11] Li L, Ding X, Qian K, Ding Y and Yin Z 2011 *J. Anim. Vet. Adv.* 10 1738-42
[12] Ryckeboer J, Mergaert J, Coosemans J, Deprins K and Swings J 2003 *J. Appl. Microbiol.* 94 127-37
[13] Tiquia S, Tam N and Hodgkiss I 1997 *Environ. Pollut.* 98 97-104