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Preliminary Study on the Application of Municipal Sludge to Agriculture

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Sludge is one type of special municipal wastes and it is increasingly urgent to manage sludge as sewage treatment becomes widespread in cities throughout the world. It is still necessary to look for some practical way to treat sludge in developing countries although there are already many approaches in sludge disposal (Wu, 1981; Jin & Liu, 1988; Wang et al., 1999; Wei et al., 1998; Davis, 1996; Yao, 2000).

Guilin, with 565 km^2 of urban area and a population of 600, 000, is a heart of a world-famous scenic tourist area in Guangxi Zhuang Autonomous Region in Southern China. There are four sewage treatment plants and about 100 tones of sludge, with some 80% moisture, are produced per day. At present, the sludge is simply used in farmland for crops. Unfortunately, there exist some sanitary problems, such as its bad smell and attractiveness to flies. It is of a great environmental significance to dispose the sludge properly. In general, the heavy metal concentration in the sludge from sewage treatment in Guilin is low because there are few factories discharging wastewater containing heavy metal. Therefore, this study investigated the feasibility of making organic complex fertilizer using composted sludge.

MATERIALS AND METHODS

All of the sludge samples in the investigation were taken from the Fourth Sewage Treatment Plant in Guilin. First, the sludge was sampled and analyzed for plant nutrients, including organic matter, nitrogen, phosphorus and potassium. Then, the sludge was composted. The process was classified into aerobic fermentation step and anaerobic fermentation step (Ge et al., 1995). After the moisture content of the sludge was reduced from 80% to about 60% , 20 cm thick sludge and 2 cm of thick sawdust were put alternately into a stack-box which was made of bricks and was 1m in height with a bottom of 4m × 4m. It took two weeks to digest the sludge under aerobic conditions using a forced air supply. In the first week, air

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was fed into the sludge pile at the frequency of 10 minutes per hour by a blower with a power of 200 w and working efficiency of 4 m^3 of air per minute. The frequency was decreased to 5 minutes per hour in the second week. After aerobic fermentation, the sludge was put away at room temperature for 30 days. Finally, the composted sludge was made into a specific organic complex fertilizer after adding nitrogen, phosphorus and potassium, mixing and granule formation.

In order to determine the effect of the organic complex sludge fertilizer, it was applied to crops, including spring rice (from April to July, 1999) and autumn rice (from July to October 1998), and sugarcane field from July 1998 to January 2000. There were four types of fertilizers tested in the experiments: (1) organic complex sludge fertilizer for rice (SR), with 11% nitrogen, 4% phosphorus and 5% potassium. (2) organic complex sludge fertilizer for sugarcane (SS), with 14.3 % nitrogen, 4% phosphorus and 5% potassium. (3) complex fertilizer bought on the market (CF), with 13% nitrogen, 5% phosphorus and 7% potassium, and (4) Mixed fertilizer using urea, calcium-magnesium phosphate and potassium chloride (MF), with 15% nitrogen, 5% phosphorus and 5% potassium.

Each plot of rice was 13.3m^2. SR and CF were used as base fertilizer at three nitrogen levels, i.e., 3kg nitrogen per Mu (1 Mu is equal to 66.67 m^2), 4.5kg per Mu and 6 kg per Mu. There were also three control plots where no base fertilizer was applied. There were seven sugarcane plots, each plot measuring 21.6m^2. SS and MF were used at three different nitrogen levels, 18.5 kg nitrogen per Mu, 23 kg nitrogen per Mu and 30 kg nitrogen per Mu, while CF was used at a rate of 23 kg nitrogen per Mu, which was the amount of fertilizer commonly used in sugarcane field in the Guilin region. In all cases, 50% of the fertilizer was used as base fertilizer and the other 50% as top-dressing.

Protection rows were constructed around the plots. Field management was the same for every plot. The crops were observed and recorded regularly. When they were harvested, the output of each plot was independently calculated.

In order to detect heavy metal contamination, the sludge from the Fourth Sewage Treatment Plant and rice harvested from the spring rice plots were sampled and analyzed for heavy metals. The plant nutrients of this sludge were analyzed in the Guilin Botanical Research Institute. Heavy metal analyses were completed in the Key Laboratory of Central South University using plasma atomic emission spectrometry.

RESULTS AND DISCUSSION

The dried sludge from the Fourth Sewage Treatment Plant contained 39.6% organic matter, on average. Nitrogen, phosphorus and potassium content were 48.3g/kg, 21.1g/kg and 8.5 g/kg on average, respectively. The plant nutrient content was the same as or a little higher than the sludge in other cities such as Guangzhou, and Tianjin in China (Table 1).

In the rice field experiments the methods of rice seeding and growing were almost same in the plots where SR and CF were used as base fertilizer and the control plots. The outputs of spring rice in plot SR and plot CF increased by 19% and 13%, respectively, on average compared with that in control plot O (Table 2). Similarly, The outputs of autumn rice in plot SR and plot CF increased by 13% and 12% on average (Table 3). Therefore, the organic complex sludge fertilizer for rice (SR) had a clear effect and its fertilizer value was a little higher than the complex fertilizer bought on the market.

Table 1. Main plant nutrient composition of sludge.

Sewage treatment plant	Organic matter (%)	Total nitrogen (g/kg)	Total phosphorus (g/kg)	Total potassium (g/kg)
Guilin[a]	39.6	48.3	21.1	8.5
Tianjin[b]	40	35	13.2	3.9
Guangzhou[c]	39.8	28	22	1.2

[a]The data of Guilin are the averages of 6 samples.
[b]Source Reference: National Environmental Protection Bureau of China,1997.
[c]Wu Qitang, Lin Yi, Zeng Haisi, 1992.

Table 2. Output of spring rice in different plots (kg).

Fertilizers used and control[a]	Plot 1	Plot 2	Plot 3	Average output of a plot	Comparison with control plot
SR	9.71	10.56	8.88	9.72	+19%
CF	8.87	10.23	8.52	9.21	+13%
O	8.15	8.08	8.26	8.16	

[a]SR and CF represent the rice subplots where the organic complex sludge fertilizer for rice and the complex fertilizer from the market were used as base fertilizer, respectively. O stands for the control rice subplots where no base fertilizer was used.

Table 3. Output of autumn rice in different plots (kg).

Fertilizers used and control[a]	Plot 1	Plot 2	Plot 3	Average output of a plot	Comparison with control plot
SR	10	9.75	10.5	10.08	+13%
CF	9.75	10	10.25	10	+12%
O	8	9	9.75	8.92	

[a]See footnote to Table 2.

Field observation and measurements showed that there were no differences in the rate of sugarcane emergence and sugarcane height in any of the plots. The average output of sugarcane in plot SS, plot MF and plot CF were 176.2 kg, 171.8 kg and 163.5 kg, respectively (Table 4) and average concentrations in three plots were 14.65%, 14.89% and 14.58%, respectively (Table 5). The output of sugarcane in plot using SS was a little higher than those in plots using other fertilizers, while sugar concentrations in the cane were very similar in plots using different fertilizers.

Table 4. Output of sugarcane in different plots (kg).

Fertilizers used[a]	Plot 1	Plot 2	Plot 3	Output of subplots on average
SS	164	199.5	165	176.2
MF	181.8	154.5	179	171.8
CF				163.5

[a]SS and MF represent the sugarcane subplots where the organic complex sludge fertilizer for sugarcane and the mixed fertilizer of urea, calcium-magnesium phosphate and potassium chloride were used, respectively.

Table 5. Sugar concentration of in the cane in different plots (%).

Fertilizers used [a]	Plot 1	Plot 2	Plot 3	Average sugar concentration
SS	14.53	14.62	14.80	14.65
MF	14.95	14.83	14.90	14.89
CF				14.58

[a]See footnote to Table 4.

The concentration of As, Cd, Cr, Cu, Ni, Pb and Zn in the sludge from Guilin sewage treatment plants was 37, 0.9, 594, 154, 98, 199 and 506 mg per kg dried sludge, respectively (Table 6). Most of the heavy metal content in the sludge of Guilin is lower than that in other Chinese cities, only the arsenic content was higher. The heavy metal elements in the sludge of Guilin are in accordance with the requirements of National Pollutants Control Standards of Sludge for Agricultural Use in China (the Technical Supervision Bureau of China, 1984a).

Table 6. Heavy metal content in sludge (mg/kg dried sludge).

	As	Cd	Cr	Cu	Ni	Pb	Zn
Guilin[a]	37	0.9	594	154	98	199	506
Tianjin[b]	10	3	728	336		669	1095
Guangzhou[c]			1550	2200	462	245	1790
The Standard in China[d]	75	5~20	600	250	100	300	500

[a]The heavy metal data in Guilin are the averages of 4 samples.
[b]Source Reference: National Environmental Protection Bureau of China,1997.
[c]Technical Supervision Bureau of China,1984.

Table 7. Heavy metal content in rice (mg/kg).

Fertilizers used and control subplots[a]	As	Cd	Cr	Cu	Ni	Pb	Zn
SR	<0.05	0.023	9.3	15	8	11	19.3
CF	<0.05	0.02	9	12	8	9.3	31
Control plots	<0.05	0.023	10	14	9	9.3	34.3

[a]See footnote to Table 2.

The heavy metal content of spring rice is shown in Table 7.The arsenic content of rice was under the detectable limit in 3 plots. The average content of Cd, Cr, Cu, Ni, Pb and Zn in rice from the plots showed little variation.

The sludge from the Fourth Sewage Treatment Plants in Guilin contained 39.6% organic matter on average. The average content of nitrogen, phosphorus and potassium were 48.3g/kg, 21.1g/kg and 8.5 g/kg, respectively, while the content of heavy metals in the sludge was low and is in accordance with the requirements of national standards of sludge for agricultural use. Therefore, the sludge is suitable for agricultural utilization after composting. Field experiments show that the sludge fertilizer has a good effect. The increase production rates of organic complex sludge fertilizer for spring rice and autumn rice was 19% and 13%, respectively, compared with the control plots. The fertilizer value is clear and a little higher than that of the fertilizer bought on the market. When different fertilizers were used in the sugarcane field, the sugar concentration in the cane in all plots was almost the same. The sugarcane output in the plot using organic complex sludge fertilizer was a little higher than those using the other two kinds of fertilizer sold on the market. There was no distinct difference in the heavy metal content of rice after different fertilizers were applied. At the same time, the method of disposal of the sludge after composting can eliminate the above-mentioned sanitary problems.

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