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COMPOSTING OF SEWAGE SLUDGE AND DIFFERENT PLANT RESIDUES

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ABSTRACT

Ten-week composting experiment was conducted at Faculty of Agriculture Farm, Suez Canal University, Ismailia Governorate, during Summer 1999. Sewage sludge has been stabilized by composting in mixtures with the following plant residues at rates 10 and 20 : 1 w/w; 1) wood carpentry refuse, 2) peanut shells 3) rice straw, 4) wheat straw, 5) corn straw, 6) sugar cane refuse, 7) grass clippings, 8) peanut shoots, 9) chickpea residues and 10) lupine residues. The objective of the experiment is to produce a compost environmentally safe material that is free from pathogens, and can be used beneficially on agricultural newly reclaimed soil as a organic fertilizer by composting of sewage sludge with plant wastes.

The data indicated that, organic C content of sludge-plant residue treatments was gradually significant decreased with the time till the end of the experiment (10th week). Increasing the rate of sewage sludge application resulted in a marked decrease in total N content of the mixture. It can be arrange the different plant residues according to low C/N ratio as well `as high organic C decomposition rate in the following order: chickpea residues > peanut shoots > wheat straw > lupine residues > corn straw > grass clippings > sugar can refuse > wood carpentry refuse > peanut shells > rice straw at 10:1 sewage sludge : plant waste. While, wood carpentry refuse > corn straw = grass clippings > peanut shoots > chickpea residues = sugar can refuse > wheat straw > lupine residues > rice straw > peanut shells at 20:1 sewage sludge : plant waste.

Salinity levels of the different treatments of the final compost product were still low and practice for agricultural use, K content not significantly increased, N content decreased and P content significantly increased by increasing the rate of sewage sludge upto 20:1 plant residues. Total Cd, Pb, Cu, Zn and Ni concentrations in the final compost are very lower than maximum permissible concentrations for agricultural use.

Raw sewage sludge has pathogenic bacteria and parasites in the range of the infective dose to human. However, composting conditions of sewage sludge-plant residues were greatly effective in reduction of total bacteria and coliforms, pathogenic bacteria i.e. *Salmonella sp*., *Shigella sp*. and *Vibrio sp* and pathogenic parasites i.e. *Ascaris lumbericoides*, *Trichuris trichiura*, *Entrobius vermiculus* and *Hyenolepis spp*.

Keywords: Sewage sludge, compost, NPK, heavy metals, pathogenic bacteria and Parasites.

INTRODUTION

The rise and the localization of most of the population in restricted areas has forced all developed countries to find methods which keep environmental impact of waste disposal as low as possible. The application of solid or liquid municipal waste to agricultural land is generally thought to be the method of disposal which at the same time economical and least harmful to the environment. In this way valuable amounts of nutrients are supplied to plants, and humus forming materials are added to soil.(Levi-Minzi et al, 1985; Campbell et al, 1986 and Sommerfeldt et al, 1988). The latter aspect is of particular importance in Egypt where soils are generally low in organic matter and structural problems are quite common.

Sewage sludge contains nitrogen, phosphorus and potassium. In addition to these nutrients, sludge contains small amounts of agents of which some are necessary trace elements for crop growth; some are on the other hand harmful heavy metals. Techniques used in sewage sludge stabilization provide different final products, responsible for different effects after their application to agricultural land. Liquid digestion, lime treatment, composting produce sludges characterized by different physical, chemical and biological properties. Agronomic performance, application rates and environmental effects can consequently vary (Dumontet et al., 1985).

The agricultural use of sludge not taken into account in the conception of many sewage treatment plants and it is always a problem to organize an efficient spreading operation. If a sludge sanitation process is required for agricultural use, it can be discourage the plant manager because of technical constraints or of the costs it represents. The kinds of sanitation processes must be distinguished: those that either modify or do not modify the basic characteristics of the sludge. For instance, in case of composting, the marketing policy of the producer cannot be the same for liquid or dewatered sludge. It is much easier to market a fertilizer than an organic soil conditioner. However, some specific equipment can improve both the sludge sanitary quality and spreading operations. Long storage, for instance, is required in order to match sludge production with spreading periods. It can also reduce the members of disease germs (Merillot, 1985).

U.S. Department of Agriculture at Beltsville, Maryland in cooperation with the Maryland Environmental Service (Willson et al., 1983), recently developed an Aerated Pile Method for composting sewage sludge. The method transforms sludge into usable compost in about 7 weeks, during which time the sludge is stabilized, odors are abated and human pathogenic organisms are destroyed.

The objective of the present work is to produce a compost environmentally safe, free from pathogens, and can be used beneficially on land as a fertilizer and soil conditioner by composting of sewage sludge and different plant residues.

MATERIALS AND METHODS

Ten-week composting experiment was conducted at Faculty of Agriculture Farm, Suez Canal University, Ismailia Governorate, during Summer 1999. Sewage sludge from the Wastewater Treatment Plant of Serabium, Ismailia Governorate, has been stabilized by composting in mixtures with the following plant residues at rates 10 or 20: 1 weight by weight: 1) wood carpentry refuse, 2) peanut shells, 3) rice straw, 4) wheat straw, 5) corn straw, 6) sugar cane refuse, 7) grass clippings, 8) peanut shoots, 9) chickpea residues and 10) lupine residues. Characteristics of sludge and plant residues are presented in Tables (1) and (2).

Table (1). Some characteristics of sewage sludge.

pH*	7.17	Total N, g kg^{-1}	3.50
EC, dSm^{-1}**	11.83	Total P, g kg^{-1}	12.11
Soluble cations, $meql^{-1}$		Total K, g kg^{-1}	1.40
Na^{+}	32.17	Organic matter, %	28.70
K^{+}	6.50	Trace metals	
Ca^{2+}	53.34	Cd	5.13
Mg^{2+}	26.32	Pb	28.34
Soluble anions, $meql^{-1}$		Cu	33.11
CO_3^{2-}	nd	Zn	30.80
HCO_3^{-}	17.35	Ni	12.15
Cl^{-}	40.14	Fe	41.02
SO_4^{2-}	60.81	Mn	4.72

***= sludge water suspension 1:2.5**
***= sludge saturated paste**
nd= not detected

Table (2). Some characteristics of selected agricultural residues.

Waste type	C	N	P	K	C/N ratio
	%				
Wood carpentry refuse	52.5	0.35	0.10	1.00	150
Peanut shells	54.0	0.40	0.10	0.70	135
Rice straw	50.0	0.50	0.10	1.00	100
Wheat straw	32.0	0.40	0..15	1.25	80
Corn straw	21.0	0.50	0.10	1.20	42
Sugar cane refuse	19.5	0.65	0.15	0.95	30
Grass clippings	27.9	0.90	1.10	1.20	31
Peanut shoots	23.1	1.10	0.15	1.65	21
Chickpea residues	23.8	1.40	0.20	1.80	17
Lupine residues	22.5	1.50	0.20	1.30	15

Cubic concrete with 1m in dimensions were constructed. At the bottom of each basin, a 5cm in diameter hole was made to drain the access water to prevent the undesirable reduction conditions. Plant residues were ground and thoroughly mixed with sewage sludge. Mixture of the different treatments was filled in the basins, mixed twice weekly and moisture content was adjusted to 50% by weight. After the second mixing process, three samples were weekly collected from each sludge-plant residue treatment and dried at 70 ^{0}C. Organic C, total-C, and -N in different treatments were determined as described by APHA, (1985).

At end of the experiment (tenth week), electrical conductivity, soluble cations (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}) and anions (CO_3^{2-}, HCO_3^{-}, Cl^{-} and SO_4^{2-}) in compost-water paste, and pH in compost-water suspension 1:2.5 were determined according to standard methods recommended by the U.S. salinity laboratory, Richard's, (1954). Samples were digested by oxidizing acids (HNO_3; $HClO_4$; 4:1) and total-P, -K and -elements of Zn, Pb, Ni and Cu according to APHA, (1985) were determined by colorimeter, flame photometer and atomic absorption spectrometry, respectively.

A fresh compost composite sample was taken from three samples of each treatment for the following bacteriological analysis according to APHA, (1985):

1. Total bacterial count by using yeast extract peptone agar medium.
2. Total coliforms by using lactose peptone broth medium.
3. Some of pathogenic bacteria i.e. *Salmonella sp.* (causes typhoid fever), *Shigella sp.* (cause shigellosis, or bacillary dysentery), by using shigella salmonella (SS) agar medium and *Vibrio sp.* (causes cholera) by using TCBS medium. *Salmonella* colonies appeared black or black centered with transparent borders and *Shigella* colonies appeared colorless, transparent and flat on SS medium.

Six grams from fresh compost composite sample were added to a 150ml beaker and 100ml NaOH 10% were added to the sample. After 48 hours, 0.1 ml was taken from the surface of the sample and spreads on slide cover for the microscopic examination of the following intestinal parasites according to Lawrence et al., (1985)

1. *Ascaris lumbericoides* (large roundworm causes coughing, chest pain, shortness of breath, fever and eosinophilia).
2. *trichuris trichiura* (whipworm causes intermittent abdominal pain, bloody stools, diarrhea, anemia, loss of weight or rectal prolapse in very heavy infections).
3. *Entrobius vermiculus* (pinworm causes itching and discomfort in the perinea).
4. *Hyenolepis spp.*(dwarf tapeworm causes nervousness, insomnia, anorexia, loss of weight, abdominal pain, digestive disturbances).
5. *Taxocara canions* (dog roundworm causes fever, appetite loss, cough, asthmatic episodes, abdominal discomfort, muscle aches).

RESULTS AND DISCUSSION

Organic carbon content and degradation

Table (3) provides data for organic carbon content of the different composting materials. Generally, increasing sewage sludge application rate from 10 to 20: 1 plant residues had no effect on organic carbon content of the different composting mixtures. Organic C content of all treatments was gradually significant decreased with the time till the last week, since the mean of organic C content values were decreased from 18.10 to 10.29% for the rate of 10: 1 sludge-plant residue treatments and 17.41 to 10.55% for the of 20: 1 treatments at the beginning and the end of the experiment, respectively.

Highly significant differences between treatments were found, since mean of organic C content values ranged between 12.64-15.83% for grass clippings and wheat straw and 12.50-15.49% chickpea residues and rice straw at 10 and 20:1 sewage sludge to plant residues.

Table (4) provide data for organic carbon cumulating percentages degraded from native sludge-plant residues organic matter as a result of sewage sludge application rate and composting time. Generally, most treatments received low rate (10:1) of sewage sludge had significant higher mean organic C decomposition rates than treatments received high rate (20:1). Organic C decomposition rates were 23.38 and 27.79% for 10 and 20: 1 sludge: plant residue, respectively.

Table (3). Organic carbon content (%) of the different sewage sludge-plant residues mixtures as affected by sewage sludge application ratio and composting period.

Treatment	Weeks							
	0	1	2	4	6	8	10	Mean
	Sludge : plant residues, 10:1							
1	19.91	19.02	17.68	12.74	11.84	11.26	10.06	14.64
2	20.05	16.56	16.22	11.82	11.12	10.72	10.54	13.86
3	19.68	15.50	13.12	13.10	12.56	11.74	9.84	13.65
4	18.05	17.69	17.34	16.99	15.36	12.86	12.54	15.83
5	17.05	16.71	15.98	11.90	10.76	10.06	9.02	13.07
6	16.91	16.60	14.52	12.44	10.06	9.80	9.18	12.79
7	17.67	16.50	13.58	11.86	10.90	9.86	8.08	12.64
8	17.24	16.98	16.90	13.60	13.30	12.12	12.04	14.60
9	17.30	15.02	13.52	12.66	11.58	10.58	9.84	12.93
10	17.18	15.36	13.14	12.98	12.30	11.96	11.74	13.52
Mean	18.10	16.59	15.20	13.01	11.97	11.10	10.29	13.85
	Sludge : plant residues, 20:1							
11	18.35	17.98	17.82	15.22	12.54	12.24	11.14	13.04
12	18.43	15.58	13.08	11.80	10.90	10.72	9.10	12.80
13	18.24	17.80	16.86	16.60	14.52	12.58	11.86	15.49
14	17.38	17.00	16.40	16.00	12.86	11.20	10.96	14.54
15	16.86	16.50	16.10	12.20	10.98	10.52	9.64	13.26
16	16.79	16.10	15.36	13.52	12.14	10.78	9.42	13.44
17	17.19	16.86	13.82	13.66	11.48	10.70	9.62	13.33
18	16.96	16.28	16.00	15.58	14.72	13.24	12.10	14.98
19	16.99	14.72	13.10	11.28	11.26	10.38	9.76	12.50
20	16.93	15.42	14.38	13.60	12.36	12.08	11.90	13.81
Mean	17.41	16.42	15.29	13.95	12.38	11.44	10.55	13.92
G. Mean	17.76	16.51	12.25	13.48	12.18	11.27	10.42	13.84

1 and 11 wood carpentry refuses
2 and 12 peanut shells
3 and 13 rice straw
4 and 14 wheat straw
5 and 15 corn straw
6 and 16 sugar can refuses
7 and 17 grass clipping
8 and 18 peanut shoots
9 and 19 chickpea residues
10 and 20 lupine residues

	$LSD_{0.05}$
Sludge ratio	**NS**
Treatments	**0.48**
Weeks	**0.40**

Mean of the organic carbon decomposition rate was significantly affected by the composting period, since it significantly increased from 7.08 and 5.65% at the first week to 42.93 and 38.92% at the end of the experiment for 10:1 and 20:1 sludge: plant residues, respectively.

Significant differences between treatments were found, since mean of organic carbon decomposition were ranged between 17.88 and 35.81% at 10:1 sludge-plant treatments and 12.88 and 36.63% at 20:1 sludge-plant treatments for peanut shoots and shells respectively. These findings are in a good agreement with those obtained by Vigerust (1984).

Table (4). Organic carbon decomposition (%) of the different sewage sludge-plant residues mixtures as affected by sewage sludge application ratio and composting period.

Treatment	Weeks						Mean
	1	2	4	6	8	10	
	Sludge : plant residues, 10:1						
1	4.47	11.20	36.01	40.53	43.45	49.47	30.86
2	17.21	18.90	40.84	44.34	46.33	47.25	35.81
3	21.33	33.33	33.43	36.18	40.35	50.00	35.77
4	1.99	3.93	5.87	14.90	28.75	30.53	14.33
5	1.99	6.28	30.21	36.89	41.00	47.10	27.25
6	1.83	14.13	26.43	40.51	42.05	45.71	28.44
7	6.62	23.15	32.88	38.31	44.20	54.27	33.24
8	1.51	1.97	21.11	22.85	29.70	30.16	17.88
9	13.18	21.85	26.82	33.06	38.84	43.12	29.48
10	10.59	23.52	24.45	28.44	30.38	31.66	24.84
Mean	8.07	15.83	27.79	33.60	38.51	42.93	27.79
	Sludge : plant residues, 20:1						
11	2.02	2.89	17.06	31.66	33.30	39.29	21.04
12	15.46	29.03	35.97	40.86	41.83	50.62	35.63
13	2.41	7.57	8.99	20.39	31.03	34.98	17.56
14	2.19	5.64	7.94	26.01	35.56	36.94	19.05
15	2.14	4.51	27.64	34.88	37.60	42.82	24.93
16	4.11	8.52	19.48	33.65	35.80	43.90	24.24
17	1.92	19.60	20.54	33.32	37.76	44.04	26.20
18	4.01	5.66	8.14	13.21	21.93	24.35	12.88
19	13.36	22.90	33.61	33.73	38.91	42.55	30.84
20	8.92	15.06	19.32	26.99	28.65	29.71	21.44
Mean	5.65	12.14	19.87	29.47	34.24	38.97	23.38
G. Mean	6.86	13.98	23.84	31.53	36.37	40.92	25.58

			$LSD_{0.05}$
1 and 11 wood carpentry refuses	**6 and 16 sugar can refuses**		
2 and 12 peanut shells	**7 and 17 grass clipping**	**Sludge ratio**	**1.14**
3 and 13 rice straw	**8 and 18 peanut shoots**	**Treatments**	**2.55**
4 and 14 wheat straw	**9 and 19 chickpea residues**	**Weeks**	**1.98**
5 and 15 corn straw	**10 and 20 lupine residues**		

Total N content and C/N ratio

Data on the effect of sewage sludge application rate and composting time on total N content of different sludge-plant residue mixtures are presented in Table (5). Generally, increasing the rate of sewage sludge application to different plant wastes from 10 to 20:1 resulted in a marked decrease in total N content of the mixture. Mean of total N contents were 0.80% for 10:1 and 0.75% for 20:1 sludge-plant residue treatments. Total N content of the different sludge-plant residue treatments was significantly increased by extending the composting period till the end of the experiment (10 weeks). However, mean of total N content values were 0.39% at the begging and 1.25% at the end of the experiment and 0.40 and 1.17% for the same periods at 10 and 20: 1 sludge: plant residue treatments, respectively.

There are significant differences between treatments, since the minimum mean total N content value was 0.48% for wood carpentry refuse and the maximum value was 1.20% for lupine residues at 10:1 treatments while they were 0.48 and 1.12% for the same plant wastes at 20:1 sludge: plant residues.

Table (5). Total nitrogen content (%) of the different sewage sludge-plant residues mixtures as affected by sewage sludge application ratio and composting period.

Treatment	Weeks							
	0	1	2	4	6	8	10	Mean
	Sludge : plant residues, 10:1							
1	0.35	0.49	0.49	0.49	0.50	0.51	0.51	0.48
2	0.36	0.54	0.57	0.46	0.47	0.52	0.60	0.50
3	0.36	0.55	0.50	0.53	0.56	0.66	0.62	0.54
4	0.36	0.63	0.65	0.71	0.81	1.30	1.45	0.84
5	0.36	0.61	0.63	0.69	0.79	1.07	1.09	0.75
6	0.38	0.64	0.58	0.84	0.83	1.06	1.12	0.78
7	0.40	0.64	0.55	0.82	0.95	1.11	1.11	0.80
8	0.42	0.67	0.71	0.96	1.27	1.64	1.91	1.08
9	0.46	0.60	0.57	0.93	1.40	1.55	1.86	1.05
10	0.46	0.73	0.63	1.05	1.53	1.78	2.23	1.20
Mean	0.39	0.61	0.59	0.75	0.91	1.12	1.25	0.80
	Sludge : plant residues, 20:1							
11	0.35	0.46	0.50	0.49	0.50	0.50	0.53	0.48
12	0.35	0.40	0.45	0.45	0.48	0.51	0.44	0.46
13	0.60	0.57	0.63	0.65	0.65	0.64	0.74	0.64
14	0.35	0.57	0.61	0.67	0.61	0.70	1.01	0.65
15	0.36	0.59	0.64	0.53	0.71	0.93	1.07	0.71
16	0.36	0.60	0.62	0.67	1.02	1.03	1.24	0.79
17	0.38	0.65	0.56	0.71	0.99	1.17	1.41	0.84
18	0.39	0.65	0.70	0.83	1.33	1.49	1.81	1.03
19	0.40	0.59	0.61	0.72	1.04	1.30	1.55	0.89
20	0.41	0.68	0.75	1.11	1.32	1.64	1.93	1.12
Mean	0.40	0.58	0.61	0.68	0.87	0.99	1.17	0.75
G. Mean	0.38	0.60	0.60	0.72	0.88	1.06	1.21	0.78

			$LSD_{0.05}$
1 and 11 wood carpentry refuses	**6 and 16 sugar can refuses**		
2 and 12 peanut shells	**7 and 17 grass clipping**	**Sludge ratio**	**0.03**
3 and 13 rice straw	**8 and 18 peanut shoots**	**Treatments**	**0.06**
4 and 14 wheat straw	**9 and 19 chickpea residues**	**Weeks**	**0.05**
5 and 15 corn straw	**10 and 20 lupine residues**		

Table (6) also provide data obtained for the effect of sewage sludge application rate and composting period on the C/N ratio of the different sludge-plant residue treatments. A decrease in C/N ratio was recorded in all sewage sludge-plant residue treatments as a result of decreasing of sewage sludge from 20:1 to 10:1. A gradual significant decrease in C/N ratio of the different treatments was occurred by extending composting period. Mean of C/N ratios were decreased from 46.94 and 47.14 at the beginning to 10.24 and 11.13 at the end of the experiment for 10 and 20:1 sludge-plant residues, respectively.

Table (6). Carbon/nitrogen ratio of the different sewage sludge-plant residues mixtures as affected by sewage sludge application ratio and composting period.

Treatment	Weeks							
	0	1	2	4	6	8	10	Mean
	Sludge : plant residues, 10:1							
1	56.89	38.82	36.08	26.00	23.68	22.08	19.73	31.90
2	55.69	30.67	28.46	25.70	23.66	20.62	17.57	28.91
3	54.67	28.18	26.24	24.72	22.43	17.79	15.87	27.13
4	50.14	28.08	26.68	23.93	18.96	9.89	8.65	23.76
5	47.36	27.39	25.37	17.25	13.62	9.40	8.28	21.24
6	44.50	25.94	25.03	14.81	12.12	9.25	8.20	19.99
7	44.18	25.78	24.69	14.46	11.47	8.88	7.28	19.50
8	41.05	25.34	23.80	14.17	10.47	7.39	6.30	18.36
9	37.61	25.03	23.77	13.61	8.27	6.83	5.29	17.20
10	37.35	21.04	20.86	12.36	8.04	6.72	5.26	15.95
Mean	46.94	27.63	26.10	18.70	15.27	11.89	10.24	22.39
	Sludge : plant residues, 20:1							
11	52.43	39.09	35.64	31.06	25.08	24.48	21.02	32.69
12	52.66	31.80	29.06	26.23	22.71	21.02	20.68	29.17
13	50.67	31.23	26.76	25.54	22.34	19.66	16.03	27.46
14	49.66	29.82	26.88	23.88	21.08	16.00	10.85	25.45
15	46.83	27.97	25.16	23.02	15.46	11.31	9.09	22.69
16	46.64	26.83	24.77	20.18	11.90	10.47	7.60	21.20
17	45.24	25.94	24.68	19.24	11.60	9.15	6.82	20.38
18	43.49	25.05	22.86	18.77	11.07	8.89	6.69	19.55
19	42.48	24.95	21.48	15.67	10.83	7.98	6.30	18.53
20	41.29	22.68	19.17	12.31	9.36	7.37	6.17	16.91
Mean	47.14	28.54	25.65	21.59	16.14	13.63	11.13	23.40
G. Mean	47.04	28.08	25.87	20.15	15.71	12.76	10.68	22.90

			$LSD_{0.05}$
1 and 11 wood carpentry refuses	**6 and 16 sugar can refuses**		
2 and 12 peanut shells	**7 and 17 grass clipping**	**Sludge ratio**	**1.04**
3 and 13 rice straw	**8 and 18 peanut shoots**	**Treatments**	**0.46**
4 and 14 wheat straw	**9 and 19 chickpea residues**	**Weeks**	**0.87**
5 and 15 corn straw	**10 and 20 lupine residues**		

Differences between treatments were high significant, since the lowest mean of C/N ratios (15.95, 16.91) were recorded for sludge: lupine residues, while the highest ratios (31.90, 32.69) were recorded for sludge: wood carpentry refuse at both sewage sludge application rates. Vigerust (1984) found that total N content is not much changed during composting, and degradation of organic carbon in result C/N ratio decreases. The loss of organic matter results in a corresponding decrease in mass.

Table (7) shows the relationship between composting time and C/N ratio of different sewage sludge-plant residue treatments. A significant negative correlation was found between composting periods (weeks) and C/N ratios for all of the different investigated waste mixtures. Correlation coefficient (r) for C/N ratio were used for comparison between the organic C decomposition rate of the different treatments. So, the higher r value occupied with narrow C/N ratio and higher decomposition rate. Therefore, it can be arrange the different plant residues according to low C/N ratio as well as high organic C decomposition rate in the following order: chickpea residues > peanut shoots > wheat straw > lupine residues > corn straw > grass clippings > sugar can refuse > wood carpentry refuse > peanut shells > rice straw at 10:1 sewage sludge : plant waste. While, wood carpentry refuse > corn straw = grass clippings > peanut shoots > chickpea residues = sugar can refuse > wheat straw > lupine residues > rice straw > peanut sat 20:1 sewage sludge : plant waste.

Table (7). Relationship between composting time and C/N ratio of different sewage sludge-plant residues treatments.

Treatment	Variables X	Variables Y	Regression equation	Correlation coefficient (r)
Sludge-plant residues, 10:1				
1	Time, weeks	C/N ratio	Y = 45.570 - 3.084X	-0.875**
2	"	"	Y = 40.718 - 2.666X	-0.789*
3	"	"	Y = 39.076 - 2.698X	-0.780*
4	"	"	Y = 38.577 - 3.346X	-0.896**
5	"	"	Y = 35.604 - 3.244X	-0.887**
6	"	"	Y = 33.476 - 3.039X	-0.880**
7	"	"	Y = 33.283 - 3.105X	-0.886**
8	"	"	Y = 31.829 - 3.041X	-0.908**
9	"	"	Y = 30.378 - 2.975X	-0.927**
10	"	"	Y = 27.985 - 2.718X	-0.889**
Sludge-plant residues, 20:1				
11	"	C/N ratio	Y = 44.437 - 2.653X	-0.912**
12	"	"	Y = 39.644 - 2.366X	-0.792*
13	"	"	Y = 38.717 - 2.542X	-0.836*
14	"	"	Y = 38.517 - 2.950X	-0.885**
15	"	"	Y = 36.419 - 2.094X	-0.903**
16	"	"	Y = 35.424 - 3.212X	-0.895**
17	"	"	Y = 34.598 - 3.208X	-0.903**
18	"	"	Y = 33.069 - 3.054X	-0.899**
19	"	"	Y = 31.855 - 3.009X	-0.895**
20	"	"	Y = 29.447 - 2.832X	-0.855*

1 and 11 Wood carpentry refuse	**2 and 12 Peanut shells**	**3 and 13 Rice straw**	**4 and 14 Wheat straw**
5 and 15 Corn straw	**6 and 16 Sugar cane refuse**	**7 and 17 Grass clippings**	**8 and 18 Peanut shoots**
9 and 19 Chickpea residues	**10 and 20 Lupine residues**		

At low rate of sewage sludge application, the relatively easily decomposable substances and high N content of plant wastes, i.e. legume wastes, may be the reason for their faster decomposition. However, increasing sewage sludge application rate to the relatively difficult decomposed wastes, i.e. wood carpentry refuse and grass clippings, may be increased other easily decomposable organic C that increased microbial population which accelerated these wastes decomposition (Alexander, 1977).

Salinity, NPK and some heavy metals

Electrical conductivity (EC) of the saturated past of final compost product of different sewage sludge-plant residues are given in Table (8).

Table (8). Changes in macro- and micronutrients in the final compost products of the sewage sludge-plant residues.

Treatment	EC*	N	P	K	Cd	Pb	Cu	Zn	Ni
	dSm^{-1}	%			$Mg\ kg^{-1}$ dry matter				
Sludge : plant residues, 10:1									
1	2.76	0.51	0.483	0.49	0.210	0.359	0.262	1.563	0.287
2	2.30	0.60	0.538	1.49	0.183	0.320	0.325	1.563	0.307
3	2.60	0.62	0.574	1.53	0.200	0.345	0.331	1.363	0.260
4	2.85	1.45	0.578	0.61	0.193	0.354	0.275	1.522	0.276
5	2.99	1.09	0.594	0.60	0.227	0.536	0.320	1.615	0.283
6	2.80	1.12	0.570	0.59	0.199	0.278	0.339	1.373	0.223
7	2.40	1.11	0.538	1.30	0.205	0.371	0.342	1.682	0.297
8	2.30	1.91	0.602	1.08	0.226	0.359	0.285	1.563	0.287
9	2.60	1.86	0.652	0.61	0.212	0.316	0.292	1.394	0.265
10	2.91	2.23	0.618	1.22	0.204	0.319	0.338	1.309	0.318
Mean	2.65	1.25	0.575	0.95	0.210	0.366	0.311	1.500	0.280
Sludge : plant residues, 20:1									
11	3.69	0.53	0.633	0.60	0.274	0.406	0.457	1.841	0.325
12	3.08	0.44	0.808	1.79	0.239	0.485	0.342	1.774	0.388
13	3.04	0.74	0.633	1.20	0.283	0.377	0.341	1.775	0.428
14	3.80	1.01	0.808	0.52	0.286	0.520	0.430	1.710	0.416
15	3.40	1.07	0.744	0.53	0.228	0.504	0.431	1.839	0.403
16	3.29	1.24	0.618	0.63	0.282	0.421	0.375	1.988	0.336
17	3.29	1.41	0.662	1.32	0.238	0.552	0.408	1.904	0.520
18	3.12	1.81	0.824	1.78	0.239	0.428	0.375	1.823	0.482
19	3.70	1.55	0.626	1.18	0.256	0.398	0.353	1.767	0.342
20	3.60	1.93	0.649	1.24	0.255	0.478	0.365	1.763	0.382
Mean	3.40	1.17	0.701	1.07	0.258	0.457	0.388	1.818	0.402
G. mean	3.03	1.21	0.638	1.01	0.234	0.412	0.350	1.659	0.341
$LSD_{0.05}$:									
Treatment	0.38	0.37	Ns	0.49	Ns	Ns	Ns	Ns	Ns
Sludge ratio	0.17	Ns	0.070	Ns	0.020	0.050	0.040	0.010	0.04
Maximum permissible concentration in sludge,mg kg^{-1}**					**20**	**1200**	**1200**	**3000**	**200**

*** in sludge saturation paste.**
**** proposed by the German Ministry of the Environment in August, 1990.**
Ns= not significan

1 and 11 wood carpentry refuses	**6 and 16 sugar can refuses**
2 and 12 peanut shells	**7 and 17 grass clipping**
3 and 13 rice straw	**8 and 18 peanut shoots**
4 and 14 wheat straw	**9 and 19 chickpea residues**
5 and 15 corn straw	**10 and 20 lupine residues**

There are significant differences between treatments. It was found that EC of final compost product of plant residues received sewage sludge at rate of 1:20 w/w had usually EC higher than those received sewage sludge at rate of 1:10 w/w. Since, EC mean values were ranged between 2.65 and 3.40 dSm^{-1} for the different treatments at 10 and 20:1 sludge: plant residues, respectively. This means that increasing the rate of sludge mixing to different plant residues increased the EC values of the final compost. Salinity level of the different treatments as a result of sewage sludge application at both rates of 10 and 20: 1 residues were still low and practice for agricultural use of the final compost product.

The NPK contents of the different sewage sludge-plant residue composts are given in Table (8). There are significant differences in total N and K contents between the different types of composts. Generally, N content of the plant wastes not significantly decreased, while, P content significantly increased and K content not significantly increased with increasing sewage sludge rate from 10 to 20:1 plant residues. The lowest N content mean values were 0.50% for wood carpentry refuse and 0.44% for peanut shells, while highest values were 2.23 and 1.93% for lupine residues, at 10 and 20:1 sludge: plant wastes, respectively. The lowest P content mean values were 0.483 wood carpentry refuse and 0.618% for sugar can refuse, while highest values were 0.652% for chickpea residues and o.824% for peanut shoots, at 10 and 20:1 sludge: plant wastes, respectively. The lowest K content mean values were 0.49% and 0.60% for wood carpentry refuse, while highest values were 1.53% for rice straw and 1.79% for peanut shells, at 10 and 20:1 sludge: plant wastes, respectively. It means that increasing the rate of sewage sludge upto 20:1 plant residues not significantly increased K content, decreased the N content and significantly increased P content of the final compost product. Similar results were obtained by Dam Kofoed (1983). He found that, composting of plant residues treated with sewage sludge, N content of the compost product not greatly changed, while P and K contents increased.

It is well known that heavy metal concentrations in sewage sludges are not constant. Values of heavy metals in the final composts of the different sludge-plant residues treatments were compared with maximum permissible values (related by future threshold heavy metals values in soils) proposed by the German Ministry of the Environment in August, 1990 (Sauerbeck and Leschber, 1992) for sewage sludge agricultural use. Although increasing sewage sludge rate to different plant residues from 10 to 20:1, total Cd, Pb, Cu, Zn and Ni concentrations in the final compost of these mixtures are very lower than maximum permissible concentrations for agricultural use (Table 8).

Data obtained for total microelement concentrations for the final compost of different sewage sludge-plant residue treatments are shown in Table (8). Total microelement contents of the final compost of different sludge-plant residue mixtures not differ greatly.

Pathogens

Sewage sludge usually contains pathogens, both bacteria and parasites, which can infect human and animals. This has to be considered if sludge is to be used in agriculture. Data obtained for total bacterial, coliforms and some of pathogenic bacterial counts i.e. *Salmonella sp.*, *Shigella sp.* and *Vibrio sp.* and some of pathogenic helminths i.e. *Ascaris lumbericoides*, *Trichuris trichiura*, *Entrobius vermiculus* and *Hyenolepis spp.* in raw sewage sludge and the final compost product of sludge-plant residue treatments are presented in Table (9). It was found that raw sewage sludge has pathogenic bacteria and parasites in the range of the infective dose to human according the levels introduced by Kowal (1989). Composting conditions resulted in decreasing the counts to levels below the infective dose.

The reduction percentages in pathogenic organisms as a result of composting of 20 sludge-plant residue treatments are presented in Table (10). Generally, composting conditions of sewage sludge-plant residues were greatly effective in reduction of pathogenic bacteria and parasites (Table 10)

as compared with raw sewage sludge (Table 9). Reduction percentages were higher in 10: 1 sludge-plant residue treatments than in 20: 1 treatments. Composting process transforms sludge and plant wastes into stable product relatively free from pathogenic organisms. The finding of decreasing pathogenic organisms by means of "composting" of sewage sludge was reported by Block (1985), Pike (1985), and Dam Kofoed (1983).

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كمر حمأة المجارى مع المخلفات النباتية المختلفة

صالح سليمان مبروك
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أجريت تجربة كمر لمدة ١٠ أسابيع فى مزرعة كلية الزراعة – جامعة قناة السويس خلال صيف ١٩٩٩. تم استخدام حمأة المجارى مع المخلفات النباتية الآتية بنسبة ١:١٠ ، ١:٢٠ وزن/وزن :-
١-نشارة الخشب ٢- قشر الفول السودانى ٣- قش الأرز ٤- قش القمح ٥- قش الذرة ٦- مصاصة القصب ٧- مخلفات المسطحات الخضراء النجيلية ٨- عرش الفول السودانى ٩- مخلفات الحمص ١٠- مخلفات الترمس.

وكان الهدف من الدراسة هو محاولة الحصول على مكمورة ذات صفات جيدة وآمنة بيئيا من حيث خلوها من الممرضات حتى يمكن تحقيق أقصى استفادة من حمأة المجارى واستخدامها كسماد عضوى للتربة.

وقد أشارت النتائج الى الآتى:

١. تناقص محتوى الكربون العضوى تدريجيا وبدرجة معنوية مع الوقت حتى نهاية التجربة ، أدت زيادة بسيطة فى محتوى المخلوط من النتروجين ، ويمكن ترتيب معاملات المخلفات النباتية مع الحمأة تصاعديا طبقا لقيم نسبة الكربون الى النتروجين على النحو التالى: مخلفات المحص – عرش الفول الفول السودانى – قش القمح – مخلفات الترمس – قش الذرة – المخلفات النجيلية – مصاصة القصب – نشارة الخشب – قشر الفول السودانى وأخيرا قش الأرز عند معدل ١٠ حمأة : ١ مخلفات نباتية. بينما كان الترتيب على النحو التالى: نشارة الخشب - قش الذرة = المخلفات النجيلية - عرش الفول السودانى - مخلفات المحص = مصاصة القصب – قش القمح – مخلفات الترمس – قش الأرز – وأخيرا قشر الفول السودانى عند معدل ٢٠ حمأة : ١ مخلفات نباتية.
٢. كان مستوى الملوحة فى المنتج النهائى لمكمورة المعاملات المختلفة مناسبا للاستخدام الزراعى. كما أدت زيادة معدل اضافة المجارى الى نقص فى محتوى المكمورة من النتروجين وزيادة البوتاسيوم والفوسفور، وكانت تركيزات عناصر الكادميوم والرصاص والنحاس والزنك والنيكل أقل كثيرا من الحدود المسموح بها للاستخدام الزراعى.
٣. كما أشارت النتائج الى احتواء الحمأة الخام على أعداد عالية من البكتيريا والطفيليات الممرضة وفى الحدود التى يتسبب عنها أمراض للإنسان ، إلا أن ظروف عملية كمر المعاملات المختلفة أدت الى اختزال هذه الممرضات الى الحدود الآمنة للإستخدام الزراعى لها.

Table (9). Density of some bacterial pathogens and intestinal parasites in raw sewage sludge and the final compost product of the different sewage sludge-plant residues.

Organism	RSS	Sewage sludge-plant residue (10:1) treatments									
		1	2	3	4	5	6	7	8	9	10
		Sewage sludge-plant residue (10:1) treatments									
Bacteria											
Total count, $x10^8$	1.5	0.01	0.01	0.02	0.05	0.03	0.05	0.03	0.05	0.04	0.03
Total coliforms, $x10^5$	1.4	0.01	0.04	0.05	0.03	0.03	0.05	0.03	0.01	0.03	0.05
Salmonella sp. $X10^4$	38.0	0.0001	0.00015	0.00016	0.00023	0.00021	0.00032	0.00023	0.00014	0.00016	0.00016
Shigella sp. $X10^4$	0.1	0.00024	0.00012	0.00024	0.00014	0.00025	0.00018	0.00032	0.00016	0.00019	0.0002
Vibrio sp $x10^4$	1.0	-	-	-	0.0006	0.0001	0.0009	0.0008	-	-	0.0001
Intestinal parasites (egg $x10^2$/g)											
Ascaris humbericoides	5.0	0.12	0.1	0.11	0.13	0.01	0.02	0.05	0.05	0.04	0.03
Trichuris trichura	1.1	-	-	-	-	-	-	-	-	-	-
Entrobius vermiculus	0.1	-	-	-	-	-	-	-	-	-	-
Hyenolepis sp.	1.0	-	-	-	-	-	-	-	-	-	-
Taxocara canions	2.4	-	-	-	-	-	-	-	-	-	-
		Sewage sludge-plant residue (20:1) treatments									
Bacteria											
Total count, $x10^8$	1.5	0.092	0.051	0.043	0.043	0.063	0.083	0.096	0.064	0.053	0.043
Total coliforms, $x10^5$	1.4	0.054	0.054	0.064	0.036	0.032	0.055	0.054	0.065	0.057	0.058
Salmonella sp. $X10^4$	38.0	0.001	0.0015	0.001	0.002	0.0021	0.0023	0.0026	0.0021	0.0023	0.0022
Shigella sp. $X10^4$	0.1	0.00068	0.00034	0.00054	0.00038	0.00055	0.00033	0.00042	0.00062	0.00053	0.00044
Vibrio sp $x10^4$	1.0	0.0016	0.0083	0.0033	0.009	0.0052	0.0042	0.0032	0.0045	0.0012	0.0055
Intestinal parasites (egg $x10^2$/g)											
Ascaris humbericoides	5.0	0.5	1.5	1.0	0.5	0.5	0.5	1.0	1.5	0.5	1.0
Trichuris trichura	1.1	-	-	-	-	-	-	-	-	-	-
Entrobius vermiculus	0.1	-	-	-	-	-	-	-	-	-	-
Hyenolepis sp.	1.0	-	-	-	-	-	-	-	-	-	-
Taxocara canions	2.4	-	-	-	-	-	-	-	-	-	-

-, not detected

Infective dose to human (according to Kowal, 1989).

Bacterium	Percent of volunteers Developing illness			
	1-25	**26-50**	**51-75**	**76-100**
Salmonella spp.	10^5	10^5-10^8	10^4	10^8-10^9
Shigella sp.	10-10^2	10^2-10^4	10^3	10^4
Vibrio cholera	10	10^3-10^8	10^4-10^6	

1 and 11 wood carpentry refuses
2 and 12 peanut shells
3 and 13 rice straw
4 and 14 wheat straw
5 and 15 corn straw
6 and 16 sugar can refuses
7 and 17 grass clipping
8 and 18 peanut shoots
9 and 19 chickpea residues
10 and 20 lupine residues

Table (10). Reduction percentages (%) of some bacterial pathogens and intestinal parasites from the different sewage sludge-plant residues after 10 weeks composting.

Organism	Sewage sludge-plant residue (10:1) treatments									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	Sewage sludge-plant residue (10:1) treatments									
Bacteria										
Total count	99.33	99.33	98.67	96.67	98.0	96.67	98.0	96.67	97.33	98.0
Total coliforms	99.29	97.14	96.43	97.86	97.86	96.43	97.86	99.29	97.86	96.43
Salmonella sp.	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Shigella sp.	99.76	99.88	99.76	99.86	99.75	99.82	99.68	99.84	99.81	99.8
Vibrio sp	100.0	100.0	100.0	99.94	99.99	99.91	99.92	100.0	100.0	99.99
Intestinal parasites										
Ascaris humbericoides	97.6	98.0	99.8	97.4	99.8	99.6	99.0	99.0	99.2	99.4
Trichuris trichura	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Entrobius vermiculus	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Hyenolepis sp.	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Taxocara canions	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	Sewage sludge-plant residue (20:1) treatments									
Bacteria										
Total count	93.87	96.60	97.13	97.13	95.8	94.47	93.6	95.73	96.47	97.13
Total coliforms	96.14	96.14	95.43	97.43	97.71	96.07	96.14	95.36	95.93	95.86
Salmonella sp.	100.0	100.0	100.0	100.0	100.0	99.99	99.99	100.0	99.99	99.99
Shigella sp.	99.32	99.66	99.46	99.62	99.45	99.67	99.58	99.38	99.47	99.56
Vibrio sp	99.84	99.17	99.67	99.10	99.48	99.58	99.68	99.55	99.88	99.45
Intestinal parasites										
Ascaris humbericoides	90.0	70.0	80.0	90.0	90.0	90.0	80.0	70.0	90.0	80.0
Trichuris trichura	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Entrobius vermiculus	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Hyenolepis sp.	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Taxocara canions	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

1 and 11 wood carpentry refuses
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