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PATHOGEN DESTRUCTION IN SEWAGE SLUDGE BY COMPOSTING AND CEMENT KILN DUST BLENDING

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ABSTRACT

An experiment for pathogen removal from a raw sewage sludge (SS) by composting and addition of cement kiln dust (CKD) was carried out at the Experimental Farm of the Faculty of Agriculture, Suez Canal University, Ismailia Governorate. SS from the Wastewater Treatment Plant at Serabium, Ismailia, was mixed with ground rice straw (RS) on equal weight basis. The mixture of SS and RS was composted individually or blended with CKD, on weight basis as follows: SS-RS mixture, SS-RS mixture+5%CKD, SS-RS mixture+10%CKD, SS-RS mixture+15%CKD and SS-RS mixture+20%CKD. Different compost mixtures were regularly mixed in elongate piles 5 m long and 1 m high and wide. Temperature and pH values were recorded, total coliforms, *Salmonella spp., Shigella spp., Klebsiella spp., Vibrio spp.* and *Ascaris humbericoides* ova counts were counted at various composting stages (0, 1, 2, 3, 5, 7, 15, 30, 45 and 60 days). Data for all composting treatments indicated that:

Temperature was gradually increased by increasing composting period and application rate of cement kiln dust till the 5th or 7th day and then again declined till 60th day (the end of the experiment).The pH decreased as composting progressed till the end of composting and increased by increasing application rate of cement kiln dust at all composting stages.

Total coliforms, *Salmonella spp., Shigella spp., Klebsiella spp., Vibrio spp., and Ascaris humbericoides* ova counts decreased as composting progressed till the end of composting. Pathogenic bacteria and Ascaris parasite ova counts of mixtures decreased and the reduction percentages increased by increasing application rate of cement kiln dust.

Ascaris parasites were more resistant to the composting and CKD blending than other pathogens. Also, total coliforms and *Salmonella spp.* were less resistant to destroy by composting and CKD blending than other pathogenic bacteria.

Keywords: sewage sludge, cement kiln dust, rice straw, composting, pathogens, parasites, temperature, pH, recycling.

INTRODUCTION

As the world's population is increasing, the need for arable soil became essential, also the amount of wastes increases, and all human wastes should be recycled. Recycling of organic wastes in urban farming is an effective approach to address urban waste management problems to provide important resources for agricultural production and making urban agriculture more sustainable (EPA, 1994; Stoll and Parameswaran, 1996; Poulsen and Hansen, 2003). Application of organic wastes to the soil would provide many benefits. Furthermore, an organic waste provides a stabilized form of organic matter that improves the physical, chemical and biological properties of the soil (Haug, 1993; Wang *et al.*, 1998).

Several problems that occur when raw and unstable human organic wastes, such as sewage sludge, are directly applied to the soil (Mabrouk, 2000; Watanabe *et al.*, 2002). There are two groups of micro-organisms that may cause diseases i.e., primary and secondary pathogens. Primary pathogens, which are normally present in raw sewage sludge and cause infection to healthy individuals, including bacteria, viruses, protozoa and helminth eggs. Most of the infections they cause, diarrhoea and dysentery, are spread via faecal-oral transmission routes. Secondary pathogens are micro-organisms, fungi and acid-producing bacteria, that grow during biological decomposition. These pathogens are less important, but they can cause primary infections and respiratory diseases usually in people with a weak immune system (Polprasert, 1989). Thus, the treatment of sludge resulting from sewage treatment plants to remove pathogenic micro-organisms and to improve its impact on the environment was considered as the main objective of several investigators.

The purposes of the current study were to: (1) investigate the effect of composting and application of cement kiln dust on destroying pathogens already present in the sewage sludge, (2) prevent the recolonization of pathogens after treatments, and (3) improve the quality of the end-product to be used as an effective and safe fertilizer and/or soil conditioner.

MATERIALS AND METHODS

A composting experiment was carried out at the Experimental Farm of the Faculty of Agriculture, Suez Canal University, Ismailia Governorate. The aim of the present study was to evaluate the effect of composting and addition of cement kiln dust on pathogen removal from sewage sludge (the by-product of the treatment of municipal wastewater). Sewage sludge (SS) from the Wastewater Treatment Plant at Serabium, Ismailia, was mixed with ground rice straw (RS) on equal weight basis. The mixture of SS and RS was composted individually or blended with cement kiln dust (CKD). RS samples were oven dried at 70 °C, ground, digested and analyzed according to Chapman and Pratt (1961). SS and CKD samples were prepared and analyzed according to Page *et al.* (1982). Some characteristics of SS, RS and CKD are presented in Table (1). The SS-RS mixture and CKD were thoroughly mixed on the following weight basis:

1.SS-RS mixture
2.SS-RS mixture + 5% CKD
3.SS-RS mixture +10% CKD
4.SS-RS mixture +15% CKD
5.SS-RS mixture +20% CKD

The mixtures of the different composts were regularly mixed in elongated piles shap-like haystack up to 5 m in length. The cross- section of the pile was 1 m wide. The composts were turned twice weekly. Their moisture content was adjusted to about 55-60% by weight. Pile temperature (before turning) and pH (1:2.5 H_2O) were measured and 3 samples were collected from each compost at various stages (0,1, 2, 3, 5, 7, 15, 30, 45, and

60 days). Collected samples were packed in polyethylene bags, put in an icebox and sent to the lab at the same day. Upon arrival, the samples were kept in a refrigerator at 4° C. Fresh 3 samples of each treatment were taken for the microbiological analyses. Plate counts were carried out in samples using the following nutrient media according to APHA (1992): lactose peptone broth medium for total coliforms, and *Shigella Salmonella* (SS) agar medium for *Salmonella spp.* and *Shigella spp.*, MCIC agar medium for *Klebsiella spp.*, and TCBS medium for *Vibrio spp*

Table (1): Some characteristics of the sewage sludge (SS), rice straw (RS) and cement kiln dust (CKD) used in the experiment

SS	
pH (in 1: 2.5 water suspension)	7.2
EC, dSm^{-1}(in saturated paste extract)	11.8
Total N, mg kg^{-1}	9.0
Total P, mg kg^{-1}	7.5
Total K, mg kg^{-1}	1.4
C/N ratio	26
Total coliforms (CFU g^{-1})	$1.4x10^5$
**Salmonella spp.* (CFU g^{-1})	$3.7x10^5$
Shigella spp. (CFU g^{-1})	$7.2x10^3$
Klebsilla spp. (CFU $^{g-1}$)	$8.4x10^3$
**Vibrio spp.* (CFU $^{g-1}$)	$3.7x10^3$
Ascaris humbericoides (egg g^{-1})	$5.0x10^2$
RS	
Total N, mg kg^{-1}	6.0
Total P, mg kg^{-1}	1.0
Total K, mg kg^{-1}	7.0
C/N ratio	90
CKD	
pH (in 1: 2.5 water suspension)	11.6
EC, dSm^{-1} (in saturated paste extract)	60.7
$CaCO_3$(mg kg^{-1})	312

***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	10^8	10^8-10^9
Shigella spp.	10-10^2	10^2-10^3	10^3	10^4
Vibrio spp.	10	10^3-10^4	10^4-10^6	10^6

Six grams from fresh sample were put in a 150 ml beaker and 100ml NaOH 10% were added to the sample. After 48 h, 0.1 ml was taken from the surface of the sample and spreads on slide cover for the microscopic examination of *Ascaris lumbericoides ova* according to Lawrence *et al.*,(1985).

RESULTS AND DISCUSSION

Data of temperature for sewage sludge-rice straw mixture composted individually or blended with different rates of cement kiln dust at different composting stages are presented in Figure 1. Generally, temperature was gradually increased by increasing composting period till the 5th or 7th day and then again declined till 60th the day (the end of the experiment).

As shown in Figure 1, the temperature-time course of the composting process can be divided into 4 phases: (1) During the first phase a diverse population of mesophilic bacteria and fungi proliferates, degrading primarily the readily available nutrients and thereby raising the temperature to about 45° C. (2) After a short lag period there occurs a second more or less steep rise of temperature. This second phase is characterized by the development of a thermophilic microbial population comprising some bacterial species, actinomycetes and fungi. The optimum temperature of these micro-organisms is between 50-65° C. (3) The third phase can be regarded as a stationary period without significant changes of temperature because microbial heat production and heat dissipation balance each other. The microbial population continues to consist of thermophilic bacteria, actinomycetes, and fungi. (4) The fourth phase is characterized by a gradually temperature decline; it is best described as the maturing phase of the composting process. At the end of this stage, the material is no longer self-heating, and the mature compost is ready for use. Such temperature course can be found in the literature, as has been stated by EPA (1998), Lasaridi *et al.*, (2000) and Zayed and Mabrouk (2003).

In all cases, the 4 phases mentioned were distinct as characterized very closely to the composting process. Since the composting temperature is regarded to be about 50-60°C, measures are being taken to prevent further self-heating except for a rather short period up to 70 ° C to guarantee the elimination of pathogens (EPA, 1993).

Increasing application rate of cement kiln dust increased the temperature of composts at all composting stages. When cement kiln dust is blended with sludge, in addition to the raising of the pH, there is an autothermic effect and the temperature of the mixture is raised to 70 ° C (when CKD blended at rates of 10 and 20 %). The same results were found in the European Community, (2001).

Data of pH for sewage sludge-rice straw mixture composted individually or blended with different rates of cement kiln dust at different composting stages are presented in Figure 2.The pH of all treatments decreased as composting progressed till the end of composting. The pH was decreased from 7.65, 9.50,10.90,11.11 and 11.27 on day 0 to 7.10, 8.30, 9.48 and 9.50 on day 60 for sewage sludge blended with 0, 5, 10, 15, and 20 % cement kiln dust, respectively. As bacteria and fungi digest organic matter, they release organic acids. In the early stages of composting, these acids often accumulate. The resulting drop in pH encourages the growth of fungi and the breakdown of organic matter. Usually the organic acids become further broken down during the composting process. Aeration usually is sufficient to return the compost pH to acceptable ranges (Hellmann *et al.*, 1997; Zibjiske, 1998).

As shown in Figure 2, the pH of the mixtures increased greatly by increasing application rate of cement kiln dust up to 10% at all composting stages. The raising of the pH of sewage sludge to a high value by the use of CKD has the effect of suspending microbiological activity and reducing the hazard from pathogens. European Community (2001), reviewing the work of others suggests that a high pH value by the use CKD will reduce many pathogens to insignificant numbers. Extreme caution should be used to avoid overliming. If soil pH is raised above the optimum level for crop production then deficiencies of some micronutrients become common. Krogmann *et al.*, (2001) suggested that lime stabilized sewage sludge, or advanced alkaline stabilized sewage sludge, should normally not be applied if ericaceous crops that require low pH soils are be grown.

Raw sewage sludge contains a wide variety of pathogens including bacteria and parasites (helminthes). The pathogens generally include salmonella and helminth ova. Total coliforms are used as a general indicator for the presence of pathogenic bacterial found in sewage sludge. *Salmonella spp.* bacteria are subject to regulation because outbreaks of gastro-enteritis have in the past been relatively common and experience has shown that reducing salmonella to a law, as with total coliforms, provides a high degree of assurance that other bacterial pathogens do not constitute a health risk. *Salmonella spp.* are so common in the environment that the proper control of salmonellosis is through food hygiene, sewage sludge properly used in agriculture is not involved in the transmission of human salmonella (New Zealand Water&Wastes Association, 2002). It was found that raw sewage sludge has pathogenic bacteria and parasites in the rang of the infective dose to human according to the level introduced by Kowal (1989) as has been shown in Table 1.

Sewage sludge treatment processes (composting and CKD blending) significantly reduce the number of pathogens originally present in the raw sewage sludge to the levels below the infective dose. Figures 3-8 show total coliforms, *Salmonella spp., Shigella spp., Klebsiella spp. ,Vibrio spp. and Ascaris humbericoides* ova counts for sewage sludge-rice straw mixture composted individually or blended with different rates of cement kiln dust at different composting stages. The counts of the different pathogens for all treatments decreased as composting progressed till the end of composting.

The reduction percentages (based on initial counts in the raw sewage sludge) in total coliforms, *Salmonella spp., Shigella spp., Klebsiella spp., Vibrio spp.* and *Ascaris humbericoides* ova counts as a result of composting and CKD blending are presented in Table 2. Generally, composting and CKD blending conditions of sewage sludge were greatly effective in reducing of pathogenic bacteria and Ascaris parasites. The reduction percentages in pathogenic bacteria counts increased as composting progressed till the7th day and in Ascaris parasite ova counts till the 60th day. Most pathogenic bacteria were almost removed completely during the first 7 days. Reduction percentages were ranged from 97.9 to 99.9 % for *Shigella spp.* and total coliforms, respectively at 20% CKD blending. Total coliforms and *Salmonella* *spp.* were almost disappeared after a few days from starting the treatments (3-5 days). Reduction percentages were ranged from 99.2 to 99.9 % for *Salmonella spp.* and total coliforms, respectively at 20% CKD blending. However, for the sludge to be practically acceptable for soil use it must also be stabilized, so composting should be carried out over a period sufficient to stabilize the sludge and produce an acceptable product. These results are in a good agreement with those founded by Shaban (1999). The Ascaris parasites are still present during the first 7 days, but the counts decreased gradually and were almost removed completely at the end of treatments. Reduction percentages were ranged from 98.0 to 99.6 % at 0 and 20% CKD blending, respectively .So, from the previous results it is clear that, Ascaris parasites were more resistant to the composting and CKD blending than other pathogens. Also, total coliforms and *Salmonella spp.* were less resistant to destroy by composting and CKD blending than other pathogenic bacteria.

Tiquia *et al.*, (1998) concluded that temperature was the main factor affecting the elimination of pathogens in windrow composting of organic wastes. Stenbro-Olsen *et al.*, (1995) studied the patterns of temperature development and temperature distribution in windrows used for composting of municipal wastes over a period of 25 days. They concluded that, these plots revealed a sequential pattern of temperature development, which indicated that, the destruction of pathogens and the vast majority of the windrow contents were maintained at a temperature in excess of 65° C fore periods of four to five days.

Joshua *et al.*, (1998) studied the temperature profiles in an organic waste windrow processing system. The highest and lowest temperatures were 72.8 and 17.6°C, respectively. They concluded that predominantly thermophilic conditions were maintained in the windrows throughout processing and virtually all material was subject to the commonly recognized 55 °C for three days which ensures the destruction of potential pathogens in organic wastes.

Pathogens count of mixtures at all composting stages decreased and the reduction percentages in pathogenic bacteria and Ascaris parasite ova counts increased by increasing application rate of cement kiln dust as shown in Figures 3-8 and Table 2.

Krogmann *et al.*, (2001) reported that lime stabilized sewage sludge results from sewage treatment processes in which CKD is used to eliminate pathogens, or to stabilize sewage sludge for storage. The combination of elevated temperature caused by chemical reaction and high pH, as discussed in the time-pH and time-temperature courses of the composting process, Figures (1 and 2), produced a partial pathogen destruction and a product called advanced alkaline stabilized sewage sludge.

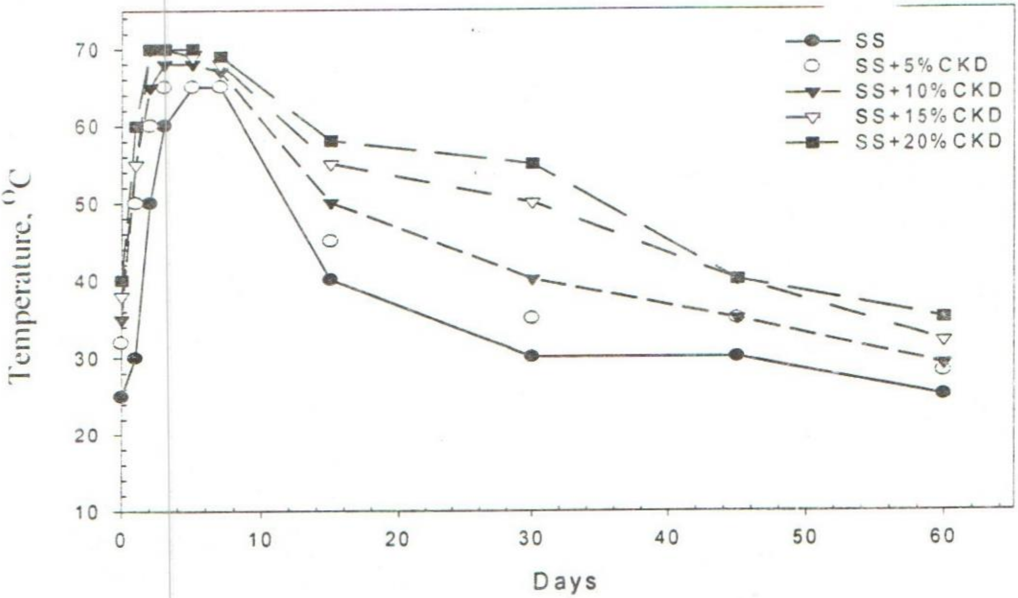

Figure (1): Periodical changes in temperature for sewage sludge (SS) and its different mixtures with cement kiln dust (CKD), during a composting time course.

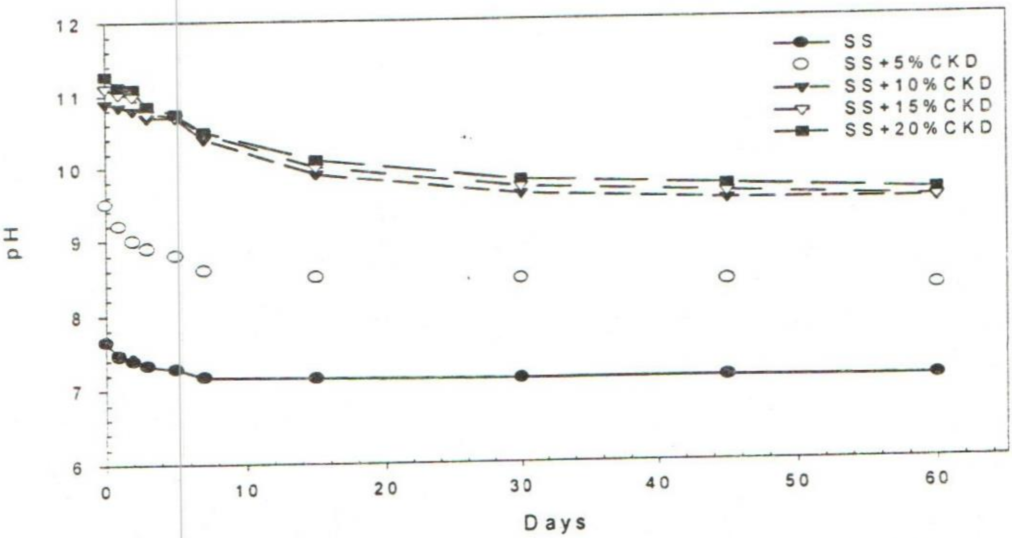

Figure (2): Periodical changes in pH for sewage sludge (SS) and its different mixtures with cement kiln dust (CKD), during a composting time course.

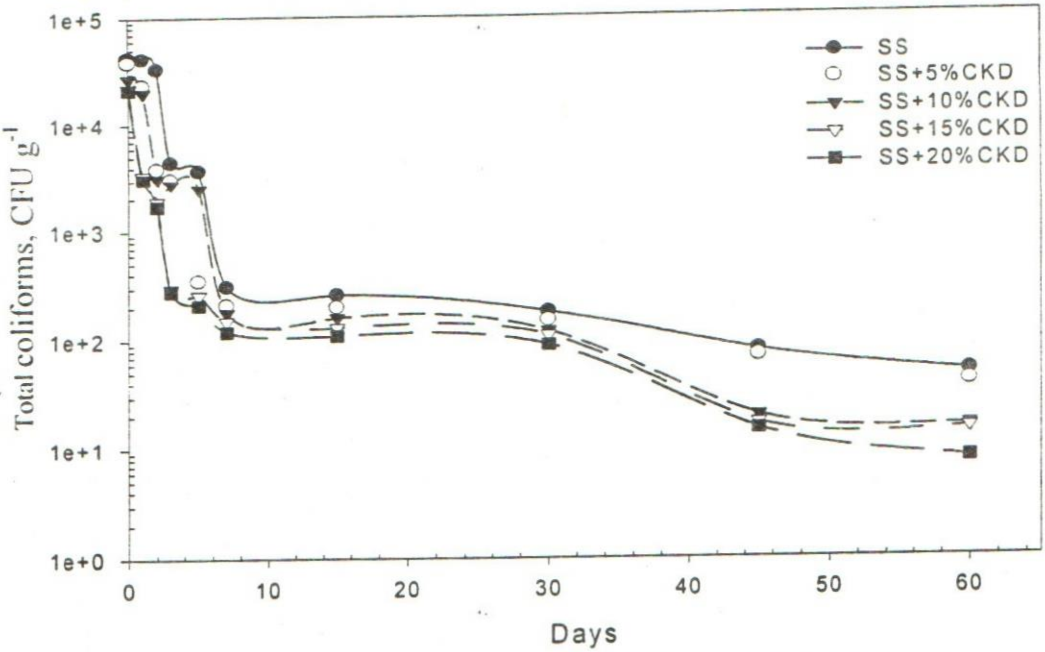

Figure (3): Periodical changes in total coliforms counts for sewage sludge (SS) and its different mixtures with cement kiln dust (CKD), during a composting time course.

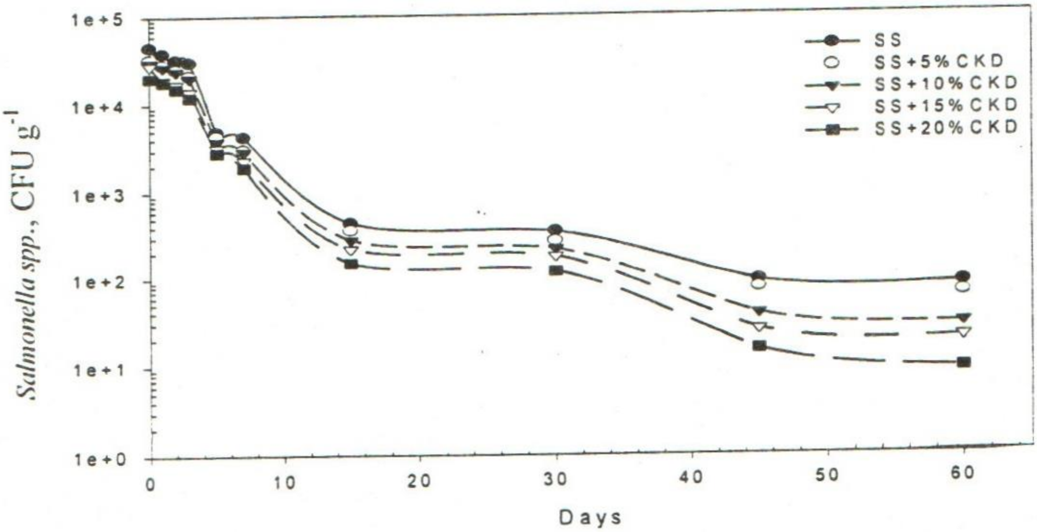

Figure (4): Periodical changes in *Salmonella spp.* counts for sewage sludge (SS) and its different mixtures with cement kiln dust (CKD), during a composting time course.

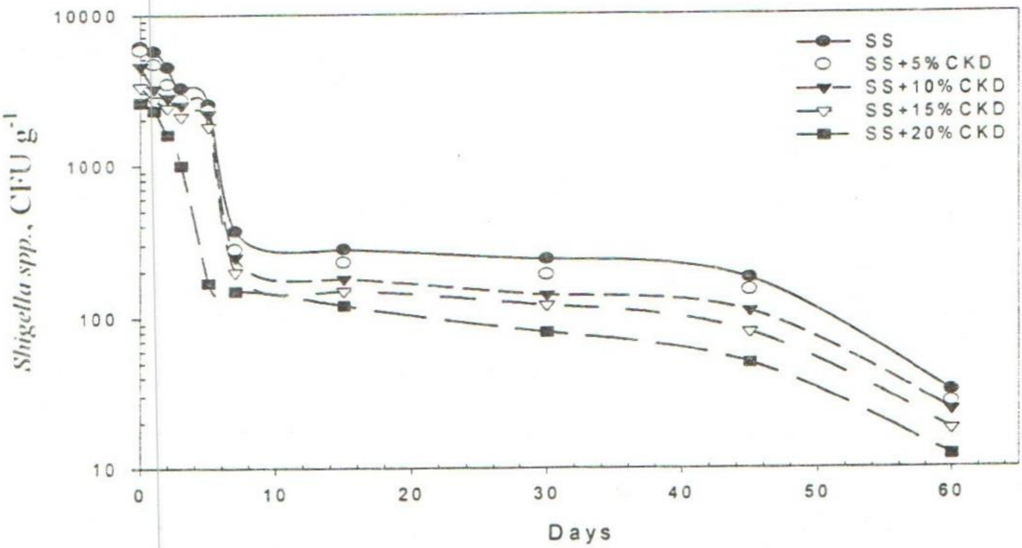

Figure (5): Periodical changes in *Shigella spp.*counts for sewage sludge-rice straw mixture (SS-RS) and its different mixtures with cement kiln dust (CKD), during a composting time course.

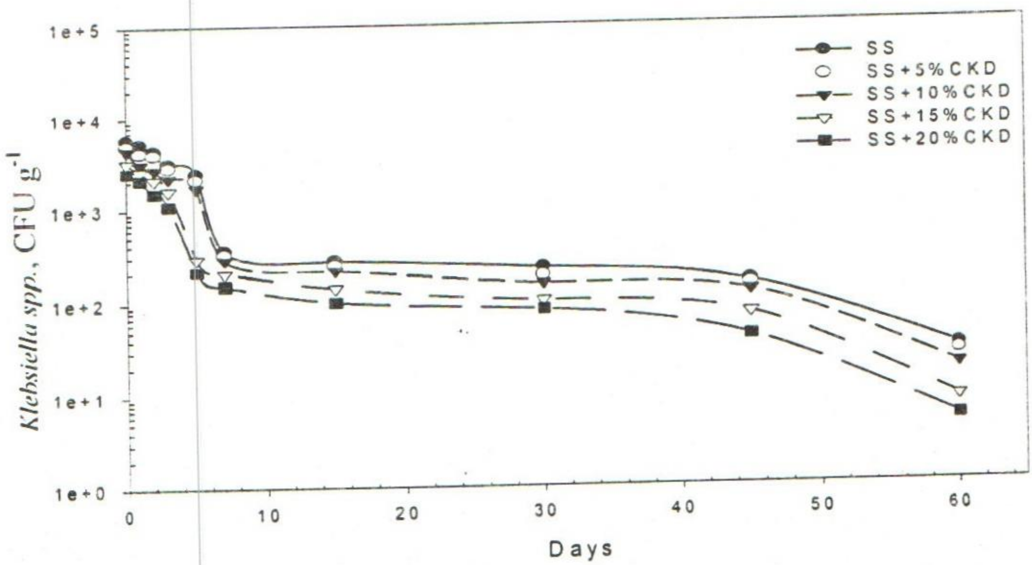

Figure (6):Periodical changes in *Klebsiella spp.* counts for sewage sludge (SS) and its different mixtures with cement kiln dust (CKD), during a composting time course.

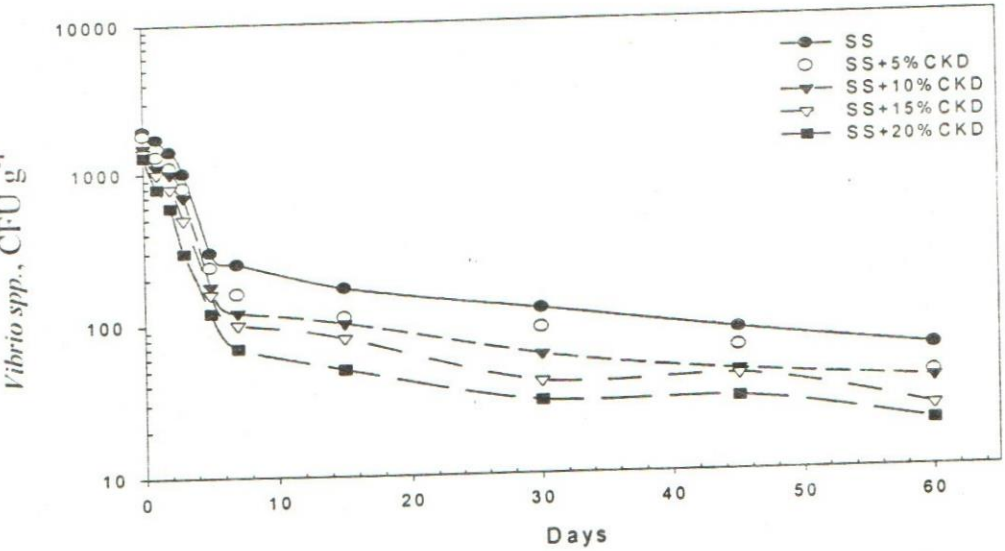

Figure (7): Periodical changes in *Vibrio spp.* counts for sewage sludge (SS) and its different mixtures with cement kiln dust (CKD), during a composting time course.

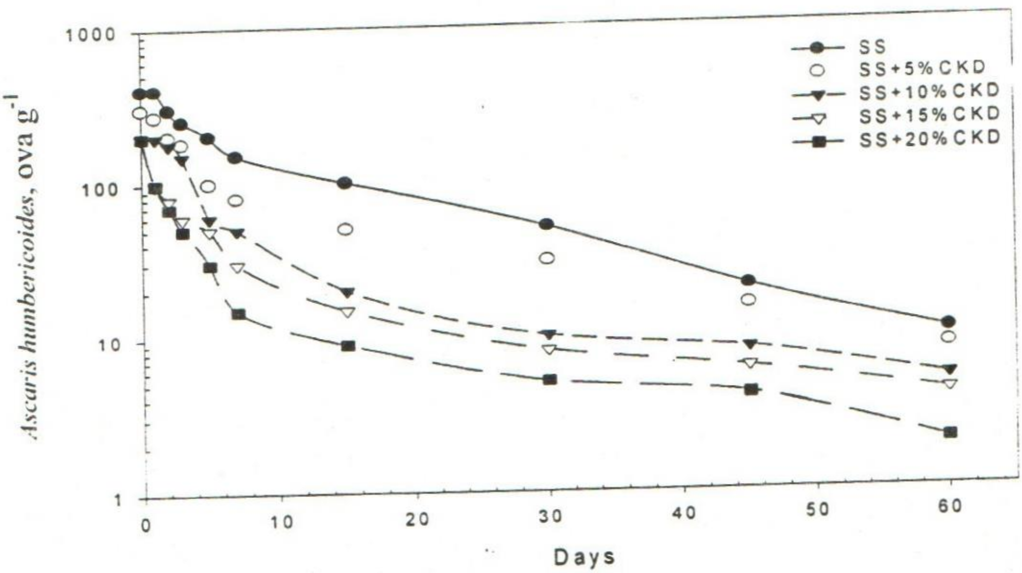

Figure (8): Periodical changes in *Ascaris humbericoides* ova counts for sewage sludge (SS) and its different mixtures with cement kiln dust (CKD), during a composting time course.

Table (2): Periodical changes in the reduction percentages (%) of pathogenic bacteria and Ascaris parasites for sewage sludge and its different mixtures with cement kiln dust (CKD), during a composting time course

Days	CKD, %				
	0	5	10	15	20
			Total coliforms		
1	70.7	83.6	85.7	97.6	97.8
2	76.4	97.2	97.7	98.6	98.8
3	96.8	97.8	98.0	99.8	99.8
5	97.3	99.8	99.8	99.8	99.9
7	99.8	99.9	99.9	99.9	99.9
			Salmonella spp.		
1	89.7	92.4	92.7	94.9	95.1
2	91.4	93.2	93.5	95.4	95.9
3	91.9	94.3	94.6	96.2	96.8
5	98.7	98.8	99.0	99.1	99.2
7	98.9	99.2	99.2	99.4	99.5
			Shigella spp.		
1	22.2	36.1	55.6	62.5	68.1
2	38.9	52.8	61.1	66.7	77.8
3	55.6	62.5	65.3	70.8	86.1
5	65.3	68.1	69.4	75.0	97.6
7	94.9	96.1	96.5	97.2	97.9
			Klebsiella spp.		
1	38.1	51.2	63.1	69.0	75.0
2	48.8	53.6	67.9	75.0	82.2
3	63.1	69.0	73.8	81.0	86.9
5	71.4	75.0	79.8	96.5	97.5
7	95.8	96.2	96.7	97.6	98.2
			Vibrio spp.		
1	54.1	64.9	70.2	72.9	78.3
2	62.2	70.3	73.0	78.4	83.8
3	73.0	78.4	81.1	86.5	91.9
5	91.9	93.5	95.1	95.7	96.8
7	93.2	95.7	96.8	97.3	98.1
			Ascaris humbericoides		
1	20.0	46.0	60.0	80.0	80.0
2	40.0	60.0	64.0	84.0	86.0
3	50.0	64.0	70.0	88.0	90.0
5	60.0	80.0	88.0	90.0	94.0
7	70.0	84.0	90.0	94.0	97.0
15	80.0	90.0	96.0	97.0	98.2
30	90.0	94.0	98.0	98.4	99.0
45	96.0	97.0	98.4	98.8	99.2
60	98.0	98.4	99.0	99.2	99.6

CONCLUSION

According to the obtained results, it may be concluded that composting process control can potentially help removal of pathogens from sewage sludge. As an alternative to composting, pathogen destruction can be achieved by blending with alkaline by-products such as cement kiln dust.

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تحطيم ممرضات مخلفات الصرف الصحي باستخدام عملية الكمر والخلط بتراب أفران الأسمنت

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أجريت تجربة كمر فى المزرعة التجريبية لجامعة قناة السويس . لدراسة تأثير عملية الكمر و إضافة تراب الأسمنت على الممرضات الموجودة فى حمأة المجارى الخام الناتجة عن معالجة مياه الصرف الصحي بمحطة سرابيوم بالإسماعيلية.تم خلط حمأة المجارى الخام مع مطحون قش الأرز ثم تم كمر هذا المخلوط منفردا أو مضافا إليه تراب الأسمنت بالنسب الاتية:

١-مخلوط حمأة المجارى الخام مع مطحون قش الأرز (١:١ وزنا)
٢-مخلوط حمأة المجارى الخام مع مطحون قش الأرز +٥ % تراب أسمنت
٣-مخلوط حمأة المجارى الخام مع مطحون قش الأرز +١٠% تراب أسمنت
٤-مخلوط حمأة المجارى الخام مع مطحون قش الأرز +١٥% تراب أسمنت
٥-مخلوط حمأة المجارى الخام مع مطحون قش الأرز +٢٠% تراب أسمنت

تم خلط المكونات المختلفة وعمل أكوام بطول ٥ م و عرض ١م مع المحافظة على المحتوى الرطوبى عند ٥٥-٦٠ % تقريبا بالوزن و التهوية مرتان أسبوعيا لمدة ٦٠ يوم . تم متابعة درجة حرارة المكمورة و رقم الحموضة و العدد الكلي للكولي فورم ، السالمونيلا، الشيجلا، الكسبيلا، الفيبرو و كذلك بويضات ديدان الإسكارس على فترات صفر، ١،٢،٣،٥،٧،١٥،٣٠،٤٥،٦٠ يوم.

وقد تم الحصول على النتائج التالية:

١-تزداد درجة الحرارة تدريجيا مع زيادة فترة الكمر حتى اليوم الخامس أو السابع ثم تتناقص بعد ذلك تدريجياحتى اليوم الستين (نهاية التجربة)،كما أنها تزداد مع زيادة معدلات إضافة تراب الإسمنت عند جميع مراحل الكمر.

٢-يتناقص رقم الحموضة مع زيادة فترة الكمر و لكنه يزداد مع زيادة معدلات إضافة تراب الإسمنت عند جميع مراحل الكمر.

٣-يتناقص العدد الكلي للكولي فورم ، السلمونيلا، الشيجلا، الكسبيلا، الفيبرو و كذلك بويضات ديدان الإسكارس مع زيادة فترة الكمر و كذلك تزداد النسبة المئوية لمعدل التناقص مع زيادة فترة الكمر ومع زيادة معدلات إضافة تراب الإسمنت عند جميع مراحل الكمر.

٤-كانت ديدان الإسكارس أكثر مقاومة من البكتريا الممرضة ، وكذلك كانت بكتريا الكولى فورم و السالمونيلا أقل مقاومة من باقى البكتريا الممرضة للتحطم بواسطة عمليتى الكمر و إضافة تراب الإسمنت.