University of Benghazi
Faculty of Education Al marj
Global Libyan Journal

جامعة بنغازي
كلية التربية المرج
المجلة الليبية العالمية

العدد الرابع والثلاثون – 30/ ديسمبر (2017)

ENALUATION OF BIOSOLIDS COMPOST MATURITY AS FERTILIZING SUBSTANCE FOR SOIL

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ENALUATION OF BIOSOLIDS COMPOST MATURITY

AS FERTILIZING SUBSTANCE FOR SOIL

ABSTRACT

The composting process is a useful method of producing a stabilized material that can be used as a source of nutrients and soil conditioner. Maturity of compost is essential for its optimal use as a soil amendment and a source of plant nutrients as well. Immature composts pose problems of malodors and flies and phytotoxicity and pollution during use. Stability and maturity both are required for compost quality control. Compost maturity tests can be classified into physical, chemical, plant, and microbial activity assays. In this study, different methods of evaluating the stability and maturity of composted biosolids were compared based on physical, chemical and biological properties. The sludge used of composting was obtained from the windrow of Tobruk wastewater treatment plant. The results showed that, C/N ratio after 42 days of composting reached to 27/1 for the mixture ratio 90-10 (w/w) . The numbers of fecal coliforms and E. coli in the initial sewage sludge compost show high contents and at the end of composting were low contents, and the compost process provided class A pathogen criteria. Use of physical, chemical and biological parameters exhibited three phases: rapid decomposition (1st two weeks), stabilization and maturation (day 42-45) in biosolids compost. Thus, the biosolid compost was mature and ready for use as an agricultural substrate after about 45 days of composting.

KEY WORDS: Biosolids, sewage sludge, compost, wastewater, pathogenic agents, nutrients, soil conditioner, fertilizers.

ملخص البحث

نظراً لما تشكله الحمأة أو المخلفات العضوية الصلبة الناتجة عن عمليات المعالجة لمياه الصرف الصحي بكميات ضخمة من مشاكل جمة في كيفية التخلص منها بشكل آمن دون الإضرار بالصحة العامة والبيئة لما تحتويه هذه المخلفات من عناصر ضارة وكائنات وعوامل ممرضة قد تضر بالإنسان والحيوان والنبات، لذا فإن هذا البحث يطرح بعض الحلول الممكنة في كيفية التخلص من هذه المخلفات بأساليب آمنة صحياً وبيئياً والاستفادة منها في الوقت ذاته كمادة مخصبة ومكيفة للتربة، وذلك لما تحتويه من عناصر ذات قيم غذائية للنبات مثل الفوسفور، النيتروجين، البوتاسيوم والكبريت. وبالتالي فإن هذه الدراسة تهدف إلى تحويل هذه الحمأة إلى مادة أكثر ثباتاً وأقل ضرراً وهي الكمبوست.

لقد أجريت هذه الدراسة على الحمأة الناتجة عن محطة طبرق لمعالجة مياه الصرف الصحي، حيث تم أخذ خمس عينات مركبة من مواقع التكديس Windrow ممثلة لكافة الحمأة الناتجة بالمحطة عبر فترات زمنية مختلفة، كما تم خلط الحمأة مع مادة عضوية أخرى بنسب مختلفة وهي نشارة الخشب كعامل حجمي تساعد على زيادة التهوية لإتمام التفاعل الهوائي، ومن ثم زيادة النشاط

البكتيري في تحلل وتفكك المادة العضوية، وقد تراوحت الفترات الزمنية للكمبوست ما بين 0 و 42 يوماً حيث أظهرت النتائج نضوج الكمبوست في نهاية هذه الفترة الزمنية من واقع التحاليل التي أجريت عليه وذلك من خلال حساب نسبة N/C. كما تم استخدام بعض أنواع من البكتيريا المحللة كمنشط ميكروبي. حيث أجريت التحاليل على الحمأة الأولية (بدون منشط ميكروبي) والحمأة المنشطة لتعيين بعض العوامل الكيميائية مثل الأس الهيدروجيني، المحتوى العضوي للكربون، محتوى النيتروجين، محتوى الرطوبة ومحتوى المادة العضوية، وذلك خلال فترة زمنية تراوحت ما بين 0 و 45 يوماً، وقد أظهرت النتائج نضوج الكمبوست في نهاية الفترة الزمنية.

لقد تم دراسة الخواص الفيزيائية والكيميائية والبيولوجية للكمبوست الناتج وقد أسفرت النتائج عن التخلص من العوامل الممرضة بدرجة كبيرة، حيث لم يعد يشكل أي خطورة بيئية أو صحية حال استخدامه كمادة مخصبة أو مكيفة للتربة وفقاً لتعليمات ومعايير كل من الوكالة الأمريكية لحماية البيئة والاتحاد الأوروبي لتطبيق الحمأة على الأرض الزراعية.

مفتاح الكلمات

المخلفات العضوية الصلبة، حمأة الصرف الصحي، الكمبوست، المواصفات الفيزيائية والكيميائية، العوامل البكتيرية، التربة، العناصر المغذية.

INTRODUCTION

Most wastewater treatment processes produce a sludge which has to be disposed of. Conventional secondary sewage treatment plants typically generate a primary sludge in the primary sedimentation stage of treatment and a secondary, biological, sludge in final sedimentation after the biological process. The characteristics of the secondary sludge vary with the type of biological process and, often, it is mixed with primary sludge before treatment and disposal. Approximately one half of the costs of operating secondary sewage treatment plants in Europe can be associated with sludge treatment and disposal. Land application of raw or treated sewage sludge can reduce significantly the sludge disposal cost component of sewage treatment as well as providing a large part of the nitrogen and phosphorus requirements of many crops. The sewage sludge contains, in addition to organic waste material, traces of many pollutants used in our modern society. Some of these substances can be phytotoxic and some toxic to humans and/or animals so it is necessary to control the concentrations in the soil of potentially toxic elements (PTE) and their rate of application to the soil.

Sewage sludge also contains pathogenic bacteria, viruses and protozoa along with other parasitic helminths which can give rise to potential hazards to the health of humans, animals and plants. The numbers of pathogenic and parasitic organisms in sludge can be significantly reduced before application to the land by appropriate sludge treatment and composting.

1. What is sludge?

Residuals, biosolids, septage, sewage, wastewater byproduct, compost: there are many names for sludge and sludge products. The term “sludge” is used as most people understand it: the sometimes solid, sometimes liquid material generated by wastewater treatment plants and used as fertilizer on fields, in gravel pits, and on forestry lots throughout the state. Sludge may classified as “Class A” if it has been treated to reduce germs to background levels (levels normally found in soils) and “Class B” if it has been treated so that germs are reduced by an estimated 90%.

2. Composition of sewage sludge

The nature of the sewage sludge depends on the waste water treatment process and on the source of the sewage. In general it contains both toxic and non-toxic organic wastes. Of the two, non-toxic compounds are most prevalent comprising all materials of plant and animal origin, including proteins, amino acids, sugar and fats. Toxic organic compound comprises Poly-nuclear aromatic hydrocarbons (PAHs), alkyl phenols, polychlorinated biphenyls (PCBs) organo-chlorine pesticides, monocyclic aromatics, chloro-benzenes, aromatic and alkyl amines, polychlorinated dioxins, phenols etc. In addition to these organic waste material sewage sludge also contains traces of many pollutants like Copper, Zinc, Nickel, Cadmium, Lead, Arsenic, Chromium, Selenium etc. Some of these substances can be phytotoxic and some toxic to humans and / or animals, so it is necessary to control the concentrations in the soil of potentially toxic elements and their rate of application to the soil. Sewage sludge also contains pathogenic bacteria, viruses & protozoa along with other parasitic helminthes which can give rise to potential hazards to the health of humans, animals and plants. Apart from those components of concern sewage sludge also contains useful concentrations of N, P and organic matter. Each component of the sludge has its own environmental impact, which must be taken into account when choosing the disposal route.

3. Processing of sludge

Increasing urbanization and Industrialisation have resulted in a dramatic increase in the volume of waste water produced around the world. The waste water treatment step concentrates the various pollutants (upto 90%) in the waste water into sludge, normally containing between 1% and 2% by weight dry solids.

4- The benefits of sewage sludge on agricultural land

• Valuable agricultural nutrients like Nitrogen, Phosphorus, Potassium and Sulphur can be returned to the land

• Soil organic matter levels have been increased to 12% – 15%

• Ground water and surface water quality are maintained
• Decrease bulk density and increase the non-capillary pore space

• Improve the aggregation of soil particles

• No significant health or nuisance problems occur

MATERIALS AND METHODS

The sludge used in this study was obtained from the drying beds of wastewater treatment plant in Tobruk. In this study, composting was performed to stabilize the mentioned sludge by mixing it with saw dust of different ratios as an organic material (bulking agent) through an incubation periods. The mixture content of sludge is ranging from 40-65%. To control and adjust the moisture content to 60%, sludge was mixed with the sawdust at different ratios (90-10 w/w, 80-20 w/w and 70-30 w/w). The composite samples were taken from five different points of windrow. Total carbon content was determined through combustion in ovens at 750ºC for 2hr. Total nitrogen was measured by the Kjeldhl digestion method where the sample was pretreated using salicylic acid and thiosulphate. C/N ratio was calculated by dividing the amount of total carbon to the amount of total nitrogen.

Fecal coliforms and *E. coli* were determined according to the technique, which is presented in part 9221E of Standard methods for examination of water and wastewater (APHA, 1992). The duration of composting biosolids was 42 days for unactivated sludge and 45 days for activated sludge.

RESULTS

The results of chemical parameters for the stability-composted biosolids such as total carbon, total nitrogen, C/N ratio, pH values and moisture content, organic matter and nitrogen contents, , and heavy metals and their changes during incubation period of compost are show in Tables 2, 3, 4, 5, 6 and 7, as well as Figs. 1, 2, 3, 4, 5, 6, 7, 8.

DISCUSSION

The sewage can be converted into compost, composting may be divided into two categories by the nature of the decomposition process. In aerobic composting takes place in the presence of oxygen. In this process, aerobic microorganisms break down organic matter and produce carbon dioxide (CO_2), ammonia, water, heat and humus, the relatively stable organic end product. Composting objectives may also be achieved through the enzymatic degradation of organic materials as they pass through the digestive system of microorganisms. This process is termed vermicomposting.

The aerobic composting and vermicomposting processes have been carried out through this study, where the sludge was mixed with sawdust as organic material (Bulk agent) (Table 1), at different ratios (90:10 w/w, 80:20 w/w and 70:30 w/w). The incubation period of composting ranging from 0 to 42 days, where the mixture at the end of this period is a fine dark texture which called mature compost.

Thus sewage sludge composting reaches the maturation between 42 to 45 days. All chemical and biological parameters exhibited three phases:

- Rapid decomposition during the first two weeks
- Stabilization and maturation after 42 and 45 days for unactivated and activated biosolids respectively.

Hence, the compost in this study was mature and ready for use as an agricultural substrate after about 42 days of composting.

The study shows that the organic carbon content decreasing with the duration of composting, where the highest decreasing ratio reached 15.48% after the maturation period 42 days for the mixture 80-20 (w/w) (Table 2) and (Fig. 1), consequently the ratio of organic matter content decrease at the mixture ratio 80:20 (w/w) (Table 2).

The nitrogen content has been decreasing from the first week of composting period (1.32%). The lowest value of total nitrogen after 42 days has been detected in the mixture 70-30 (w/w). (Table 3). Figure (2) illustrates the change of nitrogen content through composting process.

This experiment regards as preliminary test to choice the optimum mixture ratio, where the organic carbon content was decreasing at the mixture ratio 80:20 w/w, hence the study of the chemical and biological characteristics were carried out on compost at this ratio in the presence of microbial activator.

The C/N ratio is an indicator for compost stabilization and available of nitrogen. The compost which have high content of nitrogen (> 25) will tie the available nitrogen and make it unavailable for use, while the compost which contain a low content of nitrogen (< 20) release the organic nitrogen to be available for plants (Brodie, et al., 2000).

The C/N ratio of the composting materials was decreased to 27 after 42 days of composting (Table 4). The maximum reduction in the C/N ratio happened during the mixture 80:20 (w/w) of composting. The change in C/N ratio illustrated in fig. (3).

The effect of microorganisms

There are different types of bacteria that can be used as microbial activator in composting process. *Actinomycetes (streptomyces sp)* and *(Bacillus sp)* are used in this study for the sludge at a mixture ratio 80:20 w/w of bulking agent. The experiment has been carried out on the sewage sludge with microbial activator and without an activator for composting period 0 to 45 days. Organic carbon and nitrogen contents have been determined for all samples in addition to the following parameters:

pH value

The pH value is a measure of acidity in compost. According to the experimental work, this value ranges from 5.0 to 8.5, but the neutral value (7.0) is desired for all applications. The variation of pH value during composting period in the investigated unactivated sludge are ranging from 6.4 to 7.2 with an average 6.7, where in activated sludge are ranging from 6.5 to 7.3 with an average 6.8 (Table. 5).

The highest variation in the pH values has been recorded through the 20 days incubation period for the unactivated sludge (7.2), and the period 30 days for activated sludge (7.3) (Table 5). This increasing in pH values may be referred to the liberation of amonia and nitrification during the different stages of composting process. On the other hand the pH values began to decrease at the end of composting period after 42 days, 6.4 and 6.5 respectively. In general these values of pH within the range of municipal compost 5.0 - 8.5 (Brodie et al, 2000). Fig. (4) shows the variation in pH values.

Moisture content %

The mixture content in the compost is depending on the capacity of water holding in the original substances. Materials that have high content of organic material holding more water, hence they have a high mixture content. The mixture content is ranging from 48.60 at the beginning of composting process, and 53.40% at the end of process. The activity of microorganisms increases with increasing of mixture content (Gidarakos, 2007). The results show that the averages of mixture content in the final compost are 50.15% and 51.20% for unactivated and activated sludge respectively (Table 5), (fig. 5).

Organic Matter (OM%)

The organic matter content in the final compost ranging from 30-70% (on the basis of solid weight). It is preferring that the organic matter content in the used compost more than 60% (Diaz, et al 2002). In this study the organic matter content in both unactivated and activated sludge is 67.20 and 68.42 respectively (Table 6). The content of organic matter has been increased after addition of the saw dust as organic material and bulk agent. It is noticed that from this study the decreasing of organic matter content through the incubation period of composting (Fig. 6).

Total nitrogen (N%)

It includes all nitrogen forms e.g. amonia, nitrates and organic nitrogen. The total nitrogen in the final compost is ranging from 0.5 to 2.5% (on the basis of dry weight). The results show that the total nitrogen decreases from the first 7 days, and then increases through the incubation period (Table 6), and (Fig. 7)

Changes in heavy metals

Table (7) illustrates the comparison between the concentration of heavy metals in the sludge mixtures at the beginning and ending of compost period, as well as EU, USEPA regulation for the sludge application on the land (USEPA, 1994 & 1995). The results show that the concentration of heavy metals in the sewage sludge with the additional organic matter was lower than these values of EU and USEPA regulation (USEPA, 1992a). Composting process can leads to the increase or decrease the concentration of heavy metals in the sludge (Zorpas, et al 2003). The decreasing of heavy metals content depending on the loss of these elements through leaching (Canarutto, et al 1999). The metal content can be decreases through leaching process in composting during Thermophilic phase (Hsu, et al 2001; Soumare, et al 2003).

The analysis show that there is no much differences in the heavy metals concentration through composting process, except the cadmium (Cd) concentration 0.33 mg/kg of dry solids at the end of composting process (Table 7) and (Fig. 8).

Physical, chemical and biological characteristics of compost

It is necessary to convert the biosolids to compost to decompose the organic matter by microorganisms action to lower the pollutants content (Cooperband, 2000), in addition destroying many of pathogenic agents. Hence the compost can be used as manure matter to improve the soil because it has nutrient elements for crops. So it is necessary to study the physical, chemical and biological characteristics of the final compost. The results are presented in Table (8).

The physical characteristics are represented by the study of the distribution of compost grain sizes and their volumetric density. The compost can be classified according to the volumetric density into light compost if the volumetric density less than 0.25 g/cm^3, medium if the volumetric density ranging from 0.35 to 0.60 g/cm^3 and heavy compost if the volumetric density more than 0.60 g/cm^3. According to the obtained data from this study the compost can be classified as light compost where the average value of the volumetric density is 0.22 g/cm^3 (Table 8).

From Fig. (9) it is clear that the largest size which ranging from 15-25 mm is representing the lower ratio, 1.1% and 1.2% by weight and volume respectively. While the grains that exceed these diameter are zero ratio. On the contrast for the grains of diameter less than 2 mm are representing the highest ratio in the compost, 69.2% and 63.5% by weight and volume respectively. On the other hand, the volumetric density show the highest value among the grains of less than 2 mm (0.25 g/cm^3).

The compost maturity depends on the chemical constituents present in a compost feedstock. In this study several chemical and biological parameters related to composted biosolids maturity were compared and the stabilization and maturation time were determined.

The number of pathogenic organisms in initial sewage sludge compost was 2.5 x 10^6 and 3.6 x10^5 MPN/g of total solids for *fecal coliforms* and *E. coli* respectively, at the end of composting was less than 102 and 84 MPN/g of total solids for *fecal coliforms* and *E. coli* respectively, indicating that the compost process was extremely effective in inactivating *fecal coliforms* and *E. coli*. Hence, the compost can be applied on the land as a fertilizer for soil.

CONCLUSION

The sewage sludge (biosolids) can be converted into compost. The composting process is a useful method of producing a stabilized material that can be used as a source of nutrients and soil conditioner.

The sewage sludge composting reaches the maturation between 42 to 45 days. All chemical and biological parameters exhibited three phases: rapid decomposition during the first two weeks, stabilization and maturation after 42 and 45 days for unactivated and activated biosolids. The compost was mature and ready for use as an agricultural substrate after about 42 days of composting.

The study shows that the organic carbon content decreasing with the duration of composting, where the highest decreasing ratio reached after the maturation period 42 days for the mixture 80-20 (w/w), consequently the ratio of organic matter content decrease at the mixture ratio 80:20 (w/w).

The C/N ratio of the composting materials was decreased to 27 after 42 days of composting. The maximum reduction in the C/N ratio happened during the mixture 80:20 (w/w) of composting.

The results show that the concentration of heavy metals in the sewage sludge with the additional organic matter was lower than these values of EU and USEPA regulation.

According to the obtained data from physical study the compost can be classified as light compost where the average value of the volumetric density is 0.22 g/cm^3.

The number of pathogenic organisms in initial sewage sludge compost for *fecal coliforms* and *E. coli* respectively can be lowered at the end of composting to less than 102 and 84 MPN/g of total solids for *fecal coliforms* and *E. coli* respectively, indicating that the compost process was extremely effective in inactivating *fecal coliforms* and *E. coli*. Hence, the compost can be applied on the land as a fertilizer for soil.

REFERENCES

American Public Health Association (APHA) (1992) . Standard methods for the examination of water and wastewater 19 thed. American Public Health Association, Washington, D.C

Brodie, H.L., L.E. Carr, and P. Condon (2000). A comparison of static pile and turned windrow methods for poultry litter compost production. Compost Sci. Util. 8:178–189.

Canarutto, S., Petruzzelli, G., Lubrano, L., & Guidi, G.V. (1999). How composting affects heavy metal content. BioCycle, 32, 48–50.

Cooperband, L. R., (2000). Composting: art and science of organic waste conversion to a valuable soil resource, Laboratory Medicine 31 283–289.

Diaz, L. F., Savage, G. M. and Golueke, C. G., (2002). Composting of Municipal Solid Wastes. in: G. Tchobanoglous and F. Kreith (Eds.), Handbook of Solid Waste Management, McGraw Hill USA, New York, pp. 11-70.

Gidarakos, E (2007). Municipal solid waste management, Lecture Notes, Treatment technologies of toxic and hazardous wastes. Technical University of Crete.

Hsu, J.H., &Lo, S.L. (2001). Effect of composting on characterization and leaching of copper, manganese, and zinc from swine manure. Environmental Pollution, 114, 119–127.

Soumare, M., Tack, F.M.G., &Verloo, M.G. (2003). Characterisation of Malian and Belgian solid waste composts with respect to fertility and suitability for land application. Waste Manage. 23, 517–522.

USEPA. (1992a). Sewage sludge use and disposal rule (40 CFR Part503) –Fact Sheet. EPA-882-F-92-002. Office of Water, Fact SheetWH-556. U.S. Environmental Protection Agency, Washington,DC.

USEPA, (1993). 40 CFR Part 503- Strandards for the Use and Disposal of Sewage Sludge: Final Rule. Fed. Regist. 58:9248-9415.

USEPA , (1994). Land Application of Sewage Sludge - A Guide for Land Appliers on the Requirements of the Federal Standards for the Use or Disposal of Sewage Sludge, 40 CFR Part 503. December 1994. U.S. EPA Office of Enforcement and Compliance Assurance, Washington, D.C.1.

USEPA (1995). Guidance for Writing Permits for the Use and Disposal of Sewage Sludge. September 1995. U.S. EPA Office of Wastewater Management, Permits Division. Washington, D.C.

Zorpas, A.A., Arapoglou, D., & Panagiotis, K. (2003). Waste paper and clinoptilolite as a bulking material with dewatered an aerobically stabilized primary sewage sludge (DASPSS) for compost production. Waste Manage. 23, 27–35.

Table (1) Chemical properties of bulk agent added to sewage sludge

Characteristics	Organic carbon (OC%)	Nitrogen (N%)	Phosphorus (P_2O_5%)	pH	Ash (%)
Bulking agent (Organic matter)	55.12	0.22	0.010	5.19	< 1

Table (2) Total organic carbon change through incubation period of compost (%)

Biosolids	Composting period (days)							Decreasing ratio %
	0	7	14	21	28	35	42	
Initial sludge	32.90	31.19	30.14	29.15	28.02	27.66	27.52	16.35
Mixture ratio 90-10 (w/w)	45.51	44.70	44.06	43.37	42.35	41.73	40.85	10.24
Mixture ratio 80-20 (w/w)	47.92	46.70	45.14	44.27	43.48	42.26	40.50	15.48
Mixture ratio 70-30 (w/w)	49.53	46.80	45.15	44.20	44.05	43.20	42.81	13.57

Table (3) Total nitrogen change through incubation period of compost (%)

Biosolids	Composting period (days)						
	0	7	14	21	28	35	42
Initial sludge	3.54	2.91	2.07	2.26	2.18	2.14	2.12
Mixture ratio 90-10 (w/w)	1.95	1.79	1.65	1.60	1.56	1.48	1.45
Mixture ratio 80-20 (w/w)	1.66	1.58	1.51	1.54	1.53	1.52	1.50
Mixture ratio 70-30 (w/w)	1.45	1.42	1.43	1.40	1.38	1.33	1.32

Table (4) Carbon-nitrogen ratio (C/N) during composting period

Biosolids	Composting period (days)						
	0	**7**	**14**	**21**	**28**	**35**	**42**
Initial sludge	9.29	10.72	14.56	12.90	12.85	12.92	12.98
Mixture ratio 90-10 (w/w)	23.34	24.97	26.70	27.11	27.15	28.20	28.17
Mixture ratio 80-20 (w/w)	28.87	29.55	29.89	28.75	28.42	27.80	27.0
Mixture ratio 70-30 (w/w)	34.15	32.95	31.57	31.57	31.92	32.48	32.43

Table (5) change in pH values and moisture content during composting period

Type of biosolids	Composting period (days)							
	0	**10**	**20**	**30**	**40**	**45**	**Range**	**Average**
Sewage sludge (SS)	6.7	6.6	7.2	6.5	6.6	6.4	6.4-7.2	6.7
Moisture content (%)	48.7	48.5	48.2	50.3	51.4	53.5	47.5-53.5	50.15
Sewage sludge with activator (SSA)	6.8	6.6	6.9	7.3	6.6	6.5	6.5-7.3	6.8
Moisture content (%)	48.4	49.8	50.2	49.3	52.9	52.2	48.6-53.4	51.2

Table (6) Organic matter and nitrogen contents during composting process

Biosolids		Composting period (days)					
		0	**10**	**20**	**30**	**40**	**45**
Sewage sludge (SS)	OM	71.75	67.83	67.91	70.06	69.16	67.20
	N	1.80	1.70	1.83	1.91	1.85	2.05
Sewage sludge with activator (SSA)	OM	72.30	72.15	70.62	69.46	68.89	68.42
	N	1.82	1.68	1.72	1.79	1.85	1.86

Table (7) Compost content of heavy metals (mgkg-1 DS) USEPA. (1992a and 1993)

Composting period	**(0 days)**		**(45 days)**		**Compost application on land**	
Heavy metals	sewage sludge (SS)	Sewage sludge with activator (SSA)	sewage sludge (SS	Sewage sludge with activator (SSA)	USEPA	EU
Co	115.4	102.2	112	110.4	-	-
As	10.5	9.4	11.5	8.4	-	-
Cu	44.5	40.2	41.3	40.8	4300	1750
Zn	85.0	76.2	80.5	84.2	7500	4000
Pb	62.50	60.4	62.25	60.9	840	1200
Ni	45.8	46.2	44.3	40.1	420	400
Cr	23.4	22.5	23.2	20.5	3000	-
Cd	0.80	0.65	0.40	0.33	85	40

Table (8) Chemical, physical and biological characteristics of compost

Chemical characteristics										
Parame-ters	pH (H_2O)	EC(m mhos/ cm)	OM (%)	TN (%)	C:N Ratio	TCa (g kg^{-1})	TMg (g kg^{-1})	TP (g /kg)	NH_4-N (g kg^{-1})	NO_3-N (g kg^{-1})
Charact-eristics	6.9	2.4	64	1.22	27.5	119.9	4.8	1.25	440	320

Physical characteristics					
Particles size (mm)(	12.0-9.5	9.5-6.5	6.5-4.0	4.0-2.0	>2.0
%By weight	0.0	7.5	6.8	19.2	66.5
%By volume	0.0	8.4	7.6	21.4	62.6
Bulk density (g/cm^3)(	0.0	0.23	0.21	0.19	0.26

Biological characteristics	
Pathogenic agents in compost)MPN/g(	
Fecal coliform	102 <
E. coli	< 84

All data's except pH and EC are expressed on a dry weight.

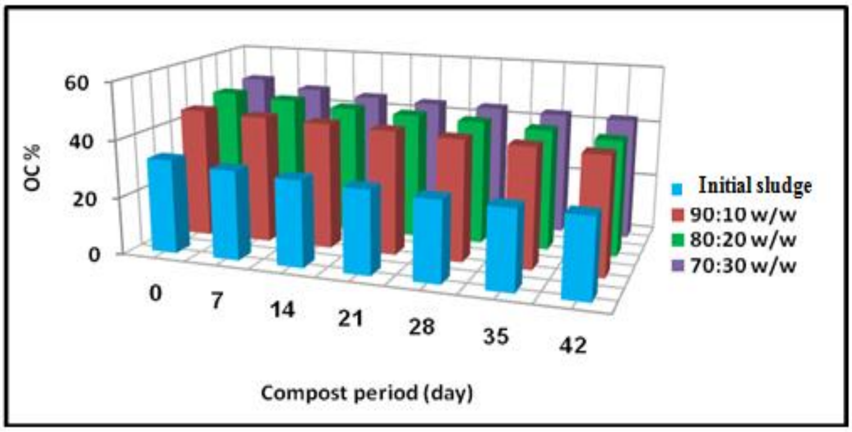

Fig (1) Change of organic carbon ratio in the composting process

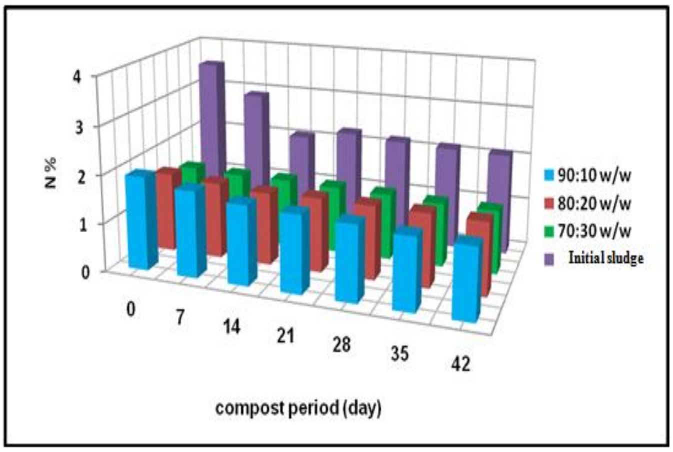

Fig. (2) Change of nitrogen ratio in the composting process

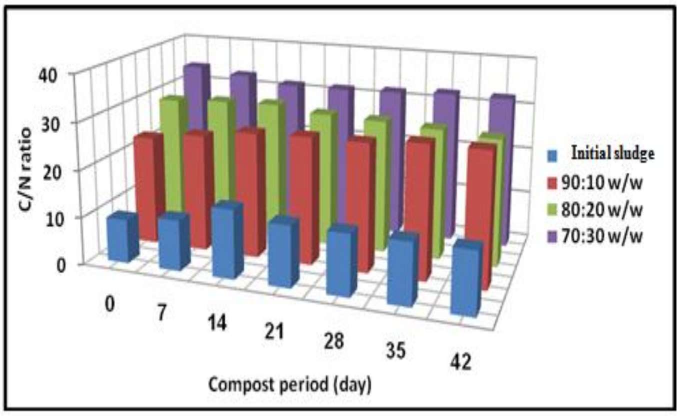

Fig (3) Change of carbon and nitrogen ratio in the composting process

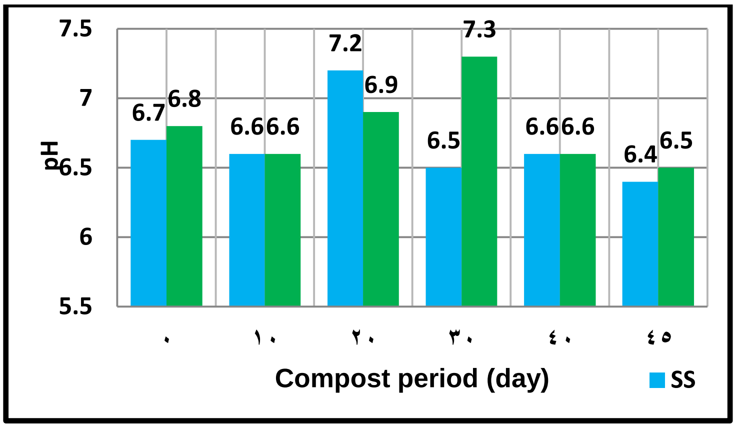

Fig. (4) pH changes in sewage sludge (SS) and sewage sludge with activator (SSA) in compost

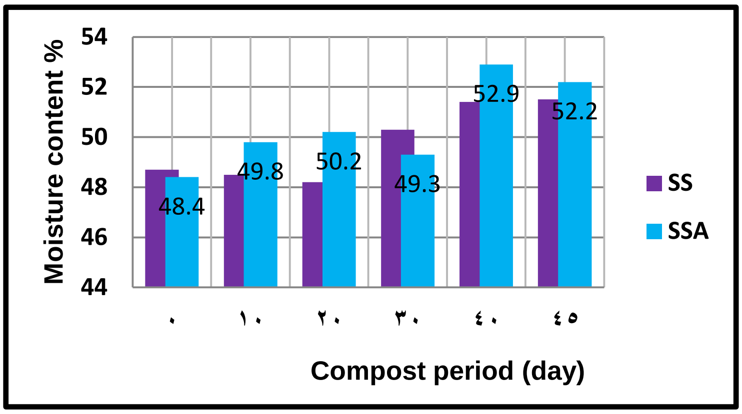

Fig. (5) Moisture content changes in sewage sludge (SS) and sewage sludge with activator (SSA) in compost

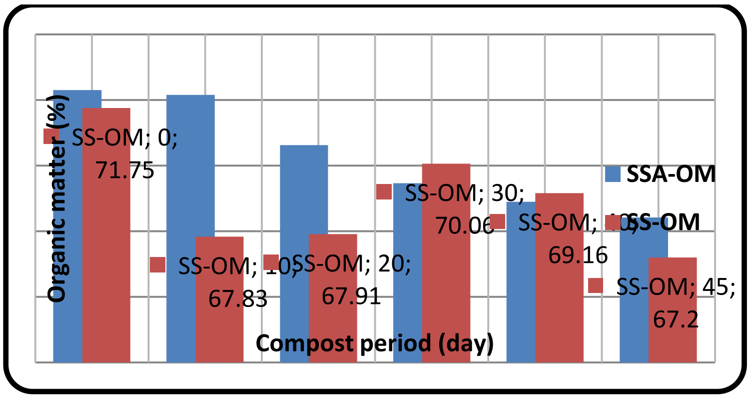

Fig (6) Organic matter content in sewage sludge (SS) and sewage sludge with activator (SSA) in compost

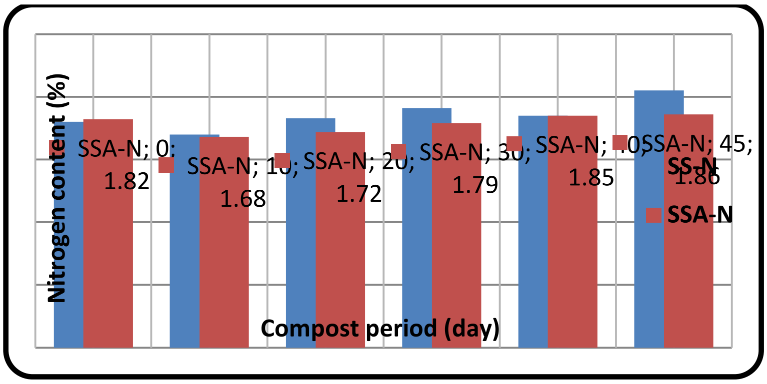

Fig (7) Nitrogen content in sewage sludge (SS) and sewage sludge with activator (SSA) in compost

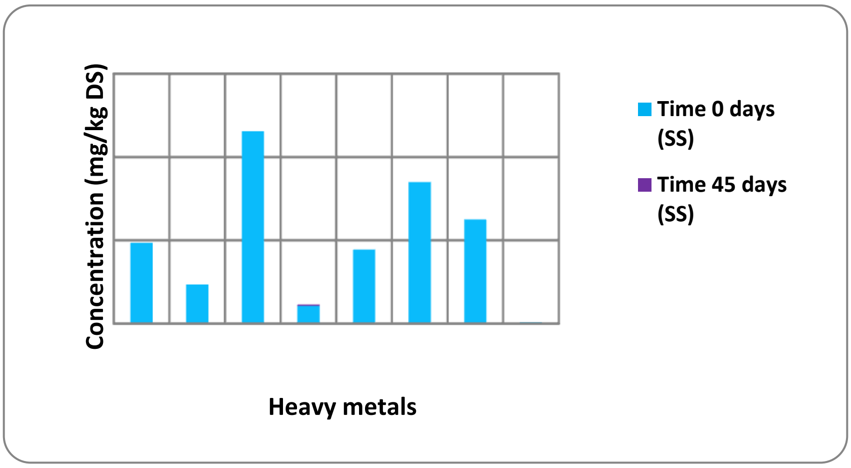

Fig. (8) Changing of heavy metals concentration during composting process

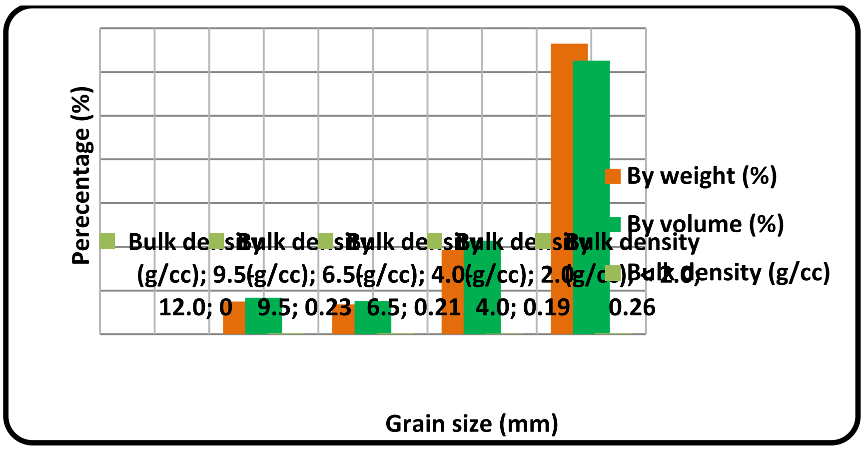

Fig (9) Particles size and volume distribution of mature compost against bulk density