Composting primary sewage sludge of Mar del Plata city

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Abstract
The composting (windrows) was studied as alternative of sewage sludge management (25 tons / day), evaluating: the process during summer and winter, relationships support: sludge (1:1, 0,5:1 and 0:1), turning diary or to demand and quantitative, physical-chemical and microbiological characteristics of the sludge and leached.
In summer all the relationships can be applied, in winter only 1:1.Turning to demand allows better control of the process. More support means less leached, time of treatment and recontamination risk. They were low concentrations of heavy metals in sludge and leached. It demonstrates the process feasibility and the class A product

Keywords
Sewage sludge; leached; compost; reuse

INTRODUCTION

Mar del Plata is a coastal city of the Argentina Republic of 564.056 inhabitants (1). It is located in the southeast of the Buenos Aires County (38º of LS, 57º35 'LO).During the summer period, the population is increased in 25% approx. with an increase in the city activities. Consequently, it is overturned to the sewerage a variable volume of effluents according to the time of the year.
Mar del Plata possesses a sewer system that allows the combined recollection of the domestic and industrial effluents. This consists of sewerage and four sewer main pipeline that transport the effluents of 84 % (2010) from the city to the Wastewater Pretreatment Plant of "Eng Baltar" located 10 Km. north at present time. The pretreatment consists on separation solids through 0,5 mm sieves and dehydration of the sludge retained by compactation, generating 20-25 daily tons of primary sludge that are transported to a nursery for its anaerobic stabilization. The physical chemistry characterization of the primary sludge is presented in the Table 1 (2).
This study was carried out in the integral treatment project of effluents management that includes the remodeling of the pretreatment plant and the construction of submarine emissary. At the present time the last work is in execution.
Mar del Plata Public Sanitation Works have decided to optimize the treatment of the sewage sludge, outlining the necessity to make a technician-economic and environmental analysis of different treatment technologies to select the most appropriate alternative to the local reality. The analyzed technologies were: vermicomposting, high pH treatment with lime and composting (3). In the first case, a pilot test (4) allowed to observe the benefits and disadvantages in this method.
The comparative results indicated, that a treatment like composting was the most appropriate system because this technology is considered environmentally sound since it minimizes the risks toward the health (public and environmental) and also reduce the use of chemical fertilizers in the agriculture. The composting is a controlled aerobic process that accelerates the natural degradation of the organic matter of the waste that becomes a product innocuous and stable enough to be employed as a soil conditioner. This process is applicable to organic wastes that possess heavy metals content lower than values in reference normative and guides (Table 2).
The composting consists on mixing a substrate with a bulking agent (sawdust, wood chip, pruning material, etc.).The composting process, which times of vary from weeks to months (5 or 6) depending on the system used (reactors, piles or windrows), has three stages of microbial activity and associate temperatures are observed: mesophilic (<55ºC), thermophilic (≥55ºC) and cured.

Table 1: Characterization of sewage sludge in compound samples of 24 hs. (2000 – 2010)

		n	Mean	Máx	Min	S D
Moisture	%	90	76,95	87,00	63,80	5,00
Total solids	%	34	20,38	28,87	14,7	3,64
Fixed solids	%	27	3,41	8,23	1,7	1,44
Volatile solids	%	27	16,90	21,65	12,5	2,68
Organic matter	%	35	85,56	89,88	77,1	2,94
Total phosphorus	gP/Kg	36	6,24	15,13	1,8	2,83
T.K.N.	gN/Kg	36	24,29	33,28	17,4	3,76
Oil and grease	g/Kg	30	180,25	275,00	64,8	49,60
Total hydrocarbons	g/Kg	15	5,78	10,40	2,5	2,59
Zn	mg/Kg	25	317,15	417,05	248,5	59,04
Cu	mg/Kg	25	537,18	813,69	302,1	197,17
Cd	mg/Kg	24	1,24	2,82	0,7	0,73
Pb	mg/Kg	25	60,21	83,11	44,2	14,43
Ni	mg/Kg	22	14,47	36,00	7,9	9,88
Cr	mg/Kg	25	25,47	60,58	12,8	17,76
Hg	mg/Kg	14	0,61	1,65	0,2	0,47

Table 2–Comparative ranges of heavy metals content in Mar del Plata sludge and values from the national and international reference normative

Elements (mg/Kg)	Primary sludge	National Resolution Nº 97/2001 (5)	USEPA 1993 (6)	European Union 1986 (7)
Cadmium	0,7-2,82	20 – 40	39 – 85	20 – 40
Chromium	12,8-60,58	1000 – 1500	1200 – 3000	1000 – 1750
Copper	302,1-813,69	1000 – 1750	1500 – 4300	1000 – 1750
Mercury	0,2-1,65	16 – 25	17 – 57	16 – 25
Nickel	7,9-36	300 – 400	420	300 – 400
Lead	44,2-83,11	750 – 1200	300 – 840	750 – 1200
Zinc	248,5-417,05	2500 - 4000	2800 - 7500	2500 - 4000

The Sanitation Works decided to analyze the application of composting as an alternative technology of sludge treatment. The project consisted, in a real scale pilot test under different climatic conditions (summer and winter). There are no previous antecedents in the country on composting of primary sludge; that's why this study presents an experience of application for these wastes, which is based on the development of treatment for secondary sewage sludge in the Bariloche city (8).

OBJECTIVES

The objectives of this study are (a) a pilot scale evaluation in the feasibility of composting of these wastes, (b) a chemical and microbiological characterization of the sewage sludge, final product and leached generated during the treatment and (c) the design parameters for a real scale treatment.

METHODOLOGY

Operative aspects

The two pilot test was carried out in a parcel given by the owner of the nursery, the summer it starts at the beginning of February 2001 .The composting process used windrows with mechanical turning in 4 waterproof platforms of concrete (6 m x 6 m) with their corresponding recollection leached

system. To compare the efficiency and behavior in each platform, the 27 Ton sewage sludge arrived and wood chip different proportions were used: windrows 1 and 2, equal parts (R: 1:1); windrow 3, two solid parts and one of bulking (R: 0,5:1) and the windrow 4, only solid (R:0). The approximate size of each windrow was 1,30 m (height), 2,80 m (wide) and 5 m (long). The windrow 2 was turned daily and the remaining ones to demand of the process using a steer loader (photo 1).
The system behavior was evaluated with the measurement of the following parameters:

- climatic conditions: ambient temperature, orientation of the wind and quantity of fallen rains.
- temperature: the measurement was made in four points of the windrow, excluding the extremes(photo 2) and at two different depths (20 cm and 60 cm). The results of these four points for each depth were averaged and from these two final data the greater was adopted. The days of turning, the measurement was made after turning.
- the leached and rain volumes: the platforms were built in order to allow the gathering for separated from these liquids since each windrow occupied half of the same ones maintaining the other lateral free (photo 2).
- the volume occupied by the windrow
- odors level: was adopted a subjective scale on a growing order of intensity : not perceptible (0), perceptible (1), not very annoying (2), annoying (3), very annoying (4) and aggressive (5).
- vector attraction (especially flies and mosquitos): arbitrary scale was assigned consistent in: few (+),some (++) and enough (+++).


photo 1


photo 2


photo 3

The compost was obtained using a mechanic sieve (photo 3) recovering the wood chip for reuse.

Analytic aspects
The samples were extracted taking portions of sludge in 6 different places from each windrow and to 30 cm of depth, being a total of approximately 1 kg sample for each windrow that was placed in plastic bags. For the determination of ascaris eggs, in particular, samplings were made at two depths: between 0 and 50 cm and between 50 and 100 cm. The samples were conserved for their transport to the laboratory, where the analytic treatment began in immediate form. The time lapsed among the taking of samples and its analysis was of 2 hours. For the analysis of chemical parameters, the sludge was dried in stove to 60 ºC and they were milled previous separation of the chip. All the analyses were carried out by duplicate. For the microbiological analysis the humid sample was analyzed by quadrupled**.**

RESULTS

Generated initial leached
The generated volume in absence of rain during the first 24 hours, previous to the windrows setting up was 750 litters corresponding to the 27 tons of sewage sludge; consequently it was 28 l/ton.

Mesophilic phase
The climatic conditions for both mesophilic and thermophilic phase in the summer test were average ambient temperature of 27,25 ºC and 5 rainy days, including a precipitation of 70 mm

fallen approximately in three hours. Under these climatic conditions the duration of mesophilic phase was: 1 day for windrow 1 and 2; 2 days for windrow 3 and 7 days for windrow 4 (fig. 1). It can be seen an inversely proportional relationship between the number of days and the quantity of bulking. The odour level in the first day was 5, the maximum of the scale in all the windrows, decreasing proportionally to the increment of bulking. For this reason, the windrow 4 (only sewage sludge) was the most odorous.

Thermophilic phase

The aim of this phase is the pathogen reduction by thermal treatment. Table 3 shows the thermophilic period for each windrow and the different parameters of process control.

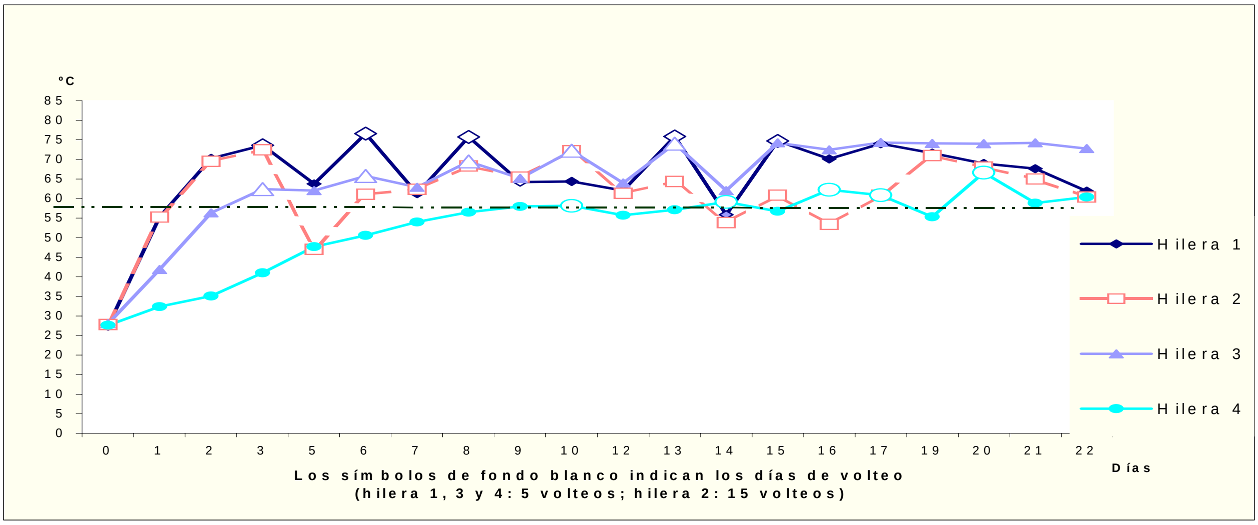
Table 3. Thermophilic Phase Process control

Windrow	Duration (days)	Turns	Volume reduction (%)	Odour	Vector attraction
1	15	5	20.33	0 a 1	+
2	17	15	32.87	0 a 1	++
3	15	5	24.32	1 a 2	++
4	15	5	21.22	3 a 4	+++

In all the cases the turns of windrows increased the odour level, with maximum intensity during the first turn of the windrow 4, detected at a distance of 15 meters. Regarding the vector attraction it was observed presence of worms in windrows and in leached.

The temperature-time profiles for each windrow during mesophilic and thermophilic phases and the days of turn are shown in fig 1. It can be observed that the falls of temperature relates directly to the cooling produced by the turns, however, the previous values are rapidly reached. When temperature-time profiles of the three windrows with wood chip are compared, it is found that in general the one that had daily turns (windrow 2) reaches smaller temperatures during the whole phase. In this case, capacity of thermal recovery seems to be more relevant.

Fig. 1 - Temperature-time profiles for each windrow during mesophilic and thermophilic phases



Generated leaches

During the first 48 hrs the leaches generated were consequence of the sewage sludge drainage. Then only were registered leaches after rains. It was indeed observed that, in the first 48 hrs after setting up the windrows, different sewage sludge: wood chip ratio produced different leached volumes as a consequence of the liquid absorption by the bulking. The windrow 4 (10 m^3, only sewage sludge) leached a total volume of 600 l (60 l/tn): 420 l during the first 24 hrs (42 l/tn) and 180 l more in the next 24 hrs (18 l/tn). The leached results and the wood chip absorbent capacity (sponge effect) using for the calculations 60 l/tn as the total leaching capacity, are presented in Table 4.

Table 4. Quantitative analysis of the initials leached

Windrows		Windrows volume (m^3)			Leached volume(l)		Retention bulking		Bulking absorption (%)
N°	Ratio	Sludge	Bulking	Total	48 hs	Leaching cap	Leaching capacity (l)	l/m^3 of chip	
1	1:1	5	5	10	68	300	232	46	77
2	1:1	5	5	10	50	300	250	50	83
3	0.5:1	6.6	3.3	10	280	396	116	35	30
4	0:1	10	0	10	600	600	0	0	0

The sewage sludge initials leached, are called in general "strong" or "loaded". They are consequently those that can cause more impact to the environment due to its acidity or alkalinity, high toxic elements contents, organic matter, nitrogen, etc.In Table 5 it is reported the chemical characterisation of the collected leached at the beginning and the end of the thermophilic phase.
The heavy metals levels founded were very low. The heavy metals concentrations, both, in the leached from the discharge day and at the beginning and final thermophilic phase, meet the normative of application requirements for overturn to absorbent soils. (9).

Table 5. Characteristic of the initial and final thermophilic phase leached

Parameters	Discharge day	Initial Phase				Final Phase			
		Windrow				Windrow			
		1	2	3	4	1	2	3	4
pH	6.50	6.90	6.90	6.20	6.20	6.80	6.90	6.80	7.30
S.S. 2 h (ml/l)	0.40	0.20	0.10	< 0.1	< 0.1	< 0.1	0.10	< 0.1	< 0.1
B.O. D. (mg/l)	4990	9430	8070	11310	11230	233	181	298	485
C.O.D. (mg/l)	8290	14700	13460	15180	21360	1126	881	1494	2736
T.K.N. (mg/l)	385	---	---	---	---	94.64	93.55	102.35	275.09
Nitrates (mg/l)	---	---	---	---	---	0.44	0.09	1.37	0.24
Phosphorus (mg/l)	103	73	67.70	106	126.5	43.28	18.64	19.20	19.90
Potassium (mg/l)	154	487	555	1008	1144	58	44.5	34.10	58.60
Cu (mg/l)	0.07	0.11	0.11	0.11	0.08	0.25	0.22	0.64	0.71
Zn (mg/l)	0.20	0.24	0.26	0.28	0.18	0.11	0.12	0.16	0.23
Pb (mg/l)	< 0.1	<0.1				<0.1			
Cd (mg/l)	<0.005	<0.005				0.007	0.008	0.009	0.009
Ni (mg/l)	0.188	<0.132	<0.13	0.152	<0.132	<0.13	<0.13	<0.132	0.159
Cr (mg/l)	0.037	<0.021	<0.02	0.041	0.028	<0.021			
Hg (mg/l)	<0.001	<0.001				<0.001			

Cured phase

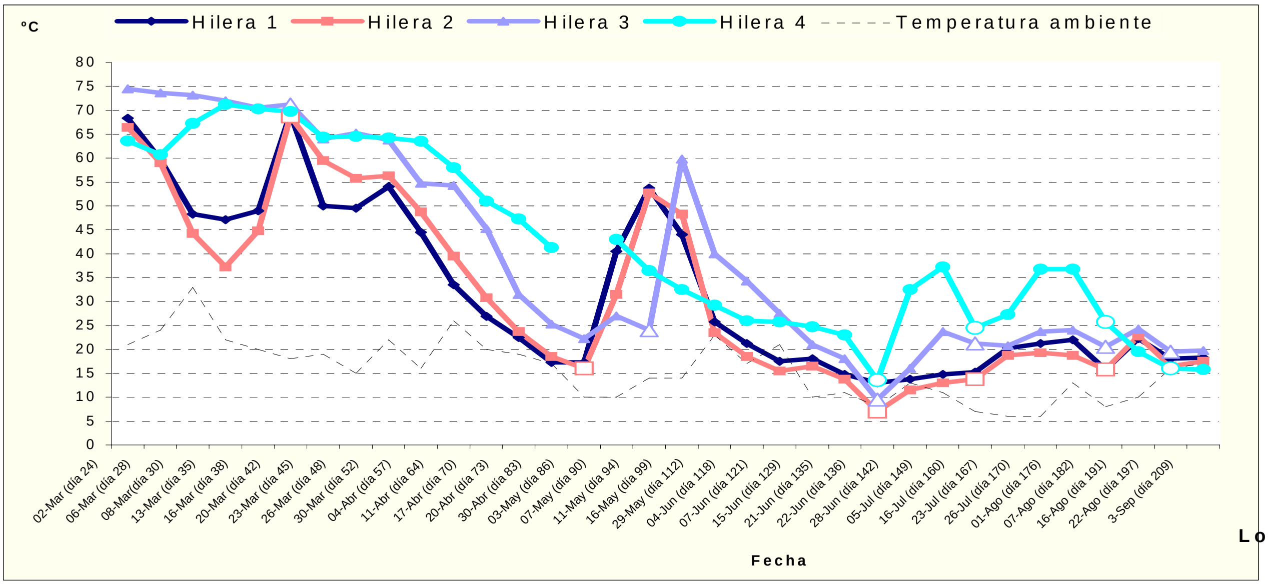
The aim of this stage is to reach stability and maturity of the product. The results are detailed in the Table 6. The frequency of turns (20 to 30 days) and temperature measurements were increased, and these measurements were made until reaching constant ambient temperature (stabilized product).
The temperature-time profile in the windrows during this stage and ambient temperature are shown in figure 2.Turns produce oxygenation of the windrows with a possible overheating when hydrolysable organic matter is available. The stabilization is achieved when overheat is not registered

Table 6. Cured Phase. Process control

Windrow	Duration (days)	Index of maturity (% red. of M.O.)*	Volume reduction (%)	Odour	Vector attraction
1	101	45.43	41.9	0	-
2	99	41.04	54.5	0	-
3	158	43.64	53.8	0	-
4	181	43.05	60.6	1	+

(*) Data for the total process from the beginning of the treatment

Fig. 2. Temperature-time profile for the four windrows during the cured stage (white symbols indicate the day of turn)



The figure indicates that over 30 days thermophilic temperatures (55 ºC) were maintained in all windrows, minimizing reinfection risks. The temperature-time profiles in all windrows show great similarities (windrow 4 displaced in the time), the ones with higher bulking proportion present a faster temperature decrease. While the treatment advances, organic matter concentration is reduced due to the bacterial degradation. As the change in one of the variables alters the system, the organic matter decrease produces the attenuation of the whole process. Consequently, a lower bacterial density, which is followed by a reduction in temperature, is observed. Finally, the initial sewage sludge becomes mature and stabilized product.The Mar del Plata sewage sludge maturity has been evaluated with these two reference methodologies: organic matter reduction and WSC/TN relationship. The organic matter reduction had analytical and operative advantages than the WSC/TN index. In addition, organic matter analysis by calcination is an easy, economic and fast method that allows a more frequent control as well as an intensive sampling frequency to resolve sewage sludge unhomogeneity inconvenience. According to the discussion above, a value of 40 % of organic matter reduction is proposed to assure the stability and maturity of non-homogeneous windrows.

Final Product.

The sludge physicochemical and microbiological characterisation, before and after the composting treatment during the summer, is presented in table 7. This information shows that the primary sludge became into a disinfected and slightly more alkaline final product, with reduction in more than 50% of the organic carbon content and heavy metals levels below reference norms and guides.

The sum of nitrogen, phosphorous and potassium concentrations is lower than 5%. Consequently this stable and mature product (see corresponding section) meet the organic amendment requirements (law of fertilisers) (10) and their quality is in agreement with the USEPA Class A (without use restriction) and with the National Resolution 97/01 A.1 category (5).

Table 7. Characteristic of the raw mud and of the product and final

Parameters	Raw Sewage Sludge				Compost			
	Array 1	Array 2	Array 3	Array 4	Array 1	Array 2	Array 3	Array 4
Moisture (%)	73.5	75.1	76.6	76.4	55.9	58.0	61.5	65.5
pH	6.20	6.80	6.10	6.40	7.87	7.92	7.72	7.98
E.C. ($\mu S\ cm^{-1}$)	1802	1869	2640	1807	611	600	809	685
T.O.C. (g/Kg)	385	395	409	395	183	212	219	225
T.K. N. (g/Kg)	20.4	16.0	21.2	20.0	17.6	18.1	23.4	22.2
Phosphorus (g/Kg)	4.78	4.70	6.08	4.82	4.6	6.68	10.83	9.97
Potasium (g/Kg)	0.91	0.92	1.15	1.04	0.56	0.61	0.64	0.39
Nitrates (g/Kg)	0.137	0.014	0.027	0.009	0.010	0.003	0.004	0.002
Fecal Coliform (MPN/100 ml)	$9.05\ 10^{6}$	$2.01\ 10^{7}$	$5.54\ 10^{7}$	$2.54\ 10^{7}$	96	55	932	778
Ascaris Eggs	be absent				be absent			
W.S.C. (g/Kg)	58.95	68.60	88.10	69.40	11.05	11.60	11.44	12.70
TOC/ NT	18.73	24.67	19.27	19.71	10.37	11.73	9.36	10.13
WSC/ NT	3.03	4.31	4.19	3.47	0.63	0.64	0.49	0.57
% M.O. Reduction	0	0	0	0	52.57	46.33	46.32	43.05
Cu (mg/kg)	81.4	105.8	935.6	104.3	524.4	451.4	1072.1	1779.3
Zn (mg/kg)	419.2	224.2	322.1	240.0	335.2	368.6	556.0	622.8
Pb (mg/kg)	123.9	33.1	39.3	49.2	71.6	195.9	116.5	508.0
Cd (mg/kg)	0.30	0.38	0.32	0.41	0.47	0.57	0.88	0.92
Ni (mg/kg)	23.3	21.4	7.1	3.9	27.2	7.8	12.9	12.0
Cr (mg/kg)	14.5	11.7	10.8	9.5	20.5	15.9	15.7	41.8
Hg (mg/kg)	0.14	1.26	0.21	0.51	0.31	0.90	0.56	2.58

CONSIDERATIONS

The winter Pilot Test was carried out (August 2001), where only the type of wood chip was modified (recent pruning of the city). Some comparative aspects regarding the summery experience can be affirmed like: the duration of the mesophilic and thermophilic phases for the relationships assayed (R:1:1 and 0.5:1) are observed in Table 8 and the bulking proportion significance.

Table 8. Comparative periods of mesophilic and thermophilic phases for the summer and winter tests

Duration of the phase (days)	Relationship 1:1		Relationship 0,5:1	
	Summer	Winter	Summer	Winter
Mesophilic	1	5	2	23
Thermophilic	15	25	15	-----

The difference observed in the thermophilic phase duration (R:1:1) is due to the noticeable decreases of temperatures registered during the turns and to the difficult of thermal recovery, attributed to the winter climatic conditions: low temperatures, high rains frequency.In the case of 0.5:1 (bulking:sludge) ratio the thermophilic phase could not overcome the ninth day probably because of the lower bulking proportion, which in summer time did not present inconveniences.

The same bulking:sludge ratio, it was found that while the windrow with fresh wood chip complete the whole thermophilic phase, the one with wood chip stored at open air(outdoors) could not get to the thermophilic phase. This appears to be due to its moisture content. Consequently, it is reasonable to assume that a roof structure without walls, for the wood chip storage would be needed. On the other hand, it is appropriate to underline that although in both tests wood chip of different trees species was used, both were efficient for the treatment.

CONCLUSIONS

- In summer, all the bulking: sludge ratios could be applied while in winter only the 1:1 bulking: sludge ratio completed the thermophilic phase.
- The more bulking proportion, the lower leached volumes during the whole process (smaller administration requirement), vector attraction, odour generation, time of treatment and both, regrowth and bacterial contamination risk are obtained.
- The use of humid bulking affects unfavourably the process.
- The daily turns in summer did not have relevant incidence over the process.
- The organic matter reduction result the most appropriate maturity index for the Mar del Plata sewage sludge.
- The obtained final product meets the National Resolution 97/0 A.1 category (5) and the USEPA Class A without use restriction (6), and it reaches the organic amendment category (nitrogen, phosphorous and potassium concentrations below 5%) fertilisers law (10).
- Design parameters to real scale for composting Mar del Plata City primary sludge were obtained.

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