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SOLID WASTE MANAGEMENT AND BIOELEMENTS IN SOIL

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Summary. - *Two studies are reported in the field of solid waste management. The first concerns heavy metal migration below a landfill site. The results show that total and leachable heavy metal concentrations are more variable in refuse than in soil samples, as refuse is not homogeneous but can be influenced by local conditions and the seasons. In the soil below refuse, the concentration of total metals is low and similar to control soil samples, whereas leachable metals behaved differently in the two drillings, their mobility depending on soil characteristics. The bulk of heavy metals, however, remains immobile. The second study regards the utilization of compost as a filter bed for pig slurry to reduce its pollution load hence enriching the compost of the nutrients it lacks. A pilot plant was installed utilizing pressed straw bale containers filled with compost through which pig slurry was filtered. The filtering tests demonstrated a reduction of the pollution load of slurry and at the same time evidenced the possibility of utilizing the entire filtering system as a fertilizer to improve compost, with heavy metal concentration tolerance limits lower than the ones proposed at a national level to prevent environmental pollution.*

Riassunto (Bioelementi nel suolo nella gestione dei rifiuti solidi). - *Sono riportati i risultati di due indagini effettuate nel campo della gestione dei rifiuti. La prima ha preso in considerazione la migrazione di metalli pesanti in una discarica per rifiuti solidi urbani e nel terreno sottostante. I risultati delle analisi hanno messo in evidenza una variabilità maggiore nei rifiuti rispetto al suolo dovuta alla disomogeneità dei materiali smaltiti che è influenzata da situazioni locali e dalle stagioni. Il comportamento della parte rilasciabile dei metalli è diversa nelle due perforazioni essendo la loro mobilità legata alle caratteristiche del suolo. Tuttavia la maggior parte dei metalli risulta immobilizzata. La seconda ricerca è stata mirata allo studio della utilizzazione del compost quale letto filtrante per i liquami di allevamenti suinicoli, con l'intento di ridurre il carico inquinante di questi e contemporaneamente arricchire il compost degli elementi nutritivi. Dopo varie fasi di sperimentazione in laboratorio è stato costruito un impianto pilota che utilizzava balle di paglia pressata come vasca di contenimento riempita di compost come filtro. I risultati delle prove di filtraggio del liquame hanno mostrato una riduzione del carico inquinante di questo e messo in evidenza la possibilità di utilizzare l'intero sistema filtrante quale concime con un contenuto di metalli pesanti al di sotto dei limiti previsti dall'attuale normativa nazionale.*

Introduction

The use of land as a waste management alternative involves technological and potential health problems that need further research. Investigation of landfill sites indicates that most sites have problems associated to leachate migration that pollutes the environment. Disposal or recycling of increasingly large amounts of agricultural wastes also poses a problem. Lack of comparable control and technology has made disposal of agricultural wastes more of a pollution hazard than municipal wastes.

The elimination or improvement of these problems lies in the understanding of the quantitative aspects regarding the transfer of pollutants through soils and in a better knowledge of the soil environment in which each waste application is located.

Soil characteristics

Soil is a heterogeneous and complex three-phase system containing solid, liquid and gaseous components. The size of the solid particles between which pore space is formed is occupied by the liquid and gaseous phases in constantly changing proportion.

According to statistical studies on soil composition the mean values are as follows: 50% oxygen, 25% silicon, 15% sesquioxide-forming elements and 10% water. The solid fraction of soil is composed mainly of inorganic materials such as silicates, oxides and phosphates: the organic soil content is low and it results from biological degradation of wastes, both animal and vegetal. Its low quantity is compensated by being very reactive.

The soil properties, both physico-mechanical and chemical are related to solid particle size. In particular, the mobility and accumulation of pollutants is chiefly controlled by their reaction with the solid phase; it depends on solid particle size, on the amount, size and shape of pore space and on the amount and type of soil mineral.

The solid particles taken into account are less than 2 mm in diameter and are mixtures of sand, silt and clay in relative proportions. The latter has a particle size smaller than 0.002 mm. Solids with particles larger than 2 mm in diameter constitute the soil skeleton, such as gravel, stone and conglomerates. Their large pores provide a continuous channel, so they do not chemically influence the pollution phenomena of soil.

Sand and clay, differ from each other both in dimension and chemical composition. Sand is composed of quartz and silicates, whereas clay consists of a group of silicate minerals known as clay minerals. These clay minerals comprise cations coordinated tetrahedrally and octahedrally, forming either sheets or chains.

Moreover, trace elements occur in soil at a low concentration and steady state. Sometimes these elements are found in particular locations in unusually high concentrations. Neverthless, they do not cause pollution since they are naturally immobilized. In fact, an example is the presence of Fe in Elba soil and Hg near mount Amiata.

The liquid phase enveloping the solid phase contains dissolved substances both organic and inorganic, which influence their mobility. Water is a fundamental component because it is the principal carrier of possible pollutants. Air, the third component of the soil system, tends to attain equilibrium with the soil solution. Air is present in the first soil layers where the biological living matter, microrganisms and plant roots breathe. In the deeper layers, instead, pore spaces are gradually filled with water, thus developing anaerobic conditions. This type of environment supports the diffusion of facultative anaerobic microrganisms that can also live without oxygen and later favours the growth of obligate anaerobic bacteria.

Soil pollution

When due to human activities a pollutant penetrates the soil system in large quantities, not only it can alter the composition and functioning of soil, but also and above all, it can produce groundwater pollution as a consequence of the migration of substances not connected with the natural environment by transporting them into water solution causing change of its physical, chemical and microbiological properties.

Soil migration

Transport and accumulation of various pollutants in soil is controlled by physical, chemical and biological mechanisms. The physical mechanisms are: diffusion caused by the thermal motion of ions and molecules; dispersion due to velocity variation in pore space; dilution with passage of fluids from unsaturated zones to saturated ones below a clay layer; physical sorption which involves the attachment of the sorbent and sorbate through the Van der Waal forces, and filtration through solid particles.

The chemical mechanisms are: precipitation and solution characterized by the establishment of a chemical equilibrium between the liquid and solid phases; adsorption (the adhesion of ions or molecules in extremely thin layers to the surface of soil solids with which they are in contact); desorption (the opposite phenomenum); complexation (the chemical reaction between metal ions with anions and with organic chelant to form organic and organometallic complexes); and ion exchange (the interchange between a cation in solution and another cation adsorbed on a surface of any surface-active material).

Microbiological mechanisms are the most difficult to quantify. They have enormous influence on the migration of toxic pollutants, with consequences on redox processes, mineralisation, immobilisation and complexation reactions.

Objectives

Considering that land disposal and treatment must be taken as separate alternatives, the purpose of this study was two-fold:

1) to document the behaviour of pollutants in a landfill and their migration in the soil below refuse;

2) to study the possibility of maximum utilisation of agricultural wastes and, at the same time, to provide public health protection.

Analytical methods

The determination of total heavy metal content was performed on air-dried, sieved and pulverized samples by atomic absorption spectrometry (AAS), predigesting the samples with nitric acid under pressure and heat.

The leachable heavy metal concentration was determined on fresh samples placed in a vessel with deionized water in a 1:16 ratio and continuously stirred for 24 h adding 0.5 N acetic acid to reach the pH of 5 ± 0.2. The liquid phase obtained after centrifugation (and filtered if necessary) was analyzed by means of AAS with graphite furnace.

Migration from landfill sites

The first part of this study regards the disposal of municipal solid wastes and the consequences it has on soil pollution. The oldest and most diffused method of household refuse disposal consists in dumping into pits or trenches digged expressly for that purpose or in excavated gravel or sand pits, clay quarries and other lands otherwise unsuitable for cultivation or construction. After the refuse is dumped and compacted, it is covered with soil, minimizing the problem of odors, fires and vectors which are critical environmental factors in sanitary landfill plants. If the design and construction of landfill and operation plants are not adequately done, the refuse disposal can cause damage to soil because fill leachates can migrate to underlying groundwater, eventually causing contamination. Leachates are pollutants caused by inflow of rainfall and produced by organic solid waste decomposition that can contain dissolved and suspended organic and inorganic material.

The present legislation (DPR 915/82 and its regulation) prohibits landfills which are not sanitary and prescribes technical guidelines according to waste characteristics, to be employed for landfill site design, construction and operating procedures.

It is necessary, however, to consider old open dumps that do not comply with sanitary regulations and that were not regulated by law at the time they were filled. Even small quantities of abusive disposal may cause pollution due to toxic substance contents.

To verify the way in which refuse can contribute to harmful dispersion in soil, a survey of several municipal landfills included in various territorial contexts was carried out in collaboration with the Veneto region (Fig. 1) [1-3]. In these landfills, drillings were performed using a hollow steam rotating auger and samples of refuse and soil beneath the landfill were drawn in the zone of influence of leachates produced by refuse. Analyses of significant parameters to monitor pollution such as chemical oxygen demand (COD), conductivity, organic carbon, phosphate and nitrogen were performed together with a survey of

Fig. 1. - Location of Veneto landfill drilling. Landfills: 1) Ponzano Veneto; 2) Altivole; 3) Campodarsego; 4) Cerea; 5) Este; 6) Sandrigo; 7) Rosà.

heavy metal concentrations. To evaluate the amount leached, refuse and soil samples were analyzed by a standard elution test to determine the release and the evaluation of what is supposed to take place on a long-term basis.

The results presented in this paper were taken from the municipal solid waste landfill of Ponzano Veneto in the Treviso area. This landfill is located in an abandoned gravel pit where the refuse is disposed of in a way that cannot be considered "controlled" because the soil is permeable and easily leachable by liquids that also contain inorganic pollutants. Fig. 2 reports a cross-section of this landfill, the drilling sites and the different depths.

Results and conclusions on migration from landfill sites

Tables 1-5 report the analyses carried out in refuse and soil samples obtained from two drillings and also from soil samples collected in three sites further away from the landfill area at 1 m depth.

From the results the following conclusions can be drawn:

1) metal concentration in refuse layers does not present a regular trend as the materials disposed of are not homogeneous, e.g. even household refuse is determined by local influences such as socioeconomic conditions, recreational areas (picnic and camping sites) and commercial and institutional areas. Moreover, yard-wastes, a part of municipal refuse, can vary with the seasons. The municipal waste disposal system of piling up and compressing refuse without homogenizing it, can greatly affect these results;

2) the higher concentrations of total metals are found in refuse layers;

3) the high level of total Cr in drilling site no. 1 is probably due to industrial waste disposal in that zone evidenced also by the presence of ammonium and sulfur fumes during drilling operations;

4) the higher values of total Fe, Cu and Zn in drilling site no. 2 prove the disposal of household refuse in that zone because of the metals normally present in many materials discarded;

5) total metal concentrations in soil samples beneath the landfill are inferior to those of refuse samples, but similar to those of control soil samples at three sites beyond the zone of influence of the refuse;

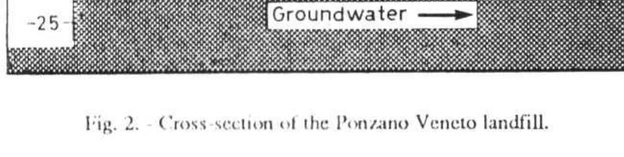

Fig. 2. - Cross-section of the Ponzano Veneto landfill.

Table 1. - *Ponzano Veneto landfill: analytical results of refuse samples collected at drill no. 1* (μg/g)

Depth (m)		Fe	Mn	Cu	Zn	Cr	Ni
1.5	t	8446.08	174.25	297.25	1094.70	430.50	61.50
	r	0.98	12.68	0.10	73.17	0.10	3.42
	% r/t	0.01	7.28	0.03	6.68	0.02	5.56
4.5	t	7633.26	298.50	149.25	76.89	149.25	21.32
	r	1.92	25.00	1.92	0.10	2.88	2.88
	% r/t	0.03	8.38	1.29	0.13	1.93	13.51
8.5	t	8837.21	348.84	181.40	171.60	139.53	23.26
	r	5.19	116.54	1.79	25.55	2.69	4.48
	% r/t	0.06	33.41	0.99	14.89	1.93	19.26
11.5	t	12596.90	436.05	218.02	171.27	268.90	48.45
	r	5.29	176.40	1.60	10.74	3.05	7.52
	% r/t	0.04	40.45	0.73	6.27	1.13	15.52
12.5	t	8551.31	251.50	50.30	96.28	299.30	167.50
	r	118.53	50.49	2.52	88.61	7.57	36.43
	% r/t	1.39	20.08	5.01	92.03	2.53	21.75
Average	t	9212.95	301.83	179.24	322.15	257.50	64.41
	r	26.38	76.22	1.59	39.63	3.26	10.95
	% r/t	0.31	21.92	1.61	24.00	1.51	15.12
Standard deviation	t	1943.81	98.80	90.77	434.00	119.83	60.11
	r	51.55	68.89	0.90	39.11	2.70	14.36
	% r/t	0.61	14.80	1.96	38.39	0.97	6.19

wastes clay silt sand and gravel

t: total
r: released

Table 2. - *Ponzano Veneto landfill: analytical results of soil samples collected at drill no. 1* (μg/g)

Depth (m)		Fe	Mn	Cu	Zn	Cr	Ni
13.5	t	4951.92	264.42	24.04	40.48	120.19	12.02
	r	154.33	136.73	6.01	6.01	5.21	6.84
	% r/t	3.12	51.71	25.00	14.85	4.33	56.91
14.5	t	5377.91	319.76	29.07	59.01	87.21	14.53
	r	57.18	199.95	10.00	10.20	4.20	6.12
	% r/t	1.06	62.53	34.40	17.29	4.82	42.12
15.5	t	6459.23	236.31	39.39	67.31	118.16	41.00
	r	35.75	152.65	6.03	2.53	3.82	9.78
	% r/t	0.55	64.60	15.31	3.76	3.23	23.85
16.5	t	6301.37	246.57	27.40	68.49	191.78	25.00
	r	44.90	128.90	4.01	3.25	2.00	7.71
	% r/t	0.71	52.28	14.64	4.75	1.04	30.84
17.5	t	4991.21	193.32	17.57	63.99	72.06	17.57
	r	1.85	56.37	1.85	1.61	0.10	2.83
	% r/t	0.04	29.16	10.53	2.52	0.14	16.11
18.5	t	5586.29	201.46	36.63	84.25	119.05	18.31
	r	18.92	119.80	4.03	4.09	2.01	7.05
	% r/t	0.34	59.47	11.00	4.85	1.69	38.50
Average	t	5611.29	243.64	29.02	63.92	118.08	21.41
	r	52.16	132.40	5.32	4.62	2.89	6.72
	% r/t	0.97	53.29	18.48	8.00	2.54	34.72
Standard deviation	t	643.36	46.04	8.05	14.27	41.45	10.55
	r	53.60	46.78	2.77	3.12	1.86	2.23
	% r/t	1.11	12.84	9.40	6.46	1.74	2.28

wastes clay silt sand and gravel

t: total
r: released

Table 3. - *Ponzano Veneto landfill: analytical results of refuse samples collected at drill no. 2* (μg/g)

Depth (m)		Fe	Mn	Cu	Zn	Cr	Ni
1.5	t	17660.00	710.70	37.52	108.80	11.82	25.90
	r	844.60	365.25	0.40	5.94	0.40	0.60
	% r/t	4.78	51.39	1.07	5.46	3.38	2.32
2.5	t	13310.00	539.80	117.89	107.90	28.63	20.10
	r	665.63	267.85	0.20	5.80	0.40	2.40
	% r/t	5.00	49.62	0.17	5.38	1.40	11.94
3.5	t	19970.00	778.80	2730.02	398.70	52.28	48.70
	r	225.95	289.94	0.20	3.80	0.20	3.00
	% r/t	1.13	37.23	0.01	0.95	0.38	6.16
4.5	t	40100.00	412.10	232.59	347.20	53.25	69.20
	r	164.05	92.03	0.80	6.20	2.00	7.20
	% r/t	0.41	22.33	0.34	1.79	3.76	10.40
5.0	t	19130.00	677.00	72.86	137.70	35.79	74.50
	r	192.01	274.00	1.42	3.80	0.80	2.00
	% r/t	1.00	40.47	1.95	2.76	2.24	2.68
Average	t	22034.00	623.68	638.18	220.06	36.35	47.68
	r	418.45	257.81	0.60	5.11	0.76	3.04
	% r/t	2.46	40.21	0.71	3.27	2.23	6.70
Standard deviation	t	10420.09	146.87	1171.68	140.15	17.33	24.59
	r	314.34	100.53	0.52	1.20	0.73	2.49
	% r/t	2.23	11.64	0.80	2.07	1.39	4.38

wastes   clay   silt   sand and gravel

t: total
r: released

6) the presence of higher metal concentrations in some layers of drilling no. 1 is due to retention of small layers of clay and silt;

7) the percentage of leachable metals is very low with respect to the total amount. The soil below the landfill site shows similar values to those of control soil, with the exception of Ni present in the soil of drilling no. 1 and of Cr in the soil of drilling no. 2;

8) if we consider leachable metals as a whole (i.e., both drillings) different behaviours can be observed. In drilling no. 1, the concentration of leachable Fe, Mn and Zn decreases in soil layers, whereas the concentration of Cu, Cr and Ni increases in soil as compared to refuse. In drilling no. 2, the concentration of Zn, Cr and Ni decreases in the soil below the landfill and the concentration of Fe, Mn and Cu increases with respect to refuse. As far as the concentration of Mn, Zn, Cr and Cu is concerned, the higher release occurs two-three meters below the refuse, where a series of sand and gravel layers in clay and silty matrix are present. Leachable Cr and Fe tend to decrease in proportion to depth. However, in the last soil layer, an increase was observed.

Compost and agricultural wastes

The second study regards both the treatment of land through which nutrients return to their natural cycle and the disposal of wastes in such a way that any adverse impact can be examined and controlled. The resource values of wastes must be safe for public health and environmental reasons.

Composting is a decomposition and mineralization process, under controlled conditions, for converting municipal solid wastes into a product that can be used in agriculture without causing damage to public health. The chief agricultural utilisation of compost is as a soil conditioner for its organic matter content, but its use is limited because it lacks nutritional elements such as N and P, necessary for plant growth.

In the field of pig husbandry many industrialized countries converted from traditional methods of farming with production of farmyard manure to modern methods with the concentration of large numbers of animals in intensive rearings. This type of industrial breeding has created enormous problems of disposal or utilisation of vast quantities of animal waste that exceed the quantities that can be utilized by soil. Excessive applications throughout the year may cause pollution of surface water for the following reasons: organic matter, salt and chemical run-off, pollution of groundwater because of nitrate, nitrite, salt and chemical leaching, reduction of crop yield due to nutrients build-up, and damage to soil properties (pH, structure, salinity, etc.) because the excreta is applied in semiliquid form.

The prospect of reducing the pollution level of liquids and at the same time of enriching compost with the elements it lacks, has stimulated research of systems that use compost as a filter bed. In this manner, a harmless disposal of the two types of refuse can be carried out without causing environmental pollution.

Table 4. - *Ponzano Veneto landfill: analytical results of soil samples collected at drill no. 2* (µg/g)

Depth (m)		Fe	Mn	Cu	Zn	Cr	Ni
5.5	t	7690.00	225.30	35.75	78.20	33.36	39.00
	r	15.80	54.00	0.63	1.20	2.20	1.20
	% r/t	0.21	23.97	1.76	1.53	6.59	3.08
6.0	t	8260.00	268.90	63.05	97.40	25.59	54.60
	r	27.51	69.31	1.42	2.73	2.31	4.62
	% r/t	0.33	25.78	2.25	2.80	9.03	8.46
6.5	t	6690.00	205.20	32.06	41.68	27.58	18.00
	r	27.19	65.86	2.08	7.01	2.55	2.55
	% r/t	0.41	32.10	6.49	16.82	9.25	14.17
7.0	t	8670.00	262.80	17.98	42.56	25.86	21.50
	r	20.85	82.53	0.87	1.95	2.61	2.61
	% r/t	0.24	31.40	4.84	4.58	10.09	12.14
7.5	t	7100.00	215.90	26.02	43.97	26.92	19.00
	r	13.41	68.10	1.51	2.55	2.13	3.62
	% r/t	0.19	31.54	5.80	5.80	7.91	19.05
8.0	t	7020.00	219.30	24.38	50.80	51.98	17.70
	r	13.48	79.15	0.44	1.28	3.85	2.78
	% r/t	0.19	36.09	1.80	2.52	7.41	15.71
8.5	t	2940.00	160.30	50.15	92.87	38.85	45.50
	r	8.38	69.15	1.68	2.72	2.30	3.98
	% r/t	0.29	43.14	3.35	2.93	5.92	8.75
9.0	t	5550.00	203.90	19.99	34.97	22.39	16.30
	r	13.60	54.00	0.80	2.80	2.60	2.80
	% r/t	0.25	26.48	4.00	8.01	11.61	17.18
9.5	t	5070.00	187.60	16.82	43.60	38.19	20.40
	r	23.00	80.01	2.00	6.20	3.54	3.80
	% r/t	0.45	42.65	11.89	14.22	9.27	18.63
Average	t	6554.44	216.58	31.80	58.45	32.30	28.00
	r	18.14	69.12	1.27	3.16	2.68	3.11
	% r/t	0.28	32.57	4.69	6.58	8.56	13.02
Standard deviation	t	1784.78	34.01	15.70	24.15	9.37	14.40
	r	6.76	10.42	0.58	2.02	0.65	1.07
	% r/t	0.09	6.94	3.19	5.30	1.78	5.36

wastes clay silt sand and gravel

t: total
r: released

Table 5. - *Ponzano Veneto landfill: analytical results of soil samples collected in three locations out of landfill site* (µg/g)

Sample		Fe	Mn	Cu	Zn	Cr	Ni
1	t	7730.67	249.88	49.88	62.84	109.73	23.69
	r	6.25	80.39	2.68	3.57	3.57	4.47
	% r/t	0.08	32.24	5.37	5.68	3.25	18.87
2	t	5854.51	249.13	49.83	28.64	92.18	39.36
	r	9.76	99.58	1.99	2.79	1.99	5.97
	% r/t	0.17	39.97	3.99	9.74	2.16	15.17
3	t	6836.33	324.35	137.23	34.43	144.71	24.95
	r	7.99	109.86	2.00	3.36	3.00	5.09
	% r/t	0.12	33.87	1.46	9.76	2.07	20.40
Average	t	6807.17	274.29	78.98	41.97	115.54	29.33
	r	8.00	96.61	2.22	3.24	2.85	5.18
	% r/t	0.12	35.36	3.61	8.39	2.49	18.15

wastes clay silt sand and gravel

t: total
r: released

The research developed in two subsequent stages. In the first stage, slurry was filtered (with or without recycling or under ventilation) through the compost held in plexiglass lysimeters [4, 5]. The second stage consisted in the introduction of straw into the filters leading to a substantial improvement of the filtering capacity and to a reduction of pollution load [6-8]. In the third stage, a pilot plant was installed in a farm with intensive methods of pig rearing [9, 10].

A tank was built with the sides and bottom made of pressed wheat straw bales and spread with a 30 cm layer of compost. The tank was filled at a rate of 2.5 l/s and successively with 2147 l of liquid pig manure, via a supply pipe coming from a nearby lagoon (Fig. 3). Complete analyses of liquid manure, compost and effluent were done regularly.

After 10 days, when the leaching of the liquid manure was completed, the filtering system was sectioned and various layers were identified. Dry fraction of manure, straw and compost samples of various layers were taken and analyzed. Finally, the filtering system was destroyed and the material was carefully mixed.

The analyses were done considering two different aspects: environmental and agronomical. The analyses of the original and filtered liquid manure evidenced a decrease in biological oxygen demand (BOD), COD, suspended solids (SS), N and P and an increase in the BOD/COD ratio, an indicator of biodegradability. From the agronomical point of view, the material obtained from the mixing of the filtering system presented a higher content of N and P than the compost.

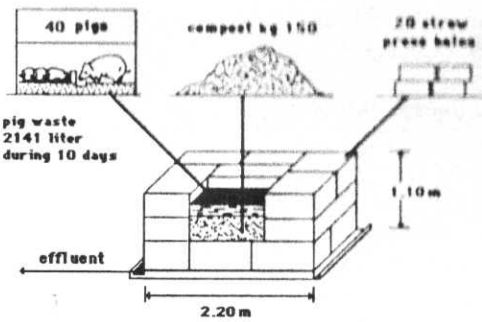

Fig. 3. - Pilot plant scheme.

In addition, the presence of heavy metals in the experimental system was studied to verify whether their concentrations constitute a health or environmental hazard. Results are reported in Table 6.

The total and theoretical quantities of the experimental system were estimated and the results reported in Table 7.

Table 6. - *Heavy metals concentrations carried out in the single layers*

Layer	Material	Concentration (μg/g)							
		Zn	Cu	Cr	Pb	Co	Ni	Mn	Cd
1	SL	1265.7	565.1	53.8	28.8	15.6	32.2	746.8	28.2
2	SL	1592.3	681.3	54.5	29.7	11.1	67.7	1150.6	18.5
3	SL	1539.8	595.8	33.7	40.3	6.8	18.8	868.2	15.5
4	SL + CO	664.6	279.7	45.2	370.1	13.7	39.7	416.4	19.1
5	SL + CO + ST	625.1	278.2	102.5	279.7	16.8	69.2	417.4	12.9
6	SL + ST	2267.5	133.9	21.6	150.8	9.3	38.1	272.1	4.5
7	ST	229.4	145.6	<5	62.7	19.9	89.8	65.6	48.4

SL: sludge; CO: compost; ST: straw

Table 7. - *Total amount of heavy metals in the whole filtering system*

Layer	Material	Amount (g)							
		Zn	Cu	Cr	Pb	Co	Ni	Mn	Cd
1	SL	7.4	3.3	0.3	0.2	0.1	0.2	4.4	0.2
2	SL	30.1	12.9	0.9	0.6	0.2	1.3	21.8	0.3
3	SL	98.1	37.9	2.1	2.6	0.4	1.2	55.2	1.1
4	SL + CO	19.7	8.3	1.3	11.1	0.4	1.2	12.3	0.6
5	SL + CO + ST	7.6	3.4	1.3	3.4	0.2	0.8	5.1	0.2
6	SL + ST	194.8	115.1	1.9	12.9	0.8	3.3	23.4	0.4
7	ST	11.1	6.9	0.1	2.9	1.1	4.3	3.2	2.3
Total (g)		368.8	187.8	7.9	33.7	3.2	12.3	125.4	5.1
Concentration (μg/g)		278.1	141.6	6.1	25.4	2.3	9.3	94.6	3.8
Limits (μg/g)	EEC	2500	1000	750	750	none	300	none	20
	Italy (Decree no. 915/82)	2500	600	200	400	20	100	1000	10

SL: sludge; CO: compost; ST: straw

The maximum heavy metal concentration values proposed by the EEC and those prescribed by the Decree of the President of the Republic (DPR) no. 915/82 are also reported in this table. The results showed concentrations below the values proposed.

Conclusions on migration from compost and agricultural wastes

The experimental system is an effective pretreatment plant for the separation of the solid fraction of pig slurry with low energy consumption. Moreover, the utilized wastes (straw, compost and solid fraction of pig slurry) are completely recycled because the whole plant can be used as organic fertilizer better than compost at the end of the filtering cycle. The heavy metal content is not dangerous for the agricultural environment, as it was below the proposed limit values. This system can also be developed for pratical use.

These studies represent two practical examples of sound and effective procedures to protect soil from undue contamination from the elements. They also reflect the overall waste management trends to be further encouraged and applied.

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