

Potential sewage sludge utilization to fertilize forage surfaces in Galicia

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Abstract

Sewage sludge is an extensively used fertilizer in Galicia, where more than 70% of the sewage sludge produced is used in agriculture. Nevertheless, before using sewage sludge as a source of nutrients for soil, special attention has to be paid to its content of heavy metals, which could be quite high. For this reason, there are European and Spanish regulations that take account of the levels of heavy metals in soils, in sludge and the maximum amount of heavy metals that can be applied for a period of ten years. Based on previous evaluation at the Spanish scale, Zn is the regulated heavy metal with the highest levels in the sludge. In the present study, a survey of around 2600 soils was performed in order to evaluate the levels of heavy metals in soils and the implications of these levels on the potential use of sewage sludge. Sewage sludge could be used in more than 94% of the analysed soils. Ni was the most limiting heavy metal for sludge application, mostly associated with soils that have serpentine rock as the parent material.

Keywords: heavy metal, biosolid, grassland

Introduction

The production of municipal sewage sludge in Europe has increased since the start of the 1990s due to the implementation of the 91/271/CEE Directive, which makes the progressive purification of municipal sewage compulsory in municipalities. The residue from sewage treatment should be recycled as fertilizer as it has a good proportion of N, P and organic matter. However, the higher proportion of heavy metals in these residues, compared with the soil, needs the development of adequate regulations to reduce potential negative impacts of these heavy metals on soils and crops, and therefore for animals and human health.

The European Union sewage sludge working document (EU 2000-Brussels, 27 April 2000 – ENV.E.3/LM) provided some rules to control the use of sewage sludge based on the heavy metal contents in the sludge, in the soil, and on the maximum quantity of different heavy metals that could be accumulated over a 10-year period on a field. Zn, Cu, Hg, Cd, Cr, Pb and Ni are the current heavy metals to be evaluated to determine the suitability of a soil to receive sewage sludge as fertilizer. The implications of the levels of heavy metals of the sludge and of corresponding policy rules were previously evaluated in Spain by Mosquera-Losada *et al.* (2010). Main conclusions indicated that, taking into account the sludge working document, it will not be possible to use sludge as a fertilizer in the future, unless the concentrations of Cd, Pb, Zn, and Hg in the sludge are reduced. In this paper, we compared the levels of heavy metals of 2597 soils to be used for forage production and the limits described in the current sewage sludge Spanish regulations based on Directive 91/271/EEC.

Materials and methods

The study was carried out in Galicia, a region of more than three million hectares in the north-western part of Spain. It is localized in the south-western part of the Atlantic

bio-geographic region of Europe. From 2007 to 2010, 2597 soil samples, which had previously never been fertilized with sewage sludge, were randomly sampled to define if they were suitable to receive sewage sludge. Soil depth sampled was 25 cm, as established by the Spanish Royal Decree 1310/90. Once taken, all soil samples were transported to the laboratory and air dried. Afterwards, soil samples were sieved through a 2 mm sieve and digested using a microwave (CEM) with nitric acid. Subsequently, concentrations of Ni, Cd, Zn, Cr, Cu and Pb were measured by using an atomic spectrophotometer, and Hg with a hydride generator (VARIAN VGA-76). Soil pH was also measured in a water suspension (1:2.5).

Results and discussion

Soil pH ranged from extremely acid to basic (Table 1), but most of the soils had a pH below 7 (only 38 soil samples had a water pH above 7). Heavy metal availability is usually higher in acid soils (Smith, 1996). This underlines the importance of evaluating the concentration of heavy metals in Galician soils. All mean concentrations of heavy metals (Table 1) were below the limits given by the Spanish regulation (Royal Decree 1310/90), but most of the maximum values were above this level with the exception of Hg. Zn and Hg concentrations were within the usual range for soils described by Davies (1980) which were between 10 and 300 mg kg⁻¹ for Zn and between 0.01 and 2 mg kg⁻¹ for Hg, while Cr (1.4–1389 mg kg⁻¹) and Pb (3–189 mg kg⁻¹) were within those given by Kabata-Pendías and Pendías (1985). However, some concentrations were above the soil limits considered as usual for Ni (10–100 mg kg⁻¹), Cd (0.07–1.1 mg kg⁻¹) and Cu (10–80 mg kg⁻¹) given by Carter (1993), Kabata-Pendías and Pendías (1985) and Davies (1980), respectively.

Table 1. Mean, minimum (Min) and maximum (Max) values and their standard deviation (SD) of water pH and heavy metals of 2559 soils tested in this experiment

Property	Value	Min-Max	Mean	SD	Spanish regulation
pH-H ₂ O		3.44–10.22	5.21	0.72	
Cd (mg kg ⁻¹)		0.01–2.50	0.05	0.15	1
Ni (mg kg ⁻¹)		0.001–169.50	12.20	14.28	30
Pb (mg kg ⁻¹)		0.01–118.50	10.21	12.13	50
Zn (mg kg ⁻¹)		0.01–306.70	45.33	30.46	150
Hg (mg kg ⁻¹)		0.01–0.80	0.054	0.05	1
Cr (mg kg ⁻¹)		0.01–236.94	10.03	16.54	100
Cu (mg kg ⁻¹)		0.01–212.00	16.38	17.98	50

Table 2 shows the number of samples below and above the limits defined by the Spanish regulation and Directive 91/271/EEC. None of the basic soils had heavy metal levels above the current limits. The heavy metal most limiting a possible sewage sludge application, in 6% of the sampled acid soils, was nickel. This could be explained by the occurrence of serpentine as parent rock material (Reeves *et al.*, 1999). Copper followed by zinc and lead concentrations in some soils were also above the Spanish limits. However, more than 99% of soil samples fulfilled the current Spanish regulations, except for Ni content. The rainfall regime in the region explains the acidity of the soil. This could also lead to heavy metals leaching and so to the observed concentrations below the current regulations.

Table 2. Number of samples for each heavy metal with values above Spanish and EEC current directives depending on pH

	Legal requirements for use of sewage sludge in soils. Samples below/above the limits					
	R.D. 1310/1990 (<i>Directive 91/271/EEC</i>)					
	pH \leq 7; $n = 2559$			pH $>$ 7; $n = 38$		
	limit	below	above	limit	below	above
Cd (mg kg ⁻¹)	1	2557	2	3	38	0
Ni (mg kg ⁻¹)	30	2408	151	112	38	0
Pb (mg kg ⁻¹)	50	2548	11	300	38	0
Zn (mg kg ⁻¹)	150	2540	19	450	38	0
Hg (mg kg ⁻¹)	1	2559	0	1.5	38	0
Cr (mg kg ⁻¹)	100	2550	9	150	38	0
Cu (mg kg ⁻¹)	50	2542	55	210	38	0

Conclusions

More than 94% of the analysed Galician soils fulfilled the current Spanish and European limits allowing the application of sewage sludge to soils. Nickel was the heavy metal that was the most limiting for sewage sludge application, and was usually associated with the presence of soil which had serpentine as parent material.

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