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Proposing policy changes for sewage sludge applications based on zinc within a circular economy perspective

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ABSTRACT

Sewage sludge production has been increased in the last years because the wastewater treatment is mandatory in urban areas with more than 2000 inhabitants since 2005. Most adequate disposal of sewage sludge should be agricultural soils to improve their fertility and fulfill bioeconomy and circular economy requirements. However, the higher level of heavy metals in sludge than in soils makes necessary to consider the inputs of heavy metals in soil as have been done by regulation 86/278/EEC and more recent documents (EU 3rd Draft Directive or the Environmental, economic and social impacts of the use of sewage sludge on land). Sewage sludge application is restricted by the mean amount of heavy metals applied with sewage sludge in soil in a 10-year period and the concentrations of heavy metals in the sludge and soils. The aim of this study was to evaluate the current and foreseeable limits of the application of different types of sewage sludge (anaerobic, pelletised and composted) considering the current and the possible future legislation of the most abundant heavy metal in the sewage sludge, which is Zinc (Zn) and taking into account the existing levels in acid soils in Galicia (NW Spain). Main results highlighted the adequacy of using composted sludge as amendment, while anaerobic and pelletised sludge as fertilisers to reduce future possible soil contamination. Sewage sludge regulations should aim to reach mean values of Zn to ensure soil microbial health and sustainability adequate levels of Zn in crops or pasture. Low quality sewage sludge application should be reduced in frequency or doses, allowing soils to get benefits of increasing soil organic matter without strong changes in Zn soil contents.

1. Introduction

The implementation of the Urban Waste Water Treatment (EU, 1991) in all EU Member States has increased the quantities of sewage sludge requiring disposal. From an annual production of around 5.5 million Mg of dry matter (DM) in 1992, the European Union headed towards nearly 9.8 million Mg in 2012 (Eurostat, 2016). The fertiliser utilization is one of the most promoted uses of sewage sludge among scientists and policy makers in order enhance the recycling of sewage sludge nutrients (EU, 1991; Mosquera-Losada et al., 2011a,b) because, if adequately managed, improves soil fertility increasing soil organic matter (BOE, 1990) therefore fulfilling bioeconomy and circular economy requirements.

The stabilization process of sewage sludge modifies its fertiliser value and therefore the dose of application to fulfill crop needs (EPA, 1994; Mosquera-Losada et al., 2010). The form of stabilization is usually selected depending on the volume of sewage sludge production and if composting is chosen it depends on the existence of materials or residues to mix within the area where the sewage sludge is produced (Mosquera-Losada et al., 2010). The most common and promoted treatments of sewage sludge to reduce microbial contamination and odors, as well as to favor the agronomic use, are anaerobic digestion and compost which are accompanied of a short and longer time of treatment, respectively. After anaerobic treatments, sewage sludge pelletization is useful when the volume reduction is pursued to decrease sewage sludge storage and transport costs, while improving soil application facilities.

The higher levels of heavy metals, pathogens and no-desirable organic compounds in the sludge than in the soil also causes environment concerns to the population, policy makers and scientists. Heavy metal limitations to use sewage sludge were established by the European Commission in 1986 (EU, 1986) and summarized by the Join Research

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Centre in 2012 (JRC, 2012). Nowadays, there are three conditions that limit the use of the sewage sludge in agriculture: (i) maximum concentration values in the sludge (ii) maximum concentration values in the soil and (iii) maximum amount of heavy metal that can be applied as a mean for a period of ten years in kg per hectare and year.

However, there is an agreement between policy makers, scientists and population that heavy metals thresholds should be further limited by modifying the current EU Directive 86/278/CEE (EU, 1986). For this reason, the European Commission delivered the 3rd draft working document on sludge in 2000 (EC, 2000), that was not finally implemented due to the costs and the problems associated with the proposed more restrictive limits. The European Commission (EC, 2008) in the "Environmental, economic and social impacts of the use of sewage sludge on land. Final Report" document has evaluated these limits and posed several scenarios with less and more restrictive limits than the before mentioned draft (EC, 2000), estimating the implementing cost they have. In both drafts, more stringent standards, especially for heavy metals, were introduced compared with the Directive 86/278/CEE (EU, 1986), being the sewage sludge application banned in soils with pH below 5. Moreover, the Final Report (EC, 2008) proposed several scenarios with less and more restrictive limits to provide the European Commission with the necessary information for a decision whether or not a revision of the Directive 86/278/CEE 8 (EU, 1986) is needed and lays the basis for a possible revision. However, the Directive 86/278/CEE (EU, 1986) was not modify due to the lack of consensus among the Member States of the European Commission which confirms that it is not easy to establish more strict limits at European level.

Producing high quality sewage sludge is the first issue to be dealt with in order to use a residue in a sustainable form to improve soil fertility. Secondly, the evaluation of soils is highly relevant because the acidity and heavy metal baseline levels are essential to evaluate the fertility needs of the soil as well as the risk of sewage sludge inputs into the soil and the subsequently possibility of heavy metals reaching human beings causing health problems. The evaluation is more relevant in those regions with high demand of fertilisers due to their good environment growing conditions (temperature, humidity, radiation) and with acid soils, due to the fact that heavy metals are more available in acid soils (Porta et al., 1999). In Europe, there is a large amount of soils that limits plant growth due to its acidity (Clea et al., 2014), where the dominance of natural factors determining the acid pH of agricultural soil at the continental scale (Salminen et al., 2005) should be compensated by the addition of calcareous amendments, that can be partially replaced by sewage sludge.

Zinc (Zn) is the heavy metal with higher sewage sludge concentration from those regulated (EU, 1991; López-Díaz et al., 2007). But, at the same time, Zn is an essential trace metal for animals and plants. Zinc deficiency occurs usually associated to excessive calcium in soil linked to high soil pH (Tóth et al., 2016). Zinc can be toxic in excess, being animal exposure typically associated to dietary ingestion (Tóth et al., 2016).

Acidic Galician (NW Spain) soils could be considered representative of a large part of the Atlantic biogeographic region of Europe (EC, 2005; EEA, 2003) due to its acidity and the large agronomic and livestock production it has. This Spanish region which occupies around 3 million ha (IGE, 2011), producing 53% of wood in Spain (data from 2012)) (INE, 2015), produces also 34% of the Spanish milk supply (data from 2013) mainly based on forage (crops like maize) and grasslands (INE, 2015). Currently, 97% of sewage sludge produced in the region (188.384 t in 2014) is valorized as fertilizer or soil improver. The aim of this study was to evaluate the current and foreseeable limits of the application of different types of sewage sludge (anaerobic, pelletised and composted) considering the current (Directive 86/278/CEE) and the possible future legislation (3rd draft working document on sludge and Final Report) of the most abundant heavy metal in the sewage sludge (Zn) and taking into account the existing levels in acid soils in Galicia.

2. Materials and methods

2.1. Characteristics of the study site

The study was carried out in Galicia, a Spanish region placed in the southwest part of the Atlantic biogeographic region of Europe, which occupies around 3 million ha. Galicia is characterised by the high rainfall levels, with well over 1000 mm a year across almost the entire region, which together with the type of bedrock (mainly quartz) imply soils with a high acidity.

2.2. Soil samplings and laboratory analyses

From 2007 to 2010, a set of 2597 soil samples from agricultural lands of Galicia (NW Spain), which were not previously fertilised with sewage sludge, were randomly taken at a depth of 25 cm as established 86/278/EEC regulation (EU, 1986). Out of this 2597, a number of 2424 soil samples were selected for this study using as criteria the fulfilment of the 86/278/EEC regulation (EU, 1986) transposed in the Spanish regulation 1310/90 (BOE, 1990) for sewage sludge use in agriculture. The regulation 1310/90 (BOE, 1990) establishes that those soils with values of Zn, Cu, Cr, Cd, Ni and Pb over 150, 50, 100, 1, 30 and 50 mg kg^{-1}, respectively, in soil pH below 7 and over 450, 210, 150, 3, 112 and 300 mg kg^{-1}, respectively, in soil pH above 7 are not suitable to receive sewage sludge. Soil samples were mostly taken from the agrarian based counties of the Galician region, where more fertiliser is needed compared with the predominantly forested counties. The main agrarian activity in Galicia is related to forage crops such as maize and pasture to feed dairy and meat cows (IGE, 2011) and has a high rate of fertiliser needs and use. The number of hectares of the sampled plots represents approximately 1.5% and 20% of grasslands and agrarian soils (including forage crops and grasslands) of Galicia, respectively. Once taken, all soil samples were transported to the laboratory, where they were air dried. Afterwards, soil samples were sieved through a 2 mm sieve. Water soil pH was measured (1:2.5) (Guitián and Carballas, 1976) and the concentration of Zn was analysed with the VARIAN 220FS spectrophotometer using atomic absorption (VARIAN, 1989), after a nitric acid digestion made in a CEM MDS-2000 microwave (CEM, 1994).

2.3. Statistical and mathematical analysis

Descriptive statistics (mean, median, standard deviation, robust coefficient of variation, skewness, kurtosis, etc.) of the soil Zn were performed in the 2424 samples. The descriptive statistics include median absolute deviation (MAD), which is a robust method for evaluating dispersion. Statistical analyses were carried out with SPSS (PASW 18.0) for windows.

For the soil Zn study, soil samples were split in 4 groups of range of soil pH (pH < = 5, 5 < pH < = 6, 6 < pH < = 7 and pH > 7) because this allows to compare the samples within (i) the different limits for Zn given by 86/278/EEC (EU, 1986) regulation for soils, (ii) the European Union 3rd draft of the Directive (EUDWD) (EC, 2000), and those described in the Final Report "Environmental, economic and social impacts of the use of sewage sludge on land" (EC, 2008) in two scenarios, (iii) "Moderate changes" of the limits of Zn concentration in soil (S1) (iv) "More significant changes" (S2) (Table 1). Even though the 3rd draft working document on sludge was not approved due to the lack of consensus between the different countries, we use the intervals of pH to compare it with the current soil values, because it could give us an idea of the next steps that will be taken in the future regulation of the use of sewage sludge in agriculture at European level. In case of soil without established limit (pH < = 5) we compare the soil Zn concentration with those provided for soils with pH between 5 and 6.

Both regulations, 86/278/EEC (EU, 1986) and EUDWD (EC, 2000), indicate that a soil is suitable to receive sewage sludge depending on (i)