Chapter

The Use of Composted Municipal Solid Waste under the Concept of Circular Economy and as a Source of Plant Nutrients and Pollutants

María Belén Almendro-Candel, Jose Navarro-Pedreño, Ignacio Gómez Lucas, Antonis A. Zorpas, Irene Voukkali and Pantelitsa Loizia

Abstract

The European Union (EU) is one of the major producers of municipal solid wastes and has a common policy based on circular economy to reuse the wastes. However, there are differences between countries and the methods for disposal and treatments. Municipal solid waste (MSW) can be composted and recycled as a source of plant nutrients and improves soil properties. This chapter analyzed the production in the EU and the effects on plant nutrients and environmental pollutants when MSW is added to the soil. The origin of the waste and the compost-like output (CLO) derived is important to determine the expectative of nutrient availability and other possible risks. MSW is so heterogeneous, but after a good pretreatment, an organic-rich matter mix can be composted giving a stabilized organic matter. The addition of the CLO to the soils can improve the nutrient status and favor the bioavailability of nutrients (macronutrients and micronutrients). In general, an increment of N and P was found in the soils. Moreover, important micronutrient availability (Fe, Mn, Cu, and Zn) has been described. However, the presence of pollutants and their mobility should be considered as an environmental risk.

Keywords: circular economy, MSW compost, nitrogen, plant nutrients, pollutants

1. Introduction

In Europe, each of the half billion citizens (500 million people) produces waste. The quantities of municipal solid waste (MSW) have been growing for many years in many countries. This is on top of massive amounts of waste generated from several activities like manufacturing (360 million t) and construction (900 million t), while water supply and energy production generate more than 95 million t [1]. More or less the entire EU produces up to 3 billion t/y in 2011 according to Eurostat [2]. As a definition of MSW [3], "Municipal waste is mainly produced by households, though similar wastes from sources such as commerce, offices and public institutions are included. The amount of municipal waste generated consists of waste collected by or on behalf of municipal authorities and disposed of through the waste management system."

The amount of waste we are creating is increasing, and the nature of waste itself is changing, partly due to the dramatic rise in the use of hi-tech products. According to the latest official Eurostat statistics [2], the total waste generation in the EU-27 was more than 2.62 billion t. The statistics indicated that the total amount of municipal solid waste is continuously rising [4–6] and the amount up to 98 million t (or 3.7%) was classified as hazardous. On 2008, each European citizen produced more or less 5.2 t/y of waste, of which 196 kg were hazardous [2]. As indicated from the Organization for Economic Co-operation and Development (OECD) [7], MSW increased up to 54% in major EU countries such as Switzerland, Denmark, Portugal, the Netherlands, and Greece in 20 years (1980–2000). OECD [7], Jacobsen and Kristoffersen [8], and Zorpas et al. [9] investigated the connection between economic growth and quantity of waste and proposed that a decoupling is needed in order to reduce the increasing burden from waste management.

MSW from 2000 has slightly minimized in the EU-27, although the gross domestic product (GDP) was increased by 33% between 2000 and 2013, due to economic crisis [9]. However, waste generation in new member states has remained relatively stable by weight since the 1990s. This may be due to a reduced incidence of heavy mining and construction waste and increased lighter paper and packaging waste. Decoupling economic growth from the environmental impacts associated with waste generation is a key objective of the EU [10]. The target is not only to monitor the generation of waste but also to reduce the waste production [5].

1.1 Production of MSW in the EU countries

Among the EU countries, there are huge differences in the production as well as in the treatment of MSW. The average production per country varies from 254 kg/y in Romania to 758 kg/y in Denmark with the average to be 474 kg/y. Cyprus produced approximately 630 kg/y, Greece 650 kg/y, and Spain 495 kg/y (**Figure 1**).

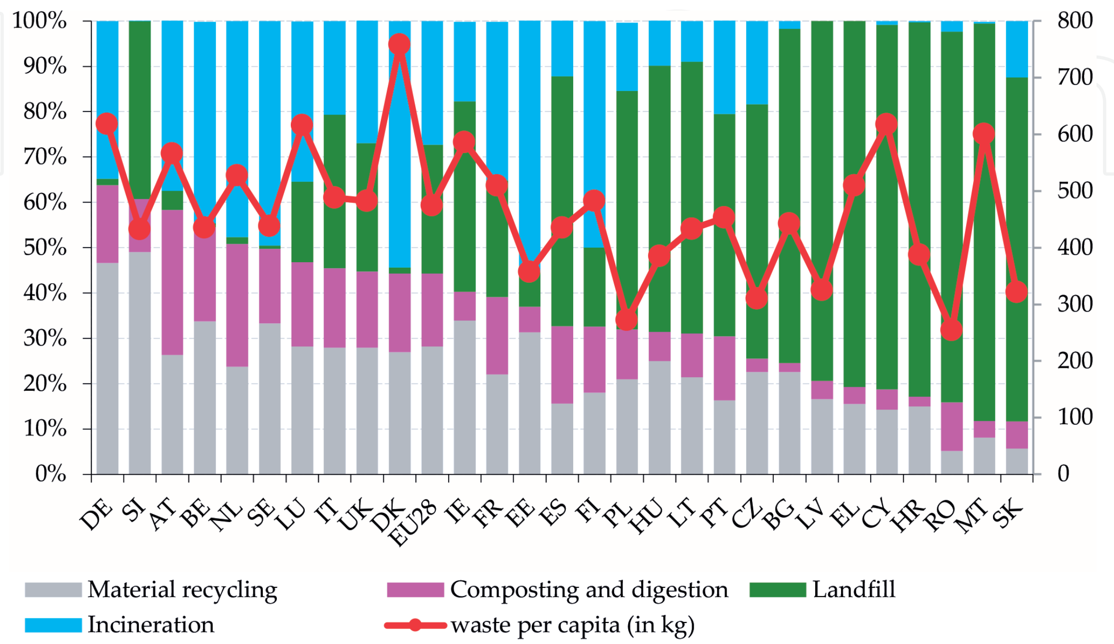

Figure 1.
Waste production and management in the EU countries.

Municipal waste per capita in the EU decreased from 523 kg per person in 2007 to 474 kg per person in 2014, in part because of the economic downturn.

The share of recycled or composted municipal waste in the EU-28 (including Croatia) increased from 31% in 2004 to 44% in 2014. According to the European Environment Agency (EEA) [3], trends in the past decade also include a shift away from landfilling and a 56% drop in net greenhouse gas emissions from municipal waste management between 2001 and 2010. Recycling and composting range from 64% in Germany to 12% in Slovakia and Malta (EU average, 44%). Six member states landfill less than 5% of their municipal waste, 8 member states landfill over 70% of their municipal waste (EU average, 28%), 10 member states incinerate over 35% of their municipal waste, and 8 member states incinerate less than 2% of their municipal waste (EU average, 27%) [11]. The overall increase in the recycling rate appears in some items like paper/cardboard, glass, metals, plastics, and textiles. In contrast, increases in biowaste recycling are much more modest [3].

Packaging waste in the EU in 2011, measured by weight, is made up of paper and cardboard (40%), glass (20%), plastic (19%), wood (15%), and metal (6%), according to Eurostat [2]. In 2013, 65% of packaging was recycled in the EU-28, although material-specific recycling rates varied a great deal: 85% for paper and cardboard packaging, 74% for metallic packaging, 73% for glass packaging, 36% for wooden packaging, and 37% for plastic packaging. Moreover, in yearly base almost 9 million t of end-of-life vehicles (ELV) are generated in the EU and can be recovered almost 80% of ELV materials [11, 12].

A significant issue of MSW is the food waste (FW), and according to FAO [13], in 2011 it is estimated that 35% of food (including supply chain) is mostly lost at the consumer level. Moreover, 1.3 billion t of edible foodstuffs (equivalent with one-third of the global food production) are lost yearly [13, 14], and this is sufficient to feat one-eighth of worldwide population [15]. Additionally, the total CO_2 equivalences of greenhouse gases (GHG) from the entire FW is about 3.49 billion t [15], and the annual bulk-trade value of produced and unconsumed food is estimated at 936 billion $.

The management of MSW is an increasing problem in small communities as well as in insular communities such as (Malta, Crete, Sicily, and Cyprus) because of the fast increase in population density, which is leading to the collapse of landfill sites [9]. It is open of question nowadays as indicated by Zorpas et al. [15], "how a small island will implement the concept of circular economy" with all the ambitious targets that were set. This perspective presents a significant challenge for any insular community as the European Union Landfill Directive has presented stringent requirements for waste disposal sites and requires a reduction for waste (biodegradable) being dumped [16].

1.2 Circular economy and wastes

According to Winans et al. [17], there are limited data about the clear evidence of the origin of the concept of circular economy. However, according to Ellen MacArthur Foundation [18], some contributions include researches from the United States as may also have been stimulated by Rachel Carson's Silent Spring [19] , which states that "limits to growth" thesis of the Club of Rome in the 1970s, the "spaceship earth" metaphor presented by Barbara Ward and Kenneth Boulding, and work by eco-economist Herman Daly [20]. Pearce and Turner [21] proposed the general framework of circular economy with emphasis on product resource and pollution. The main principles were presented by Zorpas and Lasaridi [5], Wu et al. [22], and Zorpas et al. [23], and more specifically the well-known 3Rs (reduce, reuse, recycle) and the 6Rs (reuse, recycle, redesign, remanufacture, reduce, recover) by Jawahir and Bradley [24]. Moreover, Zorpas [25] indicated the concept of "11R," which starts from refuse and ends to recover.

Waste generation is the other side of the coin of resource exploitation and potential scarcity. Therefore, it is interwoven with global environmental security and governance, posing a problem that has grave environmental, social, and economic repercussions for all nations, for the current and future generations.

The concept of circular economy appeared in Europe in 1980 and 1990 with several other policies that also appear in the EU drawing on ideas that can be traced to 1970 [26]. Following the concern around high commodity prices, the European Commission (EC) launched a *flagship* initiative on resource efficiency, which at the beginning was operationalized through the roadmap for a resource-efficient Europe [27]. This was followed up with the declaration of a range of policy measures known cooperatively as the Circular Economy Package.

During 2014, the European Commission (EC) published a statement entitled "Toward a circular economy: A zero waste program for Europe." This report provides emphasis on the "the EU and the Member States should encourage investment in circular economy innovation and its take-up" [28]. Nevertheless, before the end of 2014, the proposals on the circular economy were eliminated as part of the drive to cut red tape [29]. During 2015 a new proposal focused on circular economy was realized by the European Commission. The new proposal entitled "Circular Economy closing the Loop – An EU Action Plan for the Circular Economy" sets out the new targets, the policies on the circular economy [30].

The EC's action plan for the circular economy has an ambitious goal: "to treat waste as a resource and to turn Europe into a circular economy." Although the recommended policies go far beyond the waste division, waste division management plays a key role in the transition to a circular economy. As such, the EC's 2015 action for a circular economy sets the current scene for a new approach to waste management in Europe.

The action plan sets out a policy framework that builds on and integrates existing policies and legal instruments. In particular, the European Circular Economy Action Plan proposes amendments to legislation relating to waste and landfills (which were due for revision). Changes on the following legislations were proposed by the EC in order to turn Europe into a circular economy: (i) Directive 1999/31/EC [16] on the landfill of waste, (ii) Waste Framework Directive (WFD) 2008/98/EC [31] on waste, (iii) Directives 2000/53/EC [32] on end-of-life vehicles, 2006/66/EC [33] on batteries and accumulators and waste batteries and accumulators, 2012/19/EU [34] on waste electrical and electronic equipment (WEEE), and (iv) Directive 94/62/EC [35] on packaging and packaging waste. The action plan suggests three specific changes to the regulations by including the following targets by 2030: (a) a target to prepare 65% of municipal waste for reuse and recycling, (b) a binding landfill target to reduce landfill to a maximum of 10% of municipal waste, and (c) a target to prepare 75% of packaging waste for reuse and recycling by 2030 (with supplementary targets for specific packaging material).

On the one hand, it is important to achieve a reuse or recycling of 65% of MSW and reduce binding landfill. On the other hand, the use of MSW in soils as a source of nutrients and the main way to reuse the organic matter is not an optional target in the EU and for extension to other countries (**Figure 2**). In fact, this is an essential part of the circular economy, and the role of the administrations to ensure this use is crucial. However, we should consider that the "requirements that have to be content by a material derived from waste to confirm that the quality of the material is such that its use is not detrimental for human health or the environment" [36].

Considering developing and promoting recycling in the concept of circular economy, the main fraction of MSW is organics; those could be very useful to

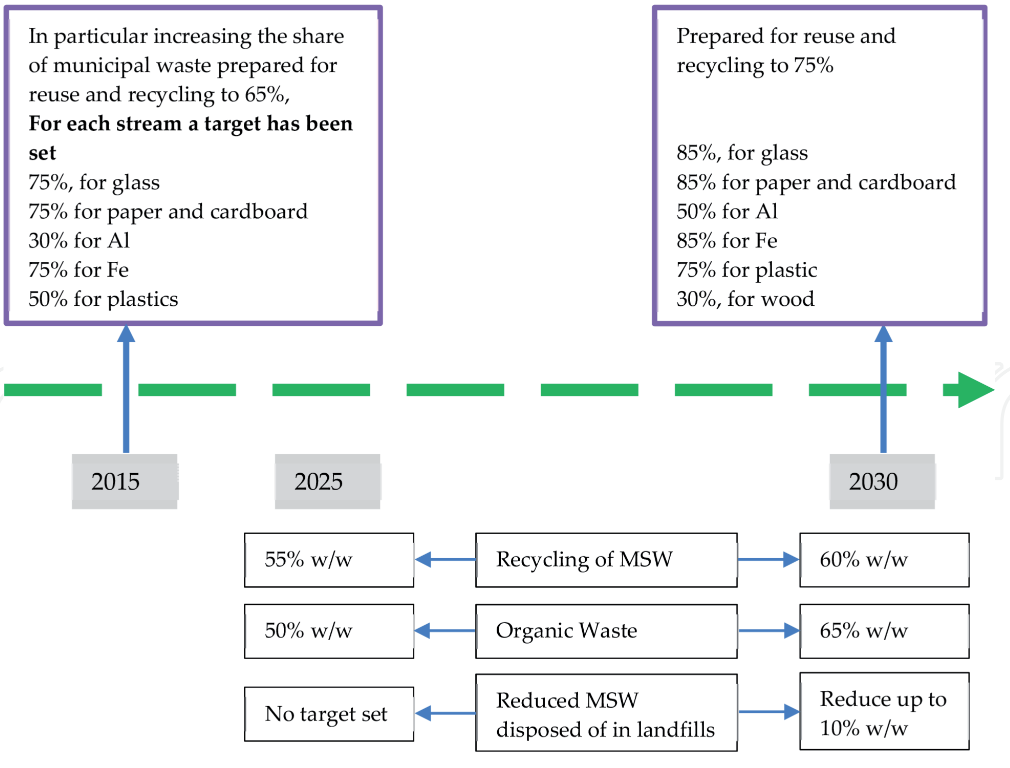

Figure 2.
Circular economy time line from 2015 to 2030.

provide several nutrition to soils as an acceptable method to treat them is composting [37, 38]. However, composts should cease to be waste only if they are placed on the market for specific purpose and only if acceptable criteria will be given [6]. Creating compost delivers economic and more specific ecological and environmental benefits. The production of compost with high and reliable quality expands its use and avoids unnecessary regulatory burden or other legal certainties. Nowadays, the quality of composted materials is determined only by the end use and classified according to its physicochemical characteristics. Having in mind the cure of circular economy and industrial symbiosis, the development of end waste criteria (EWC) for any organic material before the production of compost could be extremely helpful. For example, a bad quality compost with low C/N ratio or low organic matter or low bulking density could be useful for restoration of mining activities [39].

2. Macronutrients and environmental pollution

The application of organic amendments to the soil is a very common practice, especially in areas with low organic matter content [39]. The application of MSW as a source of organic matter and nutrients has been described for agriculture, mining restoration, and gardening [39, 40]. But it carries the associated risk of possible pollution, focused mainly in the nitrate contamination of surface and groundwater, since the mineralization of this organic matter can release large amounts of ammonium that will oxidize to nitrate [41, 42]. However, there are also other risks derived from the composition of MSW (hazardous materials) and the presence of plant nutrients as phosphorus [43], chloride, and sulfur [44].

A common composition of a composted MSW is indicated in **Table 1**. This composition shows important amounts of plant nutrients (i.e., phosphorus) as well as the presence of environmental pollutants like nickel and cadmium [39].

The urban wastes can differ in origin and changes due to the different style of life, conditioning the composition, and the total amount of wastes. The

Variables	Amounts[a]
Sand (20 < ∅ < 2000 μm)	42%
Silt (2 < ∅ < 20 μm)	28%
Clay (<2 μm)	30%
pH in water (1:2.5)	6.9
Electrical conductivity (EC) (1:5)	705 dS/m
Oxidizable organic matter (OM)	416 g/kg
Phosphorus (P)	4610 mg/kg
Potassium (K)	2100 mg/kg
Sodium (Na)	1010 mg/kg
Calcium (Ca)	60 mg/kg
Magnesium (Mg)	45 mg/kg
Iron (Fe)	9800 mg/kg
Manganese (Mn)	177 mg/kg
Copper (Cu)	89 mg/kg
Zinc (Zn)	186 mg/kg
Nickel (Ni)	18.8 mg/kg
Cadmium (Cd)	0.8 mg/kg

[a] *Amounts on a dry matter basis.*

Table 1.
Composition of a composted MSW [39].

composition of waste in landfills could differ due to the joint storage of industrial and domestic waste containing toxic elements [45]. Moreover, the composition of MSW can be different considering the seasons of the year and seasonal impacts should be taken into consideration when dealing with MSW [46].

2.1 Nitrogen and organic matter

Nitrogen is one of the major nutrients for plants, and soil is the main source in terrestrial ecosystems. Nitrate is the preferable chemical form for the absorption of most of the plants. However, this is a very mobile chemical form [42]. In order to minimize the risk of groundwater contamination, Jorge-Mardomingo et al. [41] recommend the use of stable organic amendments (with a more stabilized organic matter), which could produce a lower content of leachable nitrogen forms. Risk is also minimized by planting rainfed crops and particularly by choosing crops with a high demand for nitrogen such as wheat or maize [47].

Applications of MSW (composted or not) should be planned to avoid the coincidence of peaks of soluble nitrogen forms with rainfall periods in order to prevent their transport to groundwater and increase their residence time in the root zone. Diffuse nitrogen losses from agricultural fields are the major cause of excessive nitrate concentrations in ground- and surface waters [48].

MSW compost contains large amounts of organic matter and both organic nitrogen and inorganic nitrogen [49]. The organic matter plays a key role in improving soil properties such water retention capacity or soil structure, among others [50]. The use of composted organic wastes produces changes in soil physical, chemical, and biological properties and can enhance plant growth after its application [51].

Moreover, the organic matter added with MSW can be the main source of nitrogen in impoverished soils with low organic matter content.

The amounts of plant-available nitrogen and phosphorus from MSW are closely related to the degree of compost maturity, the addition of mineral fertilizers, soil characteristics, and environmental parameters [49]. All of them can affect the availability of nutrients. For instance, the addition of inorganic fertilizers can increase the plant and microbial activity of soils and may induce an increment of the mineralization of the organic matter of MSW, favoring the inorganic nitrogen forms.

Not only the plant nutrition is directly affected by using MSW, but also improving soil properties, the plant can response positively. Civeira [51] studied the response of an urban-degraded soil to different MSW compost application rates, as an alternative to MSW disposal and soil recovery. As indicators from soil response, physical (bulk density, soil moisture, and water infiltration) and chemical (pH, electrical conductivity, organic C, total N, and extractable P) parameters were evaluated. Compost application positively affected total N content in soils, improving soil physical properties in a similar way to chemicals, after MSW compost addition.

After the application of MSW compost to the soil, nitrogen is transformed into mobile forms, which can be accumulated in the soil, absorbed by plants, or released into the atmosphere or water system. The amount of nitrogen released into the soil solution determines the form of nitrogen availability to the plant and, consequently, the yield. Nevertheless, the environmental risks are well known. The amendment of the soil with organic fertilizers containing easily decomposable organic carbon compounds can trigger denitrification processes [50].

If MSW is poor in nitrogen or the rate C/N is inadequate for the mineralization of the organic matter, additional sources of nitrogen are needed. Mkhabela and Warman [52] found that the low availability of compost-N means that supplementary nitrogen in the form of inorganic fertilizer may have to be added together with compost in order to enhance N availability to crops. They observed that inorganic fertilizer (NPK) and a mixture of MSW compost and inorganic fertilizer produce higher yields than MSW compost alone.

2.2 Phosphorus and other macronutrients

Some authors observed that MSW compost effectively supplies phosphorus to soil with its concentration increased when increasing application rates. MSW composts provided equivalent amounts of phosphorus to soil as mineral fertilizers [52, 53].

In an experiment in plots in a quarry restoration, where 3 kg/m^3 of MSW were applied to a substrate composed by limestone outcrop from the rejection of the quarry, an increment of nutrients associated to the composition of the composted MSW was obtained. In the plots in which MSW was applied, an important increase in the soil content of N-Kjeldahl, available P, and the rest of macro- and micronutrients was found, favoring the plant growth [54]. The results reflected the contribution of MSW to the plant nutrition and reinforced the idea of the positive use of the organic fraction of MSW in mining and landfill restoration (**Figure 3**).

Baldi et al. [55] studied the effect of applying 5 and 10 t dw/ha·year of composted MSW to a nectarine crop for 11 years. They found that the content of N, P, macro-, and micronutrients increased with respect to the control, both in the plant and in the fruit. The authors concluded that in their experiment the slow release of nutrients in the soil from compost mineralization seemed to match with plant demand, supporting the hypothesis that compost can be used effectively in fruit

Figure 3.
Composted MSW for soil restoration in a landfill area and a quarry with compost derived from MSW. The use of compost of MSW for seed germination (Photos from J. Navarro Pedreño).

tree nutrient management, since it promotes an increase of tree growth and yield by maintaining an optimal nutritional status of plants.

Calleja-Cervantes et al. [56] studied the effect that 13 years of applying three different composted organic amendments have had on soil quality, GHG emissions, and the dynamics of its microbial communities 15 days after the annual application. They found that total nitrogen increased with respect to the control by amending with organic fraction of municipal solid waste. Organic amendment application resulted in higher levels of phosphorus and potassium in the soil. They concluded that significantly higher organic matter contents, total N, P, and K contents, in the soil when compared to the control validate the fact that organic waste-based fertilizers contribute to enhanced soil fertility.

The balance between the addition of nutrients that can be available for plant nutrition and the possible pollution, especially of waters with N-forms, needs to study previously the type of soil and, in general, the environmental conditions where MSW is going to be applied. The criteria established to control the addition of MSW as amendment to the soil might be improved including new criteria based on environmental conditions.

3. Micronutrients and trace elements from MSW

As it has been shown in the previous sections, the use of MSW can be very positive due to the addition of plant essential elements and the availability of them in the soils and due to the improvement of some physical properties [50]. However, trace elements should be identified and considered as environmental risk.

In the EU, as in the rest of the world, several treatments are used for MSW, mainly landfill disposal. However, landfill and composting are not the only treatments for urban wastes. Incineration has been increased (with or without recovering energy), and it is an important treatment used with MSW in the EU.

It is important to consider that countries with limited natural resources should have an interest in resource reuse [57] and the addition of MSW to soil has positive benefits. For these reasons, the composting process for municipal solid waste should be implemented as far as possible due to the great organic fraction of MSW.

Composts have been frequently used as nitrogen and organic carbon amendments to improve soil quality and to support plant growth, with the additional benefit of reducing waste disposal costs [49]. Nevertheless, the environmental risks from the use of MSW begin within the previous treatments before its addition to soil. The composting process is recommendable before its use, although health risk assessment of odor emissions (i.e., sulfides and aromatics) from waste composting is important [58].

Regarding with the major potential environmental impacts related to landfill, the main problem identified in the municipal wastes consisted of untreated leachates [59]. The leachate pollution of groundwater and surface waters can be categorized into four groups (dissolved organic matter, inorganic macrocomponents, heavy metals, and xenobiotic organic compounds) [60]. Kjeldsen et al. [60] defined these groups for MSW landfill leachates as follows:

- Dissolved organic matter, quantified as chemical oxygen demand (COD) or total organic carbon (TOC), volatile fatty acids, and more refractory compounds such as fulvic-like and humic-like compounds.
- Inorganic macrocomponents: calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), potassium (K^{+}), ammonium (NH_4^{+}), iron (Fe^{2+}), manganese (Mn^{2+}), chloride (Cl^{-}), sulfate (SO_4^{2-}), and hydrogen carbonate (HCO_3^{-}).
- Heavy metals: cadmium (Cd^{2+}), chromium (Cr^{3+}), copper (Cu^{2+}), lead (Pb^{2+}), nickel (Ni^{2+}), and zinc (Zn^{2+}).
- Xenobiotic organic compounds (XOCs) originating from household or industrial chemicals and present in relatively low concentrations (usually less than 1 mg/l of individual compounds). These compounds include among others a variety of aromatic hydrocarbons, phenols, chlorinated aliphatics, pesticides, and plasticizers.

The inorganic macrocomponents can be complemented considering other nitrogen forms derived from the oxidation of ammonium that are easily leachate as nitrate (NO_3^{-}) and nitrite (NO_2^{-}) due to the composition of MSW (organic matter is the major fraction) and its biodegradation. The overuse of nitrogen fertilizer can cause the leaching of NO_3^{-} to the surrounding water source and the emissions of N_2O and NO to the atmosphere [61].

The use of MSW as soil amendment, after a good composting process, can produce several environmental risks, which can be summarized as:

- The excess of nutrients/pollutants/organic-soluble compounds that can affect waters and plants
- The persistence of undesirable objects and fragments of objects, plastics, glass, and other materials that are difficult to biodegrade in the soil

Moreover, the presence of fragments and objects in MSW is a major concern related to the use of MSW as soil amendment because of the addition to the topsoil of undesirable objects. Farmers and other potential users (i.e., gardeners) do not want to use amendments and fertilizers that look unpleasant and contain materials that cannot be easily integrated into the soil.

Most of these problems (presence of solid fragments of major size, XOCs, etc.) can be solved in the treatments previously carried out on urban waste treatment plants, including sieving processes before and after composting. The problem of MSW is more serious in developing countries [62] without the application of an adequate treatment to the municipal wastes before applying them to soils.

The excess of nutrients and other elements like trace pollutants is a more difficult problem to solve in the treatments carried out in the municipal waste plants before the application of MSW. The urban waste is usually composted before soil addition facilitating the stabilization of the organic compounds although its application has environmental risks due to soluble organic carbon forms [63], nutrients, and the increment of pollutants, especially by leaching them to waters. Yusof et al. [63] found direct influences of leachate from MSW in the form of inorganic nitrogen and heavy metals in waters.

In general, after an adequate treatment of MSW, we pay our attention in the pollution of the soil–plant system and water, due to the excess of micronutrient or pollutants available from this waste.

The heavy metal pollution of surface soil horizons is characteristic for the sites of solid waste storage and their impact zones irrespectively of climatic conditions, ways of waste management, and stages of the life cycle [45]. At the same time, heavy metals accumulate in ruderal herbaceous plants [45]. However, soil moisture, irrigation, and climate conditions (rain) can affect the mobility and displacement of pollutants to surface water and groundwater and favor their presence in the root environment. In this case, it is possible to incorporate the pollutants into the food chain by plant uptake.

So, there would be a serious risk associated with the availability and mobility of trace elements, including the excess of micronutrients. In general, the addition of MSW increases the presence of trace elements in the soil [62]. Long-term application of municipal solid waste compost may result in accumulation of toxic metals in amended soil, as it has been demonstrated [64].

In general, an increment in leaching and changes in plant composition have been observed and can lead to environmental problems related to water contamination and the accumulation in the food chain of trace elements. Rezapour et al. [62] observed that soils were significantly enriched by the available and total fractions of the metals in the sequences of Zn > Pb > Ni > Cd > Cu and Cd > Zn > Ni > Pb > Cu, respectively. Nevertheless, only the Cd content exceeded the standard levels. However, many works found Cd-soluble concentrations in leachate below the detectable rates and an increment of the soluble fractions of Zn and Ni [65]. Cu and Zn availability is increased with MSW [66], as well as it has been reported for landfill sites [67].

Trace elements are accumulated in different parts of the plants. For instance, Cd, Cr, and Pb were accumulated in roots and stems in mulberry trees [64] and the Cu and Zn concentration in grains of wheat [68]. Adamcová et al. [69] found the highest degree of accumulation for Cd under the use of MSW. Cd, as well as Cr, Ni and Zn are accumulated mostly in the leaves, whereas Co, Cu, Fe, Hg, Mn, and Pb are accumulated mostly in the roots in the case of tansy (*Tanacetum vulgare* L.).

The application of MSW and derived materials from them, as the compost-like output (CLO) is most of the times used based on the nitrogen content as it is an important parameter for soil fertilization. However, metal pollution should be considered as heavy metal concentrations could exceed water quality limits at the higher application rates. This was found when applying amounts over 3000 kg N/ha [70]. However, the type of soil and the irrigation are important factors that can control the pollution to waters.

Another negatives effects were described. Leachates also pose pressures on biochemical and chemical oxygen demand (BOD and COD), TOC, ammonium and sulfur compositions, and heavy metals in soil and groundwater [71].

Salinity of soils and water can be increased by using MSW and biosolids [44, 69]. Hamidpour et al. [68] detected after a 3-year experiment the increment of soil salinity due to the use of MSW. This means that soluble salts (inorganic ions) are presented in the soil solution derived from MSW. However, in saline soils, MSW compost, with high organic matter content and low concentrations of inorganic and organic pollutants, allows an improvement of physical, chemical, and biochemical characteristics and constitutes low-cost soil recovery [72].

Biological activity of soils can be affected by the addition of MSW, both in positive and negative ways. Farrell et al. [73] showed the increment of microbial activity in contaminated soils with Cu, Pb, and Zn. Composts can successfully immobilize heavy metals and promote ecosystem diversity/function; surface incorporation had little remedial effect below the surface layer over the course of our short-term trial. On the other hand, the presence of XOCs can alter the soil biota.

It is obvious that there are environmental risks associated to the use of MSW due to the possible pollution of water, the plant uptake of pollutants with an impact in the food chain, and the presence of undesirable fragments. Nevertheless, the use of MSW compost, considering these risks and the type of soil where it is applied, can be controlled or minimized the risks.

4. Conclusions

MSW is a worldwide problem, even if we are able to reduce the amount produced every year. However, developing countries are increasing the MSW production parallel to the effort of developed countries to reduce their production. In the EU countries, there is no harmonization of the treatments applied in each country, but all of them are promoting the reuse based on the circular economy. In the case of MSW, the composting process of the important organic fraction is one of the best strategies to improve soil properties, reduce the landfill disposal of this waste, and recycle the nutrients. However, two important environmental risks should be considered even if MSW is well pretreated and composted. The excess of nutrients can contaminate waters and the presence of trace elements can has a negative effect on the food chain.

The risks can be minimized if pre- and posttreatments on MSW are applied and if the composted matter is added in a soil under adequate environmental conditions. This is a key factor to improve circular economy and ensure the use of these wastes. Nitrogen and other nutrients, especially micronutrients, are presented in MSW and can be bioavailable for plants. Nevertheless, in the same way, pollutants with emphasis in trace elements increase their availability.

The criteria for the recycling of MSW and compost-like output (CLO) derived as amendment should consider the end use but the previous treatments of MSW and have to look for a balance between the input of nutrients and the environmental risks associated with the soil conditions.

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