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Environmental Forensic

THE ROLE OF THE PRECAUTIONARY PRINCIPLE IN THE AGRICULTURAL REUSE OF SEWAGE SLUDGE FROM URBAN WASTEWATER TREATMENT PLANTS

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The precautionary principle

Society is constantly striving to achieve a high enough level of protection for human health and the environment, including animal and plant health (COM, 2000). In most cases, policies making it possible to achieve this high level of protection can be determined on a satisfactory and acceptable scientific and technical basis. However, when there are reasonable causes for concern that potential hazards may directly or indirectly affect ecosystems and, at the same time, the scientific information is insufficient, inconclusive, or uncertain, the precautionary principle has been politically accepted as a risk management strategy in the EU and USA (Silva and Jenkins-Smith, 2007).

The precautionary principle is now manifesting as the founding rule of the "law of uncertain science" (Rosario, 2020): uncertainty, relativization and the intrinsic nature of scientific acquisitions, combined with the incessant (and even sometimes "out of control") evolution of technologies, has led to an increase in the instances in which the application of the precautionary principle is seen as the only solution to analyze the problem.

At the international level, the precautionary principle is recognized and enshrined in a number of legal acts, including the Rio Declaration, the Convention of Biological Diversity (CBD), and the Climate Convention (UNFCCC) (Lavrik, 2022). At the EU level, the importance of applying the precautionary principle is also emphasized to uphold a high level of environmental protection (Art. 191 of Treaty on the Functioning of the European Union, TFEU), and the principle is explicitly expressed in most of the environmental Directives. Guidance as to when, i.e., in what situations, the precautionary principle is applicable is provided by the European Commission: "Recourse to the precautionary principle presupposes that potentially dangerous effects deriving from a phenomenon, product or process have been identified, and that scientific evaluation does not allow the risk to be determined with scientific certainty" (COM, 2000).

In the current column, the precautionary principle is analyzed in relation to the very "hot topic" of the management of sewage sludge.

The precautionary principle and the environmental forensic

There is a strict connection between the precautionary principle and the environmental forensic approach. This is particularly evident for the 'Shifting the burden of proof' concept, a central component of the precautionary principle that is perhaps the most important in regard to legal redress of environmental issues and consequently for environmental forensics (Kriebel et al., 2001). Following the European Commission document, the precautionary approach put up to the producer or user "to demonstrate the nature of a danger and the level of risk of a product or process" (COM (2000) 1 final).

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Consider the case of sludge use in agriculture. The decision of an environmental agency to use sewage sludge for agricultural activities may invite objections from the neighborhood that may eventually lead to parties approaching courts for redress. Where sewage application on agricultural fields is practiced, residents in the vicinity may raise complaints of health issues that they attribute to sewage spreading. During the legal procedure, the burden of proof, which otherwise would have been with the person(s) filing the complaint, shifts to the agency that changed the status quo if the precautionary principle is applied. In other words, the legal stand of "innocent until proven guilty" changes to "guilty until proven innocent" (Van den Belt and Gremmen, 2002). This shift in the burden of proof is important for the forensic investigation carried out for the case in many respects. Apart from establishing if legal limits of pollutants are exceeded, it may also become necessary to identify and establish the uncertainties associated with facts in question for the application of the precautionary principle. Application of the principle may also imply a shift in the responsibility of investigation.

Basic principles of sewage sludge management in the EU

Sewage sludge consists of residues collected at different stages of the wastewater treatment process. It is a kind of "biological-organic cocktail" containing large amounts of organic material and nutrients, such as phosphorus and nitrogen, as well as possible residual concentrations of pollutants, including heavy metals (HMs), organic pollutants and pathogens (Fijalkowski et al., 2017).

In particular, the focus of the current column is on sewage sludge originating from the treatment of domestic or urban wastewater treatment plants (WWTPs) and from the treatment of other wastewater with a similar composition. Industrial sludge is not considered here. However, it should be noted that the WWTPs in some countries also allow the entry of a considerable proportion of industrial wastewater, which may lead to sewage sludge contaminated by high concentrations of pollutants (Collivignarelli et al., 2019b; Feng et al., 2015).

The legal nature of sewage sludge is ambiguously used in the scientific community because both the terms "byproduct" and "waste" are used. However, following Directive 2008/98/EC (WFD 2008), these are two distinct concepts: a "waste" is any substance or object, which the holder discards or intends or is required to discard (Article 3(1)); and a "byproduct" is a production residue that fulfils the specific conditions (Article 5(1)) and can be commercialized.

According to the European Waste Catalog (EWC) (CEC, 2001), sludge from urban WWTPs is identified by the code 190805 "Sludge from treatment of urban wastewater" under the subchapter 19 08 "wastes from wastewaters treatment plants not otherwise specified".

In the EU, the use of sewage sludge as a fertilizer is separately regulated by the Sludge Directive (86/278/EEC). The Directive sets rules for the use of sewage sludge as fertilizer to prevent harm to human and environmental health by "ensuring that the nutrient needs of the plants are considered and that the quality of the soil and of the surface and ground water is not impaired." However, the Sludge Directive is now over 30 years old and has only been updated a few times since its adoption (last, by Regulation (EU) 2019/1010).

In summary, EU regulation indicates the following principles regarding the use of sewage sludge in agriculture (see also Figure 1):

1. Compliance with quality limit values for sewage sludge. The Sludge Directive only sets limits for some HMs (Cd, Cu, Hg, Ni, Pb and Zn). Several European countries have adopted more stringent requirements and limit values for concentrations of other heavy metals (Cr, As), synthetic organic compounds (PCB, AOX, LAS, DEHP, NP/NPEPAH, PCDD/F) and microbial contaminants (pathogens such as Clostridium perfringens, Enterobacteria, Enterococci, Enterovirus, Escherichia coli, Fecal streptococci, Helminths eggs, Salmonella, Thermotolerant coliforms).
2. Compliance with quality limit values for soil where biosolids are used. In addition to restrictions regarding chemicals in biosolids, EU law sets limit values for HMs in soil to avoid long-term accumulation. In most Member States, these limit values are set lower than those required by the Sludge Directive.
3. Compliance with the maximum amount of biosolids that can be spread on land per year and per unit of surface. This quantity is not directly prescribed in the Sludge Directive, but it states that it is necessary to limit the amount of HMs added to cultivated soil; therefore, many countries have adopted specific rules for this point.
4. Compliance with specific conditions for the agricultural land in which the sludge is used. The Sludge Directive (article 7) provides restrictions regarding the spreading of biosolids on grazing and pastureland and on land on which vegetables and fruits are grown. These provisions have been transposed by Member States, which often have introduced additional requirements for land spreading (for example, restrictions in the cases of sloping land, wet land, or after heavy rain).
5. A ban on using untreated sludge. According to the Sludge Directive, sewage sludge must, as a main rule, be treated before its use in agriculture. The use of untreated sludge can, however, be allowed in the case of injection or if the sludge is worked into the soil. While most Member States have prohibited all use of untreated sludge, France, Ireland, and the UK are exceptions (Collivignarelli et al., 2019). It is also important to note that the Sludge Directive does not specify what treatment technology has to be used.

There are relevant studies that compare and analyze how different EU countries have regulated the use of biosolids on agricultural land (Collivignarelli et al., 2019a; Hudcová, et al., 2019; Mininni et al., 2015; Kelessidis and Stasinakis, 2012).

In some countries, such as Ireland, the United Kingdom and Spain, a large proportion of sewage sludge is used in

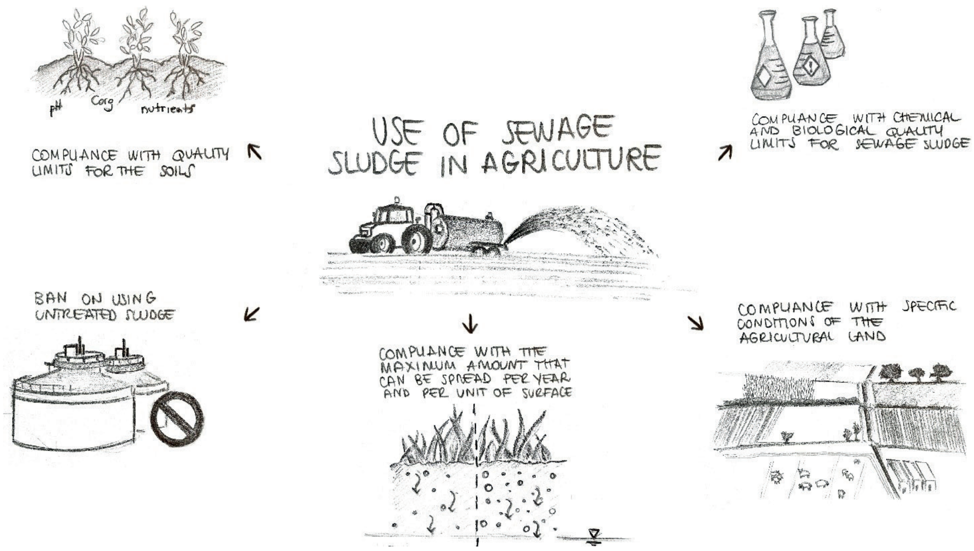

FIGURE 1: Conditions for the use of sewage sludge in agriculture.

agriculture (> 70%), while in others, such as Italy and France, it ranges between 20 and 40%, and still others, such as Germany, where less than 20% of the sludge is used in agriculture (Eurostat, 2022). Finally, there are countries (e.g., Switzerland and, more recently, the US state of Maine) in which the use of sludge in agriculture is completely banned (Collivignarelli et al., 2018; Guardian, 2022).

Although in general soil needs exogenous organic matter to maintain its functionality (and Mediterranean one need more addition of organic matter than those of central and northern Europe), it is reasonable to assume that different physical and chemical characteristics of the soil, i.e., pH, organic matter content, texture, redox potential, etc., can contribute to determining different environmental risks.

The term "biosolid" means sewage sludge that is treated for reducing human and environmental pollution risks and producing more stabilized residues. In fact, biological sewage sludge from WWTPs is usually a liquid or semi-solid liquid that typically contains 3% solids (97% liquids), whereas biosolids are typically 15-90% solids. The characteristics of biosolids vary depending on their origin and the treatment process (Collivignarelli et al., 2019b).

A wide range of sludge treatment technologies is used in the EU Member States (MS), defining its further "indirect" or "direct" agricultural use. The most common stabilization method intended for the "indirect" use of sewage sludge in agriculture is anaerobic and aerobic digestion, pursuing the recovery operation R3 "Recycling/reclamation of organic substances which are not used as solvents (including composting and other biological transformation processes)" (WFD, 2008). Sewage sludge is commonly biologically treated with other biowastes, and additional requirements may be set, including the maximum amount of sewage sludge in the cocomposting feedstock.

Methods such as mechanical sludge dewatering, drying beds, and thermal drying are widely implemented in many countries and can be considered "light" technologies to treat sewage sludge before its "direct" use in agriculture, in compliance with "R10 Land treatment resulting in benefit to agriculture or ecological improvement" (WFD, 2008).

Further treatment methods, such as lime stabilization, chemical treatment, and chemical disinfection processes (i.e., ozonation and Fenton oxidation), thermal treatment and innovative treatments are outside of the scope of this column.

Strategies for the reuse of sewage sludge in agriculture

There is a strong heterogeneity in the application of the abovementioned rules regarding sewage sludge use in EU Member States, which indicates a difference in the interpretation of the precautionary principle. It is important to note that different interpretations of this principle do not necessarily imply a lesser or greater risk for the environment. For example, with neutral-basic and/or calcareous soils, more "permissive" concentrations of some metals can be adopted when compared with acid soils without increasing the risk. Increasing or more in-depth knowledge of the specific problem thus calls for different applications of the precautionary principle.

In regard to the use of sewage sludge on agricultural land, two rather extreme alternatives concerning the role of the precautionary principle can be discerned:

a) A complete ban of all spreading of sludge in agriculture, combined with a demand for recycling in the form of material recycling where the phosphorus is extracted from the sludge. Very small facilities or sludge with low phosphorous content may be exempted from the recycling requirement. Therefore, under this alternative, the possibility of recovering sewage sludge after cocomposting and/or codigestion with biowaste (biological treatments) is banned.
b) The possibility of spreading or/and injecting sewage sludge, which meets the previously mentioned legal requirements, on agricultural land.

Both these alternatives are founded on the precautionary principle but in different ways. With regard to alternative (a), the risk of serious health and environmental consequences as a result of the spread and/or injection of sludge is not considered controllable by limit values or quality demands, and the ban is based on an real proven risk. Under alternative (b), the role of the precautionary principle is instead to direct decisions or exceptions based on quality demands.

It is important that the scientific and technical community improve the knowledge on this topic without being a sort of "supporter of a soccer team" for one or another strategy.

Following the European Commission Guidelines, the precautionary principle measures should be proportional to the desired level of protection; nondiscriminatory and consistent with similar measures taken in similar situations; based on an examination of the potential benefits and costs of action or lack of action (including where appropriate and feasible, an economic cost/benefit analysis); subject to review, in light of new scientific data; capable of assigning responsibility for producing the scientific evidence necessary for a more comprehensive risk assessment (COM, 2000). Risk can rarely be reduced to zero, but incomplete risk assessments may greatly reduce the range of options available to risk managers (COM, 2000). With this in mind, the proportionality test is highly relevant. All European Constitutional Courts have developed expertise in such a test (Butti 2007; Lang 2020; Butti and Toniolo 2018).

Any evaluation should start with as complete as possible scientific analysis of the evidence and, where possible, with a comparison of the different points of view. In Table 1, technical and scientific evidence supporting options "a" and "b" are listed.

TABLE 1: Technical and scientific evidences supporting options "a" (a complete ban of all sewage sludge in agriculture) and "b" (the possibility of spreading or/and injecting of sewage sludge).

Technical and scientific evidences supporting option "a"	Technical and scientific evidences supporting option "b"
Legal aspects	
The requirements and limits established in the Sewage Sludge Directive (86/278/EEC) are based on an old toxicological body of knowledge, i.e., not updated to the most recent research outcomes, with particular reference to the so-called Emerging Contaminants (e.g., perfluorinated compounds, polycyclic aromatic hydrocarbons -PAHs-, personal care products, pharmaceuticals, antibiotic resistance genes, microplastics, pathogens, etc.). In fact conventional WWTPs are not designed to remove these emerging contaminants that can be present in wastewater effluents (for example the antibiotics range from ng/L to µg/L) and accumulate in sewage sludge and biosolids (Silva et al., 2021; Grenni, 2022).	The main aim of the Sludge Directive (86/278/EEC) is to regulate the use of sewage sludge in agriculture preventing harmful effects while encouraging its correct use (Art. 1). Therefore, a complete ban of the use of sewage sludge would not meet the aims of the EU law framework, at least as formulated in the Sewage Sludge Directive. The current challenge should be the improvement of the overall quality of sewage sludge by means of several measures: improving the quality of wastewater optimizing the dedicated infrastructures (i.e., differentiated sewage systems), improving the efficiency of treatment systems of sewage sludge; promoting environmental education among the population to minimize the release of specific substances to the sewage system (e.g., pharmaceuticals, etc.)
Sewage sludges could contain a "cocktail" of many regulated and still not regulated substances. In this context, operators shall be aware of possible environmental crimes related with their agricultural reuse. This can be exacerbated by the continuous technological development of analytical tools capable of monitoring an increasing number of substances, also at very low concentrations.	
The general compliance with concentration limits is based on a limited set of parameters (i.e., HMs). However, the portion of sludges suitable to agricultural reuse decreases when more restrictive limits are imposed or new substances are included in the checklist for land spreading (e.g., by national or regional regulations).	Chemical characterization of sewage sludge is generally compliant with legal limit values established for the agricultural reuse.
Circularity	
For a better inclusion into the most updated regulation framework of circular economy, the implementation of the end-of-waste procedure for sewage sludge should be assured, including criteria derived from the expertise of the agronomic sector. However, the discussion by the European Joint Research Center (JRC) in Seville regarding the application of end-of-waste criteria for human organic residues (compost, digestate, biosolids) has produced a final document (IPTS 2014) where sludge was excluded from the organic wastes admitted for producing an end-of-waste.	The banned use of sewage sludge is not in agreement of the so-called "circular economy" action plan. Because the Circular Economy Action Plan (2020) requires the commission to consider revising the Sewage Sludge Directive, EU lunched in 2021 a public consultation on Sewage sludge use in farming (European Commission, 2021.).
The current prescriptions established for agricultural reuse does not just requires compliance control of the treated substrates. The current regulation includes further requirements expressed in terms of maximum amount of sludge applied and specific conditions for lands. This regulatory framework could hinder the large-scale agricultural use of sewage sludge.	
Supply of organic matter	
Soil improvers derived from biowaste and agricultural residues (i.e., compost and digestates without addition of sewage sludge) should be preferred to sewage sludge in terms of meeting the demand of organic matter to agricultural soils. Moreover, biochars from thermal treatment can be considered as candidate for this purpose; however, further research shall be performed to avoid the occurrence of contaminants such asPAH. Regarding HMs, quite strong evidence support biochar as a mean of HMs immobilisation in contaminated soils (Arabi et al., 2021), reducing HMs plant-uptake and related risks (El Naggar et al., 2021, 2022).	Direct or indirect agricultural use of sewage sludge represents a very convenient and sustainable solution to fulfil the supply of organic matter required by agricultural soil. The application of biosolids has been identified as a promising strategy to increase C sequestration in soils, directly by increasing Soil Organic Carbon (SOC) from their residual C, and indirectly by improving soil health and thereby increasing biomass production (Wijesekara et al., 2021).

Technical and scientific evidences supporting option "a"	Technical and scientific evidences supporting option "b"
Supply of nutrients	
Recovery of nutrients from sewage sludge can be achieved without their direct or indirect land reuse. Several conventional and innovative technologies of nutrients recovery from sewage sludge are available in the market or under development (e.g., Struvite crystallization technologies, P-recovery technologies from the ashes and thermal oxidation materials) (Gianico et al., 2021; Kirchmann et al., 2017)	Direct or indirect agricultural use of sewage sludge is the primary solution to fulfil the supply of nutrients required by agricultural soil, especially nitrogen and phosphorus.
Potential accumulation of pollutant in the soil	
In addition to general compliance with regulation limits, the agricultural application of sewage sludge could lead to a potential long-term accumulation of toxic elements in the soil ecosystem. In particular, occurred accumulation of HMs in sewage sludge amended soil has already been thoroughly reported by scientific literature (Charlton A., et al., 2016a, 2016b, Black A., et al., 2011). Further evidence was recently discussed about the accumulation of emerging contaminants, mainly related with pharmaceutical active products, such as antibiotics and nonsteroidal anti-inflammatory drugs, nanomaterials and microplastics (Grenni et al., 2022; Buta et al., 2021; Collivignarelli et al., 2021; Sorinolu et al., 2021; Fu et al., 2016; Kim et al., 2017; Wang et al., 2018. Yaseen et al., 2022). Residual concentrations of antibiotics in soils receiving biosolids may contribute to the antibiotic resistant pathogen abundance (Zhang et al., 2022; Kaviani Rad et al., 2022). In fact, the residual antibiotic concentrations in soil receiving biosolids can exceed the ecotoxicity effect trigger value (100 μg/kg; Yang et al., 2018).	Regarding the problem of potential accumulation of pollutants in the soil, compliance to regulation limits guarantees a fair level of safety. Lowering the current limits or broadening the list of regulated compounds could determine unsustainable characterization and managements costs.
Potential transfer of pollutants from soil to plants	
Land application of sewage sludge could lead to contaminants uptake by crop plants cultivated on amended soils. Thus far, experimental evidence of occurred transfer to plants from sludge amended soils are already available in the scientific literature, regarding both regulated (as HMs) and nonregulated substances (Buta et al., 2021, Sorinolu et al., 2021). In particular, antibiotics and their related resistance genes may enter the human food chain through the consumption of harvested vegetables (Sorinolu et al., 2021). Whether the absorbed quantities could determine a risk for human health (e.g., through the "contamination" of the food chain), it should still be further investigated (Madikizela et al., 2022; Wang et al., 2022).	Regarding the problem of the potential transfer of pollutants from soil to plants, compliance with regulation limits guarantees a fair level of safety. Lowering the current limits or broadening the list of regulated compounds could determine unsustainable characterization and managements costs.
Time quality trend of sewage sludge	
Some exceptions to the general reduction over time of the quality of produced sewage sludge can be found for specific pollutants: • In the study of Liu et al. (2021), the mean Cu concentration has remained relatively static and contemporary concentrations are similar to those observed in the early 1990s. • In the study of Olofsson et al. (2012) some emerging contaminants in sewage sludge such as alternative flame retardants showed an increasing trend; this could be due to nonefficient environmental policies to reduce the emission of these compound in the environment.	The quality of produced sewage sludge has generally improved over time (Kirchmann et al., 2017). • Liu et al. (2021) reported data from 75 wastewater treatment plants (WWTPs) in the United Kingdom, for the period 1989–2017. Only inorganic compounds (heavy metals mostly) were statically analysed: Zn, Cu, Ni, Pb, Cd, Hg, Cr, Mo, As, Se and F. The study showed that trace element concentrations decreased significantly in response to declining pollutant emissions, demonstrating the environmental benefits of effective source control and cleaner technologies. • Olofsson et al. (2012) reported data for the period 2004-2010 in Sweden. Metals, POPs, pharmaceuticals and personal care products (PPCPs), and other organic compounds in sludge were analysed. The study indicated that many of the sludge contaminants (75% of the contaminants for which statistically significant trends were found) followed a decreasing trend due to regulatory actions. • Kirchmann et al. (2017) reported data for the period 1970-2010 in Sweden. Only metals were analysed: Ag, Cd, Hg,Pb, Cu, Zn. The study showed that the quality of sewage in terms of heavy metal content has greatly improved over the past 20 years.
Land application techniques	
The current regulatory framework does not provide sufficient requirements for the modality of land application (spreading, spraying, injection, incorporation, etc.)	Relevant negative impacts (odors, ammonia emission, etc.) due to unsuitable spreading techniques (ex. splash-plate spreading) can be easily minimized by available agronomic best practices (i.e., soil injection).
The role of thermal treatments and landfills	
The management of sewage sludge should not be achieved through agricultural reuse. To do so, the capacity of the thermal treatment sector shall be increased exploiting both conventional and innovative processes. In any case, landfill disposal shall be guaranteed for residual sludges that cannot be treated alternatively.	Considering the ongoing minimization of landfill disposal (established by regulations) and the current under capacity of the thermal treatment sector, agricultural reuse is fundamental to achieve the efficient management of sewage sludge.
Competitive treated organic residues (compost, digestate, biosolids, etc.)	
Composting plants can provide a more rigorous quality control of input feedstocks than what can be achieved by a wastewater treatment plant. Moreover, the law framework related to compost production and use is more up-to-date and generally stricter (e.g., in terms of lower concentration limits of contaminants).	In the past years, composts from biowaste and agricultural residues were deemed by the agricultural sector as not suitable or convenient soil improvers. Conversely, composts are currently considered as safe, sustainable and high-quality amendments for agricultural use.

Technical and scientific evidences supporting option “a”	Technical and scientific evidences supporting option “b”
Currently, the quantitative value expressing the real amount of organic carbon needed by agricultural soil is generally not addressed by waste management plans. This information is very important to support decisions on the agriculture reuse of different treated organic residues (compost, digestate, biosolids, etc.).	The amount of produced digestates and composts is not enough to cover the soil requirements for organic carbon in most of the area.
The “zero risk” concept	
The search for a high level of health and safety and environmental and consumer protection belongs in the framework of the single market, which is a cornerstone of the Community.	Zero risk for the agricultural reuse of human organic residues (compost, digestate, biosolids) in reality cannot be achievable even if the residues are treated. Moreover, the reuse with zero risk is unfeasible with sustainable costs.
LCA studies	
Several authors used the LCA methodology (and its limits) to show that it is preferable to avoid use of sewage sludge in agriculture (Harder et al., 2016; ten Hoeve, 2018; Siegert et al., 2020; Teodosiu et al., 2016; Heimersson et al., 2016; Avadi, 2020). The main raisons to support this point-of-view are related to potential effects of the nutrients (nitrogen and phosphorous compounds) on environmental categories (as climate change, abiotic resources depletion and freshwater eutrophication), pollutants responsible for toxicity impacts (such as heavy metals), and the damage associated with specific pharmaceuticals (as hormones and anticancer drugs). Other motivations to support this perspective are the uncertainty of environmental effects related to long-term damages in ecosystem, the behavior of metabolites in sewage treatment plants, and the inability of LCA models to quantify the adverse effects of pathogens on human health.	Several LCA studies reported better environmental impacts for the agriculture use of treated sewage sludge respect chemical fertilizers (Herrera et al., 2022; Di Maria et al., 2016; Chiew et al., 2015; Tidåker et al., 2006; Suh and Rousseaux, 2002; Hareder et al., 2017; Hospido et al., 2005; Brockmann et al., 2018; Muñoz et al., 2017; Chiu et al., 2016). From these studies the combination of anaerobic digestion and agricultural land application appears the most environmentally convenient option thanks to less emissions and less consumption of energy, by avoided mineral fertilizers. Environmental criticalities related to heavy metals released seem to be negligible contribute to the impacts on human toxicity and ecotoxicity. Better wastewater management strategies can be developed combining different treatment methods. Any new risks associated with chemicals in wastewater can be minimized by improving the quality of the data with which LCA studies are performed.
Monitoring the use of sewage sludge	
A sustainable and reliable planning requires, as fundamental input data, the true amount of sewage sludge used in agriculture. However, at the moment in EU there are not harmonized criteria to evaluate this information. The EU database (Eurostat, 2022) shows a high level of missing information on this topic. Moreover, the accurate amount of sewage sludges biological treated (composting, anaerobic digestion) in agriculture is difficult to quantify because: the declaration of the type of soil improvement is not mandatory; the majority of farmers do not like to report the real application amount of sewage sludge even though they are qualified.	

Conclusions

The issue of the role of the precautionary principle in the management of sewage sludge in the European Union is giving rise to much debate, and the arguments put forward are often contradictory. In addition, the process in which the precautionary principle is applied is characterized by a need to balance the social and economic impacts of bans or restrictions, with the necessity of reducing the risk of adverse effects on the environment, including human, animal and plant health.

Based on the premise of the precautionary principle - to guide decisions in case of uncertainty - some points can be highlighted. One is the need for knowledge. With more knowledge, uncertainty decreases, and thus the need to apply the precautionary principle; in such cases, it may be sufficient to prescribe suitable precautionary measures that reduce the negative effects of the activity. More knowledge may, however, not always be achievable; a certain degree of uncertainty is likely to prevail even for less complex issues than the effects of the use of sewage sludge in agriculture. If that is the case, a recourse to the precautionary principle is an appropriate way to assess whether the individual activity, in that context, entails risks that it should not be permitted.

However, more information as a (partial) answer to the question of what role the precautionary principle should play also points to the need to both acquire and disseminate this important knowledge. This in turn requires not only research and resources but also dialog, both between different scientific areas and between science and practice.

The scientific community has yet to reach a shared position on this topic, and in the current column, two extreme alternatives have been discussed. No joint message can therefore be conveyed to authorities, farmers, or the public regarding the risks of using sewage sludge as fertilizer.

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