Organic waste as a source of nutrients in agriculture - the potential of sewage sludge, animal manure and digestate

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Modern agriculture faces the challenge of sustainable management of natural resources, especially in the context of organic waste management and soil fertilisation. In the context of the growing challenges associated with the need to implement the principles of the circular economy (CE) (COM no. 98, 2020), increasing attention is being paid to the possibilities of using organic waste as alternative sources of fertiliser components. Particularly promising sources of waste containing a significant amount of these components are sewage sludge, slurry and digestate. Their use can contribute to reducing the use of mineral fertilisers, closing the nutrient cycle, and reducing the negative impact on the environment. Still, appropriate processing methods and quality control are required (Smol, 2021). This paper presents an overview of these waste groups in terms of their component content, including nutrients and contaminants, affecting their possible use as alternative fertilisers, i.e. from waste materials. Furthermore, legal acts concerning the use of these waste groups in the fertiliser sector were analysed and the increasing role of performing environmental, economic and social assessments of waste products and waste management technologies in agricultural sector was emphasised.

sewage sludge | animal manure | digestate

Figure 1. Potential sources of alternative fertilisers analysed in paper

Sewage sludge generated in municipal wastewater treatment processes is characterised by a high content of nutrients such as nitrogen (N), phosphorus (P) and potassium (K), but its use may be limited by the presence of heavy metals and potentially hazardous organic substances. To increase the safety of their use, treatment processes such as chemical, biological or thermal stabilisation are necessary, which minimise the risk of soil and groundwater contamination (Chojnacka et al., 2020). Animal manure, which is a waste product of animal origin, is a valuable source of nutrients and organic matter, contributing to the improvement of soil properties. The high N content makes it an effective fertiliser, but its application requires appropriate management to avoid nutrient losses. A key aspect is to adapt the doses and methods of application to soil conditions and legal regulations limiting the eutrophication of surface waters (Ociepa et al., 2007). Digestate is a by-product of anaerobic fermentation in biogas plants, distinguished by a high content of easily assimilable minerals and a lower level of harmful substances compared to raw sewage sludge or unprocessed slurry. Its use as an organic fertiliser can contribute to closing the nutrient cycle in agriculture and reducing the demand for mineral fertilisers. However, its physicochemical composition cannot be treated as constant, because it depends on the type of biomass processed, which requires individual analysis before use in crops (Smol and Szołdrowska, 2021).

Table 1. Chemical composition of the analysed waste streams (mg/kg)

Parameters	Sewage sludge	Animal manure	Digestate from municipal waste biogas plant
N^+	277	20 900	12 501.2
P^+	356	21 400	14.3
K^+	25	18 700	-
Mg^+	79	4 600	3.91
Ca^+	540	23 800	2.21
Mn^+	197	314	2.21
Fe^+	540	1 405	3.91
Cu^+	438	411	0.96
Zn^+	1 607	419	0.63
Cd	23	-	0
Cr	1 592	-	0.24
Hg	2	-	-
Pb	312	-	0.03
Ni	960	-	0.27

Reference	(Tabatabai and Frankenberger, 1979)	(Gondek and Filipek-Mazur, 2006)	(Urbanowska and Kotas, 2019)

To fully assess the impact of the use of sewage sludge, liquid manure and digestate on the environment and society, it is necessary to conduct comprehensive ecological and social assessments. One of the key tools for this analysis is the life cycle assessment (LCA) method, which allows for the identification of potential benefits and risks resulting from the use of these wastes in agriculture. LCA analysis allows for the determination of the balance of greenhouse gas emissions, impacts on soil quality and potential risks related to the mobility of heavy metals. Life cycle cost assessment (LCCA), on the other hand, is a systematic assessment that takes into account all costs associated with a specific asset, project or process from beginning to end. In addition, social aspects, such as social acceptance of the use of wastes in agriculture, can have a significant impact on the implementation of these solutions on a larger scale. They can be evaluated with the use of social LCA (S-LCA). The integration of environmental, economic and social assessments is crucial for the effective management of organic wastes and their use in sustainable agriculture (Orner et al., 2022).

In the context of future directions of development and research on organic waste management, a holistic approach covering technological, environmental and social aspects is crucial. The implementation of new technologies for waste treatment and purification, including innovative methods for the stabilisation of sewage sludge and improvement of the quality of digestate, can significantly increase their safety and efficiency in agriculture. In addition, changing legal regulations and growing ecological awareness of society influence the development of strategies for managing these resources, which may contribute to their wider use (Smol and Szołdrowska, 2021). In the future, it will also be crucial to develop analytical tools that allow for a better assessment of the impact of these materials on the environment and the effectiveness of their use in agriculture, which can support decision-making by farmers.

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