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PERSPECTIVES ON THE USE OF SEWAGE SLUDGE IN SWEDEN - AN EMPIRICAL INVESTIGATION OF THE CONDITIONS FOR DEVELOPMENT AND IMPLEMENTATION OF DIFFERENT TECHNICAL SOLUTIONS

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Abstract
Land application of sewage sludge has long been subject to concern. Among the reasons for these concerns are for example the occurrence of odors and the risk of spreading heavy metals, pathogens, and nitrates, but also a negative perception regarding the use of sludge. In this paper, we focus on the part concerning perceptions of sludge use and investigate, through a series of interviews with key actors and stakeholders in the sewage sludge management chain, how technical advancements, and the regulatory frameworks for land use application of biosolids is perceived.

Introduction
Land application of sewage sludge has long been subject to concern, both by farmers and by the general public. Among the reasons for these concerns are for example the occurrence of odors and the risk of spreading heavy metals, pathogens, and nitrates, but also on how sewage sludge is perceived, as the perception of risk heavily impacts the acceptance for (potentially) health and environmentally hazardous activities (Krogmann et al. 2001; Whitehouse et al., Robinson et al., 2012).

There are several ways to dispose of sewage sludge; the main routes being incineration, landfilling, land-based applications, including structural soil improvement, soil buffer, and soil amendment. However, according to Lamastra et al. land use application of biosolids has the capacity to cover “the larger part of the nitrogen and phosphorus requirements for many crops” (Lamastra et al. 2018).

Empirical studies show that land use application or recycling of biosolids are generally not favored in the tradeoff between costs (risks) and benefits. On a more general level, Kirchherr et al. examine stakeholder perception on circular economy barriers using a stakeholder survey. Out of four main barriers (cultural, market, regulatory and technical) their research concludes that cultural aspects in the form of consumer behavior is the most mentioned detriment by the respondents and technical being the fewest. The survey provides a helicopter perspective throughout the EU and does not take differences such as between sectors, businesses, or countries (Kirchherr et al., 2018).

Previous studies on the perception on land applications of sewage sludge include empirical studies in a North American context, both in the form of interviews (Krogmann et al. 2001) and surveys (Whitehouse et al., 2018). These studies confirm that public perception is a major concern and stress the importance of obtaining public acceptance, for example by “bringing the public into the decision-making process” (Krogmann et al., 2001:123). More recent studies show that males are more likely to perceive sludge use as positive than females (Nicholas et al., 2022), and that in an Indian context, the concerns with using sewage sludge are focused on bad odour, and fear of infection (Singh et al., 2022).

Interview studies targeting sewage sludge use has also been conducted in Sweden. In 2018, Nedelciu et al. interviewed 23 actors with the purpose of assessing to what extent global supply of phosphorous will be sufficient for regional fertilizer consumption given population growth, aiming to provide national level policy recommendations that can contribute to the development of phosphorous in the wastewater recycling sector (Nedelciu et al. 2020). The study however only covered Stockholm (and Budapest). During 2021, Ekane et al. did 17 interviews in the southern parts of Sweden with the aim of understanding "the underlying mechanisms on how different stakeholders see and explain the productive use of sewage sludge and associated risks (actual and potential), and the role these play in influencing their choices or decisions regarding sewage sludge and the purpose for which it should be used." Ekane et al. conclude that land application of sewage sludge is "an important way of recirculating nutrients and organic matter to grow crops" (Ekane et al. 2021:6). However, the study also shows that the mere origin of sludge – i.e., not (just) its chemical characteristics – is marked by strong negative attitudes, including fear of contamination and feelings of disgust (ibid.).

The present study adds to this knowledge by targeting how perceptions on sewage sludge **impact the dissemination of technology and regulatory development**. Thus, despite the presence of both regulation and, in some cases, voluntary certification schemes for wastewater treatment aiming to reduce levels of, e.g., heavy metals, pathogens and drug residues in the "final product", the differences of opinion regarding how the sludge can and should be used are wide-ranging.[1]

Aim and methodologies

As the perception of risk derives from the values, beliefs, and experiences of the individual - which can also be shared by larger groups or communities - it is particularly important to investigate into these matters *empirically*. In this study, a number of interviews with key sludge actors – producers as well as users – have been carried out in Sweden during 2022 with **the overarching aim** of investigating how technical advancements and the regulatory frameworks for land use application of biosolids is perceived in Sweden.

The interviews were semi-structured, thus allowing for elaboration on the questions depending on the specific actor's role in the context. The overarching aim of the interview study was twofold:

a) To explore what drives the technological development of sewage sludge treatment and whether the actors perceive any barriers to the development and implementation of new sludge treatment technologies; and
b) To explore the adequacy of the legal framework; are the laws and regulations governing the use of sewage sludge clear and unambiguous, i.e., can they be applied or are there uncertainties about what is permitted/prohibited? Is the regulatory framework sufficiently complete or is there a lack of regulation around certain issues?

The legal analysis is based on studies of legal sources to present 'the legal situation' with respect to land use application of sewage sludge. For the analysis of how this use is perceived, we rely on both written materials and interviews with key actors.

To provide a necessary background to the interview responses, the paper begins with an introduction to the legal framework governing the use of sewage sludge on different levels. Thereafter, the methods for sewage sludge treatment used in Sweden today are described, followed by the results of the empirical investigation. The paper concludes with a discussion regarding potential technical as well as institutional barriers against the use of sewage sludge as a resource based on the results of the study.

The legal framework for land use application of sewage sludge

The legal starting point for the use of sewage sludge in agriculture is Council Directive 86/278/EEC

[1] The Swedish Nature Conservation Association for example opposes sludge use, pointing to the environmental toxins in the sludge, and holds that land use application of sewage sludge contradicts several of Sweden's environmental goals, for example "Good built environment", "A rich agricultural landscape" and "Toxic-free environment" (Swedish Nature Conservation Association: https://www.naturskyddsforeningen.se/artiklar/slam-fran-ditt-avlopp-blir-godsel-pa-akern/).

of 12 June 1986 on the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture. The Directive, which applies to all EU Member States, sets limit values regarding the content of the sludge, for example regarding heavy metals, and aims at encouraging appropriate use of sludge in agriculture while preventing harmful effects on soil, vegetation, animals, and humans. The Directive has been transposed into Swedish legislation, where the use of sludge is regulated by provisions, ordinances and prescriptions following the Environmental Code. This includes content limit values for metals, requirements for record keeping, spreading restrictions, maximum permitted supply of phosphorus, nitrogen, etc., spreading times, and requirements for permits for sewage plants. The best possible technology must be used, and the statutory obligations also include conserving raw materials and energy and ensuring the quality of the sludge; it must be possible to use the sludge without causing inconveniences to human health or the environment.

In addition to the formal institutional framework, i.e., the legislation, a special certification system, Revaq (Cert. SCPR 167), has been introduced in Sweden at the initiative of the industry organization Swedish Water. The purpose of Revaq is to reduce the flow of hazardous substances to treatment plants and to create a sustainable return of plant nutrients, as well as to manage risks in connection with this. Of approximately 1,300 treatment plants in Sweden, 43 were Revaq-certified at the end of 2020. The use of sewage sludge in Sweden is thus partly governed by EU law, partly by national legislation and partly by the requirements set for certification.

Wastewater and sewage sludge treatment in Sweden

According to Mininni et al., “many urban wastewater treatment plants in Europe are unable to produce sludge suitable for final outlets” as the facilities are aging and the infrastructure dated. The treatment units are developed and equipped in the 1980s, and thus insufficient in relation to new rules on landfilling or incineration disposal (Mininni et al., 2015:7361). In Sweden, several processes for treating sludge are utilized, for example dewatering, stabilization and disinfection, and thermal drying, the most common being anaerobic digestion (Bauer et al., 2020; Lu et al., 2012).

Results

The interviews show:

Regarding the legal framework, several respondents expressed that the legislation is outdated and constitutes a barrier to technological development, e.g., in that uncertainty regarding whether current requirements will be subject to legislative changes negatively affects the willingness to invest. Because the legislation does not set “enough” strict requirements, there is no incentive to invest in new (and better) technology. Regardless of this, the sludge is cleaner today than a decade ago, which indicates that some technological development is taking place despite the lack of policy instruments to this effect.

On the other hand, respondents also did not think that the legal framework was considered an obstacle to the current use of sewage sludge, even if there are certain interpretation problems regarding the use of digested and undigested sludge.

Some respondents indicated that the present legal framework (i.e., the requirements set by law) were not fully “utilized,” which implies that, under current legislation, there is scope for stricter requirements on resource recovery from the sludge.

All respondents also called for an update of the current legislation (on both EU and national level), and some believe that the government is waiting for an EU initiative.

The certification system is seen as positive - the cleaner the sludge can get, the better.

In general, it was also pointed out that the risks of using sludge outweigh the benefits – no one wants to be responsible for reports of harm relating to the use of sludge.

Discussion and conclusions

The general negative perception of use of sewage sludge for agricultural purposes has consequences for resource management and, by extension, the promotion of a circular material flows. In Sweden, the protracted debate concerning whether use of sewage sludge is at all

appropriate, and if so to what extent and in what context, has resulted in a less-than-optimal situation where e.g., all sludge-fertilized crops are sold for export, while, at the same time, there are no guarantees that imported foodstuffs are not sludge-fertilized. Despite relatively extensive scientific support that the use of quality-assured sewage sludge entails low risks for human health and the environment, the Swedish government as well as several referral bodies have insisted on the introduction of a general ban on the use of sludge in agriculture (e.g., SOU 2020:3).

Regarding sewage sludge as a phenomenon, the study confirms the perception of sludge as "charged with emotion", and that this affects the scope for using the sludge as a resource. One respondent expressed e.g., that "Sludge is not a bestseller - you won't win elections by addressing the sludge issue" as an explanation for why the legal framework has not been subject to any major amendments since 1994 (SNFS 1994:2).

The current (legal) situation in essence creates two separate sludge qualities, one that is Revaq-certified (thus, is required to be 'cleaner') and one that is not Revaq-certified (i.e., it potentially contains higher levels of pollutants). Since Revaq certification is voluntary, expensive, and time consuming, small WWTPs are typically not certifying their sludge.

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