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Achilles heel of environmental risk from recycling of sludge to soil as amendment: A summary in recent ten years (2007–2016)

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ABSTRACT

Recycling sludge as a soil amendment has both positive and negative effects because of its enrichment in both nutrients and contaminants. So far, the negative effect has to be extensively investigated that the severities of different types of contaminants also remain unclear. The environmental behavior and risk of organic contaminant and pharmaceuticals, heavy metal and salt as well as pathogenic microorganisms brought by sludge amendment are summarized and discussed here. Organic contaminants and pharmaceuticals are typically found at low concentrations in sludge, the risks from sludge-amended soil decrease over time owing to its biodegradability. On the other hand, application of sludge generally increases soil salinity, which may cause physiological damage to plants grown in sludge-amended soil. In some extent, this negative effect can be alleviated by means of dilution; however, greater attention should be paid to long term increasing possible risk of eutrophication. Heavy metal (particularly of mobile heavy metals, such as Cd) with high concentrations in sludge and soil receiving considerable sludge can cause its incremental abundance in soil and crop contamination, further posing risks to humans, but most cases showed that there remained not excessive in heavy metal caused by sludge amendment. It is worth noting that increasing soil organic matter content may reduce transfer of heavy metal from soil to crops, but not restrict its uptake by crops at all. Combined literature together, it is summarized that heavy metal becomes a relatively severe bottleneck in recycling of sludge as soil amendment due to its non-biodegradability and potential damage to health by adventuring contamination from agricultural products. Particular attention should therefore be paid to long term monitoring the change of heavy metals concentration in sludge amended soil.

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1. Introduction

Sludge is a typical solid organic waste that is mainly made up of the residues produced after sewage was treated. Similar to other organic wastes, sludge contains high concentrations of nutrients including nitrogen, phosphorus, and organic matter. Because of this, sludge is usually applied as a soil amendment, to improve soil fertility. In the last ten years (since 2007), assessments of the risks posed by sludge amendment to soil have moved from being traditional environmental risk study to being total lifecycle assessment (Dong et al., 2014; Liu et al., 2013; Mills et al., 2014; Yoshida et al., 2013). In addition to the potential for recycling sludge to land leading to soil pollution, such lifecycle assessment take into consideration the effects will have on greenhouse gas emissions, the land area required, the carcinogenic risks posed to humans, and even the costs of treating or disposing of the sludge. The environmental risks posed and advantages offered are comprehensively evaluated so that the optimal way of recycling sludge can be objectively identified. However, the problem posed by heavy metals in sludge still have not be resolved even though these risks were not exactly identified after the practice of amending sludge to soil began. Meanwhile, the risks posed by organic contaminants and pharmaceuticals in sludge, potential pathogenic microorganisms and increasing soil salinity have been paid increasing amounts of attention in the last couple of decades.

Sludge can be regarded as a mixture of valuable substances and environmental pollutants because it is produced by enriching wastewater treatment products. This means that recycling of sludge as a soil supplement will have both positive and negative effects like a double-edged sword. The negative effects need to be assessed further than has currently been the case. The most important negative effect could be called the 'Achilles heel' here. This effect must be studied in as much detail as possible and effectively controlled to keep environmental risks posed within a reasonable range. For example, after being amended by sludge, a positive and statistically significant relation between sludge dose and heavy metal content of soil and maize leaf was obtained (Shomar et al., 2013), but if sludge dose was not exceeding 30 ton per hectare, any pollution to amended soil and various plant parts was not caused (Ntzala et al., 2013). So, the risk posed by sludge amendment here refers to accumulation of sludge dose to some extent to soil even level of harmful contamination in agricultural product.

The risks posed by organic contaminants, pharmaceuticals and heavy metals as well as increased soil salinity and possible eutrophication triggered from sludge amendment are assessed, summarized and discussed here (methodology is briefly outlined in Fig. 1). Excess organic contaminants, pharmaceuticals and heavy metals in sludge will lead to more pollutants importing soil environment, even impair human health when sludge is amended to soil at high frequency and dose, but changes in soil salinity caused by sludge will only affect the biomass and physiological function, ultimately influence soil quality and yield of plant grown in soil receiving sludge.

However, only from the viewpoint of basic theory of pollutants or harmful substance input from sludge to soil and uptake from soil to plant, therefore, the different types of risk are regarded equally important when assessing the environmental risks posed by the recycling of sludge to soil here. Because once one of those aspects is ignored, the progress of sludge being recycled to soil will be hindered or adventured for higher environmental risk. The original intention of this article is to elaborate in parallel and comparatively current situations and main environmental problems rising when sludge was recycled to soil so that attracts more attentions to be clear what is the focus point.

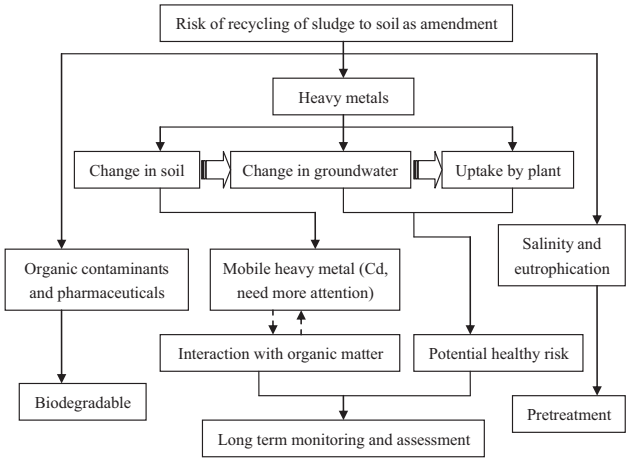

Fig. 1. The outline of methodology on risks triggered by recycling of sludge to soil as amendment.

2. Organic contaminants and pharmaceuticals in sludge and the changes that occur when sludge is recycled to soil

Sludge can contain a wide range of organic contaminants and pharmaceuticals at a wide range of concentrations because these chemicals were found in domestic wastewater. Most of the organic contaminants and pharmaceuticals become concentrated in sludge after sewage or effluent is treated, either through being precipitated or precipitated to particles in the sludge. More attention than is currently the case therefore needs to be paid to organic contaminants in sludge.

Antibiotics and their metabolites, excreted by people taking antibiotics as medicine, are poorly removed from wastewater because sewage or effluent treatment processes are primarily designed to remove chemical oxygen demand (COD), nitrogen, and phosphorus from wastewater. Antibiotics are degraded more slowly in sludge systems than in aqueous systems, and this has been attributed to antibiotics being strongly adsorbed by sludge particles (Cheng et al., 2014). And they also found sixteen different antibiotics in sludge, and main types with relatively abundant levels were fluoroquinolones, tetracyclines and sulfonamides. These antibiotics can cause problems, such as disorder of soil biology, at the concentrations that have been found in sludge, so it is necessary to limit antibiotic use and to establish standards to ensure that sludge is safely disposed of Zhang et al. (2014) found polychlorinated naphthalenes in sludge and the predominant homologs, the mono- to tetra-chloronaphthalenes, accounted for approximately 85% of the total polychlorinated naphthalene concentration and that the polychlorinated naphthalenes had probably been released from industrial sources. Liu et al. (2015) detected 11 synthetic phenolic antioxidants in sludge, and eight appeared to have been identified in environmental medium for the first time. 2,6-Di-*tert*-butyl-4-methylphenol (BHT), 4-*tert*-octylphenol, and 2,4,6-tri-*tert*-butylphenol constitute the dominant synthetic phenolic antioxidants, and other BHT metabolites were also found. Gonzalez et al. (2012) stated that linear alkylbenzene sulphonates (LAS), one of anionic surfactants, in sludge should not be expected to pose risks to the environment shortly after sludge was recycled to the soil, but another non-ionic surfactants, nonylphenolic compounds (NPE), have been found to have the potential to cause toxic effects during two months after sludge application to the soil.