Sludge on Soil Pollution and Prevention Measures Research

Huanyuan Wang\textsuperscript{1,2,3,4,*}, Siqi Liu\textsuperscript{1,2,3,4}, Xiao Xie\textsuperscript{1,2,3,4}

\textsuperscript{1}Shaanxi Provincial Land Engineering Construction Group Co., Ltd., Xi'an 710075, China.
\textsuperscript{2}Institute of Land Engineering and Technology, Shaanxi Provincial Land Engineering Construction Group Co., Ltd., Xi'an 710075, China
\textsuperscript{3}Key Laboratory of Degraded and Unused Land Consolidation Engineering, the Ministry of Natural Resources, Xi'an 710075, China
\textsuperscript{4}Shaanxi Provincial Land Consolidation Engineering Technology Research Center, Xi'an 710075, China

*Corresponding author e-mail: 181073033@qq.com

Abstract: With the increasing of urban capacity, the amount of sludge produced rapidly increase, more and more sludge has been disposal to land. Sludge is a solid part of sewage and a common semi-solid waste. It is complex in composition, which need to be effectively treated and utilized. The sludge on soil pollution and the prevention has become an important content of environmental science. The article systematically expounded the basic properties of the sludge, sludge on soil pollution and prevention measures, as well as other related research, which is meaningful to environmental improvement and can provides help for production practice hopefully.

Keywords: sludge, soil pollution, prevention, heavy metal.

1. Introduction
Sludge is a solid part of sewage, and its composition is a semi-solid waste between organic and inorganic substances\textsuperscript{[1]}. One million tons (80% treatment rate) of sewage is treated daily in a medium-sized big city. According to the calculation of suspended matter in sewage water, the daily production of sludge reaches 800-900 tons\textsuperscript{[2]}. Such a large amount of sludge must be further effectively treated and utilized. In recent years, sludge land disposal has become an important way of sludge disposal in order to save the cost of sludge disposal and make waste resources. Therefore, it is of great significance to study the harm of sludge to soil and to develop corresponding preventive measures. The author summarized and discussed the present situation of sludge contamination on soil and preventive measures, trying to provide help for production practice.

2. Basic properties of sludge
Sludge produced by sewage treatment plants is a solid or fluid substance with water content between 700-970 g kg\textsuperscript{-1}. The solid components are mainly organic debris, bacteria, inorganic particles and colloids, but mainly organic components, which contain organic matter, N, P, K and various micro-elements of potential use value for agriculture. Quantitative element nutrients. Organic matter usually accounts for 30% to 40% of the dry weight of sludge, which is equivalent to general farm manure\textsuperscript{[3]}.
Because the sludge comes from various sewage, it inevitably contains various toxic and harmful substances, such as heavy metals, organic pollutants and pathogens, and because the sludge contains more easily decomposed or decayed components, it usually emits an unpleasant odor. The coexistence of beneficial and harmful components in sludge makes it a complicated problem.

3. Sludge on soil pollution

3.1. Beneficial effects of sludge use on Soil

Sludge is a very effective biological resource, which contains abundant nutrients beneficial to plant growth and a large number of organic substances. Its total nitrogen, phosphorus, potassium and so on are similar to those of stable hypertrophy. Organic substances in sludge have good effects on soil structure (such as porosity, aggregate stability), soil hydraulic properties (such as water holding capacity, water stability), soil chemical properties (such as adsorption, substitution, buffer), and soil biological properties. It can promote the formation of aggregates, increase soil porosity, facilitate ventilation, exhaust, improve water storage capacity, improve soil tillage, but also increase the activity of soil microorganisms and some important enzymes, which is the reason why sludge is used as soil amendment [4-5].

3.2. Pollutants harmful to soil from sludge

3.2.1. Heavy metals in sludge. In undeveloped countries, due to economic and policy constraints, the risk of sludge management is greater than that of sewage irrigation. Heavy metals are one of the most important pollutants in sludge. There are many kinds of heavy metals in sludge, such as copper, phosphorus, zinc, nickel, chromium, Hg and cadmium, which are the main obstacles to sludge utilization. Heavy metals are difficult to migrate, easy to enrich and harmful to agriculture, which has become the most important factor restricting the agricultural use of sludge. Statistical analysis of domestic (1994-2001) data on heavy metals in sludge shows that the contents of heavy metals Ni, Pb, Cr, Cu and Zn in sludge vary greatly in China, with a range of up to several thousand mg/kg; zinc is the most abundant element, followed by copper and chromium; the toxic heavy metals Hg, Cd and As are often low, usually. In the range of a few to a dozen milligrams/kilograms [6]. According to the statistical results and the agricultural standards of sludge in China, Cu and Zn are the most abundant elements in sludge in China, and they are also one of the main factors restricting the land use of sludge.

However, Guo Lan [7] studied the effects of land use of sludge and sludge and garbage compost on heavy metal accumulation in soil. When agricultural application was carried out according to the general fertilization rate, the accumulation of heavy metals in soil would not occur. When the amount was as high as 4 times of the usual amount, the contents of Zn, Cr and Pb in soil did not exceed the soil safety control standard.

3.2.2. Organic pollutants in sludge. Sludge often contains some organic pollutants, such as chlorophenol (CPS), chlorobenzene (CBs), nitrobenzene (NBs), polychlorinated biphenyls (PCBs), polychlorinated dibenzodioxin/bark (PCDD/Fs), phthalate cruel (PEs), polycyclic aromatic hydrocarbons (PAHs) and organochlorine pesticides (OCPs). Agricultural sludge often increases the concentration of PAHs in soil. Considering the harm to human beings, PAHs has been listed as an important organic pollutant in sludge.

Simon et al. [8] carried out a long-term study on the behavior and direction of organic pollutants after sludge land use. The main object of study was PAHs. PAHs were detected in the continuous sludge and non-sludge fields from 1942 to 1961. Soil samples from 1942 to 1984 were collected and preserved. The results showed that the concentration of PAHs in soil after sludge application had increased more than three times by 1984. The analysis of 444 sludge samples from Britain showed that the detection rates and concentrations of PCBs, r-HCH and dieldrin were higher than those of aldrin and endrin. Any organic compound entering the environment may be found in sludge. However, the content of organic...
pollutants detected in many sludge is several times, tens or even thousands times higher than the local soil background value.

There are few studies on organic pollutants in sludge in China, and most of them are investigative. The content of PAHs in 11 sludge in China and Hong Kong was determined by Mo Cehui et al. [9], ranging from 2.27 to 143.8 mg kg\(^{-1}\). The content of PAHs in some sludges was higher than that of some sludge in Hong Kong and abroad, and the content of benzo-a-pyrene in some sludge exceeded the standard of agricultural sludge in China. The content of PAHs in the soil was between 0.01 and 6.92 mg kg\(^{-1}\), mainly 1, 2, 4-trichlorobenzene and hexachlorobenzene. Cai Quanying et al. also found that the content of PAHs in the soil after agricultural use of sludge increased significantly, mainly 3, 4 and 5-ring compounds.

3.2.3. Pathogens in sludge. There are four main types of pathogens that can cause human diseases: bacteria, viruses, protozoa and parasites, which can be detected in sewage sludge. According to the statistics of pathogens in sludge by some scholars of EPA and other organizations, at least 24 kinds of bacteria, 7 kinds of viruses, 5 kinds of protozoa and 6 kinds of parasites have been identified in sludge [11]. The content of these pathogens in sludge depends on the health status of residents in the sewage source area, sewage treatment technology and sludge treatment methods.

So far, the investigation data of pathogen content in sludge are very limited. Sun Yuhuan et al. [12] investigated fecal coliform (FC) in sludge from 45 sewage treatment plants in several cities of the Yangtze River Delta. The results showed that the maximum possible number of FC in sludge (MPN) ranged from 0 to 3.41 x 106 MPN G\(^{-1}\) (dry base), with an average of 3.79 x 105 MPN G\(^{-1}\) (dry base), and the detection rate of FC in different types of sludge was 89.6%. The quantity of FC in sewage sludge and sludge products from rivers is the lowest, while the quantity of FC in sewage sludge mainly composed of domestic sewage and mixed sewage is higher. Therefore, there are many kinds and quantities of pathogens in the sludge. When the sludge is used for land use, pathogens can enter the soil environment with the sludge and increase the content of pathogens in the soil. If the sludge is treated or applied improperly, it will pollute the external environment and threaten human health.

Under suitable conditions, the decomposition of some easily decomposed organic matter in sludge will release a large number of gases containing NH\(_3\), H\(_2\)S, SO\(_2\), organic sulfur, amines and methyldione with strong odor and toxic and harmful [13], pollute the atmospheric environment, and breed mosquitoes and flies to transmit various diseases, making the surrounding environment worse and affecting sensory perception. And landscape.

3.2.4. N and P excess in sludge. Studies have shown that leaching loss of NO\(_3\) and surface runoff are important causes of groundwater and surface water pollution, respectively. The problem of NO\(_3\)-N leaching contaminated groundwater has been paid great attention all over the world. The World Health Organization stipulates that the NO\(_3\)-content of drinking water should not exceed 45 mg L\(^{-1}\). The United States limits NO\(_3\) to less than 10 mg L\(^{-1}\). Since 1985, our government has also requested that NO\(_3\) should not exceed 20 mg L\(^{-1}\). Studies have shown that the decomposition and mineralization of organic matter in sludge are in progress. The first six weeks were faster and then slower [14]. Foreign studies have found that the contents of NO\(_3\)-N and NH\(_4\)-N in soil leachate of sludge application season are higher than those of control treatment. Although high yield can be obtained by a large amount of application, the leaching rate of N is higher, which will pollute groundwater and may cause eutrophication of water body. Considering the comprehensive consideration of guaranteeing yield and preventing water pollution, it is more reasonable to utilize N in a few times than in a large amount at a time.

3.3. Pollutants harmful to soil from sludge
The pollution of soil caused by sludge application is mainly reflected in the pollution of plants. Sludge or sludge compost contains a large amount of organic matter and plant nutrients, which can significantly promote plant growth. However, there are also reports of plant seedling death after the application of a
large amount of sewage sludge. The effects of heavy metals in sludge or sludge compost on plant and plant edible parts have also been reported.

3.3.1. Effects on the growth of crops and vegetables. Sludge or sludge compost is used in food crop production in many countries. The environmental quality survey of sewage irrigation area in Tianjin found that mercury, cadmium and lead accumulated in the soil with large amount of sludge. The cadmium content of vegetable leafy vegetables (Chinese cabbage and spinach) was 2.7 mg kg$^{-1}$ (fresh weight was 0.135 mg kg$^{-1}$) and fruit vegetables was 15 mg kg$^{-1}$ (fresh weight was 0.75 mg kg$^{-1}$) after perennial application of sludge in Zhaoguli Garden, Eastern suburb.

But at the same time, there are some studies this year that the sludge application has not produced obvious heavy metal or organic pollution while promoting crop production [15-17]. The author believes that the reason may be related to the different quantity and nature of the sludge and the amount of the sludge tested, and a lot of experiments are needed to further verify.

3.3.2. Effects on the growth of crops and vegetables. The application of sludge can obviously increase the biomass of trees and flowers, but at the same time, it will bring serious harm. Shen Rongyan et al. showed that in the plant and soil system of potted snow leek, clover and Alfalfa Planted with sludge, the contents of 19 compounds of PCBs, OCPs and PAHs detected by the three plants and roots increased to different degrees compared with those of the control plants [18].

Li Guibao et al. [19] sampled the forest soil after 15 months of sludge application. The results showed that the content of Zn and Cr in 0-20 cm soil increased significantly after sludge application in Eucalyptus forest, but the range was not large, the content of Pb increased by 3.8-11.8 mg kg$^{-1}$, and the difference of other heavy metals was not obvious. Except for Pb, the increase of other heavy metals in 20-40 cm soil was not significant. The content of Pb in 0-20cm sludge of Yinxiang woodland soil increased by 4.40 mg kg$^{-1}$ compared with the control, while the other heavy metals did not increase significantly. The contents of Zn, Cr and Pb in 20-40 cm soil sludge increased by 6.1, 11.25 and 3.85 mg kg$^{-1}$, respectively, compared with the control, while there was no significant difference in other heavy metals. Comprehensive analysis showed that the application of sludge had little effect on heavy metal residues in forest soil, which varied with the amount of sludge applied, and the high application of sludge had higher Pb residues, whereas the reverse was less.

3.3.3. Effects on the quality of agricultural products. Xiao Ling et al. [20] potted experiments were conducted to study the effects of digested sludge from Xi'an Sewage Treatment Plant on wheat growth. The results showed that the accumulation of zinc, cadmium and copper in roots was higher than that in stems and leaves, i.e. more transfers to the aboveground parts, while the accumulation of lead and nickel was opposite. The correlation coefficient between the amount of copper, nickel, lead and cadmium in roots and the amount of sludge application reached a very significant level, while the change of the content in stems and leaves was relatively small, and the relationship between the amount of copper, nickel, lead and cadmium application and the amount of sludge application was not significant. When the sludge application rate was less than 2%, the contents of copper and zinc in wheat stems and leaves were within the normal range, and the contents of lead and cadmium were similar to those of the control.

Many studies have explored the availability and intake of heavy metals in sludge compost by vegetables. The results show that leafy vegetables, especially lettuce and kraft, accumulate more zinc and cadmium than fruit vegetables and underground stem vegetables. Their accumulation also depends on the concentration, form, amount of heavy metals applied in compost and the value of soil.

3.4. Impact of land use of sludge on water quality

3.4.1. Effects on groundwater. Nitrogen in sludge forms part of N$_2$ and NO$_3$ and escapes into the atmosphere. The other part forms nitrate nitrogen through nitrification, which pollutes groundwater as water moves in the soil. Some countries have carried out indoor and outdoor experiments. Zhang Qiang
et al. [21] have carried out indoor simulation tests on the leaching of nutrient elements and their effects on soil fertility and groundwater after municipal sludge was applied to soil. The results show that in the first few months, only a small part of the mature sludge or raw sludge will be leached, but in the long run, a large amount of nitrogen will be leached to the soil or groundwater. Nitrogen leaching from sludge can pollute groundwater, which is mainly determined by nitrate nitrogen, the final form of nitrogen. Liu Fengxia [22] and other municipal sewage sludge experiments in woodland indicated that sludge fertilization should avoid rainy season and hot and dry weather, and excessive nitrate nitrogen in sludge leachate would pollute groundwater.

3.4.2. Effects on surface water. The sludge is rich in N, P and other nutrients. If a large amount of N and P is applied on the land with large rainfall and loose soil, the decomposition rate of organic matter is faster than the absorption rate of N and P by plants, it is likely to be lost along with the water flow, which will lead to eutrophication of water body and nitrate pollution of groundwater.

4. Prevention of Soil Pollution by Sludge

4.1. Sludge control
Heavy metals in sludge are important indicators affecting sludge quality as fertilizer directly or indirectly. The best way to control heavy metals is from the source. In order to reduce the content of heavy metals in sludge, the discharge of industrial wastewater containing heavy metals should be strictly controlled. The wastewater must be treated deeply in the factory, and the discharge will not be allowed until the indicators of various heavy metals meet the standards [23].

4.2. Sludge detection and classification
Sludge has different origins and properties, such as breweries, food factories and domestic sludge. Heavy metals and organic pollutants in sludge are less, and some of them can be directly used as agricultural fertilizers. If the content of harmful substances is too high, other ways can be further considered. At the same time, we should pay attention to the following problems in use: which kind of sludge is suitable for grain crops, which is suitable for cash crops or only for ecological fertilizer; which kind of soil can be used and which cannot be or not be used by the same kind of sludge fertilizer; which kind of sludge compound organic fertilizer can be used for melons, fruits and vegetables, and which kind can only be used for food crops or only for ecological fertilizer.

4.3. Sludge consumption
Current studies have proved that sludge application in a certain amount of scope, generally will not cause significant pollution. Cao Renlin et al. [24] studied the impact of composting sludge application on the environment of garden green land, pointed out that the pollution of nitrate to surface water and groundwater was the most concerned problem, but when the sludge application rate was controlled within 50 t hm\(^{-2}\), it would not cause the harmful effects of nitrate and phosphorus on surface water and groundwater.

4.4. Treatment technology
In recent years, the technology of sludge innocuity has been continuously developing and progressing. This is the most effective and direct way to prevent sludge contamination of soil. The purpose of sludge stabilization and innocuous treatment is to further reduce the water content of sludge, kill bacteria and pathogens in sludge, eliminate odor, degrade organic matter in sludge, reduce heavy metal content or activity in sludge, and reduce toxicity of toxic and harmful substances in sludge. The main methods include anaerobic digestion, aerobic digestion, sludge composting, heat treatment, biological leaching and so on [25].
4.4.1. Anaerobic digestion. Sludge anaerobic digestion process is also known as sludge biological stabilization process. Macromolecular organic matter in sludge decomposes under the action of anaerobic microorganisms, and eventually produces methane-based biogas. After anaerobic digestion, sludge can be reduced and stabilized. This method is widely used at home and abroad.

4.4.2. Aerobic digestion. Aerobic digestion of sludge refers to aeration of sludge for a long time without adding substrates, so that microorganisms in sludge can oxidize themselves and the biodegradable part can be oxidized and removed. Aerobic digestion technology is still popular in some small sewage plants. Aerobic digestion has the advantages of high digestibility of sludge, less excess digested sludge and simple operation and management. The disadvantage of aerobic digestion is that biogas cannot be recovered, the operation cost is high, and the operation stability is greatly affected by temperature.

4.4.3. Sludge composting. Sludge composting is the most common stabilization and harmless treatment method. It has the characteristics of economy, practicability, no need for additional energy and no secondary pollution. At present, hundreds of sludge composting facilities and dozens of composting processes have been put into use in the world. Sludge composting treatment in developed countries such as the United States, Japan and the United Kingdom has accounted for a considerable proportion, and various scale composting plants have been built. At the same time, the research on composting fermentation technology and technical measures has also made rapid progress. In the early 1990s, the utilization rate of sludge as bio-fertilizer in the United States has exceeded 30%. At present, there are sludge bio-fertilizer plants in every state, whose famous brands are “Eart”, “Nihumus”, etc. [27]. In the process of sludge composting, microorganisms such as conditioner, expander, adsorbent, nitrogen fixing bacteria, FM bacteria and EM bacteria are often added to reduce the content of exchangeable heavy metals, increase the content of stable heavy metals, significantly reduce toxic substances, decrease the number of bacteria, actinomycetes and other microorganisms, and improve the quality of composting. At the same time, in the composting process, sludge can be combined with other solid wastes such as fly ash, at the same time, many pollutants can be turned into treasures, and the defects in separate use can be eliminated [28–29].

4.4.4. Bioleaching. Bioleaching technology is a technology to separate and leach heavy metals from sewage sludge through oxidation, reduction, complexation, adsorption and dissolution processes, using the indirect effect of microorganisms directly acting as Sichuan or its substitute products. The main microorganisms used are Thiobacillus, Sulfur Bacillus and Acidophilic Bacteria. The leaching effect is affected by temperature, concentration, initial pH, sludge type and concentration, bottom species and concentration, etc. Compared with chemical removal of heavy metals, this method has the advantages of high removal rate, less acid consumption and strong practicability. It is an economical, effective and potential method for heavy metals removal. However, the main bacteria used in bioleaching such as Thiobacillus proliferate slowly, and the long period of bioleaching is the main obstacle to its large-scale application.

4.4.5. Thermal spray treatment. Thermal spraying treatment is a treatment technology in which the material is placed in a pressure tank to pass through steam, keep high temperature and high pressure for a short time, and then release all the pressure instantaneously. Using this technology to treat sludge can shorten the treatment time, improve the degree of harmlessness, and possibly improve the nutrient supply capacity of sludge. Thermal spraying treatment is a new sludge treatment method developed in recent years. It is accomplished by special equipment and its special technology, and has not formed a large scale in production.

4.5. Improvement of management and supervision system
The Agricultural Sludge Pollutant Control Standard promulgated by China in 1984 has played a guiding role in controlling sludge abuse. However, it is difficult to adapt to China's soil, biological and climatic
types because it is a foreign standard for reference and lacks the support of domestic long-term positioning experimental data [27]. The restriction of heavy metals in sludge is so strict that a large number of sludge in China cannot be used in agriculture.

5. Conclusion
There is no doubt that the soil is polluted by sludge application, but there is still much controversy about plant pollution. In recent years, the prevention measures of sludge on soil have been developed and improved step by step, but there are still many technical and policy problems to be solved. These aspects should be further studied and discussed in the future.

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