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Research Progress on Improvement of Saline Alkali Soil

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Abstract

Soil salinization is one of the most important issues threatening agricultural production, food security and sustainability in arid and semi-arid regions worldwide. The improvement and comprehensive utilization of saline alkali soil is of great significance for cultivating healthy soil, ensuring global food security and mitigating climate change. This paper summarized the research progress of saline alkali soil improvement technology, and described briefly the causes of saline-alkali land. Moreover, the physical, chemical and biological methods of saline-alkali land improvement were analyzed. The improvement characteristics and effects of different materials and technologies are described. And we proposed suggestions for future research and development of desalination materials and technologies to provide a useful reference for the research and development of efficient improvement technology of saline-alkali soil, and accelerate the improvement of saline-alkali land and improve the quality of cultivated land to a greater extent.

Keywords

Saline-alkali Soil; Physical Improvement; Chemical Improvement; Biological Improvement.

1. Introduction

Soil salinization and secondary salinization is one of the main types of land degradation, which is a global resource and ecological problem. Soil salinization and secondary salinization caused by irrigation mainly occur in arid and semi-arid areas with poor natural conditions, scarce rainfall, strong evaporation and high groundwater level [1]. According to statistics, the area of global salinized soil is about 9.52×10^8 hm^2, which is about 10% of the earth's land area. And the area of secondary salinized soil is about 0.77×10^7 hm^2, 58 % of which occurs in agricultural irrigation area. And about 20% of arable land is affected by salinization, and this proportion is increasing [2]. Soil salinization is increasing, which seriously threatens the local ecological environment security and affects the development of social economy. All kinds of saline-alkali soil are formed under specific natural conditions. The essence is mainly the redistribution of various soluble salts on the ground in the horizontal or vertical direction, so that the salt gradually accumulates in the soil surface of the salt collecting area. Saline-alkali soil is characterized by high pH value, poor air permeability and water permeability, easy surface

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hardening, low nutrients and rich in harmful salts, which seriously affect crop emergence and root growth [3]. And most plants are difficult to survive. Soil salinization and secondary salinization seriously affect global land sustainability and food security, which has become a hot issue of common concern in the world. Therefore, scholars have carried out a lot of studies on the improvement and utilization of saline-alkali land.

After years of research by researchers, a variety of improvement measures for saline-alkali land have been summarized. The main measures are physical measures, chemical measures, biological measures, etc. Physical measures such as land leveling, deep ploughing, guest soil pressing, sand pressing improvement and so on. Although some measures can effectively improve the soil environment, there are some shortcomings, such as not completely eliminating salt, large amount of engineering and difficult implementation, which are not easy to popularize in a large area [4]. The main principle of chemical measures is to change the adsorbed ion composition of soil colloids, which can completely eliminate salt and exchangeable Na^+ in the soil, thereby improving the physical and chemical properties of the soil. Meanwhile, Chemical measures such as the application of soil amendments has fast effect and convenient implementation. In recent years, the research on the improvement of salinized soil by soil conditioner has also reached a new level, and the research on different varieties and components of salinized soil conditioner has also emerged in large numbers. Biological measures such as adjusting agricultural structure, rational distribution of crops, planting salt-tolerant varieties and so on, can improve economic efficiency and are also the most lasting and efficient methods. And planting plants (salt tolerant plants or halophytes) can improve saline alkali soil for a long time [6]. The effect of any single improvement measure is limited, and salinization is easy to occur repeatedly. Comprehensive management can combine the advantages of these three measures. Therefore, in the practice of saline-alkali land improvement, it is often used in combination to gradually form a comprehensive technology integrating physical measures, chemical measures and biological measures. Furthermore, it can achieve the best effect of improving saline-alkali land, rapidly improve the physical and chemical properties of salinized soil, and provide a good growth and development environment for crops to achieve high yield and high efficiency of crops. The physical, chemical and biological methods of saline-alkali land improvement were analyzed. And the improvement characteristics and effects of different materials and technologies are described. In addition, we proposed suggestions for future research and development of desalination materials and technologies to provide scientific basis for the research and development of efficient improvement technology of saline-alkali soil.

2. Causes of Salinized Soil

Saline-alkali soil is widely distributed in the world. Saline-alkali soil exists not only in desert and semi-desert areas, but also in fertile rivers, coastal areas, alluvial plains and irrigated areas. The total area is about 9.52×10^8 hm^2, and it increases at the rate of 1 million to 1.5 million hm^2 every year [7]. the natural conditions, soil-forming process, main types and characteristics of saline-alkali soil in the world are different. The detailed situation and classification basis of saline-alkali soil research are not consistent, and the classification system adopted is not completely unified. From the classification system of saline-alkali soil commonly used in major countries in the world, it is basically the same to divide saline-alkali soil into saline soil and alkaline soil. Generally, saline soil is a kind of soil that contains more than 2 g / kg soluble salts and affects the normal development of crops. And alkaline soil refers to the soil in which the proportion of exchangeable sodium ions to soluble cations (expressed as ESP, unit %) is greater than 20 % and the pH value is greater than 8[8]. Saline soil and alkaline soil usually are mixed. The essence of the formation of saline-alkali soil is the redistribution of soluble salts in the soil,

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and the accumulation of salt in the soil surface exceeds the normal value. The main reasons affecting soil salt accumulation are natural factors and human factors. Natural factors are the internal causes of saline-alkali soil formation, including climate, topography, hydrological activities and vegetation factors. Human factors are the external causes of the formation of saline-alkali soil, especially the formation of secondary saline-alkali soil [9]. At present, the area of secondary salinization soil in the world is still increasing. The main reasons are climate warming, rising sea level, increasing lack of fresh water resources, increasing environmental pollution, unreasonable application of chemical fertilizers and unreasonable irrigation. Saline-alkali soil has various types, complex causes, and large temporal and spatial changes. It is urgent to develop rapid, economical and long-term ecological treatment technology.

3. Physical Measures of Saline-alkali Soil

3.1. The Technological Principles of Physical Measures

The physical measures are mainly to regulate the evaporation precipitation ratio of saline-alkali land by improving soil physical structure [10]. Physical improvement measures are generally water conservancy, land preparation, agronomic and other engineering measures to reduce soil salinity, which mainly include traditional improvement methods such as open ditch drainage, subsurface pipe drainage, in-situ soil layer rectification, guest soil improvement, deep tillage and sunning soil, and micro-area soil improvement, as well as new processes such as biological materials and ground coverage.

3.2. Improvement Effects of Physical Measures

Water conservancy projects with large water resources and high maintenance costs, and limited by water resources is difficult to promote on a large scale. Some covering materials and salt insulation materials and some agronomical measures such as deep tillage and sunning soil with low cost and great benefits on society and economy are common improvement methods. A large number of crop straws and forest by-products have been developed as salt-isolated materials for salinized soil, which have achieved significant salt control and moisture conservation effects, and also improved the straw returning rate and the utilization efficiency of forest by-products. It is found that straw returning to saline-alkali soil can significantly improve soil physical properties and increase soil fertility. Li et al. [12] studied the effect of straw returning on the physical properties of saline alkali soil and found that straw returning could significantly reduce soil bulk density, and the content of soil water-stable aggregates increased significantly after 2 years of returning. Han et al. [13] found that straw returning could improve soil chemical properties to a certain extent, and the effect of decomposed straw on saline-alkali soil was better than that of undecomposed straw. When the ratio of straw to sludge was 2:1, the soil ESP, pH and exchangeable Na^+ decreased the most. In addition, the application of sand mixing or sand covering to improve saline-alkali land has a long history and good improvement effect. Sun found that sand mixing has obvious desalination and pressure-alkali effect, which reduces soil salt content and pH value, increases water content, and improves the growth environment of crops in saline-alkali soil [14]. Song found that soil mixing with sand can improve the infiltration capacity of soil, and soil infiltration rate increases with the increase of sand mixing ratio [15]. Compared with the control group, sand mixing 25 % significantly accelerated the cumulative infiltration and wetting front process. Sand mixing also significantly inhibited the daily evaporation and cumulative evaporation of soil, and the inhibitory effect increases with the increase of sand mixing ratio. A variety of non-toxic, harmless, low-cost, and widely-sourced inorganic materials such as zeolite and slag have been developed saline alkali soil desalination materials, and have played an important role in saline alkali soil improvement. Studies have found that zeolite interlayer can significantly reduce the soil salt content and soil salt solute concentration in 0-80 cm soil layer in coastal saline-alkali

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soil, and improve the photosynthetic characteristics of *Robinia pseudoacacia*, and promote its growth. The net photosynthetic rate, transpiration rate, stomatal conductance and water use efficiency of leaves are significantly increased, and the growth of tree height and ground diameter are significantly increased. The effect is better than ceramsite and river sand [16]. Using slag as the interlayer (particle size of 2 ~ 25 mm, 20 cm thickness at the bottom of the tree hole) can reduce the soil conductivity and promote the photosynthesis of *Fraxinus chinensis*. The net photosynthetic rate, transpiration rate and stomatal conductance of the leaves were significantly increased, and the effect was stronger than sand. Furthermore, synthetic organic materials are widely used in saline-aliali soil improvement due to their convenient use and long action time. The application of soil structure stabilizer polyacrylamide (0.02 g / kg) can effectively reduce soil bulk density, improve soil porosity, water stability, permeability and 0-60 cm soil water content, and promote the growth of maize [18]. In the heavy saline-alkali land in the arid desert oasis area, the thickness of 0.08 mm polyethylene plastic film was filled with 10 cm stones, slag, etc., and the retaining wall was built on all sides after the filter pipe is paved, and finally the soil is filled to 60 cm above the ground. With the irrigation leaching, the soil salinity decreases and the growth of lawn grass becomes better year by year [19].

4. Chemical Measures of Saline-alkali Soil

4.1. The Technological Principles of Chemical Measures

Chemical improvement measures often apply a certain number of harmless substances to saline-alkali soil. The acid or acidic substance of the additives neutralize the alkalinity of the soil, or the additives change the type and proportion of cations adsorbed by the soil colloid (mainly to reduce the content of exchangeable Na^+ in the soil), thus reducing soil pH and salt content, improving soil environment. According to the source of raw materials, soil amendments can be divided into natural inorganic amendments such as fly ash, limestone, bentonite, gypsum, vermiculite, perlite, etc., natural and organic amendments such as paper mill sludge, municipal sewage sludge, municipal solid waste, crop straw, leguminous green manure, livestock and poultry manure, polysaccharide, cellulose, resin glue, tannic acid, humic acid, lignin, peat, etc., artificial synthetic amendments such as polyacrylamide, polyvinyl alcohol, polyethylene glycol, urea-formaldehyde resin, etc., natural-synthetic copolymer amendments, humic acid-polyacrylic acid, cellulose-acrylamide, starch-acrylamide/acrylonitrile, zeolite/ attapulgite-acrylamide, sulfonated lignin-vinyl acetate, etc.

4.2. Improvement Effects of Chemical Measures

Bello et al. [20] proved that gypsum can improve the physical and chemical properties of saline-alkali soil, reduce soil pH, ESP and bulk density, and increase soil water content and porosity. Wang et al. found that [21] using wood vinegar to improve coastal saline-alkali soil can significantly increase soil organic matter, readily oxidizable carbon, soluble organic carbon and available nutrients, and significantly reduce soil pH and SAR. It reported that using fly ash to improve saline-alkali soil can quickly reduce the content of Na^+ in soil, with changing the chemical properties of soil, increasing soil porosity, making soil structure loose, enhancing soil permeability and water permeability, and making vegetation roots grow better [22]. Although the chemical improvement measures are easy to get quick results and have good effects, they are expensive, and the improper use is easy to cause secondary pollution to the environment. From the perspective of sustainable development, soil amendments also have some limitations in terms of application scope and applicable conditions.

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5. Biological Measures of Saline-alkali Soil

5.1. The Technological Principles of Biological Measures

Biological improvement measures are to increase surface coverage by planting plants, reduce soil moisture evaporation, and inhibit soil salt return. At the same time, plant roots can improve soil physical properties to a certain extent, and their debris can be transformed into organic matter under the decomposition of microorganisms, which can improve soil microbial activity and soil chemical properties. Some salt-accumulating plants and salt-secreting plants can achieve soil desalination by absorbing salt in the soil. Biological measures are cheap, environmentally friendly and effective, and can produce economic benefits, which have gradually become a hot topic in the research of saline-alkali soil treatment. Those mainly include planting salt-tolerant plants, applying biological modifiers and organic fertilizers.

5.2. Improvement Effects of Biological Measures

Li et al. [23] found that after planting salt-tolerant plants in saline-alkali soil, the soil salt content decreased significantly, and the soil available nutrients and organic matter content increased compared with the control. Planting some salt-tolerant economic crops in saline-alkali soil can reduce the salt content of soil and improve the economic value of saline alkali soil by picking and mowing. The application of green manure and microbial agents can promote the proliferation of soil microorganisms and the formation of soil organic matter in saline-alkali land, with improving soil fertility and soil physical and chemical structure.

6. Conclusion and Perspectives

Scholars have realized the advantages and disadvantages of single improvement measures in the research of saline-alkali land treatment. In practice, various methods are gradually integrated and used according to local conditions. But there are still many shortcomings.

(1) The improvement and utilization of saline-alkali land should be combined with various factors, such as regional characteristics, saline-alkali degree and land use patterns. The appropriate improvement technology should be selected according to local conditions, such as saline-alkali land formation process, obstacle factors, hydrological conditions, crop layout and other aspects in different climatic zones.

(2) There is a very important problem in the improvement of saline-alkali soil. With the extension of time, the improvement measures fail, and the ecological restoration effect is weakened, and secondary salinization is prone to occur. Therefore, the research on the improvement of saline-alkali land should be based on long-term monitoring, and various measures should be continuously improved and adjusted with a development perspective. And we should focus on strengthening regional information and secondary salinization, potential salinization prediction, prediction research, strengthening biotechnology research and improving plant salt tolerance research. In addition, the combination of traditional saline-alkali land improvement measures and plant salt tolerance genes is of great significance for the treatment of saline-alkali land.

(3) The application of soil amendments has achieved good results, but there are also some problems. For example, the natural modifier reserves are small, and large-scale promotion is not feasible. The cost of synthetic polymer improved materials is high, and the potential risk of environmental pollution is not very clear, and the recognition of farmers is not enough.

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