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Full length article

Research on saline-alkali soil amelioration with FGD gypsum

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ABSTRACT

Flue gas desulfurization (simplified as FGD) gypsum, a kind of byproduct from wet FGD process of coal-fired power plants, was used to ameliorate saline-alkali soil. The FGD gypsum can react with the main content of saline-alkali soil to improve the soil properties. The technology has been applied for around 120 km^2 in China with impressive results. Detailed field studies showed the productivity of the plants grown in the ameliorated soil increased a lot, and also the physical and chemical characteristics of the soil improved evidently. Both field and laboratory studies showed the technology is safe considering the heavy metal concentration in the soil and plants grown on it. The SOC (soil organic carbon) analysis revealed that the saline-alkali soil amelioration can fix more carbon, so contributing to the global warming mitigation. It was concluded that the saline-alkali soil amelioration with FGD gypsum is a promising technology, and worthy of widely application in the world.

1. Introduction

As we know, coal is the dominant energy in Chinese energy mix. Almost all of the coal-fired power plants are required to equip desulfurization facility to remove SO_2 in the flue gas, as illustrated in Fig. 1. The most popular desulfurization technology is wet-FGD using limestone, with the product called FGD-gypsum, which main content is $CaSO_4$. According to the China Electricity Council (Pan et al., 2015), the production of FGD-gypsum has been increased sharply since 2005, as shown in Fig. 2. And it can be expected that more and more FGD gypsum will be produced in the future for stricter and stricter regulation on the SO_2 emission limit.

As FGD gypsum contains large amounts of moisture and ash, it can be used as building gypsum only after purification and dehydration; this represents an economic disadvantage compared with natural gypsum produced in China. Somewhere, FGD gypsum was used as additives to cement, but the amount is very limited comparing to its huge productivity. If the FGD gypsum was to be directly disposed of without any utilization or treatment, a vast area of land would be required. Such an approach will be a waste of valuable land resources and represents a potential threat of secondary pollution to the environment.

At the same time, there are huge amount of saline-alkali soil in the world. These soils are unsuitable for growing agricultural crops, and some such soils are unable to support any plant growth whatsoever. These barren lands severely limit agricultural production in their countries and have a negative impact on the ecosystem. According the statistics data (Agriculture Department of China, 2015), there are around 340,000 km^2 saline-alkali soil in China, amongst of which, around 124,000 km^2 can be potentially used for agricultural production after amelioration. The distribution of these soils are shown in Fig. 3. The amelioration of saline-alkali soils over such an enormous area is one of the greatest challenges facing Chinese agriculture.

The amelioration of saline-alkali soil using FGD gypsum would make use of tens of millions tons of FGD gypsum, thereby boosting the application of FGD technology and the development of the pollution-control industry. In addition, the huge extent of barren saline-alkali soils ameliorated with the FGD gypsum would then be suitable for growing agricultural crops; this would be of significant benefit to both agricultural development and the improvement of local ecosystems.

In fact, FGD gypsum has been used as a type of modifier for acid soil in the US and other countries (Chen et al., 2001; Li et al., 2004; Dontsova, 2005). Dick W.A. gave a good review on the agricultural application of FGD gypsum (Dick, 2006). For saline-alkali soil, it was Tsinghua University who firstly proposed and experimentally studied the amelioration using FGD gypsum.

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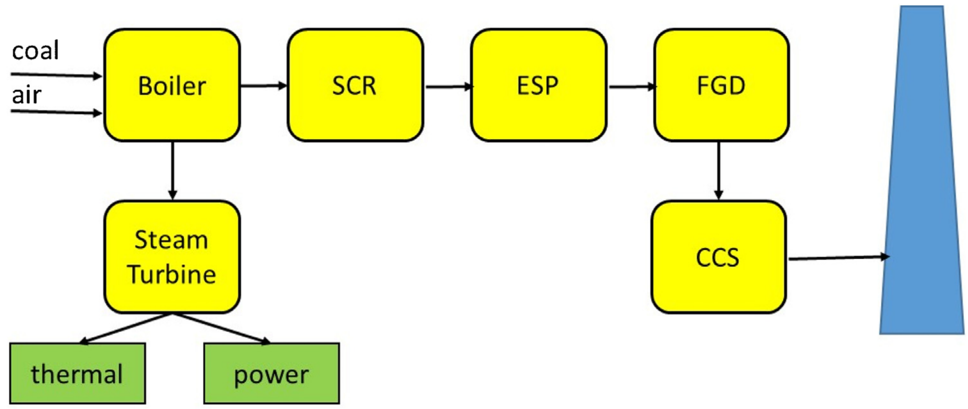

Fig. 1. General layout of coal-fired power plant. (SCR: Selective Catalyst Reduction for NOx removal; ESP: Eletrostatic precipitator; FGD: Flue Gas Desulfurization; CCS: Carbon Capture and Storage).

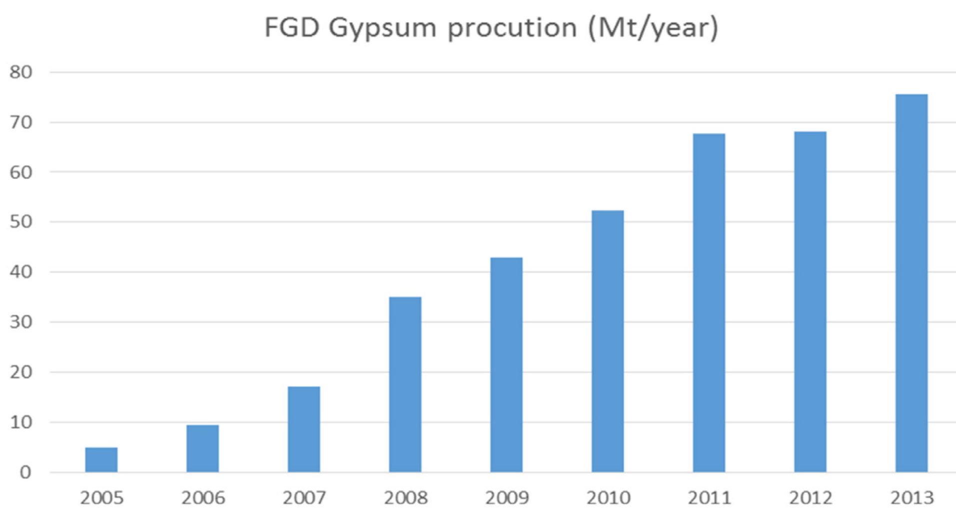

Fig. 2. FGD gypsum production in China from 2005 to 2013.

As early as in the year 1995, cooperated with Tokyo University, Tsinghua University started the 24 m^2 field test on the amelioration of saline-alkali soil with FGD gypsum in Kangping County of Shenyang City, Liaoning Province, China, with very good results (Matsumoto, 1998; Chen et al., 2005), which showed the feasibility of the technology.

In 1999, the field test started cooperated with Inner Mongolia Agricultural University, locating at Tumd Left Banner in Inner Mongolia with the area of 3 ha. Maize was planted in the barren alkali soil ameliorated with FGD gypsum, good harvest was gain, as shown in Fig. 4. In the test, productivity, soil characteristics, and environmental quality were studied in detail, and will be reviewed in the following parts. The field test provided the basis for the widely application of the technology.

Then in 2005, the alkali soil of around 1 ha was selected in Qianjin Farm in Yinchuan, Ningxia Autonomous Region to test the feasibility of the technology in the region. Helianthus were planted and gain good harvest even without fertilizer application, as shown in Fig. 5. In the following several years, the technology was widely applied in Ningxia Autonomous Region. By the end of 2015, the total area of the soils where the technology applied was about 80 km^2.

After that, a series test were conducted separately in the north of China, as Tanggu district of Tianjin, Baicheng City and Daan City of Jilin, Zalaid Banner of Inner Mongolia, Zhangbei County of Heibei, Aksu City of Xinjiang (Li et al., 2010a), and so on. By the end of the year 2015, the total area of ameliorated soils was up to 120 km^2. The distribution of the technology application in China is shown in Fig. 6.

During the technology application, many research works were done. In the paper, the main research results achieved will be reviewed to show the overall status of the technology. Firstly, the principle of saline-alkali soils amelioration with FGD-gypsum is introduced. Then some typical studies are presented to show the effectivity of the technology. These studies were carried out in early 2000s', which is the basis for the technology application. With the application in large areas, environmental problem, especially the influence of heavy metal contents in FGD gypsum, should be addressed carefully. Some important results are given in the paper. Also, the amelioration of saline-alkali soil has some environmental benefits, one of which is the ameliorated soil can fix more carbon. So the soil carbon content changes will be presented in the paper.

2. Technology basics

2.1. Facts of FGD gypsum

Gypsum has been known to be an amelioration agent for saline-alkali soils for more than 100 years; however, it has been used only rarely because of the high cost for the exploitation, transportation, and crushing of natural gypsum. FGD gypsum, therefore, was proposed to substitute natural gypsum.

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