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# The current situation and countermeasures for resource utilization technology of sewage sludge: Taking Sichuan province as an example

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***Abstract:*** *Sewage sludge is an inevitable solid waste of wastewater treatment. Its low-carbon treatment and resource utilization is becoming an urgent and inevitable issue. In this paper, the production status of sewage sludge in Sichuan Province was investigated, the current treatment process and disposal status of sludge projects were summarized. Additionally, the new approaches of resource utilization were reviewed with a view to providing reference for the optimization of sewage sludge treatment and disposal processes for other cities and the industry.*

***Keywords:*** *Sewage sludge, Sichuan province, Treatment and disposal, Resource utilization*

## 1. Introduction

Sewage sludge is a semisolid by-product derived from municipal wastewater treatment. It consists of organic and inorganic phases [1]. The organic components mainly include lignocellulose, carbohydrates, microorganisms and animal and plant residues, et al. Additionally, the lignocellulose is derived from toilet paper, shredded vegetable leaves, weeds and leaves et al. Inorganic components are generated from soil particles, inorganic salts and inorganic nutrient elements (such as nitrogen, phosphorus and potassium) [2]. The dual attributes of "pollution" and "resources" are defined due to the complex components [3]. If not properly treated, it will cause serious environmental pollution and consumption of resources. Owing to the rapid development of urbanization, the amount of sewage sludge is increasing year by year, and its disposal has become an urgent issue. According to the latest statistical data shown in Figure 1[4], the production of sewage sludge with moisture content of 80% in China has exceeded $8688\times10^4$t in 2023, and is increasing at an annual rate of 5-20%. It is expected to exceed $9000\times10^4$t in 2025 [5], and about 700 million tons of urban sludge will be produced in 2060. Although the sharp increase of sewage sludge has urged the government and scholars to concern the sludge treatment and disposal and its recycling. A series of standards, relevant plans and policies have been issued to drive the transformation of sludge management from "emphasis on water but neglect mud" to "emphasis on both sludge and water". However, the rate of harmless disposal and resource utilization of sludge in China is still at a relatively low level [6]. Specifically, the harmless disposal rate of sludge is only 73.5% [7], while the resource utilization rate is less than 30% [8]. Sichuan province as China's strategic hinterland, the selection of sludge treatment technology and equipment can provide a reference for other provinces and cities in China.

Thus, the aim of the study is to summarize the current situation of sewage sludge production in Sichuan Province and the current ways of sewage sludge treatment and disposal. Some advanced new ways of resource utilization have been analyzed in order to provide reference for the optimization of sludge treatment and the selection of disposal technology in the industry and other cities.

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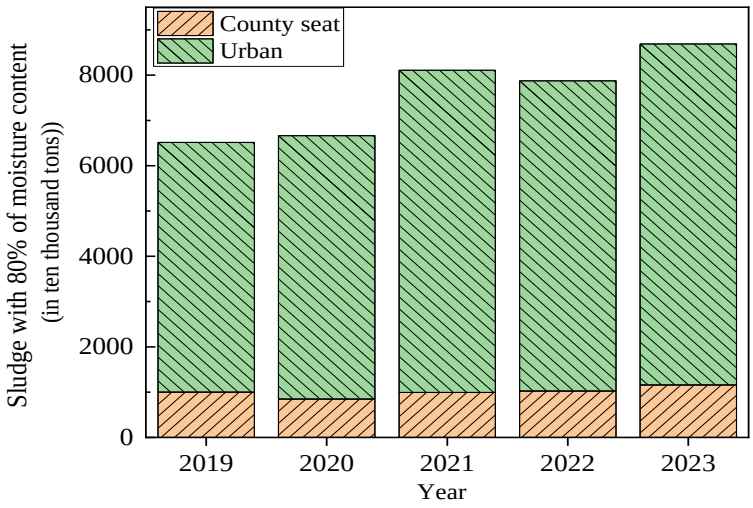


*Figure 1: Quantity of sludge produced in the past five years*

## 2. The current quantity of dry sludge in Sichuan province

By December 2023, there were 338 sewage treatment plants in urban and rural of Sichuan Province, with the annual amount of municipal wastewater reaching 395,668,5200 $m^3$, of which the daily treatment capacity of urban was 10,169,500 $m^3$ and that of county town was 2,572,900 $m^3$ [4]. In general, each ton of municipal wastewater produces about 0.0016 tons of dry sludge [5]. According to the Statistical yearbook of urban and rural construction issued by the Ministry of Housing and Urban-Rural Development, the data trend chart of dry sludge production in Sichuan Province in the past six years was calculated, as shown in Figure 1. Figure 1 showed the quantity of dry sludge produced and treated has been increasing year by year in the past six years. In 2018, the quantity of urban dry sludge produced was 336,408.31 tons, while the quantity of dry sludge produced in county seat was 73514.57 tons. By 2023, the quantity of urban dry sludge had increased to 542,711.17 tons, and the dry sludge production in the county seat had increased to 15,095.26 tons [4], with an increase of 61% and 104% in the urban and county seat respectively. The quantity of dry sludge in 2023 accounted for 3.12% of the total sludge production of China, ranking 9th in the country. However, as is shown in Figure 2, because the sludge disposal rate has been improved, it's deduced the government and scholars have begun to pay attention to the treatment and disposal of sludge and resources utilization with the large increasing amount of sludge. According to the calculation, in Sichuan province, the dry sludge disposal rate of the city and county seat in 2018 and 2023 was 96.7% and 99.9%, respectively.

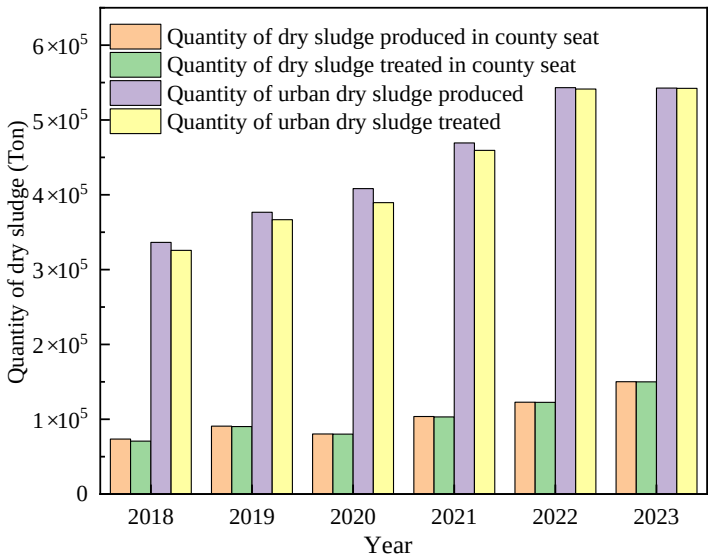


*Figure 2: Quantity of dry sludge produced and treated*

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## 3. The status of resource utilization of dry sludge in Sichuan province

Due to the large production of sewage sludge and lack of land resources, the government and company should select reasonable sludge treatment routes and technical routes according to the sludge source, output and sludge quality, combining with local natural geographical conditions, land conditions, environmental capacity and economic development level. At present, the sludge treatment and disposal in Sichuan Province are mainly dry incineration, co-incineration (domestic waste and cement kiln), and building materials utilization. Taking Chengdu as an example, there are 15 disposal units in operation, including Chengdu Xingrong Environmental Technology Co., LTD., and the treatment process is mainly drying and incineration [9]. Owing to the high moisture content of sludge, direct incineration or pyrolysis need high energy consumption. The remaining sewage sludge should be dried before incineration. In addition, Chengdu has a high degree of population concentration and large sewage sludge production, and the local economic conditions are sufficient to support the construction of centralized sludge incineration facilities, which can not only quickly and efficiently dispose of sewage sludge, but also achieve better reduction effects. But a large amount of residual sludge ash is generated from incineration process. Generally, the residual sludge ash is discarded on waste landfill or used as soil-filling material which will occupy a large amount of land resources and pollute soil and groundwater. Thus the harmless disposal and resource utilization of sludge incineration ash should be strengthened and be the hot topic in the future.

In other prefectures of Sichuan province, anaerobic digestion, aerobic fermentation, dry incineration, land use, building materials utilization are adopted to treat and dispose of sewage sludge. The designed treatment capacity is relatively low. Due to the low sludge production, the corresponding designed treatment capacity is enough to treat and disposal the sewage sludge so that a high disposal rate can be achieved. Aba Tibetan and Qiang Autonomous Prefecture, Liangshan Yi Autonomous Prefecture and Tibetan Autonomous Prefecture of Garzê mostly use landfill to treat sewage sludge. Taking Aba Tibetan and Qiang Autonomous Prefecture as an example, the sewage sludge in Jiuzhaigou and ngapa county are treated by incineration process, while the rest of the counties use sanitary landfill. It is because of the low quantity of dry sludge produced in those counties. Specially, the quantity of dry sludge produced in Aba Tibetan and Qiang Autonomous Prefecture was only 4200 tons with the disposal rate of 99.89%。

## 4. The new approaches of sewage sludge resource utilization

Nowadays, some disposal methods for sewage sludge, such as landfilling and land use, have become obsolete due to secondary pollution. Although drying and combustion is regarded as the most efficient treatment process, it is not the main priority owing to high energy consumption. Meanwhile, the residual sludge ash would result in a second environmental pollution for soil and groundwater. Thus, an urgent requirement of an effective, economical, and environmentally friendly technology to treat sludge improperly is coming to being.

### *4.1. Recycling useful compositions from sewage sludge*

In the latest research, the cellulose composition of sewage sludge shown in Table 1 was determined using the Van Soest method. Sewage sludge was consisted of 48.9% cellulose, 2.1% hemicellulose, and 23.1% lignin, which illustrated the potential for making use of sewage sludge. Besides, a valuable source of various compounds of environmental and industrial value, i.e. carbohydrates, proteins, lipids, minerals, which can be recovered by various methods for their beneficial use. The element composition of sewage sludge in Table 2 demonstrates that it may provide additional organic matter for soil and nutritive elements for the crops. Thus, sewage sludge may be an alternative to the inorganic chemical fertilizers. Additionally, the researcher explored the bioplastics using sewage sludge and mycelium via self-growing process, and owing to the filling effect and strengthening effect of sewage sludge, the compressive strengths of the bioplastics increased significantly with increasing sewage sludge proportion [10]. In the self-growing process, the bioplastics could be pollution-free and can be completely degraded after use, which is conducive to the concept of “cradle-to-grave” recycling.[11]

*Table 1: Cellulose composition of sewage sludge.*

| Types | Cellulose (%) | Hemicellulose (%) | Lignin (%) |
|---|---|---|---|
| Content | 48.9 | 2.1 | 23.1 |

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*Table 2: Element composition of sewage sludge.*

| Types | N(%) | C(%) | H(%) | S(%) | C/N |
|---|---|---|---|---|---|
| Content | 2.94 | 15.03 | 4.90 | 3.18 | 5.11 |

### *4.2. Sludge Hydrothermal Oxidation Treatment Technology*

The approach discussed in section 3.1 relyies on the hazard-free treatment of sludge. Hydrothermal oxidation treatment technology can also deal with sludge alone with low energy consumption and environmental impact. Using air or pure oxygen as the oxidant, organic matter are deeply oxidized in the liquid phase without drying, which is regarded as a cleaner and more straightforward process owing to less energy consumption and better carbon emission reduction. [12] The heat released from the oxidation reaction can be recovered to support energy need in treatment system. Some antioxidative intermediate products in the effluent, mainly including acetic acid and humic acid derivates are generated at moderate temperatures and low pressure. A valuable source of various compounds, such as acetic acid and other volatile fatty acids can be used as carbon sources. Although hydrothermal oxidation treatment technology can treat digested sludge, it requires multi-integration between disposal industries and resource utilization enterprises.

### *4.3. Recycling sewage sludge incineration ash*

Sewage sludge incineration ash still contains high content of heavy metals and is defined as a pollutant. Tables 3 listed the chemical compositions of sewage sludge incineration ash. Since the chemical composition of sewage sludge incineration ash is similar to that of building materials, the waste may constitute a potential substitute for construction industry. Due to its high silica content, sewage sludge incineration ash may be successfully incorporated into building product as well and improve its physical properties. Additionally, the construction industry could valorize the heavy etals in sewage sludge incineration ash.

*Table 3: Chemical composition of sewage sludge incineration ash*

| Types (%). | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | CaO | $P_2O_5$ | $Na_2O$ | $SO_3$ | MgO |
|---|---|---|---|---|---|---|---|---|
| Content | 28.969 | 27.49 | 5.193 | 9.255 | 14.366 | 5.541 | 3.643 | 1.99 |
| Types (%). | $TiO_2$ | $K_2O$ | MnO | ZnO | CuO | $Cr_2O_3$ | SrO | PbO |
| Content | 1.68 | 1.318 | 0.187 | 0.133 | 0.056 | 0.055 | 0.021 | 0.013 |

## 5. Conclusion

With the rapid development of urbanization, the amount of sewage sludge is increasing, and its disposal has become an urgent issue for the government and scholars. It is pivotal to realize the harmfulness, reduction and recycling of sewage sludge. With respect to sewage sludge treatment, some new modes of sewage treatment should be explored, and sewage sludge treatment technology must be improved to promote the resource efficiency rate of sewage sludge, expanding the application scope and enhancing the utilization rate of sewage sludge integrally.

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