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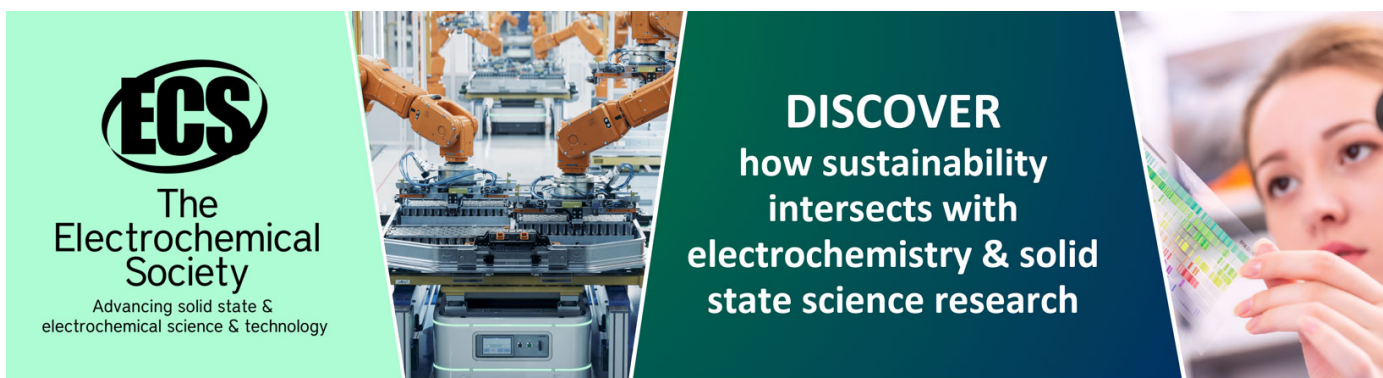
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To cite this article: Zhang Xiaoxin *et al* 2020 *IOP Conf. Ser.: Earth Environ. Sci.* **510** 042036

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Current Status of Technology and Standards of Sludge Recycling in China

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Abstract: This paper sorts and analyzes current states of technologies and standards, existing problems and demands of the sludge recycling industry in China, in order to further promote the establishment of sludge recycling standard system in China, standardize key technologies, devices and processes of efficient sludge recycling, and promote the application and utilization of advanced technical equipment, thus providing solid technical support and guarantee for the enhancement of overall performance level and pollutant up-to-standard emission of sludge recycling industry in China.

1. Current Status of Technologies of Sludge Recycling in China

Along with economic development and constant promotion of urbanization progress in China, there will be more and more urban sewage and wastewater; as the byproduct of wastewater treatment, the amount of sludge will also be increased rapidly. Meanwhile, the requirements of people for living environment are constantly enhanced, and whether the sludge can be treated properly will directly influence environmental benefits of wastewater treatment. For a long time, in construction of sewage plant in China, people always “emphasize water but neglect sludge”, so the sludge treatment technology has been halt. In 2015, the annual output of urban sludge reached 35 million tons, with the year-on-year growth of 16%, but effective treatment rate of sludge is only about 30%.

The disposal of sludge has become a more and more difficult task. Traditionally, the final disposal methods for sludge are shown as below: landfill, compost and combustion. The sanitary landfill is low-cost, with simple method, accounts for a large proportion in sludge disposal. However, the sludge is not eliminated thoroughly, especially that the organic toxic matters and heavy metals will pollute underground water and soil. France has prohibited landfill of sludge since 2002. The compost can degrade organic matters in sludge, and can be used as farmland fertilizers, but it requires a large land area, and will release foul gas, and cannot degrade heavy metal elements, which may cause environmental pollution. Incineration is one of the methods that may deal with sludge thoroughly, but its disposal cost is high, and there may be secondary pollution problems due to dioxin and flying ash during combustion, and the EU has issued multiple laws and regulations to limit the application and management of sludge incineration technology. The traditional disposal methods have their own limits respectively, and there are a series of problems, for example, the harmless treatment of pollutants is not thorough, the soil waste is severe, the treatment cost is high, and there is potential secondary pollution. Therefore, along with constant enhancement of sludge disposal standard, there shall be sludge disposal method which is more efficient and environment-friendly. The sludge pyrolysis can not only reduce sludge amount greatly, but cause less secondary pollution and has lower cost compared with combustion. In addition, it adapts to various scales of sludge disposal. Meanwhile, the pyrolysis can realize sludge



resourcing, and the pyrolysis residue can be used as absorbent, and both pyrolysis gas and pyrolysis oil can be used as energy for collection and utilization.

To solve insufficiency of existing sludge treatment technology, the sludge pyrolysis technology has become a new research direction globally. The sludge pyrolysis technology is a kind of sludge treatment disposal technology which develops rapidly in recent years; through this technology, the dewatered and dried sludge undergoes pyrolysis under high-temperature and anaerobic conditions, and the macromolecules of organic matters in sludge are decomposed into micromolecule matters, and the existing form becomes liquid or gas from original solid status. If the pyrolysis reaction is through sufficiently, the sludge pyrolysis products can be transferred into solid product and gas product. Compared with traditional sludge treatment technology, the advantages of sludge pyrolysis are shown as below:

(1) The harmless effect is good. There is no dioxin during the process. During incineration, there are four ways which may generate dioxin: direct release, high-temperature gas phase generation, solid catalyzed synthesis of precursors, and de-novo synthesis. The direct release means that the dioxin in the solid waste still exists after incomplete decomposition and damage during incineration, and compared with the dioxin generated in other ways, the amount of this part is very small. For the generation of high-temperature gas phase, different predecessors of dioxin (such as chlorophenol and polychlorinated biphenyl) react with each other at high temperature and under oxygen, thus generating dioxin. The solid catalyzed of predecessor means that dioxin predecessor is generated under the function of catalyst (metal or its oxide) at low-temperature combustion region. The de-novo synthesis means that the dioxin is generated through oxidation and condensation reactions of basic elements (carbon, oxygen, chlorine and hydrogen) which form dioxin under the function of catalyst.

From above four processes which form dioxin, it can be known that the conditions for generating dioxin include: basic elements (carbon, oxygen, chlorine and hydrogen) or predecessor which form dioxin, a certain temperature scope, metal catalyst, and oxygen required by oxidation. The pyrolysis process is conducted under the reduction condition, which can effectively inhibit synthesis of dioxin. Secondly, after purification treatment, there is no substance (metal or its oxide) which has the catalytic function in the pyrolysis gas. The high-temperature combustion process is a thorough and clean oxidation process.

In addition, the organic matters in sludge are all decomposed into micromolecule matters and carbon completely at the high-temperature anaerobic conditions; wherein, the micromolecule matters can be lightened directly; after combustion, the organic matters can be decomposed thoroughly; in the products, there are some pollutants containing nitrogen and sulfur elements, but they are all oxide micromolecules, which can be eliminated through simple harmless processes. Finally, the sludge pyrolysis is in favor of heavy metal solidification. The heavy metal elements which may exist in sludge react with silicon, oxygen, aluminum and other relevant elements at high temperature, thus generating inorganic compound with extremely high stability and complicated structure, insoluble in water, thus being fixed in sludge pyrolysis solid product. From this, it can be known that the sludge pyrolysis process can eliminate pollution of organic pollutants and heavy metals in sludge thoroughly.

(2) Equipment occupy area is small. The sludge pyrolysis technology adopts high-temperature chemical reaction, so the treatment efficiency is high, and the thorough pyrolysis to sludge can be realized only within a very short time period. Therefore, the sludge pyrolysis equipment occupies a very small area.

(3) Resourcing rate is high. The sludge pyrolysis solid product is a kind of material containing a lot of hole structures and high specific surface area, possesses good absorption performance, can be used as water treatment absorbent and soil improvement agent, and has a certain economic value; the sludge pyrolysis gas product can be used as a kind of excellent fuel after purification, and its calorific value is approximate to that of coal gas, and it can be recycled. From this, it can be known that all the sludge pyrolysis products can be recycled to create economic benefits; meanwhile, they can be used to offset the sludge pyrolysis treatment cost.

2. Current Status of Standards of Sludge Recycling in China

According to statistics, there are 39 standards related to sludge recycling in China at present; wherein, there are 11 national standards and 28 industrial standards. Among national standards, 1 of them is mandatory national standard, and 10 of them are optional national standards. Among industrial standards, 17 of them are urban construction industry standards, 7 of them are mechanical industry standards, 3 of them are petroleum industry standards, and 1 of them is chemical industry standard. The detailed standards are shown in Table 1.

Table 1. Standards in Sludge Recycling Field in China

S/N	Standard No.	Name of Standard	Standard Type
1	GB 4284-2018	Control Standards of Pollutants in Sludge for Agricultural Use	Mandatory National Standard
2	GB/T 23484-2009	Disposal of Sludge from Municipal Wastewater Treatment Plant – Classification	Optional National Standard
3	GB/T 23485-2009	Disposal of Sludge from Municipal Wastewater Treatment Plant – Quality of Sludge for Co-land Filling	Optional National Standard
4	GB/T 23486-2009	Disposal of Sludge from Municipal Wastewater Treatment Plant – Quality of Sludge Used in Gardens or Parks	Optional National Standard
5	GB/T 24188-2009	Quality of Sludge from Municipal Wastewater Treatment Plant	Optional National Standard
6	GB/T 24600-2009	Disposal of Sludge from Municipal Wastewater Treatment Plant – Quality of Sludge Used in Land Improvement	Optional National Standard
7	GB/T 24602-2009	Disposal of Sludge from Municipal Wastewater Treatment Plant – Quality of Sludge Used in Separate Incineration	Optional National Standard
8	GB/T 25031-2010	Disposal of Sludge from Municipal Wastewater Treatment Plant – Quality of Sludge Used in Making Brick	Optional National Standard
9	GB/T 27857-2011	Chemicals – Anaerobic Biodegradability of Organic Compounds in Digested Sludge – By Measurement of Gas Production	Optional National Standard
10	GB/T 34687-2017	Treatment and Disposal Method for Iron-containing Chemical Sludge	Optional National Standard
11	GB/T 36690-2018	Method of Determination for 26 Elements (Copper, Nickel, Lead, Zinc, Cadmium, Chrome, etc.) Content in the Sludge from Industrial Waste Liquid Treatment	Optional National Standard
12	CJ/T 221-2005	Determination Method for Municipal Sludge in Wastewater Treatment Plant	Urban Construction Industry Standard
13	CJ/T 239-2007	The Disposal of Sludge from Municipal Wastewater Treatment Plant – The Classification	Urban Construction Industry Standard
14	CJ/T 247-2007	Quality of Sludge from Municipal Wastewater Treatment Plant	Urban Construction Industry Standard
15	CJ/T 248-2007	The Disposal of Sludge from Municipal Wastewater Treatment Plant – The Quality of Sludge Used for Afforestation in Gardens or Forests	Urban Construction Industry Standard
16	CJ/T 249-2007	The Disposal of Sludge from Municipal	Urban Construction

		Wastewater Treatment Plant – Sludge Quality for Co-land Filling	Industry Standard
17	CJ/T 289-2008	The Disposal of Sludge from Municipal Wastewater Treatment Plant – The Quality of Sludge Used in Making Brick	Urban Construction Industry Standard
18	CJ/T 290-2008	Disposal of Sludge from Municipal Wastewater Treatment Plant – Quality of Sludge Used in Separate Incineration	Urban Construction Industry Standard
19	CJ/T 291-2008	Disposal of Sludge from Municipal Wastewater Treatment Plant – Quality of Sludge Used in Land Improvement	Urban Construction Industry Standard
20	CJ/T 309-2009	Disposal of Sludge from Municipal Wastewater Treatment Plant – Control Standards for Agricultural Use	Urban Construction Industry Standard
21	CJ/T 314-2009	Disposal of Sludge from Municipal Wastewater Treatment Plant – Quality of Sludge Used in the Production of Cement Clinker	Urban Construction Industry Standard
22	CJ/T 362-2011	Disposal of Sludge from Municipal Wastewater Treatment Plant – Quality of Sludge Used in Forestland	Urban Construction Industry Standard
23	CJ/T 507-2016	Peripheral Drive Thickener for Gravity Sludge Thickening Tank	Urban Construction Industry Standard
24	CJ/T 508-2016	Belt-filter Press for Sludge Dewatering	Urban Construction Industry Standard
25	CJ/T 510-2017	Standard for Sludge Stabilization Treatment of Municipal Wastewater Treatment Plant	Urban Construction Industry Standard
26	CJ/T 540-2019	The Suspending Center Driving Thickener for Gravity Sludge Thickening Tank	Urban Construction Industry Standard
27	CJ/T 3014-1993	The Suspending Center Driving Sludge Scraper for Gravity Sludge Thickening Tank	Urban Construction Industry Standard
28	CJ 3025-1993	Wastewater and Sludge Disposal Standard for Municipal Wastewater Treatment Plants	Urban Construction Industry Standard
29	JB/T 11245-2012	Fermentation Warehouse with Turn and Aeration Equipment for Sludge Compost	Mechanical Industry Standard
30	JB/T 11824-2014	Advanced Dewatering Equipment for Sludge	Mechanical Industry Standard
31	JB/T 11825-2014	Technical Specification for Incinerator of Sludge from Municipal Wastewater Treatment Plant	Mechanical Industry Standard
32	JB/T 11826-2014	Technical Specification for Sludge Incineration Treatment of Municipal Wastewater Treatment Plant	Mechanical Industry Standard
33	JB/T 11832-2014	Drum-type Screw Sludge Thickening Equipment of Wastewater Treatment Plant	Mechanical Industry Standard
34	JB/T 12578-2015	Multi-disc Screw Press Sludge Dewatering Machine	Mechanical Industry Standard
35	JB/T 13171-2017	Blade Dryer for Sludge Drying	Mechanical Industry Standard

36	SY/T 6851-2012	Code for Design of Oil Field Oily Sludge Treatment	Petroleum Industry Standard
37	SY/T 7300-2016	Technical Specifications of Oily Sludge Treatment and Pollution Control for Onshore Oil & Natural Gas Exploitation	Petroleum Industry Standard
38	SY/T 7301-2016	Pollution Control Requirements of Oily Sludge Recycling and Utilization for Onshore Oil & Natural Gas Exploitation	Petroleum Industry Standard
39	HG/T 5364-2018	Determination of Copper Content in Copper-containing Sludge	Chemical Industry Standard

As shown in Table 1, the sludge pyrolysis equipment is developing rapidly, while the research and development of standards about sludge pyrolysis equipment and system operation performance are still lagged, and there is a lot of vacancy to be filled up. The sludge pyrolysis industry lacks technical standards about monitoring and evaluation to technical and economic properties of advanced equipment and operation performance of complete set of equipment, so the advanced technology and equipment cannot be promoted, which hinders the technical reformation and industrial development of the industry. Therefore, the research and development of national standards about sludge pyrolysis equipment and system operation performance need to be conducted urgently, so as to promote large-scope promotion and application of sludge pyrolysis equipment, thus generating the following benefits:

(1) Leading Technical Advance and Filling up Vacancy of the Standardization of Sludge Pyrolysis Resourcing

The equipment of industrial sludge pyrolysis resourcing has been greatly promoted and applied in municipal sludge and oily sludge fields, and the development of relevant standards will make such technology expanded and applied to a wider field. In addition, this standard can promote implementation of energy conservation, emission reduction and clean production of enterprise by matching the implementation of a series of sustainable development policies issued by Chinese government, reducing the discharge of pollutant by enterprise to the environment, and making contribution to environmental protection.

(2) Providing Technical Direction for Enterprises

The standards about sludge pyrolysis equipment and system operation performance evaluation will provide detailed rules on general rules for equipment operation performance and evaluation, evaluation requirements (index system and index value), evaluation method, and evaluation report, and these can be used as technical basis for design, manufacture, inspection and debugging for equipment of sludge pyrolysis resourcing, provide technical direction for manufacturer, lead equipment manufacturer to promote constant completion and improvement of equipment for sludge pyrolysis resourcing, thus enhancing their production and management efficiency.

(3) Standardizing Market and Enhancing Product Competitiveness

On one hand, the development of standards about sludge pyrolysis equipment and system operation performance can supplement the vacancy of such standard in China, while on the other hand, it can standardize the market order, and provide relevant standard basis for engineering tendering and bidding, thus enhancing the product competitiveness.

Acknowledgements

This research was supported by National Key R&D Program of China (Grant No.2018YFF0213200) .

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