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Controlling measures of micro-plastic and nano pollutants: A short review of disposing waste toners

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ABSTRACT

Micro-plastic and nano-particle have been the focal pollutants in environmental science. The printer toner is omitted micro-plastic and nano pollutant. It is comprised of micro polyacrylate styrene and nano-Fe_3O_4 particles. Polyacrylate styrene and nano-metal were proved to be irreversibly toxic to biological cells. Therefore, toners have the potential environmental risk and healthy harm due to include micro plastics and nano-metal. To our knowledge, few studies provided the specific collection and treatment of micro-plastic pollutant. This paper has chosen a kind of micro-plastic and nano pollutant toxic toner and provided technical guidance and inspiration for controlling the micro-plastic and nano pollutants. The method of vacuum-gasification-condensation was adopted for controlling the micro-plastic and nano pollutant toner. We believe this review will open up a potential avenue for controlling micro-plastic and nano pollutants for environmental protection.

1. Introduction

Micro-plastic and nano-particle are widely used in various fields, such as drug carriers, semiconductors, clothing and cosmetics ect, involved various aspects of the social production and life. However, the security of micro-plastic and nano-particle appears to be ambiguous and unoptimistic (Nel et al., 2006; Nel et al., 2009). A large number of non-degradable plastics enter the marine environment and progressively evolve into micro plastic particles (< 1 mm) or even smaller (Law and Thompson, 2014; Julia, 2014; Sacha, 2016). On the other hand, nanotechnology is widely used in electronic products. However, with the increasing amount of electronic wastes, nanotechnology has begun to expose the negative effects, such as toner particles in the printers. Toner will release volatile particulate contaminants in printing process, such as mirco-polyester, nano-Fe_3O_4 and SiO_2. Meanwhile, toner can cause critical contamination once it enters the soil (Ruan et al., 2013). Therefore, this focus is directed towards that how to control and deal with such a large amount of potential discarded toner particles. Currently, the researches on the risk of nanoparticle mainly involves the investigation and ecological or human health risk assessment, concretely focusing on their environmental behavior, ecological effects and nanotoxicology (Ivask et al., 2014; Puzyn et al., 2011; Tsang et al., 2017). Few studies offered the technology of specific collection and treatment of micro-plastic and nanoparticle pollutants. This study aims at proposing representative collection methods and treatment technologies of a novel micro-plastic and nano pollutant toxic toner particles, and provided inspiration for controlling micro-plastic and nano pollutants.

2. Materials

2.1. Waste toner

The waste toner obtained from the recycled waste toner cartridge. The initial contents of toner were shown in Table 1.

The toner was composed of four parts including polyacrylate styrene copolymer, ethylene-propylene copolymer, Fe_3O_4, and SiO_2. Among them, polyacrylate styrene copolymer accounted for 55–60%, as the main organic component of the waste toner, Fe_3O_4 accounted for 25–30%, as the main inorganic component of the waste toner.

3. Methods

3.1. Characterization methods

Thermal field emission scanning electron microscope (Quanta 400F) was employed to show the morphology and particle size of toner particles. X-ray photoelectron spectroscopy (ESCALab250) showed elements that the toner contains. The thermogravimetry (NETZSCH, TG209F1 libra) and the one coupled with the Fourier transform infrared

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Table 1
Components of waste toner from waste-toner cartridges.

	Component			
	Polyacrylate styrene copolymer	Ethylene-propylene copolymer	Fe_3O_4	SiO_2
Weight %	55–60	2–4	25–30	1–3

spectrometry (Bruker, EQUINOX 55) were employed to test thermodynamic properties.

3.2. Observations of the internal section of toner particles

Tweaking of the toner particles was done under an ultrathin microtome (Leica, EM UC6/FC6). The epoxy resin was used to infiltrate and embed the toner for 72 h, and then the flakes were obtained using a 230 mesh carbon-plated copper mesh. Slice samples were observed with a field emission scanning electron microscope (FESEM, Zeiss/Bruker, Gemini 500). The Inlens probe and the Esb probe were employed, which enable imaging of the topography of the sample with a high resolution at low voltages.

4. Results

According to our recent work, we proposed a set of technology to recover and dispose the waste toner. First, we have established and validated a production line for recovering resources from waste toner cartridges (Ruan et al., 2013; Ruan et al., 2011; Ruan and Xu, 2011). Waste toner cartridge contains materials with different physical properties, including 8 wt% residual toners, 45 wt% magnet metals, 12 wt% aluminum and 35 wt% plastics (Ruan and Xu, 2012). The recovery process involved shearing process, magnetic separation, and eddy current separation. The recovery process was shown in Fig. 1, the waste toners were separated by cyclone separator, the magnet metals were separated by magnetic separator, and the aluminum and the plastics were separated by Eddy current separator. The waste toner cartridges are crushed to 10 mm or less of particle size in crusher. Then the mixture of crushed toner cartridges was sent into the magnetic separator. In the two processes, the cyclone separator directly connected with the crusher and magnetic separator, under the action of wind, the waste toners were separated from the mixed crushed cartridges. We improved cyclone separator that make it can provide a negative pressure during the separation, improving the recovery efficiency and avoiding diffusion of toners into environment (Ruan et al., 2011). Moreover, we conducted an environmental benefit analysis of the above production line. The crushing and separation processing employed the airtight and soundproof design. Noise emission level reduced to 67.6 dB (A), meeting the control standard of industry and business enterprise (GBJ87-1985) (GBJ87-1985) in China. TSP tests showed that organic components were safe at 0.026 mg/m^3, without toner leaking into the environment, meeting the first level criterion of National Ambient Air Quality Standard (GB 3095-2012) in China (Ruan et al., 2013). We had demonstrated that the collection efficiency of toners in this line is up to 95%, and the other 5% remain in the closed system. The total working power of the production line was 190 kW/h, the recovery capacity was 500 kg/h and the recovery rate was 98.2%. Waste toner cartridges are usually replaced and remanufactured by specialized companies, so it provides the feasibility to gather the residual toners in cartridges for centralized treatment.

Toners are the major environmental pollutant of waste toner cartridges and they easily spread into the air due to their non-agglomeration and insolubility in liquid properties partly due to the toner particle size in 5 μm. In order to prevent from diffusing into the environment again, we innovatively adopted vacuum gasification to obtain the harmless and high value-added recycling of toners. Under high temperature and vacuum conditions, the hazardous toner was heated. When the temperature reached a certain value, the organic components

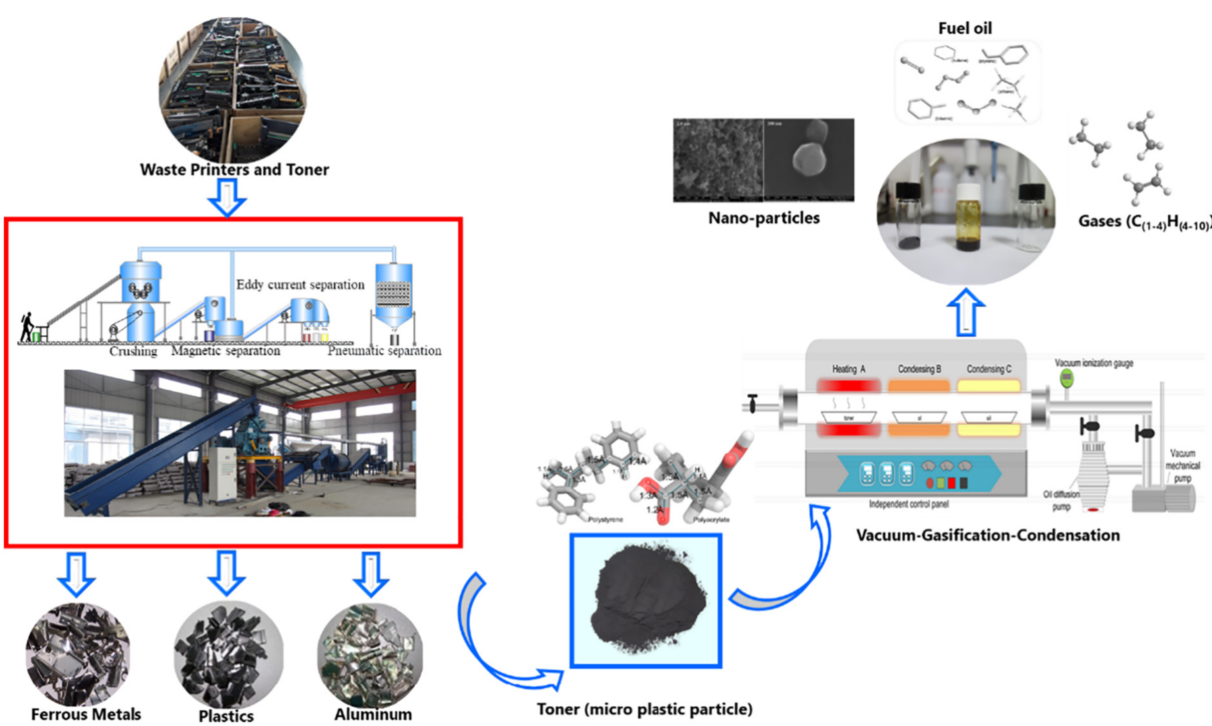

Fig. 1. In the left part, schematic illustrations of the crushing and separation production line of waste cartridges. The production line mainly includes closed crusher, magnetic separator, eddy current separator, cyclone separator and bag filter, to select the magnetic metal and non-ferrous metal respectively. The waste toner cartridges are crushed to 10 mm or less of particle size. Cyclone separator directly collects toner particles from the crusher and magnetic separator. In the right part, the prepared oil, gas, and residual solid are collected effectively through the three-temperature vacuum gasification process. SEM observations of residue show that nano-Fe_3O_4 particles were obtained, with a homogeneous particle size of 150 nm.