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Editorial

Special Issue on "Resource Recovery and Harmless Treatment Processes for Industrial Organic Pollutants"

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Industrial transformation has brought about huge changes to the human society in many different aspects. During industrial production, a large amount of organic and inorganic substances are used as raw chemicals or produced as products. However, when these chemicals are released or discharged to the environment, this leads to serious environmental pollutions, such as wastewater, solid wastes, and polluted gases (i.e., VOCs, H_2S, NO_X, etc.). Intrinsically, these pollutants or wastes are resources which can be recovered as new products. There are many different recovery methods or processes being proposed to recover these organic materials from different mixtures, including extraction, adsorption, absorption, distillation, membrane separation, hydrothermal conversion, microbial extraction, flotation, combustion, or combined processes, etc. A large number of functional materials and pieces of equipment have also been developed for application in the above separation and conversion processes, and some of these techniques have already been applied in industry. These advancements in pollutant treatment can provide more insights into developing recovery and harmless treatment technologies, as well as their potential applications.

This Special Issue of *Processes*, entitled "Resource Recovery and Harmless Treatment Processes for Industrial Organic Pollutants", showcases advances in the development and application of processes for resource recovery and the harmless treatment of industrial pollutants. We have collected 11 papers for the publication in this Special Issue. The SI is available online at: https://www.mdpi.com/journal/processes/special_issues/industrial_organic_pollutants_treatment_processes (accessed on 10 November 2022).

1. Treatment of Waste Oil–Water Mixture

Oil–water emulsions or mixtures are widely generated in industries. In positive sense, this has the potential to facilitate a number of processes. (e.g., transportation of heavy oil, storage of milk, synthesis of chemicals or materials, etc.). In negative way, this can lead to serious upgrading or environmental issues (e.g., pipeline plugging, corrosions to equipment, water pollution, soil pollution, etc.). In practice, due to the complex composition, the treatment for this kind of oil–water mixture is highly technology-dependent.

In a paper by Tian and co-workers [1], the authors systematically summarized the sources, classification, formation, stabilization, and separation of oil–water emulsions. Additionally, they overviewed the introduction of some industrial equipment and advanced combined processes. They also discussed the gaps between demulsification processes and industrial applications. Finally, the development perspectives of oil–water treatment technology are discussed for the purpose of achieving high-efficiency, energy-saving, and multi-functional treatments. This review paper has the potential to bring forward the challenges in and opportunities for future research in the fields of petroleum production, coal production, iron making, and environmental protection (treatment of oily water and

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oil–sludge, etc.), etc. This review will help the young students and engineers to quickly understand emulsions.

In the petroleum industry, the breaking of heavy oil emulsions is considered to be among the challenges during oil exploitation due to the high content of asphaltenes in heavy oil emulsions, as well as their high densities and viscosities. Zou and co-workers [2] investigated the demulsification behaviors of HYW (Hong Yi Wu line) heavy oil emulsion in Xinjiang Oilfield (Karamay, China), which could not be demulsified even at 90 °C with 260 mg/L demulsifier concentration due to its high viscosity (up to 120,000 mPa·s at 40 °C). They developed a new thermochemical demulsification process for this kind of emulsion. They used SE low-viscosity oil (640 mPa·s) as blended oil to reduce the viscosity of the heavy oil. In this way, after optimization, the viscosity of heavy oil could be reduced to less than 1000 mPa·s when the content of SE line was 30% at 80 °C. The authors applied this method in field tests, obtaining a demulsification efficiency over 90% when the demulsifier concentration was 160 mg/L. This experiment lays a foundation for the demulsification of highly emulsified crude oil developed by heavy oil in a Xinjiang oilfield. It is also a good case for the separation of other heavy oil–water emulsions around the world.

2. Harmless Treatment and Recovery of High-Valued Materials from Wastewater

In industry, different kinds of wastewater are produced that contain large amounts of different toxic materials, such as heavy metals, salts, organic substances, etc., for dissolution or accumulation. These toxic materials lead to serious pollution damage to the environment if discharged directly without treatment. Many different methods have been proposed to treat the industrial wastewater by recovering or degrading the pollutants.

The environmental pollution of phenol-containing wastewater is an urgent problem, especially in the coal chemical industry. Duan and co-workers [3] developed an extraction process using natural deep eutectic solvents to treat the phenol-containing wastewater. In their paper, they synthesized a series of natural deep eutectic solvents with L-proline and decanoic acid as precursors. Natural deep eutectic solvents possess good thermal stability and perform well in extracting phenol (up to 62%) from wastewater under mild conditions. These natural deep eutectic solvents can also be recycled at least 6 times without sacrificing too much extraction efficiency. The promising results demonstrate that natural deep eutectic solvents are efficient in the field of phenolic compound extraction in wastewater.

Dong and co-workers [4] developed a reactive extraction process for the separation of levulinic acid (LA) and formic acid (FA) from the deep hydrolysate of cellulose. In their paper, the kinetic and thermodynamic parameters of the reaction process were studied. They found that the conditions, such as temperature, catalyst dosage, and raw material ratio, exert significant influence on the reaction extraction process. To reduce the energy consumption during the separation, they combined process simulation to optimize the process. They found that reactive extraction can achieve the purpose of efficiently separating levulinic acid and formic acid from the aqueous solution with yields of 99.1% and 99.9%, respectively.

Although different than the use of physiochemical separation for pollutant recovery, the degradation of pollutants is also widely accepted for the harmless treatment of some organic wastewater. Valentina and co-workers [5] used electro-oxidation treatment to decolorize the effluents that contain reactive dyes. They found that when Na_2SO_4 was used as an electrolyte, the discoloration reactions followed first-order kinetics, the values for which were also highly dependent on the concentration of NaCl and dyes in the effluent. The obtained model was applied to two real effluents. The authors evaluated the feasibility of individually treating the effluents from the dyeing process and those from the subsequent wash-off process. Based on the comprehensive evaluation, they recommended mixing both effluents before treatment to improve decolorization, especially when the dye concentration is high.

In addition to the process aids, the reactor is also important for the separation of pollutants from the wastewater. In the work by Li and co-workers [6], a three-dimensional

CFD transient model is established to predicting species concentration distribution in the biodegradation of phenol in an airlift reactor (ALR). The gas–liquid flow in the ALR is determined by the Euler–Euler method coupled with the standard k-ε model, and the bubble size is predicted by the population balance model (PBM). In their model, no empirical methods are needed. Good agreement is found between simulated and experimental results in the literature. Finally, the hydrodynamic characteristics and biodegradation performance of the proposed model in a novel ALR are compared with those in the original ALR. This work will help to develop a novel structure for the reactors.

There are also many inorganic polluted wastewaters. Nikolay and co-workers [7] investigated the physicochemical regularities (kinetics and isotherm) of phosphorus and beryllium recovery by sorbents based on polyacrylonitrile (PAN) fiber and $Fe(OH)_3$ obtained via various methods. They found thar the adsorption of ^{7}Be, ^{32}P, and ^{33}P from seawater matched well with Langmuir, Freudlich and Dubinin–Radushkevich models, respectively. They also obtained the kinetic data and fitted them using kinetic models of intraparticle diffusion and the pseudo-first-order, pseudo-second-order, and Elovich models. In this way, they obtained the optimal conditions for the adsorption process.

3. Resourceful Treatment of Organic/Inorganic Contaminated Solid Wastes

Billions of tons of solid waste are produced and discharged to the environment every year during industrial production and from global social life. Oil sludge is among the solid wastes that is produced from oil exploitation, the coal industry, the steel industry, etc. It is estimated that over 6 million of tons oil sludges are generated every year in China. Different kinds of methods have been proposed to treat the oil sludges, including pyrolysis, washing by water, combustion, solvent extraction, froth flotation, etc.

Ma and co-workers [8] investigated the feasibility of froth flotation in recovering oil from oil sludge in a Shengli oilfield. In this paper, they found that Na_2SiO_3 was the suitable flotation reagent treating the oil sludges. According to their results, increasing flotation time, impeller speed and the ratio of liquid to oil sludge could enhance the pulp shear effect, facilitate the formation of bubble and reduce pulp viscosity, respectively. Under the optimized parameters, the oil content of oil sludge residue could be reduced to as low as 0.6%. Most oil could be recovered. Similarly, Que and co-workers [9] investigated the treatment of cold-rolling oily sludge by pyrolysis, where the oil and iron resources could be recycled. In this paper, they investigated the pyrolysis behavior and volatile products of oily sludge using TG-FTIR and a pyrolyzer coupled with GC/MS. They found that the pyrolysis process could be divided into three stages: the H_2O drying and CO_2 desorption stage (<393 K); the volatilization of low-molecular-weight organics and the covalent bond cleavage of C=C, C-O, and C-H in the medium-molecular-weight organics (393–844 K); and chain scission of the high-molecular-weight organics and reduction of iron oxides by CO (>844 K). They also analyzed the kinetics and products of the pyrolysis for each stage in order to assist them to understand the pyrolysis of oil sludge.

Carlos and co-workers [10] conducted a study to recover valuable metals from Bayer red mud using hydrometallurgical techniques, and subsequently used the solid remaining after leaching as the principal component of fired bricks. In this paper, water, sulfuric acid, and sodium hydroxide were used as leaching agents. The authors conducted a comprehensive study from the aspects of technical, economic, and environmental considerations. After the leaching process, the remaining solids were mixed with clay and water to produce bricks. For reasons of safe application, the environmental safety of the bricks manufactured (leaching of heavy metals and radionuclides) was also studied by the authors. Their results showed that it was more favorable when red mud was treated instead of fresh red mud being used. This work would be a good case study for the treatment of other similar inorganic solid waste.

4. Removal and Recovery of Industrial Waste Gases

During industrial production, not only were wastewater and solids, but some waste gases were also generated, including organic waste gases (i.e., VOCs) and inorganic waste gases (i.e., H_2S, SO_2, NH_3, NO_x, CO_2, etc.). During the past decades, different kind of methods have been proposed and applied for recovering or converting the pollutants in waste gases, including adsorption, absorption, condensation, combustion, pyrolysis, catalytic oxidation, biodegradation, etc.

Liu and co-workers [11] applied absorption to treat natural gas containing acid components (CO_2 and H_2S) and organic sulfur (COS and CH_3SH). They developed a rate-based absorption model coupled with an improved thermodynamic model to characterize the removal of the above components from natural gas with an aqueous sulfolane–MDEA solution. They tested the accuracy of the thermodynamic model and validated the results via the experimental data from the literature, as well as the industrial test data. Based on the validated coupled model, the authors analyzed the total mass transfer coefficient and mass transfer resistance of each solute component at different column positions. The effects of the gas–liquid ratio, overflow weir height, and absorption pressure on the absorption performance of each component were studied. They also found that the improved absorption model could better characterize the absorption performance, which was conducive to the optimal design of the absorber column.

The above papers demonstrate the versatility and technical importance of the area of pollution control for industrial wastes, including the treatments of oil–water emulsions, organic/inorganic contaminated wastewaters, organic/inorganic contaminated solid wastes, and waste gases. Although the basic principles of pollutants treatments are well understood, the articles in this Special Issue address outstanding challenges related to recovery and harmless treatment of industrial pollutants in different ways in terms of both application and theoretical perspectives. Going forward, much remains to be explored. With the enormous variety and number of the applications currently under development, we feel confident for the longevity and future of this subject.

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