Industrial Waste and Adsorption Application: A Mini Review

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ABSTRACT

Expansion of industrial sectors is known to cause waste management problem especially in developing countries. Application of industrial wastes for other purpose is a good approach in reducing the bulk and also practicing circular economy for better consumption of materials. Reuse of industrial wastes in adsorption process is promising since it is a low-cost precursor, offers high efficiency and uses green alternative source. Hence, this paper reviews the potential use of industrial wastes as adsorbents for environmental applications.

Keywords: Industrial waste, adsorption, waste water, flue gas, coal fly ash, steel slag.

1. INTRODUCTION

With the rapid development of industrial activities, a lot of industrial wastes are generated and the management of these wastes is very crucial to avoid any potential concern on environmental and public health. Enforcement of the regulations might be able to curb environmental pollution, but insufficient to cater for environmental issues in landfill and economic sustainability due to the rising costs associated with waste disposal. Thus, instead of practicing the "Cradle to Grave Concept" there is a need to reuse or recover this industrial waste as well as promoting "Cradle to Cradle Concept".

The demand for sustainable green development has led to many researchers starting to find solutions to reuse industrial wastes especially in adsorption studies. In the recent years, industrial solid wastes (fly ash and red mud) have been used to produce low-cost adsorbents for the removal of various contaminants from solutions [1]. In addition, using industrial waste as adsorbent can be considered cost-effective since the material is cheap and made from the waste.

Therefore, in this paper we will review industrial wastes that have potential for use in adsorption studies and parameters that should be considered during the adsorbent preparation.

2. TYPE OF POTENTIAL INDUSTRIAL WASTE

Among the many industrial wastes generated, the most commonly employed in adsorption studies are:

2.1 Coal Fly Ash (CFA)

Coal fly ash (CFA), a solid byproduct generated during the combustion of coal in thermal power plants, serves as a cost-effective resource for silica and alumina [2]. Zeolite prepared using aluminum residue from CFA by hydrothermal synthesis method have higher purity and better crystallinity based on chemical composition analysis [3]. Some modification to fly ash using NaOH and $FeCl_3$ can enhance the adsorptive properties for removal fluoride from water [4]. Zeolization

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of CFA provides a potential alternative for creating high-added- value products. However, the type and purity of zeolite depend on the preparation parameters [5].

Recycling CFA is the best solution that not only prevents environmental concerns, but also creates new economic opportunities [2]. Therefore, exploring CFA as adsorbent is one of the efficient ways to reuse CFA.

2.2 Steel Slag

Steel slag is a byproduct from crude steel smelting process in steel mills manufacturing and mainly composed of the oxides of calcium, silicon, aluminum and iron. This structure give it very strong alkaline properties as well as high adsorption and precipitation capacity [6]. However, most of it is landfilled in an open area which can be released to the air and leached into groundwater. Due to that, extensive research [6][7] has been conducted to turn steel slag from industries as resources.

2.3 Hardened Cement Mortar

Portland cement concrete is a primary substance employed in construction and building activity, with an average consumption of nearly three tons of concrete per person each year and the second-most-used material after water [8]. Due to the massive amount of concrete being produced and the huge amount of demolition waste from old concrete structures, the reuse and recovery of concrete waste by the construction industry is becoming increasingly significant [9]. Hardened cement mortar (HCM) is particles which developed from waste concrete blocks. HCM found in waste concrete can be viewed as a strongly alkaline and calcium-rich multi-mineral aggregate. As a result, it has the potential to be employed for the adsorption and neutralization of sulfur dioxide (SO2) in flue gas [8]. Table 1 summarizes the industrial wastes used as an adsorbent in adsorption studies.

Table 1 Industrial wastes used in adsorption studies

Type of adsorbent/ support	Function	Ref.
Fly ash and coal gangue/ biochar composites	Phosphate removal from aqueous solution	[1]
Zeolite from aluminum residue coal fly ash	Adsorption of volatile organic compounds	[3]
Zeolite from coal fly ash	Acetone adsorption	[5]
Steel slag	Removal of lead from natural water	[6]
Steel slag	SO_2 removal at coal-fired power stations	[7]
Hardened cement mortar	SO_2 removal in flue gas	[8]
Coal fly ash (mesoporous HZSM-5 nano-zeolite)	Elimination of benzene, toluene and m-xylene from aqueous solutions	[15]
Industrial solid waste	Adsorption of heavy metal from industrial effluents	[16]

Other than wastes listed in Table 1, there are still a lot of potential industrial wastes which can be considered and applied in adsorption of environmental contaminants. The materials' capacity in adsorbing contaminants may depend on the industrial waste characteristics and its affinity for certain environmental contaminants.

3. Application of Industrial Wastes in Environmental Resolution

Industrial waste that has good characteristics like large specific surface area and porous structure, particles sizes, high adsorption capacity, high thermal and reversible adsorption may have the potential to be a good adsorbent.

Most of the research reported that pristine industrial wastes need to undergo some process or modification like hydrothermal synthesis [1] and addition of other support [10] which can improve and enhance the existing structure such as specific surface area.

The industrial wastes which have been altered show high potential in removal of pollutants with the adsorption capacity range 0.55 mg/g to 20.6 mg/g from flue gas and wastewater via adsorption process. Coal fly ash-based catalysts and adsorbents have strong capabilities to purify gaseous streams like CO_2, SO_2 and NO_x in flue gas [2], while Chen *et al*. [13] used zeolization ceramsite to remove ammonia nitrogen from wastewater and Ranasinghe *et al*. [4] used Fly ash and coal gangue/biochar composites to eliminate fluoride from wastewater.

The wastes can also be functionalized with chemicals like amine and metal groups to increase the surface properties of the adsorbent.

In addition, there are various other factors also affecting the effectiveness of industrial waste as adsorbent. Parameters that should be considered during the adsorption experiment are temperature, adsorbent loading, pH, contact time, initial concentration of adsorbate, etc.

4. CONCLUSION

This paper focused on the reuse of industrial wastes in adsorption process to promote sustainability in materials production and usage. Researchers have proven that industrial wastes have the capability to be reused, a better approach instead of being sent to landfill as final disposal. Industrial wastes can be altered and functionalized to improve their surface properties for higher adsorption capacity.

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