

Review Article

Sequestration of Ben(a)pyrene from Coking Wastewater - Review

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Abstract

Since coal is the most used commodity for electricity supply, several coal mines have been abandoned. These coal mines have resulted in releasing a chemical compound known as polycyclic aromatic hydrocarbons (PAHs). Coal is the second largest resource after oil, and it has multiple uses in several applications. Coal mining and its impact on the environment has exacerbated the quality of water. Ben(a)pyrene (BaP), one of the most toxic pollutants has been given attention according to the World Health Organization (WHO) as the most toxic pollutant amongst the 16 PAHs that are mostly found in water bodies and contact with humans. It is also known to be highly concentrated in coking wastewater and poses significant health implications of having carcinogenic properties which have urged for its sequestration. Several technologies have previously been employed in mitigating the challenges however, the limitations of these technologies have resulted in suggesting an alternative method that could be introduced. In this review, these techniques are being reviewed and discussed on the fate of BaP-PAHs in coking wastewater. The advanced oxidation method has been considered as the most preferred method in aiding to sequester BaP-PAHs however, some studies have proven that the biological method using mushrooms can be used in sequestering BaP-PAHs. However, the future perspective in determining the fate of BaP-PAHs can be considered in functionalizing the mushrooms with a metal oxide in aiming to sequester PAHs in coking wastewater.

Keywords

Coking, Coal Tar, Wastewater, Polycyclic Aromatic Hydrocarbons

1. Introduction

The abundance of coal mines is the most significant economic, ecologic and hydrologic in a country [1]. In South Africa alone, several abandoned coal mines are still being neglected. The by-product of these coal mines named coal tar which consists of polycyclic aromatic hydrocarbons (PAHs) is making a debut by worsening the water bodies [2, 3].

Their presence influences the physiochemical properties of water bodies, which eventually affect the surrounding environment, including humans. Coal is a conventional source that produces about 70% of electricity [4] particularly in the sustainability of the energy crisis makes it demanding [5, 6]. Figure 1 depicts the importance of coal as the second-largest

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source of energy after oil and the main energy source to generate about 40% of electricity worldwide [7]. It is believed that population growth is directly proportional to the increase in energy consumption [8-10].

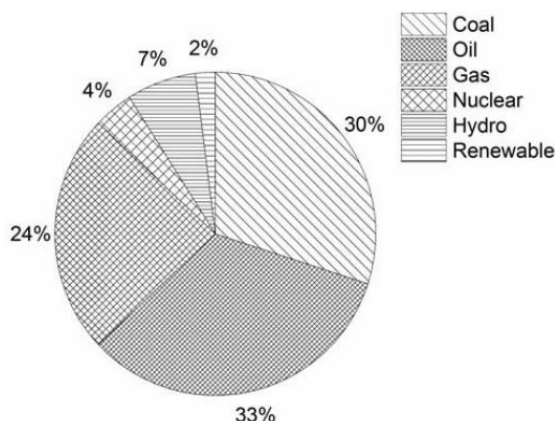


Figure 1. The world's energy consumption dated 2012 [11].

The mining activities sector in the United States of America (USA) contaminates over 20000km of water bodies [12]. A study by Batchamen Mounol, et al. [13] has proven that the leaching of coal tar into various water bodies increased drastically over time due to the physiochemistry properties of the wastewater such as temperature, ionic strength, pH and dissolved organic carbon. The higher dissolution of PAHs coal tar was found in the acid mine drainage followed by alkaline mine drainage.

Wang, et al. [14] reported that, the limitation of six PAHs amongst the 16 such as fluoranthene, benzo(b)fluoranthene, benzo(k)fluoranthene, ben(a)pyrene, benzo(g, h, i)perylene and indeno(1,2,3-cd)pyrene were mostly found in wastewater and that should not exceed $0.2\mu\text{gL}^{-1}$. Ben(a)pyrene (BaP) is recommended as the most harmful pollutant and should not exceed $0.01\mu\text{gL}^{-1}$ as per European Union (EU) and World Health Organization (WHO) regulations.

According to Zungum and Imam [15], 16 PAHs have been classified by the United States Environmental Protection Agency (USEPA) as part of our social life and activities. This review focused on previous approaches conducted to destroy and eliminate PAHs, with emphasis on BaP in coking wastewater. The hazardous level of BaP amongst other PAH families has urged for its removal.

2. Sign Effect of PAHS

PAHs are organic pollutants consisting of two or more fused rings. Their chemical composition has made them undesirable because of their carcinogenic properties and ability to resist biodegradation [16]. This organic pollutant is inevitable since it is commonly found in petroleum-related substances. Additional acute such as lung, complications in res-

piratory, bladder malfunction and skin cancer can be associated with PAHs [17]. Its deposition in the environment has given BaP attention as the most prominent PAH in terms of its high toxicity in comparison to other PAHs [18]. Exposure to PAHs can result in a high possibility of cancer or even fatal death [19].

2.1. Various Methods for Treating PAHs in Wastewater

Various methods have been employed and the advanced oxidation processes (AOP) including a membrane, adsorption, and aerobic and anaerobic bioprocess have been selected as the most effective methods for sequestering PAHs in wastewater. The concentration of PAHs and precisely BaP has been marked as one of the most toxic PAHs. It is vital to employ an effective technique like an AOP that has previously been proven to destroy PAHs.

Coking wastewater contains different chemical compositions deriving from the coking processes with BaP-PAHs being the most predominant organic pollutants. The discharge of immeasurable toxic pollutants into water bodies known as coking wastewater has been given less attention [20, 21].

A study by Saber, et al. [18] used various techniques to remove PAHs from coking wastewater and biological waste was able to remove a substantial amount of PAHs. The study also proves that, the activated material was able to account for the higher removal efficiency of PAHs.

Another study, but this time by Guedes, et al. [22] used chemical oxidation with Fenton's reagent to remove PAHs from coking wastewater. The chemical oxidation process is known as a technique that involves chemical reagents to undergo oxidation with the aid of a light source. The purpose of this process is to produce radicals that are effective in destroying PAHs. In most studies hydrogen peroxide (H_2O_2) is mostly considered a chemical reagent in Fenton's reaction; however, most studies have revealed that, adding metals or transition metals ions can purposely activate H_2O_2 to improve the oxidant potential yield to form hydroxyl radicals (OH^\bullet).

An interesting study by Premnath, et al. [23] reviewed on "Polycyclic aromatic Hydrocarbons - Environmental occurrence and strategies for microbial degradation". The study was mostly focused on several microbial applications aiming for the degradation of PAHs in soil. The study proves that the introduction of microbial was highly compatible with soil to degrade PAHs. The ability of these microbial to produce biosurfactants makes them effective. The biosurfactants consist of hydrophobic and hydrophilic tails allowing them to sequester a wide range of pollutants.

According to Ren, et al. [24], multiple techniques such as coagulation, sand filtration, ultrafiltration, adsorption, nanofiltration and reverse osmosis were aimed at removing selected PAHs in coking wastewater. It was proven that, adsorption was the best technique to be employed however under anaerobic conditions (no oxygen). On the contrary, a

study by Varjani, et al. [25] revealed, the biological method to be the most promising and economical method through adsorption in removing PAHs.

A “comprehensive review of polycyclic aromatic hydrocarbons in water sources, their effects and treatments” by Mojiri, et al. [26] were conducted. Several techniques such as biological, physical and chemical were reported to be assessed in treating PAH in wastewater. It was reviewed that adsorption was the most effective method and even better when coupled with other techniques; in doing that, a removal efficiency of nearly 100% will be obtained.

A review by Yadav, et al. [27] on “mycoremediation of environmental pollutants: a review with special emphasis on mushrooms” was explored. Mushrooms have been given attention due to their enzymatic machinery from their nutrient source as protein, which turns into a valuable mechanism. Mushrooms contain mycelium and extracellular enzymes that can obliterate organic pollutants. The extracellular enzymes possess the functionality of producing free radicals that are prominent for destroying PAHs.

Gaurav, et al. [28] reviewed on the “polycyclic aromatic hydrocarbons (PAHs) migration from wastewater”. The removal techniques were reviewed and discussed. It was found that 99% of the highest molecular weight consisted of 5 or 6 rings while 79% of the lowest molecular weight was removed using 1.64 mL/L of titanium catalyst. From the study, it was concluded that, advanced oxidation and catalytic oxidation were considered the best techniques for removing almost 100%. Based on the evidence, the AOPs incorporated with catalyst were preferred.

Zhang, et al. [29] reviewed “the fate and enhanced removal of polycyclic aromatic hydrocarbons in wastewater and sludge treatment system”. The study highlighted that the lower molecular weight (LMW) PAHs were highly concentrated in wastewater which was easily disassociated while the higher molecular weight (HMW) was concentrated in sludge [13]. The study proves that, the introduction of the microorganism was highly effective in removing LMW in wastewater while the adsorption technique was proved to be effective in removing HMW in sludge.

2.2. Recommendation

From the review, less attention has been given to the fate of PAH in coking wastewater, interesting more attention should given to the mushrooms and probably their functionalization. Although various studies have been conducted using metal oxide, owing to their ability to produce radicals, a similar function using mushrooms could be given priority as the next generation of biological waste that can be employed in improving water quality.

3. Conclusion

It was evidence that the incorporation of biological en-

zymes with metal oxides was proven to be a better approach to sequestering PAHs in wastewater. Overall, adsorption was proven as the most effective followed by the photocatalytic technique. However, less attention has been given to microbial application alone in removing BaP in coking wastewater. The mushrooms were proven to have a similar performance as the metal oxide in producing radicals that are responsible for destroying PAHs.

Abbreviations

PAHs	Polycyclic Aromatic Hydrocarbons
BaP	Ben(a)pyrene
AOP	Advanced Oxidation Processes
LMW	Lower Molecular Weight
HMW	Higher Molecular Weight

Author Contributions

Jean Bedel Batchamen Mognol: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing

Maxwell Mewa: Writing – review & editing

Conflicts of Interest

The authors declare no conflicts of interest.

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