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Review Article

Speculative Study of Possible Natural Remediation Methods for Airborne Poly-aromatic Hydrocarbons Engendering Several Respiratory Diseases in Humans: A Review

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ABSTRACT

Polycyclic aromatic hydrocarbons (PAHs) have carcinogenic, toxic and mutagenic traits. They are generated during incomplete combustion of coal, oil, petrol, volcanic activities, and wood. The metabolism of PAHs transpires through oxidation or hydroxylation of the cytochrome P450-mediated mixed-function oxidase system. Technologies such as air purifiers and air filters are now available in the market, but it is strenuous for a common man to afford due to its higher cost. Heretofore, researchers have not been able to find low-cost effective remediation techniques for airborne PAHs which requires sincere attentiveness. The objective of this article is to propose a penny-wise and environmentally friendly remediation method for airborne PAHs. In this review article, it is hypothetically suggested that the plants which can influentially play a significant remediating role against benzene can also be effective in exterminating the polyaromatic hydrocarbons from the environment.

Key words: Polycyclic aromatic hydrocarbons, Pollutants, Air pollution, PHYTO-remediation, Indoor and outdoor.

1. INTRODUCTION

Polycyclic aromatic hydrocarbons (PAHs) belong to the subcategory of polycyclic organic matter. They posses only one hydrogen and one carbon, and belong to a large class of organic compounds [1]. They are categorized under organic chemicals and have two bonded polyaromatic hydrocarbon benzene rings or more than two bonded benzene rings. PAHs are divided into two parts according to their molecular weight [2]. Lower molecular weight polycyclic-aromatic hydrocarbons have 2–3 aromatic rings. They exist in the environment in form of the vapor phase, whereas higher molecular weight polycyclic-aromatic hydrocarbons have five or more aromatic rings. Higher molecular weight PAHs are abundantly found in nature and bind with the particles present in the environment [3]. They are originated in the atmosphere from the incomplete combustion of organic substances. For instance, biomass [4], coal, fossil fuel (Figure 1) [5], agricultural and industrial activities, and mining or natural geo-genic inputs are the primary component of it [6,7].

The adversity of PAHs is increased when it gets bounded with soils, sediments, and air particulate matter [7].

Polyaromatic hydrocarbons are omnipresent and pervadative contaminant obtained from the igniton of fossil fuels in heat along with power generation, refuse burning, coke ovens, and motor vehicle operation [8,9]. They are also produced from fuel pools, open biomass burning, and the combustion of polymers [10,11]. Naturally, they are made from volcanoes or hydrothermal methods and forest fires [1-14]. Most of thePAHs have potent carcinogens that results in biological and mutagenic effects in the human body (Figure 2) [15].

It is reported that most of the particle bond-sized PAHs are linked with small-sized particulate chemicals that enter the respiratory system in the form of aerosol [16]. Many researchers also reported and estimated that the spreading of 3–20% of the PAHs in the atmosphere is governed by the air. Air acquires the second position after food in spreading polyaromatic hydrocarbons among humans and in the environment. It was estimated by Menzieef al. that the range of inhalation of potential dose of the carcinogenic PAHs lies in between 0.02 μg/day and 3 μg/day accompanied by a median value of 0.16 μg/day, which is 20 times more than the estimated food close and 25 times more than of the potential dose with drinkable water [3,17].

Exposure to PAHs through the air is the root cause of many respiratory illnesses, for instance, chronic obstructive pulmonary disease, asthma, respiratory infections whereas in extreme cases, lung cancer is the most common [17,18]. But in the era of advanced technology, everything is attainable. Natural methods such as bioremediation, green roofs, outdoor-indoor plantation are possible methods through which we can combat the PAHs toxicity from the air. This review paper will discuss a speculative study on possible natural methods to combat polycyclic-aromatic hydrocarbon toxicity from the air.

2. SOURCES OF PAHS AND THEIR ANALYSIS

Mostly polycyclic-aromatic hydrocarbons are generated from the combustion of fossil fuels and materials that contain hydrocarbons [19,20]. The combustion process is divided into two types of mechanisms. The first is "pyro-synthesis" of polycyclic-aromatic carbon from the

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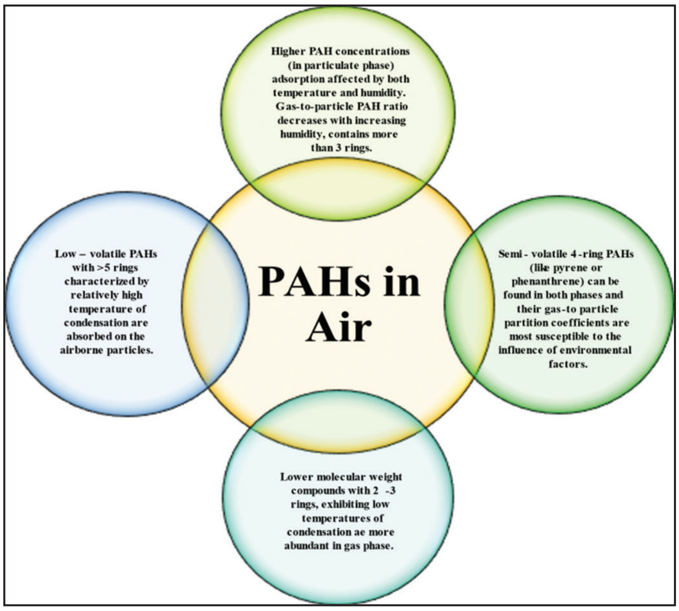

Figure 1: Types of polycyclic aromatic hydrocarbons and their contaminating properties.

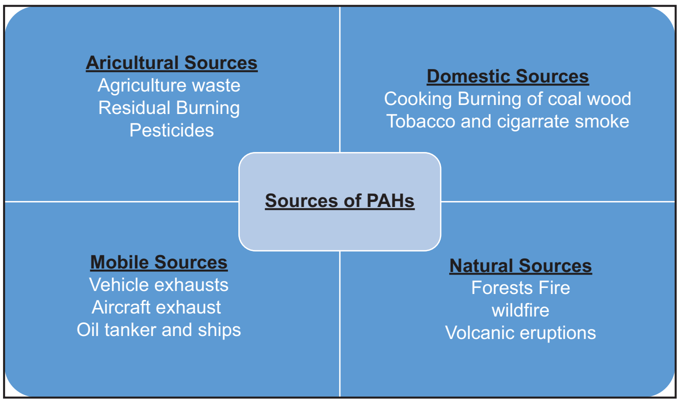

Figure 2: Possible airborne sources of polycyclic aromatic hydrocarbons.

aliphatic and aromatic hydrocarbon species. The second is "Survival" PAHs within starter fuel (Figure 3). "Priority Pollutants" designated by the 16 United States Environmental Protection Agency and European Union becomes the standard ensemble of compounds entailed in many environmental researchers of polycyclic aromatic hydrocarbons. The 16 PAHs are; acenaphthylene, naphthalene, acenaphthene, phenanthrene, fluorene, anthracene, fluoranthene, benzo [*b* and *k*] fluoranthene, benzo [*a*] pyrene, benzo [*ghi*] perylene, chrysene, pyrene, dibenzo [*a,h*] anthracene, benzo [*b* and *k*] fluoranthene, indeno [1,2,3-*cd*] pyrene.

The main purpose of selecting the sixteen PAHs is to determine the concentration of the PAHs in an environment [21].

PAHs in environmental matrices can be measured using analytical methods. Measurement of PAHs is a tedious task. This complexity arises when we categorize environmental samples into different phases such as gaseous or particulate matter (air), organic fluids or oil, sludge or solids, biological, and multiphase samples.

Usually, multiphase samples require phase separation before initiating the analytical process, i.e., filtration. Chromatographic techniques (Table 1) are pretty valuable for the extraction of the PAHs from the environmental samples that include gas chromatography or liquid chromatography, respectively [22].

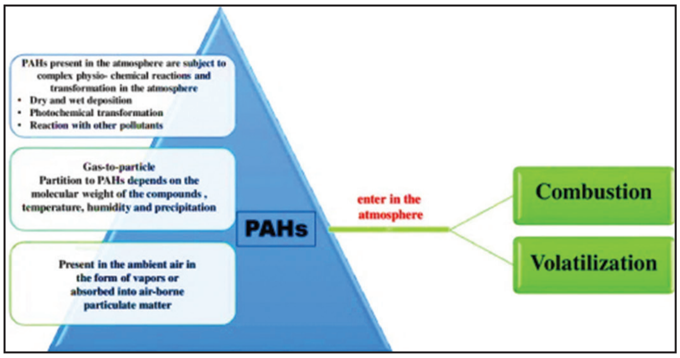

Figure 3: Combustion process of polycyclic aromatic hydrocarbons.

3. CONSEQUENCES ON EXPOSURE TO AIRBORNE POLYCYCLICAROMATIC HYDROCARBONS

Exposure to PAHs leads to the development as well as exasperation of several non-malignant respiratory illnesses [17,18,23-25], including obstructive lung diseases, asthma, impaired respiratory functions, and risk of respiratory infections. It is estimated that asthma has been affecting every eight children worldwide (Table 2) [26]. Study conducted in the region of the Czech Republic showed the excessive concentration of PAHs. It was found that prenatal PAHs exposure causes higher respiratory morbidity and intrauterine growth retardation in the area [27]. Another study conducted in Krakow, Poland reported the vulnerability to airborne PAHs results in reduced birth weight [25]. Many other studies also said, the utero-exposure of offspring to the PAHs abnormally regulates the development of lungs which outcomes respiratory symptoms early after birth [28]. Therefore, it is understandable from the above data that the circulation of the toxicant can be transmitted from the pregnant woman to the offspring from inhalation and food containing PAHs.

4. CONSEQUENCES ON EXPOSURE TO PAHS

Experimental reports suggested that PAHs are also responsible for increased susceptibility to bacteria and viruses. Exposure to PAHs can influence innate and adaptive immune responses, i.e., disruption of immunity. These deteriorations will reduce the ability to recognize pathogens and killing, abnormal cytokine release, and surface receptor expression to pathogen products [41]. Other factors such as reduced mucociliary clearance, lung epithelial barrier, Th2- skewed response, abnormal clearance of infectious agents [42], and retarded recovery from the severe disease are also caused by PAHs exposure [28,29].

It has been reported, the concentration of PAHs varies seasonally. Most of the time, it is said that the PAHs concentration is more remarkable in the indoor environment than outdoor. Menichini *et al*. conducted a study to assess the pertinence of the indoor air in benefaction to the extensive exposure of the urban population, in which they have found, the concentration of benzo[a] pyrene (BaP) was higher in the indoor environment (0.1–4.6 ng m^{-3}) than outdoor (0.7–2.3 mg m^{-3}) [31]. Masih *et al*. measured the concentration of 23 PAHs in indoor and outdoor environments of ten homes near the roadside and urban sites in the north-central part of India. They have found that the concentration of total PAH (TPAH) in the urban areas is 1946.84 ng/m^3 in the kitchen >1666.78 ng/m^3 in the living room >1212.57 ng/m^3 in outdoor [30]. Naumova *et al*. represent the data of collected samples within the relationship of Indoor, Outdoor, and Personal Air study. The total PAHs concentration ∑ PAH in the outdoor was 4.2–64 ng m^{-3} in Los Angeles <10–160 ng m^{-3} Houston < and 12–110 ng m^{-3} in Elizabeth [32], whereas in the indoor samples, the concentration

Table 1: Chromatographic technique for analysis of polycyclic aromatic hydrocarbons.

S.NO.	PAHs	Chromatographic techniques	References
1.	16 EPA PAHs	HPLC-FLD	Payanan *et al.* 2013 [36]
2.	16 EPA PAHs	GC-MS	Fromberg *et al.* 2007 [37]
3.	15+1 EU PAHs	GC/GC TOFMS	Purcaro *et al.* 2007 [38]
4.	BaP (Benzo[a] pyrene)	GC-MS; HPLC (DACC)-FLD	Bogusz *et al.* 2004 [39]

Table 2: Consequences on exposure to PAHs

Short term	Long Term
Vomiting	Cataracts
Nausea	Hemolysis due to naphthalene
Skin irritation	Decreased Immunity towards Heart and Lung disease
Eye irritation	Pulmonary abnormalities
Confusion	Liver damage

of ∑PAH 21–310 ng m^{-3} in Houston >22–350 ng m^{-3} in Elizabeth >16–220 ng m^{-3} in Los Angeles [32].

Whether it is outdoor or indoor, the presence of PAHs is injurious to the environment. Using QMA quartz filters, we can determine the concentration of particulate matter (PM 2.5 and PM 10) in the air. However, only a few methods have been invented to combat airborne PAHs from this perspective.

Analyzing airborne poly-aromatic hydrocarbons in the environment is possible, but the exact and cost-effective remediation method still needs some more research. High prized air filters, for instance, CM265, City-Flo F7, CM285, and CM295 (product of Camfil-AB) [33], are used in ventilation systems for hospitals, offices [32], public buildings, and dwellings [32]. Still, we cannot use these filters in typical homes as not everyone can buy them. That"s why we proposed, a high cost-effective methods, to combat airborne PAHs from the environment.

Several studies have been made to get rid of gaseous PAHs from the air, but all are not economical. A new technique named as bioremediation, also known as the waste management technique, involves plants and organisms to neutralize or eradicate pollutants from polluted sites (air, soil, and water). Here, we have discussed one cost-effective natural remediation or also called phytoremediation method to eliminate airborne PAHs from the environment. PAHs, by definition, have multiple fused cycles of benzenes. Although benzene, PAHs are different in terms of chemical and physical properties but due to benzene's primary aromatic unit, we can assume, the plants which are effective in eradicating benzene from the air can also help in the remediation of airborne PAHs.

Hedera helix (English ivy), *Epipremnumaureum* (Money plant), *Spathiphyllumwallisli* (Peace lily), *Aglaonema modestum* (Chinese evergreen), *Sansevieria trifasciata "Laurenti"* (Snake plant), *Dracaena marginata* (Red-edged dracaena), *Gerbera famesonii* (Borberton daisy), *Chrysanthemum monfolium* (Florist's Chrysanthemum), *Aloe vera* (*Aloe vera*), and *Dracaena deremensis "*Warneckei" (Warneckei) are the eleven natural indoor purifiers which are effective against air pollutants such as benzenes and may be for PAHs (Figure 4) [34].

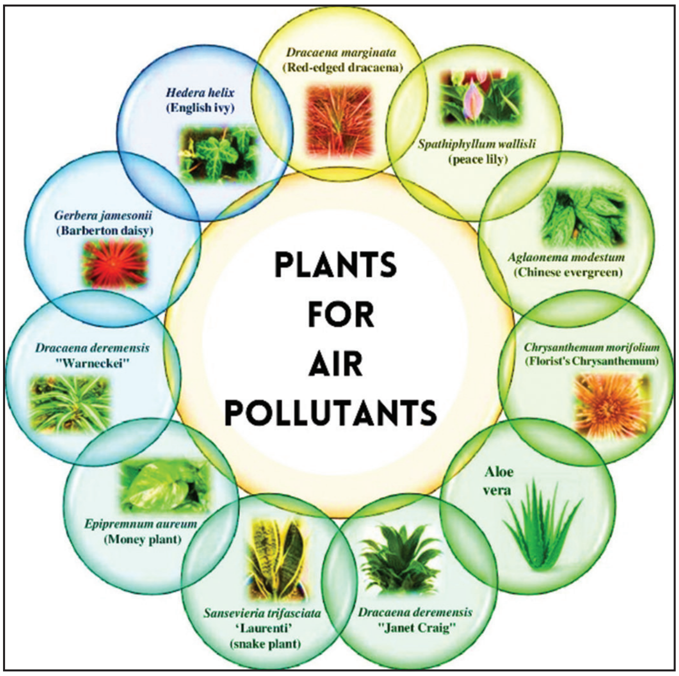

Figure 4: Eleven natural purifiers that could be effective against airborne polycyclic aromatic hydrocarbons.

Ficus benjamina (Weeping fig), *Chamaedorea elegans* (Parlor Palm), *Dracaena warneckii* (White Jewel), English Ivy, *Barberton Daisy* (Gerbera Daisy) are some more outdoor-indoor plants that may be effective against airborne PAHs as they are effectual against benzene. Hence, it is necessary to conduct intense research on the above hypothesis in order to examine the efficiency of the suggested that can act against airborne PAHs.

5. CONCLUSION

PAHs are present either in the form of vapor or a particulate form. They also have the property to evaporate from the soil to air and travel a long distance before the particle settling and getting mixed with rainfall. PAHs enter through lungs and it is yet unidentified that how quickly their spreading occurs in the respiratory system [41]. It is estimated that 100,000 deaths due to carcogenic PAHs exposure [39], and unfortunately, the cases of death due to lung cancer is increasing every year. The inefficacious and polluting household energy systems lead to hazardous environmental impacts; therefore, cost-effective strategies to combat airborne PAHs pollution are essential, especially for below poverty line citizens. This hypothesis is anticipated to benefit both the environment and humanity as it provides opportunities for practicing cost-effective and less complex natural remediation methods. It is assumed that the above proposed eleven natural air purifiers are capable of removing the airborne PAHs but not completely successful to remediate the airborne pollutant from the indoor or outdoor site. Nevertheless, if we employ advanced technologies like transgenic indoor or outdoor plants then may be we can achieve desirable results in removing the airborne PAHs from the environment [35].

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