



POLY AROMATIC HYDROCARBONS AND THEIR IMPACT ON ENVIRONMENT AND HUMAN HEALTH- A REVIEW

SAURABH DAVE and HARDIK PATHAK*

Dept. of Chemistry, School of Science, JECRC University, Jaipur, Rajasthan

*Dept. of Biotechnology, School of Science, JECRC University, Jaipur, Rajasthan

**Corresponding author : E-mail: hardikaeshu@gmail.com

Polycyclic aromatic hydrocarbons (PAHs) are primary environmental pollutants which produced during the incomplete burning of organic materials (e.g. coal, oil, petrol, and wood). They are not soluble in water due to the presence of long aliphatic side chain. Various emission sources of PAHs affect their chemical characterization, distribution, as well as their toxicity. Due to the many sources they are scattered in environment. Subsequently some PAHs are considered as potent carcinogens and made serious threat to human health. When PAHs enter water from any source they generally do not dissolve in water as they have a large aliphatic side chain in their structure. So they stick to solid soil particles and settle to the bottom of lakes and rivers. The main aim of this review is to discuss the impact of on the environmental and their impact on human health.

Keywords: Carcinogens; Environmental pollutants; PAHs; Persistent; Toxicity.

Introduction

The Polycyclic Aromatic Hydrocarbons (PAHs or polyaromatic hydrocarbons) have been studied globally to understand for their distribution, fate and effects in the environment¹. They are the aromatic compounds having 2 or more benzene rings. They can have a variety of substituents such as alkyl, nitro, and amino groups in their structure². Most of the PAHs are made up of Carbon and Hydrogen however Nitrogen, Sulphur, and Oxygen atoms can also be integrated into their ring system³. When these compounds react with nitrogen oxides, ozone and sulphur dioxide, they give the compounds like diones, nitro- and dinitro-PAHs, and sulphonic acids. A diversity of microorganisms is capable to degrade PAHs compounds in soil⁴. Crude oil or many

natural products, such as steroids, that have been chemically converted to aromatic hydrocarbons over time⁵. They are distributed extensively in the environment. Several natural process such as volcanic eruptions and forest fires, also contribute to an ambient presence of PAHs. PAHs can be existed in both particulate and gaseous phases, depending upon their volatility. PAHs can be divided into Low molecular weight PAHs and High Molecular PAHs. Light molecular weight PAHs (LMW PAHs) that have two or three aromatic rings and are emitted in the gaseous phase, while high molecular weight PAHs (HMW PAHs), are with five or more rings, and emitted in the particulate phase. They also have toxic effects on organisms through several activities. Most of the PAHs are manmade.

The foremost route of exposure to is from breathing ambient (and indoor) air, eating food containing PAHs, smoking cigarettes, or breathing smoke from open fireplaces⁵. A majority of PAHs from tobacco smoke are alleged human carcinogens⁶. Effects have been recognized to alter immune system development, humoral immunity and on host resistance⁷. This paper provides updated information on sources, emissions and toxicity of PAHs for the better understanding for its bioremediation challenges.

Sources of PAHs

There are many sources and fate of PAHs in the environment which is very significant due to their harmful impact on human health. Industrial activities, vehicle washing, fossil fuel combustion, open dumps⁸, and solid waste burning are recognised

anthropogenic sources of PAHs⁹. They enter into the atmosphere either by *Pyrogenic*, *Petrogenic* or *Biological*. This is usually accomplished by observing PAH fingerprints that show the relative PAH abundances¹⁰. Once unconstrained to the environment, the PAHs are prone to a wide variety of degradation processes, including, dissolution, emulsification dispersion, evaporation, adsorption on suspended materials, photo-oxidation, microbial degradation (biotic or biodegradation) and interaction among the contaminants and sediments¹¹.

It is worth mentioning that crude oils contain PAHs that formed over millions of years at temperatures as low as (100–150 °C)¹². (Fig. 1) Illustrate such mode of PAHs formation^{13, 14, 15}.

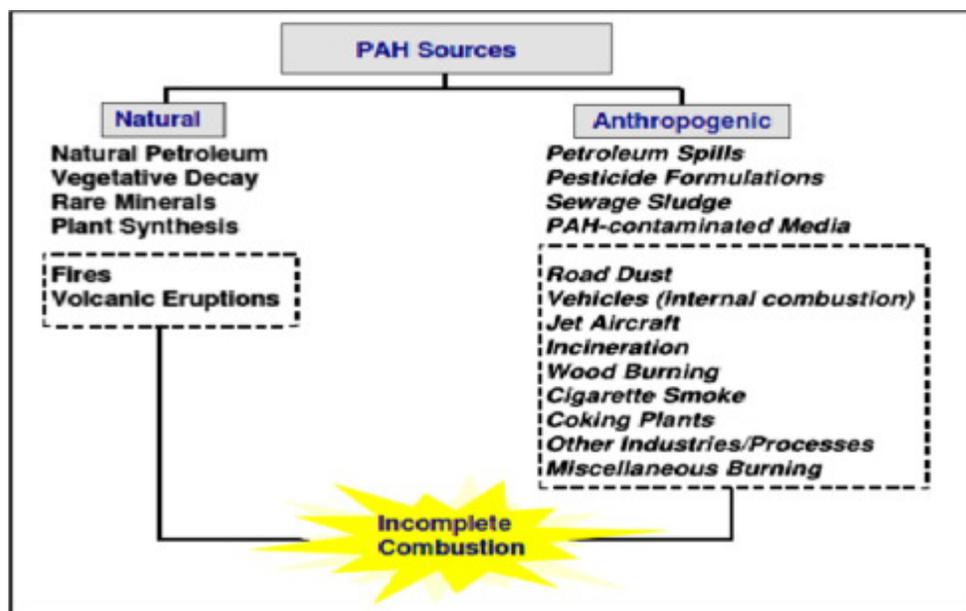


Fig. 1. Chief Sources of PAHs found in the environment (Shafy and Mansour, 2016)

1. Emissions of PAHs:

Across the world many developing countries, such as India, China, Sudan and Brazil are related with burning of biomass,

including biofuel usage and wild savanna fire. Especially, entire emissions of PAHs from China and India were virtually 40% of

Table 1. Table showing physical and chemical properties of PAHs arranged on the basis of their toxicities¹⁹.

S. No	PAHs	Chemical formula	Molecular Weight (g/mol)	Melting Point	Boiling Point	Density (g/cm ³)	Solubility in water
1.	Acenaphthalene	C ₁₂ H ₁₀	154.21	95°C	96.2°C	1.222	0.4mg/100 ml
2	Acenaphthylene	C ₁₂ H ₈	152.20	92-93°C	265-275°C	0.8987	Insoluble
3.	Anthracene	C ₁₄ H ₁₀	178.23	218 °C	340 °C	1.25	Insoluble
4.	Benzo(a)anthracene	C ₁₈ H ₁₂	228.2879	158 °C	438 °C	1.19	0.010mg/L
5.	Benzo(a)pyrene	C ₂₀ H ₁₂	252.31	179 °C	495 °C	1.24	0.2 to 6.2 ug/L
6	Benzo(e)pyrene	C ₂₀ H ₁₂	252.31	178-179°C	310-312°C	1.286	6.3x10 ⁻³ mg/L
7	Benzo(b)fluoranthene	C ₂₀ H ₁₂	252.3093	168 °C	-	1.286	0.0012mg/L
8	Benzo(ghi)perylene	C ₂₂ H ₁₂	276.3307	278 °C	500 °C	1.378	2.6x10 ⁻⁴ mg/L
9	Benzo(j)fluoranthene	C ₂₀ H ₁₂	252.3093	165 °C	-	1.286	6.76x10 ⁻³ mg/L
10	Benzo(k)fluoranthene	C ₂₀ H ₁₂	252.31	217 °C	-	1.286	-
11	Chrysene	C ₁₈ H ₁₂	228.28	254 °C	448 °C	1.274	Insoluble
12	Dibenz(ah)anthracene	C ₂₂ H ₁₄	278.3466	262 °C	-	1.232	5x10 ⁻⁴ mg/L
13	Fluoranthene	C ₁₆ H ₁₀	202.26	110.8 °C	375 °C	1.252	265 µg/l
14	Fluorene	C ₁₃ H ₁₀	166.223	116-117 °C	295 °C	1.202	1.992 mg/L
15	Indeno(1,2,3-cd)pyrene	C ₂₂ H ₁₂	276.3	163.6°C	530°C		0.062mg/L
16	Phenanthrene	C ₁₄ H ₁₀	178.23	101 °C	332 °C	1.18	1.6 mg/L
17	Pyrene	C ₁₆ H ₁₀	202.25	145-148 °C	404 °C	1.271	0.135 mg/l

the global whole amount of emissions.

(i) Atmospheric emission

The natural sources include volcanoes and forest fires. While the anthropogenic sources are vehicle exhaust, agricultural fires, power plants, coke plants, steel plants, foundries and other industrial sources. The variability in vapour pressures of different PAH

compounds cause the individual PAHs to distribute in different concentrations.^{16,17,18}. Quantification of PAHs are performed using GC-MS method. It is consistent and accurate to determine the concentrations of PAHs and their derivatives¹⁹.

(ii) Surface soil emission

When PAHs are accumulated onto the

earth's surface, they convert into mobile substance. PAHs in the soil will be bound to soil particles²⁰. The most important factors which influence PAHs mobility is the soil particle size. As Soil physical properties like soil texture have also been considered to be very important for bioremediation because several factors affecting the degradation process like soil aeration, movement of nutrients through soil profiles, water holding capacity and several other chemical properties are also under the direct and indirect influence the soil physical properties.

2. Toxicity of PAHs:

The level toxicity of PAHs mainly depends on physical and chemical properties of PAHs specially its solubility and its bioavailability. In a study Benzo[a]pyrene was assessed to be responsible for 48 to 52% of the added risk of sediment and for 44 to 54% in other sediment. When also concentrations benzo[a]anthracene and dibenzo [a, h] anthracene were included 90% of the added risk could be valued. This proves that concentrations of these compounds, in mixture with other environmental factors, are useful for risk estimation of PAHs²¹. Although the health effects of individual PAHs are differ in one or other way, In succeeding, are the 17 PAHs (Table.1) which have been recognized as being of greatest concern with regard to approaching exposure and unfavorable health effects on humans and are thus considered as a group in a profile issued by the Agency for Toxic Substances and Disease Registry (ATSDR).

The toxicity of PAHs to marine ecosystem is exaggerated by metabolism and photo-oxidation by many microorganisms. They are usually more toxic in the occurrence of ultraviolet light.

The rapid absorption of PAHs by humans results in a high potential for biomagnification in the food chain. In general, the greater the number of benzene rings, directly increased the toxicity of the PAH¹².

References:

1. Haftka J 2009, Bioavailability of polycyclic aromatic hydrocarbons in sediments: experiments and modelling. PhD Thesis, University van Amsterdam, Amsterdam, Netherlands.
2. Fieser LF and Fieser M 1956, Organic Chemistry, 3rd edition. Boston: D. C. Heath and Co. Chapter 21.
3. McElroy AE, Bates S, Rice SD and Korn S 1985, Bioavailability of polycyclic aromatic hydrocarbons in the aquatic environment. In: Varanasi U, editor. Metabolism of polycyclic aromatic hydrocarbons in the aquatic environment. Boca Raton: CRC Press. pp. 1-39.
4. Fredslund L, Sniegowski K, Wick LY, Jacobsen CS, Mot RD and Springael D 2008, Surface motility of polycyclic aromatic hydrocarbon (PAH)-degrading mycobacteria. *Res Microbiol.* **159** 255-262.
5. Feng X, Pisula W and Müllen K 2009, Large polycyclic aromatic hydrocarbons: Synthesis and discotic organization. *Pure Appl. Chem.* **81** 2203-2224.
6. Armstrong BG, Hutchinson E, Unwin J and Fletcher T 2004, Lung Cancer Risk after Exposure to Polycyclic Aromatic Hydrocarbons: A Review and Meta-Analysis. *Environ Health Percept* **112** (9) 970-978.
7. ACGIH (American Conference of Governmental Industrial Hygienists) 2005, Polycyclic aromatic hydrocarbons (PAHs) biologic

- exposure indices (BEI) Cincinnati, OH. American Conference of Governmental Industrial Hygienists.
8. Zakaria MP, Geik KH, Lee WY and Hayet R 2005, Landfill leachate as a source of polycyclic aromatic hydrocarbon (PAHs) to Malaysian waters. *Coastal Mar. Sci.* **29** 2 116–123.
 9. Karthikeyan R, Kulakov P, Leven, B, Pierzynski, G and Erickson LE 2000, Vegetated treatment of vehicle wash sediments: a field demonstration. Proceedings of the 2000 Conference on Hazardous Waste Research, Denver. May 23–25. pp. 159–166
 10. Douglas GS, Emsbo-Mattingly SD, Stout SA Uhler AD and McCarthy KJ 2007, Chemical fingerprinting methods. In: Murphy BL, Morisson RD (eds) Introduction to environmental forensics, 2nd edn. Academic, New York, NY.,pp 311–454.
 11. Gogou A, Bouloubassi I and Stephanou EG 2000, Marine organic geochemistry of the Eastern Mediterranean: 1. Aliphatic and polyaromatic hydrocarbons in Cretan Sea surficial sediments. *Mar Chem.* **68** 265–282.
 12. Shafy HIA and Mansour MSM 2016, A review on polycyclic aromatic hydrocarbons: Source, environmental impact, effect on human health and remediation *Egyptian Journal of Petroleum.* **25** (1) 107-123.
 13. Tolosa I, Bayona JM and Albaiges J 1996, Aliphatic and Polycyclic Aromatic Hydrocarbons and Sulfur/Oxygen Derivatives in Northwestern Mediterranean Sediments: Spatial and Temporal Variability, Fluxes, and Budgets. *Environ. Sci. Technol.* **30** 2495-2503.
 14. WHO (World Health Organization) 2000, Polynuclear aromatic hydrocarbons in drinking-water. Background document for development of WHO Guidelines for Drinking-water Quality; [WHO/SDE/WSH/03.04/59].
 15. Seo JS, Keum YS and Harada RM 2007, Isolation and characterization of bacteria capable of degrading polycyclic aromatic hydrocarbons (PAHs) and organophosphorus pesticides from PAH-contaminated soil in Hilo, Hawaii. *Agric Food Chem.* **55** 5383-5389.
 16. Wang Z, Ren P, Sun Y, Ma X, Liu X and Na G 2013, Gas/particle partitioning of polycyclic aromatic hydrocarbons in coastal atmosphere of the north Yellow Sea. *Environ Sci Pollut Res: China.* **20** 5753-5763.
 17. Kameda T 2011, Atmospheric chemistry of polycyclic aromatic hydrocarbons and related compounds. *J Health Sci.* **57** (6) 504-511.
 18. Kuo CY, Chien PS, Kuo WC, Wei CT and Jui-Yeh RJY 2012, Comparison of polycyclic aromatic hydrocarbon emissions on gasoline- and diesel-dominated routes. *Environ Monit Assess.* **185**(7) 5749-5761.
 19. Pandey SK, Kim KH and Brown RJC 2000, A review of techniques for the determination of polycyclic aromatic hydrocarbons in air. *Trends Anal Chem.* **30**(11) 1716-1739.
 20. Cachada A, Pato P, Rocha-Santos T, Ferreira DSE and Duarte AC 2012, Levels, sources and potential human health risks of organic pollutants in

- urban soils. *Sci Total Environ.* **430** 184-192.
46 Dave & Pathak
21. Shor LM and Kasson DS 2004, Combined effects of contaminant desorption and toxicity on risk from PAH contaminated sediments. *Risk Analysis.* **24**(5) 1109-1120
22. Renner R 1999, EPA to strengthen persistent, bio accumulative and toxic pollutant controls-mercury first to be targeted. *Environ Sci Technol.* **33** 62A.