

Sources, properties and health risks of carcinogenic polycyclic aromatic hydrocarbons

Pankaj Vikas^a, Renu Sharma^a, Vaneet Kumar^b and Saruchi^c

^aNIMS University, Department of Chemistry, Jaipur, Rajasthan

^bDepartment of Applied Sciences, CT Group of Institutions Jalandhar, Punjab, India

^cSardar Swarn Singh NIBE, Kapurthala, Punjab

ABSTRACT

In the present review article focus on highlighting the sources, properties and health risks of carcinogenic PAHs both on human health and environment. Polycyclic Aromatic Hydrocarbons (PAHs) comprises a broad family of compounds that are also described as semi volatile organic compounds (SVOC). This term refers to the fact that PAHs are distributed between gas and particle phases. In fast budding cities of India, limited research work has been done on air contamination and distribution behaviour of PAHs, where vehicles (cars, trucks, buses and two wheeler) as old as one to twenty years run on the same roads. The trouble is further multiplied due to lack of maintenance, poor planning, socio economic condition and slow pace of infrastructure development. In the city atmosphere smaller vehicles (two, three and four wheelers) running mainly on petrol and diesel fuels are foremost contributor of PAHs. Due to increase in urbanization, industrial development, increase in population and vehicular traffic over the past decades the demand of fossil fuels has increased resulting in the rise of emission of PAHs to the atmosphere. PAHs are omnipresent including soil, water and air. They are generally stuck to the solid sediments. PAHs existence in the atmosphere results in troubles because consuming products obtained from sources like processed petroleum products and agricultural produce could be ruinous as it causes tumours in animals and cancers in human beings

Keywords: PAHs, Pollutants, environment, contaminants, atmosphere

INTRODUCTION

Polycyclic Aromatic Hydrocarbons PAHs are influential environmental pollutants that encompass of fused aromatic rings. During incomplete combustion of carbon-based materials such as wood, coal, oil, gasoline etc PAHs are characteristically moulded and are present approximately everywhere in the environment. According to Researchers [1] PAHs are also present in crude oil, coal tar and asphalt. In urban areas and in agricultural based areas where bush burning is usually used for agricultural reasons followed by in petroleum exploration and refining operations the concentration of PAHs is expected to be high [1]. Since as a pollutant, some PAHs have been recognized as carcinogenic, mutagenic and teratogenic, these are of immense concern for Human beings [2]. PAHs are primarily found in soil, sediment and oily substrates. In comparison to soil PAHs concentration in water or air is comparatively small. The type, nature as well as intensity of the fire arises from forest fires and agricultural bush burning is responsible for the actual amount of PAHs produced [3]. The majority of the PAHs do not degrade rapidly and may thus be inherent in environment for the prolonged periods of the time when once exposed to the atmosphere and during this period winds may distribute these pollutants over a huge area. PAHs compounds

includes two to seven membered (fused) benzene rings. They mix easily with oil then water and are thus termed as hydrophobic compounds with aqueous solubility decreasing almost linearly with upsurge in molecular mass [4]. PAHs may be classified as low molecular weights (LMW) or high molecular weights (HMW). Low Molecular Weights PAHs are those containing two or three benzene rings, whereas those containing four or more rings are called HMW PAHs. Low molecular weight PAHs are comparatively soluble in water i.e. are hydrophilic in nature whereas those containing four or more rings are quite hydrophobic and unsolvable [5].

Toxic Organic Micropollutants (TOMPs) consist of Polychlorinated Dibenzo-p-Dioxins, Polychlorinated Dibenzofurans (PCDD/Fs) and Polychlorinated Biphenyls (PCBs). During various industrial, chemical and combustion processes PCDD/Fs and PAHs are formed as unwanted by-products. Until 1986, PCBs were formerly manufactured for use in an extensive range of electrical and other products. These highly toxic and persistent species are omnipresent in the environment, but are normally present at extremely low concentrations, the atmosphere being the major route for their redeployment in the environment. PAHs emitted to the air can be transported over long distances before they are deposited with atmospheric precipitation on soils, vegetation or sea and inland water. The existence of PAHs in all these elements of the atmosphere may build a risk not only to the human beings but all the living organisms [6, 7]. The objective of this manuscript is to review existing information on sources, fate and risk associated with the presence of these compounds in the atmosphere [28].

MATERIALS AND METHODS

2.0 Sources of PAHs

At home, residential heating, tobacco smoking and cooking are the major sources of PAHs pollution. In many cities Vehicular emissions are also the major sources of PAHs. For a number of people, the primary exposure to PAHs occurs in the workplace. For example, workers in a coke manufacturing factory receive high exposures to PAHs produced in their workplace.

Human exposure to PAHs is also caused by inhalation of air containing PAHs. The exposure of traffic policemen to ambient PAHs is mainly from inhalation of vehicle exhaust and road dust containing PAHs. Through food and water consumption or skin contact PAHs can also enter the body. PAHs are transported into all tissues of the human body containing fat. They can be stored in fat, liver and kidneys and can accumulate by frequent and long-term exposures.

In all processes of incomplete combustion of organic substances PAHs are emitted [8]. The production of PAHs is favoured by an oxygen-deficient flame, temperatures in the range of 650-900°C and fuels which are not highly oxidized. Natural sources of pyrogenic PAHs such as volcanic activity and forest fires do not significantly contribute - for the present - to overall PAHs emission [9]. The combustion of materials for energy supply (e.g. coal, oil, gas, wood, etc.) and combustion for waste minimization (e.g. waste incineration) are the two categories on the basis of which anthropogenic sources are divided [10].



Figures 1: Different sources of PAHs in the environment

The first category includes stationary sources like industry (mainly coke and carbon production, petroleum processing, aluminium sintering, etc.), residential heating (furnaces, fireplaces and stoves, gas and oil burners), power and heat generation (coal, oil, wood and peat power plants) and mobile sources like cars, lorries, trains, airplanes and sea traffic (gasoline and Diesel engines). The second category covers incineration of municipal and industrial wastes. Other miscellaneous sources contain unregulated fires such as agricultural burning, recreational fires, crematoria, etc., cigarette smoking as well as volatilization from soils, vegetation and other surfaces [29-35]. Figure 1 indicated the different sources of PAHs in the environment.

2.1 Properties of PAHs

Polycyclic aromatic hydrocarbons PAHs mix more easily with oil than water and are thus lipophilic in nature. High molecular weight PAHs are less water-soluble and less volatile (i.e., less prone to evaporate). They are found primarily in soil, sediment and oily substances in water or air due to lipophilic nature.

PAHs are also found adsorbed on surface of particulate matter (PM) suspended in air. Polycyclic Aromatic Hydrocarbons are also found in coal tar, crude oil, creosote, and roofing tar. These PAHs are used in medicine or dyes, plastics and pesticides. Naphthalene, Fluorene, Anthracene, Phenanthrene, Fluoranthene, and Pyrene are the polycyclic aromatic hydrocarbons generated for commercial use [11]. PAHs usually exist as colorless, white or pale yellow-green solids.

In the Table-1 the physical properties of selected PAHs has been shown. The properties of these compounds vary widely with molecular weight as indicated by the table-1 [12]. As the number of rings increases from two to seven the vapor pressure of PAHs decreases over 11 orders of magnitude. Naphthalene tends to partition to a greater degree into the vapor phase in the environment because of its high vapor pressure. In the environment larger PAHs (three- and four-ring) will partition between the gaseous and solid phases. On the other hand PAHs with five or more aromatic rings are found almost completely linked with particulate or solid phases [13]. With increasing molecular weight, water solubility of PAHs with two to six rings decreases. Therefore, two and three-ring PAHs are more likely to be found in aquatic environments in the dissolved phase, whereas, higher molecular weight PAHs, are associated with dissolved organic matter (DOM) and solid phases such as soot [14].

With increase in the size of the molecule, the tendency of PAHs to accumulate in soils, sediments, and biota also increases. The soil/sediment partition coefficient δK_{oc} is a measure of the affinity of a compound to partition into natural organic matter and soot in soils and sediments. For PAHs, log K_{oc} values are relatively high, indicative of a strong tendency for soils and sediments to become sinks for PAHs even though most PAHs are initially dispersed into the atmosphere [15].

In view of the fact that chromatographic separations are mainly based on differences in physical properties, the significant variability described above for PAHs makes sampling, sample preparation, and analysis. PAHs with 2-3 rings, which are generally low carcinogenic, are mostly found in the gas phase whereas the heavier ones are mostly associated with airborne particles. By adsorption or by condensation upon cooling of flue gases, heavier PAHs (with more than three rings) are rapidly attached to existing particles (usually soot particles) [16]. The environmental occurrence of PAHs has been linked with undesirable effects on public health [17-19]. In both gaseous and particulate forms the persistent organic pollutants (POPs) are transported in the atmosphere to short and long distances. Even though some POPs are released gradually into the atmosphere [20], these omnipresent compounds are subjected to redistribution and transformation processes [21, 22].

The Atmospheric deposition constitutes the foremost input of semi-volatile organic compounds to soil. Once these PAHs entered in the soil they build up in horizons rich in organic matter where they are liable to be retained for many years due to their persistence and hydrophobicity. Therefore, soil is a significant reservoir for these compounds and exchanges between soil and the atmosphere is to be broadly studied. Over the last few decades, with the increase in fossil fuel combustion, resulting from the industrial expansion, traffic and population growth, the atmospheric concentrations of PAH in Asian countries are anticipated to be high. Consequently, it is essential to acquire information about this environmental compartment and its role in micro pollutant cycle [23]. Table 1 indicated the general properties of PAHs.

Table 1: Properties of PAHs

Sr. No.	Property	PAHs< 3 Rings	PAHs> 4 Rings
1.	Water Solubility (mg/l)	32+0.07	0.26 + 0.0003
2.	Volatility	5.0E-2 +7.9 E-4	3.5E-4 + 2.2E-6
3.	Sorption Affinity	3.4 +4.6	5.2 + 7.7
4.	Condensation Temperature	-50 + -10	-10 + 30
5.	Ecotoxicity	+	+/-
6.	Carcinogenicity	-	++
7.	Example	Naphthalene (2 Rings) Acenaphthene (3 Rings) Fluorene (3 Rings) Anthracene (3 Rings)	Pyrene (4 Rings) Chrysene (4Rings) Benzo(a)pyrene (5 Rings) Benzo(ghi) perylene (6 Rings)

Risk to Human

Human beings are exposed to PAH vapor or PAHs contained in dust and other particulate matter outdoors or indoors at the home or workplace in the ambient air. The cigarette smoke, vehicle exhaust, residential heating, agriculture burning, waste incineration, and emissions from industrial processes are the sources of human exposure to PAHs. The foremost exposures of the U.S. population to PAHs according to the United States Agency for Toxic Substances and Disease Registry (ATSDR), include the inhalation of tobacco smoke, wood smoke, and ambient air with PAHs from traffic emissions and consumption of food containing PAHs [40]. Many adverse affect on different types of organisms, including plants, birds, and mammals have been reported due to air with high concentrations of PAHs. A number of studies reported that there is a considerable positive correlation between mortality by lung cancer in humans and exposure to PAHs from exhaust from coke ovens, roofing-tar, and cigarette smoke. Some PAHs have been established to be carcinogenic in humans and experimental animals, and they are classified as carcinogenic materials by various organizations, including the United States Agency for Toxic Substances and Disease Registry (ATSDR), the International Agency for Research on Cancer (IARC), the Department of Health and Human Services (DHHS), the National Occupation Safety and Health Administration (OSHA), and the US-EPA

On the whole, the particle-bond carcinogenic PAHs are associated with small-size respirable particles in the atmosphere [24]. In common, effect of these chemicals administered to the lung as fine particulates, in aerosol form, are likely to be more bio-available than those administrated in solid matrices like food [25]. According to Menzieef *al.* [25] estimated potential doses of carcinogenic PAHs by inhalation range between about 0.02 $\mu\text{g}/\text{day}$ and 3 $\mu\text{g}/\text{day}$ with a median value of 0.16 $\mu\text{g}/\text{day}$, which is nearly 20 times less than the calculated food dose and about 25 times more than the potential dose with drinkable water. For humans, research shows [26] that air contribute 3-20% of total human exposure to PAHs and come in second position (after food) as a source of these pollutants. In some cases, where urban/industrial atmospheres contain the highest ambient concentrations of PAHs, air is a predominant exposure route [25]. Cigarette smoke can drastically contribute to potential PAH doses via inhalation (over 50% of total exposure) [36-39]. The ambient standards regarding exposure to PAHs refer usually to Benzo (a)Pyrene. For example in Germany and Poland permissible Benzo (a)Pyrene concentration in air as a daily exposure is 5 ng/m^3 and as a year exposure - 1 ng/m^3 . The similar atmospheric Benzo (a)Pyrene levels are accepted in the US (year exposure in the range 0.3-0.7 ng/m^3) [27].

Figure 2 indicated the risk and toxicity assessment of PAHs in our environment

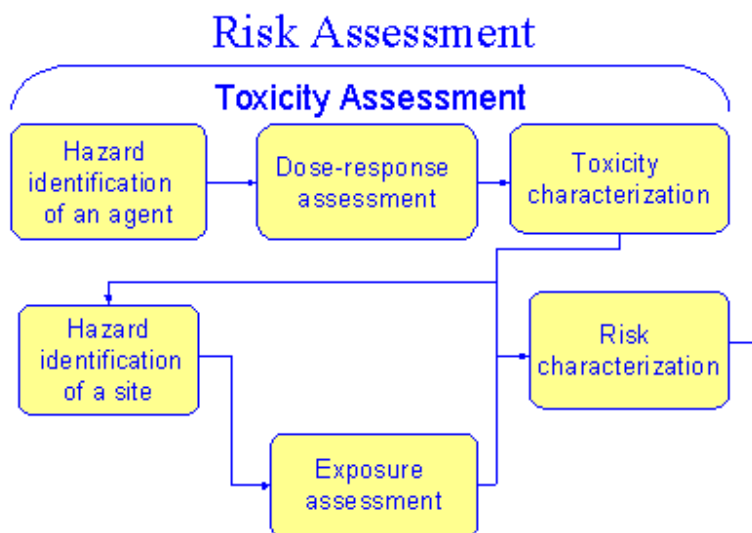


Figure 2: A diagram which show how the risk assessment processes flow

CONCLUSION

Contemporary information on the concentrations, sources, effect and fate of PAHs in atmosphere were reviewed. The partitioning of these carcinogenic compounds in the environment is evaluated, with reference to the historical trends in PAHs emissions. In the end study concludes that we should form certain objectives and moral codes to handle environmental degradation.

- Imparting Knowledge: We should impart knowledge concerning the problems individual can face because of Increasing PAHs.
- Spreading Awareness: We should aware the individual as well as different social groups working for the Environment protection regarding the consequences of PAHs .
- Developing Skills: We should develop the skills in the individuals to find out the problems related with PAHs and then the ways to solve those problems
- Developing Attitude: To develop a positive attitude that it's our responsibility to protect our planet Earth in every individual as well as the social groups working for Environment protection.
- Active participation: We should encourage the active contribution of each and every individual to solve this issue pertaining growth of increasing PAHs to stop environmental degradation & human health problem.

Acknowledgement

One of the authors, Pankaj Vikas, is grateful to CT Group of Institutions, Jalandhar, and NIMS University for providing financial assistantship and laboratory facilities to carry out the present research work.

REFERENCES

- [1] Fetzer J C, *The Chemistry and Analysis of the Large Polycyclic Aromatic Hydrocarbon* (2nd ed.,). New York: Wiley Publishers, **2000**, 27-29.
- [2] Larsson B K, Sahlberg G P, Eriksson A T and Busk L A, *Journal of Agriculture and Food Chemistry.*, **1983**, 31, 867-873.
- [3] Platt M M, and Mackie P R, *Nature*, **1980**, 280, 576-578.
- [4] Parrish Z D, Banks M K, and Schwab A P, *International Journal of Phytomediation*, **2004**, 6, 119-137.
- [5] Cerniglia C E, *Biodegradation*, **1992**, 3, 351-368.
- [6] Volkering F, Breure A M, Van Andel J G, and Bulkens W H, *Applied and Environmental Microbiology*, **1995**, 61, 1699-1705.

- [7] Wang X K, Chen G H, and Yao Z Y, *Chinese Chemical Letters*, **2003**, 14, 205-208.
- [8] Bodzek D, luks-betlej K, and warzecha L, *Atmospheric Environm.*, **1993**, 27A, 759.
- [9] Arey J, Zielinska B, Atkinson R and Winer A, *Atmospheric Environm.*, **1987**, 21, 1437.
- [10] Wild S R, and Jones K C, *Environm. Poll.*, **1995**, 88, 91.
- [11] Franck H G, and Stadelhofer J W, Springer-Verlag, Berlin, **1987**, 308-380.
- [12] Sverdrup L E, Nielsen T, and Krogh P H, *Environmental Science and Technology*, **2002**, 36, 2429 – 2435.
- [13] Gundel L A, Lee V C, Mahanama K R R, Stevens R K and Daisey J M, *Atmospheric Environment*, **1995**, 29, 1719–1733.
- [14] Chin Y P, Aiken G R, and Danielsen K M, *Environmental Science and Technology*, **1997**, 31, 1630–1635.
- [15] Krauss M, and Wicke W, *Environmental Science and Technology*, **2001**, 35, 2319 – 2325.
- [16] Kamens R, Odum J, and Fan Z H, *Environmental Science and Technology*, **1995**, 29, 43-50.
- [17] Grimmer G, Jacob J, Naujack K W, and Detbarn G, *Analytical Chemistry*, **1983** 55, 892–900.
- [18] Yang H H, Lee W J, Chen S J, and Lai S O, *Journal of Hazardous Materials*, **1998** 60, 159–174.
- [19] Rost H, Loibner A P, Hasinger M, Braun R, and Szolar O H J, *Chemosphere*, **2002**, 49, 1239–1246.
- [20] Harner T, Mackay D, and Jones K C, *Environmental Science and Technology*, **1995**, 29, 1200–1209.
- [21] Reilley K A, Banks M K, and Schwab A P, *Journal of Environmental Quality*, **1996**, 25, 212–219.
- [22] Motelay M A, Ollivon D, Garban B, Teil M J, Blanchard M and Chevreuil M, *Chemosphere*, **2004**, 55, 555–565.
- [23] Mohanraj R, and Azeez P A, *Resonance*, **2003**, 8, 20–27.
- [24] Menzie C A, Potocki B B and Santodonato J, *Environm. Sci. Technol.*, **1992**, 26, 1278.
- [25] Nielsen T, and Ramdahl Bjorseth T, *A Health Perspectives*, **1983**, 47, 103.
- [26] Schuetzle D, Jensen T E and Ball J C, *Environm. Intern.*, **1985**, 11, 169.
- [27] Simonich S L, and Hites R A, *Nature*, **1994**, 370, 49-55.
- [28] Kumar V, and Kothiyal N C, *International Journal of Environmental Science and Technology*, **2011**, 8 (1), 63-72.
- [29] Kumar V, and Kothiyal N C, *Asian Journal of Chemistry*, **2011**, 23(3), 1363-1368.
- [30] Kumar V, and Kothiyal N C, *Journal of Environment Research and Development*, **2011**, 5(3), 584-590.
- [31] Kumar V, and Kothiyal N C, *Environmental Monitoring and Assessment*, **2012**, 184 (10), 6239–6252.
- [32] Kumar V, and Kothiyal N C, *Journal of Environmental Science and Engg.*, **2012**, 54(1) 55-63.
- [33] Kumar V, Kothiyal N C and Saruchi, *Polish Journal of Chemical Technology*, **2014**, 16(1), 48-58.
- [34] Kumar V, Kothiyal N C, Saruchi and Masih A, *Journal of the Chinese Advanced Materials Society*, **2014**, 2(2), 82-98.
- [35] Kumar V, Kothiyal N C, Saruchi, Mehra R, Parkash A, Sinha R R, Tayagi S K, and Gaba R. *Journal of Earth System Science*, **2014**, 123(3) ,479-489.
- [36] Kumar V, Kothiyal N C and Saruchi, *International Journal of Research in Chemistry and Environment*, **2014**, 4(2), 50-62.
- [37] Gurjeet, Priyanaka, Kumar V, Kothiyal N C and Saruchi, *Journal of Environment Research and Development*, **2014**, 8 (3), 395-405
- [38] Kumar V, Kothiyal N C and Saruchi, *Polycyclic Aromatic Compounds*, **2015**, DOI:10.1080/10406638.2015.1026999
- [39] Vikas P, Kumar V and Saruchi, *Journal of the Chinese Advanced Materials Society*, **2015**, 3(2), 102-118.
- [40] Abrantes R, Assuncao J V and Nobrega R B, *Atmospheric Environment*, **2004**, 38, 1631-1640.