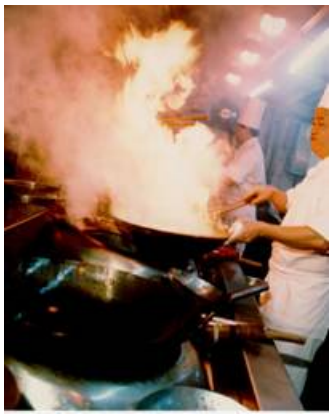
Health Hazard Associated with PAHs



In an urban city like Hong Kong, it is not surprising that tons of pollutants are produced everyday. Among these pollutants, polycyclic aromatic hydrocarbons (PAHs) have recently attracted a lot of attention. Actually, PAHs are emitted to the environment through natural processes (*e.g.* volcanoes and forest fires) and man-made sources (*e.g.* burning of wood, factories, vehicles and restaurants).

Research studies have shown that several illnesses are related to long term exposure to high concentration of PAHs in the environment. Some of the PAHs *e.g.* benzo[a]anthrancene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[k]fluoranthene, dibenz[a,h]anthracene, indeno[1,2,3-cd]pyrene have been identified as carcinogenic to human. In many places, rules and regulations have been implemented to monitor regularly the levels of PAHs.

What are PAHs?

PAHs are compounds containing two or more benzene rings, fused together in different arrangements to form numerous PAH isomers and derivatives. PAHs can either be synthetic or naturally occurring. There are more than 100 PAH compounds. Pure PAHs are generally lipophilic solids with either white or pale yellow-green color. The solubility of PAHs in water decreases with increasing molecular mass. PAHs containing two to four rings are classified as low molecular PAHs, whereas those with more than five rings are called high molecular PAHs. PAH can exist as vapor and solid. In vapor phase, PAHs containing two or three rings prevail, while those with five or more rings occur as small particles with size <2.5 μm. PAHs with four rings can exist in both vapor and particle phase depending on the surrounding conditions.

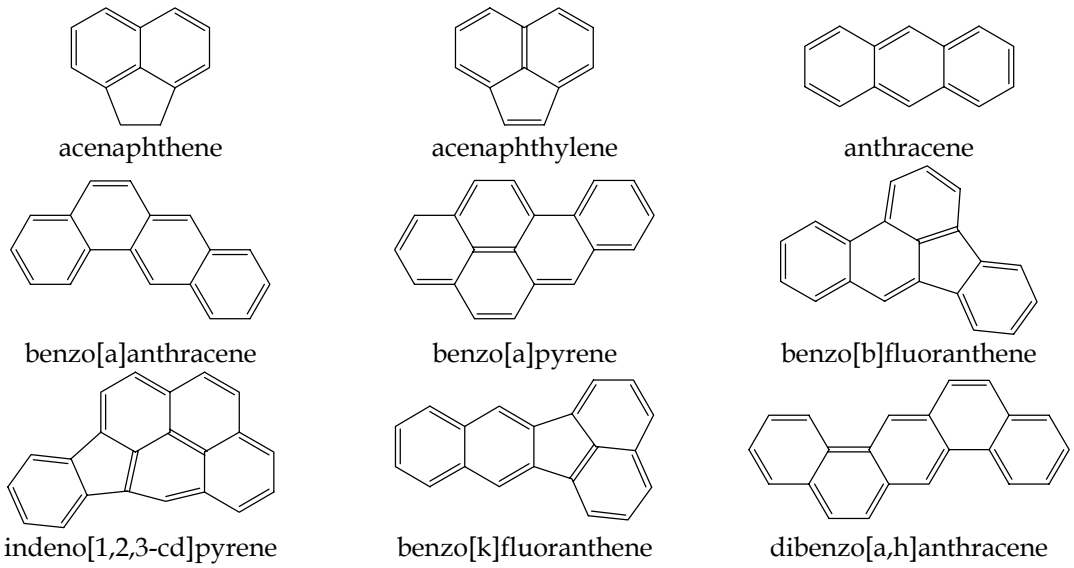
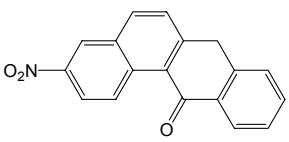
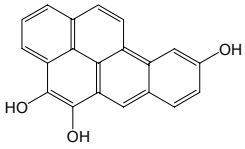


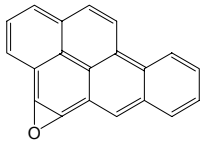
Fig. 1: Structures of polycyclic aromatic hydrocarbons



3-nitrobenzanthrone



benzo[a]pyrene-4,5,9-triol



benzo[a]pyrene-4,5-oxide

Fig. 2: Examples of nitro-PAHs, hydroxyl-PAHs and oxygenated-PAHs

How are PAHs formed?

PAHs can be formed during the incomplete combustion of fossil fuels, wood, garbage, or other organic substances, such as tobacco and charbroiled meat. It is generally believed that PAHs are formed from simple aromatic compounds such as benzene and naphthalene via the so called Hydrogen Abstraction Acetylene Addition (HACA) mechanism. Depending on the reaction temperature, PAHs with different number of benzene rings are formed. Usually, low reaction temperature favours the formation of low molecular PAH, while high reaction temperature promotes the formation of high molecular PAH. In a typical HACA mechanism, simple aromatic compounds either undergo ring-ring condensation or with the addition of acetylene to form the corresponding PAH.

When PAHs are subjected to electrophilic aromatic substitution, oxidation or reduction, a vast amount of different derivatives are formed. For example, nitro-PAHs, hydroxy-PAHs and oxygenated-PAHs are produced when PAHs undergo photochemical reactions with other air pollutants, such as O_3, SO_2, NO_2, HNO_3, and N_2O_5 in the atmosphere. These PAH derivatives are more toxic than their parent compounds.

How might humans be exposed to PAHs?

PAHs can enter our body through different pathways *e.g. via* the water we drink, the food we eat and the soil we have touched. The most significant route for PAHs to enter our body is through the contaminated air we breathe in. Once PAHs entered our body, they dissolve rapidly in the lipid tissues in kidneys, liver, spleen, adrenal glands, and ovaries, *etc.* Most of the PAHs will be excreted in feces and urine. However, some of them accumulate in our body and cause health problem.

In what way PAHs affect my health?

Carcinogenicity

A substantial number of known PAHs are classified as human carcinogens. Clinical studies have shown that exposure a mixture of highly concentrated PAHs may cause various cancers, such as skin, lung, stomach and liver cancers. It is generally convinced that PAHs are responsible for the increasing cancer risks as PAHs are capable of damaging genetic materials and thus initiating the development of cancers.

Initially, specific enzyme (*e.g.* Cytochrome P450) in our body will convert the PAHs we absorbed into the corresponding electrophilic derivatives (*e.g.* diol epoxides, quinines, conjugated hydroxyalkyl derivatives) *via* the steps called multiple metabolic transformations. Some of these derivatives, such as epoxides, can spontaneously rearrange to phenols, or undergo hydrolysis to dihydrodiols. Since these PAH derivatives are stereoselective, they have a tendency to metabolize to different isomers with predominantly the formation of the most stereo-stable isomer,

an isomer that has the highest mutagenic and tumor inducing activity. These carcinogenic stereo-stable isomers have a preference to form covalent bond with the DNA in our body, and leads to the formation of PAH-DNA adducts in our cells and organs.

Among all PAH derivatives, PAH diol epoxides have shown to have the highest metabolism towards nucleic acid molecules. The extranuclear amino groups of guanine and adenine are most susceptible to PAH diol epoxides attack, forming the PAH-DNA adducts. For people who are long-term smokers, these PAH-DNA adducts have been found in the endothelium of their internal mammary artery.

Mutagenicity

Mutagenicity/Genotoxiciy are the words used to describe the potentiality of a chemical substance to induce mutations in DNA and living cells. Because of the mechanistic link between PAH-DNA adduct formation, mutations, and cancer outcome, mutagenicity of PAHs has shown to be related to its carcinogenicity.

PAHs undergo photochemical reactions with other chemicals, such as nitrogen dioxide, ozone, nitric acid, sulfur dioxide *etc*, in the air to form the more mutagenic nitro-PAH and hydroxy-PAH. This usually takes from a few days to a few weeks. Among these PAHs, certain nitro-PAH derivatives are highly mutagenic that they are already bioloigically active without being metabolized, the so-called Promutagen. Typical examples of Promutagen are benzo[a]pyrene and various derivatives of nitropyrenes. Benzo[a]pyrene has such a high mutagenicity that it can induce gene mutations in both the prokaryotic and eukaryotic cells causing unscheduled DNA synthesis in mammalian cells. It is generally convinced that high dose of benzo[a]pyrene is the main cause of several types of malignant tumors. Unlike the promutagenic nitro-PAH derivatives, other nitro-PAHs and hydroxy-PAHs have to undergo an enzymatic reaction to become biologically active before they have the ability to induce mutations in human body.

Questions

1. What are PAHs?
2. How might you be exposed to PAHs?
3. How can PAHs enter and leave your body?
4. How can PAHs affect your health?
5. Search for information about the analytical methods for determination of PAHs in air particulates and soil sediments. Write a short report of not more 500 words to summarize your findings.

References

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