PAH DISTRIBUTION AND CHARACTERISTICS IN WASTE FROM INDUSTRIAL PROCESSES IN KOREA

Tae-Wan Jeon, Jong-Eun Park, Mi-Jeong Jeong, Lee Ji-Young, Seong-Kyeong Jeong, Jin-Mo Yeon, Sun-Kyoung Shin*, Gil-Jong Oh

Resource Recirculation Research Division, National Institute of Environment Research, Hwangyeong-ro 42, Seo-gu, Incheon– 404-708, Republic of Korea

Introduction

Polycyclic (or Polynuclear) aromatic hydrocarbon (PAHs) compounds are a class of complex organic chemicals, which include carbon and hydrogen with a fused ring structure containing at least 2 benzene Rings[1]. Among compounds of PAHs, Benzo(a)pyrene is classified by the U.S.EPA as B2: a probable human carcinogen. Naphthalene, Phenanthrene, Anthracene, Benzo(a)pyrene, Fluoranthene, Benzo(a)anthracene, Benzo(b)fluoranthene is being managed in Marine dumping regulation in Korea. PAHs also belong to the group of persistent organic pollutants (POPs)[2]. PAHs are produced in all processes of incomplete combustion of organic substances. Anthropogenic source can be devised into 2 categories: the combustion of material for energy supply (e.g. coal, oil, gas, wood, etc.) and combustion for waste minimalization. Maliszewska-Kordybach B. According this report, annual amount of PAHs by industrial processes is very high as 40~60%[1]. The emissions from various industrial stacks (blast furnace, basic oxygen furnace, coke oven, electric arc furnace, heavy oil plant, and cement plant), including an industrial waste incinerator, a diesel engine and a gasoline-powered engine were investigated by Yang et al.[3]. Thus the objective of this study is to determine the concentration characteristics of PAHs in various waste from industrial processes. To the best of our knowledge, this may be the first study to report PAH present in the hazardous waste of various processes in Korea.

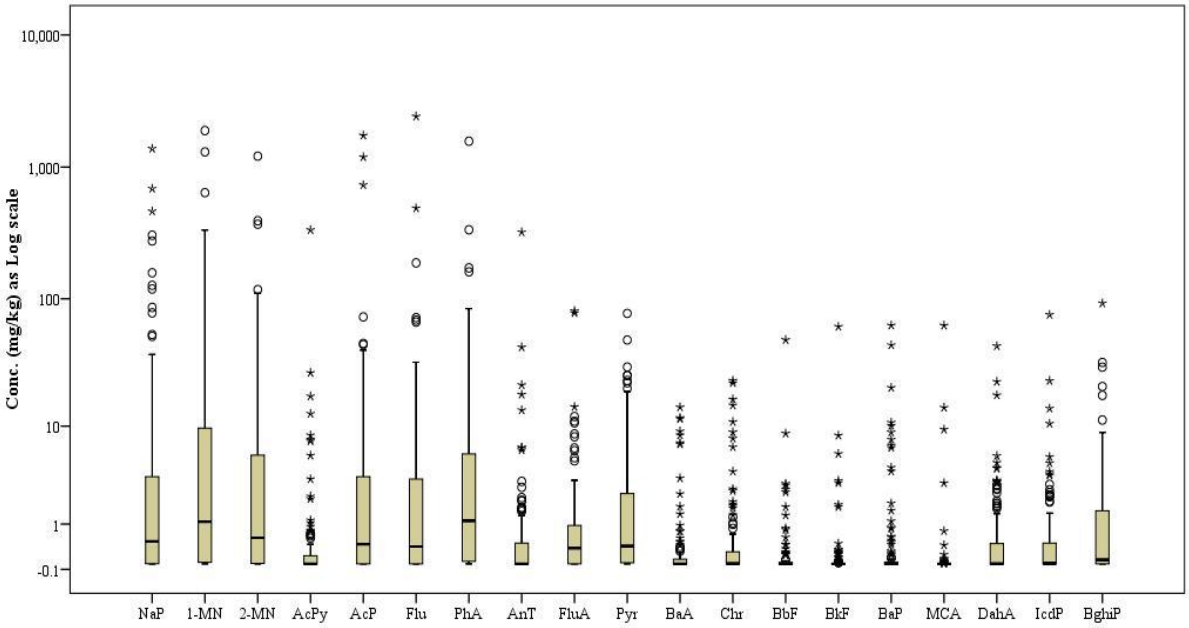
Materials and methods

In order to select the PAHs contaminated waste sample, approximately 100,000 work sites were chosen using the Korean Waste system, also called the “Olbaro System”. Based on the waste discharge report and general waste/designated waste discharge report, wastes that could be categorized under the 20 big European Waste Catalogue (EWC) such as oil sludge, liquid waste, waste organic solvent, mineral-based non- chlorinated hydraulic oils, fuel oil, waste wrapping agents, absorbents, construction waste, recycled household waste, and etc. were classified. Among the industrial processes, output waste, emission rates, and manufactured products were considered to select the waste emission work sites. Finally, a total 123 samples of waste from possible PAHs contamination industrial processes were collected. PAHs was carried out using US EPA method 8100. The analysis was conducted in SIM (Selective Ion Monitoring) mode with GC/MS(Gas Chromatography/ Mass Spectrometry) using a DB-5 (30 m × 0.25 mm i.d., 0.1 ㎛, J&W Scientific) column. And descriptive statistics and correlation analysis were applied to evaluate the analytical data using SPSS software. Principal component analysis (PCA) was performed with Varimax rotation with Kaiser Normalization in the study.

Results and discussion

1. Concentration and distribution of PAHs in waste

Fig. 1 shows the concentration of 19 PAHs in waste from various industrial processes. The PAHs concentrations in waste oil have been observed with Phenanthrene recording the highest concentration of 1,570 mg/kg. The carcinogenic PAH detected at waste were Benzo[b]fluoranthene, Benzo[a]pyrene with concentration of 48.4 mg/kg and 62.6 mg/kg respectively as maximum. The concentrations of PAHs excluding not detected samples in the waste ranged from 0.001 mg/kg to 1,380 mg/kg for Naphthalene. Fluoranthene and Benzoanthrancene were lower than other with 3.3 mg/kg and 1.3 mg/kg as average value.



NaP: Naphthalene, 1-MN: 1-Methylnaphthalene, 2-MN: 2-Methylnaphthalene, AcPy: Acenaphtylene, AcP: Acenaphthene, Flu: Fluorene, PhA: Phenanthrene, AnT: Anthrancene, FluA: Fluoranthene, Pyr: Pyrene, BaA: Benzo(a)anthranthene, Chr: Chrysene, BbF: Benzo(b)fluoranthene, BkF: Benzo(k)fluoranthene, BaP: Benzo(a)pyrene, MCA: 3-Methylcholanthrene, DahA: Dibenzo(a,h)anthracene, IcdP: Indeno[1,2,3-cd]pyrene, BghiP: Benzo(g,h,i)perylene

Fig. 1. PAHs Concentrations in waste from industrial processes

Table 1 shows the concentration distributions of 7 PAHs that is being managed in marine dumping regulation of Korea in waste from various industrial processes. All compounds of PAHs were higher than Marine dumping regulation when comparing with average valus. In case of Naphthalene and Phenanthrene, they were 54 and 28 times higher concentrations than criteria.

Table 1. 7 PAHs concentration distribution compared with regulation

	NaP	PhA	AnT	FluA	BaA	B(b)F	B(a)P
No. of detected samples	97	102	60	93	66	49	45
No. of Not detected Samples	26	21	63	30	57	74	78
min (mg/kg)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
max (mg/kg)	1,380.0	1,570.0	321.2	80.8	14.3	48.4	62.6
average (mg/kg)	**42.3**	**28.4**	**7.9**	**3.3**	**1.3**	**1.6**	**4.4**
median(mg/kg)	1.3	2.2	0.5	0.5	0.1	0.0	0.2
Marine dumping regulation of Korea (mg/kg)	**0.8**	**1**	**0.8**	**2.5**	**1**	**0.8**	**0.8**

The total PAHs concentration was regarded as the sum of concentration of 19 individual PAH. In order to assess PAH homologue distribution for each waste sample, the concentration and ratio of PAHs compounds with low molecular weight (LM-PAHs; containing two- to three ringed PAHs), middle molecular weight (MM-PAHs; containing four-ringed PAHs), and high molecular weight (HM-PAHs; containing five-, six, and seven-ringed PAHs) were determined[4]. Fig. 2 shows the distribution of PAHs homologue in waste from various processes. It can be seen that LM-PAHs were the most dominant homologue for No. 5 waste as accounting for 98%. The others were also accounted for 66~86% excluding No. 12 and No. 20, in which ratio of LM-PAHs were 52% and 46%.

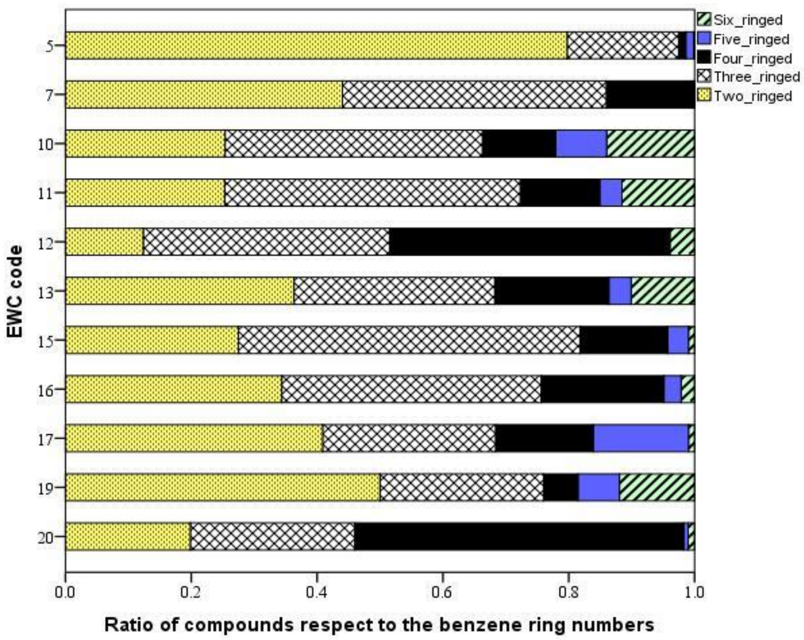


Fig. 2. PAHs distribution in waste from industrial processes

2. Principal component analysis of PAHs

To identify associations of PAHs between waste and soil, PCA was performed. Two principal components (PC) with eigenvalues higher than 1 were extracted by applying a Varimax rotation with Kaiser Normalization in PCA. PC1 and PC2 explained 24.9% and 20.5%. As shown Fig. 3, Benzo(k)fluoranthene, Benzo(b)fluoranthene, Dibenzo(a,h)anthracene, Indeno[1,2,3-cd]pyrene, Benzo(g,h,i)perylene were found to have a positive correlation while Phenanthrene, pyrene, Anthrathene, Chrysene, Fluoranthene, Benzo(a)anthranthene and Benzo(a)pyrene demonstrated negative correlation for principal components 1.

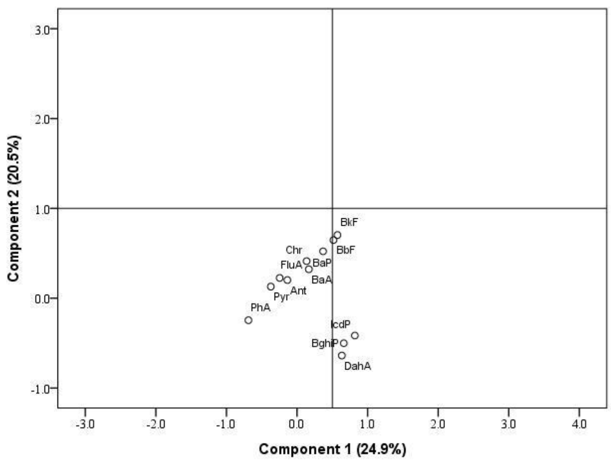


Fig. 3. Factor loading plot (PC1 vs. PC2) of PAHs

As shown Fig. 4, most of waste samples were weighted in a negative direction for principal component 2 and clustered with characteristics from Phenanthrene, pyrene, Anthrathene, Chrysene, Fluoranthene, Benzo(a)anthranthene and Benzo(a)pyrene. In contrast, soil sample was a little different as placing in positive direction, depending on Benzo(k)fluoranthene, Benzo(b)fluoranthene, Dibenzo(a,h)anthracene, Indeno[1,2,3-cd]pyrene, Benzo(g,h,i)perylene. In this result, we couldn't determine that the waste from industrial processes has affected the soil directly. If the concentration in environmental matrix such as atmosphere, water and sediment are given, it will be possible to determine whether the waste from industrial process is source of PAHs.

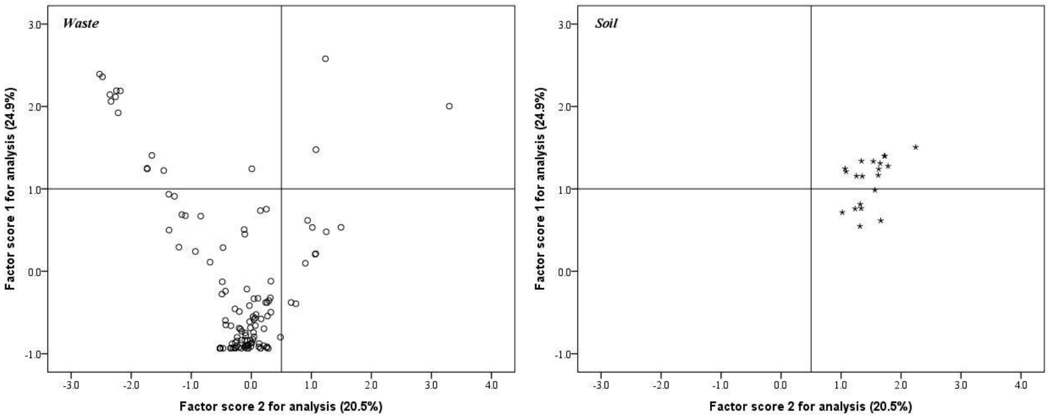


Fig. 4. Factor score loading plot (PC1 vs. PC2) of waste and soil

Acknowledgements:
The authors are thankful to the Ministry of Environment, Republic of Korea for funding the project.

References:

1. Ravindra K., Sokhi R., Grieken R.V. (2008); Atmospheric Environment 42: 2895-2921
2. Yim U.H., Hong S.H., Shim W.J. (2007); Chemosphere 68: 85-92
3. Yang, H.H., Lee, W.J., Chen, S.J., Lai, S.O. (1998); Journal of Hazardous Materials 60: 159-174.
4. Lee W.J., Liow M.C., Tsai P.J., Hsieh L.T. (2002); Atmospheric Environment 36: 781-790