An Analysis of Hazardous Air Pollutant Emissions of Different Casting Materials, Using Furan Resin As Binder with Reclaimed Sand and Its Effect on Environment

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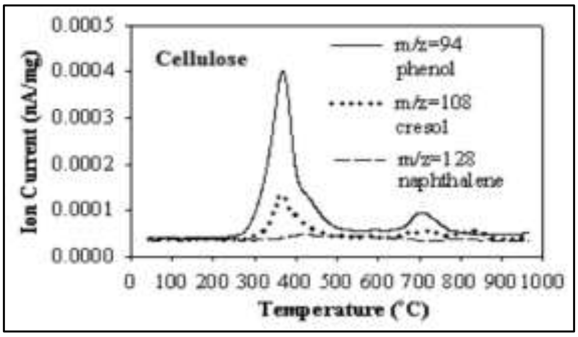
Abstract— We have conducted TG–MS (Thermo-gravimetric analyzer pyrolysis–mass spectrometer) tests to reveal the temperature pattern or code where the major HAP (Hazardous Air Pollutant) species were released. We have used five casting materials for these tests. These materials were heated to a temperature of 1000 o C with the raising temperature rate of 20 °C/min. the whole process was carried out in a thermo-gravimetric analyzer (TG). During the process some HAP were emitted which we have monitored and recorded for different different material with the help of an online mass spectrometer during the heating process.As we have shown here in figure 1, TG-MS analysis, all five casting materials shown different different emission profiles. In general cases, HAP material would be emitted from the casting materials through two main mechanisms, (a) Evaporation (b) Thermolysis. At low temperatures like 150 to 200 °C evaporation occurred For example, phenol released from the two PUB binders in the beginning at temperatures of approximately 150 °C. At higher temperature like 250°C to 400°C Thermolysis of the casting materials occurred, For example, Thermolysis of cellulose begin at 250°C and Thermolysis of Bituminous coal started at 360°C. At relatively higher temptrature like 500°C to 1000°C, devolatilization was usually completed and minimal HAP emissions were released at higher temperatures than that during the TG-MS analyses. Here we have used furan resin as a binder mixed up with reclaimed sand and fresh molding sand to see its effect on environment and emission of HAPs, PAHs, BTEX in this particular case when it is thermally decomposed during casting process.

Keywords: Foundary Sands, TG-MS (Thermo-gravimetric analyzer pyrolysis–mass spectrometer), HAP (Hazardous Air Pollutant), PAH (Polycyclic Aromatic Hydrocarbons), BTEX (Benzene, Toluene, Ethylbenzene, Xylenes)

I. INTRODUCTION

In the following figures we can see the TG–MS data and detailed measures of relative release of HAP type when the casting materials were heated at the rate of 20°C/min. although from this analysis we don't get to know the concentration of HAP released.



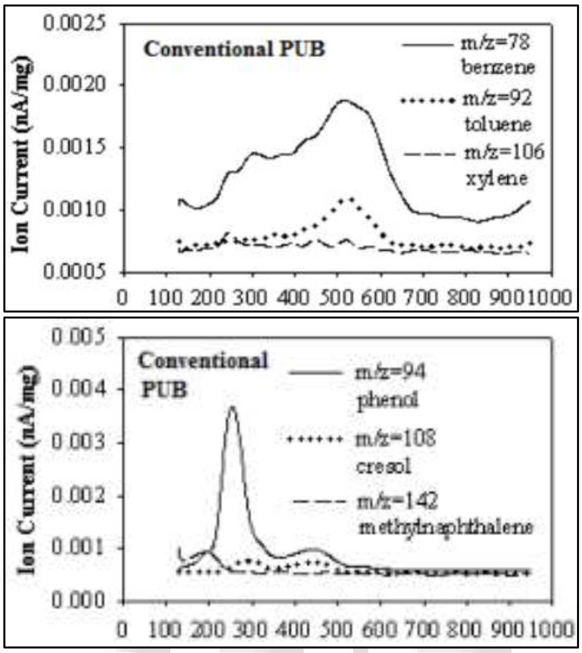
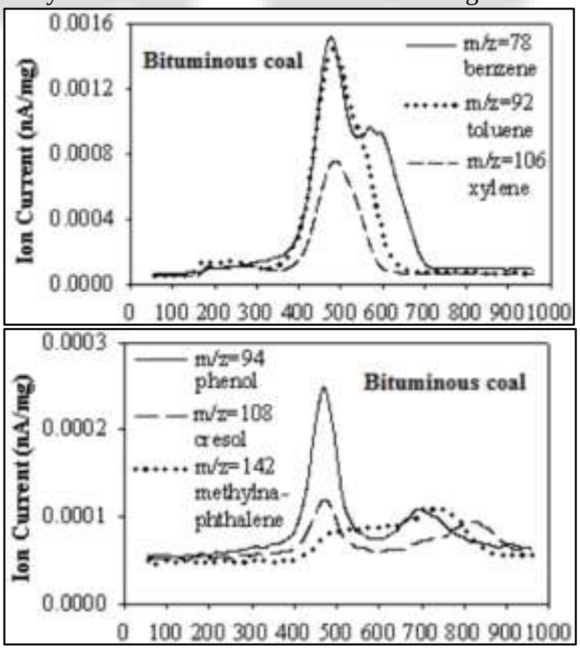


Figure 1: TG-MS analysis

As we can see here for conventional PUB we have got emission of phenol and benzene with toluene cresol xylene similarly for bituminous coal and cellulose we got.



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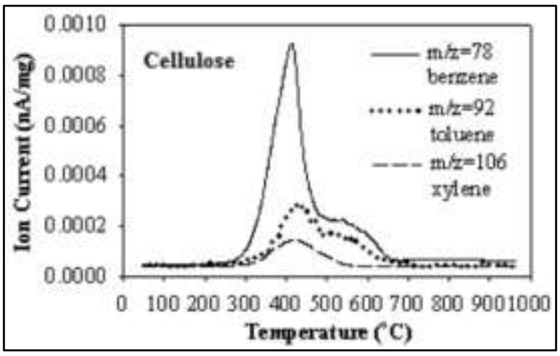

Fig. 2: TG-MS analysis of Bituminous and Cellulose

Maximum quantity of phenol and benzene but can't quantify or find out there potential specifically,

Therefore, Curie-point pyrolysis was conducted for the all chosen casting materials to obtain their "potentials" Normally HAPs are not generated at lower temperatures during pyrolysis, therefore we used 900 °C and 1040 °C (highest temperature- Curie-point pyrolysis can reach)

In the preliminary tests to investigate the effect of temperature on HAP emissions. The results show that the HAP emissions from 900°C and 1040 °C Curie-point pyrolysis were the same (see Figure 2), and there were very minute increases of HAP emissions as the temperature increased from 900 °C to 1040 °C (Figure 3;standard deviations shown for triplicate analyses).

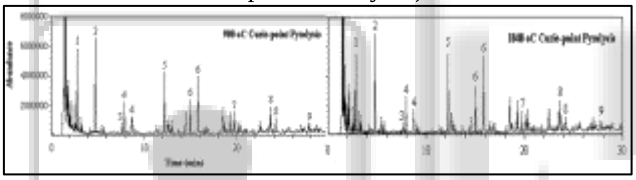

Fig. 3 : GC–MS responses for the pyrolysis products of bituminous coal core sample

PEAK	HAP
1	Benzene
2	Toluene
3	Ethylbenzene
4	m,o,p-xylene
5	Phenol
6	m,o,p-cresol
7	Naphthalene
8	Methylnaphthalene
9	Dimethylnaphthalene

Table 1: Peak No. and Corresponding Hap

Accordingly we will test and obtain the values for furan resin used as a binder with fresh molding sand and reclaimed sand.

II. METHOD AND MATERIAL

We have tested the furan resin based molding sand. It contains less than 25 % free furfuryl alcohol. In addition, it contains the following:

– 0.2 % of free formaldehyde
– 3.20 % of nitrogen
– Less than 3.0 % of ethyl alcohol
– Less than 2 % ethanediol.

The hardner that we have used for this contains 65% p-toluenesulfonic acid and 1 % of sulfuric acid. Matrices of these moulding sands were of high-silica sand and a reclaimed sand (of a lost on ignition, LOI=0.78%) obtained by the mechanical reclamation process, and originated from the moulding sand of the same composition as the tested one (a temperature of liquid metal poured into the mould was equal to 1350 °C, metal mass: moulding sand mass=1:3).

Moulding sands of the following composition were prepared:

– Moulding sand 100PS containing 100 % of a fresh sand, 1 % of resin, and 0.5 % of a hardener, LOI=1.32 %;
– Moulding sand 50PS 50R containing 50 %of a fresh sand and 50 % of a reclaimed sand, 1 % of resin, and 0.5 % of a hardener, LOI=2.18 %;
– Moulding sand 100R containing 100 % of a reclaimed sand, 1 % of resin, and 0.5 % of a hardener, LOI=3.15 %.

Cores made of these moulding sands were poured with liquid cast iron of the temperature of 1350 °C, and after the casting knock out, the samples were taken.

A. Investigations of the Gases Emission

Investigations of the gases emission in the test foundry plant were performed according to the original method developed in the Faculty of Foundry Engineering, AGH UST (Polish Patent, No P-398 709 2012). The schematic presentation of the experimental stand is given in Fig. 1. A sample of the investigated moulding sand of a roll shape of dimensions F 50×50 mm, weight about 150 g, compacted by a moulder's rammer stroke, is poured with liquid cast iron of a temperature of 1350 °C. The liquid metal mass was 9 kg. Gases emitting from the sample— after pouring it with liquid metal are led by means of a steel pipe via the drying system and the capsule with active carbon (during the BTEX measurement) or polyurethane foam 1 (during the PAHs measurement) into a tightly sealed container with liquid, from which they push out the liquid. The weight of displaced liquid was measured as a function of time. The whole mould (weight 24 kg) is made of green sand.

PERAMETERS	UNITS	MOULDING SAND			UNITS	MOULDING SAND		
		100PS	50PS 50R	100R		100PS	50PS 50R	100R
Arsenic	mg/kg ds	0.018	0.102	0.019	mg/kg ds	0.0018	0.01	0.0019
Barium	mg/kg ds	1.84	1.46	0.584	mg/kg ds	0.184	0.146	0.0584
Cadmium	mg/kg ds	0.029	0.044	0.022	mg/kg ds	0.0029	0.0044	0.0022
Chromium—total	mg/kg	<0.03	0.089	0.24	mg/kg	0.003	0.0089	0.024

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	ds	0			ds			
Copper	mg/kg ds	0.143	0.306	0.525	mg/kg ds	0.0143	0.0306	0.0525
Mercury	mg/kg ds	<0.005	<0.005	0.006	mg/kg ds	<0.0005	0.0005	0.0006
Molybdenum	mg/kg ds	<0.040	<0.040	<0.040	mg/kg ds	<0.004	<0.004	<0.004
Nickel	mg/kg ds	0.361	0.533	0.56	mg/kg ds	0.0361	0.053	0.056
Lead	mg/kg ds	0.15	0.604	1.23	mg/kg ds	0.015	0.06	0.123
Antimony	mg/kg ds	<0.010	<0.010	<0.010	mg/kg ds	<0.001	<0.001	<0.001
Selenium	mg/kg ds	<0.010	<0.010	<0.010	mg/kg ds	<0.001	<0.001	<0.001
Zinc	mg/kg ds	4.39	5.31	3.28	mg/kg ds	0.439	0.531	0.328
Chlorides	mg/kg ds	<20	<20	<20	mg/kg ds	<2.0	<2	<2.0
Fluorides	mg/kg ds	<1.0	<1.0	<1.0	mg/kg ds	<0.1	<0.1	<0.10
Sulfates	mg/kg ds	51	100	83	mg/kg ds	5.1	10	8.3
Phenolic index	mg/kg ds	0.31	0.3	0.24	mg/kg ds	0.031	0.03	0.024
Dissolved organic carbon (DOC)	mg/kg ds	1610	2420	3120	mg/kg ds	161	242	312
Total dissolved solids (TDS)	mg/kg ds	3780	5920	7160	mg/kg ds	378	592	716
Total organic carbon (TOC)	mg/kg ds	7400	13,100	20,000	mg/kg ds	740	1310	2000
pH		4.4	4.1	3.1		4.4	4.1	3.1
Benzene, toluene, ethylbenzene,xylenes—total (BTEX)	mg/kg ds	0.19	0.7	0.6	mg/kg ds	0.019	0.07	0.06
Polychlorinated Biphenyls—total(PCB)	mg/kg ds	<0.020	<0.020	<0.020	mg/kg ds	<0.002	<0.002	<0.002
Mineral Oil (C10–C40)	mg/kg ds	9.17	12.1	11.3	mg/kg ds	0.917	1.21	1.13
Polycyclic aromatic								
hydrocarbons—total (PAHs)	mg/kg ds	<0.10	<0.10	<0.10	mg/kg ds	<0.01	<0.01	<0.01
Water content	%	<0.5	<0.5	<0.5	%	<0.5	<0.5	<0.5

Table 2: HAPs and BTEX released during thermal decomposing of different grad of moulding sands

III. Investigation of Results and Their Discussion

We have observed that if we add Reclaimed sand to the fresh moulding sand it increases the emission of organic carbon as: dissolved organic carbon (DOC) and total organic carbon (TOC) (Fig. 4).in the case when we have added 100% of reclaimed sand to the binder it shownen nearly 2 times more DOC and 3 times more emission of TOC. In addition, nearly 2 times more solid dissolved substances (TDS) were eluted. It is also observed that when reclaimed sand added the pH value of the obtained filtrate was relatively lowered. As pH value of fresh moulding sand was 4.4, pH of 100% reclaimed said mixture observed to be 3.1. It was due to introducing a reclaimed sand of an acidic reaction in place of high-silica sand of a neutral reaction.

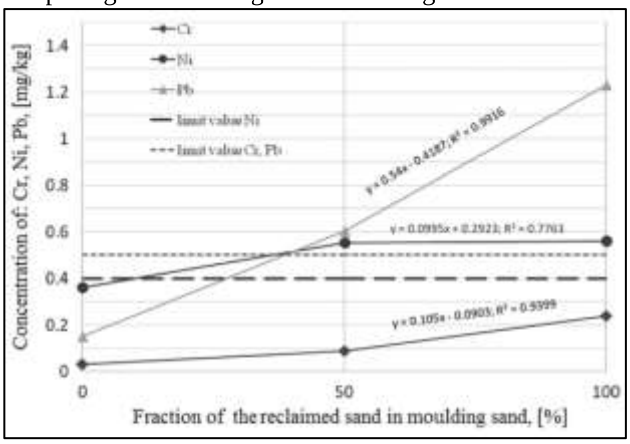

Fig. 4: The influence of reclaimed sand addition on concentration of Cr, Ni, and Pb in leachates

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A. Emissivity from Moulding Sands:

1) Emissivity of BTEX Group:

Following (table -2) are the obeservations that are collected during the thermal decomposition of sands of different grades i.e. - 100PS (100% fresh sand), 50PS 50R (50% fresh and 50 % reclaimed sand) and 100R (100% reclaimed sand).

MOULDING SAND	LOI%	Volume of gases,dm3/kg moulding sand	Emission of gases, mg/kg moulding sand				
			Benzene	Toluene	Ethylbenzene	Xylenes	∑BTEX
100PS	1.32	14.945	654.5	10.1	0.6	1.2	666.4±66.6
50PS50R	2.18	19.933	1198.6	89	1.8	7.7	1297.1±129.7
100R	3.15	24.669	1770.4	122.1	2.2	11.8	1906.1±190.6

Table 3: Concentration of BTEX formed during thermal decomposition of moulding sands

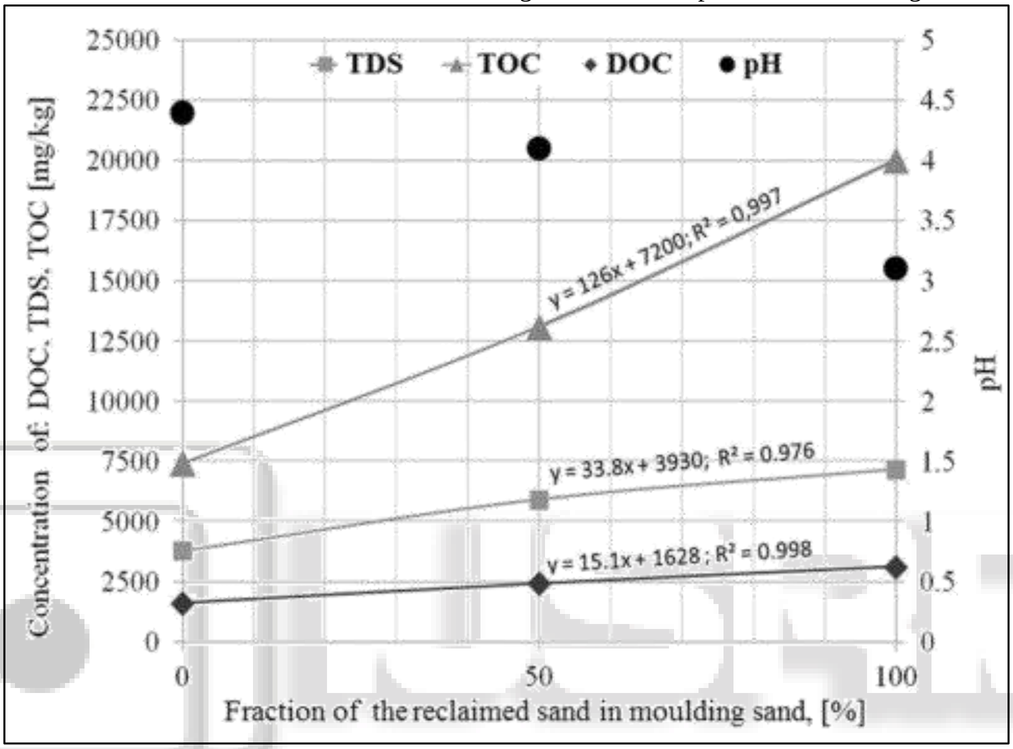

Fig. 5: The influence of reclaimed sand addition on concentration of TOC, DOC, and TDS in leachates

2) Emissivity of PAHs Group

Following (table – 4) are the PAHs that are emitted during the decomposition of moulding sand.

SUBSTANCES/ PERAMETERS	MOULDING SAND concentration mg/kg		
	100PS	50PS 50R	100R
Naphthalene 91-20-3	5.42	10.98	8.79
Acenaphthene 83-32-9	0	0	0
Fluorene 88-73-7	0.18	0.94	0.46
Phenanthrene 85-01-8	0.6	1.6	2.89
Anthracene 120-12-7	0.19	0.44	0.94
Fluoranthene 206-44-0	1.97	4.72	5.97
Pyrene 129-00-0	1.23	3.03	2.84
Benz(a)anthracene 56-55-3	1.23	0.21	0.48
Chrysene 218-01-9	0.1	0.18	0.63
Benzo(b)fluoranthen 205-99-2	0.22	0.49	1.01
Benzo(k)fluoranthene 207-08-9	0.28	0.15	0.28
Benzo(a)pyrene 50-32-8	0.21	0.47	0.82
Dibenz(a,h)anthracene 53-70-3	0.22	0	0
Benzo(g,h,i)perylene 191-24-2	0.07	0.36	0.4
Indeno(1,2,3-c,d)pyrene 193-39-5	0.18	0	0
Total PAHs±20 %	11.76±2.35	23.64±4.73	25.56±5.11

Table 4: Concentration of PAHs formed during thermal decomposition of moulding sands

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IV. SUMMARY AND CONCLUSION:

There shuld be an assessment for the better safety of employees and environment from these type of harmfulness, so it is necessary to have proper investigation in the industry for elution of PAHs and BTEX group in the environment during their management and storage. These investigations indicated that addition of reclaimed sand to the moulding sand have quite negative impact on environment and working conditions. Main concern is about carbon substances, which increases as the fraction of reclaimed sand increases. Specially attention needed for the emission of PAHs and BTEX groups.

Also in eluents Carbon compounds (DOC and TOC) and TDS significantly increase their concentrations when the reclaimed sand fraction in the moulding sand increases.

A sudden change in emission of the PAHs group observed for the sand which has 50% of reclaimed sand in relation to the moulding sand containing only the fresh sand (increase 3 times). After that reclaimed sand additions were causing only a small increase of the PAHs amount.

PAHs emission can also be described with the equation: $y = 0.138x + 13.42$
at $R2 = 0.8521$.

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