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VOCs characteristics and their relation with rheological properties of base and modified bitumens at different temperatures

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HIGHLIGHTS

- VOCs emissions of bitumens at typical high temperatures were characterized.
- The degradation of the SBS decreased its inhibition effect on the VOCs emission.
- The relation between the VOCs emission and the rheological properties was built up.

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ABSTRACT

During heating process of bituminous materials, volatile organic compounds (VOCs) will be released, and it is harmful to the skin, the respiratory and nervous system of the human body, especially increasing its carcinogenic tendency. In this study, the VOCs emission of base and modified binder was characterized as the function of typical temperatures by gas chromatography coupled with mass spectrometry (GC/MS). The rheological behavior of each binder before and after the emission of VOCs was compared. The relation between the VOCs emission of bitumen and its rheological properties was researched. The results indicated that a higher temperature can lead to increase of VOCs components of binder. The addition of SBS modifier can reduce VOCs components of its base binder. However, the degradation of the SBS modifier decreased its inhibition effect on the VOCs emission of bitumen at 220 °C. Naphthalene release and carcinogenic index of polycyclic aromatic hydrocarbons (PAHs) increased with the increase of temperature. The complex-flow activation energy E_a increased after VOCs emission. Naphthalene content exhibited a better linear relation with E_a.

1. Introduction

In the last decades, bitumen has been widely used in the area of roofing and pavement construction [1–3]. In most cases, bitumen has to be heated to behave like a fluid [4–6]. Then, it can be applied with an excellent workability [7]. During this process, volatile organic compounds (VOCs) will be released from this material, which are harmful to the skin, the respiratory and nervous system of the human body, especially increasing its carcinogenic tendency [8]. Besides, VOCs emission can lead to a performance deterioration of bituminous materials [2].

VOCs emission is often influenced by the temperature, the atmosphere pressure and the humidity [9]. The temperature is the key factor to cause the emission of VOCs in the bitumen [1]. These VOCs contain a large number of organic compounds, some of which are hazardous chemicals [10,11], e.g. aromatic hydrocarbons (benzene and alkylated benzenes) and polycyclic aromatic hydrocarbons (PAHs) [12]. Cui's research indicated that the temperature increase can enhance the VOCs emission [13]. The types and amounts of chemical compositions in VOCs can also change significantly as function of the temperature [14]. Recent epidemiological studies indicate that bitumen fumes display a carcinogenic effect in humans, and its condensates display a mutagenic activity and can induce the formation of DNA adducts both in vitro and in vivo [15].

However, only few studies are performed to understand the characteristics of the VOCs of bitumen because of the temperature changes during the whole application process of asphalt mixture. During mixing, the surface temperature of aggregates can be up to 200–220 °C [16]. Due to the influence of the moisture content, part of aggregates could be even over heated. But during its storing

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Table 1
Characteristics of the study patients (n = 52).

Variable	Total, n (%)	DM, n (%)	P[a]
No. of patients	52 (100)	20 (39)	
Time to occurrence (months), median (range)		13 (0–57)	
Sex, male	22 (42)	10 (50)	.278
Age (years), median (range)	52 (17–77)	56 (18–77)	
>60	19 (37)	10 (50)	.141
Tumor size, >4 cm	15 (29)	12 (60)	<.001
Histological grade			
Low/intermediate/high	23/19/10 (44/37/19)	7/8/5 (35/40/25)	.432
Extraparenchymal extension (n = 48)[b]	26 (54)	15 (88)	<.001
Perineural invasion (n = 48)[b]	30 (63)	12 (71)	.423
Lymphovascular invasion (n = 48)[b]	19 (40)	11 (65)	.002
Site of primary tumor			
Parotid/SMG/SLG/minor	12/13/6/21 (23/25/12/40)	2/4/4/10 (10/20/20/50)	.109
TNM stage at initial presentation			
T1–T2/T3–T4	20/32 (38/62)	3/17 (15/85)	.005
N0/N1–N2	50/2 (96/4)	18/2 (90/10)	.003
M0/M1	46/6 (88/12)	14/6 (70/30)	–
Overall stage I–II/III–IV	20/32 (38/62)	3/17 (15/85)	.005
Treatment			
Surgery alone/surgery + RT	19/29 (37/56)	3/14 (15/70)	.031
CRT + chemotherapy	4 (8)	3 (15)	
Resection margin (n = 48)[b]			
Not involved/very close or involved	22/26 (42/50)	7/10 (41/59)	.596
Follow-up information			
Median (range), months	72 (5–152)	54 (5–78)	<.001
Recurrence or progression: any site[c]	28 (54)	20 (100)	
Local/regional/distant[c]	7/3/20 (13/6/38)	1/2/20 (5/10/100)	
Last status			
NED/DOD/DOC/AD	29/14/0/9 (56/27/0/17)	0/11/0/9 (0/55/0/45)	<.001

Abbreviations: AD, alive with disease; CRT, chemoradiotherapy; DOC, died of other causes; DOD, died of disease (index cancer); DM, distant metastasis; RT, radiotherapy; SLG, sublingual gland; SMG, submandibular gland; TNM, tumor-node-metastasis staging proposed by the American Joint Committee on Cancer (AJCC, 7th ed., 2010).

[a] Log-rank test except for follow-up duration (t-test), $P < .05$.

[b] Calculated from patients who underwent primary surgery with or without radiotherapy.

[c] Mutually overlapping in recurrent or progression sites.

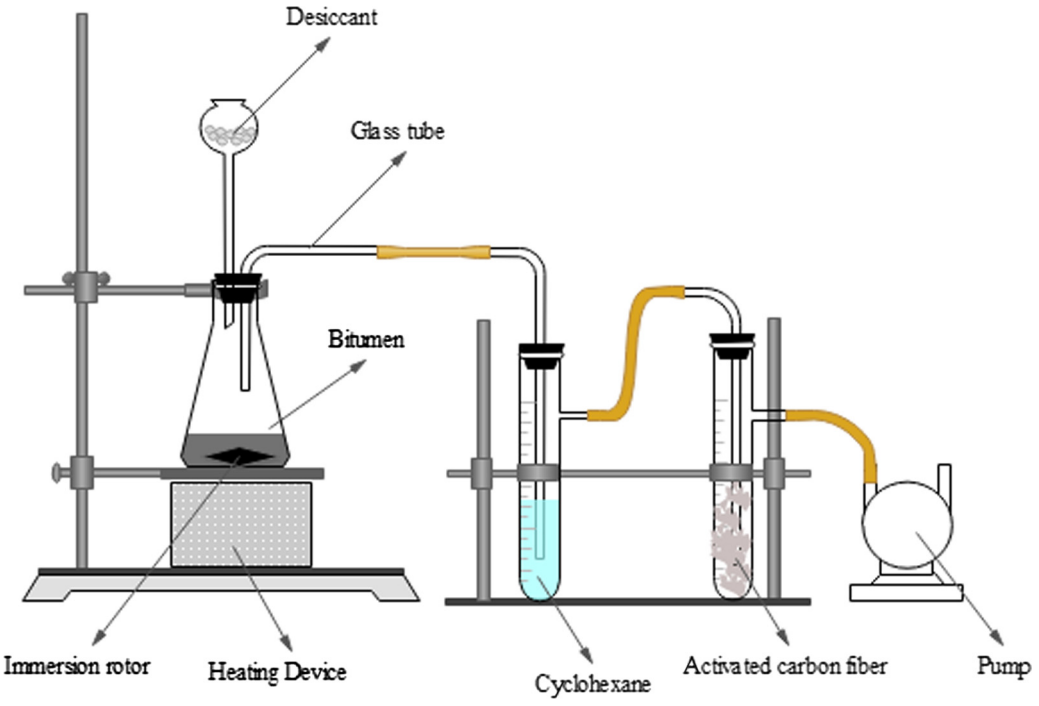

Fig. 1. Schematic diagram of VOCs sample collecting.

and transporting, the temperature of asphalt mixture will drop to 160–180 °C [17]. These typical temperatures should be taken into account when characterizing the VOCs emission. On the other hand, hardly any research can be found that investigates the relation between rheological properties and VOCs emission of bitumen.

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