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Degradative Effect of I.R Radiations on the Constituents of Bitumen

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Authors' contributions

This work was carried out in collaboration between all authors. Author OBN designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors OM and ACO managed the analyses of the study. Author ACO managed the literature searches. All authors read and approved the final manuscript.

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Short Communication

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ABSTRACT

Sample of natural bitumen were taken from bitumen well in Agbabu town in Odigbo Local Government of Ondo State. These samples were separately irradiated with infrared radiations for a period of seven hours. Part of the sample was withdrawn at interval of One, Three and Seven hours. The withdrawn sample was later separated into maltene and asphaltene fractions. The maltene fraction was further separated into saturated, aromatic and polar fraction. The saturated and aromatic fractions were subjected to gas chromatography analysis. The Saturated and aromatic profiles of the bitumen were found to vary with the period of irradiation. The Chemical composition of both the saturated and aromatic compounds in the bitumen decreased with the period of irradiation.

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Thus, decrease in the chemical composition of bitumen as a result of irradiation cause aging of bitumen. Therefore, I.R radiations were found to have a degradative effect on the composition of bitumen.

Keywords: Bitumen; radiations; gas chromatography; degradative effect.

1. INTRODUCTION

The greatest use of bitumen is in paving and road building, particularly flexible pavements. Examples of such areas of usage are in Highways Street and driveways, airfields, Parking areas, service (petrol) stations and industrial floors among several others [1]. Bitumen is thermoplastic as it consistency or degree of hardness varies with temperature. On exposure to different radiation, bitumen behaves in a different manner which will affect it quality. Bitumen is very sensitive to any form of radiation which leads to a degradative effect on its constituent thereby affect its usefulness for engineering purposes [2]. However, because of external environmental effects such as oxygen [3] and ultraviolet (UV) radiation [4, 5], bitumenous properties do not always satisfy operating requirements [6].

Virginie M. et al carried out a research on Study of UV rays effects on the evolution of bituminous mix behavior. The influence of UV radiation on the ageing of bituminous mixtures containing elastomer modified bitumen cannot be totally ignored. The UV impact can be distinguished and found to be dominant for the production of carbonyl functions, the disappearance of C=C double bond of SBS and the increase of binder’s hardening [7]. Nurfazilah Binti Mat Salleh work on effects of overheating bitumen on hot mix asphalt Properties. It was concluded that by increasing the bitumen heating temperatures before mixing procedure proven to oxidize and harden the bitumen at earlier stages. Meanwhile, maximum heating temperatures for 60/70 PEN bitumen before loss it HMA properties should be less or equal to 189°C. Asphaltic concrete with overheated bitumen which is not exceeded the maximum heating temperatures do increase the adhesion between the aggregate particles, durability and possibility to minimize the deformation of road wearing course [8]. Mello M.S et al. investigated on the effects of gamma irradiation on bitumen. He concluded that the penetration results of CAP 50/70 showed that doses below 5 Gy inhibited the influence of gamma radiation in the bitumen mechanical properties. The results of MR tests agree with White oak, leading to conclusion that the gamma radiation causes aging in Bitumen and Asphaltic mixes [9].

The aim of this is to study the degradative effect of Infrared radiation on the composition of bitumen which is one of the major causes why the quality of bitumen is being compromise.

2. MATERIALS AND METHODS

The bitumen used for the degradation experiments were collected from one of the observatory wells in Agbabu, Ondo State, Nigeria. Agbabu is one of the major towns located in the Nigerian natural bitumen belt and the place where bitumen was first discovered in Nigeria (Adegoke, 2000) [10]. The raw natural bitumen obtained from Agbabu was purified as described by the method employed by Olabemiwo et al. The Chemicals used for this research are products of BDH Limited which includes iso – octane (2,2,4-trimethylpentane) [11].

2.1 Radiation of Bitumen Samples with I.R

Dry Petri dish (Pyrex) was weighed and 10 g of purified natural bitumen was put on it. Thin layer of the natural bitumen was formed on the petri dish with thickness of about 0.1 cm. The petri dish containing the purified natural bitumen was subjected to I.R radiations(with wavelength of about 3000 nm) for a period of Seven hours at interval of One, Three and Seven hours respectively. Some of the irradiated sample was withdrawn into petri dish at interval of One, Three and Seven hours to be analyzed. From the withdrawn irradiated sample, 0.6 g of it was carefully and accurately weighed into a beaker and 20 cm^3 of iso – octane was added to precipitate out the Asphaltene component.

Filtration process of the solution was now carried out by making use of filter paper. From the filtration process, two components were obtained which was residue and filtrate. The residue is asphaltene and filtrate is maltene. The Maltene was collected into a sample bottle while the asphaltene was washed about five times with 20 ml iso – octane. By the method employed by Olabemiwo et al. using Column Chromatography, maltene fraction which is the filtrate was separated into saturated hydrocarbons, polycyclic aromatic hydrocarbon and polar compounds.

2.2 Analysis of Gas Chromatographic

The gas chromatographic analysis used was 5890 series (Hewlet Packard) that is equipped with flame ionization detector. The stationary phase used for the analysis is a fused – silica capillary column coated with 0.25 m film of HP-5. For hydrocarbons that are saturated, about 3µL of sample was injected. The column temperature started at 60°C, held for 2minutes isothermally and then increased to 200°C at the heating rate of 10°C/min for 20minutes. It was held at this temperature for 2minutes and then increased to 320°C at the heating rate of 12°C for 5 minutes. The carrier gas used was nitrogen at a pressure of 30 psi. At pressure of 22 and 28 psi, Hydrogen and air were introduced respectively. 300°C and 320°C were used for injector and detector temperature respectively.

The column temperature was held for 2 minutes at about 70°C column temperature for the aromatic hydrocarbons and later increase to 250°C at heating rate of 15°C for 20 minutes.It was held at 260°C for 6 minutes isothermally and then increased to 320°C for 6mnutes at heating rate of 15°C and it was at this temperature for 10 minutes. Nitrogen, which is the carrier gas for this experiment was used at a pressure of 35 psi. At a pressure of 25 and 30 psi, hydrogen and air was introduced respectively. At temperature of 300 and 320°C was when injector and temperature was used respectively and the sample of injected volume is 2 µL. By making use of the standards supplied by the Gas Chromatography equipment manufacturer, Calibration curves for the standard and aromatic hydrocarbon were prepared.

3. RESULTS AND DISCUSSION

Gas Chromatography result of the saturated and aromatic fraction of irradiated bitumen with infrared.

3.1 Bitumen Samples Irradiated with Infra – Red Radiations

3.1.1 Saturated fractions

The total amount in g/kg of the aliphatic hydrocarbons was found to decrease as the period of exposure of the bitumen to ultraviolet radiation increases. This can be contributed to cracking and recombination of product. The irradiation of bitumen brought about the cracking of some higher molecular mass hydrocarbons to lower molecular mass radicals [5].

Table 1. Aliphatic hydrocarbon profile of bitumen irradiated with infra – red radiation

PAH	Amount (g/mg)			
	RAW BT	IRO 1 SAT	IRO 3 SAT	IRO 7 SAT
C_{11}	304.33	371.745	227.238	194.829
C_{12}	3.7772	2.5146	1.5918	2.3541
C_{13}	37.3414	25.7805	56.4245	24.6311
C_{14}	4.4330	2.99145	1.7349	3.1931
C_{15}	45.1838	32.5694	19.69	27.9708
C_{16}	4.1187	2.7674	1.6251	2.6861
C_{17}	6.6893	5.0672	2.8083	4.3397
C_{18}	4.0167	3.3583	1.9249	2.7063
C_{19}	3.9041	2.9776	1.7255	2.5150
C_{20}	8.9376	9.1302	5.0815	6.2955
C_{21}	3.9808	6.6905	3.5853	4.0090
C_{22}	11.4659	8.1386	6.0837	6.2387
C_{23}	2.2465	2.2687	1.2912	1.6358
C_{24}	115.834	40.9511	40.6723	50.120
C_{25}	5.9590	6.3874	4.9352	5.5857
C_{26}	39.1534	25.049	16.561	17.788
C_{27}	10.5277	13.1155	8.0830	9.3792
C_{28}	7.3891	17.6333	4.0959	4.9437
C_{29}	1.0401	0.8327	0.7083	0.7928
C_{30}	1.8928×10^{-5}	-	-	$9.16933 * 10^{-5}$
TOTAL PAH'S	620.4383	579.9684	405.8604	372.0145

Table 2. Polycyclic aromatic hydrocarbon profile of bitumen irradiated with infra – red

PAH	Amount (g/mg)			
	RAW BT	IRO 1 SAT	IRO 3 SAT	IRO 7 SAT
Napthalene	0.7122	0.1160	0.12459	0.11831
Acenapthylene	0.0000	0.0000	0.0000	0.0000
Acephathene	0.0083	0.01394	0.005290	0.00575
Fluorine	0.1980	0.08268	0.06521	0.026631
Phenathrene	0.12949	0.07757	0.062855	0.02038
Anthracene	0.02884	0.02988	0.010598	0.00679
Fluoranthene	0.02289	0.012464	0.006254	0.00255
Pyrene	0.01795	0.03190	0.01187	0.006787
Benzo(a) anthracene	-	0.01750	0.0085474	0.0031555
Chrysene	-	0.01833	0.07822	0.002763
Benzo (b) fluoranthene	0.02399	0.003922	-	$7.858 * 10^{-4}$
Benzo (k) fluoranthene	0.10900	-	-	0.0010659
Benzo (b) pyrene	0.0000	-	-	0.0000
Indeno (1,2,3 – cd)	0.08438	-	-	-
Dibenzo (a,h) anthracene	-	-	-	-
Benzo (g,h,i)	0.0246	-	-	-
TOTAL PAH'S	1.3596	0.4041	0.3734	0.1949

3.1.2 Aromatic fractions

The total amount in g/kg of the polycyclic aromatic hydrocarbons was found to decrease as the period of exposure of the bitumen to infra-red radiation increases. Benzo (a) anthracenes and chrysene which were absent in the control sample appeared after irradiation with infra-red radiations. Indeno (1, 2, 3-cd) pyrene and Benzo (g, h, i) perylene which were present in the control sample disappeared after irradiation with infra-red radiations. Acenaphthylene, Benzo (a) pyrene and Dibenzo (a, h) anthracene were absent in the control and irradiated sample. Benzo (b) fluoranthene which was present after one hour of irradiation disappeared after three hours of irradiation. Benzo(k) fluoroanthene which was present in the control sample disappeared after three hours of irradiation and later reappeared in minimal amounts of seven hours if irradiation.

4. CONCLUSION

Exposure of the bitumen to I.R Radiation resulted in the decrease in the polycyclic and aliphatic aromatic hydrocarbon component of bitumen as the time of irradiation increases which was the same as reported by Olabemiwo et al. Absorption of I.R Radiation by the bitumen resulted in photolytic degradation of aliphatic and polycyclic aromatic hydrocarbon component of bitumen (Esan A.O et al.). However, irradiation of bitumen can be used as a means of remediating a land polluted with bitumen. Extensive investigation into the applicability of I.R radiation in environmental remediation of bitumen polluted environment is therefore suggested.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDIX

DEFINITION OF ABBREVIATION

PAH : Polycyclic Aromatic Hydrocarbon
RAW BT : Raw Bitumen
IRO SAT 1 : Saturated fraction of bitumen irradiated with infrared for one hour
IRO SAT 3 : Saturated fraction of bitumen irradiated with infrared for three hours
IRO SAT 7 : Saturated fraction of bitumen irradiated with infrared for Seven hours
°C : Degree Centigrade
cm^3 : cubic centimeter
UV : Ultraviolet
60/70 Pen : 60/70 Penetration bitumen
C=C : Carbon Double bond
Nm : Newton Meter
HMA : Hot mix asphalt
g/ mg : gramme per milligram
μL : Mircolitre
psi : Pounds per square inch
g/ kg : Gramme per kilogram
°C/ min : degree centigrade per minute
Gy : Gray
SBS : Styrene –Butadiene-Styrene
HP : Hewlet Packard
BDH : British Drug House
MR : Methyl Red
CAP : Covers and Protects
PEN : Penetration

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