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THERMAL AND FTIR STUDY OF WATER IMMERSED COAL OF RANIGANJ COALFIELD, WEST BENGAL

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ABSTRACT

This study investigates the impact of water immersion on the physicochemical properties of coal from two mines within the Raniganj coalfield (RCF). The first sample is taken from Chora Colliery 10 Pit, which is an underground coal mine, and another sample is taken from Dahibadi Basantimata Colliery, which is an open-cast coal mine. Coal samples were subjected to proximate analysis, differential scanning calorimetry (DSC), and Fourier-transform infrared spectroscopy (FTIR). After this, these coal samples were immersed in water in the ratio of 1:10 in the lab environment. These coal samples were taken out after 15, 30, 90, and 180 days and studied by the above method. Proximate analysis revealed a significant increase (30-50%) in moisture and volatile matter content in water-immersed coal compared to raw coal. DSC analysis showed a decrease in ignition temperature of water-immersed coal samples that may increase the risk of spontaneous combustion. FTIR spectroscopy showed that the relative concentration of organic compounds increased in water-immersed coal, which also may favour spontaneous combustion. Volatile matter analysis also confirms the finding of FTIR analysis. These results collectively demonstrate that water immersion significantly enhances the propensity for spontaneous combustion in coal by increasing moisture, volatile matter, and the concentration of reactive organic compounds while lowering the ignition temperature.

Keywords: DSC, FTIR, Spontaneous Combustion, Organic Compounds of Coal, Proximate Analysis

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INTRODUCTION

In this modern era, many countries around the world depend on coal-based thermal power stations for power generation.[1] This is mainly due to the abundant availability of coal, its affordability, and ease of mining. Besides thermal power stations, steel industries, cement industries, and other metallurgical industries also directly depend on coal, and many small and large-scale industries indirectly rely on coal.[2,3] The importance of coal can be ascertaining from the fact that even today, maximum electricity production in India is done by coal-based thermal power stations. India's steel, cement, and thermal power industries are completely dependent on coal. India's name is also included in the world's largest coal-producing country. The main coal-producing areas in India are Jharia, Raniganj, etc. The economy of the coal field area is completely dependent on the coal industry. In the coal field area, several problems like environmental pollution, land subsidence, acid mine drainage, coal mine fire, etc., arise due to the coal industry.[4,5] Among all these problems, coal mine fire is a grave issue. The main cause of a coal mine fire is the spontaneous combustion of coal. This is a natural process in which coal slowly reacts with the oxygen present in the coal mine atmosphere, and a small amount of energy is released, because this reaction is exothermic. This energy keeps getting accumulated inside the mine because of improper ventilation, and the combustion process becomes fast. As a result of this fast reaction, a large amount of energy is released, which takes the form of a coal mine fire after a certain time. Due to a coal mine fire, valuable natural resource coal gets wasted by burning uselessly. The concentration of CO_2, CO, SO_2, and oxides of nitrogen increases in the region of the coal mine fire. After a long time, the coalmine fire baked the surrounding soil and caused land subsidence in the coal mine fire area. Scientists and scholars across the world are trying to solve the problem of coal mine fires, but have not been able to solve it completely. Almost all the coal-producing countries of the world are suffering from the problem of coal mine fires. The problem of coal mine fires is horrifying in waterlogged coal mines, and this problem is exclusive to underground coal mines. This paper aims to find

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out the relationship between the dewatering of coal mines and the spontaneous combustion of underground and open-cast coal samples of the Raniganj Coalfield Region.

EXPERIMENTAL

Materials and Methods

We have taken coal samples from two selected coal mines of the Raniganj coalfield region, West Bengal. The sampling process is done according to the Indian standard. At first, the coal samples were ground into a 212-micron size and further went through the process of analysis via proximate analysis, differential scanning calorimetry (DSC) analysis, and Fourier-transform infrared spectroscopy (FTIR) analysis. After this, these coal samples were immersed in water in the ratio of 1:10 in the lab environment. These coal samples were taken out after 15, 30, 90, and 180 days and studied by the above method.

Sample Collection and Preparation

Raniganj Coalfield region, West Bengal, India, has been selected for this research work. The main reason for choosing the Raniganj Coalfield region is that the Raniganj Coalfield has been facing the problem of coal mine fires for more than 100 years, and India's first coal mining industry was started in the Raniganj Coalfield Region. For this research work, the coal samples were collected from two different coal mines of Raniganj coalfield (RCF). The details of the coal samples are given in Table-1. The first sample is taken from Chora Colliery 10 Pit, which is an underground coal mine, and another sample is taken from Dahibadi Basantimata Colliery, which is an open-cast coal mine. A part of these coal samples was converted to a particle size of 212 microns as per the Indian standard, and four main components, such as moisture, volatile matter, and fixed carbon, were detected by commonly accepted proximate analysis. The organic functional groups were also detected by the FTIR analysis method. The remaining part of the samples was immersed in water in a 1:10 ratio in granule size. These water-immersed coal samples were taken out after 15, 30, 90, and 180 days and were converted to 212-micron size by the above-mentioned method and analyzed.

Proximate Analysis

This is a universally accepted traditional method of coal analysis. As per the Indian standard, this method is done by taking proper care. In this method, we have taken 1 1-gram coal sample having a size of 212 μ, and inserted it into a hot air oven at 110° C for an hour. The weight difference after heating is the inherent moisture value of the coal.[6] Another one-gram sample having a size of 212 μ is taken into a cylindrical silica crucible and heated at 950° C, and weight after heating the weight difference gives the volatile matter content of coal. Finally, we have taken 1 1-gram coal sample in a silica crucible and inserted it into the furnace for an hour at 820 ° C after heating, the remaining mass in the silica crucible is the ash content of the coal.[17] The fixed carbon of coal is calculated by using the above data and the following formula:

$$\text{Percentage Fixed Carbon} = 100 - (\%\ \text{Ash} + \%\ \text{VM} + \%\ \text{IM})$$

The proximate analysis processes have been done in CSIR- CIMFR, Barwa Road, Dhanbad.

Differential Scanning Calorimetry (DSC)

DSC is a thermal analysis method in which the sample is first heated by the help of instrumental heat, and then by examining the heat emitted or absorbed by the sample, it is ascertained whether the sample reacts exothermically or endothermically with oxygen in the presence of air. We have used this instrument to study the spontaneous behaviour of coal, for which we have placed about 10 mg of coal sample in a sample holder and heated the sample at a temperature ranging from 30 to 750 degrees Celsius in the presence of normal air and studied the changes in the thermal behaviour of the sample. Several experiments, including repeatability, were performed for the two coal samples from the RCF to determine their spontaneous heating behaviour, and their results are presented in Fig.-2,3,4, and 5.

Fourier Transform Infrared Spectroscopy (FTIR)

Among all the spectroscopy techniques, FTIR spectroscopy is one of the reliable and effective techniques. FTIR spectroscopy mainly detects various functional groups present in an unknown compound by absorbing infrared (IR) light at a specific frequency. The IR spectrum range lies between the visible and microwave regions of the electromagnetic spectrum.[12] The Infrared (IR) region is divided into three parts, namely, the near IR, which is from 12500 to 4000 per cm, the mid IR, which is from 4000 to 200 per cm, and the far IR, which is in the range of 200 to 10 cm. Apart from this, this spectroscopy has a fingerprint region which is from 650 to 1500 per cm, which gives the specific identification of the molecule of each compound. For identifying most of the organic compounds, the instrument displays the absorption peak at 4000 to 400 per cm.[13,14,15] Experts identify these peaks and estimate the organic compounds present in them. For this they use previously known reference absorptions like O-H, C-H and N-H stretches in the range of 3000 to 4000 per cm, triple bonds in the range of 2050 to 2500 per cm, C=O (aromatic ester) or C-N (aromatic amine) in the range of 1126 to 1036 per cm, C-H (aromatic bonds) in the range of 900-700 per cm, C=O (aromatic carbonyl) in the range of 1700-650per cm etc.[16,17,18,19] This instrument has been used to study the functional groups present in raw coal and coal immersed in water.

RESULTS AND DISCUSSION

Proximate Analysis

On doing proximate analysis of raw coal samples, the value of IM was obtained as 4.6% and 1.3%, the value of VM was found to be from 32.26% to 23.29% and the value of Ash was found to be from 18.12% to 32.94%. On adding all these values and subtracting them from 100, the value of fixed carbon was found to be from 49.62% to 43.77%. Thus, the IM and VM, and Ash of water-immersed coal samples were obtained as follows in Tables-1 and 2. In all these results, basically a lot of difference was seen in the moisture and volatile matter content, whereas no major difference was found in fixed carbon, as shown in Fig.-1a and 1b.

Table-1: Proximate Data of Raw Coal and Water Immersed Coal Samples from Chora Colliery Sites.

Sample Code	Seam Name	Colliery Name	M_{ad}	VM_d	A_d	FC_d
TR6/0D	R-VI	Chora Colliery 10 Pit	4.76	32.26	18.12	49.62
TR6/15D	R-VI	Chora Colliery 10 Pit	7.17	28.13	13.47	52.41
TR6/30D	R-VI	Chora Colliery 10 Pit	5.99	37.28	28.42	28.31
TR6/90D	R-VI	Chora Colliery 10 Pit	1.05	34.88	44.02	20.05
TR6/180D	R-VI	Chora Colliery 10 Pit	1.38	33.89	44.46	20.27
Mean			4.07	33.288	29.698	34.132
Range			1.05-7.17	28.13-37.28	18.12-44.46	20.05-52.41

Table-2: Proximate Data of Raw Coal and Water Immersed Coal Samples from Dahibadi Basantimata Colliery Sites

Sample Code	Seam Name	Colliery Name	M_{ad}	VM_d	A_d	FC_d
DGP/0D	GP	Dahibadi Basantimata Colliery	1.03	23.29	32.94	43.77
DGP/15D	GP	Dahibadi Basantimata Colliery	1.63	23.52	32.61	42.85
DGP/30D	GP	Dahibadi Basantimata Colliery	1.02	23.49	23.29	52.2
DGP/90D	GP	Dahibadi Basantimata Colliery	5.6	35.58	28.49	30.33
DGP/180D	GP	Dahibadi Basantimata Colliery	4.87	35.75	19.78	52.2
Mean			2.83	28.326	27.422	44.27
Range			1.02-5.6	23.29-35.75	19.78-32.94	30.33-52.2

Differential Scanning Calorimetry (DSC)

On studying the DSC results, it is found that the change in the thermal behaviour of the coal sample is an endothermic change at around 40 to 110 degrees Celsius, which is definitely due to IM, whereas above 200 degrees Celsius, exothermic changes can be easily seen, which is definitely due to the volatile matter present in the coal and the ignition of coal. This exothermic level continues till 600 degrees Celsius, and after that it becomes stable. The ignition temperature of raw coal and coal immersed in water has been detected mainly by DSC analysis, which is found to be 248.8 degrees Celsius for raw coal of DGP mines and 245.5 degrees Celsius for coal immersed in water. Whereas the ignition temperature of raw coal of Chora 10 pit mines was 224.5 degrees Celsius, the ignition temperature of coal immersed in water was 226.5 degrees Celsius. 219.5 degrees Celsius has been found. DGP mines is an open-cast mine, and Chora 10 pit mines is an underground coal mine, shown in Fig.-2 to 5. After the coal of both types of mines comes in contact with water, the ignition temperature of both types of them decreases, which increases the risk of spontaneous combustion of coal.

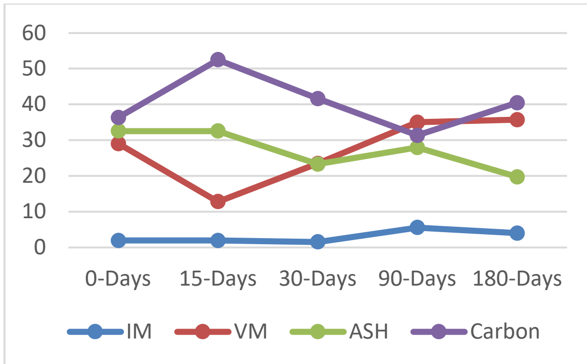

Fig.-1A: Proximate Data Graph of DGP Mines

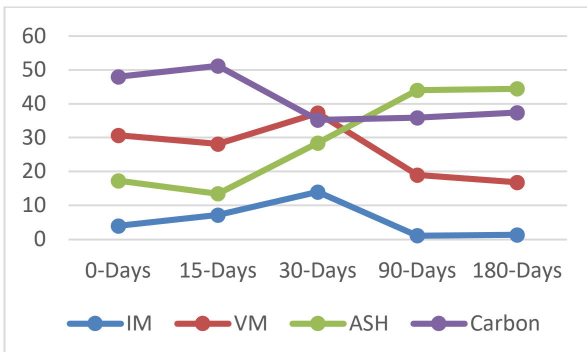

Fig.-1 B: Proximate Data Graph of Chora 10 Pit Mines

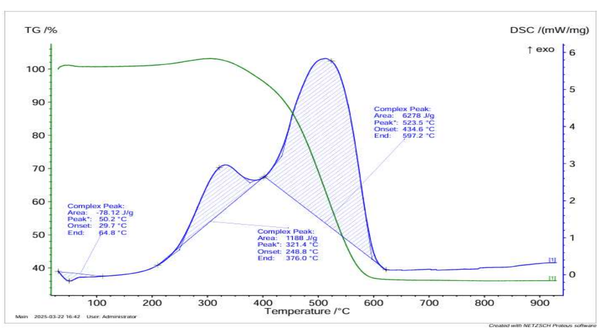

Fig.-2: TG/DSC Graph of RAW COAL SAMPLE of DGP Mines

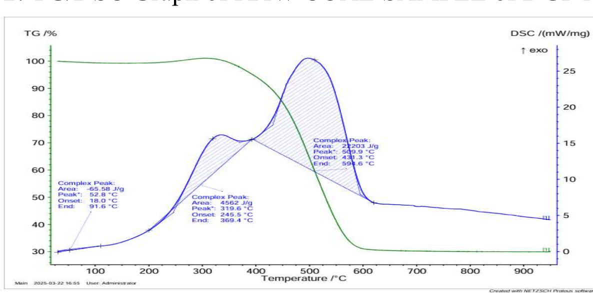

Fig.-3: TG/DSC Graph of Water-Immersed Coal Sample of DGP Mines

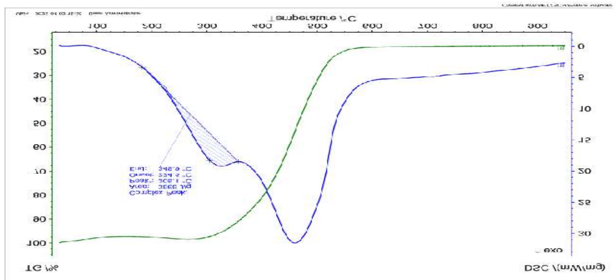

Fig.-4: TG/DSC Graph of Raw Coal Sample of CHORA 10 PIT Mines

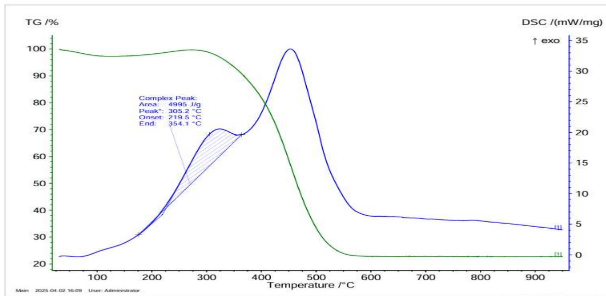

Fig.-5: TG/DSC Graph of Water-Immersed Coal Sample of CHORA 10 PIT Mines

Fourier Transform Infra-Red Spectroscopy (FTIR)

FTIR spectra of the coal sample are shown in Fig.-6 and 7. The peaks found in the FTIR spectra of raw coal and water immersed coal are mainly in the range of 500 to 900 per cm indicates that aromatic compounds and unsaturated hydrocarbons may be present, similarly 1000 to 1600 per cm indicates that carbonyl compound, 1780-2100per cm may due to amides and triple bonded hydrocarbons and 3100 to 3600 per cm indicates presence of hydroxyl group. The plotted graph in terms of absorbance versus wave number showed that the peak of aromatic compounds, carboxylic acid, aldehyde, ketone, unsaturated hydrocarbon, alcohol, etc., is found at a high level, which favours spontaneous combustion.

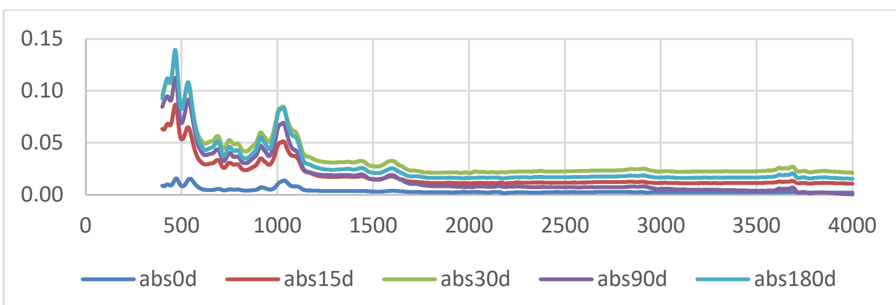

Fig.-6: FTIR Blend Graph of Fresh and Water-Immersed Samples of DGP Mines

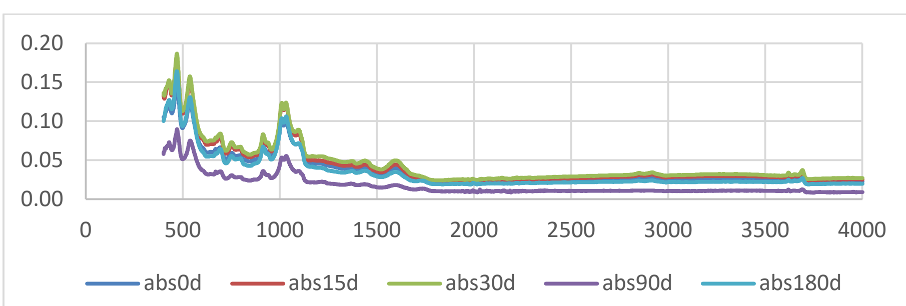

Fig.-7: FTIR Blend Graph of Fresh and Water-Immersed Samples of CHORA 10 PIT Mines

CONCLUSION

The results obtained from the Proximate, DSC and FTIR analysis of raw coal and water immersed coal elucidate that after being in contact with water, the volatile matter content of coal increases to a high level and the amount of organic functional groups present in coal also increases to a high level, as a result of which the ignition temperature of coal decreases and due to this the risk of spontaneous combustion in coal increases. These results also clarify that after being immersed in water, the risk of spontaneous combustion in coal from both open-cast and underground mines increases, which may be due to the increase in organic compounds and volatile matter of water-immersed coal.

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CONFLICT OF INTERESTS

The authors declare that there is no conflict of interest between them.

AUTHOR CONTRIBUTIONS

The present work is related to *SDG-12: Responsible Consumption and Production*. All the authors contributed significantly to this manuscript, participated in reviewing/editing and approved the final draft for publication. The research profile of the authors can be verified from their ORCID ids, given below:

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