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Spontaneous combustion liability of coals and coal-shales in South African coalfields

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ABSTRACT

Spontaneous combustion is one of the major challenges in the South African coal mining sector. The event involves a range of complex physical and chemical processes, caused by the chemical reaction between coal, coal-shale and oxygen. Coal and coal-shale undergo low-temperature oxidation when exposed to oxygen in the air. The frequent occurrence of self-heating of coal-shale was reported in some South African coal mines to be the likely cause of spontaneous combustion but not the coal alone. Coal-shale found between layers (above and below) of coal seams vary considerably in intrinsic properties and proneness to spontaneous combustion. This thesis evaluates the main factors which most strongly affect the spontaneous combustion liability of coal and coal-shale.

In South Africa, the widely accepted spontaneous combustion liability index, the Wits-Ehac Index was used to measure the spontaneous combustion liability index of fourteen (14) bituminous coal samples and 14 coal-shale samples respectively. The results of the Wits-Ehac Index show that most of the samples are liable to spontaneous combustion. However, the Wits-Ehac Index was unable to obtain a liability index during the testing of some coal-shale samples. This necessitated the development of a new device.

A new apparatus which accurately measures the spontaneous combustion liability by using the reactivity of oxygen within coal and coal-shale was developed. A series of spontaneous combustion tests were conducted with this apparatus and a new liability index referred to as the Wits-CT Index was created. The Wits-CT Index uses the total carbon content and the temperature variations obtained from the samples during their reaction with oxygen to predict their spontaneous combustion liability. It was found that coal and coal-shale with a high Wits-CT Index are more liable to spontaneous combustion. The results from the two liability indices were compared with respect to what is happening in the mines and proved that samples with higher spontaneous combustion liability indices are more prone to spontaneous combustion than those with lower liability indices.

The relationships between the spontaneous combustion liability (obtained from the Wits-Ehac Index and Wits-CT Index) and the geochemical data ((proximate and ultimate analysis, total sulphur and sulphur forms, petrographic composition, X-ray fluorescence (XRF) and X-ray diffractometer analysis (XRD)) of the samples were evaluated. The experimental results show that intrinsic properties of these materials complement the spontaneous combustion liability

test results. Comparative analyses of the intrinsic properties and spontaneous combustion liability indicated similarities between the mechanism of coal oxidation and that of the oxidative processes undergone by coal-shale. It was found that the coal samples have higher intrinsic properties and spontaneous combustion liability than the coal-shale samples. This study indicates that the South African coal and coal-shale are enriched with more inertinite macerals than the vitrinite and liptinite macerals. The distribution of the macerals has been shown to have reasonable influences on spontaneous combustion liability. The contents of the main ash oxides are strongly related to the mineral constituents of the samples as indicated by the XRF. The quantity and mineral constituents in coal and coal-shale were evaluated by chemical procedures and optimised by the XRD analysis. The XRD analysis confirmed the presence of mineral constituents in the samples as identified by the XRF.

The influence of the intrinsic properties of coal-shale in relation to coal properties affecting spontaneous combustion liability was established using a statistical method (regression analysis). The results provide quantitative descriptions and show the relationships between the dependence of the spontaneous combustion liability index (the Wits-Ehac Index and the Wits-CT Index) and independent variables (intrinsic properties). The linear regression analysis shows that the spontaneous combustion liability index indicates linear relationships with some of the intrinsic properties based on the set criterion and thus, identifies the major intrinsic factors affecting spontaneous combustion liability. It was found that a definite positive or negative correlation coefficient exists between the intrinsic factors and spontaneous combustion liability. A set of models to predict the spontaneous combustion liability was derived by using multiple regression analysis between the dependent variables and independent variables. The best significant correlation along with the most appropriate model as indicated by the R-squared values, the coefficient of correlations and standard error was used to predict the most reliable spontaneous combustion liability index. The results obtained from these models have been used as a reliable tool to support previous works on the role of intrinsic properties on spontaneous combustion liability.

The application of chemical inhibitors on coal and coal-shale under laboratory studies were found to create an oxidative barrier on the surface of these materials to prevent self-heating and spontaneous combustion. The study indicated that by altering the self-heating characteristics (i.e. chemical and physical characteristics of a coal and coal-shale surface) through the use of chemical inhibitors, spontaneous combustion liability can be minimized.