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THEORETICAL APPROACHES TO ADDRESSING THE PRIMARY CAUSES OF HARMFUL AND EXCESSIVE GAS EMISSIONS DURING EXPLOSION PROCESSES, AS WELL AS STRATEGIES FOR MITIGATING THESE EMISSIONS

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Abstract
While ANFO is effective for rock fragmentation, its use raises concerns regarding the environmental impact of gas emissions generated during the detonation process. This study emphasizes the need for improved predictive models for assessing the amount and types of gases and dust released during open-pit mining blasts. By understanding the relationship between blasting parameters—such as charge weight, depth, and surrounding geological conditions—and the resulting emissions, we can develop strategies to minimize atmospheric contamination. The gases produced, including harmful constituents like nitrogen oxides and carbon monoxide, contribute to air pollution and have implications for public health and environmental sustainability. Thus, the research presented herein aims to provide deeper scientific insights into the dynamics of explosive gas emissions. By analyzing the factors influencing these emissions, we can enhance blasting practices to reduce their ecological footprint while maintaining mining productivity. Furthermore, recommendations will be proposed for the adoption of alternative technologies and materials to mitigate the release of harmful gases and promote environmentally responsible mining practices.

Keywords: Air pollution, dust, gases, explosions, open-pit mining, emissions, blasting parameters, environmental impact, ammonium Nitrate-Fuel Oil (ANFO), detonation, predictive methods, rock crushing, gas release, water vapor (H2O), carbon dioxide (CO2), nitrogen (N2), sustainable practices, emission control, mining productivity, environmental safeguards, blasting technology.

Introduction

Dust and gases generated during explosions are one of the main factors that cause air pollution. Existing methods of predicting gas and dust released into the atmosphere during open-pit mining processes using current methods and data require a deeper scientific justification of the reasonable parameters of blasting [1,2]. It is known that gases are the main energy caused by the explosion, which causes the crushing of rocks, but the excess of these gases is considered one of the man-made factors that cause damage to the atmosphere.

Picture 1: General view of gas and dust caused by blasting process in open pit mining.

The types of gases that are released due to detonation during the explosion are as follows [3]:

- H_2O water vapor
- CO_2 carbon dioxide
- N_2 nitrogen
- NH_4 ammonium gas
- CH_4 methane gas
- CO carbon monoxide
- NO nitrogen oxide
- N_2O nitrogen oxide
- NO_2 nitrogen dioxide

Ammonium Nitrate-Fuel Oil (ANFO) is a two-component explosive that is now widely used, consisting of ammonium nitrate granules (94%) and fuel additives (6%). Despite the low detonation speed and detonation pressure, ANFO has a high detonation efficiency due to the release of a large amount of gas detonation pressure (GDP). The ANFO product, which includes these characteristics, is a cheap and widely used explosive in the industry [3,4]. One of the main factors that cause the release of harmful and excess gases is a violation of the oxygen balance. During the explosion process, the correct reaction of substances and the effect of energy on the full-fledged rock depend absolutely on the oxygen balance being at a normal level [5].

The rate of detonation in the substance also affects the release of gases. Ammonium nitrate granule size is also highlighted as a factor influencing the detonation rate [6].

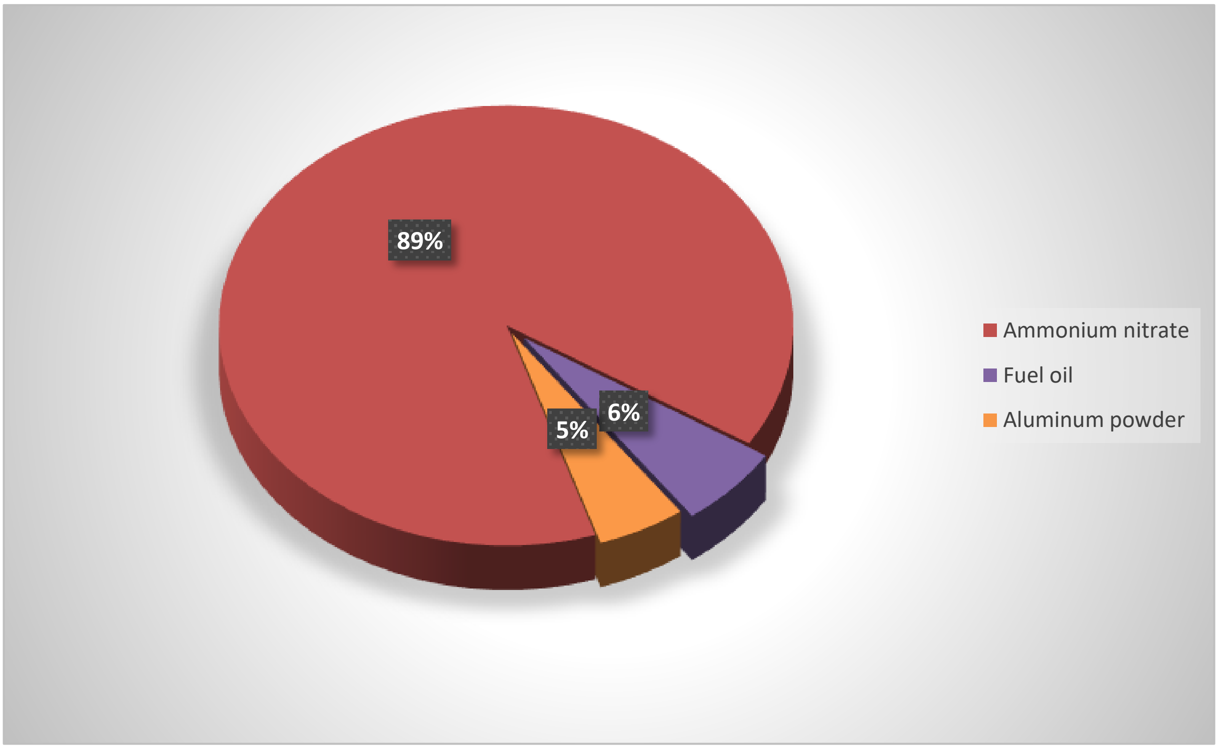
In the event of an explosion, the excess of gas release depends on the following factors:

- Oxygen balance
- Sizes of granules
- Violation of substance composition
- Increase in humidity in the environment

One of the theoretical technological factors of measures to reduce the level of excessive release of gases is the ability to choose the optimal fuel or additional substances for the main substance used as a propellant and to achieve the standard oxygen balance. it is also necessary to ensure that it does not mix with other substances. We will illustrate the topic using the ANFO explosive substance mentioned above.

ANFO = AN (ammonium nitrate) + FO (fuel oil)

Ammonium nitrate is mainly divided into 2 types depending on its application. They are FGAN (Ammonium Nitrate, Fertilizer Grade), i.e., the type used in the production of fertilizers for the agricultural industry, and the second is TGAN (Ammonium Nitrate, Technical Grade). that is, it is intended for technical fields. Although their chemical composition is the same, the degree of porosity of the granules is different. The porosity of TGAN type ammonium nitrate differs from FGAN type and is designed to better absorb the fuels used for explosion [7]. For normal oxygen balance, it is necessary to choose the optimal type of fuel (FO-fuel oil). In addition, a small amount of aluminum powder (Al) is added to ANFO in order to increase its explosive energy [8].



Picture 2: Basic composition of ANFO explosive.

Diesel fuel is the main additive used as fuel in ANFO. However, the following substances can be added as fuel or used as a mixture to prevent oxygen starvation and the release of excess gases:

Methanol CH3OH
Ethanol C2H5OH
Nitromethane CH3NO2

The table below shows the composition of harmful gases released as a result of fuel combustion:

Carbon dioxide CO2
Water vapor H2O

Ethanol - C2H5OH + 3O¬2 2CO2 ¬+ 3H2O

Carbon dioxide	**CO_2**
Water vapor	**H_2O**

Methanol - 2CH3OH+3O¬2 2CO2 ¬+ 3H2O

Carbon dioxide	**CO_2**
Water vapor	**H_2O**

Nitromethane - CH3NO2+3O¬2 4CO2 ¬+ 6H2O+4N2

Carbon dioxide	**CO_2**
Water vapor	**H_2O**
Nitrogen	**N_2**

Diesel – C26+1902 12CO2+13H2O

Carbon dioxide	**CO_2**
Water vapor	**H_2O**
Nitrogen	**N_2**
Nitrogen oxide	**NO_x**
Sulfur dioxide	**SO_2**
Carbon monoxide	**CO**

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