
# COAL FLOTATION IN MIXTURES OF INORGANIC SALTS

By

**Rawya Gamal Mohamed Saad**

A Thesis Submitted to the
Faculty of Engineering at Cairo University
In Partial Fulfillment of the
Requirements for the Degree of
**MASTER OF SCIENCE**
In
**MINING ENGINEERING**

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**Title of Thesis:**

# COAL FLOTATION IN MIXTURES OF INORGANIC SALTS


**Key Words:**
Coal; flotation; salts solutions; hydrophobic; statistical design.


**Summary:**


Coal is not only an indispensable source of energy but also it has various applications. However, its impurities limit its usage. Although the flotation is the most common beneficiation technique, it consumes a considerable amount of water. Therefore, different types of water were tested in coal flotation. In particular, saline water was found to enhance the flotation of naturally hydrophobic coal particles. In this research, two coal samples differ in their ash content were subjected to flotation using some inorganic salts. Statistical design was used to study the binary, tertiary salt mixtures and to optimize the flotation process. It was observed that Mg ions have positive effect

# Disclaimer

I hereby declare that this thesis is my own original work and that no part of it has been submitted for a degree qualification at any other university or institute.

I further declare that I have appropriately acknowledged all sources used and have cited them in the references section.

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Finally, I dedicate this work to my family especially my mother, my father and my husband for everything they have done for me.

# Table of Contents

# List of Tables

# List of Figures

# Abstract

Coal is a complex yet abundantly available energy source. The primary problem in using coal is the necessity to minimize its combustion products. Therefore, coal cleaning processes to remove these impurities and reduce their effects on the environment is one of the solutions to overcome this problem.

Wet processing techniques, especially the flotation techniques, are the most commonly used in coal processing plants. The depletion of distilled/de-ionized water as well as the presence of the most of the processing plants in desert areas mandates the searching for other resources. These resources include the sea water as well as the processing water. The main concern in using these types of water is the presence of appreciable concentration of salts. The previous studies showed that although the presence of salts deteriorates the flotation process for some minerals, it has several advantages in the flotation of the hydrophobic particles like coal. The advantages of using seawater in flotation not only include reducing the treatment costs obviously incurred from the use of distilled water, but also reducing the costs and the negative impacts of chemicals. Most of the reported studies use single salt and consequently illustrate the effect of salts on enhancing the recovery. However, either the process water or the sea water has several types of salts. Therefore, studying the flotation of coal in water with single, binary and tertiary salt mixtures needs to be tested to investigate the effect of each salt as well as the interaction of these salts.

Therefore, in this work, Canadian and Egyptian coal samples were obtained, prepared and characterized by proximate and ultimate analyses using ASTM standards. The characterization study of ash, moisture, volatile matter and fixed carbon revealed that Canadian and Egyptian samples can be classified as medium rank high volatile bituminous (b) class coal. The two coal samples were subjected to sampling procedures using coning and quartering technique followed by grinding and screening. In addition, the flotation of these coal samples was tested in the presence of different inorganic salts such as: NaCl, $MgCl_2$, $CaCl_2$ and $MgSO_4$.Two statistical designs were used to study the main effects as well as the interactive effects of used salts on the coal flotation taking the ash removal as a response. The first design is used to investigate the single and interactive effects between the used salts on both El-Maghara and Canadian coal samples by showing the effects of single, binary and tertiary mixtures of NaCl, $MgCl_2$ and $CaCl_2$ on ash removal from both coal samples. On the other hand, the second design was used to study the factors that affect the flotation process such as: pulp density, conditioning time, particle size and doses of $MgCl_2$ and $MgSO_4$ and consequently to find the optimum conditions of flotation and the best performing salt. In Canadian coal, the first design showed that $MgCl_2$ and $CaCl_2$ has the lowest and highest ash percentage 7.1 and 8.2 with dose 4 kg/t, respectively. In the second design, the lowest ash percentage 7.8 was at particle size of 400 µm, dose of 4 kg/t $MgSO_4$ and at 15 min conditioning time. It was observed that the magnesium salts affect the flotation positively in terms of ash removal while the presence of calcium in any mixture leads to reducing the ash removal. For recovery %, the highest recovery was 89.18 %. In El-Maghara coal, tertiary (NaCl, $MgCl_2$ and $CaCl_2$) and binary ($MgCl_2$ and $CaCl_2$) showed the highest and the lowest ash reduction, respectively. For recovery %, the highest recovery was 47 % with binary mixtures 4Kg/t MgCl2 and 4 Kg/t $CaCl_2$.

# Chapter 1 : INTRODUCTION

## 1.1. Background

In geological sense, coals are not minerals, but series of rocks layers that formed by piling up of vegetable matter and plant remains [1]. It also defined as combustible black or brownish-black sedimentary rock consists of carbon and hydrocarbons. The coal seams are mostly interbedded with sandy, silt, clayey formations, were originally horizontal or nearly horizontal. For coal forming, the most suitable areas are shallow-swampy environments. After accumulated of vegetable matter and plant remains in situ or drifted by water, chemical decay reduced under wet condition that subjected to bacterial action resulting in the formation of peat. Under high temperature and pressure of the plant material, chemical and physical changes were caused in the vegetation that was transformed it to peat and then to coal. The process of transforming plant remains to peat is known as the humification stage. Transformation of peat deposits into coal seam is known as a coalification process which gradually converts peat into lignite, sub-bituminous coal, bituminous coal, anthracite and under very high temperature may be produced a graphite that known as meta-anthracite, as shown in Fig 1.1[2].

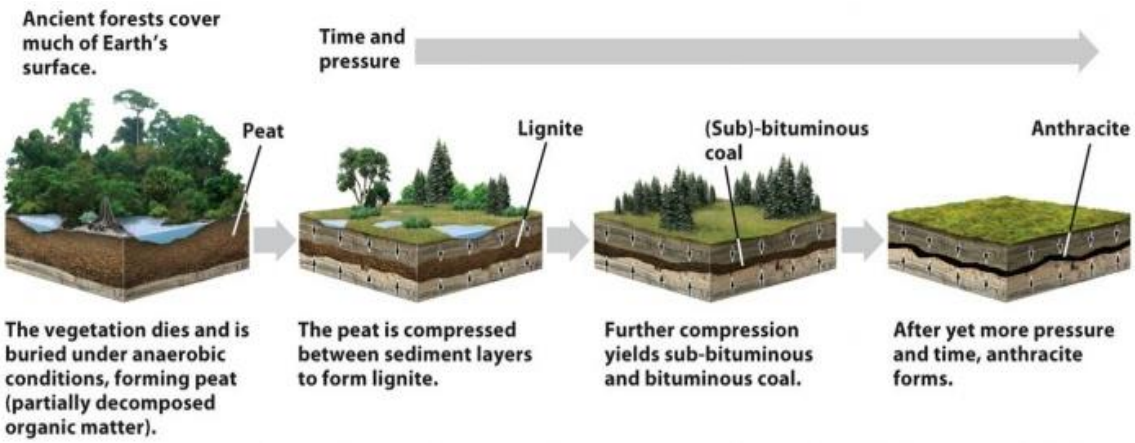


**Figure 1.1: Transformation of coal**

Coal is an organic material of complex nature and structure. It consists of carbon and hydrocarbon. Coal does not have specific chemical formula. It consists of many groups and units, aromatic, aliphatic, oxygen and nitrogen in smaller amounts. A simplified formula is shown in Fig 1.2 [3].

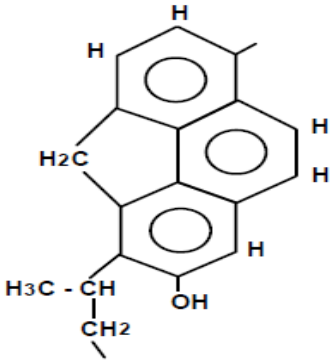


**Figure 1.2: Simplified coal structure indicating its typical chemical groups [EU, ESF]**

It is one of the most important sources of energy. This important role has been played for centuries not only supplying electricity, but also an important fuel for production of steel, cement, and the other industrial products. The fluctuation on the oil and gas prices keeps the coal as an alternative resource. Figure 1.3 shows the importance of coal in our lives through a simple example for what the coal can do in just 24 hours.

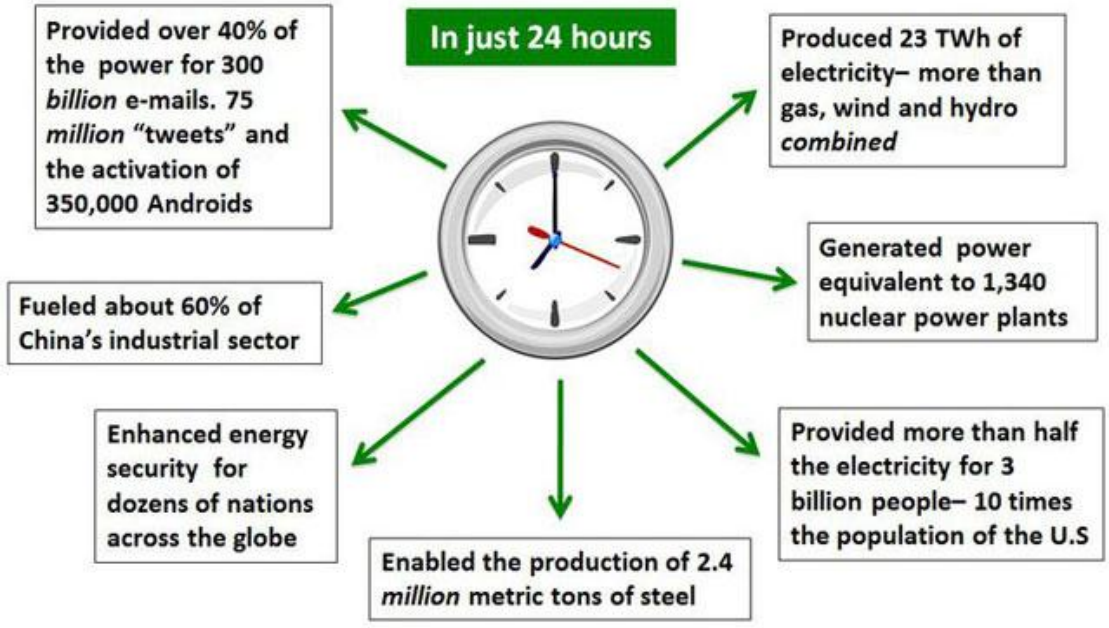


**Figure 1.3: Importance and impact of coal in one day [IEA, EIA 2010]**