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Waste Management in Coal and Oil Industry in Context of Alternative Sources of Energy Development

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ABSTRACT

The global energy landscape is changing. Traditional centers of demand are being overtaken by fast-growing emerging markets. Oil and coal exploration and production activities aside from a necessity, are responsible for various environmental accidents around the world. Inadequate treatment of those wastes can threaten the human health and safety as well as the environment. The article is dedicated to the actual problem today - the recycling of waste oil and coal industry and the search for ways to minimize their impact on the environment. In addition, the main goal of the work is to find ways of obtaining alternative energy in the process of waste processing. The authors analyzed the state of the oil and coal mining industry and considered the main ways of processing their waste. Among all analyzed methods of processing waste oil and coal industry, the authors pay special attention to the methods of thermal impact on waste, since they allow us to obtain an additional source of energy.

Keywords: Coal Industry Waste, Oil Industry Waste, Alternative Energy, Environment
JEL Classifications: Q32, Q42, Q53

1. INTRODUCTION

The global energy landscape is changing. Traditional centers of demand are being overtaken by fast-growing emerging markets. The energy mix is shifting, driven by technological improvements and environmental concerns (Helmy and Kardena, 2015). More than ever, industry needs to adapt to meet those changing energy needs. The demand for oil, coal, and other energy sources are growing dramatically with the worldwide energy consumption that projected to increase by 37% in 2035. Rising demand driven by world's population which predicted to increase by 25% in the next 20 years. Oil and coal exploration and production activities aside from a necessity, are responsible for various environmental accidents around the world. Inadequate treatment of those wastes can threaten the human health and safety as well as the environment (Kapitonov and Voloshin, 2017).

The overall demand for energy looks set to continue to expand, as increasing prosperity in fast-growing emerging economies lifts billions of people from low incomes. Plentiful supplies of energy enable this rise in living standards, with virtually all the growth in energy demand expected to come from outside the developed world. The extent of this increase is likely to be curbed by improvements in energy efficiency, as increasing attention around the world is devoted to using energy more sustainably (Teleuyev et al., 2017).

Recycling of industrial waste is an actual problem of the modern world. A large number of harmful substances are produced as a result of industrial activity of enterprises and plants. The share of hazardous workings is about 15% of the total number of production wastes (Medvedev et al., 2003). But their harmful properties, even with a small amount can cause serious damage to human health and the environment in general. This fact forces us to develop quality processing methods.

The aim of the article is to find the best ways of obtaining energy from the processing of wastes from the oil and coal industry.

2. LITERATURE REVIEW

Waste is a consequence of the nature management process that creates a material basis for normal production and intellectual and spiritual development of mankind for an indefinite time on the basis of limited natural resources, without degradation of the environment (Alekseev, 2014). To meet the needs of people annually extracted up to 30 billion tons of minerals, moves 100–150 billion tons of earth's interior (Lotosh, 2007). During subsequent processing, a significant part of the fossil is not included in the final commodity products, forming waste. This creates problems for their storage, burial, protection of the environment.

Chemicals contained in industrial waste contaminate water basins in the areas where industrial plants are located, which ultimately leads to pollution of the waters of the World Ocean, which contributes to a sharp decline in its biological productivity and adversely affects the climate of the planet (BP, 2017, Chernyaeva, 2013). The generation of waste as a result of the activities of industrial enterprises adversely affects the quality of the soil. In the soil, excessive amounts of harmful living organisms, including carcinogens, accumulate (Medvedev et al., 2003; Petrov et al., 1997).

Among all the analyzed methods (Bagabiev et al., 2003; Medvedev et al., 2003; Lotosh, 2007; Alekseev, 2014) of processing waste oil and coal industry, the authors pay special attention to the methods of thermal impact on waste, since they allow us to obtain an additional source of energy (Senkevich et al., 2016; Kurnosov et al., 2010; Medvedev et al., 2002).

3. METHODOLOGY

The authors analyzed the state of the oil and coal mining industry and considered the main ways of processing their waste. Among all analyzed methods of processing waste oil and coal industry, the authors pay special attention to the methods of thermal impact on waste, since they allow us to obtain an additional source of energy. Method of the high-temperature pyrolysis and industrial coking mode of coal and coal slurries indicate that thermal processing of the feedstock makes it possible to produce coke oven gas and then use it in open-hearth, blast-furnace and other high-temperature furnaces. Method of the technical processing of thoil industry waste by using light thermal cracking means that products of thermal cracking of oil waste, due to their properties, may be widely used in motor oil and other kinds of fuel production.

4. RESULTS AND DISCUSSION

4.1. Obtaining Alternative Energy Sources from Oil Industry Waste

The oil industry of the world represents the leading branch of the world economy and the fuel and energy industry, in particular, which influences the trends of this economy and even the political relations of countries. The oil industry is characterized by large capital investments, the number of oil wells in the world that are currently exploited for resource extraction reaches a million.

In 2016, world crude oil production inched up by 0.35 m b/d or 0.5% as compared to 2015, to reach 75.48 m b/d, marking a seventh consecutive year of growth (Table 1). The top three crude oil producing countries were Saudi Arabia (10.46 m b/d), Russia (10.29 m b/d) and the United States (8.88 m b/d). World oil demand averaged at 95.12 m b/d in 2016, up by 1.5% year-on-year, with the largest increases in Asia and Pacific, particularly China and India, Western Europe, North America and Africa (OPEC, 2017).

Oil wastes are hydrocarbon mixtures that are different in composition and physicochemical properties and are formed in the processes of storage, transportation and use of oil fuel, oils and lubricants, as well as petroleum products that have lost commercial qualities and are unfit for further use as intended. Petroleum products and oil waste that enter the environment are toxic and explosive and fire hazardous. Their presence worsens the already complex ecological situation in any city and region.

With increasing consumption of petroleum products, the amount of oil waste is growing. Sources of oil-polluting contaminants are various vehicles, service and repair points, warehouses and points of delivery of combustive-lubricating materials, heat-power complexes and other objects. In addition, each installation (a boiler, an oven, a gas turbine, a diesel engine and a carburetor engine) is a source of oil waste. It burns liquid hydrocarbon fuel. Oil wastes enter the environment in both liquid and gaseous state, with gaseous hydrocarbon contaminants capable of transporting over significant distances (up to 2000–3000 km in 2–3 days) and dispersing over huge areas.

Under existing regulations, oily water and oil waste must be collected and disposed of for further purification, regeneration or disposal in designated areas. At current status, problem full utilization of hydrocarbon wastes is relevant. First of all, from point of view the negative impact on the environment. However, a current method is not always possible to achieve best of possible results. Ecological problems become are critical danger, and also decreasing of oil supplies - to force people to search for new technology in waste management.

Table 1: List of countries for oil production in 2016 according to OPEC (OPEC, 2016)

No	Country	Oil production (bbl/day)
1.	Saudi Arabia	10460,2
2.	Russian Federation	10292,2
3.	United States	8874,6
4.	Iraq	4647,8
5.	China	3981,8
6.	Iran	3651,3
7.	United Arab Emirates	3088,3
8.	Kuwait	2954,3
9.	Venezuela	2510,0
10.	Brazil	2372,5

At present day disposing of waste must be seen in the context with other live support problems, including a looming environmental and financial crisis. In this respect, it is highly desirable that, in addition to environmental safety, technology has been profitable or has to opportunities to decrease a negative energy balance. Method for thermal processing of waste is widely distributed at present time. Advantage of this method is to deal issue of the biological disposal.

Oil waste is one of the most dangerous component of natural environment. Oil waste is a strong polydisperse system that is formed as a product of oil, water and mechanical admixtures interaction. An oxidation of organic part of the waste by the oxygen of air and catalytic action of metals of this oxidation have a great impact on the formation of such system and lead to formation of resinous substances. The average oil waste consists of oil component (35–45%), mechanical admixtures (under 35%) and water (20–30%). The composition of oil waste may be various and depends on place and period of its formation. This circumstance may strongly complicate the problem of waste utilization. Considering all main world tendencies in petrochemical industry, it should be mentioned that Ukrainian oil refineries realize the closed cycle principle which means using waste as a raw in technological process. This way allows to create a technology with the least amount of waste and decrease the negative influence of waste on the environment and produce the great amount of secondary raw as well. All kinds of oil wastes at the oil refineries are traditionally collected and kept in the special vessels, which are called waste collectors (or slurry tanks), and are divided into three layers: The upper one is emulsion, the middle is waste water and the lower is a sediment with a big amount of mechanical admixtures. These collectors occupy the large territory, which is completely excluded from the agriculture. The technologies, which are used for oil waste processing, can be divided into the following groups (Senkevich et al., 2016):

- Thermal: Burning in the different types of ovens, formation of asphalt residue;
- Physical: Saving into the deep geological repository, separation in the centrifugal field, vacuum filtration and filtration under the pressure;
- Chemical: Extraction by solvents (solidification by using cement, glass or clay) or organic additions (epoxy or polystyrene resin etc.)
- Physical and chemical: Using special reagents that change physical and chemical properties with further processing on the appropriate facilities;
- Biological: Microbiological decomposition in the ground directly in the place of keeping and biothermical decomposition

Difficulty of oil waste recovery is determined by the following factors:

- Oil waste is a hardly-separated emulsion;
- Oil waste has its own features about the environmental safety;
- Oil waste provokes corrosion and this circumstance requires using high-quality sorts of metal for equipment production.

Among all existing methods of waste recovery and utilization, the most effective are:

- Delivery of waste to the refinery, where bruiqetted fuel is produced;
- Chemical rendering harmless. In this case, petroleum substances of waste are combined by reagent (quicklime and surfactants (CaO: 92–93%, Synthetic detergents: 7–8%) and as a result the non-toxic product is produced and this product may be used as a construction material);
- Mechanical separation into the components: Water, mechanical admixtures, petroleum products by centrifuges, separators and decanters.

Mechanical destruction of stable water-oil emulsions is based on technological method of artificial changing of concentration of disperse phase with further coalescence of small drops of this phase.

A great amount of technological facilities which provide the interfacial separation of oil waste have designed nowadays. These facilities include separators, centrifuges and hydro cyclones. Very often the filtration is used as an effective way to separate the inverse emulsions mechanically. The advantage of this method is the high yield of commodity oil, and the disadvantage is the high price for equipment.

The chemical way of oil emulsion separating for its regeneration and recycling of hydro carbonaceous products by direct appointment (light fractions, oil etc.) is based on using special surfactants as the demulsifying agents. The main disadvantage of this process is the cost of reagents and their high consumption by one ton of oil waste. Since practically all liquid hydrocarbons are lighter than water, the separation of oil emulsion is accompanied by forming a layer on its surface. This layer basically includes petroleum products and less than 5% of water and allows gathering that emulsion for further salvaging. Different kinds of polyelectrolytes, such as salts of highmolecular sulfonic acids may be used as the colloidal substances. It is also known, that at Russian oil refineries the main way of recovery and salvaging of oil waste includes the following steps: Centrifugation, extraction, electrolytical separation of heavy metals, composting or production of waterproofing materials, salvaging on the solid wastes polygon. The disadvantages of this way are connected with the difficulty of implementation of complex-designed equipment.

The authors (Senkevich et al., 2016) propose to realize technical processing by using light thermal cracking. Products of thermal cracking of oil waste, due to their properties, may be widely used in motor oil and other kinds of fuel production. For example, the diesel fraction is a valuable component for production of commodity diesel fuel, fuel for low-speed engines of agricultural equipment, road and building vehicles. A gasoline fraction, after it's purification from sulphur-containing and resinous components, may be used as a component commodity gasoline compounding or in oil solvents production. A kerosene fraction, after its deep purification from water, sulphur-containing and resinous components, may be used in a jet fuel production and as lighting kerosene. A fuel oil or tar is completely available for boil fuel production and as a crude for motor fuel, distillate base oil,

oil coke production by pyrolysis, a crude for road and building bitumen production.

4.2. Methods of Obtaining Energy in Processing Coal Industry Waste

The coal industry and global supply chains associated with it play a key role in economies of many countries, creating jobs, developing national infrastructure and eradicating poverty, especially in developing countries. It is reported by the International Labour Organization (2018), that the industrial sectors, including construction, manufacturing, mining, quarrying and utilities, accounted for around 22% of total employment in lower middle-income and developed countries in 2017, and for around 10% in developing countries. Globally, more than 7 million people are directly engaged in the coal industry (including more than 153 thousand people in Russia) and millions of workplaces are created in related industries.

In 2016, around 90% of global coal production (Figure 1) was mined by 7 leading coal-mining countries (China, USA, Australia, India, Indonesia, Russian Federation, South Africa). Despite the fact that in 2016 world coal production fell by 6.2%, or 231 million tons of oil equivalent (mtoe), as it is reported by BP Statistical Review of World Energy (2017), and coal's share of global primary energy consumption fell to 28.1%, coal production in Russia and India rose by 3.1% and 2.4%, respectively.

In 2016, global coal consumption fell by 1.7 % or 53 mtoe. Nevertheless, China and India remained the leaders in coal consumption (the share of China - 50.6 %, or 1887.6 mtoe, the share of India - 11.0%, or 411.9 mtoe). Moreover, the Asia and Pacific region still occupied the leading place in global coal consumption (73.8% of total coal consumption in terms of mtoe).

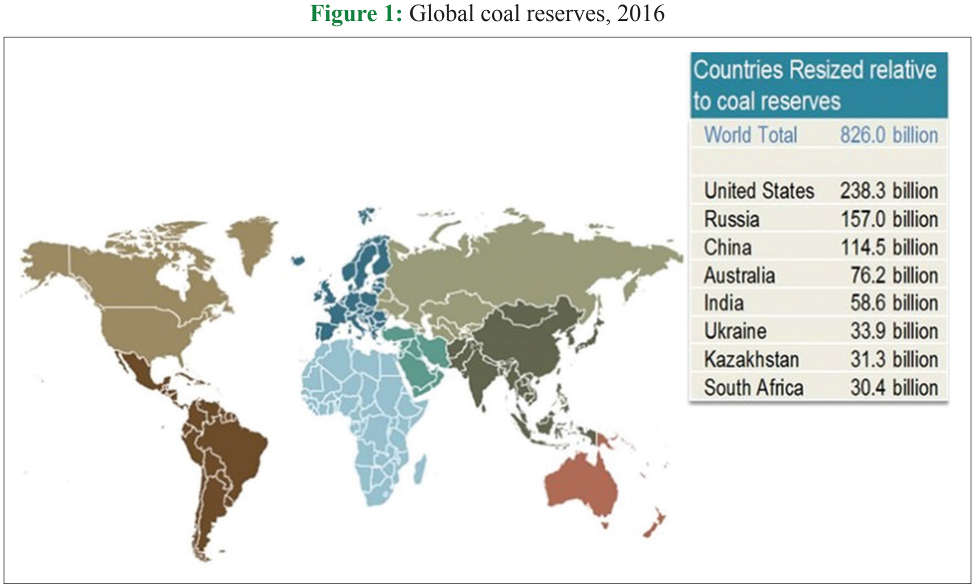
Prospective is the search for new sources of energy resources, among which an important place is determined by the methods of coal processing. Studies have shown that one of the important sources of gas, heat and electricity generation can be coal waste and low-grade coals (Petrov et al., 1997; Saranchuk et al., 2006). Solving the problem of processing low-grade coal and sludge, it is necessary to determine the most rational method, which allows to obtain economically advantageous products of decomposition of coal molecules, to carry out waste-free processing of the entire mass of waste, and to reduce the ecological load on the region (Medvedev et al., 2006). The most promising direction for the processing of carbon-containing raw materials is energy technology, which consists in the thermal processing of combustible components, as a result of which steam-gas products are used in various technological processes, and the mineral portion remaining during the combustion of the raw material is used for building and other materials (Makarov and Kharlampovich, 1986; Yakunin and Agroskin, 1978). The composition of components in the waste of coal mining and enrichment includes:

- Combustible material (coal crumb, coal dust, water-coal suspension);
- Natural stone (stone material);
- Gravel, sand;
- Clay rocks (clays, coalites, orgillites, loams);
- Burned clay rocks.

The authors consider one of the possible options for thermal processing of coal and coal slurries – high-temperature pyrolysis (Medvedev et al., 2002; Bagabiev et al., 2003), which is carried out in laboratory conditions with a final temperature of heating the feedstock to 1000°C according to the methods provided by the current standards. By pyrolysis in the general case, the process of decomposition of organic compounds of coal under the influence of high temperatures should be understood. In the process simulated at the laboratory, coking of the initial coal-bearing raw material under oxygen deficiency conditions was carried out, which helps to reduce the yield of solid and liquid reaction products and increase the yield of gas volumes as the temperature rises (Glushchenko, 1980).

Under identical conditions of thermal processing, the yield of gaseous products depends on the structure and properties of the starting products. In this case, the general trends of thermal

Figure 1: Global coal reserves, 2016



destruction (decomposition of the initial molecule under the action of temperature) of coals together with coal slurry look as follows. Drying the fuel, i.e. removal of the main amount of free moisture, is completed to 100–125°C. Up to a temperature of 300°C, the first stage of thermal degradation of carbon-containing substances is released, and when heated above 300°C there is an intense formation of volatile substances (Figure 2). The temperature ranges 510–600°C is the optimum semi-coking temperature, when the formation of resins is completed. An increase in the fuel heating temperature above 600°C is accompanied by the conversion of char to coke and the subsequent increase in the yield of gases. These trends can be traced both in the samples of slime and in coals.

The results of laboratory studies (Kurnosov et al., 2010) of coal and coal slurries in the high-temperature pyrolysis and industrial coking mode indicate that thermal processing of the feedstock makes it possible to produce coke oven gas and then use it in open-hearth, blast-furnace and other high-temperature furnaces. Thermal processing of slimes in the industrial coking mode allows to obtain gas volumes of the order of 200–220 m^3/t with a combustion heat of 15–25 MJ/m^3, which exceeds the same indicator for humic coal by 2–5 times, and by sapropel in 1.5–2 times. The additive to the sludge of the humic coal contributes to an increase in the release of gas by a factor of 1.5–2 with the same conditions for thermal treatment of the sludge. When heat treatment of a joint sample of sludge and coals in different ratios, the heat of combustion was significantly lower than the value of the heat of combustion of the pyrolysis gas from the slurry by 2–2.5 times. The prospect of obtaining coal from gases with an average and high heat of combustion (more than 18 MJ/m^3) from industrial coal coking will be revealed by the method of industrial coking. It will allow using it for long distances as well as for household purposes of individual enterprises and settlements. When coking carbonaceous wastes, such as sludges, coke gas is released from them in an amount of about 200 m^3 per 1 ton of raw materials; at the same time, gas production resources amount to approximately 20 billion m^3 per year, which is equivalent to about 10 billion m^3 of natural gas (Figure 3).

Figure 2: Dependency of time mass decreasing for a reference mass of example in various temperatures

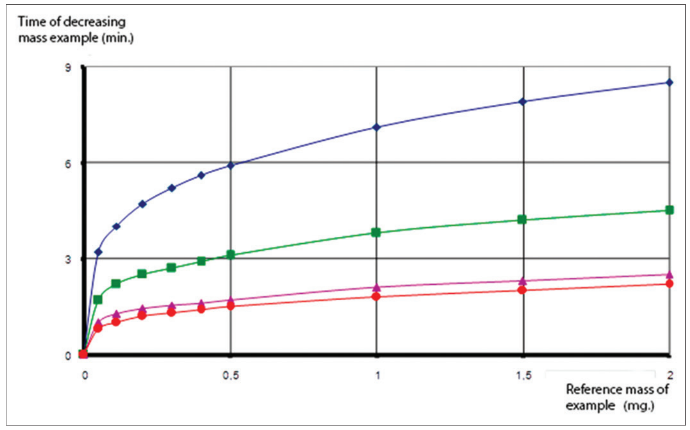
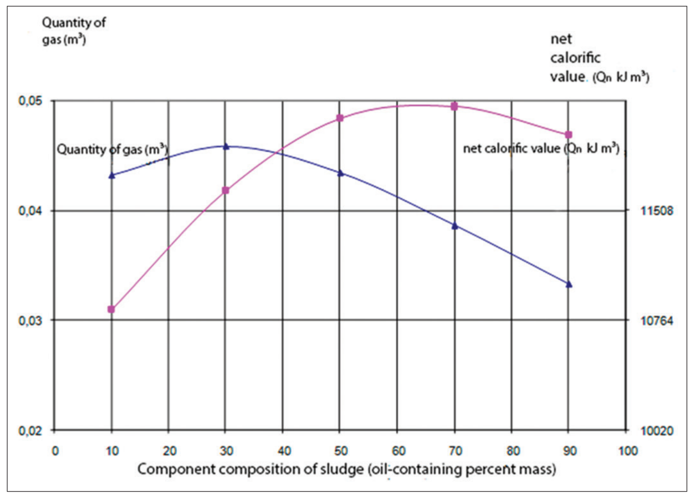


Figure 3: Dependency of quantity gas, net calorific value from heating value



5. CONCLUSION

The problem of environmental pollution in the fuel and energy sector in most countries of the world arose during the period of involvement in the use of coal, oil, shale and peat instead of fuel of vegetable origin (firewood, agricultural waste). This is due to the fact that the extraction, transportation, processing and burning of mineral fuels is accompanied by the formation of various types of waste and harmful emissions that have a negative impact on the environment in the areas where enterprises are located. This applies to all branches of the fuel and energy complex, which includes the gas, oil and coal industries, power plants, power lines and pipelines that ensure transportation of energy carriers from the place of production to the regions of consumption. The authors analyzed various options for processing waste from the oil and coal industry. It was found that as a result of the processing of coal industry waste, high-temperature pyrolysis produces gas, which can be used as an additional source of energy. And products of thermal cracking of oil waste, due to their properties, may be widely used in motor oil and other kinds of fuel production.

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