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Andrzej Gonet*, Jerzy Fijał, Aleksandra Jamrozik*, Stanisław Stryczek*, Torleiv Bilstad*****

CATEGORIZATION OF THE DRILLING WASTE AS A CRITERION OF SELECTING THE METHODS OF THEIR DETOXICATION, RECOVERY AND MANAGEMENT****

1. INTRODUCTION

Growing awareness of a deleterious impact of various waste types on the natural environment and the human health [3, 5, 9] gives rise to the development of novel technologies centered on waste detoxication, recovery and utilization [1, 2, 4, 6, 8, 10–12, 18, 22]. Mining, including also prospecting for and extraction of hydrocarbons, is one of the sectors of economy generating significant volumes of waste. The drilling waste are inherently represented by rock cuttings and spent drilling muds and fluids [7, 13, 14, 17, 19, 23], highly diversified in their chemical composition.

Such a variability of the composition requires detailed tests prior to selecting the most suitable technology of the utilization of a drilling mud.

Drilling muds are formulated generally on the basis of water. However, more and more often oil-based drilling fluids are used because of their technological advantages. As leading goals of utilization of all types of spent drilling liquids should be producing a mineral material suitable to be applied to engineering earthen works or to agriculture.

* AGH University of Science and Technology, Faculty of Drilling, Oil and Gas, Krakow, Poland

** AGH University of Science and Technology, Faculty of Geology, Geophysics and Environmental Protection, Krakow, Poland

*** University in Stavanger, Faculty of Science and Technology

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Among many technologies of detoxification, recovery and utilization of drilling waste, the following should be mentioned [7]:

- Physico-chemical methods. They include the solidification and stabilization of waste with the use of selected materials (e.g., cement, bentonite, lime or flying ash) and procedures (neutralization, precipitation of heavy metals, removal of substances hindering utilization, e.g., by leaching chlorides).
- Recycling. Understood as utilization of waste in the form of substitutes for building materials, for instance in road or railway line constructions.
- Burning or thermal transformation. It refers only to the waste containing hydrocarbons.
- Bioremediation. It also refers only to the waste containing hydrocarbons.
- Disposal. It can be done as an injection into a rock mass, deposition in the facilities that neutralize drilling waste, dumping on industrial or communal landfills.

According to general rules of waste management, the essential procedures followed in the course of drilling should include: preventing waste generation, minimizing waste volumes, and reducing a negative impact of waste by their most effective treatment and utilization.

2. CLASSIFICATION CRITERIA OF DRILLING WASTE

Based on the results of investigations of several tens of drilling muds and fluids of various types [7], a detailed evaluation of their chemical composition, physico-chemical, physico-mechanical and microbiological properties as well as a comprehensive analysis of their mineral and phase composition have been prepared. In particular, the procedures applied involved the following: instrumental chemical methods to determine main and trace elements (using, for instance, atomic absorption spectroscopy AAS, induced plasma spectroscopy ICP, X-ray fluorescence XRF); scanning electron microscopy SEM to analyse the morphology and microstructure of solid waste components and their chemical composition in microareas SEM-EDS; chromatographic analyses to identify organic compounds with a special attention to hydrocarbons. The mineral and phase composition was established using X-ray diffractometry, Fourier transformed infrared spectroscopy FTIR and combined thermal methods. In turn, microbiological analyses were used to establish ecotoxicity of spent drilling liquids, and to assess with biological tests the possibilities of utilization in water-soil environments the processed and transformed drilling waste.

The results of all the mentioned research methods and a review of standards [15, 16, 20, 21, 24] have allowed us not only to evaluate a detail quality of various types of drilling waste but also to determine adequate possibilities of their treating, detoxicating and utilizing. As a result, three categories of waste separated from spent drilling muds and fluids have been distinguished (Tab. 1).

The flow chart (Fig. 1) presents the procedures leading to the determination of a category of the spent drilling muds and fluids on the basis of their possible utilization.

Table 1

Parameters of spent drilling muds and fluids important for their utilization [7]

Category I	Category II	Category III
Σ H_2S, S^{2-}, HS^- < 5mg/dm^3	Σ H_2S, S^{2-}, HS^-: 5–150 mg/dm^3	Σ H_2S, S^{2-}, HS^-> 150 mg/dm^3
Ba < 3000 mg/kg	Ba 0.3–5 wt.%	Ba > 5 wt.%
Zn < 3000 mg/kg	Zn 0.3–1 wt.%	Zn > 1 wt.%
Cr < 800 mg/kg	Cr 0.08–0.5 wt.%	Cr > 0.5 wt.%
Σ petrol < 750 mg/kg	Σ petrol 750–3000 mg/kg	Σ petrol > 3000 mg/kg
Σ mineral oils < 3000 mg/kg	Σ mineral oils 0.3–1 wt.%	Σ mineral oils > 1 wt.%
Σ MAH < 250 mg/kg (monocyclic aromatic hydrocarbons)	Σ MAH 250 – 1000 mg/kg (monocyclic aromatic hydrocarbons)	Σ MAH > 1000 mg/kg (monocyclic aromatic hydrocarbons)
Σ PAH < 200 mg/kg (polycyclic aromatic hydrocarbons)	Σ PAH 200–1000 mg/kg (polycyclic aromatic hydrocarbons)	Σ > 1000 mg/kg (polycyclic aromatic hydrocarbons)

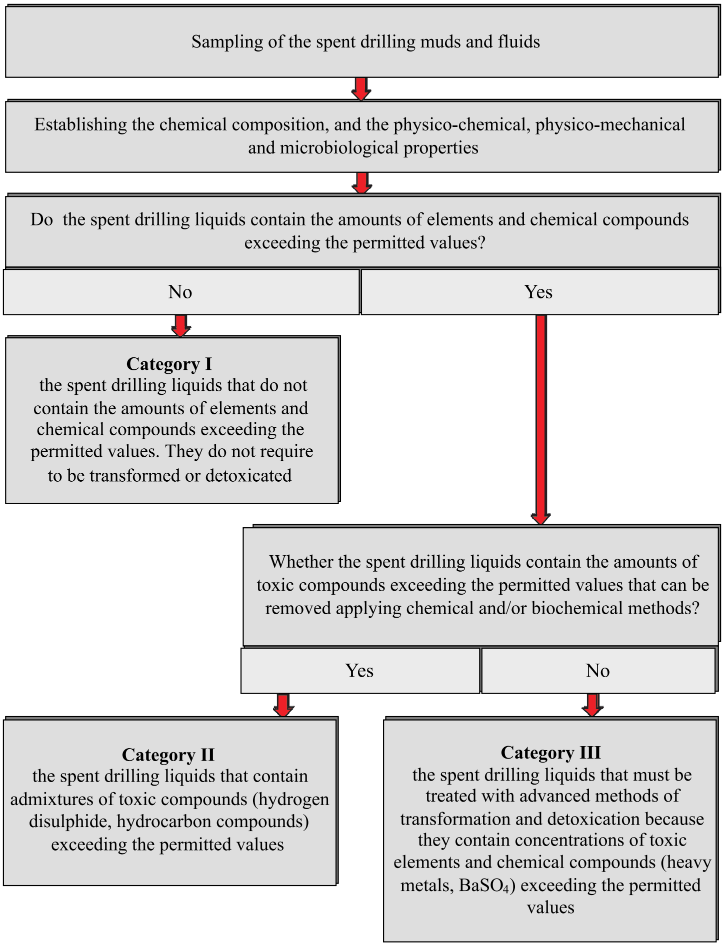

Fig. 1. The categorization procedure of spent drilling liquids based on their utilization aspect [7]

Into the category I (Tab. 1) have been included waste that are usually generated in the course of drilling shallow wellbores using drilling muds that do not contain any toxic or deleterious substances. Such waste may be treated with relatively simple methods and then separated into grain-size fractions that can be directly utilized in the natural environment. The flow chart (Fig. 2) presents details of such procedures tailored to specific utilization possibilities.

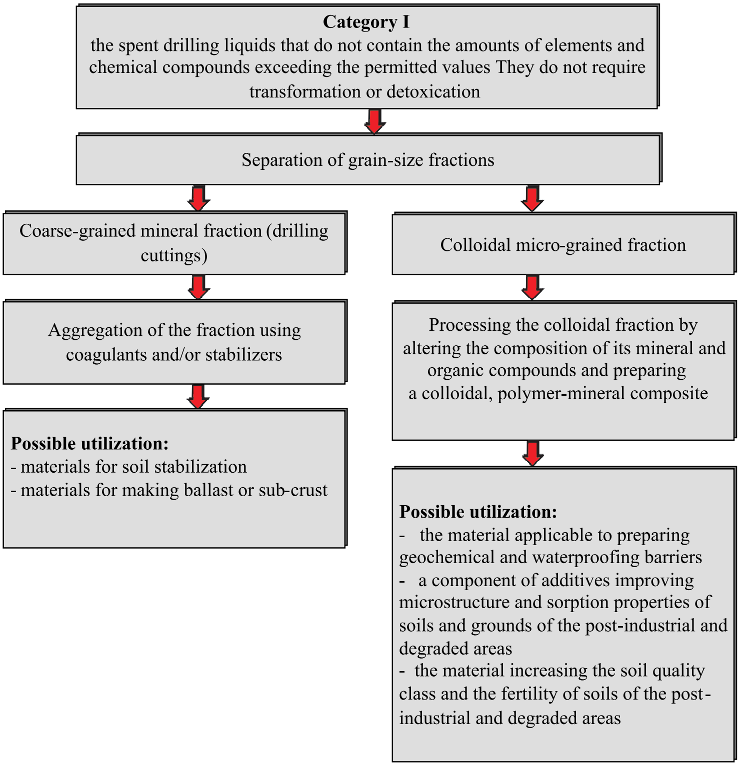

Fig. 2. Processing and utilization possibilities of the drilling waste of the category I [7]

Into the category II (Tab. 1) have been included drilling waste [3] containing either admixtures of toxic compounds (such as hydrogen disulphide and hydrocarbon compounds) exceeding the permitted values, or high concentrations of salts soluble in water. Such waste may be efficiently detoxicated with relatively simple chemical and/or biochemical methods. The detoxication and a separation into grain-size fractions make possible recovering and full utilizing useful compounds. It particularly refers to the solid phase, which represents a mineral-organic composite, highly reactive to mineral components of soils and usually possessing high ion exchange capability. Such a material may be used in agriculture in the form of compounds improving the soil microstructure and/or the soil quality class, and also the soil fertility especially in post-industrial areas [9, 21]. The saline solutions separated in the treatment processes should be de-ionized and the salts precipitated may be a useful product used in the winter maintenance of roads. The flow chart (Fig. 3) presents details of such procedures tailored to the specified utilization possibilities.

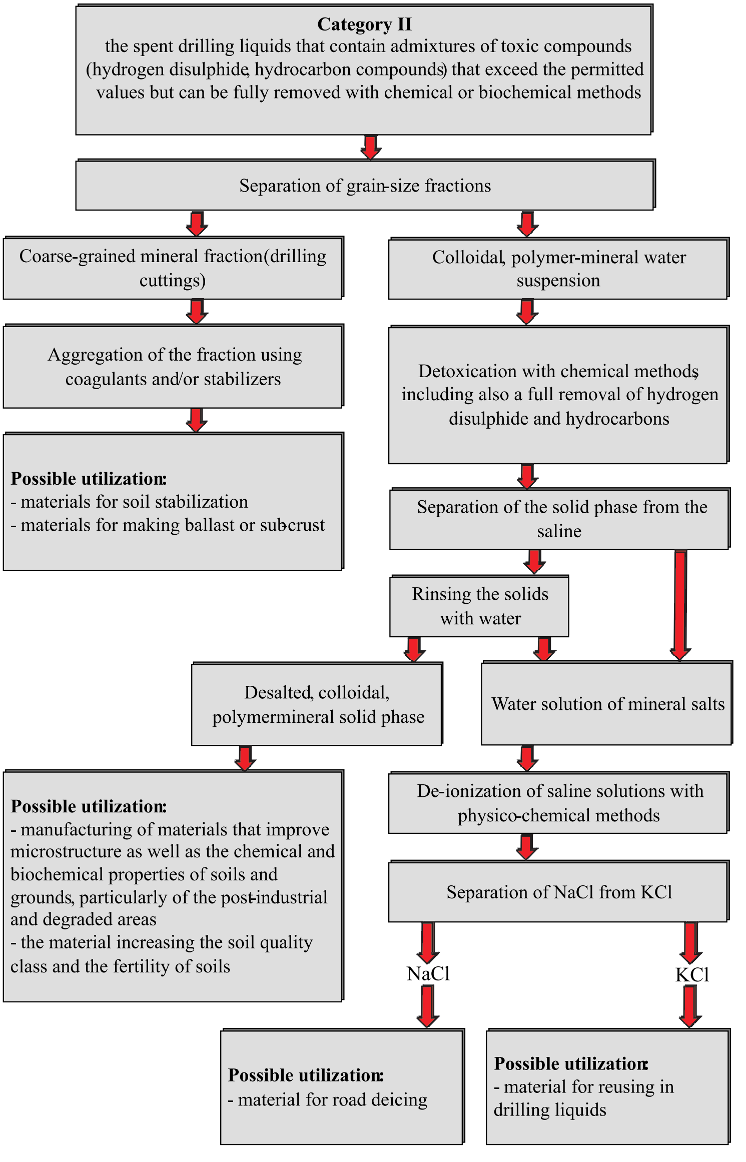

Fig. 3. Processing and utilization possibilities of the drilling waste of the category II [7]

Into the category III (Tab. 1) have been included spent drilling fluids containing concentrations of toxic elements and/or compounds exceeding the permitted values, mainly of barium as $BaSO_4$ (barite) or, sometimes, other heavy metals, whose removal using chemical methods is uneconomic. Their treating and processing requires more advanced methods. In some waste types of this category the contribution of barite to the total solid fraction separated is sometimes higher than 25 wt.%. Such drilling waste are proposed to be processed with gravitational and/or flotation methods to separate barite concentrates that can be reused to formulate highly weighted drilling fluids. If the amounts $BaSO_4$ in the solid phase are lower than 25 wt.%, such waste may be utilized for producing ceramic materials, mainly plasters and shields absorbing X-ray radiation (for instance in X-ray medical or research laboratories). The flow chart (Fig. 4) presents details of such procedures tailored to the specified utilization possibilities.

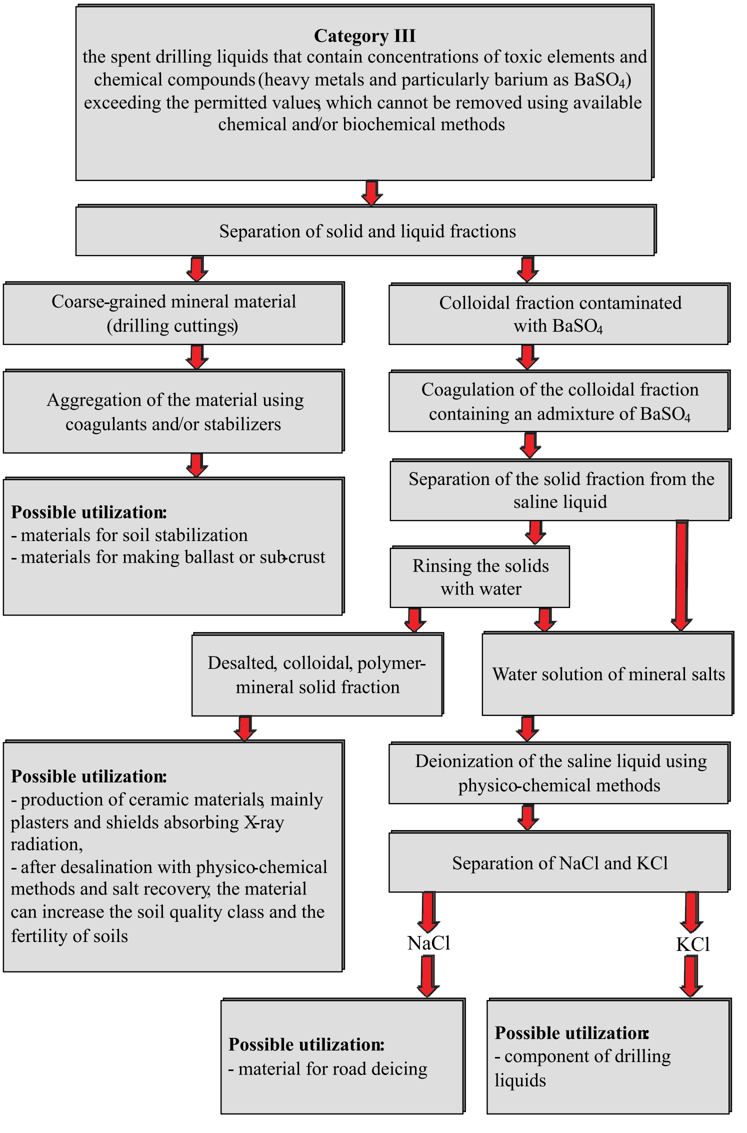

Fig. 4. Processing and utilization possibilities of the drilling waste of the category III [7]

3. CONCLUSIONS

1. A reduction of adverse impacts of the drilling industry on the natural environment can be made by designing the wellbores and by their drilling in the ways that minimize the volume of the waste generated and maximize their management.
2. Considering a substantial variability of the chemical and phase-mineral compositions of drilling waste, corroborated also by the authors, the technology of their processing should be properly selected. Some indications of the respective procedures have been shown in Figure 1, whereas some limitations in Table 1.
3. The drilling waste recognized as the category I should be processed according to the procedures shown in Figure 2 to obtain the materials for ground stabilization, for making ballast or sub-crust of transporting routes and also as additives increasing the soil quality class and the fertility of degraded or post-industrial soils.
4. The waste recognized as the category II should be treated following the procedures shown in Figure 3, including, separation, aggregation, detoxication and the final separation of the solids from the saline water solution. The final products have the same applicability as already specified in the conclusion (3), while salt phases may be used in road deicing ($NaCl$) and reused in drilling fluids (KCl).
5. The waste belonging to the category III should be treated according to the procedures shown in Figure 4, applying their separating, aggregating, coagulating and again final separating the solids from the saline water solutions. The applicabilities are generally the same as those given in the conclusion (4), and the additional ones are related to barite that may be reused in drilling fluids and used for protection against X-ray radiation (in plasters and shields).
6. The processes identified by the authors are technologically viable to be introduced in Poland. The materials proposed are commonly available and there are no restrictions as to their use. The final products fulfill an important ecological effect of representing usable materials. The only problem is of the economic nature and involves an analysis of the costs incurred and the financial benefits gained.

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