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COMPARATIVE ASSESSMENT OF SORBENTS FOR THE REMOVAL OF PETROLEUM PRODUCTS FROM OIL-REFINERY WASTEWATER

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Abstract. This paper presents a comparative analytical assessment of sorption materials used to remove petroleum products from oil-refinery wastewater. The analysis is based on source data describing oil absorption, water absorption, oil recovery by squeezing, material origin, and the practical advantages and limitations of natural, synthetic, and inorganic sorbents. The results show substantial differences among sorbents in the balance between petroleum-product uptake, water uptake, and potential for reuse. Synthetic batting, modified graphite, powdered urea-formaldehyde resin, modified basalt fiber, and sheet foam rubber exhibit comparatively high oil-absorption capacities. At the same time, low water uptake is characteristic of urea-formaldehyde resin, perlite, modified basalt fiber, and several carbon-based materials. The selection of a sorbent should therefore be based on a combination of technological, environmental, and economic criteria rather than on a single parameter.

Keywords: oil-containing wastewater, sorbent, oil absorption, water absorption, petroleum products, oil refining, sorption treatment, natural sorbents, artificial sorbents.

Introduction

Wastewater from oil refineries is a complex multicomponent system. It may contain mineral impurities, petroleum products, organic reagents, salts, and other compounds. Depending on the concentration of petroleum products, mechanical, chemical, physicochemical, and biological treatment methods are used.

According to the source material, when petroleum-product concentrations exceed 1000 mg/L, mechanical methods, including sedimentation and centrifugal separation, remove less than 60% of

petroleum products, whereas flotation and coagulation can increase treatment efficiency to approximately 70–75%. For deeper polishing, sorption methods become particularly important.

The advantages of sorption treatment include the possibility of removing pollutants from multicomponent mixtures, high efficiency at comparatively low contaminant concentrations, and, in some cases, the possibility of returning treated water to recirculating industrial water-supply systems.

However, the practical choice of a sorbent remains challenging because materials differ considerably in oil absorption, water absorption, cost, availability, and the possibility of subsequent regeneration or disposal.

Aim and Methodology of the Comparative Assessment

The aim of this study was to conduct a comparative assessment of the sorbents presented in the source material and to identify the most promising material groups in terms of the combination of oil absorption, water absorption, and the ability to recover sorbed oil.

The source data included oil-absorption capacity, water-absorption capacity, and oil recovery by squeezing for natural organic, synthetic organic, and inorganic materials. The advantages and disadvantages of natural and artificial sorbents described in the source article were also taken into account.

No new experimental results were introduced in this article. All numerical values were taken from the source table of sorbent properties. The comparative groupings and conclusions represent an analytical interpretation of those data.

Table 1. Comparative characteristics of selected sorbents

Sorbent	Oil absorption, g/g	Water absorption, g/g	Oil recovery by squeezing, %
Chopped reed leaves	6.1	4.6	31
Straw	4.1	4.3	36
Buckwheat husk	3.5	2.2	44
Ground coal	2.0	0.2	—
Sheet foam rubber	35.2	25.9	75–85
Synthetic batting	47	56	96
Lavsan (fiber)	13.2	4.3–13.9	63–80
Urea-formaldehyde resin, pieces	23.3	0.1	0
Urea-formaldehyde resin, powder	39.6	0.1	60
Granular polystyrene foam	9.2	4.4	0
Fiber	7.0–10.0	6.0–11.0	81–91
Granular polypropylene	1.6	0.8	0
Nickel foam	2.9	3.0	0
Fiberglass	5.4	1.7	60
Modified graphite	40.0–58.3	0.5–9.0	10–66
Perlite	5.1–7.1	0.4	0
Modified basalt fiber	37	0.4	28

Results and Discussion

Among the materials included in the data set, the highest oil-absorption capacities were reported for modified graphite (40.0–58.3 g/g), synthetic batting (47 g/g), powdered urea-formaldehyde resin (39.6 g/g), modified basalt fiber (37 g/g), and sheet foam rubber (35.2 g/g). These materials considerably exceed most natural organic sorbents in their specific capacity to retain petroleum products.

However, a high oil-absorption value alone does not necessarily indicate technological superiority. For example, synthetic batting absorbs 47 g/g of petroleum products, but its water absorption reaches 56 g/g, indicating intensive uptake of the aqueous phase as well. Sheet foam rubber also exhibits substantial water absorption of 25.9 g/g.

A different pattern is observed for urea-formaldehyde resin. The powdered material combines an oil absorption of 39.6 g/g with a water absorption of only 0.1 g/g and an oil recovery by squeezing of 60%. The material in pieces also has a low water absorption of 0.1 g/g and an oil absorption of 23.3 g/g, although its oil-recovery value in the source data is 0%.

Modified basalt fiber combines an oil absorption of 37 g/g with a water absorption of 0.4 g/g. This combination appears technologically attractive in terms of selectivity toward the oil phase, although its oil-recovery value is 28%, which is lower than that of synthetic batting, fiber, foam rubber, and lavsan.

Among the natural organic materials, oil absorption is much lower: 6.1 g/g for chopped reed leaves, 4.1 g/g for straw, and 3.5 g/g for buckwheat husk. Their main advantages in the source article are low cost and availability, while the main disadvantage is the risk of secondary pollution after saturation with petroleum products.

Thus, the source data confirm that no universal sorbent simultaneously provides maximum oil absorption, minimum water absorption, high regeneration potential, low cost, and environmental safety.

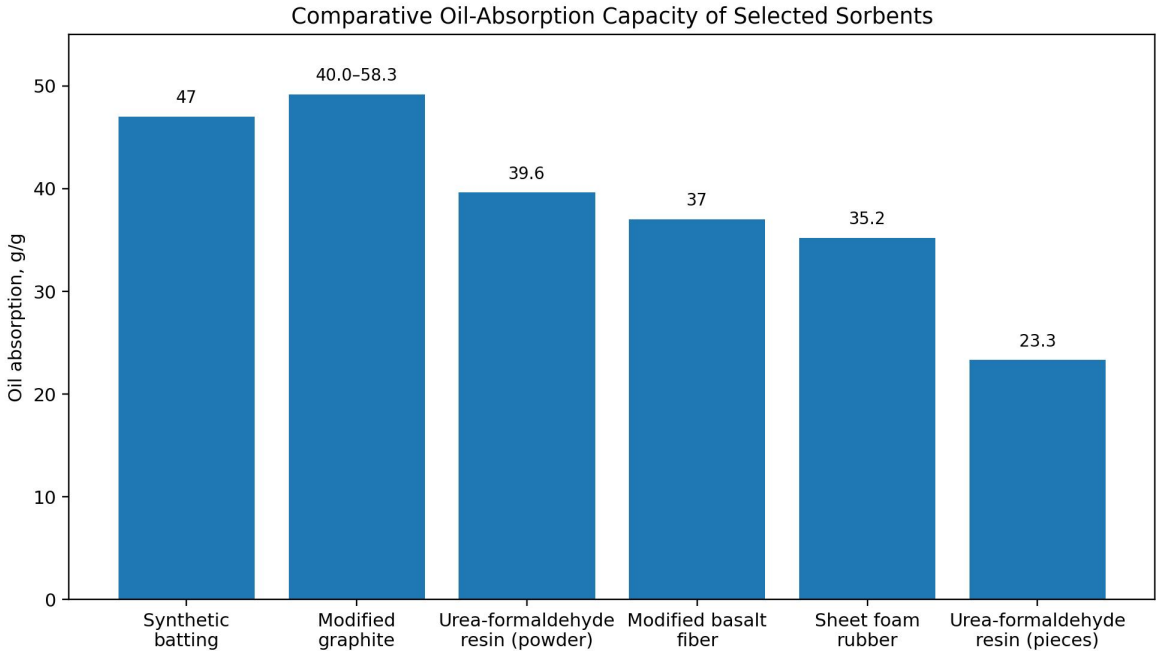


Figure 1. Comparison of oil-absorption capacities of selected sorbents based on the source data. For modified graphite, the original range of 40.0–58.3 g/g is shown above the bar; the bar height corresponds to the midpoint of the range only for visualization.

Table 2. Analytical grouping of sorbents by key operational characteristics

Analytical group	Materials from the source data	Technological interpretation
High oil absorption	Synthetic batting; modified graphite; powdered urea-formaldehyde resin; modified basalt fiber; sheet foam rubber	Promising when rapid removal of substantial amounts of petroleum products is required.
Low water absorption	Urea-formaldehyde resin; perlite; modified basalt fiber; ground coal	Preferable when it is important to reduce simultaneous uptake of the aqueous phase.

Analytical group	Materials from the source data	Technological interpretation
High oil recovery by squeezing	Synthetic batting; fiber; foam rubber; lavsan; fiberglass; powdered urea-formaldehyde resin	Advantageous when sorbent regeneration and petroleum-product recovery are considered.
Low cost and availability	Natural sorbents and plant-derived wastes	Economically attractive, but disposal of saturated material must be addressed.

Practical Approach to Sorbent Selection

Based on the comparative analysis, sorbent selection for oil-containing wastewater should be carried out step by step. First, the concentration of petroleum products and the role of the sorption stage within the overall treatment train should be considered. Next, the oil-absorption and water-absorption characteristics of the material should be compared.

If the primary objective is maximum petroleum-product removal, materials with high oil absorption should be prioritized. If minimizing water uptake is critical, low water absorption becomes more important. When sorbent regeneration and petroleum-product recovery are planned, oil recovery by squeezing becomes a key criterion.

Cost and availability must also be considered. The source article emphasizes the potential of wastes from woodworking, pulp-and-paper, and plant-processing industries, because this approach can simultaneously support wastewater purification and waste utilization.

Conclusion

1. Sorbents for petroleum-product removal differ substantially in oil absorption, water absorption, and the ability to recover sorbed oil.

2. The highest oil-absorption capacities among the listed materials are reported for modified graphite, synthetic batting, powdered urea-formaldehyde resin, modified basalt fiber, and sheet foam rubber.

3. High oil absorption should be evaluated together with water absorption. Synthetic batting and foam rubber absorb substantial amounts of water, whereas urea-formaldehyde resin and modified basalt fiber show low water absorption.

4. The highest oil-recovery values are reported for synthetic batting, fiber, sheet foam rubber, and lavsan.

5. Natural sorbents are generally inferior to several artificial materials in oil absorption, but they retain advantages in terms of cost, availability, and the possibility of using waste materials as raw materials.

6. The source data do not reveal a universal sorbent that is equally effective according to all technological, environmental, and economic criteria. A differentiated material-selection strategy based on specific treatment conditions is therefore more appropriate.

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