Evaluation of the use of Egyptian black sand for water reuse

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Abstract. The presented article refers to studies that examined the catalytic properties of black sand (AR Egypt) for its further use in water purification in fishery complexes. Also, black sand was used as a filter material in a radial filter model. According to experimental data, the stated hypotheses were confirmed.

Introduction

In the Arab Republic of Egypt there are about 600 million tons of black sand deposits located on the shores of the Mediterranean, in the cities of Baltim, Rashid and Dumyat, that is, in the regions of fish farming, the use of this natural material in technological schemes for the purification of circulating waters of fish farms in Egypt may be economically promising [1]. To substantiate this possibility is required to investigate the properties of black sand.

Goal, tasks, methods of study

In the process of laboratory research, the composition of black sand and its characteristics as a filtering material were determined. A visual inspection revealed that the sand contained yellow, black and shiny grains. To determine the fractional composition, sand was sieved on sieves of various sizes (Figure 1.).

Figure 1. Black sand size distribution
As follows from the graph of Figure 1, the sand contains mainly two fractions: particles with a size of 0.16 mm, his size is typical for yellow particles, and 0.075 mm for black particles. Black sand particles are separated by a magnetic field. It can be stated that the particle size of the black sand of Egypt is characteristic of loading slow filters, the grain size of which is 0.25–0.35 mm.

The shape of the surface of the particles and the composition of black sand was determined by the electron microscope ZEISS Cross Beam-340. The structure and configuration of sand under a microscope is shown in Figure 2.

![Image of black sand particles under a microscope]

**Figure 2.** Photos of black sand particles under a microscope with a magnification of 10 (first photo from above) and 100 times (other photos)

The data of Figure 2 confirm the heterogeneity of sand, established by granulometric sieving on sieves, as it is revealed that sand contains particles of various shapes, each of which has its own surface properties.

Using energy dispersive X-ray spectroscopy, a qualitative and quantitative analysis of the composition of black sand was performed. Data EDX - spectroscopy are is given in table 1.

| Spectrum name | Spectrum 1 | Spectrum 2 | Spectrum 3 | Spectrum 4 | Spectrum 5 | Spectrum 6 | Spectrum 7 | Spectrum 8 |
|---------------|------------|------------|------------|------------|------------|------------|------------|------------|
| List of items | O          | Na         | Mg         | Al         | Si         | Cl         | K          | Ca         |
| O             | 4          | 3          | 84         | 02         | 01         | 43         | 11         | 8          |
| Na            | 23         | 43         | 49         | 42         | 38         | 14         | 12         | 4          |
| Mg            | 48         | 36         | 98         | 76         | 58         | 14         | 19         | 08         |
| Al            | 73         | 56         | 69         | 14         | 11         | 29         | 14         | 08         |
| Si            | 76         | 25         | 25         | 14         | 25         | 14         | 14         | 24         |
| Cl            | 71         | 22         | 69         | 75         | 69         | 1          | 15         | 86         |
| K             | 15         | 86         | 96         | 75         | 96         | 1           | 15         | 26         |
| Ca            | 93         | 19         | 47         | 86         | 08         | 1           | 11         | 11         |
As a result, EDX-spectroscopy revealed that sand is mainly composed of silicon and besides other metals such as iron which gives the particles a black color. The presence of iron and metals such as manganese, magnesium, aluminum in the sand makes it possible to hypothesize that the material may have catalytic properties.

**Experimental part**

To study the filtering properties of black sand in the laboratory, the rate of filtration through it was measured by the following method: a cylindrical filter of quartz glass with a diameter of 40 mm was placed supporting layer of crushed stone 3 cm high, and on top - a layer of sand 7 cm high with a particle size of 0.16–0.325 mm; the area of filtration was 12.5 cm², the height of water in the experimental filter was in the range of 7–34 cm by design limitations. In the experiment, tap water contaminated with kaolin was used as a model fluid, with an initial concentration of suspended matter of 35 mg/l, that corresponded to the transparency "on the ring" 49.4 mm, the initial temperature of the water - 17°C. Filtering direction is top down. The flow rate of the filtrate was determined by the volumetric method with the subsequent calculation of the filtration rate.

The results of the experiment are shown in table 2 and figure 3.

**Table 2.** The rate of filtration of model water in a descending mode through the loading of black sand

| Type of loading                      | \( H_{\text{WATER}}, \,[\text{cm}] \) | \( \text{Time,} \,[\text{h}] \) | Transparency, \,[\text{mg/l}] | \( \frac{V}{\text{m}^3/\text{m}^2.\text{h}} \) | Filtrate temperature, \,[\text{°C}] |
|-------------------------------------|--------------------------------------|---------------------------------|-------------------------------|--------------------------------|---------------------------------|
| Black sand and expanded clay        | 16                                   | 0.167                           | <5                            | 0.77                          | 18                              |
|                                    | 26                                   | 0.136                           | <5                            | 0.92                          | -                               |
|                                    | 34                                   | 0.105                           | <5                            | 1.19                          | -                               |
| Black sand and clay as a supporting layer | 7                                   | 0.95                            | <5                            | 0.14                          | 18                              |
|                                    | 16                                   | 0.083                           | <5                            | 1.52                          | 18                              |
|                                    | 26                                   | 0.062                           | <5                            | 2.02                          | 17                              |
|                                    | 34                                   | 0.052                           | <5                            | 2.4                           | 16                              |

The residual concentration of contamination after filtration through a load of black sand was no more than 5 mg/l.

Figure 3 shows the dependence of the filtration rate on time when the height of the water layer above the load is 7 cm and 12 cm.
Figure 3. Shows the filtration rate with a water layers height are 7 cm and 12 cm

The results of table 4 and figure 3 show that the filtration rate decreases with time and increases with increasing pressure above the filter, which is confirmed by the existing theory of filtering.

It is known that the use of filters with a radial direction of water movement during filtration leads to a decrease in the dimensions of the filter, while ensuring the required cleaning effect compared to the downward and / or upward direction [2, 3]. The flow of purified water in radial filters is conducted from the center to the periphery of the filter or vice versa, while in both modes the water is filtered at a variable speed along the filter radius: when filtering from the center to the periphery, the speed changes from the maximum in the initial to the minimum in the final layers of the filtering material; when filtering from the periphery of the filter to the center, the speed increases from the minimum in the initial layers to the maximum in the final [4, 9, 10, 11].

Considering the above advantages of radial filters, and in order to apply a more economical solution for determining the effectiveness of loading black sand in laboratory conditions, two laboratory facilities were manufactured: a radial filter model and a mixed-loading filter model.

The principle of operation of the radial filter model is shown in Figure 4. The filter consists of 3 plastic pipes with a diameter of 50, 40 and 25 mm and a height of 150 mm, located one inside the other. The second and third pipes are provided with holes with a diameter of 1 mm for the passage of water and preventing leakage of sand that has a diameter of 1.6 mm. Filter model is loaded with two layers of black sand: the first layer is between the first and second pipes, the second between the second pipe and the third.

Figure 4. Diagram of the radial filter laboratory model: 1, 2 and 3 - the first, second, third pipes, respectively; 4 - loading; 5 - holes for the passage of water

Then, model water contaminated with kaolin was passed through the filter and the filtration rate was measured. The residual concentration of suspended solids after the filter did not exceed 5 mg / l.
The measurement results are shown in Figure 5.

![Figure 5](image)

**Figure 5.** Filtering speed in a radial filter with a pressure (with a height of water above the load) of 6 cm and 12 cm.

The graphs in Figure 5 show that with a head of 6 cm, the filtration rate is 4.72 m³/m²·h, and at a water pressure of 12 cm, the rate increases to 9.75 m³/m²·h. Comparing the data obtained with the graphs shown in Figure 5, we can conclude that the use of the radial direction of filtering can significantly increase the rate of filtering with the same efficiency for suspended substances [7, 8].

Further studies were conducted on a mixed-loading filter model.

Black sand was mixed with natural Russian sand with a grain size of 1.2–1.6 mm in a 2:1 ratio, then placed in a test funnel to determine the filtration rate, as shown in Figure 6.

Mixing with larger-sized sand was carried out with the aim of creating internal channels in the load in order to increase the filtering efficiency as a skeleton filter.

Figure 6 also shows the dependence of the obtained filtering rate on time.

![Figure 6](image)

**Figure 6.** The dependence of the rate of filtering through the filter with a mixed load. Mixed Filter Model: 1 - funnel; 2 - water with a pressure of 7 to 8 cm; 3 - loading from black sand mixed with larger sand.

According to the experimental data given in Figure 4.9, the average filtration rate through a mixed load is 2.51 m³/m²·h with a height of water column of 8 cm, which is higher than when using only black sand.
The defect of this filter model is the instability of the uniformity of loading due to the different size of sand granules, which leads to the formation and separation of the layers, especially in the upper part of the filter and when washing with reverse current.

Thus, this filter model increases the filtration rate, which reaches a value of $2.51 \text{ m}^3/\text{m}^2\cdot\text{h}$, while the residual suspended matter content is less than 5 mg/l.

**Summary**

According to the research results, it can be concluded that black sand may be used in the purification of the waters of fishery complexes as a sorbent. This fact is confirmed by the presence of metals in the sand [5, 6]. In addition, during the experiment on a radial filter model with a black sand load, a decrease in the filtration rate was found with an increase in the filtration period. This dependency indicates an existing filtering process.

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