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EXPERIMENTAL STUDY OF BIODEGRADABLE MATERIALS IN ENVIRONMENTAL PHYSICS CLASSES

SANDA VOINEA[1,*], CORNELIA NICHITA[1,2], IULIA ARMEANU[1], BIANCA ŞOLOMONEA[1]

[1] University of Bucharest, Faculty of Physics, 405 Atomistilor Street, 077125, Magurele, Romania
[2] National Institute for Chemical – Pharmaceutical Research and Development, 112 Vitan Avenue, 031299, Bucharest, Romania
[*] Corresponding author: *sanda.voinea@3nanosae.org*

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Abstract. The paper suggests an interdisciplinary laboratory, which can be used by the students in their experimental studies from the physics classes. For this purpose, the capacity of a natural absorbent to remove hydrocarbons from waters is analyzed by different methods. This absorbent based on Sphagnum moss is a biodegradable material with the main utility in environmental protection. The study of biodegradable materials can be performed by students with relatively simple tools, helping them to understand basic physical and chemical principles through experimentation.

Key words: natural absorbent, environmental protection, educational lab, water cleaning, removed hydrocarbons.

1. INTRODUCTION

Nowadays, when environmental threats come from all directions, knowing and understanding how to use ecological natural resources and to save energy without harming the environment is a priority at all levels of education [1–3]. Many studies develop new methods for learning and understanding physical concepts by classical experiments and experiments using modern technology [4–12]. An integrated and interdisciplinary approach to the methods of investigating and cleaning the environment with natural, non-destructive techniques, represents an important direction of research and also a study field for students [13–17].

This paper presents a model for an experimental lab in environmental physics classes in order to understand the use of natural and biodegradable absorbent material for water and soil cleaning. This type of absorbent is used as intervention solution in case of accidental pollution on lakes, rivers, streams, seas and oceans caused by possible spills of oils and hydrocarbons. Moreover, this is also useful for cleaning the soil affected by runoff and spills [18].

Clean water is an indispensable resource for humanity, but its availability is questionable. Only 40% of Europe's surface water accomplishes a good ecological status [19]. Nature may inspire people to use natural materials to clean the environment and it generously offers these effective remedies.

Our study analyzes the intervention with natural biological absorbent material based on Sphagnum mosses, on three types of oil: household oil (used cooking sunflower oil), pure engine oil (Diesel oil) and used engine oil. Sphagnum mosses (or peat moss) are used as hydrocarbons absorbent materials and for water treatment [18]. Sphagnum moss formations cover about 1–2% of the Earth's surface. It is usually light green or with the color varying from white to green and is found in wet and rich areas with poor soil. The hydrophilic property of the sorbent allows the absorption of water into the structure of the material, while the adhesive force keeps the oil on the surface. After a dry thermal activation process, Sphagnum mosses increase the ability to encapsulate the hydrocarbons in their structure [20, 21].

The interdisciplinary character of this experimental study provides a better understanding of different principles from biology, physics and chemistry. Furthermore, it encourages young people to keep the environment clean and improve their ability to do so.

2. METHODS AND MODELS

2.1. THE OIL ABSORPTION CAPACITY OF THE NATURAL ABSORBENT

After that, a certain amount of the natural absorbent was inserted in bags of paper filters. Five grams of natural adsorbent (m_0) had been used for each paper filter. One paper filter weighs 0.45 g. We used graduated polypropylene containers to discharge 80 ml of oil for each sample. The mass of an empty container is 10.2 g. The samples were completely immersed into each oil container for a certain amount of time: 5 s, 30 s, 90 s, 150 s, 300 s, 900 s, 1800 s and 3600 s (Fig. 1), to study the kinetics of absorption. Likewise, an empty paper filter was immersed into the oil container for the same amount of time, or until the bag reached saturation. After taking them out, the oil excess was removed with tissues from the lower ends of the bags and weighed the samples with a digital weighed. This procedure has been repeated three times for each type of oil and for each immersion time. The measured quantity represents the total mass (m_t), while the mass of the paper filter is m_f.

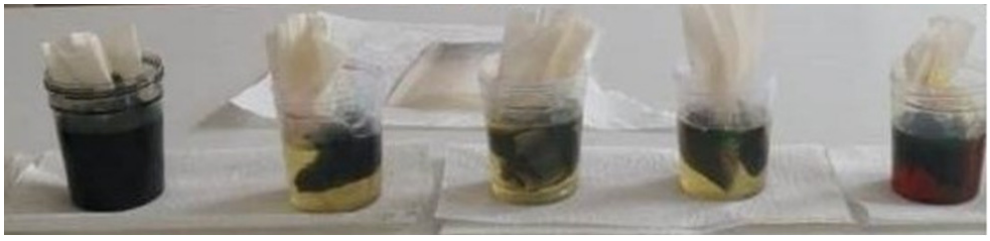


Fig. 1 – Samples of absorbent immersed in each type of oil. The full color version can be accessed at http://www.rrp.nipne.ro

To make the measurements as accurate as possible, one has to subtract the mass of the filter that was immersed in the oil from the total mass and this quantity represents the mass of the natural absorbent (m_s), after immersing in oil. In this way, the absorption capacity (C) of the natural absorbent is calculated using equation (1). The density of the oil used in the experiment was measured by weighing a certain volume of oil.

$$C = \frac{m_s - m_0}{m_0}. \tag{1}$$

2.2. THE WATER ABSORPTION CAPACITY OF THE NATURAL ABSORBENT

The water absorption capacity was determined using different water sources: distilled water, well water (from Surlari forest, Ilfov County), water from the Sabar River (Măgurele – Ilfov County) and from Căldăruşani Lake (Ilfov County). As in the previous paragraph, the natural absorbent was subjected to a dry heating process carried to a constant mass and then was inserted in bags of paper filters. For each paper filter, five grams of natural adsorbent (m_0) was used, while the bag weighs 0.45 g. Polypropylene containers, graded (in ml) were used to pour 80 ml of water. The paper filters filled with 5 g of absorbent were placed in these containers with water for 3 minutes. This procedure was repeated 3 times for each type of water. After 3 minutes, the bag with the natural absorbent was taken out from the water and drained 1 minute. After draining, in order to determine the total mass (m_t), the samples were weighed and the mass of the empty bag was subtracted from the obtained value. All the measurements were made with a XT220A Precisa balance, with 10 μg precision.

Afterward, the water adsorption capacity was computed using equation (2)

$$C = \frac{m_t - m_0}{m_0}. \tag{2}$$

The pH, the nitrates concentration and the electrical conductivity of the water had been measured before and after the natural absorbent was immersed in the water. The pH and electrical conductivity of the water were determined using an ORION 5 STAR pH and conductivity meter. We used a LabQuest Mini device, to determine the concentration of the nitrates.

2.3. UV VIS ANALYSIS

Monitoring the effect of removal of hydrocarbons from polluted waters by the natural absorbent was performed with UV-VIS spectroscopy. UV-VIS spectra

provide information about the electronic properties of molecules. All organic compounds absorb light in the ultraviolet spectrum, and some of them absorb in the visible spectrum as well [22]. The analyzed samples with UV-VIS spectroscopy method were prepared as follows: water from Căldăruşani Lake was polluted with a certain amount of hydrocarbons. Consequently, an amount of natural absorbent was immersed in water for 60 minutes (Fig. 2a). After that, the hydrocarbon-soaked absorbent was removed by filtration and the clean water was collected in a vessel for the UV-Vis analysis (Fig. 2b). The UV-Vis spectra of the samples were acquired in the range of 200–800 nm with 1 nm resolution using a Jasco, Japan, V-570 spectrophotometer with 1 cm optical path and standard cuvette.

a) b)

Fig. 2 – Preparation of the samples for UV-Vis spectroscopy: a) immersing the natural absorbent in water and oil; b) the hydrocarbon-soaked absorbent removed by filtration. The full color version can be accessed at http://www.rrp.nipne.ro

3. RESULTS AND DISCUSSION

3.1. TIME DEPENDENCE OF THE ABSORPTION OIL CAPACITY OF THE NATURAL ABSORBENT

The average values of the quantities of oil retained in the sample bags after removing them from containers (m_t for the samples with natural absorbent, m_f for bags) are shown in Table 1. The determined densities of the studied oils have the following values: 88.63 kg/m^3 for used cooking oil, 80.20 kg/m^3 for used engine oil and 72.87 kg/m^3 for crude engine oil. The used cooking sunflower oil has the

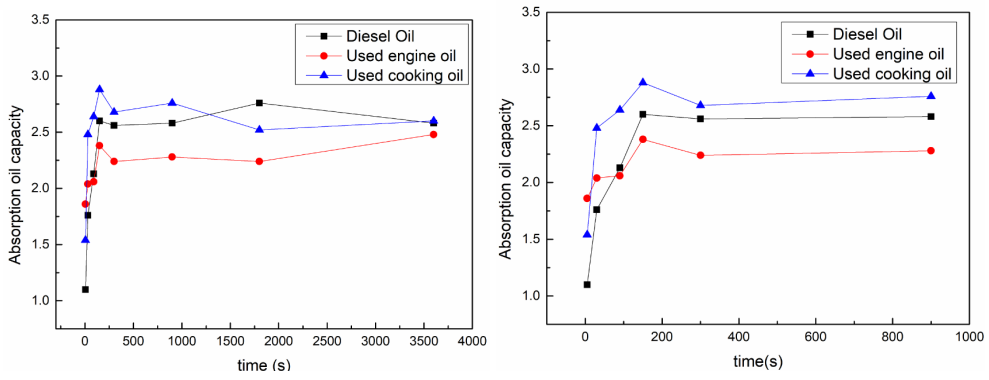
highest density, while the crude engine oil has the lowest one. Based on the values from Table 1, we calculated the absorption oil capacity of the natural absorbent from equation (1).

Table 1

Masses of the samples after immersion in different types of oil

Type of oil	After 5 s		After 30 s		After 90 s		After 150 s	
	$m_t(g)$	$m_f(g)$	$m_t(g)$	$m_f(g)$	$m_t(g)$	$m_f(g)$	$m_t(g)$	$m_f(g)$
Diesel oil	13.10	2.60	18.50	4.70	20.37	4.70	22.70	4.70
Used engine oil	16.50	2.20	17.50	2.30	17.63	2.30	19.20	2.30
Used cooking sunflower oil	14.50	1.80	19.70	2.30	20.60	2.40	21.90	2.50
Type of oil	After 300 s		After 900 s		After 1800 s		After 3600 s	
	$m_t(g)$	$m_f(g)$	$m_t(g)$	$m_f(g)$	$m_t(g)$	$m_f(g)$	$m_t(g)$	$m_f(g)$
Diesel oil	22.50	4.70	22.60	4.70	23.50	4.70	22.60	4.70
Used engine oil	18.50	2.30	18.70	2.30	19.20	3.00	20.40	3.00
Used cooking sunflower oil	21.40	3.00	21.80	3.00	20.60	3.00	21.00	3.00

Figure 3 represents the variation of the absorption oil capacity of the natural absorbent as function of time, for three different oils. This time dependence of the oil absorption points out that the absorption capacity of the natural absorbent was maximum for the used cooking oil, the material absorbing a quantity of oil almost three times its initial weight. By comparing the results, it is clear that the absorption capacity is very similar for these types of oils, around 2.5 after one hour. Figure 3b shows that the speed of absorption reaches the highest value in the first 200 seconds and further, the values varied very slowly around an equilibrium value.



a) b)

Fig. 3 – Absorption oil capacity as a function of time(s): a) during one hour; b) in the first 900 s. The full color version can be accessed at http://www.rrp.nipne.ro

For determination of the oil absorption capacity, the amount of the oil retained in the natural absorbent after 24 hours of immersion (when the system goes to equilibrium), was measured and the absorption capacity was determined using equation (1). The results are synthesized in Table 2.

Table 2

Absorption oil capacity

Type of oil	Absorption oil capacity
Diesel oil	2.50
Used engine oil	2.54
Used cooking sunflower oil	2.62

The material has the highest absorption oil capacity for used cooking sunflower oil and the lowest for Diesel oil and we assume that this behaviour is due to the density difference. The higher the density of the oil, the easier it can adhere to the absorbent and it is retained in the biodegradable material, increasing the absorption oil capacity [23].

Knowing the value of the absorption capacity of the natural absorbent is very important for establishing the quantity of material necessary for cleaning water polluted with different kinds of oil.

3.2. STUDY OF THE WATER ABSORPTION CAPACITY

The absorption water capacity measurements using equation (2) reveal approximately similar values for the three types of water, compared to the distilled water (Table 3) with the lowest value for the Căldăruşani Lake (0.62) and highest for water from the well (0.72).

Table 3

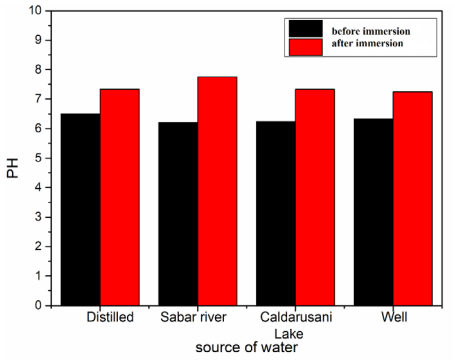
Absorption water capacity

Source of the water	Distilled water	Well water	Water from the Sabar River	Water from the Căldăruşani Lake
Absorption water capacity	0.68	0.72	0.68	0.62

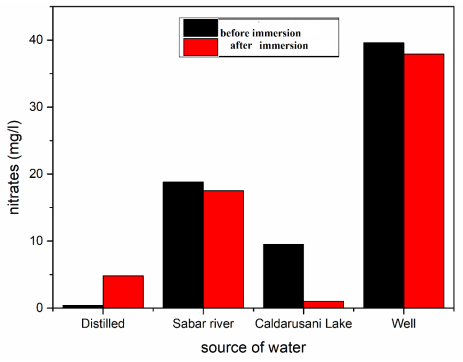
For establishing the influence of the absorbent on the water quality, we compared the pH (Fig. 4a), nitrates concentrations (Fig. 4b) and electrical conductivity (Fig. 4c) of the water samples before and after the absorbent immersion.

For all types of water, after immersion of the absorbent, the comparative study shows an increase of the pH above 7, so we conclude that the absorbent enhances the alkaline character of the water. The quantity of the nitrates from the river, lake and well water decreases after immersion of the absorbent, indicating the ability of

the natural absorbent to reduce the concentration of nitrates from water. In the case of electrical conductivity, it is observed a decrease in the initial value only for the water from the Sabar River. For the other water sources, the electrical conductivity value is approximately the same before and after the immersion of the absorbent. The results show that the quality of the water is improved after the immersing of the absorbent. As a consequence, the above considerations indicate that this type of natural absorbent can be safely used in cleaning the water from wells, lakes and rivers affected by pollution with hydrocarbons.



a)



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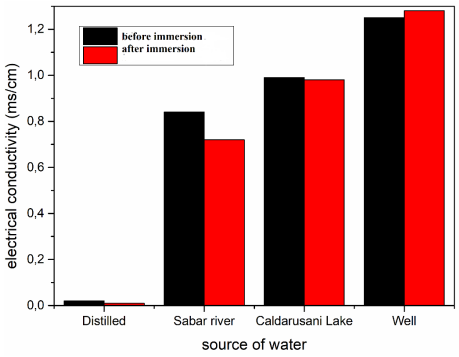


c)

Fig. 4 – Water samples' parameters before (black column) and after (red column) the immersion of the natural absorbent: a) pH; b) nitrates concentration (mg/l); c) electrical conductivity (mS/cm). The full color version can be accessed at http://www.rrp.nipne.ro

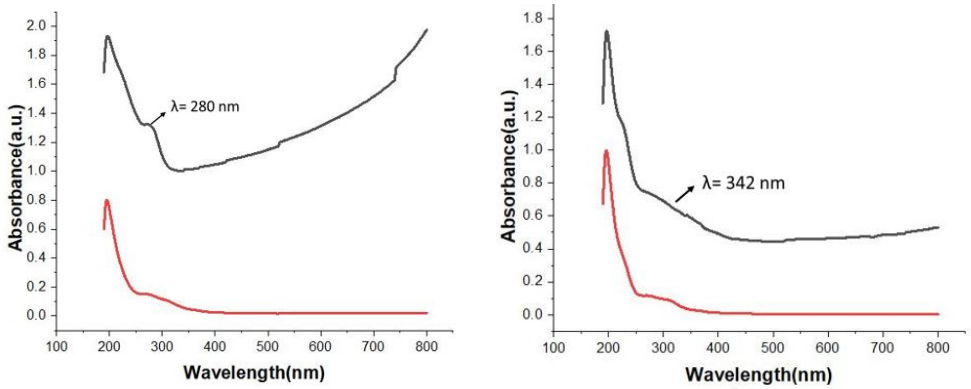
3.3. UV-VIS STUDY TO MONITOR THE REMOVAL OF HYDROCARBONS FROM THE POLLUTED WATERS

Considering the importance of the ecosystems in urban areas proximity, like Căldăruşani Lake, it is desirable to use supplementary methods as UV-VIS spectroscopy,

to highlight the ability of the absorbent to remove pollutants. The samples' spectra of the water polluted with different types of oils and of the water after cleaning it with natural absorbent are analyzed.

Figure 5a shows the presence of the peak corresponding to the sunflower oil at wavelength $\lambda = 280$ nm [24]. The absorption band from wavelength $\lambda = 280$ nm is consistent with the $\pi - \pi^*$ and $n - \pi^*$ electronic transitions due to the C = C and C = O functionalities belonging to the monounsaturated (example oleic acid) and polyunsaturated (example linoleic acid) fatty acids from the sunflower oil composition [25]. After cleaning the water sample with the natural absorbent, a significant decrease of the absorbance corresponding to the sunflower oil is detected, proving the ability to encapsulate the hydrocarbons by this natural absorbent.

Figure 5b shows the peak specific to the diesel oil spectrum with the characteristic peak highlighted at the wavelength $\lambda = 342$ nm, a value close to previous studies [26], as well as their decrease after immersion of the absorbent and application of the removal process. Overlapping UV profile of the water samples containing different types of oils, before and after cleaning, suggested the biodegradable material absorption ability. This is demonstrated by the decrease of the absorbance values at the wavelengths corresponding to the analyzed oils.



a) b)

Fig. 5 – Overlapping of the experimental UV-VIS absorption spectra of the water samples from: a) Căldărușani Lake polluted with used cooking sunflower oil (black) and after cleaning with natural absorbent (red); b) Căldărușani Lake polluted with Diesel oil (black) and after cleaning with natural absorbent (red). The full color version can be accessed at http://www.rrp.nipne.ro

4. CONCLUSIONS

The results of the study indicate the short-time absorption of the oil and the ability of oil absorption by natural absorbent based on Sphagnum moss. The absorption capacity values for all the analyzed oils indicate that the natural absorbent retains a quantity of oil almost 2.5 times its initial weight.

The absorption water capacity value is approximately 0.72 for all water sources. The water absorption capacity of the absorbent is lower compared to oil absorption capacity, which enhances the ability of the absorbent to encapsulate oil from the polluted water.

The study of the physical and chemical properties of the water cleaned with biodegradable material shows an increase in the quality of the water. For the tested water samples, it was noticed the decrease of the nitrates concentrations and the increase of the pH under 7. Also, the UV spectroscopy analyses emphasize the removal of the hydrocarbons from the polluted water using biodegradable materials. The results show that this material may be used with good efficiency and safety for cleaning the water. Using the natural and biodegradable absorbent in the case of accidents that may impact water quality and ecosystem, we could save energy and conserve resources.

Using modern laboratory equipment, the students are motivated to perform rigorous scientific research and particularly to learn new environmental protection methods.

Raising awareness among young people about maintaining a clean and ecological environment should be a priority in interdisciplinary education. In addition, the experimental activity allows the data sampling and their interpretation, to draw correct conclusions, develop the ability to work in a team, critical thinking, initiative, rigor and creativity.

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