In order to increase efficiency and implement the principles of resource saving during the elimination of emergency spills of dangerous goods when transporting them by rail, proposals have been offered to improve the method of localization and elimination of emissions of hazardous substances using the "Universal Absorbent Cloth" ("UAC")

The specificity of localization of the emergency emission site and the principles of elimination based on sorption technologies using "UAC" are described.

To manufacture "UAC", special equipment (carbonizer) was designed, which provides effective carbonization of raw materials from plant waste at sufficiently low temperatures ≤500 °C. Using a carbonizer, a universal sorbent was obtained, which is subsequently used for the manufacture of "UAC". The total carbonization time of plant waste samples did not exceed 60 minutes. The universal absorbent obtained during the carbonization process was placed in a fabric matrix to produce "UAC" absorbent cloth.

Standardized procedures for conducting experiments are described. Studies of the adsorption characteristics of the proposed "UAC" involving various model solutions (Gasoline A-95, 25 % solution of ammonia water, and 15 % solution of hydrogen peroxide) confirm its versatility and efficiency; the degree of purification reaches 92 %.

It is proposed to use certain types of railroad cars to transport "UAC" as part of a freight train, which is supported by the corresponding dynamic indicators. Recommendations for the regeneration or disposal of spent "UAC" cloth are provided.

The proposals for improving the method of emergency emission elimination using the "Universal Absorbent Cloth" ("UAC") make it possible to minimize the negative consequences of emergency spills of liquid cargoes of different hazard classes and reduce the time spent on elimination operations. These advantages ensure the competitiveness and profitability of the proposed technology

Keywords: environmental technologies, hazardous cargoes, localization of accidents, elimination of accidents, carbonization, universal absorbent cloth

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IMPROVING A METHOD FOR ELIMINATING THE SPILL OF HAZARDOUS SUBSTANCES BY USING "UNIVERSAL ABSORBENT CLOTH"

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1. Introduction

In many countries, including the states of the European Union, there is a growing understanding of the importance of solving global problems of transport systems. This is primarily due to the requirements for improving the safety and efficiency of transportation, with the growth of mobility of society, the need to reduce the impact of transport on the environment and others.

There is a significant increase in technical standards and environmental requirements for the safety of the processes of transportation of hazardous cargoes by all modes of transport. This is directly related to the environmental consequences of possible emergency or technological spills of hazardous cargoes due to violation of the regulations for their transportation.

Under certain conditions, during emergency spills during the transportation of hazardous cargoes by rail (acids, alkalis, petroleum products and their derivatives), they may enter the soil where migration and geofiltration processes take place. In addition, some liquid hazardous cargoes, such as urea-ammonia mixture (UAM), can exacerbate a fire and even cause an explosion, which can further lead to catastrophic consequences for humans and the environment. Spilled hazardous substances when released into groundwater, which further have an impact on the water supply source of settlements, can degrade the quality of drinking water. In some cases, drinking water from non-centralized water supply may become unsuitable for consumption by the population. In addition, groundwater pollution can be a side factor in reducing soil fertility and deteriorating the quality of agricultural products, which also poses a threat to life safety. At the same time, taking into consideration the entire link of negative consequences, railway transport has a significant responsibility in the field of organizing the safety of the transportation process, which is associated with a wide range of hazardous cargoes and features of the operational process. It should be noted that under modern conditions, the most priority issue should be a clear coordinated and interrelated work and responsibility in the "sender-carrier-recipient" system.

The transportation of hazardous cargoes at present will continue to be widespread, so the safety of the transportation procedure (maintaining the infrastructure, technical means and rolling stock of railroad transport in proper condition) is becoming one of the priority areas of activity in modern socio-economic conditions. Ukrainian railroads transport a wide range of hazardous cargoes (about 98,000 product categories). At the same time, the deterioration of the rolling stock at Ukrzaliznytsia reaches 90 %, almost 24 % of railroad tracks need major repairs [1, 2]. At the same time, the analysis of the state of safety of trains on railroad transport in the world for the period 2011–2021 [3] shows that disasters account for 2 % of the total number of transport events, incidents – 98 %. Given this, the risks of negative economic and environmental consequences increase sharply.

That is why scientific issues in the search for new solutions to increase the level of safety, minimize negative consequences, as well as ensure environmental friendliness and efficiency in transport are very relevant.

2. Literature review and problem statement

In an emergency spill zone, there is often a conflict of interest between the desire to protect the environment and the need to restore cargo traffic as quickly as possible. Many factors [4] directly affect the selection and implementation of an appropriate strategy for the elimination of emergency emissions. In the face of a shortage of time and many scenarios for the development of an emergency, it is not possible to quickly solve this organizational problem. Moreover, the existing technologies and regulations for carrying out elimination measures show their operational incapacity and delayed efficiency. Thus, in practice, the localization and elimination of emergency spills of hazardous cargoes is carried out partially or not at all. Summarizing, we can come to the following conclusion: conventional technologies for localization and elimination of spills of hazardous cargoes on railroad transport do not have the versatility necessary for prompt and effective environmental protection. Therefore, it is necessary to devise a new approach that, even under difficult conditions, will ensure simplicity, efficiency, versatility, and efficiency of the organization of elimination activities.

Work on the elimination of the liquid spill is divided into the following stages:

– localization of spilled liquid;
– fluid collection;
– clearing and reclamation of land.

Currently, the most common method of eliminating the consequences of emergency spills of liquid substances is the use of sorption technologies [5] because they are characterized by high cleaning effectiveness, manufacturability, and efficiency.

For example, paper [4] proposed technology for the collection of oil spills during the development, production, preparation, and transportation of oil from oil fields. The authors propose to carry out the process of primary collection of spilled oil from the surface of the earth in a combined way using pumps and mobile vacuum pumping units. In this case, a technique of flooding the sprinkled area with water can be used, and the most intensive pumping of oil can be organized from special storage pits. After collecting the spilled oil, the territory is cleaned with special absorbent materials. The authors of [4] suggest using the sorbent "Peat-Sorb". It is a sorbent for collecting oil, the main component of which is peat and sphagnum moss. This technology makes it possible to collect spills of spilled hazardous substance but the technology is quite complex, requiring several stages that significantly increase the cost of localization and elimination. However, using a sorbent based on natural materials, the issue of their small sorption capacity ($\varepsilon \geq 60$) remains unresolved; and it is not possible to increase their adsorption properties. Peat moss is also a valuable organic matter formed by peat bogs. The limited availability of peat around the world, the need for destructive peat extraction from wetlands, and as a result, a limited volume of raw materials creates problems with the logistics of producing these sorption materials and their further systematic use for localization and elimination of oil spills.

An option to overcome the corresponding difficulties may be the use of sorbents from wool and hair, reported by the authors of work [6]. Adsorbents of ecological origin, made of dog fur and human hair, show a slight advantage over other types of sorbents ($\varepsilon \geq 85$). However, the question remains regarding the regeneration of the sorbent after its use and the impossibility of returning the adsorbed substance. Also, the possibility of increasing the adsorption properties of the specified sorbent is still debatable.

Papers [7, 8] describe a technique for obtaining a sorbent from various plant wastes (straw of cereals, bran, peat). The carbonization process, the temperature of which is 900 °C, is also described. In [7], a drawing is presented with a detailed description of the laboratory unit for the production of activated carbon. Sorbent questions the economic feasibility of using this method. The use of various plant waste, owing to the carbonization process, makes it possible to increase the adsorption properties of sorbents. Nevertheless, the high temperature to obtain the sorbent casts doubt on the economic feasibility of using this method.

Therefore, one of the main issues for the manufacture of "UAC" is the selection of raw materials. All this is connected, firstly, with the complexity of finding the necessary raw materials from which the "Universal Absorbent Cloth" could be made, and secondly, with the lack of standardized procedures for checking the physicochemical properties of the obtained sorbents, which could confirm the universality of the sorbent relative to different classes of liquid hazardous cargoes.

It is worth noting that in the case of transport accidents that most often occur at linear infrastructure facilities, the use of sorbents is recommended to eliminate emergency consequences only when transporting liquid hazardous substances. Therefore, when designing a universal sorbent, emphasis is on those classes of hazardous cargoes that are characterized by a liquid fraction during transportation and can be eliminated by sorption methods, namely:

– class 3 Flammable liquids;
– class 5.1 Oxidizing substances;
– class 5.2 Organic peroxides;
– class 8 Corrosive substances.

Activated carbon [9, 10] is the only industrial sorbent with a non-polar surface. It adsorbs organic, including non-polar substances well, for example: solvents (hydrocarbons, their halogen-derivatives, simple and esters, etc.), dyes, petroleum products, etc.

Carbonization of plant materials is accompanied by parallel processes of dehydration with the formation of coal and polymerization with the formation of various resins due to levoglucosan [11–14]. Moreover, in each work, the researchers describe and analyze the carbonization process using examples of various raw materials: pine sawdust [11]; sawdust in combination with mineral (kaolin, concrete, talc, etc.) [12]; nano powder "UDP OGA" based on aluminum with water [13]; vegetable waste [14], focusing also on the carbonization temperature.

In all scientific studies [7–15], the carbonization process is classified into four stages, which fully describe the chemistry of carbonization, shown in Fig. 1.

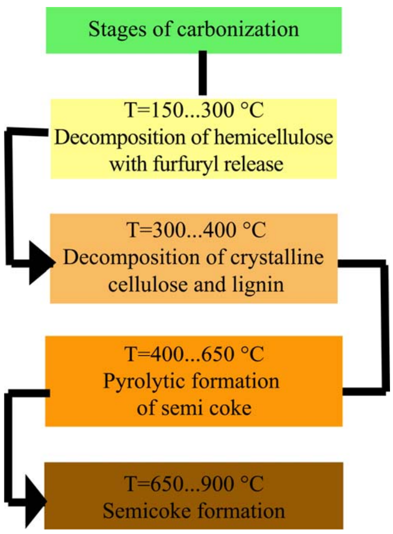


Fig. 1. Stages of carbonization process

The final carbonization of plant materials occurs at a processing temperature in the range from 800 °C to 950 °C [7–15]. However, the accompaniment of the process of obtaining the sorbent by high-temperature carbonization makes one think about finding other materials for carbonization that will not require their processing at high temperatures – this will ensure energy and economic efficiency and, as a result, reduce the cost of the product.

Works [4–15] report in detail techniques for obtaining a universal sorbent, which are used throughout the world.

However, the effectiveness of elimination activities depends not only on the methodology used but also on the effectiveness of its implementation, which forms the next problem, which also needs to be addressed. It is associated with the lack of clear coordinated and interrelated work and responsibility in the "sender-carrier-recipient" system, which also affects the safety during the transportation of hazardous substances. Papers [16–18] deal with the problems of transporting hazardous cargoes and the causes of emergencies. Thus, in [16], a quantitative model is considered for analyzing the accessibility of open sections of a railroad line under emergency conditions using a road system (Borghetti, 2014). Study [17] describes the peculiarities of risk formation associated with the transportation of hazardous cargoes, which requires strategies and tools to reduce the level of risk to society, property, and the environment. This is due to the lack of applications in tactical and operational planning to support hazardous cargoes carriers.

Paper [18] describes the problem of transporting hazardous cargoes by rail and compliance with all international transportation rules governing the actions of all participants in transportation.

However, all the issues raised by the researchers in works [16–18] are not considered in the context of the functional system "sender-carrier-recipient" but are considered as separate elements of the system that do not interact in any way. All this is a relevant task.

The above shortcomings regarding the properties of the sorbent and how to use it for localization and elimination of emergency consequences could be solved by the approach used in work [19]. Thus, the researchers describe techniques of localization and elimination of spills of hazardous substances (petroleum products and their derivatives) through the use of sorption bons, which are mounted on both sides of the cars for the transport of hazardous cargoes. However, the localization and elimination of emergency spills using the technique reported in [19] does not solve the following issues: determining the dynamic balance for re-equipped railroad cars (sorption bons attached to railroad cars); assessment of the load on the wheelsets of rolling stock and a decrease in the volume of cargo, due to an increase in the load on the wheelsets; the assessment of the material and balance efficiency of sorbents (the ratio of the volume of material to the spill area; regarding the speed of deployment of localization and elimination activities.

When analyzing the above issues, there is a need to improve the existing methods for eliminating emergency spills in order to increase efficiency, implement the principles of resource saving and environmental safety.

3. The aim and objectives of the study

The aim of this study is to improve the method of localization and elimination of emissions of hazardous cargoes using sorption technologies.

To accomplish the aim, the following tasks have been set:

– to study the waste of plant origin as a raw material for the manufacture of an absorbent cloth and improvement of the method of its carbonization;

– to fabricate the "Universal Absorbent Cloth" and optimize its application;

– to determine the adsorption characteristics of the "Universal Absorbent Cloth";

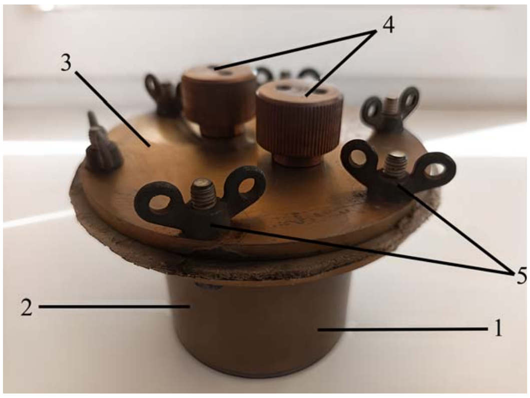
– to devise proposals for improving the method of localization and elimination of accidents through the use of the "Universal Absorbent Cloth" ("UAC").

4. The study materials and methods

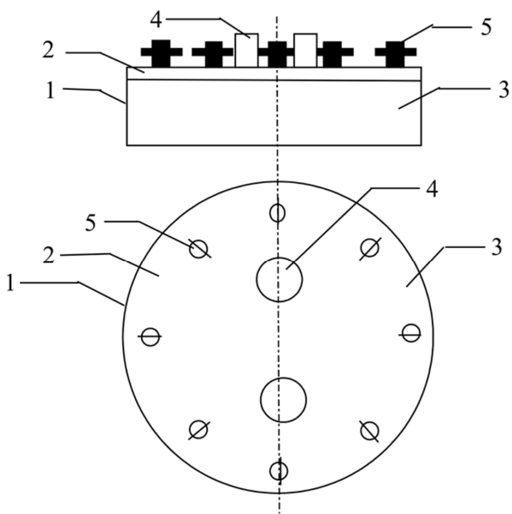
4. 1. The examined materials and equipment used in the experiment

To manufacture a sorbent, the most common materials used as raw materials (kaolinite, peat, fabric-paper waste, grain waste, non-coniferous wood chips, coffee waste, etc.) were analyzed. Among the analyzed materials, waste wood chips and coffee products were selected, which demonstrate high efficiency and high sorption properties at low energy costs. The manufacture of the sorbent was carried out by carbonization of the selected raw materials.

The process of carbonization of waste (coffee products and wood chips) was carried out in a specially designed carbonizer whose diagram is shown in Fig. 2. The carbonizer (Fig. 2) makes it possible to carry out the process of thermal transformation (activation) of plant waste in the laboratory, when coking without the use of special equipment and an inert medium. The check valves installed on the lid limit the access of oxygen in the carbonization zone and do not prevent the removal of gaseous products.



a



b

Fig. 2. Set-up for waste carbonization: *a* — general view of the carbonizer; *b* — schematic diagram of the reactor: 1 — cylindrical mold; 2 — space for waste placement, carbonization zone; 3 — mold cover; 4 — holes with check valves for removal of carbonization products; 5 — locking bolts of the lid of the mold

In [7–15], it is confirmed that the use of a laboratory carbonizer simulates the technological processes of carbonization in an industrial auger furnace. To obtain the sorbent, carbonization was performed in a muffle furnace under coking conditions at a temperature of 100 °C to 500 °C with a step of 50 °C; the carbonization time of waste samples was 60 minutes. Industrially, it is proposed to use special pyrolysis plants.

The resulting carbonization products are used for the manufacture of the "Universal Absorbent Cloth".

4. 2. Methods for determining the parameters of the "Universal Absorbent Cloth"

To establish the parameters for an absorbent cloth (the ratio of the components of the absorbent cloth, density) at which the best sorption result will be achieved, 9 models of absorbent cloth of different density and percentage composition were made. As a fabric matrix for the manufacture of "UAC", the polypropylene filter fabric TGF-8 is used; it is a durable, resistant to aggressive environment, made of polyester thread for filtration, characterized by a density of 470 g/m^2, and a temperature range from −100 °C to +90 °C [20].

Fig. 3 shows detailed models of absorbent cloth depending on the percentage of sorbent components: from 30–70 % of coffee waste and from 70 to 30 % of wood chips, respectively, and density – up to 1800 g/m^2.

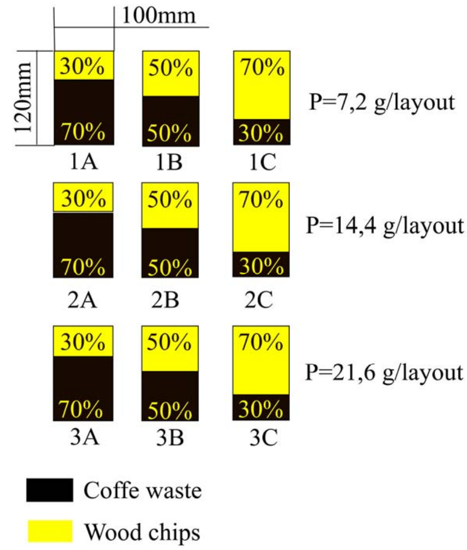


Fig. 3. Detailed layouts of absorbent cloth, with their different parameters

Note the density of "UAC" is indicated in the ratio of grams of sorbent to the layout area

In the studies of the adsorption characteristics of the proposed "UAC", gravimetric and extraction methods of analysis were used (including the procedure for measuring the mass fraction of petroleum products by the gravimetric method (MVV No. 081/12-0116-03) [21].

As model solutions, substances were used that are transported most of all by different types of transport:

– for hazard class 3 – gasoline A-95;

– for hazard class 5 – a 15 % solution of hydrogen peroxide (H_2O_2);

– for hazard class 8 – a 25 % solution of ammonia water.

We determined the indicators of properties of the absorbent cloth by imitating an emergency through making soil samples before and, conditionally, after its occurrence and using "UAC" samples to eliminate the consequences of the accident. The degree of soil purification was defined according to the residual principle: the ratio of the mass fraction of petroleum products in the soil – before and after the application of the absorbent cloth "UAC", the remaining substances – according to the ratio of the mass of conditionally clean cloth and cloth with the adsorbed hazardous substance.

5. Results of studying the indicators of "UAC" properties as a means for localization and elimination of emergency spills

5. 1. Studying the waste of plant origin as a raw material for the manufacture of absorbent cloth and improvement of the method of their carbonization

The selected waste of coffee products and wood chips, as raw materials for the manufacture of sorbents, demonstrate low cost, relative to other materials, and high efficiency. As a result of carbonization, activated carbon was obtained as a sorbent for the subsequent formation of "UAC".

The main characteristic of active coals and carbon sorbents, in general, is the adsorption properties, which are determined by the texture of the sorbent and the nature of the surface functional groups, as well as the yield of the carbonization product.

At this stage of the study, the dependence of the yield of the carbonization product on temperature was studied (Fig. 4), due to which energy and resource efficiency is achieved.

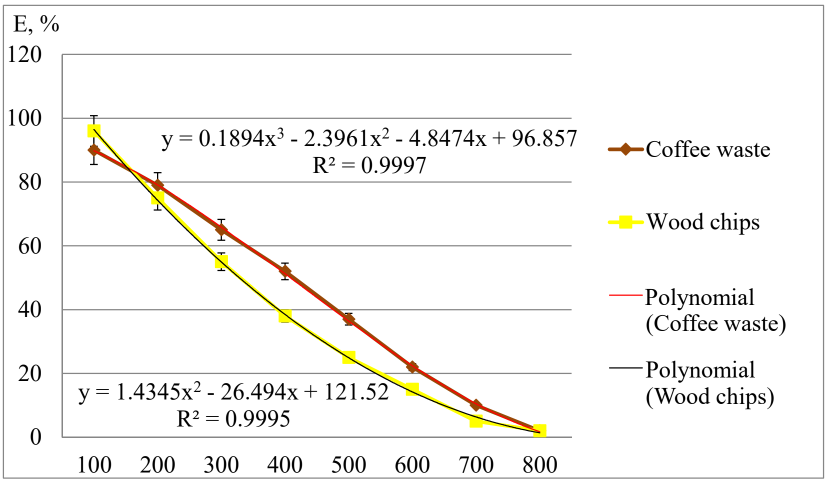


Fig. 4. Dependence plot of the yield of the carbonization product on the temperature in the carbonizer chamber

At the time of our research, the moisture content of the starting materials, namely the waste of coffee products and wood chips, was 5 %. The dimensions of the fractions were: for coffee waste – from 0.1 mm to 1.0 mm, and for waste wood chips – from 5 mm to 20 mm.

5. 2. Production of "Universal absorbent cloth" and optimization of the use of sorbent in the fabric matrix to increase the efficiency of sorption

The designed universal cloth is characterized by a density of up to 1800 g/m^2 and consists of a fabric matrix into which a composite sorbent (products of carbonization of plant waste) is integrated. The fabric matrix is made of THF-8 filter fabric.

Fig. 5 schematically shows the universal absorbent cloth that is proposed to be used for localization and elimination of the consequences of an accident during the transportation of hazardous cargoes.

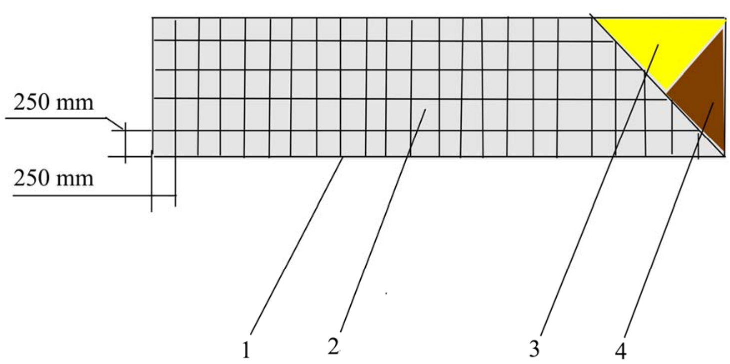


Fig. 5. Universal absorbent cloth (UAC)

The proposed absorbent cloth "UAC" contains a fabric matrix (1) made of filter cloth (2), coffee waste char (from 30 % to 70 %) (3), the char of wood chips (from 70 % to 30 %), respectively (4), with a backfill density of up to 1800 g/m^2. The optimization of the sorption characteristics of "UAC" is achieved by assembling char from various raw materials.

The optimal recommended size of sorption cloth cells is 250×250 mm.

Localization and elimination of the spill are performed by the contact technique "liquid – sorbent". Contacting "UAC" occurs in two phases: first, with a fabric matrix (1) from a filter cloth (2), and then with a composite sorbent: the char of coffee waste (3) and the char of wood chips (4).

5. 3. Determining the adsorption characteristics of the "Universal Absorbent Cloth"

A series of experimental studies to determine the adsorption characteristics of the cloth, depending on the percentage of its components and density, showed that the degree of cleaning of the soil surface using the designed models of the "Universal Absorbent Cloth" to eliminate emergency spills of hazardous cargoes of 3, 5, 8 classes ranges from 89 % to 93 %.

According to the results of model studies, it was proved that the best option for all three model solutions was a variant of sorption composite with a percentage of the char of 50 % coffee waste and 50 % of wood chips (1:1), with a density of 1200 g/m^2, while the degree of purification is 92 % (the measurement error did not exceed 4 %).

5. 4. Devising proposals for improving the method of localization and elimination of accidents through the use of the "Universal Absorbent Cloth" ("UAC")

Next, we devised recommendations for improving the method of eliminating emergency emissions through the use of the "Universal Absorbent Cloth" ("UAC").

Fig. 6 [22–26] shows an example of the devised procedure for eliminating the consequences of an accident during the transportation of petroleum products using a sorption method.

According to the scheme, the procedure for localization and elimination of emergency spills of hazardous cargoes is as follows. A locomotive (1) is joined by a combined railroad car (2) with containers (3) with "Universal Absorbent Cloth" (UAC) (8). In the event of an emergency when transporting liquid hazardous cargoes (10), from the combined railroad car (2), containers (3) with "UAC" (8) are taken out of containers (8); they are thrown in the mirror formation zone (11) of the leakage (7) to prevent the ingress of hazardous cargo (10) into the thickness of the soil and reduce the affected area of the thicker soil (9). Then the spent absorbent cloth (8) is placed back in the container (3), and, upon arrival of the locomotive (1) to the place of its permanent dislocation, the absorbent cloth (8) is regenerated; after regeneration, it can be used again.

Fig. 7 shows a container with an absorbent cloth.

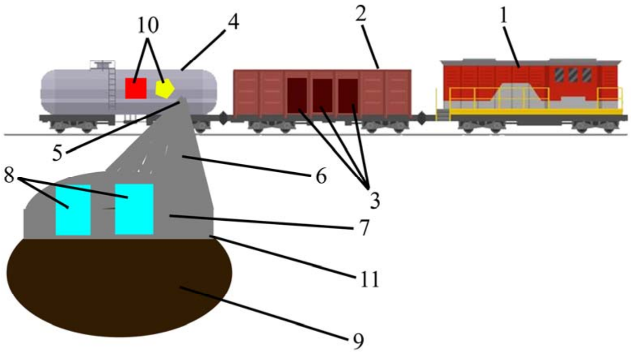


Fig. 6. Layout of equipment and materials in the elimination of the consequences of an accident during the transportation of hazardous cargoes (petroleum products): 1 — locomotive; 2 — railroad car with an absorbent cloth (8); 3 — containers with an absorbent cloth (8); 4 — tank with liquid hazardous cargoes (10); 5 — the hole through which the leakage of hazardous cargoes occurs (10); 6 — a surface runoff of liquid hazardous cargoes (10) in the terrain; 7 — the zone of formation of a mirror (11) of the leak; 8 — absorbent cloth; 9 — a zone of the affected thickness of the soil; 10 — hazardous cargoes; 11 — leakage mirror

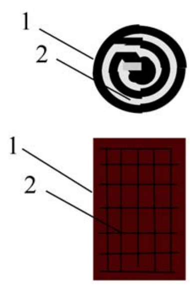


Fig. 7. Container with the absorbent cloth UAC: 1 — container for transportation of absorbent cloth; 2 — folded absorbent cloth

6. Discussion of results of fabricating "UAC" and the technology of its use

Analyzing the dependence of the yield of the carbonization product on the temperature in the manufacture of the sorbent as a component of the "Universal Absorbent Cloth" (Fig. 4), we can conclude that an increase in the temperature of waste processing reduces the yield of the carbonization product by quadratic dependence. The yield of the carbonization product of wood chips at low temperatures (up to 4,00 °C) reaches 50...60 %, at average (400–600 °C) – 25...40 %, at high (600–900 °C) – less than 15 %.

The yield of the product of carbonization of coffee waste at low temperatures (up to 4,00 °C) reaches 70...80 %, at average (400–600 °C) – 40...50 %, at high (600–900 °C) – less than 25 %. Creating an inert medium (nitrogen, argon, etc.) will increase the yield of the product, especially at average carbonization temperatures.

It was thanks to the use of plant waste as a raw material for the carbonization process that it was possible to achieve a decrease in the temperature required to produce activated carbon, an increase in the output rate (at the level of ÷50 %), and a decrease in the cost of the product. The optimum temperature considered is the range of 300–500 °C. The determined indicators of the optimum temperature of the carbonization process and product yield indicate high manufacturability (the ability to use different plant materials), efficiency (use of waste as raw materials), and environmental friendliness (energy and resource-saving). These advantages ensure the competitiveness and profitability of the proposed technology.

With the help of manufactured prototypes with different characteristics of the constituent components of the cloth (Fig. 3), the ratio of the components of the cloth (1:1) and its density – 1200 g/m^2 were experimentally determined, which confirmed its versatility and cleaning efficiency.

Analyzing the available methods of localization and elimination of emergency spills of hazardous cargoes of different classes, we can conclude that the methodology for using sorption bons [19] is effective but the issue of material balance (the number of bons relative to the spill area) remains unresolved. This, in turn, requires significant reserves of sorption bons to cover the required area of pollution. Another problematic issue in the technology of using sorption bons [19] is the time to deploy them to localize emergency spills. So, the implementation of the technological scheme shown in Fig. 6, 7 makes it possible to solve all the above-mentioned problematic issues – not only to get prompt access to the required volume of effective elimination materials in the zone of formation and localization of the spill but also to minimize the time for organizing elimination activities.

Thus, the use of the proposed universal absorbent cloth makes it possible to more effectively localize and/or eliminate spills of liquid hazardous substances of hazard classes 3, 5, 8.

As can be seen in Fig. 8, the absorbent cloth is recommended to be transported in a combined car coupled to the locomotive. It is proposed, in order not to use an additional car, to transport the absorbent cloth in railroad cars – covers that are installed between the rolling stock and the locomotive. As a carriage for the transportation of "Universal Absorbent Clothes" (UAC), it is proposed to use combined cars of models 19–795 and 19–795–01 (Fig. 8).

Fig. 8. Combined cars, models 19-795; 19-795-01, in which the transportation of "Universal Absorbent cloth" (UAC) is recommended: model [27]

The brake is automatic pneumatic with separate braking of trolleys, and parking brake. Chassis – two two-axle carts, model 18-7055 type 2, GOST 9246, or other trolleys of type 2, GOST 9246. Auto-coupling CA–3. Absorbing device class T1. Technical characteristics of the car are given in Table 1.

Table 1

Technical characteristics of the car from [27]

Specifications		
Carrying capacity, no more, t	64.0	
Body volume for bulk cargo, m^3	74.0	
Body volume, m^3 for container loads	70.0	
Tare weight, no more, t	29.1	
Calculated static load from the wheelset on the rails, kN(tf)	230.5	23.5
Car base, mm	11,500	
The length of the car along the axles of the couplings, mm	16,620	
Dimensions according to GOST 9238	1-BM	
Number of hatches:		
– loading	3	
– unloading	6	
Trolley	18-7055	
Design speed, km/h	120	
Mileage between repairs, km	210,000	
Term of service, years	26	

The combined cars of models 19-795 and 19-795-01 were chosen due to the fact that the cars have not only loading upper hatches and unloading lower hatches but also side doors through which one can also load and unload the absorbent cloth. This car is manufactured by PJSC "Kryukov Railroad Car Building Works", one of the local manufacturers, which simplifies the logistics for its purchase, delivery, and use.

After using the absorbent cloth, it can be regenerated for reuse, or disposed of.

There are three main methods of regeneration of sorbents: chemical, low-temperature, and thermal, but the regeneration method that suits us best, among the existing ones – there is mechanical processing (spinning) of the cloth. The effect of such regeneration is small and achieves 10–40 % but this method does not require significant financial costs and makes it possible to save a certain volume of lost cargo and reuse absorbent cloth. In some cases, including after their many single uses, the absorbent cloth will need to be disposed of as waste, taking into consideration its hazard class, according to the State Waste Classifier, 005-96. Disposal of waste (absorbent cloth), as one of the economic methods, can be carried out in such ways as:

1. Burning. Most often, the collected petroleum products are mixed with coal used at TEP.
2. Low-temperature distillation of volatile fractions can be applied, for example, after the sorption of petroleum products.
3. Disposal in landfills.
4. Disposal in the soil. To do this, somebody must provide drainage channels. In order for the processing of petroleum oxidative bacteria to be successful, one needs to check the acid-base balance of the soil.

To solve the issues of waste disposal, there are organizations or enterprises that, in accordance with regulatory requirements, have the right to carry out waste disposal and which can be contacted by PJSC Ukrzaliznytsia.

The high efficiency of the proposed method is ensured by the selection of a suitable sorbent. Effective choice of sorbent is a complex organizational task that is difficult to implement under the operational conditions of elimination activities. The use of the "Universal Absorbent Cloth" ("UAC") makes it possible to solve this problem in advance: the selection, acquisition, preparation, and accumulation of sorbents occur long before the emergency emission occurs. It will minimize the negative consequences of emergency spills of liquid cargoes of different hazard classes and reduce the time spent on elimination activities. These advantages ensure the competitiveness and profitability of the proposed technology.

However, it is worth noting that this methodology of using the "Universal Absorbent Cloth" ("UAC") during the elimination of spills has drawbacks. This method makes it possible to quickly eliminate small volumes of spillage of hazardous cargoes. This method is not able to eliminate large volumes of spills in full. In this case, the absorbent cloth can be used to localize the hazardous substance before the arrival of emergency squads.

This study may be advanced by improving the technologies of localization and elimination of emergency spills of hazardous cargoes and optimizing the manufacture and use of "UAC" as a cost-effective highly efficient sorption material.

7. Conclusions

1. As a raw material for the manufacture of sorbent, waste coffee products and wood chips were chosen, ensuring high product yield and high efficiency. The yield of the carbonization product is ≥50 % with the main parameters of the process: the optimal temperature range of carbonization is 300–500 °C; carbonization time – 60 minutes.
2. To manufacture the "Universal Absorbent Cloth" (UAC), carbonization products are used by integrating them in different ratios into a fabric matrix with a filling density of up to 1800 g/m^2.
3. The characteristics of the adsorption indicators of "UAC" were established, which prove the possibility of using the "Universal Absorbent Cloth" as a means of localization and elimination of emergency spills of hazardous cargoes of classes 3, 5, 8, namely, the optimal ratio of sorbent components – the char of coffee waste and wood chips (1:1) with a backfill density of 1200 g/m^2 was determined, while the degree of surface cleaning with the help of the designed "UAC" is 92 %.
4. Recommendations have been devised for improving the method of eliminating emergency emissions through the use of the "Universal Absorbent Cloth" ("UAC"), namely:

– the use of "UAC" as a means of localization and elimination of emergency spills ensures the speed of deployment of elimination means, coverage of a significant emission area and minimization of environmental consequences and cargo losses;

– it is proposed to use certain types of cars (combined cars of models 19-795 and 19-795-01) for the transportation of "UAC" as part of a freight train, which will provide convenient access to elimination materials and reduce the time spent on elimination activities due to the rapid deployment of the cloth up to 30–35 minutes;

– recommendations for the regeneration and reuse of the used cloth "UAC" are provided.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

References

1. «Elektrovazhmash» zmozhe vziaty uchast v onovlenni rukhomoho skladu «Ukrzaliznytsi». Kharkivska oblasna viiskova administratsiya. Available at: https://kharkivoda.gov.ua/news/108760
2. Elagin, Y. V., Hlushchenko, Y. V., Tsapko, L. V. (2018).State and replenishment of the rolling stock in conditions of Ukrzaliznytsia reform. The bulletin of transport and industry economics, 64, 209–216. doi: https://doi.org/10.18664/338.47:338.45.v0i64.149571
3. Lövétei, I., Kővári, B., Bécsi, T., Aradi, S. (2022). Environment Representations of Railway Infrastructure for Reinforcement Learning-Based Traffic Control. Applied Sciences, 12 (9), 4465. doi: https://doi.org/10.3390/app12094465
4. Kurbangaleeva, M. (2022). Improvement of Emergency Oil Spill Management Technology. IOP Conference Series: Earth and Environmental Science, 988 (2), 022008. doi: https://doi.org/10.1088/1755-1315/988/2/022008
5. Zelenko, J., Kalimbet, M. (2021). Production of the sorption sheet from composite materials as a liquidation agent for spill response of hazardous materials on transport. Collection of Scientific Works of the State University of Infrastructure and Technologies Series "Transport Systems and Technologies", 1 (38), 24–35. doi: https://doi.org/10.32703/2617-9040-2021-38-24-3
6. Murray, M. L., Poulsen, S. M., Murray, B. R. (2020). Decontaminating Terrestrial Oil Spills: A Comparative Assessment of Dog Fur, Human Hair, Peat Moss and Polypropylene Sorbents. Environments, 7 (7), 52. doi: https://doi.org/10.3390/environments7070052
7. Tabakaev, R. B., Astafev, A. V., Ivashutenko, A. S., Yazykov, N. A., Zavorin, A. S. (2021). Changes in thermophysical characteristics of biomass with different mineralization amount during its slow pyrolysis. Izvestiya Tomskogo politekhnicheskogo universiteta. Inzhiniring georesursov, 332 (3), 74–84. Available at: https://cyberleninka.ru/article/n/izmenenie-teplofizicheskih-harakteristik-biomassy-s-razlichnoy-doley-mineralizatsii-v-protsesse-medlennogo-piroliza
8. Brown, R. A., Kercher, A. K., Nguyen, T. H., Nagle, D. C., Ball, W. P. (2006). Production and characterization of synthetic wood chars for use as surrogates for natural sorbents. Organic Geochemistry, 37 (3), 321–333. doi: https://doi.org/10.1016/j.orggeochem.2005.10.008
9. Valeev, I. A., Gazizov, R. A. (2015). Razrabotka promyshlennoy ustanovki dlya polucheniya syr'ya, ispol'zuemogo v proizvodstve sorbenta meditsinskogo naznacheniya. Vestnik tekhnologicheskogo universiteta, 18 (15), 56–59. Available at: https://www.elibrary.ru/item.asp?id=24296313
10. Bulauka, Y. A., Mayorava, K. I., Ayoub, Z. (2018). Emergency sorbents for oil and petroleum product spills based on vegetable raw materials. IOP Conference Series: Materials Science and Engineering, 451, 012218. doi: https://doi.org/10.1088/1757-899x/451/1/012218
11. Osokin, V. M., Somin, V. M. (2013). Issledovaniya po polucheniyu novykh sorbentov iz rastitel'nogo syr'ya dlya ochistki vody. Polzunovskiy vestnik, 1, 280–282. Available at: https://journal.altstu.ru/media/f/old2/pv2013_01/pdf/280osokin.pdf
12. Davydova, S. L. (2004). Neft' i nefteprodukty v okruzhayuschey srede. Moscow: Izd-vo RUDN, 163.
13. Glazkova E. A. (2003). Novyy sinteticheskiy sorbtsionniy material. Khimiya nefti i gaza. Tomks: IOA SO RAN, 592.
14. Anurov, S. A., Anurova, T. V., Klushin, V. N. i dr. (2011). Poluchenie uglerodnykh adsorbentov iz rastitel'nykh otkhodov. Karbonizatsiya syr'ya. Elektronniy nauchniy zhurnal «Issledovano v Rossii».
15. Khokhlov, A., Khokhlova, L. (2021). Development of biocarbon sorbent from corn waste with increased destructive activity in relation to oil. Technology Audit and Production Reserves, 4 (3 (60)), 21–26. doi: https://doi.org/10.15587/2706-5448.2021.238342
16. Borghetti, F., Malavasi, G. (2016). Road accessibility model to the rail network in emergency conditions. Journal of Rail Transport Planning & Management, 6 (3), 237–254. doi: https://doi.org/10.1016/j.jrtpm.2016.10.001
17. Conca, A., Ridella, C., Sapori, E. (2016). A Risk Assessment for Road Transportation of Dangerous Goods: A Routing Solution. Transportation Research Procedia, 14, 2890–2899. doi: https://doi.org/10.1016/j.trpro.2016.05.407
18. Šolc, M., Hovanec, M. (2015). The Importance of Dangerous Goods Transport by Rail. Naše More, 62 (3), 181–186. doi: https://doi.org/10.17818/nm/2015/si17
19. Soroka, M. L., Yaryshkina, L. A. (2012). Technology for the oil spills clean-up which provides preliminary accumulation of sorbents into the area of emergence and localization oil spills. Science and Transport Progress, 42 (12), 45–55. Available at: http://stp.diit.edu.ua/article/view/9275/8035
20. Tkan' fil'troval'naya TGF-8 (56035). Available at: https://epicentrk.ua/shop/tkan-filtrovalnaya-tgf-8-56035.html?ssh=revenue&gclid=Cj0KCQiAkuP9BRCkARIsAKGLE8V7AXF7PBIj8iYH0ZnXM7_ldMfHy3o5zovisrBvI-x65f3RwcRSZegaAp0WEALw_wcB
21. MVV No. 081/12-0116-03. Grunty. Metodyka vykonannia vymiriuvan masovoi chastky naftoproduktiv hravimetrychnym metodom. Available at: http://online.budstandart.com/ua/catalog/doc-page?id_doc=76437
22. Zelenko, Yu. Myamlin, S., Sandovskiy, M. (2014). Scientific foundation of management of the environmental safety of oil product turnover in railway transport. Dnipropetrovsk: Lithographer Publ, 332.
23. Zelenko, Yu. (2010). The new technology of liquidation of Transport Accidents Involving Oil Products. Journal of Transport Problems, 5 (1), 83–89.
24. Zelenko, Yu. (2010). Developing the actions on the mitigation of the environmental consequences of the transport oil-product accidents. Dnipro, 192.
25. Zelenko, Yu. (2010). The scientific basis of the environmentally safe transportation technology and using the oil-products in the rail sector. Dnipro, 242.
26. Soroka, M. L., Zelenko, Yu. V., Yaryshkina, L. O. (2012). Doslidzhennia ekspluatatsiynykh vlastyvostei sorbentu dlia likvidatsiyi avariynykh i tekhnolohichnykh emisiy naftoproduktiv ta vuhlevodniv na transporti. Visnyk NUK imeni admirala Makarova, 3, 233–237. Available at: http://eadnurt.diit.edu.ua/bitstream/123456789/10131/1/Soroka_NUK_2012.pdf
27. Kombinovani vahony modelei 19-795 ta 19-795-01. Available at: https://www.kvsz.com/index.php/ua/produktsiya/vantazhne-vagonobuduvannya/vagoni-khoperi/item/1957-kombinovani-vahony-modelei-19-795-i-19-795-01