Rapid detection of contamination of objects and water surfaces by aggressive chemicals and uranium compounds

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Abstract. In response to the deteriorating environmental situation, timely and rapid detection of environmental pollutants by aggressive chemicals is important for protection measures. Thousands of tons of aggressive chemicals and waste from the nuclear industry are transported by rail and road every day. In order to quickly detect the straits, when these substances are scattered, it is necessary to have the means of their rapid detection. This article describes a portable chemical express laboratory for the rapid resolution of these problems. The laboratory consists of two unified cases with aerosol devices placed in them. In the first case are aerosol devices to detect aggressive chemicals of acidic, alkaline, and oxidative nature and derivatives of rocket fuel dimethylhydrazin. This set of cases allows detecting almost all types of aggressive chemicals. In the second case are aerosol devices to detect both radioactive and low-radioactive uranium compounds present in radioactive waste, which also allows controlling the leakage of spent nuclear fuel.

1. Introduction
As a result of the ecology situation deterioration, the rapid process of environmental pollutants caused by harsh chemicals identification and prevention of it becomes more and more important.

Thousands of tons of aggressive chemicals and the nuclear industry waste are daily transferred by a railway and vehicle transport. In order to identify any floods or spills caused by these substances rapidly, it is necessary to have a rapid detection treatment.

This article describes the functionality of the portable chemical express laboratory which solves the mentioned above problem. The laboratory contains two unified cases with aerosol devices placed inside. The first case contains the aerosol devices for detecting aggressive chemical substances of acidic, alkaline, oxidizing nature and derivatives of dimethylhydrazine rocket fuel. This case allows detecting almost all types of aggressive chemicals.

The second case contains the aerosol devices for detecting uranium and low-level uranium compounds present in a radioactive waste, which also allows controlling radioactive nuclear fuel leaks.

This article explains the usage of the module portable chemical express laboratory (PCEL) for combined express-detection of aggressive chemicals on the objects surfaces.

2. Methods
Substances of acidic and alkaline nature, as well as oxidizing and reducing agents are considered as aggressive chemicals. Substances of an acidic nature include strong (sulphuric, nitric, hydrochloric, and
others) and weak (acetic and others) acids. Substances of alkaline nature include strong (potassium hydroxide, sodium hydroxide, and others) and weak (ammonium hydroxide and others) bases. Oxidants include concentrated and diluted nitric acid, concentrated sulphuric acid, hydrogen peroxide, calcium hypochlorite, and others. Dimethylhydrazine and ammonia derivatives include asymmetric dimethylhydrazine (UDMH, heptyl), which is the main component of rocket fuel, ammonium hydroxyl.

The necessity of providing express identification of all these four aggressive chemicals types is explained by the fact that the spill of these chemicals can lead to chemical burns of the working people. Mixing of acids with alkalis, or oxidizing agents with reducing agents can lead to explosions and fires. That is why the combined storage of those chemicals is unacceptable. The identification of an aggressive chemical substances objects surfaces contamination type is a result of the necessity to select appropriate degassing formulations for the rapid disinfection of contaminated surfaces.

A method of using indicator papers and tickets was previously used in order to identify acidic and alkaline substances. The disadvantage is that the indicator papers and tickets allow detecting the substance only directly in the place of its contact with the examined surface. It requires the direct contact between an operator and analysed surface, it is impossible to detect surfaces contamination if an operator's access is restricted physically.

3. Results
In 2019, Federal Government Budget Institution “All-Russian Research Institute for Civil Defence and Emergencies of the Ministry for Emergency Situations of Russia” (Federal Centre of Science and High Technology) completed development of a portable chemical express laboratory module (PCEL) for express-detection of aggressive chemicals and uranium compounds. Government testing was successfully completed for PCEL and it was recommended to be used by Russian Emergency Situations Ministry [1]. There was a special working documentation O1 developed for the serial production of this laboratory.

Module 1 of the laboratory is supposed to identify aggressive chemicals on the objects surfaces. The typical module laboratory form is shown in Figure 1a. Figure 2 shows open module 1 used for the identification of an aggressive chemical substances objects surfaces contamination.

Module 1 contains four aerosol devices with indicator formulations: an aggressive chemical substances of alkaline nature (AU-2), acidic nature (AU-3), derivatives of dimethylhydrazine and ammonia (AU-5), oxidizing substances (AU-6).

If the type of aggressive chemical agent is known, an appropriate aerosol device will be used to detect it. If the type of surface contamination of objects is not known, then with the usage of all four aerosol devices, an express detection of the surface nature contamination by aggressive chemical substances will be performed [2].

Figure 1. (a) The typical module laboratory form. (b) Open module 1 (PCEL).
The express identification method of an aggressive chemical substance on the objects surface type is done by spraying an indicator formulation from a distance of 10 ... 15 centimetres from the object surface with the usage of all four types of aerosol devices made in the shape of a sealed housing filled with an appropriate indicator formulation and a spray pump [3-11].

In the aerosol devices already used, there is a special method of spraying an indicator formulation, using a special spray pump design. When you repeatedly press a spray pump button, a vacuum is created by it and an indicator formulation is fed into the spray pump, followed by its spraying onto the analysed surface.

A typical aerosol device (AU) for detecting aggressive chemicals is a 150 ml aerosol, equipped with a nebulizer and filled with the appropriate indicator formulation for aggressive chemicals. An aerosol device has a label applied by silk-screen printing, preserving the integrity of the label caused by external circumstances.

The resulting indicative effect of alkaline substances and the colour standard are shown in Figure 2.

![Figure 2](image)

**Figure 2.** Indication effect from substances of an alkaline nature (a) and standard indication effect applied to an aerosol device (b).

There are the following advantages of using an aerosol device method over other known methods, in particular over indicator paper or indicator tissue:
- no necessity for the direct contact between an operator and analysed surface;
- multiple use of one aerosol device (not less than 100 times), which makes it possible to repeatedly determine the object surface contamination;
- maintenance of a performance over a time;
- temperatures can vary from 0°C to 40°C;
- longer shelf life of the indicator formulation (more than 2 years);
- no need to use additional reagents for detection;
- providing a large control area.

The combined express detection of an aggressive chemical type is achieved by spraying four indicator formulations on different parts of the examined surface and observing the emerging indicator effect from each of it. A surface contamination type is identified by the combination of the emerging indicator effect on these four sections of the surveyed surface.

4. Conclusion
There are the following advantages of using PCEL for the combined express-detection of aggressive chemicals on the objects surface: increased speed and detection sensitivity; ease of use; no necessity to use any additional reagents for detection; no necessity for a direct contact between an operator and analysed surface; multiple usage of one aerosol device (at least 100 times); preservation of performance in a wider temperature range (from 0°C to 40°C); providing a large control area; longer shelf life of the indicator formulation (2 years).
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