MEANS OF CHEMICAL RECONNAISSANCE AND CONTROL IN THE FIGHT AGAINST CBRN TERRORISM

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The chemical, biological, radiological and nuclear terrorism (CBRN terrorism) is a special form of terrorism known for its extraordinary efficiency as super-terrorism or ultra-terrorism. Detection and identification of the presence of hazardous chemical toxic substances is very difficult and can be achieved only by using advanced detection and monitoring instruments and devices that are currently only in the equipment of units of the Fire and Rescue Service of the Czech Republic and some units of the chemical troops of the Czech Army. Instigators of chemical terrorism count on the surprise factor, as well as on the difficulty and great delay in detecting the presence of hazardous chemical toxic substances. Therefore, for early warning of the population and minimization of consequences of a terrorist attack with the use of hazardous chemicals, the ability of early detection and subsequent identification is very important.

Key words: *Chemical, Biological, Radiological and Nuclear Terrorism, CBRN agents, CBRN terrorism, CBRN Counter-Terrorism, chemical reconnaissance and survey equipment.*

1. INTRODUCTION

Analytical control is an interdisciplinary field penetrating not only chemical sciences but also a great majority of human activity. Apart from its general contribution and the use of analytical, primarily physical-chemical methods in the defense research of technical character, these problems are specifically worked out in the military research in order to provide chemical protection of the army and civil population.

Chemical reconnaissance is the most important component of chemical protection aimed at reducing the effect of chemical weapons; its goal is the early detection of chemical warfare agents, their species and the extent of atmospheric and ground pollution. The important objective of chemical reconnaissance is to determine the end of contamination

or, as the case may be, to determine when the warfare agent concentration dropped to an admissible level with the first syndromes of exposure becoming obvious only after several hours. However, this is an extraordinarily demanding task for reconnaissance.

Apart from the problems of chemical reconnaissance, detection methods and analytical procedures are also necessary for numerous tasks of chemical survey consisting primarily in the determination of the degree of contamination of surfaces and samples taken for analyses. However, it is necessary to monitor not only the contamination with chemical warfare agents but also with other militarily important substances, primarily with toxic compounds.

The detection methods that are used in the system of technical equipment for chemical reconnaissance and survey primarily involve the response time, selectivity and sensitivity. They are continuously completed with other requirements that depend on the changing military and political situation in the world, as well as on changing opinions about the use of chemical weapons in conflicts of different character and intensity.

Another factor that has to be taken into account is that new and more toxic warfare agents are being developed and stockpiled while the older and less efficient are gradually eliminated. The development of binary chemical weapons with the filling of non-toxic or only slightly toxic precursors of the nerve paralytic inhibitors of cholinesterase (at the present time the most important group of chemical warfare agents) made the availability of these mass destruction weapons to be no longer a major problem because these substances are routinely produced and processed in the chemical industry. This situation cannot be changed by monitoring the observance of the Chemical Weapons Convention even if it is organized on a large international scale.

The use of chemical warfare agents in terrorist attacks against the civil population underlines the above stated facts and the importance of detection and monitoring of toxic and militarily important agents. Furthermore, the completion and modernization of the technical equipment for chemical reconnaissance and survey is significantly influenced by the current rapid development of the technology of new materials important in this sphere, such as the electronic and optical materials. Last but not least, the results of basic research in the sphere of chemical sciences become increasingly important. The chemical reconnaissance and survey equipment can be divided into several categories depending on the purpose of its use or on the level of the technical design.

2. SIMPLE EQUIPMENT

Simple equipment for chemical reconnaissance and survey forms the first category. This is a relatively frequently used and heterogeneous group of equipment for the detection of warfare agents. Agents in liquid state are detected by using detection papers, colors or pencils; the detection is usually based on the solubility of selected pigments in warfare agents.

The combat concentrations of vapors are detected by using detection papers based on a sensitive chromogenic chemical reaction. These detection papers must be in most cases completed with necessary solvents or solutions of agents.

Simple equipment for the detection of low concentrations, which are therefore less dangerous or even admissible, cannot be based on a classical chemical principle but on a biochemical principle. This is, of course, a more demanding and therefore more expensive solution, which is justifiable in case of warfare agents with the greatest risk of use. For this reason, the current simple detection equipment using a biochemical principle is based on various types of cholinesterase; the paralytic nerve substances are their highly efficient inhibitors.

Apart from the equipment used only for atmospheric control with an enzyme in solution or only coated on a carrier, the most advanced equipment uses enzymes immobilized on a carrier, which makes it possible to analyze water, food, surfaces, etc. Low mass, simple manipulation, power supply independence, and low initial costs are the reasons why this category of equipment for chemical warfare detection is considered to be successful in the future. This equipment can easily be incorporated into the equipment of an individual person; thus it should play a vital role for surviving in extreme combat conditions, during separation from a combat unit or in other extreme situations, which are difficult to predict. An interesting trend in warfare agents' detection is the possibility of using liquid crystals, thin layers of cholesterol derivatives and analogues, which might become in the future the equivalent of detection papers based on physical and chemical principles. In the field of simple equipment based on biochemical principles, one can expect unequivocal contribution from the rapidly developing field of immunochemistry.

At present, diagnostic methods using immunochemical principles are rather widely used; some of them may be denoted as simple by their arrangement. Especially the development of preparation methods for the preparation of monoclonal substances is promising, because it would make it possible in the near future to prepare substances against low-molecular toxins, i.e., against the majority of chemical warfare agents. By this development, the necessary conditions will be created for the design of highly sensitive and selective simple equipment for the detection of warfare agents. On the other hand, in case of threat of the use of extremely toxic high-molecular toxins of natural origin or of their semi-synthetic derivatives in the category of chemical warfare agents, the immunochemical detection method is actually the only feasible solution.

3. CHEMICAL DETECTION DEVICES

The second category is formed by chemical detection devices. For this relatively simple equipment, the use of tube detectors and tube detection

devices is quite characteristic. The chemical detection devices differ by their external appearance, the technique of air sucking, range of products and the number of tube detectors or, as the case may be, by other equipment. However, their possibilities are limited by the parameters of the detection device tubes with respect to the warfare agent detection.

These chemical detection devices are widely used in all the armies in the world. The reason of their popularity is that their operation is simple, they are inexpensive and there is a broad range available of tube detectors. They make it possible to detect selectively and with great sensitivity the majority of the known warfare agents. Last but not least, the tube detectors have a long shelf-life because the necessary reagents for the chromogenic reaction are dosed in advance and stabilized by sealing into glass.

Apart from the tube detectors that use chemical reagents giving rise to characteristically colored products, the very sensitive biochemical cholinesterase reaction is traditionally used. By immobilizing the cholinesterase enzyme on the carrier in the detection device, the reaction makes it possible to detect the paralytic nerve warfare agents in the vapor-air mixture and also in water.

The development in this sphere of detection of warfare agents and other militarily important substances heads primarily towards the tube detectors that make it possible to suck the controlled atmosphere for a long period of time, furthermore towards tubes for a simultaneous detection of several agents and towards linear tubes for the semi-quantitative determination according to the length of the colored layer. The development in this sphere primarily heads towards the extension of the range of determined agents.

4. AUTOMATICDETECTORS

The greatest emphasis is laid on the third category formed by automatic detectors. Automatic detectors should ensure continuous monitoring and constitute the basis of the protection and warning system of the army troops and manpower against the effects of chemical weapons or, as the case may be, other toxic contaminants. This group is by the principle and design of equipment quite heterogeneous; in most cases, the expensive and complicated equipment often uses some of the known instrumental method of physical chemistry in a very ingenious manner.

The automatic detectors based on a sensitive chemical or more often biochemical reaction differ primarily in the way the positive reaction is evaluated, which is either done photometrically or electrochemically. Apart from these automatic detectors, instruments that are based on the flame lionization principle, ionization principle, or on the ion mobility, IMS (Ion Mobility Spectroscopy) are also used.

The significant advantage of detectors using chemicals and biochemicals is their selectivity and sensitivity. The disadvantage is their dependence on these preparations and a lower response time given by the necessary reaction time. However, the automatic detector is a source of primary information about the incidence of warfare agents in the atmosphere; the high detection speed based on the detector response time is therefore primarily required. This early information would make it possible to organize the early warning of the manpower.

The efficient and rational process of commanding on the side of higher staffs (including the warning of subordinated troops and the estimation of casualties) is ensured by connecting the automatic detector to the net of automatic data acquisition. Despite the restricted possibilities in selectivity and quantitative determination of automatic detection systems, it was just this high response speed that contributed to the widespread use of automatic detectors using the IMS principle in the advanced armies. The IMS method could be further sophisticated with the goal of removing certain drawbacks such as for example the lower sensitivity and selectivity, the water vapor interference, the ability to detect only compounds forming molecular ions and clusters with the same electric charge, or the principal inability to distinguish small molecules.

However, this is not a problem that can be easily solved and the result would be gradual merging with mass spectrometry (MS), requiring to include a preliminary separation process incorporated before the detector. Such combination is already used in the mobile analytics, namely in the combination with gas chromatography, which is GC/MS. However, we pay for gaining the high selectivity by high initial costs, considerable demands on the level of operation, and with the exception of several volatile compounds, also by loosing the response speed of the whole detection system.

Furthermore, the problems persist of the quantitative determination and the overall insufficient sensitivity. A promising sphere of further possible solutions is the development of sensors and biosensors. The ion selective electrodes and classical potentiometric biosensor were discovered many years ago. Nevertheless, the first results of practical use appeared only recently in the detection and monitoring of specific substances in the atmosphere.

The amperometric sensors use a membrane permeable by gases and separating the electrolyte with a measuring, reference and auxiliary electrode; these sensors are now the most developed detectors. The outer potentiostatic system ensures the constant voltage between the measuring and reference electrode. By the redox reaction of the analyte with the electrolyte, a current arises that is proportional to the partial pressure of the component in the vapor-air

mixture. The used membrane, chosen electrolyte and the applied voltage in fact determine the selectivity and sensitivity of the detector.

Compact systems were already described for the direct voltammetric analysis of compounds in the atmosphere without the use of liquid electrolyte. In this case, the sensor consists of a conducting polymer coated on a non-conducting carrier. The electrode system is built into the polymer; the substance is adsorbed directly from the atmosphere. The electrode system may be overlapped with an ion-exchange membrane or, as the case may be, completed with catalysts for the detection of organic substances that can be oxidized only with difficulty.

The resistor sensors on the basis of conducting polymers seem to be promising; they are investigated within the projects called rather euphemistically an „electronic nose". The basic device consists of a bunch of resistor sensors differing in sensitivity, with chemometric evaluation and comparison with standards. The classical amperometric biosensors with a built-in enzyme undoubtedly meet the requirements of the fast detectors of nerve gases and strong cholinesterase inhibitors; they are also sufficiently sensitive and selective.

An unsolved problem is the regeneration or replacement of the inhibited or inactive enzyme and therefore the automatic or continuous operation. There is a hope in this direction that this problem will be solved by using multi-channel detectors and piezoelectric imunnochemical biosensors. The advances in the miniaturization of parts guarantee the necessary potential growth of sensitiYity; the character of the antigen-haptene bond (in contrast with the rigid engine-inhibitor complex) a chance to successful solution.

4. REMOTE DETECTORS

There is no fast detector sufficiently fast for unprotected manpower situated in a targeted area hit by chemical weapons. For this reason, a lot of work and money was spent on the construction of a detector that would receive the advance information on the chemical attack, thus making it possible to manage efficiently the necessary protective measures. This requirement is met with remote detectors based on the application of spectroscopic methods. These methods are based on the interaction of radiation with the vapor-air mixture or aerosols.

Depending on their relation to the radiation sources, we distinguish the active and passive remote detection systems. The active systems that are now denoted as lidars (light radars) use the coherent radiation of lasers. The passive detectors use as a source of radiation the radiation emitted from the energetic background; they represent therefore the highest attained level. The principle of remote control of air pollution in the case of lidars or passive detectors is in most cases based on the infrared and Raman spectroscopy or differential absorption spectroscopy. The remote

detection has been used as military equipment rather exceptionally.

In view of their complexity, these systems are suitable rather for stationary monitoring than as mobile equipment. Their high initial prices so far do not allow for their purchase in major series even in the armies of economically strong countries. The efficiency of remote control on the ground is also rather disputable; in a broken topography, it will be very difficult to utilize the theoretical range of several kilometers, moreover in a zone of combat activity with the atmosphere full of dust and smoke. On the other hand, the remote control is the ideal and only possible solution for air reconnaissance of chemical contamination in the areas of interest.

5. MOBILE LABORATORIES

Mobile laboratories belong to the fourth category. Mobile laboratories represent the basic equipment for carrying out chemical controls, they specify and complete the results obtained from chemical reconnaissance. The overall design and thus the development of mobile laboratories is quite different. By its size, a mobile laboratory represents small or almost pocket equipment, or the equipment sometimes portable over small distances, up to well equipped laboratories placed on the chassis of a cross-country truck or placed in a series of containers to be transported by railways wagons, airplanes or on ships. This volume also restricts the applied methods to conventional analytical methods in the simplest case. In a more complex approach, the physical-chemical instrumentation is used with resistance increased by its construction, making it possible to identify organic compounds under the conditions of a rough terrain.

It should be stated that this category of equipment was neglected in favor of the detection systems, primarily the automatic ones. This holds for the detection and primarily for the identification of chemical warfare agents. Moreover, this category of equipment is limited by the need of professionally trained operators carrying out structural organic analyses, i.e., by specialists that are little numerous even in the sphere of civil research and development. It is also necessary to take into account the important feet that in the conditions of the world, which in most cases resigned on the use of chemical and biological (bacteriological) weapons of mass destruction, nuclear weapons could be used as retaliation to the possible use of weapons of that category. From this point of view, the importance of the reliable identification of individual chemical weapons growths above all present limits.

6. CONCLUSIONS

It can be stated that the problems of detection and analytical survey of

chemical warfare agents and other militarily important compounds are solved systematically, at all levels of chemical reconnaissance and survey. In the sphere *of simple equipment,* several development trends can be observed. First of all, it is the research of detection systems based on biochemical reactions that utilize the stabilized or, as the case may be, immobilized systems, primarily *cholinesterase* of different ethiology for the determination of nerve warfare agents. If it is possible to prepare monoclonal substances corresponding to militarily important compounds or their conjugates, the use of immunochemical procedures will be of considerable importance.

A classical development trend is the study of possibilities that provide chromogenic systems for the detection of warfare agents. These systems consist for example of thin layers of the cholesterol derivatives and liquid crystals. The reason why this category is considered to be successful in the future is the small volume and mass, undemanding use for training, inexpensiveness and a long shelve-life. It is easy to incorporate the equipment of this category into the armament of an individual. For these reasons, it should play a vital role for surviving in extreme combat conditions, during separation from a combat unit or in other extreme situations, which are difficult to predict.

The interest in *chemical detection devices* using tube detectors is continuing. This device is one of the most widely used equipment for the detection and monitoring of warfare agents that was introduced into the army equipment. The development trend is toward the extension of the detector range toward other current chemical warfare agents, toward tube detectors for long term sucking of the controlled atmosphere, small tubes for the detection of several substances and linear tubes for semi-quantitative determination. An opinion persists that the basis of the system for the detection and monitoring of warfare agents is a fast *automatic detector* connected to a net of data acquisition and evaluation. The equipment basal on the separation of clusters arising by the ionisation of the vapour-air mixture, i.e., the IMS method, is also considered to be promising.

The methods and procedures for the development of sensors and primarily biosensors intended for the direct control of the atmosphere are now intensively studied. Apart from the classical electrochemical (usually amperometric) biosensors based on the immobilized enzyme, biosensors that are based on the immunochemical principle with the piezoelectric detection and the possibility of the antigen immobilization on the surface of a piezoelectric crystal prevail. Considerable interest concentrates on the multi-detection systems that are the basis of an “electronic nose”.

In the sphere *of remote control,* the development trend is primarily toward systems using the infrared and differential absorption spectroscopy. In this sphere, equipment already appeared which could be also used in the army and not only in the stationary monitoring systems. In the field of *mobile laboratories,* a distinct

shift is obvious from the often complicated and time consuming procedures of classical analysis to physical-chemical instrumentation, preferably to the separation methods and methods generally used in the organic structural analysis. The rather small portable laboratory sets are not losing on importance for specific tasks of chemical survey.

Terrorism, especially its international form, together with organized crime and proliferation of weapons of mass destruction is one of the most serious threats to the entire human civilization. A substantial part of the world has been hit or threatened by terrorism, political and religious, actions of regional and transnational terrorist and extremist organizations and groups. Regardless of the efforts of security forces of all democratic nations to eliminate international terrorism, dozens of countries meet with its activities every year. Terrorism is not a new phenomenon. However, the methods of terrorists have changed for decades, and consequences of contemporary terrorism are equally terrifying. States and their organizations must face the phenomenon, which through the latest technology and some new forms of activities has become a serious threat to lives, health and property of people.

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