Developed Physical Detection-Possibilities of Chemical Agents

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Abstract: We can't preclude the possibility of the use of chemical agents by terrorists - I can recall the attempt committed with Sarin in the Tokyo-subway in 1995. For that reason it is necessary to know the chemical situation in the battlefield and in our urban environment as well, for example in the subway. Actually the possible detection principles of toxic-agent-detection-devices are chemical (simple detection devices: e. g. paper detector, detection tubes), biochemical, physical (ion mobility spectroscopy, flame photometry, photoacoustic spectroscopy, infrared or laser remote sensing detection-systems). To control the real time chemical situation it is essential to establish, set up an accurate and rapid reconnaissance. The solution is a monitoring system, which includes developed toxic-agent-detection-devices.

Keywords: Monitoring, real time chemical situation, toxic-agent-detection, principle of physical detection, CAM, AP2C, PAS, remote sensing detection

1 Introduction

Unfortunately, nowadays there are a lot of „chess players" all over the world: the experts suspect that many countries illegally dispose over weapons of mass destruction. According to official data the former Iraqi Dictator used chemical weapons (nerve agent and blister) against his own people. And Saddam didn't shrink from the use of chemical weapons in the war against Iran in 1988. The name of the operation was „Blessed Ramadan" and we can follow the events in *Fig 1*.

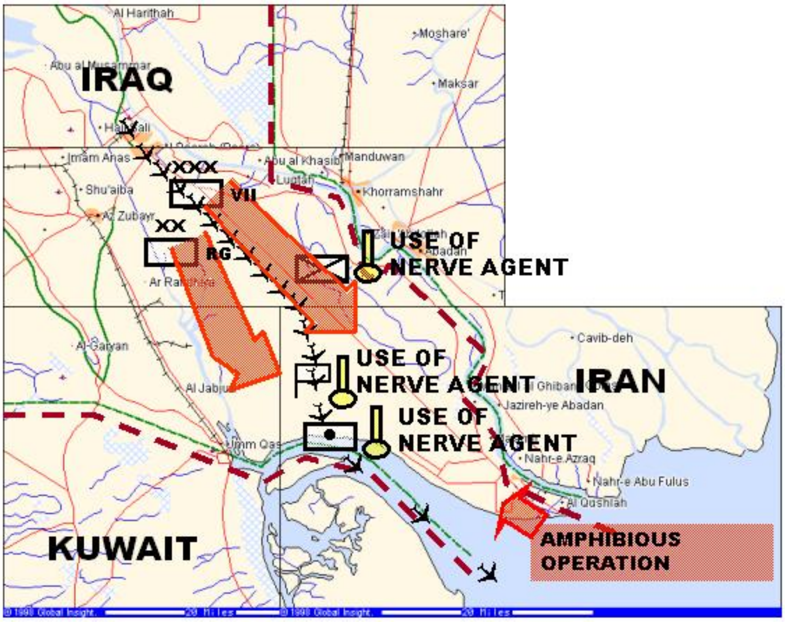

Figure 1

Operation “Blessed Ramadan” (17-21 April, 1988)

On the map the Iraqi 7th Corps and a Division of the Republican Guard are marked (the latter is an elite troop). At first the Iraqi artillery struck some mechanized infantry-troops of the Iranian Armed Forces by nerve agent then the Iraqi troops got moving and the Air Force twice attacked the enemy forces similarly with nerve agent. The operation was finished on the 5th day after an amphibious operation.

As we know during the American attack (2002) Saddam’s weapons of mass destruction disappeared and the expert-group charged by The United Nations in Iraq didn’t find them neither. Likewise we can appoint, unfortunately, there is a real and continuous chemical threat for the Armed Forces and civilian life, as well.

The most important requirements for a developed chemical-detection-device are, that the instrument must be selective, accordingly be able to detect exactly the quality of the toxic agent. It is necessary to be capable to detect simultaneously different toxic agents (e.g. nerve and blister agents together). The concentration must not exceed the 100 mg/m^2 for nerve agents and 10 g/m^2 for blisters. The optimal detection-time is 3-5 s or less. Finally it is very important that the device must be insensitive for non-toxic agents. Naturally, the instrument has to have an output to a personal computer.

2 Ion Mobility Spectroscopy (IMS)

The well known Ion Mobility Spectrometer is the Chemical Agent Monitor. The features of the instrument are the following: it is a hand-held, solder operated, post-attack device for monitoring chemical agents on personnel, equipment or in the field. It has got a Field Alarm Module (FAM), which can provide remote alarm tasks and an automatic switching between nerve and blister modes of operation.

The operational configuration:

- length-width-height: 17-4-7 inches,weight: 1.5 kgs,power supply: single 6 Volts battery (battery life: 6 hrs, continuous use, typical 15 hrs),

- agent concentration sensibility: 0.1 mg/m^2,

- unit cost: $ 6.500

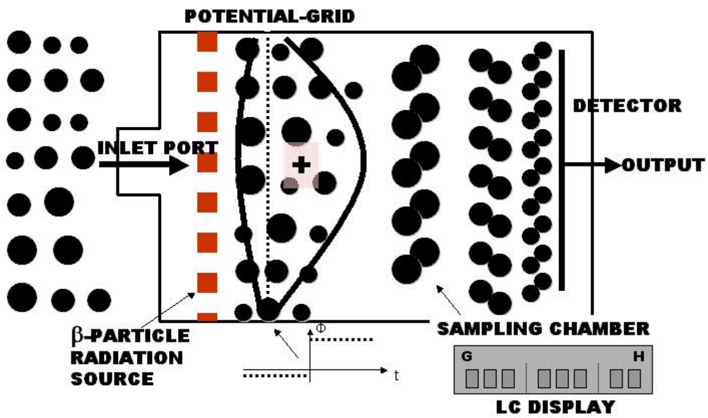

Figure 2
The cross-sectional view of the CAM

The function of CAM (*see: Fig. 2*):

1 The CAM uses a nickel-63 (63Ni) beta-particle radiation source to ionise airborne agent molecules that have been drawn into the sampling chamber by a pump. The resulting ions vary in mass and charge.

2 If the potential grid is negative it collects the positive ions close to it.

3 The form of the ion-cloud is very special due to the effect of pump.

4 If we change to positive the charge of the potential grid the ion-clusters will travel to the detector. The flying time of an ion-cluster depends on its mass (see: Fig. 3).

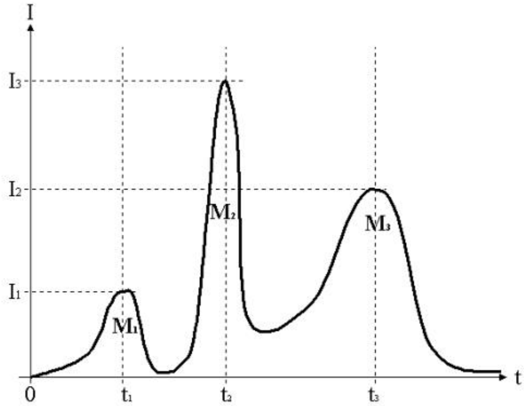

Figure 3
Characteristics of the CAM

5 Flying time data are stored in a ROM, from which the device can determine the type of agent and its relative concentration.

6 A liquid crystal display presents these data as a series of concentration-dependent bars.

7 The agent concentration depends on the wind velocity and other environmental factors, for that reason the numerical display of agent concentration in typical units is impractical.

8 So, the low agent-concentration is marked by 1 to 3 bars, a high 4 to 6 bars, and a very high 7 to 8 bars on LCD.

3 Flame Photometry

Another important principle is the flame photometry. A flame of hydrogen is allowed to burn the air-sample after at the colour of the flame is investigated by a photometer. In this way, the presence of phosphorus and sulphur can be demonstrated. E.g. the most important of this type of instruments is the French monitor AP2C (*Appareil Portatif pour le Contrôle Chimique*). The instrument is demonstrated in the *Fig. 4*.

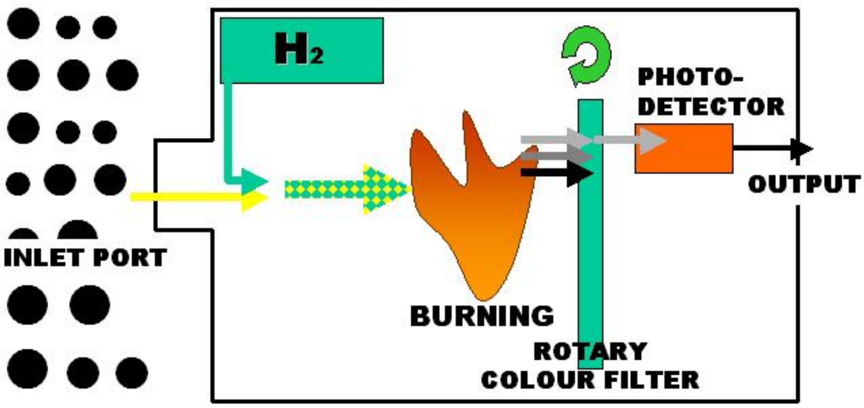

Figure 4
The AP2C (flame photometer)

The operational configuration:

- length-width-height: 16-5-6 inches,
- power supply: single 9…32 Volts battery or rechargeable battery,
- weight: 2.0 kgs,
- single handed operation,
- agent concentration sensibility
    - nerve toxic: 10^{-5} mg/dm^3,
    - blister: $4 \cdot 10^{-3}$ mg/dm^3,
- unit cost: $ 9.500,
- response time < 2 seconds,
- start up time < 1 minute,
- detects all types of mixtures and degraded chemicals,
- used to detect toxic industrial materials (TIMs).

4 Photoacoustic Spectroscopy (PAS)

The origins of Photoacoustic Spectroscopy (PAS) date back to the discovery of the photoacoustic effect by Alexander Graham Bell in 1880.

Bell found that when light was focused onto thin diaphragms, sound was emitted. In latter experiments, Bell studied the sounds produced by the irradiation of various solid samples in a brass cavity sealed with a glass window.

PAS is a non-destructive technique that is applicable to almost all types of samples. It offers minimal or no sample preparation.

PAS can be used for both qualitative and quantitative analysis. In particular, depth profiling experiments are also useful for the characterization of surface-coated and laminar materials and for studies of the diffusion of species into or out of a material.

The phenomenon known as the photoacoustic effect is the emission of sound by an enclosed sample on the absorption of chopped light.

Zero technique measurement, non-destructive invasive analysis and easy-to-use quality are the main performances of the techniques leading today to a large application of photoacoustic detections.

When a gas is irritated with light, it absorbs some of the incident light energy, proportional to the concentration of the gas. The absorbed light energy is immediately released as heat and this causes the pressure to rise. When the incident light is modulated at a given frequency, the pressure-increase is periodic at the modulation frequency. Pressure waves, or sound waves, as they commonly known, are easily measured with a microphone. They are audible if their frequency is between 20 Hz and 20.000 Hz (*see: Fig. 5*).

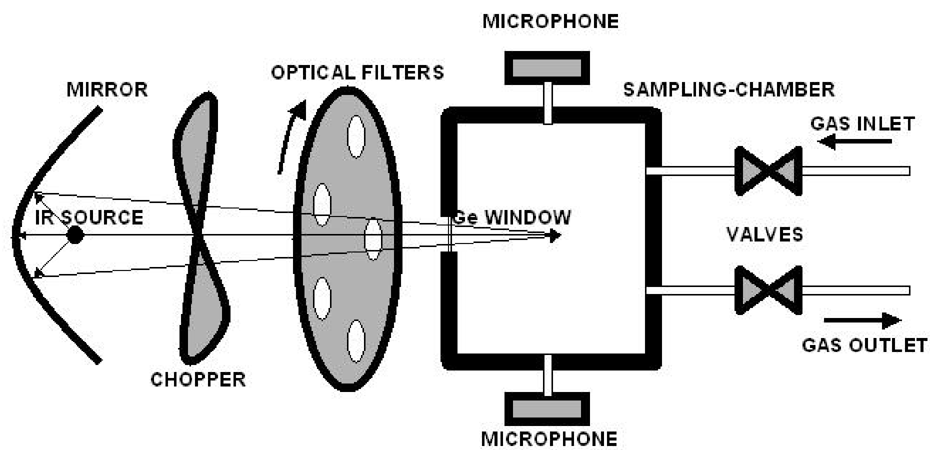

Figure 5

The set-up of the Photoacoustic Spectrometer

The intensity of the sound emitted depends on a number of factors: the nature and concentration of the substance and the intensity of the incident light.

The selectivity which can be achieved in spectroscopy is due to the fact that substances absorb light of specific wavelengths which are characteristic of that substance.

The ability to detect and monitor chemical agents in the event of an attack or after an industrial chemical accident is vital for the efficient use of military and civil defence resources. Systems offering such detection capabilities need to be reliable, accurate and easy-to-use. All principles mentioned are able to fulfil the hardest conditions of the chemical detection.

5 Infrared or Laser Remote Sensing Detection-Systems

(M21 Remote Sensing Chemical Agent Alarm)

The need for detecting a chemical agent cloud from a clean area has been evident for a long time. Advance information of a chemical agent vapour hazard will allow the commander to chose an alternate route or take protective posture just before entering the contaminated area.

The research for remotely detecting chemical agent vapours was first initiated in the late 1950's using infrared technology.

The M21 Automatic Chemical Agent Alarm provides the Army with the first ever capability of detecting chemical agent vapour clouds at a distance.

The M21 Alarm detects nerve and blister agent vapour clouds at line-of-sight distances out to 5 km (*see: Fig. 6*):

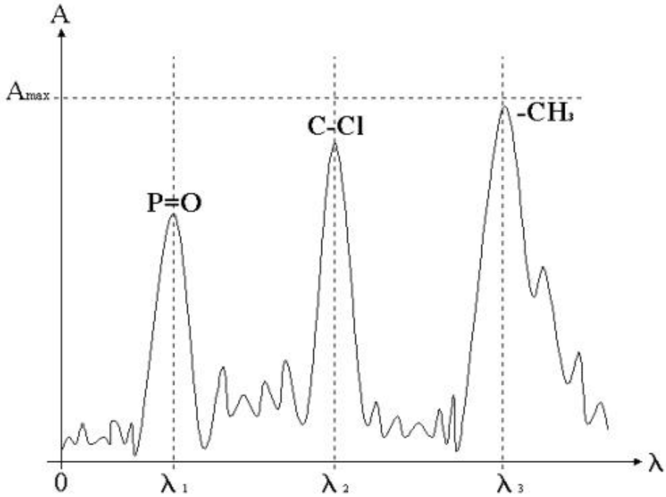

Figure 6
Characteristics of a Remote Sensing Detector

The M21 Alarm operates in the 8-12 micron region of the infrared spectrum. A Michaelson interferometer, the heart of the M21 Alarm, collects absorption or emission spectra from the chemical agent cloud and compares it to the background spectra, so it is a passive infrared device.

The next generation remote detector will provide detection on-the-move and scanning in 360 degrees.

[Lightweight Standoff Chemical Agent Detector (LSCAD)]

The LSCAD is a small, fully-automatic, standoff chemical agent detector.

It is a passive infrared detection system that detects the presence or absence of chemical warfare agents in the 800 to 1200 wave number region of the electromagnetic spectrum by monitoring the ambient background infrared radiation. The signal processing hardware discriminates between the chemical targets and the other non-toxic species in a complex battlefield environment.

The unit is capable of on-the-move, real-time detection from either aerial or surface platforms.

The unit will detect and alarm to a chemical agent cloud up to 5 kms away.

The detector also provides chemical identification information and data for activation of countermeasures to avoid contamination.

The LSCAD is equipped for visual and audible alarm and can display the agent class and relative position. This information is available locally and transmission to battlefield information networks.

LSCAD also has the capability to indicate an all-clear condition.

Conclusions

On the basis of the principles of operation and the most important characteristics of the developed instruments used for the detection of toxic agents we can state:

- the ion mobility spectrometers (and ion mobility spectroscopy) are the best in the field of the chemical reconnaissance,
- the flame photometers are indispensable during the control of decontamination,
- the photoacoustic spectrometers are outstanding in monitoring systems and finally,
- we can use remote sensing detectors if the concentration of toxic agents are relatively high.

References

[1] R. Pellérdi: The Necessities and Possibilities of the Development of the Hungarian NBC Monitoring System, Symposium, on the Most Developed Detection-Possibilities of Toxic Agents, Budapest, Hungary, 1999

[2] T. Kovacs: The Possibilities of Detection of Chemical Agents by the Most Developed Instruments, Symposium, on the Most Developed Detection-Possibilities of Toxic Agents, Budapest, Hungary, 1999

[3] F. Enguehard and L. Bertrand: Effects of optical penetration and laser pulse duration on laser generated longitudinal acoustic waves, J. Appl. Phys., Vol. 82, No. 4, August 1997

[4] Hénault, A. Cournoyer, F. Enguehard, L. Bertrand: A study of dynamic thermal expansion using a laser-generated 1-d-model, Progress in natural science, Supp. to Vol. 6, December 1996

[5] H. Marchand, A. Cournoyer, F. Enguehard, L. Bertrand: Phase optimization for quantitative analysis using phase Fourier transform photoacoustic spectroscopy, Opt. Eng., Vol. 36, No. 2, February 1999

[6] T. Kovacs, L. Bertrand: The Different Possibilities of Detection by Photoacoustic Techniques, Hungarian Military Science, No. 4, 2003, pp. 103-109