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Catastrophe medicine

Population and environmental risk posed by hazardous chemical substances (HCS) in Warsaw City Centre

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Summary:

No country, region, or township may be considered completely protected against catastrophes. Proper preparation, ability of risk assessment, as well as swift and thorough information on the occurrence of a natural or industrial disaster all add to the reduction of risks and minimization of consequences.
Not only state services governed by ministries, such as State Fire Service, Medical and Technical Services, and the Army, should be prepared to cope with the hazards, but also state and local administration, as well as business management. It is their duty to establish strategies of risk minimization, satisfy basic needs of the population and efficiently manage the squads and the equipment dedicated to life saving, prevention and damage reparation.
It is also important to prepare the population for possible disasters by systematic training and education in the most significant issues.

Key words: chemical hazard, toxic industrial chemicals, chemical terrorism.

Introduction

Providing protection against potential threats for the state, the citizens and the environment is one of the key duties of state administration. This obligation has been included in Article 5 of the Constitution of the Republic of Poland, enacted on 2nd April 1997.

Until recently, the term "contamination with chemical, radioactive or biological agents" was commonly associated only with warfare and weapons of mass destruction. To date, terms related to contamination during the time of peace, in conjunction with mass education of the population in potential consequences, means of protection and damage repair, have been uncommon.

At present, after the 11th September 2001 terrorist attacks on the World Trade Center, a different view needs to taken on our everyday hazards, such as acts of terrorism, emerging despite the time of peace. Although it is possible to define many types of potential threats with high probability, terrorist attacks are not that predictable.

Industrial development from its very beginning was connected with increased risk posed by toxic agents and substances, as well as transported, processed and stored waste.

Industrial contamination, constituting a serious danger to human life and health may occur at any time due to:

- malfunctions,
- railway, road, air and sea catastrophes,
- explosions of containers, tanks, etc., which may be the effect of external factors, such as natural disasters.

However, the most common cause of catastrophes are human errors, comprising: carelessness, haste, insufficient knowledge or inability to predict consequences, nonconformance with production technologies or transport regulations, erroneous design of construction elements and technological processes, low work discipline, insufficient supervision and lack of proper equipment for control and measurements.

Every malfunction is a result of a combination of different causes and adverse situations, and its outcome depends on the type, range, character and circumstances of the above factors.

Toxic industrial chemicals (TICs) comprise all chemical compounds (both organic and inorganic), flammable and explosive materials, biologically active substances, radioactive substances, waste and other compounds, which may produce substances directly or indirectly poisoning human environment through heat-induced or environment-induced decomposition.

In every case, propagation of TICs leads to the contamination of earth, air and water, posing threat for living organisms and inducing rapid changes within natural environmental processes. The most dangerous catastrophes, being the most common, are those related to the release of high amounts of chemical compounds, whose quantity and range of occurrence expand with industrial development.

From 450 selected chemical substances, approx. 170 have been deemed to cause toxic industrial contaminations. The most hazardous chemical substances are: nitric, sulfuric, and hydrocyanic acids, cyanogen chloride and phosgene, due to the corrosive and poisonous effect not only of their liquid forms, but also their vapours.

Long-range hazards, due to characteristic properties and effects, are posed by: ammonia, chlorine, concentrated hydrochloric acid, hydrogen cyanide, carbon disulfide, hydrogen fluoride, hydrogen sulfide, ethylene oxide, and many more, whose toxicity is described further in this paper.

Clouds of vapour or gas forming above a damaged chemical tank or container move with the wind, constituting danger even to areas located very far from the damage site.

The range of spreading of toxic substances and their air concentration largely depend on their: quantity and level of toxicity, wind velocity, vertical atmospheric stability, ambient temperature and land relief.

Many industrial facilities accumulate high quantities of liquid, solid and gaseous toxic products, as well as flammable and explosive materials.

Damage to a technological line or tanks, in which the materials are stored or transported, poses an immediate threat to both the staff and local residents. HCSs are usually transported by rail, road or inland waters.

As stated by the National Headquarters of the State Fire Service, ⅓ of the Polish territory lies within the contamination zones of 80 largest chemical plants.

The results of rail transport analysis indicate that almost all railway routes are considered as particularly dangerous. This also regards public roads, even though road transport seems less exposed to hazard due to, for example, lower capacity of road tankers.

Carelessness of the transport service providers, lack of essential information on the toxicity of transported materials, necessary security measures and procedures to be applied in case of collision, but also lack of means of protection and appropriate equipment, improper load placement, often bad technical condition of the vehicles and the cisterns, as well as higher incidence of road accidents all add up to the fact that areas located near transport routes are high risk zones. In practice, the level of knowledge regarding the risks is low, especially in the areas where the risks seem minimal.

No country, region, or township may be considered completely protected against catastrophes. Proper preparation, ability of risk assessment, as well as swift and thorough information on the occurrence of a natural or industrial disaster all facilitate the reduction of risks and minimization of consequences.

Not only state services governed by ministries, such as State Fire Service, Medical and Technical Services, and the Army, should be prepared to cope with the hazards, but also state and local administration, as well as business management. It is their duty to establish strategies of risk minimization, satisfy basic needs of the population and efficiently manage the squads and the equipment dedicated to life saving, prevention and damage reparation. It is also important to prepare the population for possible disasters by systematic training and education in the most significant issues.

Malfunctions in production plants

Depending on the character of malfunction, HCSs may be liberated to the atmosphere in a single event (e.g. an explosion) or over a certain period of time.

The quantity of toxic compounds which may be liberated in a defined time period depends, among other factors, on the construction properties of the installation, tank capacity, type of chemical compound, scale and character of the sustained damage, physical properties of the compound, as well as the type and elapsed time of actions undertaken to localize the source of the malfunction.

In every case, the amount of liberated substance may vary and span from several kilograms to hundreds of tons (Table 1).

The size of toxic leakage from damaged installations is significantly dependent on the meteorological conditions present in the disaster area.

Table 1: Names of production plants and their location in Warsaw city centre.

No.	Name and address of production plant	TIC type and amount [t]
1	Warsaw Sport and Recreation Centre. Speed Skating Rink ***“STEGNY”*** ul. Inspektorowa 1	Ammonia 9.5
2	***“KRÓLEWSKIE”*** SA Brewery ul. Grzybowska 58	Ammonia 8.5
3	***“DANONE”*** Sp. z o.o. ul. Redutowa 9/23	Ammonia 6.0
4	PZL – WOLA SA Mechanical Engineering Facility ul. Fort Wola 22	Ammonia 5.5
5	Water Supply Local Station ul. Borecka 1	Chlorine 7.0
6	Municipal Water Supply and Sewage Company. Central Pipe Waterworks. Ul. Koszykowa 81	Chlorine 6.0
7	Municipal Water Supply and Sewage Company. Praga Pipe Waterworks. ul. Brukselska 21	Chlorine 4.0
8	Elektrociepłownie Warszawskie SA. ***“SIEKIERKI”*** Power Station ul. Augustówka 1	Hydrochloric acid 350.0
9	***“KRÓLEWSKIE”*** SA Brewery ul. Grzybowska 58	Hydrochloric acid 10.0
10	Warsaw Radio Centre ***“RAWAR”*** ul. Poligonowa 30	Hydrochloric acid 9.3

Nevertheless, the scale of threat posed by every malfunction is assessed not only by the amount of the liberated substance, but also by its toxicity.

Historically, in large-scale industrial catastrophes accompanied by leakage of toxic substances the greatest danger was posed by the quantity of the liberated poisonous compounds.

A TIC contamination zone encompasses the site of malfunction (leakage) and the area in which contaminated air disperses the toxin at concentrations inducing different grades of toxic effect: lethal, moderate, mild and threshold.

Contamination zones may form circles, ellipses or irregular shapes. Surface area of these zones in adverse conditions may cover from several to more than a dozen hectares, or even several square kilometres in particular meteorological conditions.
The area damaged by the malfunction is characterized by the highest TIC toxicity. Area size (radius) depends on the type of TIC, its storage conditions and the severity of sustained

damage (malfunction). The size does not exceed 1 km for most chemical agents.

Fire expands the damaged area by 1.5 to 2 times, which may be caused by a larger TIC leak size in such case, as well as TIC dispersal as a result of explosions.

Spreading zone of contaminated air (both primary and secondary) is formed as a result of toxic substance evaporation from the malfunction site. The zone is circle slice-shaped with the centre of the circle located in the malfunction site (Figure 1).

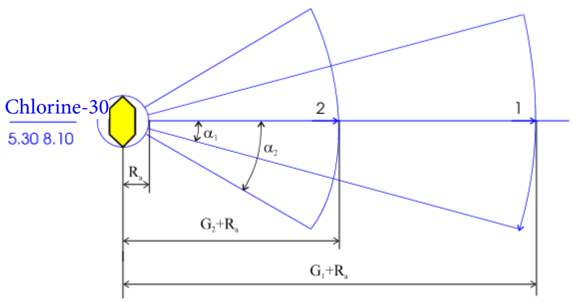

Figure 1: Schematic of predicted contamination zones after a production plant malfunction involving TICs

G1,G2 – spreading range of the primary and secondary clouds;
Ra – damaged area radius (due to malfunction)
α1,α2 – angle between the contamination zone lateral borders

Reference: Metodyka oceny sytuacji chemicznej po skażeniach toksycznymi środkami przemysłowymi, Warsaw 1993, p. 19.

The depth and angle between the contamination zone lateral borders depend on many factors, including the type and amount of the liberated TIC, topography, season of the year and meteorological conditions in lower strata of the atmosphere: wind velocity and direction, kategorii atmosfery, precipitations. A considerable amount of these factors has an effect on the range of spreading of contaminated air in different conditions.

In the case of chlorine, a substance consumed in large quantities by the chemical industry, the radius of the contamination zone may reach even several dozen kilometres.

In the rail network managed by Polish State Railways, approx. 24,000 Polish and 6,000 foreign cisterns are used every year providing approx. 350,000 transport services of hazardous materials. Annual turnover of hazardous materials is approx. 14 million tons, 700,000 of which are particularly hazardous substances.

Road transport

Approx. 6,000 road tankers designed to carry hazardous liquid materials are registered in Poland. It is estimated that every year approx. 1 million tons of such materials are transported. Several hundred road accidents take place every year and vehicles transporting hazardous materials participate in these events. The greatest potential threat is posed by toxic gaseous substances transported in urban areas, as well as by accidents involving contamination of rivers near water intake sites.

Definition and characteristics of chemical terrorism

There are over 100 contemporary definitions of terrorism. Most of them define terrorism as planned and organized activities of an individual of a group of individuals, which violate the existing legal order and are undertaken to force governments and social leaders to perform certain acts or provide certain means.

In the case of chemical terrorism, such activities are ruthlessly conducted by using highly toxic chemical substances, as well as biological and radioactive agents or nuclear weapons. Many terrorist groups are naturally difficult to identify, which reduces the chance of providing a terrorist attack alert early enough or preve-nting the attack.

The interest of terrorists in using chemical or biological weapons increased significantly after the successful attack in the Tokyo subway. Since then, the governments of the most seriously threatened states, especially the United States and Canada, have been conducting large-scales programmes of tracking potential terrorists and preventing the attacks.

National Defence Strategy of the Republic of Poland

Chemical terrorism is prevented on the basis of state acts of criminal law and special antiterrorism laws. On 23rd May 2000 the Council of Ministers of the Republic of Poland enacted the "National

Defence Strategy of the Republic of Poland" [3], Section 9 of which reads:

"We have also seen increasing threats related to the spread of weapons of mass destruction and its delivery means. The number group of countries, including rogue states, which is close to gaining possession of WMD is increasing. Also, a variety of extremist political, religious and terrorist organizations have been making attempts to gain access to this kind of weapon. If successful, this kind of weapon might be used for terrorist purposes both in and around Poland. We should also be aware of the attempts to transport these weapons through the territory of Poland with all related risks."

With the aim of preventing terrorism the Republic of Poland has ratified international conventions brought forth by such organizations as:

- International Civil Aviation Organization (ICAO),
- United Nations (Chemical Weapons Convention, CWC) [4].

The declarations have been supported by regularly increased funds for antiterrorism activities.

Chemical terrorism threat in the Republic of Poland

As a result of the successful terrorist attack employing a chemical warfare agent, ***sarin***, in the Tokyo subway (20 March 1995), as well as at least 12 other acts performed recently, governments and the public keep carefully analysing potential threats stemming from the possibility that terrorist groups may come into possession of chemical, biological and nuclear warfare agents, considered as weapons of mass destruction (WMD).

In the professional literature, this type of terrorism is frequently termed WMD terrorism (**1, 2**). Terrorism experts are trying to assess whether an individual or a group of individuals may really produce or come into possession of such weapons.

Perhaps it is more important to know how easy it would be to disperse appropriate chemical agents in the environment and what its final outcome would be. In order to illustrate thus defined terrorism, a schematic representation of an act of chemical terrorism is presented in Figure 2.

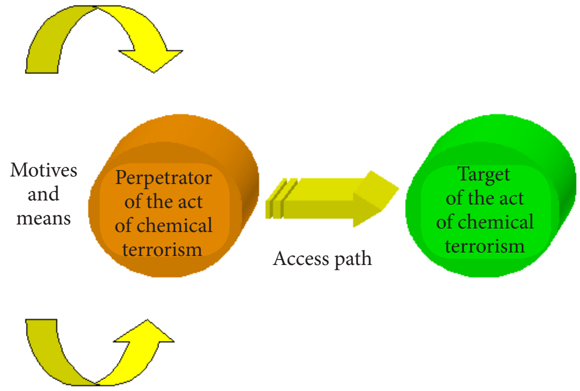

Figure 2: Schematic: perpetrator of an act of chemical terrorism – access path – chemical attack target (victims).

Perpetrators and motives of chemical terrorism

Until early 1980s, terrorists very rarely used chemical or biological agents as weapons. In the 1980s, extreme left-wing activists in Europe threatened to use those agents against civilian or military targets, but no such acts occurred in practice. Until recently, the aims of terrorist attacks were successfully reached through the use of conventional weapons, such as explosives and automatic firearms. (5)

Analyses of the changing situation indicate that, despite poor knowledge of such weapons of mass destruction as highly toxic chemical substances or biological agents, the probability of their application in terrorist attacks is currently significant and rising. (6)

Growing disproportion between the economic situation in rich and technologically advanced countries and poor, underdeveloped countries leads extremist terrorist groups to become more radical and increases their interest in causing multiple deaths and large-scale destruction.

Some examples of this phenomenon are:

- the New York World Trade Centre bombing;
- the Oklahoma City Federal Building bombing;
- the US Embassy bombings in East Africa;
- proliferation of weapons of mass destruction, including both active materials for WMD production and production technologies, along with the know-how acquired in WMD development programmes currently or formerly conducted by some states;
- radicalization of ethnic and religious conflicts in various parts of the world.

Particularly high threat is posed by the activities of apocalyptic religious cults, right-wing extremists or *ad-hoc* islamist groups, whose aim is not gaining political influence or reputation among the population, but rather causing as much destruction and as many victims as possible in the states which are considered particularly hostile by those groups.

Many of those terrorist organizations are naturally difficult to identify, which reduces the chance of providing a terrorist attack alert early enough or preventing the attack. The interest of terrorists in using chemical or biological weapons increased significantly after the successful attack in the Tokyo subway.

Intelligence agencies are aware of the interest of those groups in chemical or biological agents. Among the suspects may be found such organizations as:

- Islamic Jihad Organization and Hamas,
- Armed Islamic Group (GIA) in Algeria,
- Egyptian islamists, Sikh and Chechen terrorists,
- Kurdistan Workers' Party (PKK),
- Khmer Rouge,
- Liberation Tigers of Tamil Eelam (LTTE) and other.

What has to be mentioned is that intelligence agency reports are not always unambiguous and not all of them are verified, although a clearly increasing trend may be seen in the interest in chemical or biological terrorism.

Some of the above mentioned organizations do not exclude potential use of WMD in their acts of terrorism.

Highly toxic chemical substances

Highly toxic chemical substances, from the point of view of terrorists, have certain advantages over conventional means. It is assumed that those substances are relatively cheap and easy to use. Some of them may act immediately, other act after a latency period. This aspect depends of the type of toxic agent and its concentration.

Chemical agents with the potential of being used in terrorist attacks are both those from the military arsenal of chemical weapons and the toxic substances commonly used in industry.

Table 2: Characteristics of chemical substances potentially usable in chemical terrorism [7].

Compound name	LD_{50} [mg/kg]	NDS [mg/m^3]
acrylonitrile	78	2
ammonia	350	20
arsenic and its inorganic compounds	763	0.01
arsine	no data	0.2
arsenic trioxide	14.6	0.01
benzene	930	10
benzo[a]pyrene	no data	0.002
chlorine	n/a	1.5
zinc chloride	350	1
hydrogen chloride	n/a	5
hydrogen cyanide	no data	0.3
carbon disulfide	3188	18
phenol	384	10
formaldehyde	800	0.5
phosgene	no data	0.5
nitric acid	no data	5
picric acid	200	0.1
sulfuric acid	2140	1
methanol	5628	100
nitroglycerin	105	0.5
lead and its inorganic compounds	no data	0.05
vanadium pentoxide	10	0.05
pyridine	891	5
mercury and its inorganic compounds	1	0.05
hydrogen sulfide	n/a	10
zinc oxide	no data	5
antimony trichloride	525	0.5

Table 3: Routes of transport of HCSs to selected production plants in Warsaw city centre.

No.	Name and address of production plant receiving HCS	HCS Name ADR Code	Route of transport
1	"KRÓLEWSKIE" SA Brewery ul. Grzybowska 58	1005 AMMONIA anhydrous	Włocławek – Sochaczew – Pruszków Al. Jerozolimskie, ul.Towarowa, ul.Grzybowska
		1789 HYDROCHLORIC ACID	ul.Rzeczna, ul.Radzymińska ul.Targowa, ul.Grochowska ul.Poligonowa
2	"DANONE" Sp. z o.o. ul. Redutowa 9/23	1005 AMMONIA anhydrous	Włocławek – Sochaczew – Warszawa ul. Połczyńska
3	Elektrociepłownie Warszawskie SA. "SIEKIERKI" Power Station ul. Augustówka 1	1789 HYDROCHLORIC ACID	PKP Warszawa Okęcie – Konstancin
4	* Municipal Water Supply and Sewage Company. Praga Pipe Waterworks. ul. Brukselska 21	1017 CHLORINE	Legionowo – ul. Jagiellońska Wał Międzeszyński –ul.Brukselska
5	* Municipal Water Supply and Sewage Company. Northern Pipe Waterworks ul. Borecka 1	1017 CHLORINE	Wodociąg Północny (Wieliszew) Legionowo – ul. Modlińska ul. Płochocińska, ul. Borecka
6	*Municipal Water Supply and Sewage Company. Central Pipe Waterworks ul. Koszykowa 81	1017 CHLORINE	Wodociąg Północny (Wieliszew) Legionowo – Jabłonna – Most Grota Wybrzeże Gdyńskie, Wybrzeże Gdańskie, Trasa Łazienkowska, ul. Krzywickiego, ul. Koszykowa
7	Warsaw Sport and Recreation Centre. Speed Skating Rink "STEGNY".ul. Inspektowa 1	1005 AMMONIA anhydrous	Włocławek – Sochaczew – Warszawa ul. Pułkowa, Wybrzeże Gdyńskie, Wybrzeże Gdańskie, ul. Czerniakowska, ul. Inspektowa
8	PZL – WOLA SA Mechanical Engineering Facility ul. Fort Wola 22	1005 AMMONIA anhydrous	Włocławek – Sochaczew – Warszawa ul. Połczyńska, ul. Fort Wola
		1789 HYDROCHLORIC ACID	Łódź – Sochaczew – Warszawa ul. Połczyńska, ul. Fort Wola

The following parameters may characterize the agents potentially used in terrorist attacks:

- toxicity, defined using the LD_{50}, or LD_{100} parameters;
- availability;
- mechanism of toxicity;
- physicochemical properties (volatility, solubility, stability);
- special properties suitable for the type of terrorist attack.

Municipal Water Supply and Sewage Company: transport of chlorine to local subsidiaries is organized with attention to the safety of HCS transport following the ADR agreement (which precisely determines the entities transporting HCSs, conditions of transport, requirements for transporting vehicles, container types and quantity of transported substance, vehicle labelling, driver training, etc.). Each chlorine transport is reported to regional authorities, City

Table 4: Risks related to toxic chemical agents.

Characteristics of chemical substance			First aid	
Name	Formula	Risks	Premedical aid	Medical aid
AMMONIA	NH_3	Flammable, toxic. Toxic in the case of respiratory exposure.	Evacuate the subject from hazardous area, place the subject in a semi-lying or sitting position, protect from cold. Administer oxygen using mask. In case of breathing difficulties, administer Atrovent inhalation. Seek medical aid.	If laryngeal contraction symptoms persist, introduce secure intravenous access, administer hydrocortisone IV. No improvement is an indication for intubation and emergency medical transport to hospital.
CHLORINE	Cl_2	Toxic and irritant. Toxic in the case of respiratory exposure. Irritant to eyes, respiratory system and skin.	Evacuate the subject from hazardous area. Secure the subject in a semi-lying or sitting position, protect from cold. Administer oxygen using mask. In case of breathing difficulties, administer Atrovent inhalation. Seek medical aid.	If laryngeal contraction symptoms persist, introduce secure intravenous access, administer hydrocortisone IV. No improvement is an indication for intubation and emergency medical transport to hospital.
HYDROGEN CHLORIDE	HCl	Corrosive and irritant. Induces serious burns, irritant to respiratory system.	Evacuate the subject from hazardous area, place the subject in a comfortable semi-lying or sitting position, allow no movement, protect from cold. In case of glottal contraction, administer Atrovent inhalation. Administer breathing oxygen. Seek medical aid immediately.	If laryngeal contraction symptoms persist, introduce secure intravenous access, administer hydrocortisone IV. No improvement is an indication for intubation and emergency medical transport to hospital.

Engineer and the police. Convoy staff comprises the "Company Chlorine Emergency Squad".

"**Company Chlorine Emergency Squad**" is a group trained for any case of chlorine liberation from its containers, working for Municipal Water Supply and Sewage Company as chemical security staff. Company Chlorine Emergency Department is equipped with respiratory aids and protective clothes allowing them to minimize the damage caused by any malfunction (chlorine leakage) during the transport. The chlorine convoy is escorted by police cars.

The other production plants use services provided by independent companies, authorized to transport HCSs and equipped with appropriate vehicles, trained drivers, proper authorization documents for HCS transport, etc.

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