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Basic Concept Towards Protection Against Chemical Terrorism

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Chemical terrorism represents a problematic area with increasing importance. This type of terrorism uses chemical substances as a tool of the violence and it is real and major threat of contemporary civilization. The consequences of chemical terrorism have a wide extent of negative impacts. Primarily, chemical terrorism can cause damage to all components of the environment. Secondly, damages with direct or indirect impact to the health and human life is highly probable. Finally, reduction of basic human freedom including restrictions or aggravation of ecosystem services and causing fear and panic the population. Significance of this issue underscored by the current trend in the expansion of residential areas closer to facilities treating chemicals. Measures to ensure preparedness against chemical terrorism are not sufficiently developed nowadays. For this purpose, the article summarizes the basic ideas for creating a systematic approach to protecting against chemical terrorism in relation to industrial facilities treating chemicals thus providing a summary of current approaches to this issue. Attention is also paid to the existing measures focused at preventing chemical terrorism. Subsequently, the article deals with discussions on possible abuse potential of substances in chemical terrorism. An important part of the article is the specification of possible scenarios of terrorist attacks using chemical substances in industrial facilities. The above information will serve as a basis for the development of a methodology to protect against chemical terrorism in industrial facilities treating chemicals. In cooperation with NATO Joint Chemical, Biological, Radiological and Nuclear Defence Centre of Excellence (Czechia), it will be possible to present the basic facts for the creation of mentioned methodology soon.

1. Introduction

Potential actions by terrorist groups span the chemical, biological, radiological, nuclear, and high explosive (CBRNE) threat spectrum. Europe endured terrorist threats from a variety of sources in period 2016, including foreign terrorist organizations operating out of Iraq and Syria, such as Islamic State in Iraq and Syria (ISIS) and al-Nusrah Front (al‑Qa'ida's affiliate in Syria), and from European foreign terrorist fighters who had returned to Europe to conduct attacks. Concurrently, violent extremist groups espousing left-wing and nationalist ideologies, such as the Turkey-based Revolutionary People's Liberation Party/Front (DHKP/C) and the Kurdistan Workers' Party (PKK), respectively, continued to operate within Europe. According to the latest news and information about the chemical attacks round the world, the common industrially produced dangerous chemicals are getting to be more attractive for the misuse by terrorists, for example in the way of so called „dirty bomb"- filled by: chlorine gas, ammonia gas, sarin gas, phosphorus, napalm, mustard gas, hydrogen cyanide, liquid acid solutions, etc. (Banks, 2015). Worldwide, the issue of industrially manufactured dangerous chemicals, potentially attractive for terrorist misuse, has been addressed in some countries, but a lot of industrial facilities remains vulnerable up to 2006 (Lippin et al., 2006) and till present. In the United States there is more than ten years in action valid federal law (rule), prepared by the US DHS, which contains Appendix to Chemical Facility Anti-Terrorism Standards. This list includes more than 300 listed substances of special concern. In Australia, there is The List of Chemicals of Security Concern, created under an Australia

Government Initiative. This list contains 96 substances listed. Both lists are used to identify objects vulnerable to terrorism. In Europe, no such list has been developed so far, although a lot of efforts and energy is given to the control of chemicals (directives CLP, REACH, Seveso III).
In the conditions of the Czech Republic, in the light of above indicated situation in EU, the governmental bodies, county offices and industrial facilities started to give more efforts into the terrorism prevention. Successful results of such activities, which were focused on the support of increasing industrial and environmental security, two methodologies were certified by the Czech Ministry of the Environment in 2015 (Dobes et al., 2015):

- Certified methodology for the identification process of chemical substances, potentially attractive for the terrorists. Certificate no. 82430/ENV/15. Czech Republic. 2015.
- Certified methodology on the control process and revision of the physical security plan of the industrial facility, handling dangerous industrial chemicals and endangered by potential terrorist attack. Certificate no. 82433/ENV/15. Czech Republic 2015.

Issue of the chemical terrorism is still up-to date and its growing importance can be persuaded. Some papers are focused on analysing the probability of CBRN terrorist actions on the one hand and increasing signs of convergence between terrorism and CBRN unconventional weapons for terrorist purposes (Krstić, 2017). On the other hand, the deterministic analysis allows upgrading the physical protection system, according to possible variations in the likelihood of the attack (Villa et al., 2017; Vallerotonda et al., 2016). It is also possible to draw information from the Global Terrorism Database as an open-source database of terroristic events worldwide form the 1970 to present (NCSTRT, 2017). The inspiration for the terrorist attacks can be seen in the rising military conflicts and terrorism often involves the using of chemical warfare agents and toxic industrial chemicals (McElroy and Day, 2016). Using chemicals for the terrorist attack is demonstrable on the case of Syria. Current war acts (by the U.S. and Great Britain and France) in Syria evidently pointed out to the using chemical weapons against civilians (Syrian Network for Human Rights, 2018). Due to newly launched Czech project (TEHROCH), authors updated previously done literature research, regarding four main considered steps of successful terrorist attack on chemical facility. Focus was given on new approaches, methodologies, R&D articles and books.

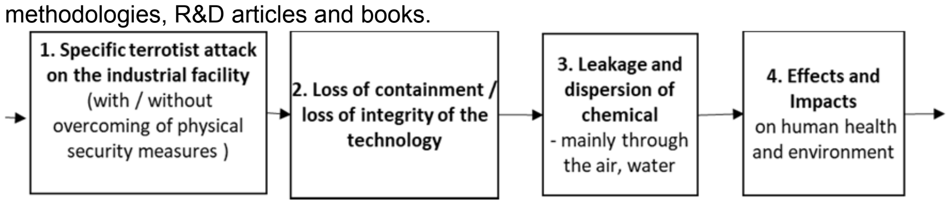

Figure 1: Four main considered steps of successful terrorist attack on chemical facility.

According to the step 1, which could be characterized by necessity to overcome physical security measures, new results has been obtained recently (for example by Argenti et al., 2017; Feng et al., 2016). Regarding to the step 2, for which analysis and evaluation could be applied wide specter of available methods from the area of risk analysis (Heinälä et al., 2013; Husin et al., 2017), should be applied also basic concepts like real application of green chemistry rules (Anastas and Hammond, 2015), inherent safety principle (Fontaine et al., 2007). Within the step 3, several models can be used to simulate leakage and dispersion of chemical in the air (SW Damage Effects, Aloha, Fluent, Flacs and many others). Particularly there is missing generally well-known models for spreading the chemical in / on the water (old SW Proteus from The Netherlands). According to the step 4, a lot of limits of toxicity of chemicals could be applied (AEGL, ERPG, PAC, LC_{50}, etc.) together with various index methodologies allowing preliminary effect evaluation on the endangered environmental compartments (ERA, Czech H&V Index, etc.). Given the variety of possible scenarios of terrorist attack (e.g. Landucci et al., 2015) and the fact that a comprehensive solution to all variants of scenarios would not lead to reasonably available results, the Czech R&D projects ZEBETER and TEHROCH has been built on two basic scenarios of possible terrorist attacks (see Dobes et al., 2015). Definition of two general scenarios has been based on holistic approach effort (general definition), consideration both quantity and hazard of the substance, consideration both stationary and mobile sources of the risks and area impact:

- Scenario 1: The direct attack or sabotage on industrial establishments, where large amounts of dangerous substances is present, and its releasing into environment.
- Scenario 2: The attack in which it could be abused smaller quantity of chemical with very high hazard (toxicity) for the human health or/and environment that terrorists could acquire either legally or illegally. They then carry out an attack on places with vulnerable components of the environment (water, soil, valuable ecosystems), which can be very far from the place of origin of the substance.

During the literature search, authors of the topic does not find the answer on the question (hypothesis no.1):

„Could currently produce common industrial chemicals (toxic, corrosive) had greater potential for abuse of chemical terrorism than substances listed in the CWC Convention as chemical weapons? “
So, on the very beginning of new project TEHROCH, working team proposed possible criteria for such evaluation and following comparison of this potential to terrorist misuse between both studied groups of chemicals.

2. Assessment of the potential of chemical substances to abuse by terrorist

The chapter presents criteria for assessment of potential effect of the CBRN substances (especially chemical weapons) and chemical substances classified by the Seveso III Directive. These criteria consider abusing of these substances and its sabotage and its deliberate releasing into the environment due to intentionally caused chemical accident and its are divided into three main parts (described subsequently).

2.1 Hazard primary assessment

The first part of suggested criteria (described subsequently) is focused on hazard primary assessment.

Criterion A1: Is the substance acutely hazardous for the human health?
The main objective of this criterion ($A1_i$) is to find out whether the substance under consideration is classified as acute toxic for the specific target organ based on a one-off exposure. It means if this substance is included in the category H1 or H2 or H3 based on the Seveso III Directive or whether substance is designated by following hazard statement, for example H300, H310, H330, H370, based on the CLP directive. On the other hand, this substance can be also classified as a “skin corrosion / irritation” category 1A or 2B or 1C with hazard statement H314 or is classified as a substance causing “severe eye damage / eye irritation” category 1 with H318. This criterion is prepared to fill with value (1) when agreeing to one mentioned condition (otherwise 0).

Criterion A2: Is the substance acutely hazardous for the aquatic environment?
Objective of this criterion ($A2_i$) is to find out whether the substance under consideration is classified as hazardous for the aquatic environment. This contains hazardous to the aquatic environment on the aquatic acute category 1 and also aquatic chronic category 1 and 2. It means if this substance is included in the category E1 or E2 on the basis of the Seveso III Directive or whether substance is designated by following hazard statement, for example H400, H410, H411. This criterion is prepared to fill with (1) when agreeing to one mentioned condition (otherwise 0).

Criterion A3: What is needed exploitable quantity of the substance?
The aim of this criterion ($A3_i$) is to find out quantity of the substance to be released (or to be detonated or to be alienated) to intentionally caused chemical accident in the current condition in the Czech Republic. Suggested assessment process for this criterion contains two choice of value option: Substances under the Seveso III Directive or substances contained in the List 2 or List 3 of the CWC Convention (OPCW, 2015). List 1 of the CWC Convention contains substances with an abusive quantity close to zero whose production and stockpiling and using is strictly controlled and strictly limited. This is a reason for the exclusion of substances contained on List 1 from the proposed assessment process. The quantity of substance is considered in accordance with quantity available at certain industrial equipment (facility) or technology. The assessment is divided as follows:

- Substance is contained in the Seveso III Directive:
  Based on the part 1 of the Annex 1 of the Seveso III Directive can be choose as limits for indexes the Column 2 and Column 3 in the case of a substance with a known hazardous category and which was not be indexed based on the part 2 of the Annex 1. Subsequently, indexes are following: 0 – none, 1 – quantity below than value in the Column 2, 2 – quantity between values in the Column 2 and the Column 3, 3 – quantity above than value in the column 3 (all in the Annex 1, part 1). Based on the part 2 of the Annex 1 of the Seveso III Directive can be choose as limits for indexes the Column 2 and Column 3 in the case of a substance directly listed in this list. Subsequently, indexes are very similar and part 2 shall be simultaneously used as the using of part 1.
- Substance is contained in the List 2 of the CWC Convention:
  Based on the CWC Convention can be choose as limits for indexes the quantity allowed to produce/process/consume of certain substance contained in the List 2 of part VII, No. 3. These limits are used as first thresholds for indexes of the criterion A3. The second thresholds for indexes of the criterion A3 are formed by limits in convention, part VII, No. 12. Subsequently, indexes for the criterion A3 are following: 0 – none, 1 – quantity below than first thresholds (part VII, No. 3), 2 – quantity between values of the first thresholds and the second thresholds, 3 – quantity above than second thresholds (part VII, No. 12).

- Substance is contained in the List 3 of the CWC Convention:
  Based on the CWC Convention the quantity allowed to produce/process/consume of certain substance is not strictly limited. It is even possible to perceive specific correspondence between substances contained in the List 3 of the CWC Convention and substances contained in the Seveso III Directive. It is also possible to perceive the similarity with Hazard statement (Seveso III Directive). Indexes for criterion A3 for substances contained in List 3 can be choose the same way as for substances in the Seveso III Directive or contained in List 2 of the convention and it is very important to use lower and stricter limits.

Crucial information for correctly determined limits (A3) is knowledge about chemical substances and attainments about content of the List 2 and List 3 of the CWC Convention and substances under the Seveso III Directive.

2.2 Hazard secondary assessment

The second part of suggested criteria (described subsequently) is focused on hazard secondary assessment.

Criterion B1: What is the boiling point of the substance at normal pressure?

The main objective of this criterion ($B1_i$) is to find out the boiling point of the substance at normal pressure. This criterion cannot be taken over from the Seveso III Directive due to missing explicit numerical value for temperature in degrees Celsius. The saturation vapor pressure of the substance is approximately about 1 bar when the boiling point is reached. The increased pressure inside the container may also lead to accidental rupture of the vessel`s cover at atmospheric storage. Subsequently, the decision about exceedance (or not exceeding) of the maximal atmospheric temperature is made. The maximal atmospheric temperature is considered as a maximal measured temperature in the Czech Republic which was 40,4 °C on 20th August 2012 (CHMI, 2018). For this purpose, the maximal measured temperature was increased due to impossibility to excluding of occurrence of the container (vessel) filled with chemical substance on the sun during summer. The increasing includes the tolerance +10 °C for final limit value for the criterion B1 on the level +50 °C. This criterion is prepared to fill with (1) when the temperature +50 °C is reached or exceed at normal pressure (otherwise 0).

Criterion B2: Can be reached or exceed substance`s boiling point under the process conditions?

The aim of this criterion ($B2_i$) is to find out the boiling point of the substance under the process conditions. It is necessary to consider substance abusing during the process and conditions of the terrorist attack. The issue of the process conditions seems to be decisive for example in the Flixborough accident in 1974 (Hoiset et al., 2000). The increasing of pressure due to the phase conversion of the cyclohexane from the liquid phase to the gaseous, probably boiling at about 100 °C and thus to the increased pressure in the technology, caused pipe burst and explosion and large fire throughout the company. This criterion is prepared to fill with (1) when the temperature +50 °C is reached or exceed under the process conditions (otherwise 0).

Criterion B3: What is the solubility or miscibility of chemical substances in the aquatic environment?

The main objective of this criterion ($B3_i$) is to find out information about the level and quality of the solubility or miscibility of chemical substances in the aquatic environment. Authors recommend that this criterion would be determined by the consensus of chemist due to consider the interconnection of other chemical properties of substances. It is possible to use information contained in the database ECHA or TOXNET. General semi-quantitative evaluation for the solubility and miscibility of chemical substances in the aquatic environment is following: 1 – slightly soluble or insoluble, 2 – moderately soluble, 3 – highly or completely soluble.

2.3 Potential impacts assessment

The third part of suggested criteria (described subsequently) is focused on hazard primary assessment.

Criterion C1: Rate of onset of the action of the evaluated substance

The aim of this criterion ($C1_i$) is to find out information about the rate of onset of the action of the evaluated substance. The rate of onset of effects depends on concentration of the substance. Acute toxic effects are rated by a higher index than chronic effects for this criterion. Authors recommends that this criterion would be determined by the consensus of chemist due to consider the possible harmful effects of evaluated substances. It is possible to use information contained in the database TOXNET or other databases and relevant information sources. General evaluation for this criterion is following: 1 – slow rate of action (long term, over 24 hours), 2 – medium rate of action (up to 24 hours), 3 – fast or instantaneous rate of operation (within 60 minutes).

Criterion C2: Effects of impingement of the substance

Objective of this criterion ($C2_i$) is to find out effects of the substance to the affected human individuals and to the population. It considers the assessment of the severity and impact effects on the human organism and whether the substance at the available concentration can cause death or serious damage to health or whether its effect will quickly disappear without long-term consequences. General evaluation was suggested as following: 0 – personal discomfort, 1 – temporary disability without long-term consequences, 2 – disability / health damage requiring longer convalescence, 3 – serious damage to health (irreversible effects) or death.

Criterion C3: Target or intention of the terrorist attack

The aim of this criterion ($C3_i$) is to evaluate the target or intention of the terrorist attack with using chemical substances. There are contradictions among scientist about worse scenario: whether the acute death of individuals or the long-term damage of the environment with a population impact. Use of the dioxin-contaminated phenoxy-acetic acids during the Vietnam War is still problem addressed today (Eriksson et al., 1990). It is possible to use information contained in the database TOXNET or other databases and relevant information sources. General evaluation was suggested as following: 1 – impact or threat a large proportion of the population or long-term damage of the environment and its components; in order to incite the panic and fear and distrust in the government and concurrently prevent or hinder the rapid recovery of ecosystem services – soil, water, biota, etc., 2 – acute death of individuals or the greatest number of injured persons in order to capture the territory and subsequently to use.

2.4 Total potential of the evaluated substances to abuse by terrorist

This part is focused on the assessment of the total potential of the evaluated substances to abuse by terrorist with acceptation of the following relationship (1).

$$T_{P_i} = \sum XY_i \qquad (1)$$

Where T_{P_i} is the total potential with corrected calculation of the i-th evaluated substance to abuse by terrorist and XY_i represents criteria where: X represents criterion from the interval (A, B, C) and Y represents number of the criterion from the interval (1, 2, 3) and i represents i-th evaluated substance.

Following criteria have not got a maximum limit value on the level 3: A1, A2, B1, B2, C3. To avoid inequality between criteria weights, the following two steps were taken: As the first, the final value of the criterion was multiplied by three when the value of the criterion could have binary values (0 or 1). As the second, this applies to criterion the A1, A2, B1, B2. The final value of the criterion was multiplied by one and half when the value of the criterion has the resulting values of 1 or 2 (criterion C3). After this adjustment the final values of all criteria may reach the same maximum values at level 3. It is possible to find original values in all criteria in the following table. It is also possible to see the corrected calculation for easier presentation. Following table presents the comparison of substance contained in the CWC Convention and the ECHA database and substances covered by the Seveso III Directive. Last column presents corrected calculation based on the above-mentioned rules.

Table 1: Comparison of the evaluated substances with the potential for terrorist abuse.

Substance	CAS No.	CWC	ECHA	Seveso	A1	A2	A3	B1	B2	B3	C1	C2	C3	Corrected calculation T_{P_i}
Hydrogen cyanide	74-90-8	List 3	X	X	1	1	2	1	1	2	3	3	2	25
Chlorine	7782-50-5		X	X	0	1	3	1	1	3	3	3	2	24
Ammonia anhydrous	7664-41-7		X	X	0	1	2	1	1	3	3	3	2	23
Phosgene	75-44-5	List 3	X	X	1	0	2	1	1	2	3	3	2	22
Methyl isocyanate	624-83-9		X	X	1	0	1	1	1	3	3	3	2	22
Arsenic trichloride	7784-34-1	List 2	X	-	1	1	2	0	0	3	3	3	2	20
BZ: 3-Quinuclidinyl benzilate	6581-06-2	List 2	-	-	0	0	1	0	0	0	2	2	1	6.5

3. Conclusions

The topic deals with recent progress on selected deliverables, which were planned in the frame of the safety & security research project, called as TEHROCH (Terrorist threat of intentional chemical accidents and vulnerability of society), granted approximately one and half year ago by the Czech Ministry of the Interior to VSB – Technical University of Ostrava. Based on the upper mentioned criteria and their preliminary testing, it could be concluded that formulated hypothesis no. 1 can be true. Specific common industrial chemicals (toxic, corrosive) could really have bigger potential for misuse during terrorist attacks than substances named in the CWC Convention. Some specific substances like phosgene and hydrogen cyanide, which poses the overlap between common industrial chemicals and lists of chemicals in the CWC Convention has high potential for abuse too. Project team, including experts from NATO JCBRN Defence COE and the Czech State Office for

Nuclear Safety will continue in testing of proposed criteria up to finished assessment of approximately 50-100 selected chemicals of special concern regards chemical terrorism. The faith of the team is that above presented partial results will be useful at least little bit for the promotion of terrorism prevention into the practice, in other countries. The main planned results of the project – certified methodology ("determination of reach perimeters terrorist-induced industrial accidents") and 1 x SW (support tool for application of the methodology), should be finished and probably certified by one of the Czech ministries in 2020.

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