ARE THE IMPROVISED CHEMICAL WEAPONS AS EFFICIENT AS MEDIA CLAIMS THEY ARE? CASE STUDY: THE SYRIAN WAR

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It is reported by various media sources that, since the beginning of the Syrian war in 2011, more than 11.5% of Syria's population has been wounded or killed. The scarcity of war resources forced the belligerents of the Syrian civil war to use many improvised weapons among which the chemical barrel bombs hold the headlines. Although the exact number of casualties produced by chemical weapons in Syria is unknown, reportedly a few thousand were killed or intoxicated. This article seeks to determine the efficiency of improvised chemical weapons used in Syria and compare them with the specially designed ones. For comparison, the military standards are to be used and the conclusion will show if the media is exaggerating or the humanity faces a new type of chemical warfare.

Keywords: chemical barrel bomb; chemical contamination; chemical warfare; lethal dose; civil war;

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BACKGROUND

The Syrian ongoing civil war started in March 2011 with anti-government protests before escalating into a *full-scale civil war*. In more than six years of armed conflict, it claimed more than 500,000 lives. The length of the war and the multitude of the belligerent groups that take part in the conflict generated a scarcity of military resources and raw material for manufacturing weapons and ammunition. Consequently, all belligerents started manufacturing and inventing new types of improvised weapons like barrel bombs, *"hell cannons"* and pipe bombs or grenades. Those improvised weaponry may be considered as *"crazy weapons"* by military designers as they are made from PlayStation controllers, rope, fertilizer, and the explosive material of unexploded bombs. The creativity of belligerents reached the maximum destructive effect by using the so-called *"barrel bombs"* technology. Although the idea of such bomb is not a new one, in Syria such weapon was manufactured at large scale and in various versions. As the conflict in Syria is mainly run in the build-up areas, the core objective of the Syrian barrel bomb program is to provide cheap and lethal damage on urban areas.

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CHEMICAL BARREL BOMBS

The barrel bomb technology was initially developed in order to be deployed by low speed aircrafts and helicopters and released over the target of interest from a low altitude. Those conditions, low speed and altitude were necessary for achieving the pinpoint accuracy of the barrel bomb and damage the only specifically identified target. However, along the conflict timeline, the belligerents were able to acquire or manufacture Man Portable Air Defence Systems (MANPADS) that deterred these low launched bombings.

The attack of the MANPADS forced the low speed aircrafts to launch the barrel bombs from a higher altitude (around 5,000 meters)

but to the detriment of the accuracy. Consequently, by decreasing the accuracy, the impact points became randomly and currently, the barrel bombs are rather used for attacking large urban areas killing humans and damaging military and civilian infrastructure.

Of specific interest for the purpose of this article is the *"chemical barrel bomb"*. This weapon was developed by using the same technology as for conventional barrel bombs but they were filled with toxic chemicals. Based on multiple open sources, videos, and social media reports, one may observe an evolution in design of such chemical barrel bomb that ranges from some simple cylinder filled with toxic chemicals to a more advance binary model.

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Based on author understanding regarding the improvised barrel bomb construction, the multiple open-source videos showing the remnants of barrel bombs and debris found at alleged chemical attacks location, he can assess that the most complicated improvised chemical barrel bombs used in attacks include the following components:

1. an outer shell (in general, an empty standard barrel or a manufactured) designed to hold inside a various number of gas cylinders;
2. a number of gas cylinders of various shapes and sizes filled with chemical compounds (which are most probably gases or liquids);
3. multiple plastic bottles filled with an chemical compound which, in reaction with the chemical compound stored in the gas cylinders, will release a toxic gas;
4. a detonation cord or an explosive mixture designed to brake the gas cylinders and the plastic bottles, allowing the chemical reaction to take place;
5. an ordinary time or impact fuse consisting of a blasting cap and a time calculated fuse wick (fuse cord);
6. several and various connectors that hold the components together;
7. some elements designed to stabilise the bomb during flight to target and for land transport and loading into the low speed aircraft.

This chemical barrel bomb releases the toxic chemical compound by using the detonation cord or an explosive mixture to destroy the walls of both the gas cylinders filled with toxic chemical and the outer shell. Improvised chemical barrel bombs designs that are observed through social media demonstrate that there is an evolution of their manufacture driven by trial and error process. By assessing and evaluating the social media pictures and videos, the author could identify three (3) generic constructions of the toxic chemical barrel bomb as they are presented below.

This version of the chemical barrel bomb is the simplest one, and it uses the chlorine cylinders as a chemical load. In general, most common sizes of chlorine cylinders contain 45 or 68 kg of chlorine. In case of Syria, there is information in the media about chlorine cylinders made in China. In this case, the capacity of the cylinder is of 50 kg of chlorine. The construction is very simple, a steel cylinder with a pressure valve. Cylinder valves are equipped with a pressure relief device consisting of a fusible metal plugin the valve body, located below the valve seat. The fusible metal is designed to melt between 70°C and 74°C to relieve pressure and prevent rupture of the cylinder in case of exposure to high temperatures. Based on those characteristics, the improvised chemical weapons construction consists of a time fuse, a detonation cord wrapped over the pressure valve sit, and an outer shell *(see Figure 1)*. The bomb is launched from a low speed aircraft and it explodes at a time controlled by the time fuse – the length of safe fuse. This time is correlated with the flying time of the bomb, the flying altitude depending of the tactical mission. The chlorine is released following the explosion of the detonation cord, which destroys the pressure valve. This improvised chemical bomb is simple by construction and cheap. However, it has some important falls. The precision of this bomb depends on the flying altitude. The increase of the flying altitude results in lower accuracy for the bomb. Also, the time fuse may not be accurately calculated and therefore the dude rate of these bombs increases, reducing the effect on target. In addition, the low altitude exposes the aircraft to MANPADS. Consequently, increasing the altitude, the bomb will tumble in the air and the accuracy is lost.

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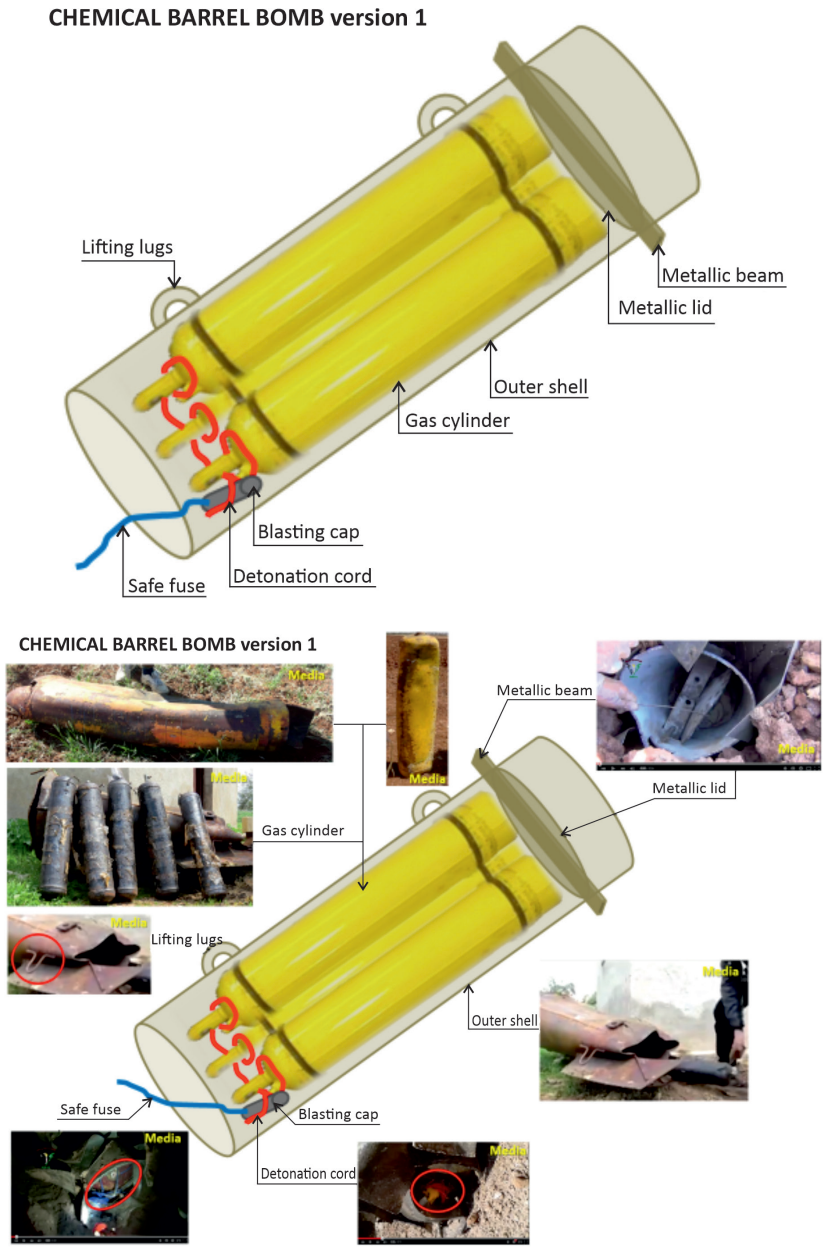

Figure 1: Improvised chemical barrel bomb, version nr. 1
(Source: Carol-Teodor Peterfi)[1]

[1] The various pictures used for drawing the sketch can be accessed in social media: http://brown-moses.blogspot.com/2014/05/photographs-from-daniele-raineri-of.html, retrieved on 16 September 2019.

Another construction defect of the bomb is that of the position of the fuse and the probability of it to detach from the overall construction at the impact of the bomb with the soil. This results in either a dude bomb or only the explosion of one cylinder, decreasing the contamination area and implicitly the tactical effect on target.

The second version of the improvised chemical bomb replaces the chlorine cylinders with the propane cylinders *(see Figure 2)*.

The author could not asses the exact reason for this change but it may be confidently assumed that it has to do with the scarcity of the chlorine cylinders as they have also important industrial purposes, most significant being water purification. The main improvement of this bomb is the transversal rebar which probably is designed to keep in place the gas cylinders when the bomb impacts the target. Also, this improvement keeps in place the time fuse and this reduces the dude rate of the improvised chemical barrel bomb. However, the author considers that another improvement of this type of bomb is the addition of a burster into the explosive train. This additional explosive is needed to destroy the steel propane cylinder as the detonation cord is unlikely to do it. The author considers that the burster is made available from the mining industry and it is not necessary to use a military explosive. As can be seen in the Figure 2, probably the burster is placed at the bottom of the propane cylinders as the cylinder valve is not destroyed. In this type of construction, chlorine is allegedly released by cracking the propane cylinder through the explosion of the burster. The rebar used to keep in place the propane cylinders improve, the effect on target of the bomb by increasing the contamination density. Also, the main advantage of such improvised chemical bomb is the availability of the propane cylinders and the main drawback is low accuracy.

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The third type of improvised chemical bomb is more sophisticated and falls in the category of binary chemical weapons. Those type of ordnance uses two or more chemical substances that combined form the chemical warfare agent and requires the mixture of the components in the last phase of the chemical warfare agent production and those components are usually not toxic or far less than the final compound.

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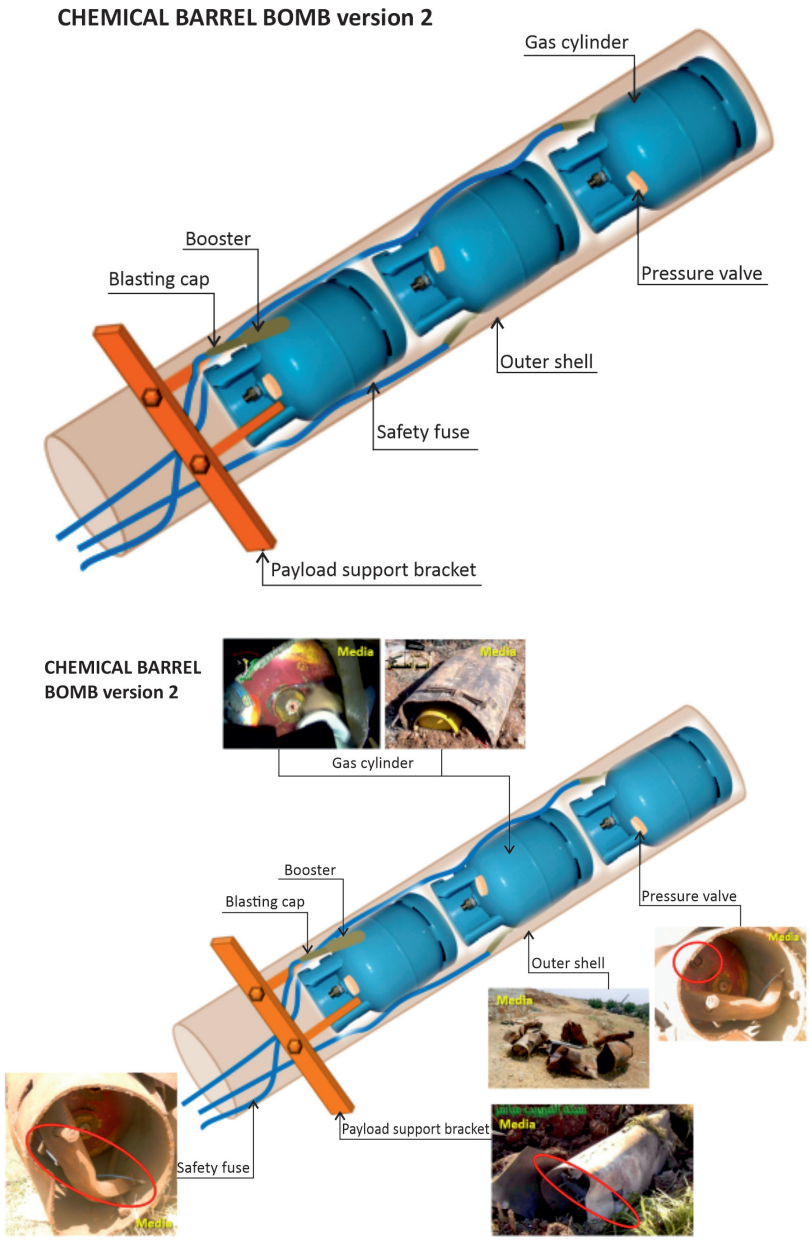

Figure 2: Improvised chemical barrel bomb, version nr. 2
(Source: Carol-Teodor Peterfi)[2]

[2] *Ibid.*

Although such binary chemical ordnances usually require a certain level of technology, it seems that the Syrian war pushed to a very ingenious improvised version *(see Figure 3)*. This type of improvised chemical bomb uses the reaction between potassium permanganate[3] and an acid, probably hydrochloric acid to produce chlorine: $2\ KMnO_4 + 16\ HCl = 2\ KCl + 2\ MnCl_2 + 8\ H_2O + 5\ Cl_2$. The construction of the improvised bomb is more complicated than the previous versions. The bomb components are: an impact plate, an outer shell, a number of bottles containing potassium permanganate and air conditioning cylinders containing hydrochloric acid. All components are wrapped into a detonation cord that, once exploded, will destroy the cylinders and bottles allowing potassium permanganate and hydrochloric acid to react. The toxic result of reaction is chlorine *(see Figure 3).*

There are some important elements in the evolution of improvised chemical barrel bombs as for example the impact plate and fins. The impact plate increases the rate of explosion as it can hit the tactical target at any angle and the explosion is initiated by the blasting caps placed under it, in between impact plate and outer shell of the bomb. Another improvement is the appearance of the stabilising fins that help the bomb flying trajectory and increases the targeting accuracy. Also, the stabilising fins allow the launching of the bomb from a higher altitude than the previous version with an improved accuracy. The rationale behind of having three stabilising fins and not more comes from practicality of deployment. For an easier transport, the improvised chemical air bombs were design with a transport train comprising of two wheels in the front and one on the back of the bomb. The three stabilising fins are the cheapest technical solution that match both transport and stabilisation requirements. Much more, some of the social media sources show the improvised bombs loaded into a helicopter. The internal design of helicopter and the launching procedures do not allow a bomb designed with four fins *(see figure 4).*

[3] Potassium permanganate is an inorganic salt. It dissolves in water to give intensely purple solutions. Potassium permanganate solution (KMnO4) is often used in analytical chemistry as an oxidising titrant for redox titrations. Solid potassium permanganate is oxidising. Solid KMnO4 is a strong oxidiser that reacts dangerously when mixed with glycerine, ethylene glycol, sulphuric acid and benzaldehyde.

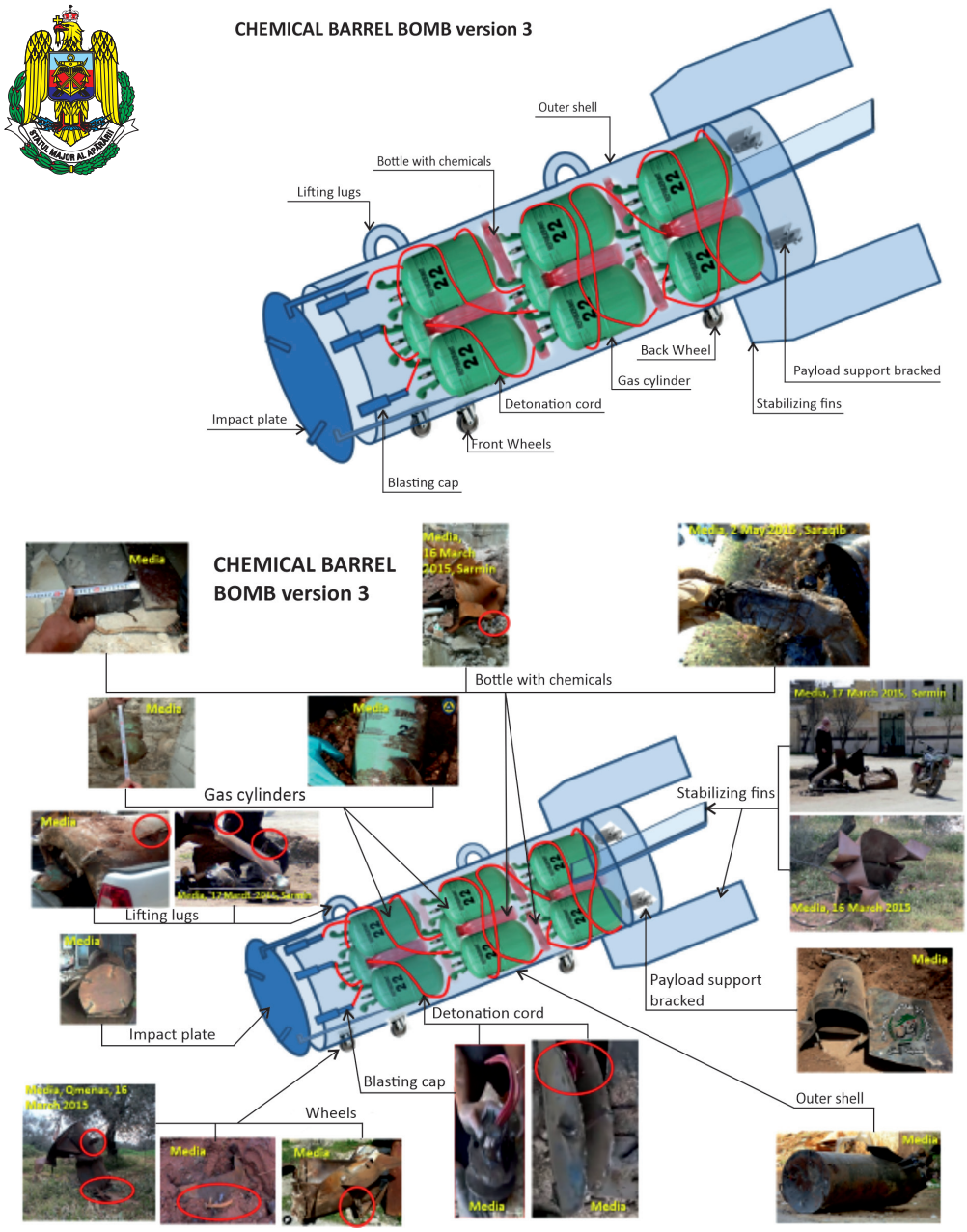

Figure 3: Improvised chemical barrel bomb, version nr. 3
(Source: Organization for the Prohibition of Chemical Weapons[4])

[4] The pictures used for forensic analysis can be accessed on social media: http://brown-moses.blogspot.com/2014/04/, retrieved on 16 September 2019.

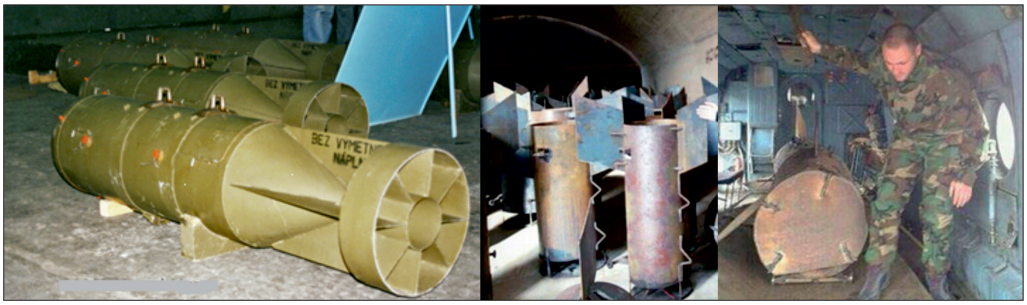

Figure 4: Comparison between classic and improvised bombs
(Bellingcat, 2015)

The most recent improvised chemical bomb used in Syria comes from the Douma chemical attack. The bomb used in that attack consist of a simple chlorine cylinder to which an interesting prefabricated harness system was attached. To that harness, the designer attached three stabilising fins and a simple transport train. This construction indicates that the cylinder and the harness have different supplier and those two parts were assembled as weapon before being loaded for launching. The harness improved the accuracy and the mobility of the weapon while the costs are kept low by using a simple chlorine cylinder. The toxic gas is released on impact when the pressure valve is ruptured or detonated. The author cannot exactly assess from the media if the improvised ordnance presented in the *figure 5* released chlorine on impact or by detonation.

The warhead is improvised and therefore can be filled as the user consider. In the improvised chemical weapons, the easiest construction is to attach to the Grad engine a propane cylinder filled with chlorine.

In addition to the aerial improvised ordnances, the media also presents some improvised versions of artillery type of chemical projectiles. In general, these types of artillery improvised chemical ordnances are designed as reactive artillery consisting of a racket engine and an improvised chemical warhead. The racket engine is in general taken from the Grad 122 mm missile[5]. The warhead is improvised and therefore can be filled as the user considers. In the improvised chemical weapons, the easiest construction is to attach to the Grad engine a propane cylinder filled with chlorine. The improvised artillery barrel

[5] The BM-21 "Grad" is a Soviet truck-mounted 122 mm multiple rocket launcher. The complete system is more commonly known as a Grad multiple rocket launcher system. In NATO countries, the system (either the complete system or the launch vehicle only) was initially known as M1964. Several other countries have copied the Grad or have developed similar systems.

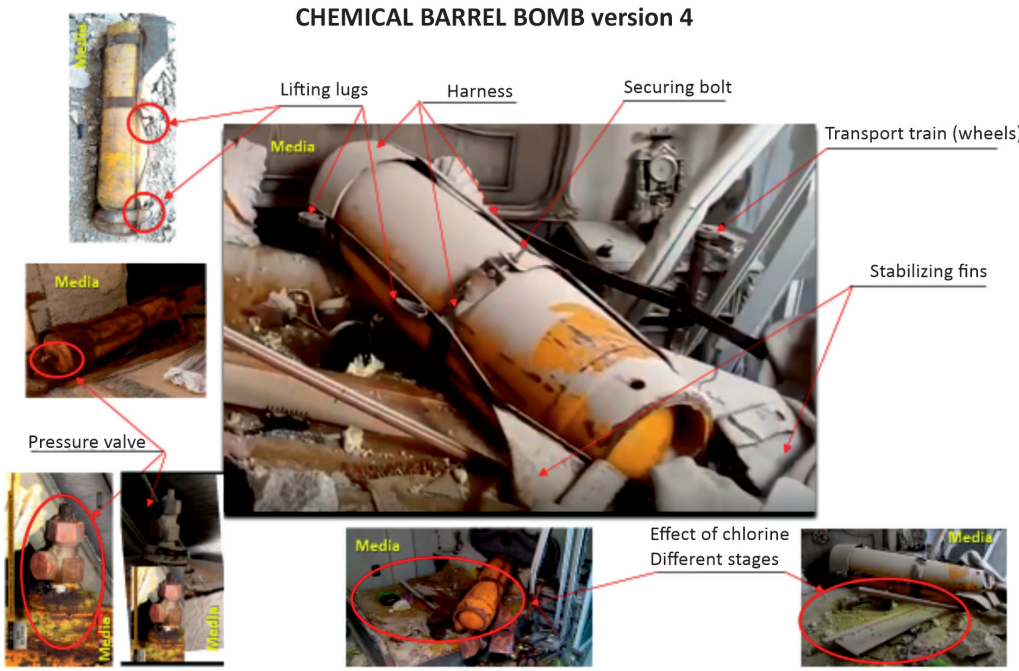

Figure 5: Improvised chemical barrel bomb, version nr. 4
(Source: Carol-Teodor Peterfi[6])

bomb lacks precision due to unpredictable trajectory. The liquid fill does not help the rocket flight and it is highly probable to tumble in the air and therefore miss the target. The effect on target is achieved by releasing the toxic chemicals at impact, by destroying the pressure valve or detonating it through a time fuse *(see figure 6)*.

METHODOLOGY

For calculating the effect of improvised chemical barrel bombs, the article uses the first responders' tools available online, mainly ALOHA and CAMEO. It calculates the effect on target based on the physical and chemical properties of chlorine assuming that only chlorine was used

[6] For forensic analysis and explanations, various social media sources were used: ttps://twitter.com/eliothiggins/status/988341105623228417?lang=ga;https://www.bellingcat.com/news/mena/2018/04/29/pieces-matter-syrias-chlorine-bombs-douma-chemical-attack/, retrieved on 16 September 2019.

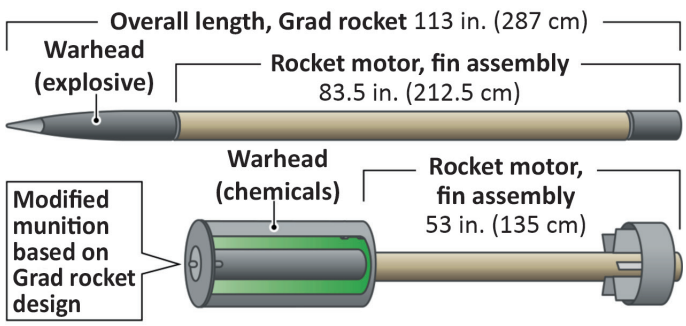

Figure 6: Improvised chemical barrel bomb based on Grad rocket
(Transcend Media Service)

as toxic chemical in the construction of those improvised chemical ordnance. The tactical norms and principles for using of chemical weapons are documented from NATO manuals and those may be different, depending on the bibliographical source and the NATO country that published it.

The source of the pictures used to analyse and draft the drawings presented in the *"Background"* are exclusively from the media. If one may google the keywords *"chemical barrel bombs"* the search engine will return about 5,890,000 results in 0.46 seconds[7]. The images used for identify the design of the above presented ordnances are taken from those results.

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As the target audience of this article are not only the CBRN specialists, the calculations are kept as simple as possible and at the level of understanding of the general public. If someone needs more details regarding those calculations, the author will be more than glad to answer to any questions regarding those and to add more scientific details as well.

For simplification of the calculation, the author will consider the physical volume of the chlorine cylinder of 50 kg and chlorine liquefied. The chlorine exposure levels and effects on humans are those recommended by Occupational Safety and Health Administration (OSHA), United States.

[7] The results displayed by Google when the expression *"chemical barrel bomb"* is searched varies depending on geographical location of the server, language used, and the operation system. The result displayed on text was obtained in Pueblo, Colorado, USA, on 16 September 2019.

Based on the results of the calculations, the author will further present the conclusion regarding the possible effect on target of those improvised chemical ordnances and will compare with the effect presented in Media.

LIMITATION OF RESEARCH

The research only rest on the media information and does not use any other information collected by specialised agencies. Therefore, the author is not in the position to confirm or deny the chemical attack happened in Syria. For the aim of the research, the author assumes that the information presented in the media are correct and the result are expected to confirm or deny the damaging potential of the improvised chemical weapons.

The research will be limited to only chlorine and it will be considered only as suffocant warfare agent. The chlorine toxic general effects will be neglected. The constructive model of the cylinders used for containing chlorine will not be analysed, the author assumes that they fit the necessary standards for this purpose (pressure, corrosivity, safety devices, etc.).

For the calculation purposes, the author will consider the most favourable meteorological conditions (temperature, air stability, wind direction and speed) in order to find out the most effect of improvised chemical barrel bomb.

Another important limitation of this research is that it does not seek to analyse or to name the perpetrators of the chemical attacks performed during the Syrian war, but only to evaluate their impact and efficiency on the security stage.

CALCULATIONS

General presentation of chlorine

Chlorine is primary used in water treatment and as disinfectant it destroys harmful organisms. The chlorine is also used to remove colour and ammonia compounds, eliminate hydrogen sulphide, oxidize iron and manganese to insoluble forms, and reduce undesirable taste and odours. In simple terms, chlorine is a very accessible toxic chemical compound and it is intensively used in the chemical industry. As such,

in spite of its toxic properties, chlorine is an essential element for daily life and welfare of any human society. Although it qualifies for the definition of chemical weapons, it cannot be considered as such because of its extensive use in industry.

The chemical symbol for elemental chlorine is Cl. Chlorine exists as a molecule containing two atoms, shown chemically as Cl_2. Chlorine has an atomic weight of 35.453, a molecular weight of 70.906, and an atomic number of 17. Some of the physical properties of chlorine are given in *Table 1.* While it is not explosive or flammable, as a liquid or gas it can react violently with many substances. This property of not being flammable is an advantage for weaponising it because it does not pose any difficulties in being released by explosion. Chlorine gas has a greenish-yellow colour. It has a typical unpleasant and pungent odour, similar to chlorine-based laundry bleaches, and it is detected by smell at concentrations as low as 0.58 to 1.16 mg/m^3(0.2 to 0.4 ppm)[8]. It is about two and a half times as heavy as air. Consequently, if chlorine gas escapes from a container or system, it will seek the lowest level in the building or area. Liquid chlorine is amber in colour and is about one and a half times as heavy as water. Chlorine is occasionally seen as a liquid because it boils (converts to a gas) at about -34°C (-29°F) at atmospheric pressure.

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Table 1: Physical properties of chlorine
(Source: Carol-Teodor Peterfi)[9]

Boiling point (liquefying point) at 1 atmosphere = 14.696 psi (101.325 kPa)	-33.97°C (-29.15°F)
Melting point (freezing point) at 1 atmosphere	-100.98°C (-149.76°F)
Liquid density at 16°C (60°F)	1,422 kg/m3(388.76 lb/cu ft)
Gas density at 1.1°C (34°F)	3.213 kg/m3(0.2006 lb/cu ft)
Specific gravity (liquid) at 0°C (32°F)	1.468 (water = 1)
Specific gravity (gas) at 0°C (32°F)	2.485 (air = 1)

[8] At 25^0 C and 1 atmosphere.

[9] For compiling data presented in the table, the author used material Safety Sheet for chlorine as in is communicated by Hazard Communication Standard: Safety Data Sheets – OSHA, *The Chlorine Manual,* 2001.

Water solubility at 21.1°C (70°F)	0.7% by weight
Vapor pressures: at 0°C (32°F) at 25°C (77°F) at 48.9°C (129°F)	 53.51 psi (368.9 kPa) 112.95 psi (778.8 kPa) 191.01 psi (1,316.8kPa)

Very important to consider for the purpose of this research are the chemical reactions of chlorine with water. Those reactions produce chemical compounds that are highly corrosive and by this reason they damage the human body. The corrosivity of hypochlorous acid and hydrochloric acid are responsible with the blindness of the soldiers attacked during the World War I with chlorine. The chlorine reacts with the human body moisture and the acids formed destroy the human tissue.

Another important characteristic of chlorine for this research is the liquid-gas volume relationship. One volume of liquid chlorine yields about 460 volumes of chlorine gas. For example, 0.5 kg (1pound) of liquid chlorine produces approximately 153 litres (5.4 cubic feet) of 100%chlorine gas when vaporized at normal temperature [20°C (68°F)] and atmospheric pressure.

Chlorine gas reacts with water to form both hypochlorous and hydrochloric acids (Eq. 1):

$$Cl_2 + H_2O \leftrightarrow HOCl + HCl \text{ (Eq. 1)}$$

(chlorine) (water) (hypochlorous acid) (hydrochloric acid)

Hypochlorous acid dissociates in water to form the hydrogen and hypochlorite ions (Eq. 2):

$$HOCl \leftrightarrow H^+ + OCl^- \textit{ (Eq. 2)}$$

(hypochlorous acid) (hydrogen ion) (hypochlorite ion)

Another important characteristic of chlorine for this research is the liquid-gas volume relationship. One volume of liquid chlorine yields about 460 volumes of chlorine gas. For example, 0.5 kg (1pound) of liquid chlorine produces approximately 153 litres (5.4 cubic feet) of 100% chlorine gas when vaporized at normal temperature [20°C (68° F)] and atmospheric pressure. Therefore, one 68 kg (150-lb) cylinder would completely fill a 3 x 3 x 2.5-meters (10 x 10 x 8-foot) room with 100% chlorine gas.

The vaporisation of liquid chlorine on skin or clothing may reduce the temperature enough to cause frostbite (even through high-quality protective clothing).

Chlorine is an irritant to the eyes, skin, mucous membranes, and the respiratory system. The main concern with exposure to chlorine

is the respiratory system, followed by the eyes. The impact of exposure to chlorine is both concentration and time dependent. Table 2 summarises exposure levels and effects on humans as are described by United States occupational safety and health.

Table 2: Toxic properties of chlorine
(Source: Carol-Teodor Peterfi)[10]

Exposure levels (mg/m^3)	**Effects**
0.58 to 1.16	Odour threshold (different by individual)
less than 1.5	No known acute or chronic effect
1.5	ACGIH 8-hour time weighted average
2.9	OSHA ceiling level (PEL[11]) TLV[12]-STEL[13] ERPG-1[14]
3 to 30	Irritation of the eyes and mucous membranes of the upper respiratory tract. Severity of symptoms depends on concentrations and length of exposure.
8.7	ERPG-2[15] (Emergency Response Planning Guidelines as values developed by AIHA) is the maximum airborne concentration below, which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects that could impair an individual's ability to take protective action.

[10] For compiling the data presented in the table, the author used data from the Safety Sheet for chlorine as communicated by Hazard Communication Standard: Safety Data Sheets – OSHA and Medical Aspects of Chemical and Biological Warfare.

[11] Permissible Exposure Limits. PELs are legal limits for the degree to which workers may be exposed to chemicals and other hazards (such as noise) without suffering harm.

[12] TLV defines the threshold limit value of a chemical substance and is believed to be a level to which a worker can be exposed day after day for a working lifetime without adverse effects. Strictly speaking, TLV is a reserved term of the American Conference of Governmental Industrial Hygienists (ACGIH).

[13] STEL defines the short-term exposure limit that is the acceptable average exposure over a short period of time, usually 15 minutes, as long as the time-weighted average (TWA) is not exceeded. STEL is a term used in occupational health, industrial hygiene and toxicology.

[14] The ERPG-1 is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hr without experiencing other than mild transient adverse health effects or perceiving a clearly defined, objectionable odour.

[15] The ERPG-2 is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hr without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual's ability to take protective action.

Exposure levels (mg/m^3)	Effects
29	NIOSH IDLH[16] (immediately dangerous to life and health)
58	ERPG-3 is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to one hour without experiencing or developing life-threatening health effects.

As the duration of exposure or the concentration increases, the contaminated individual may become apprehensive and restless, with coughing accompanied by throat irritation, sneezing, and excess salivation. At higher levels, vomiting associated with difficult breathing can occur. In extreme cases, difficulty in breathing can progress to the point of death through suffocation.

Calculations regarding release of chlorine

Calculation data:

- Location: Douma, Syria: 33°34'27" N; 36°24'20"E; elevation 659 meters;
- Building type: double stories buildings; unsheltered surroundings;
- Chemical: chlorine, pure chemical;
- Atmospheric conditions: wind 2.7 meters/second from ESE measured 3 meters above the ground; urban environment; partially cloudy; 75% humidity;
- Source: direct source; 50 kg; release duration 1 minute; release rate: 0.83kg/sec; source height 0 meters; total amount released: 49.89 kg.

The results of the calculations are displayed below. As it can be observed, the IDLH concentration is realised at surface of approx. 0.25 km^2 – 759 meters from the source (830 yards) on the downwind

[16] IDLH is defined by the US National Institute for Occupational Safety and Health (NIOSH) as exposure to airborne contaminants that *is "likely to cause death or immediate or delayed permanent adverse health effects or prevent escape from such an environment"*.

direction. As the population density in Syria is 93 per km^2 (241 people per sq mi^2)[17] means that a number of approx. 45 people will be exposed to the IDLH dose of chlorine. Although this number is not consistent with the number of victims reported in various sources of the media, the author can assume that the reported number of deaths – between 40 and 50 people – is possible in certain conditions. The reported number of injuries – more than a hundred – is also possible. In addition, although the chlorine is very volatile and in proper weather conditions its concentration decreased to at non-lethal one in 15 to 20 minutes, it may cause the death of the affected people if they do not evacuate the area in due time.

However, if the effects of the chlorine used as a chemical weapon is compared to that of sarin, a nerve agent allegedly used in the attacks at Ghouta[18] and Khan Shaykhun[19] chemical attacks (The White Helments), than the number of the victims exposed to IDLH level will rise at 1088 people *(see Figure 8)* (United Nations Security Council, 2017, pp. 25-31).

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THE USE OF CHEMICAL BARREL BOMBS IN THE SYRIAN WAR

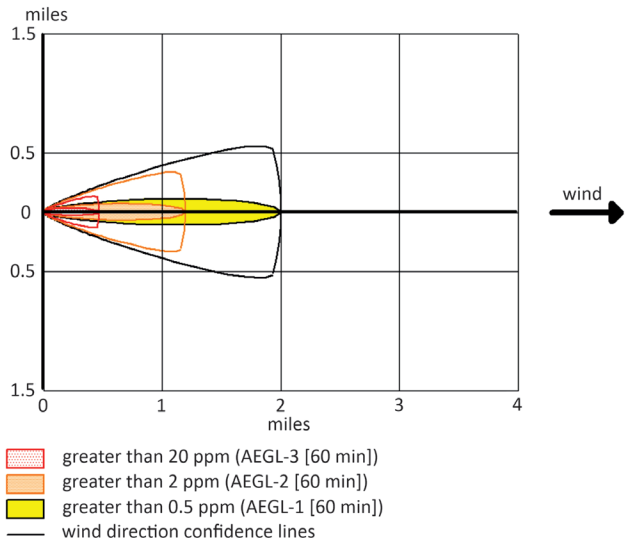
The use of improvised chemical barrel bombs and other chemical ordnances in the Syrian war is a reality which cannot be denied and cannot be considered as propaganda. However, there are some questions that have to be addressed before going to a conclusion of their efficiency in the current Syrian war. According to the principle of the chemical warfare, the use of those weapons has to have a tactical purpose and to offer an advantage over the opponent.

In the media, there is no relevant information regarding the tactical value of chemical attacks. In general, the impact areas are mostly

[17] The mile (mi) is the British Imperial Unit of length and is equal to 5,280 feet or 1,760 yards; in the International System, a mile is standardised at exactly 1,609.344 metres, by an international agreement back in 1959.

[18] The Ghouta chemical attack occurred in Ghouta, Syria during the Syrian Civil War, in the early hours of 21 August 2013. Two opposition-controlled areas in the suburbs around Damascus, Syria were struck by rockets containing the chemical agent sarin. Estimates of the death toll range from at least 281 people to 1,729. The attack was the deadliest use of chemical weapons since the Iran–Iraq War.

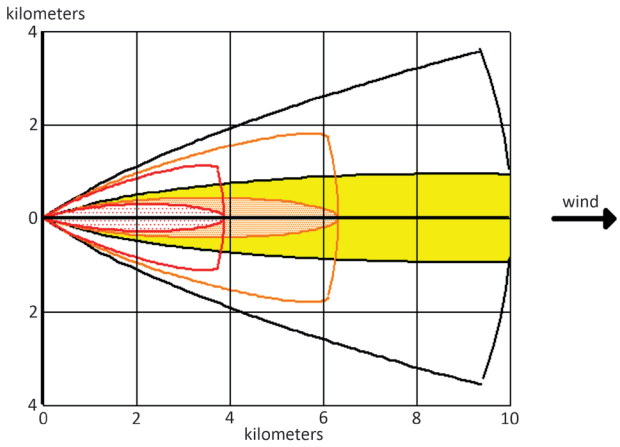
[19] The Khan Shaykhun chemical attack took place on 4 April 2017 on the town of Khan Shaykhun in the Idlib Governorate of Syria.




```
SITE DATA:
  Location: DOUMA, SYRIA
  Building Air Exchanges Per Hour: 0.40 (unsheltered double storied)
  Time: September 7, 2019  2349 hours DST (using computer's clock)

CHEMICAL DATA:
  Chemical Name: CHLORINE
  CAS Number: 7782-50-5                    Molecular Weight: 70.91 g/mol
  AEGL-1 (60 min): 0.5 ppm   AEGL-2 (60 min): 2 ppm   AEGL-3 (60 min): 20 ppm
  IDLH: 10 ppm
  Ambient Boiling Point: -32.4° F
  Vapor Pressure at Ambient Temperature: greater than 1 atm
  Ambient Saturation Concentration: 1,000,000 ppm or 100.0%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
  Wind: 2.7 meters/second from ESE at 3 meters
  Ground Roughness: urban or forest        Cloud Cover: 5 tenths
  Air Temperature: 17° C                   Stability Class: D
  No Inversion Height                      Relative Humidity: 75%

SOURCE STRENGTH:
  Direct Source: 50 kilograms              Source Height: 4 meters
  Release Duration: 1 minute
  Release Rate: 1.84 pounds/sec
  Total Amount Released: 110 pounds
  Note: This chemical may flash boil and/or result in two phase flow.

THREAT ZONE:
  Model Run: Heavy Gas
  Red    : 830 yards --- (20 ppm = AEGL-3 [60 min])
  Orange: 1.2 miles --- (2 ppm = AEGL-2 [60 min])
  Yellow: 2.0 miles --- (0.5 ppm = AEGL-1 [60 min])
```

Figure 7: Results of the calculation of the use of the improvised chlorine barrel bomb
(Source: Carol-Teodor Peterfi)[20]

[20] For calculation of dispersion model, the ALOHA software was used.



greater than 0.022 ppm (AEGL-3 [60 min])
greater than 0.006 ppm (AEGL-2 [60 min])
greater than 4.8e-04 ppm (AEGL-1 [60 min])
— – wind direction confidence lines
Note: Threat zone picture is truncated at the 10 km limit.

Text Summary

```
SITE DATA:
  Location: DOUMA, SYRIA, SYRIA
  Building Air Exchanges Per Hour: 0.40 (unsheltered double storied)
  Time: September 7, 2019  2349 hours ST (user specified)

CHEMICAL DATA:
  Chemical Name: SARIN
  CAS Number: 107-44-8                    Molecular Weight: 140.11 g/mol
  AEGL-1 (60 min): 4.8e-04 ppm   AEGL-2 (60 min): 0.006 ppm   AEGL-3 (60 min): 0.022 ppm
  Normal Boiling Point: 147.2° C
  Note: Not enough chemical data to use Heavy Gas option

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
  Wind: 2.7 meters/second from ese at 3 meters
  Ground Roughness: urban or forest       Cloud Cover: 7 tenths
  Air Temperature: 17° C                  Stability Class: D
  No Inversion Height                     Relative Humidity: 75%

SOURCE STRENGTH:
  Direct Source: 50 kilograms             Source Height: 4 meters
  Release Duration: 1 minute
  Release Rate: 833 grams/sec
  Total Amount Released: 50.0 kilograms

THREAT ZONE:
  Model Run: Gaussian
  Red    : 3.9 kilometers --- (0.022 ppm = AEGL-3 [60 min])
  Orange: 6.4 kilometers --- (0.006 ppm = AEGL-2 [60 min])
  Yellow: greater than 10 km --- (4.8e-04 ppm = AEGL-1 [60 min])
```

Figure 8: Results of the calculation of the use of the improvised sarin barrel bomb
(Source: Carol-Teodor Peterfi)[21]

[21] For calculation of dispersion model was used ALOHA software, *Ibid*.

populated area or, on the contrary, areas without a significant importance like agriculture terrain (farms), isolated buildings, crossroads etc. This situation reflects either a wrong accuracy of the improvised chemical barrel bombs or a bad targeting process. In addition, other purposes as terrorism or provocation cannot be excluded.

The chemical attacks are in general sporadic and the perpetrator generally used a very limited number of the assets. This is not in line with the principles of using chemical weapons because, by using a single *"round"*, the effect on target cannot be reached. In other words, one strike cannot reach the contamination norms[22] necessary for achieving the desired effect.

The impact areas are mostly populated area or on contrary, areas without a significant importance like agriculture terrain (farms), isolated buildings, crossroads etc. This situation reflects either a wrong accuracy of the improvised chemical barrel bombs or a bad targeting process. In addition, other purposes as terrorism or provocation cannot be excluded.

Another element that triggered the author attention, beside the single use, is the fact that the chemical munitions were used without being combined with the classic explosive munitions. It is common in the literature regarding the use of chemical weapons to be used in combination with other types of lethal munitions for increasing the effect of both. In the Syrian case, media reports only use of chemical munitions stand-alone.

The evolution of the chemical barrel bombs presented in the background of this paper suggests a sort of amateurism in the design and construction of such weapons. The simplicity of the weapons suggests that the user did not pay too much attention to the accuracy and the effect on target, but rather to affect non-protected and not chemically trained population. This suggests rather a terrorist purpose than the achievement of any military objectives.

Regarding the efficiency of the chlorine used in chemical weapons, it is clear that it cannot produce huge casualties and the protection against it is relatively simple. Chlorine was used as an efficient weapon only during the World War I and indeed produced thousands of casualties. However, the attacks were with huge quantities of chlorine and in short time, once the belligerents introduced the gas mask as protective measure, the use of chlorine was discontinued as it was

[22] The contamination norms are 10 – 25 mg/m^2 for nerve agents and 50 – 100 mg/m^2 for vesicants. Those military norms can vary from country to country. For example, in Romanian bibliography, a battery of mortars of 106.6 mm can contaminate with sarin 21 hectares in one strike realizing a contamination of 0.04 mg/l*min. This concentration can kill a 70 kg person at one single breath even at a temperature of – 10°C.

considered as ineffective. However, here is another point to consider about the chlorine attacks in Syria. During the World War I, the most affected external organ of the soldiers were the eyes. It is well-known the picture with the blind soldier lining up for movement and medical treatment. This is because chlorine reacts with water from the human body and the results, the hypochlorous and hydrochloric acid, damage the soft tissue of the eye, lungs and skin. In the Syria chemical weapons related pictures a patient with eye problems can be barely seen, most of them accusing breathing difficulties, which is also one of the main effects of chlorine contamination.

All those above elements are analysed from tactical perspective. At operational level, as the Syrian war is presented in different media sources, the author could not find any coherent operational plans or manoeuvres that are supported by those chemical attacks. In this respect, the author could not identify any kind of military operations that required a chemical attack in support of achieving an operational objective. All those chemical attacks are mainly sporadic and they seem to be uncoordinated at the operational level. In principal, those chemical attacks targeted a small tactical objective (if any) and it seems they are not part of a bigger military operation. As the judgment of such operations in Syria war are based exclusively on media reports, such operational plans may exist but, as the military operations of all belligerents were run, it is hard to believe that those chemical attacks were coordinated at operational level.

At the strategic level, the situation seems to be clearer. The chemical attacks, who ever executed them, were of huge impact worldwide. Following the Khan Shaykhun chemical attack on 4 April 2017, the United States stroke with missiles the Shayrat Airbase on 7 April 2017[23]. This is one of the first international community military actions against Syria and was triggered by the chemical attack allegedly executed with a *"sarin like"* chemicals (*The Washington Post*, 2017). This deliberate attack against Syria triggered many reactions at international level

The chemical attacks, who ever executed them, were of huge impact worldwide. Following the Khan Shaykhun chemical attack on 4 April 2017, the United States stroke with missiles the Shayrat Airbase on 7 April 2017. This it is one of the first international community military actions against Syria and was triggered by the chemical attack allegedly executed with a "sarin like" chemicals.

[23] On 7 April 2018, in response to chemical weapon attacks (most notably the Khan Shaykhun chemical attack) against Syrian civilians by the Syrian government, the U.S. launched missile strikes on the airfield from which the chemical weapon attacks were allegedly launched. This incident marked the first deliberate direct attack by the U.S. on the Assad government.

and also many controversies regarding the legitimacy of such independent actions. For example, the Russian Foreign Ministry condemned the attack as being based on dishonest intelligence and against international law, suspended the Memorandum of Understanding on Prevention of Flight Safety Incidents that had been signed with the United States, and called an emergency meeting of the United Nations Security Council (*Statement by the Russian Foreign Ministry*, 2017). Following the chemical warfare attack (2 cylinders with chlorine) that was carried out in the Syrian city of Douma on 7 April 2018, the United States, France and the United Kingdom carried out a series of military strikes against multiple government sites in Syria. Those bombing actions were also heavily criticised by Syria, Russia and their allies as those countries consider ethos attacks as staged by Syria opposition forces (Envoy to OPCW..., 2018).

The United Nations was also involved after the attack and it became the place of a fiercely diplomatic battles. On 10 April 2018, member states proposed competing United Nations Security Council resolutions to handle the response to the chemical attack. The United States, France, and United Kingdom vetoed a Russian-proposed United Nations resolution. Russia had also vetoed the United States' proposed resolution to create *"a new investigative mechanism to look into chemical weapons attacks in Syria and determine who is responsible"* ("*Russia Vetoes U.S. Resolution on Syria"*, 2018). On 14 April 2018, France, the United Kingdom and the United States hurled airstrikes against four Syrian government military objective in retaliation to the attack (ABC News, 2018). The airstrikes were claimed to effectively destroy the chemical weapons capabilities of Syria. However, according to Pentagon, the Syrian Arab Republic still retains the ability to launch chemical weapons attacks (*"Russia, Syria Trying To 'Sanitize' Chemical Attack Site",* 2018).

To sum up, those above analysed chemical weapons attacks were improvised chemical weapons were used, although without a notable efficiency at tactical and operational level, triggered a fiercely diplomatic battles on the stage of the international organisations and anyone can observe that this fight is far from coming to an end.

CONCLUSIONS

Based on the facts and calculations presented above, one may conclude that the efficiency of the improvised chemical weapons ordnances allegedly used in Syria are not of high efficiency at tactical and operational level and those have been used rather as terrorist weapons or with a provocative purpose. As it is presented by Media, the result of those attacks determined the international community to respond and some countries were fast to attack Syrian targets while other were keener to wait for a United Nations resolution in this respect. This situation may suggest two different patterns of using the chemical weapons.

The first pattern is that of terrorist attack. As any terrorist attacks, the use of chemical weapons is against civilians and has the purpose to attract the attention over some claims of a terrorist group or to achieve some 'politic' purposes (Fortna, 2015, pp. 519-556).

In general, the concept is used in this regard mostly to refer to violence during peacetime or in context of war against non-combatants (mostly civilians) (Stevenson, 2010). The chemical attacks in Syria may fall under this definition and therefore the author can confidently assume that the chemical attacks in Syria are terrorist attacks.

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The second pattern seems to bring in attention an old security concept, namely that of 'strategic caporal' (Stirm, 2019). The concept refers to low-level military leaders who have to make critical tactical decisions in complex situations that could affect the operational and strategic levels. It also refers to the high demands that military leadership places on soldiers (Jordaan, 2017, pp. 149-154). In our studied cases, the chemical attacks executed at tactical level, coordinated or not at operational level, achieved a high strategic impact that triggered the military intervention of other states in the Syrian war. Many investigations regarding those chemical attacks are ongoing and the results of some of them were already presented in various reports of various international organisations or non-governmental organisations. However, a big part of those reports are Media based and, although they tried to be scientifically accurate, more other questions are raised up. Some of the Media reports and analyses suggest that at least some of those attacks were staged.

If this is so, then the world is facing another type of chemical warfare. In this new type of war, the toxic chemicals are used not for achieving an immediate tactical or operational objective but, for achieving a bigger strategic purpose. Bearing in mind the military interventions following the chemical attacks in Syria and correlating their follow ups with the Skripal case[24] and its consequences, there are no doubts that such scenario is possible.

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