Chemical Agent Concentration Review for CS:

Recommendation against concentration calculations

By Don Whitson

Introduction

Law enforcement agencies routinely use chemical agents as a minimal force option to generate compliance. Pepper spray has been widely accepted as a personal defense option to incapacitate non-compliant individuals. Riot control agents such as CS have been used by law enforcement as a tool for crowd control in outdoor environments for decades. For more than 40 years CS has also been adopted for use against barricaded subjects to extract them from an indoor location. While it has become a widely accepted use-of-force, the law enforcement community remains divided on the methods used for delivering agents. Some agencies use a formula to determine the quantity of agent used, while others rely on a "reasonableness" calculation considering the totality of the event circumstances.

Purpose of the review

The NTOA's Less-Lethal Instructor Course offers training and background to police officers on less-lethal options, including chemical agents. In 2002, the NTOA removed the section of the chemical agent instructor course regarding the concentration calculations referred to as ICt50 and LCt50. Like many others, I had been taught to use these formulas to calculate the incapacitating and lethal concentrations for CN and CS. The concept was adapted from a study conducted by the Department of the Army, Edgewood Arsenal.[1] The study was conducted to determine the effects of CS and CN on humans. This report has been cited as the benchmark for determining the levels of CS and CN for safety concentrations. In 1993 the IACP published a recommendation regarding the calculations and stated their concern that "the mathematical formula for determining how much chemical agent should be introduced into a barricade position is out-of-date. Furthermore, in the years since this document was prepared, much new technology has been developed, including tear gas projectiles, canisters and delivery systems." (Police Chemical Agents Manual). IACP concluded by advising law enforcement to discontinue using information from the manual as standards.

The NTOA simultaneously denounced the use of the concentration formulas citing the methodology discrepancies and inconsistent comparative values used in this model.

Why, then, are some agencies still using these formulas and what relevance do the formulas have in providing safety or effectiveness for deployment? I have been told by some that they acknowledge the advisements that the formulas have little to no value or relevance to deployment considerations. At a meeting not long ago I was told, "I know these formulas are not valid, but it is better than nothing. How do we know how much chemical agent to use in a barricade operation?" That rationale, to me, is akin to driving a car with a broken speedometer, yet continuing to look at it to determine how fast you are going because it is better than nothing.

Over the past eight months I have researched information regarding the toxicity and associated heath risks concerning chemical agents used by law enforcement, specifically related to the original Edgewood Arsenal report. This task proved to be difficult since the references to this report have been archived and are not available through open source analysis. However, there is sufficient information regarding the toxicology and effectiveness of these agents for which I propose a recommendation from the Less-Lethal Section of the NTOA.

There seems to be as many opinions about this subject as there are those voicing them. I hope this brings some consistency and standardization regarding the issue of chemical agent concentrations used by law enforcement.

For the purpose of this article the emphasis will be on CS. CN is still being used by some U.S. law enforcement agencies, but far less than CS. CN has been the proximate cause for at least four deaths in the United States. CS has replaced the military use and need for CN based on its safety, effectiveness and ease of decontamination for individuals. While there are independent studies about the health risks of CN exposure, the academic body of information regarding CS is much more defined.

The most commonly asked question of the NTOA Less-Lethal instructor cadre concerns the baseline levels for CS and CN to be used in law enforcement operations, specifically during barricade situations. Most agencies utilize strategies known as "hard and heavy" or "volley" methods to deploy chemical CS or CN into the stronghold. And some rely, at least in part, on formulas established by the U.S. Army Edgewood Arsenal's Special Publication (1967). These formulas established concentration estimates for CS and CN. The toxicity of these chemical substances was measured using clinical studies to show incapacitation and lethal limits. The limits can be computed using two methods. The first determines the length of the approximate time of exposure, and the second determines the number of munitions or gram weight of the agent needed to reach those levels, described later.

Problems associated with the Edgewood model

1. The extent of poisoning caused by riot control agents depends on the amount of riot control agent to which a person was exposed, the location of exposure (indoors vs. outdoors), how the person was exposed

and the length of time of the exposure.[2] There is no consideration given to biological metabolic differences, reduced pain thresholds due to intoxication and medicines or methodology regarding dissemination concentration levels.

2. The comparison between ingestion and inhalation of the agent depends on strict methodology and extraction of variables. For example, the methodology of inhalation characteristics described in the Edgewood Arsenal report were conducted in static sealed containers with no exchange of environmental air supplies. The dissemination method used was pyrotechnic vaporization. The concentration doses were not compared to common environmental conditions like those found in law enforcement applications such as ported windows and walls.

3. The calculations of chemical agents have no relevance to the force level considerations placed on civilian police. For example, the calculations for incapacitation levels don't consider the seriousness of the crime, environmental conditions, health of the suspect and so on.

4. The levels for incapacitation are operationally too low. The lethal concentration levels are so high they are unobtainable.

5. CS was developed for the U.S. military to replace CN. It was produced for and intended to be used outdoors as a riot control agent. The mechanism for incapacitation and the methods to test its effects were for outdoor use, not indoors in a sealed environment.

6. The effects of CS depend on the dosage received and the method of dissemination. Sprays, for example, have higher levels of irritant exposure than aerosols. The dissemination of the chemical in the air depends on the carrier and the concentration of the agent. These two variables alone subject the Edgewood study to comparative criticism.

7. Because the values are estimated for 50 percent of the tested population, how does one know what percent is present at the time of the field incident?

8. Most applications used by law enforcement today rely on liquid or aerosol dissemination, not pyrotechnic dissemination (as used in the Edgewood study), which vaporizes much higher concentrations of suspended particles.

History and definitions

MSDS Safety Data for Ortho-chlorobenzylidene malononitrile (CS)

RTECS # 003675000

CAS #2698-41-1

Ortho-chlorobenzylidene malononitrile (CS) was produced in 1928 by scientists B.B. Corson and R.W. Stoughton. The agent became known as CS after the names of the creators and was later produced by Porton Downs. CS is a white crystalline solid with low vapor pressure and is almost insoluble in water. It has a pepper-like odor and has immediate irritating effects. CS was used widely in modern military history throughout the world and was originally used by law enforcement as a riot control agent.

Definitions of incapacitation

The general definition of incapacitation regarding the effects of CS exposure during clinical trials refers to the point in time at which the effected person overtly avoids or moves away from the exposed environment. That varies depending on the subject's resolve, tolerance, route of exposure and so on. It does not take into account the subject's ability to act, think and respond to additional stimuli. It merely points to the time when the subject *wants* to move away from the contaminated area.

From an operational perspective, law enforcement personnel rely on incapacitation to mean that the effects of the CS on a suspect met their operational objectives (for example, the effects allowed the officer to gain control of the suspect). The International Law Enforcement Forum has created operational definitions that are universal.

- Debilitating – Degraded function to a point of inability to present a threat. Considered by degree, but only partially or not completely incapacitating.
- Incapacitation – Physical/sensory dysfunction that is temporary and of such a degree that an individual is rendered incapable of carrying out any violent physical or threatening act.
- Effective – Normally achieves the operational (field) performance objective.[3]

How CS works

At standard daily temperatures and pressures, CS forms a white crystal with a low vapor pressure and poor solubility in water. CS aerosols thus act as a "powdered barb" with microscopic particles, which are potent sensory irritants which become attached primarily to moist mucous membranes and moist skin. The eye is the most sensitive organ in riot control because CS causes epiphora, blepharospasm, a burning sensation and visual problems. Coughing, increased mucous secretion, severe headaches, dizziness, dyspnea, tightness of the chest, difficulty breathing, skin reactions and excessive salivation are common. The onset of symptoms occurs within 5 to 60 seconds and if the exposed individual is placed in fresh air, these findings generally cease completely within 10 to 30 minutes. The main medical literature supports the safety of CS.[4,5,6]

Biochemists believe that CS acts by causing tissues to release bradykinens, substances which cause pain, tissue swelling (edema) and leakage of fluid from the capillaries.[7] It would then stand to reason that people who have a reduced pain threshold from alcohol or drugs would not be affected by CS, since the primary source of compliance comes from the sensation of pain. Anxiety, fear, resolve, mental conditions and the effects of acetylcholine or adrenaline can contribute to differences in the effects of the chemical agents as well.

There is a large gap between the effective dose and the lethal dose, even in rodent studies. In these studies it is important to remember that the effective dose is subjective at best. The rodent can't speak, so the investigator must assume the relevant dose was effective or incapacitating based on observations. All the reported studies I reviewed measure the lethal dosage as it relates to exposure time, not concentration. The time of exposure to the so-called lethal concentration is what was lacking in the original Edgewood Study. This study also did not account for tolerance levels and repeated long-term exposure rates leading to edema. Likewise, the references to human effects did not consider the extreme differences between the test animals themselves. If breathed in a confined space, where one must inhale CS into the lungs, the edema and capillary leakage will cause pneumonia and death. The lack of human volunteers for such death precludes determining the human lethal dosage by experimentation. For instance, guinea pigs die at half the dose necessary to kill rats or rabbits.[8]

Other studies indicate that guinea pigs die at one-fifth the dose required to kill mice, and rabbits at half the dose required to kill rats.[9] The lethal dose is not merely a question of how much agent but also a question of how long the subject is exposed. Tissue damage in the lungs will accumulate as the substance is inhaled, especially in a confined space with no additional air exchange. As fresh air is inhaled and the CS particles are expelled, the accumulative effect will diminish significantly. The only way to measure the effects is to maintain the constant dose levels in a close space.

When concentration levels of organic airborne particles reach some 2500 times the detectable levels without air exchange, nearly any compound can lead to pulmonary edema. The extent to which edema is caused by CS is unknown.

Clinical effects of CS

In the eye, an initial burning feeling or irritation progresses to pain, accompanied by blepharospasm, lacrimation and conjunctival injection. The intense blepharospasm causes the eyes to close. Photophobia is often present and may linger an hour. The mucous membranes of the mouth, including the tongue and palate, have a sensation of discomfort or burning, with excessive salivation. Rhinorrhea is accompanied by pain inside the nose and perhaps around the external nares. When inhaled, these compounds cause a burning sensation or a feeling of tightness in the chest, with coughing, sneezing and increased secretions. On unprotected skin, especially if the air is warm and moist, these agents cause a tingling or burning; within a few minutes, erythema may develop at the exposed sites.[10]

Tolerance to exposure

The effects of CS exposure can be seen within a few seconds to several minutes. If an individual leaves the contaminated area the effects will be minimized and abated in a short time, usually within 30 minutes. If the subject stays in the contaminated area for a longer period, irritation can be more severe. Most humans tested report marked harassment at levels of 3 to 5 mg/m3 and leave the area as soon as possible.[11]

Table 1: Clinical effects of CS

Eye	**Airways**
Burning, irritation	Sneezing
Conjunctival injection	Coughing
Tearing	Chest tightness
Blepharospasm	Irritation
Photophobia	Secretions
Skin	**Nose**
Burning	Rhinorrhea
Erythema	Burning pain
Gastro-intestinal Tract	**Mouth**
Gagging	Burning of mucous membranes
Retching	Salivation
Vomiting	

As the concentration levels increase, the acute effects cause the subject to be unable to remain in the exposed environment for long. Studies suggest that subjects can develop a tolerance to the CS. Tolerance was examined experimentally in a study in which men were placed in a concentration of 0.43 mg/m3; the concentration was slowly increased to 2.0 mg/m3 over 60 minutes. If the men were able to withstand the initial effects, they could remain in the higher concentration. During this time, some of the subjects played cards and two attempted to read.[12]

Definitions of toxicology terminology

LD50 – Lethal Dose 50, also called "Median Lethal Dose," is the quantity of a chemical compound that, when applied directly to test organisms, is estimated to be fatal to 50% of those organisms under the stated conditions of the test by any route other than inhalation. LD50 is usually expressed as milligrams or grams of material per kilogram of animal weight [mg/kg or g/kg, where 5000 mg=5g=t (one teaspoonful)]. The phrase "Rat, Oral, LD50: 200mg/kg," for example, means that 200 milligrams of the chemical per each kilogram of body weight is the lethal dose that killed 50% of a group of test rats. These are used to help establish the degree of hazard to man.

LC50 – Lethal Concentration 50, also called "Median Lethal Concentration," is the concentration of a material in air (airborne) that is expected to kill 50% of a group of test animals when administered as a single exposure in a specific time period (usually one hour) through inhalation and respiratory route. The LC50 is expressed as parts of material per liter of air, or milligrams of material per cubic meter of air (mg/m3) for dusts and mists, as well as for gases and vapors.

ICt50 – Median Incapacitating Dosage. This is the concentration of chemical multiplied by the time (duration) of exposure that will affect 50 percent of an exposed population.[13]

Incapacitation Concentration and Time (ICt50) and **Lethal Concentration and Time (LCt50)** are values representing the concentration of the chemical agent in the air multiplied by the time of exposure that is incapacitating or lethal for 50 percent of the contaminated persons. These values can be computed using a long-hand formula or there are calculators and shareware programs available that require only the entry of values to compute the dosage electronically.

Ct – The inhalation toxicity of riot control agents, as in the case with military chemicals and chemical warfare agents, is conventionally expressed by the notation Ct. This term is defined as the product of the concentration in mg/m3 multiplied by the exposure time (t) in minutes (mg-min/m3). The terms LCt50 and ICt50 describe the airborne dosage lethal (L) of incapacitating (I) to 50 percent of the exposed population. The dosage expressed as Ct does not necessarily bear a simple relationship to the amount of the toxicant actually absorbed by the organism exposed to a toxic substance. The underlying assumption is that at any given concentration absorption (uptake) is proportional to the time of exposure.[14]

Formula for CS

This is the current formula used by Armor Holdings in the company's Instructor Certification Manual: [15]

LCt50:
Lethal Concentration and Time

The established concentration parameters for calculating the LCt50 *time* of contamination:

- CS=0.70921

The established concentration parameters for calculating the *number of munitions* required for LCt50:

- CS=25 gm-min/m3

ICt50:
Incapacitating Concentration and Time

The concentration of the chemical agent in the air multiplied by the time of exposure that will incapacitate 50 percent of the contaminated persons.

The estimated concentration parameters for calculating ICt50 *time* of contamination:

- CS= 0.00057

The established concentration parameters for calculating the *number of munitions* required for ICt50:

- CS=0.01 gm-min/m3

Safety factor

The ratio of the vapor concentration of chemical agent required to produce lethal dosage (LCt50) to the vapor concentration required to produce incapacitating dosage (ICt50) is the safety factor.

- CS safety factor = 1250. It takes a dosage of 1250 times greater than an incapacitating dosage to produce a lethal dosage.

Keep in mind that the physical condition of the subject, the form of chemical agent present and the ventilation of the structure all influence the effectiveness and accuracy of these numbers (time/number of munitions and safety factor). If one were to follow the agent concentration formula, to use chemical agents effectively and safely, there are three major elements which must be considered in all cases where they are to be used in a confined area:

The volume of air (V) – This is the capacity of the area, in cubic feet or meters, in which agent will be used.

To compute the amount of air volume in feet, use the formula:

- Cubic feet = Length x Width x Height

To convert cubic feet to cubic meters, calculate cubic feet and divide this number by 36

- Cubic Meters = $\frac{\text{Cubic feet}}{36}$

Time (T) — Time for the lethal and incapacitating formulas is always expressed in minutes.

Weight (gms) — This is the amount of the agent, in grams, one is going to use and the number of munitions required to obtain that concentration. Chemical agent contents are generally specified in grams instead of milligrams. The gram weight of the DT/FL active agents (and other companies) can be found in the product specification manual.

Steps to calculate agent concentration and time:

Step 1: Determine the volume of air, in cubic feet, of a given room.

Step 2: Establish the concentration parameters. Remember that they are predetermined constants and do not change.

CS LCt50 = 0.39660

CS ICt50 = 0.00057

Step 3: Based strictly on this formula, one will be able to determine the amount of time it would take for an agent to become lethal or incapacitating. *(Remember this is not a practical formula for your situations.)* Simply divide the amount of oxygen by the gram weight of the agent of the specific munition.

$$\frac{\text{Available } 0_2}{\text{Grams of agent}} = \text{Time in Minutes}$$

Steps to calculate agent concentration and number of munitions:

Step 1: Establish the concentration parameters. Remember that they are predetermined constants and do not change.

CS LCt50 = 25 gm/min/cubic meter

CS ICt50 = .01 gm/min/cubic meter

Step 2: Determine the volume of air in cubic feet of a given room.

Cubic feet = L x W x H

Step 3: Convert cubic feet to cubic meters.

Cubic feet = $\frac{\text{Cubic feet}}{36}$

Step 4: Determine the concentration of active agent within the volume of available O_2. Simply multiply the volume of the cubic meters of air with the predetermined constant.

Cubic Meters x Constant = Total Grams

Step 5: With this formula, you will be able to determine the number of munitions it would take for an agent to become lethal or incapacitating based strictly on this method. *Remember this is not a practical formula for your situations.* Simply divide the amount of available O_2 by the gram weight of the active agent of the specific munition.

$$\frac{\text{Total Grams}}{\text{Grams of agent}} = \text{Number of munitions}$$

Conversion calculators

Currently, if one uses a concentration formula, there are some values that can be established using a conversion calculator. There are a number of methods to calculate the weight of the agent and its dissemination process. By using a concentration calculator, the constant values can be entered into the calculator and the relative levels can be demonstrated in field terms — the number of specific munitions used to reach the concentration levels. Table 2 is a sample from the Combined Tactical Systems' beta calculator that can be used without the lengthy conversion process. By entering the total volume (LxWxH) and the type of munitions used (based on gram weight of the contained agent), the calculator will determine the number of munitions to be used to reach ICt50 and LCt50 in one minute. ***Again, keep in mind that the important distinction is that the concentration levels are less important than the time/exposure values for evaluating health risks.***

Respiratory tract effects

The most common route of absorption is by inhalation. In an LCt50 study, four species (rat, rabbit, guinea pig and mouse) were exposed to aerosolized CS powder for 5 to 60 minutes. The LCt50 values (based on mortality within 14 days) ranged from 50,010 mg/min/m3 in the mouse to 88,480 mg/min/m3 in the rat. No animal died during exposure. The lungs of the dying were congested and edematous, and many had hemorrhages. The trachea was congested with moderate amounts of mucous.[16]

Pyrotechnically dispersed smoke from a CS grenade was used in a similar study design with the same four species. The LCt50 values were 76,000 mg/min/m3 and 35,000 mg/min/m3 respectively. Again, no animals died during exposure. Those that died before 14 days were edematous and congested with areas of hemorrhage and excessive amounts of mucous in the trachea and bronchi. The alveolar capillaries and intrapulmonary veins were congested, with areas of alveolar hemorrhages and hemorrhagic atelectasis. A few had edema but no inflammatory cell infiltration was noted.[17]

In a follow-up study, the concentration levels were increased to factors well above the previous levels. In most of the deaths the investigators pointed to the presence of pulmonary edema and hemorrhages in the absence of inflammatory cell infiltration, suggesting that smoke caused direct damage to the pulmonary capillary endothelium and the main cause of death was pulmonary damage.

The effects of pyrotechnical forms of CS on these animals are different from liquid suspended forms. The pathology associated with the pyrotechnic forms has a lower ICt50 value and the mechanism for death is related to pulmonary edema rather than acute effects of the chemical agent itself. This seems to suggest that the high concentration of the compound associated with smoke particles lead to the edema and resulting conditions.

Comparative analysis to current data

NIOSH has posted the Immediate Dangers to Life or Health (IDLH) as 2 mg/m3 for one minute, the incapacitating level of CS for humans.

While there are relevant studies on animal species for the effects of CS, the effects on humans remain less rigorously examined. A consensus from the literature suggests that the IDLH levels based on the U.S. Army report from 1961 is a good baseline. They reported that a two-minute exposure to concentrations between 2 and 10 mg/m3 was considered "intolerable" by 6 of 15 persons.[18]

Grant (1974) reported that human volunteers have found concentrations greater than 10 mg/m3 to be extremely irritating and intolerable for more than 30 seconds because of burning and pain in the eyes and chest.[19, 20]

As illustrated by Table 2, the dose levels for detection of CS is very small compared to the lethal dosage. These are acute levels that bring the onset for the sensation of pain. The chronic exposures are largely unknown. However, in order to reach concentration levels of more than 2500 mg/m3, the CS must be delivered via pyrotechnic vaporization.

There are certain scientific relationships accepted for comparisons between animal and human studies. While toxicologists must face the dangerous business of extrapolating from animal studies to man, the epidemiologist is never certain about exposure levels and the many variables which may have been overlooked. The toxicologist, for example, looks at the two variables – dose and response – usually discussed on toxic effects, but a third variable – duration of administration – must be considered.[21]

First, as we know, there is little or no correlation between the laboratory studies such as the Edgewood Arsenal report and our current methods of disseminating CS. The only comparison that can be drawn is when the person is subject to inhaled pyrotechnic forms of CS within a completely airtight chamber. The dose required to reach the so-called ICt50 would reach incapacitating levels in less than one minute. What we cannot extrapolate is the concentration-duration effects, or the comparative value of liquid and aerosol forms of CS.

Another profound variable that is worthy of consideration is the carrier used to disseminate the CS particles. CS is not soluble in water and must have a carrying agent. There has been extensive review in the UK concerning the health risks of carriers for liquid and aerosol CS.[22] There is considerable research into other effects of CS such as ocular and dermal exposure risks. However, given the relatively low concentrations used by law enforcement, these reports were not included in this document.

Legal considerations

As ruled in *Graham v. Connor*, 490 U.S. 386 (1989), all claims that law enforcement officials have used excessive force — deadly or not — in the course of an arrest, investigatory stop, or any other "seizure" of a free citizen are properly analyzed under the Fourth Amendment's "objective reasonableness" standard, rather than under substantive due process standard, pp. 392-399 [490 U.S. 386, 387]. The factors to be considered in determining when the excessive force gives rise to a cause of action under 1983:

1. the need for the application of force,
2. the relationship between that need and the amount of force that was used,
3. the extent of the injury inflicted and,
4. whether the force was applied in a good faith effort to maintain and restore discipline or maliciously and sadistically for the purpose of causing harm.

One can argue and interpret data, especially data as subject to variables as this topic. But what is the process by which chemical agents (CS) should be deployed in hopes of incapacitating a person? The answer can be quite simple or equally complex, depending on your frame of reference, but still tends to bring the greatest level of controversy. It is based on the premise by which all actions involving the use-of-force are evaluated — *objective reasonableness.*

The application of chemical agents is based upon this doctrine and should be the primary consideration used in deciding whether the use-of-force involving the agents is reasonable. The reason this concept is so powerful and more useful is that it takes into account the totality of each circumstance. ***The ICt50 formula is blind to the concept of law.*** By using a calculation for concentration of CS, there is no account for those attributes used to determine objective reasonableness. As in other Fourth Amendment contexts, however, the *reasonableness* inquiry in an excessive force case is an objective one — the question is whether the officers' actions are *objectively reasonable* in light of the facts and circumstances confronting them, without regard to their underlying intent or motivation. See *Scott v. United States*, 432 U.S. 128,137-139 (1978).

Because the test of reasonableness under the Fourth Amendment is not capable of precise definition or mechanical application, [*Bell v. Wolfish*, 441 U.S. 520,559 (1979)], its proper application requires careful attention to the facts and circumstances of each particular case, including the severity of the crime at issue, whether the suspect poses an immediate threat to the safety of the officers or others, and whether he is actively resisting arrest or attempting to evade arrest by flight (*Tennessee v. Garner*, 471 U.S., at 8-9).[23]

So what is the reasonable action in the deployment of CS? As Rob Cartner (Tulsa PD, Ret.) and now training manager for the NTOA says, "It depends." It depends on the factors described in *Graham v. Connor*. The notion that we deploy chemical agents at the same concentration for every circumstance due to the ICt50 formula is contrary to the very case law by which the action is measured.

In over 30 years of active use of 1% CS, no lawsuits for damages have been awarded in the litigious environment of the United States.[24]

Sgt. Jim Clark (NTOA Legal Section Chair), with the assistance of Attorney Scott Wood (NTOA Legal Advisor), has completed an extensive search into litigation regarding the use of CS. To their knowledge there have been no U.S. 1983 actions or criminal cases filed against an agency regarding the use-of-force with CS. A survey of the NTOA members has confirmed the findings of Sgt. Clark and Mr. Wood by acknowledging no such reports. This would seem to support the notion that using a calculation formula does not protect from liability issues, since there are more agencies that do not calculate concentration levels than those who do.

The decision on the use-of-force using chemical agents should not vary from that of other force options. The force used is based on a case-by-case basis and analyzed on its specific circumstance.

Table 2 is an example of some deployment munitions for CS. The calculations are for a single room measuring 10 ft. x 10 ft. x 8 ft., equal to 800 square feet. The table demonstrates the differences between estimated incapacitation levels and lethal dose levels for one minute of exposure. Note that the number of munitions to reach that level must be airborne simultaneously and the subject must inhale the agent with no fresh air exchange.

Table 2

Munition type	ICt50	LCt50
12-gauge liquid CS ferret	.651 munitions	809 munitions
12-gauge powder CS ferret	3.04 munitions	3776 munitions
37mm liquid CS ferret	.061 munitions	76 munitions
37mm powder CS ferret	.207 munitions	257 munitions
37mm muzzle blast powder	.025 munitions	31 munitions
Pyrotechnic riot canister CS	.005 munitions	6 munitions
Flameless expulsion CS	.038 munitions	26 munitions
Stingball CS	.046 munitions	57 munitions

The reason for illustrating this method is to compare the relative values to that of current operational models that don't use the formula, so as to determine the reasonableness of the action. There is a discrepancy between values for the ICt50 current operation models used by most of the police in the U.S. The ICt50 values are much lower than what one would typically define as reasonably incapacitating. It surely does not apply to dynamic and life-threatening situations where larger amounts of agent would be reasonably justified.

As a practical matter, the table shows that even the use of one 12-gauge liquid ferret would require less than one round to meet ICt50 levels. If one were to rely on these formulas to calculate incapacitation dosages, even one round would exceed the ICt50 levels. If you are relying on this formula to argue a plaintiff's position that the application of CS was excessive, you would violate your own standards of care.

Review

There have been no documented human deaths directly associated with the application and exposure to CS.

There have been no documented reports of litigation regarding the concentration levels or injuries associated with the direct application of CS to humans.

The suggested incapacitation levels from the Edgewood Arsenal study are far lower than those determined by controlled studies with human subjects.

The lethal concentration levels of CS in a single application for short durations are so high that it would be improbable that it could be introduced into the environment during law enforcement applications.

Despite any extrapolations used from animal studies, all of them require a constant comparative value; they must be evaluated in a closed environment, with similar dispersion methods, for the same amount of time and with the same concentration of the agent. One cannot compare the existing studies with the application of liquid or powder dispersal systems or munitions in an open environment.

Practical deployment considerations

The crisis situation, first and foremost, will dictate tactics — not a formula. The totality of the circumstances will identify the need and the amount of force (chemical agents) used in the situation. There is no calculus to determine the amount of force needed for every use-of-force situation.

Example A: An intoxicated person shoots a hunting rifle into the air from his back porch. Police arrive and the subject, who has put the gun away, is refusing to exit. The tactical unit called to the incident may choose to introduce just the amount of CS they believe will be incapacitating in order generate a surrender and compliance.

Example B: Fugitive detectives determine through surveillance that a homicide suspect is fortified inside a residence. He fires 12 rounds at surveillance officers in a densely populated neighborhood. The tactical team called to the incident may choose to deploy higher levels of CS into more areas of the residence, all at once, in order to bring immediate incapacitation to the suspect.

"Hard and Heavy"

I prefer to call this the "measured" response to delivering chemical agents. In the event this method is used, one would still take into account linear escape considerations for the suspect.

This concept has generated some misconceptions. It does not mean that every tactical operation requires gross amounts of chemical agent. And it does not always mean the euphemism "more is better" is accurate. Although dare I say it, *sometimes more is better*. Again, it depends on the circumstances. The concept calls for the delivery of chemical agents quickly and with enough concentration to contaminate the entire stronghold location. It seeks to gain incapacitation quickly and definitively. The advantages of this method are at least twofold:

1. It minimizes the potential that the subject can recover or create defensive positions inside the structure. It also mitigates the opportunity for the suspect to formulate a counterplan.

2. It delivers the amount of chemical agent necessary to reasonably incapacitate the suspect, without the potential for extended exposure to higher levels of volleyed agent.

The potential downside to this methodology is that property decontamination becomes more difficult as the amount of agent is increased. As a team leader, I am, as anyone deploying chemical agents should be, cognizant of the cost and time associated with cleanup — regardless of the situation. However, the decision to use the hard and heavy method should not be related directly to the decontamination, but rather the level of safety for all those involved.

Out of respect for my agency and our command staff, I am sensitive to property damage claims as a result of chemical agent contamination. I reject the notion a formula can somehow mitigate those claims. The idea that we use some type of concentration calculation in order to mitigate civil property claims is, in my opinion, dangerous and unnecessary. If our use-of-force was reasonable and necessary, and we used sound common sense and judgment, the damage to property as a result is clearly a secondary issue. Most savvy risk managers involved in these claims understand the importance of regarding life priorities over property damage. And at the margin, it is far less a risk to cover property claims than negligent injury claims.

"Volley method"

This model seeks to introduce the agent incrementally as a function of time. From a safety standpoint, it is unlikely there will be a significant health risk to a suspect exposed to CS. However, as stated before, the concentration of the agent is less important than the exposure time regarding health concerns. If a volley method is used, by gradually increasing the concentration of agent in increments, the total time of exposure becomes an issue. For example, if the concentration levels exceed or maintain 10 mg/m3 for a sustained time, the potential for pulmonary damage increases. The advantages to the volley method are commonly twofold:

1. The suspect can choose to surrender before the CS reaches its highest estimated concentration levels.

2. The chemical agent is allowed to contaminate more areas through air movement and exchange.

Research demonstrates that there are many variables when considering the relative extrapolations between animal studies and humans. One common factor is that the concentration for short periods of time is less of a health concern than with the same concentrations for a longer period. Therefore, using the volley method would increase the time in which the subject is exposed to a given concentration. Care should be given to minimize the time exposure when practical.

One should consider, however, that the method of delivery must be balanced with the need for that level of force. Most of the barricade operations law enforcement agencies deal with are criminal arrest situations. If the suspect inside is subject to arrest and has refused a lawful order to exit, he or she is actively resisting arrest. The justification to use force in the form of chemical agents is a simple one — in contrast to the dangerousness of creating jeopardy by entering the structure where the suspect has tactical advantage.

The same would be true for a suicidal suspect. If we are actively trying to take the person into protective custody, it is a deprivation of his/her freedom. If the subject actively resists that attempt by law enforcement, then the need and the amount of force must still be justified.

There needs to be some consideration given to the experience of our colleagues in previous chemical agent deployments when considering the amount used in a barricade situation. For example, Brock Simon (LASD Ret.) was involved in hundreds of incidents where CS was deployed into a structure to incapacitate a person. His experiences regarding what worked, how much agent was reasonably effective and what he defined as a "successful outcome" can be valuable information. His experiences can then be compared to experiences with other agencies. From those, commonalities can be related to the individual officer's agency experiences in order to draw a conclusion about degrees of effectiveness. Again, these are only inferences.

Most police agencies do not perform the calculations for concentration levels prior to deployment. Most grenadiers have a general idea that reaching lethal dosages of CS is impractical. And some agencies have a general "floor plan" listing incremental volume footprints. But by and large, the grenadiers do not calculate the formulas for a variety of reasons. Some agencies may have commanders that insist on calculations. However, in the end, the commander's decision will be evaluated based on the reasonableness of the action, not the calculations.

For some end-users, and especially commanders, the use of a "scientific" calculation for determining the amount of chemical agent to use is appealing. But the formula in use today does nothing to generate liability protection or enhanced safety for the use of CS. In fact, a convincing argument can be made for not using it. If you know, or suspect, the ICt50 formula is not relevant and you continue to use it, the result could be challenged because you relied on information that was not scientifically valid or defensible in the first place. Nowhere else in law enforcement use-of-force is there a "scientific standard" that relies on a formula to evaluate degrees of force for every situation. The issue of concentration levels of CS is no exception.

The major manufacturers of CS agree. For years they have included the formulas in their training material, but not one of the manufacturers I spoke with concluded the ICt50 formulas are valid. They acknowledge that relying on these ICt50 formulas can and will eventually create a negative effect during litigation. Relying on these formulas, while knowing their irrelevance, will demonstrate our industry's failure to adopt reasonable standards for deployment of chemical agents. Therefore, in a partnership with the NTOA, the following manufacturers agree to discontinue the standard of deployment by which ICt50 formulas are used in teaching and in deployment considerations:

Combined Tactical Systems ....Don Brinton

ALS ....Mike Aultman

M/K Ballistics ....Mike Keith

Defense Tech/Fed Labs ....Michael Finley

Conclusion

The standard decision model for deploying CS into a structured location should be measured by the need and amount of force reasonable to incapacitate the person. **As a general standard or guideline, one could defend concentration levels based on a combination of limited clinical studies, previous experience and common sense.**

There should be no confusion about the concept of reasonableness. Police balance their use-of-force actions against this premise every day. The reasonable levels for CS concentrations depend on the circumstances and no formula will satisfy the requirements for every incident.

To meet minimal levels of CS concentration as to become incapacitating based on relevant comparative information, the determination to introduce CS into a closed structure can be based upon the following general guideline. Based on 800 square feet of volume with minimal air exchange, with one minute of exposure to reach incapacitation, here are some values to reach a concentration level of between 0.5 mg/m3 to 10 mg/m3.

(2) 37/40mm liquid filled frangible CS ferrets

(4) 37/40mm powder filled frangible CS ferrets

(4) 12-gauge liquid filled frangible CS ferrets

(6) 12-gauge powder filled frangible CS ferrets

Other munitions will depend on the gram weight of the agent, dispersion method and delivery system used. Changing circumstances will dictate changes in concentration levels.

The NTOA Less-Lethal Section does not recommend calculating concentration formulas for determining the amount of CS agent used during deployment. We do suggest caution when using very high concentrations of CS for long durations. ◆

Endnotes

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Additional related references are available in the less-lethal member file sharing section of www.ntoa.org.