THE EVALUATION OF CS AEROSOLS AS A RIOT-CONTROL AGENT IN MAN

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April 1960 CWLR 2365

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FOREWORD

The work reported herein was authorized by the U. S. Army Chemical Corps Research and Development Program, under Project 4C08-02-023, CW Biological Sciences Research (U), Task 4C08-02-023-04, Toxicology of CW Agents (U).

The work concerns the physiological responses of man to CS aerosols administered by the respiratory route. These data were considered especially important from a medico-legal point of view since large segments of a population in all states of health might come in contact with this agent.

Acknowledgments

This task was a joint effort of the Directorate of Medical Research, and many persons contributed an immense amount of time and effort to make it possible. Lt. Arthur N. DiNicola, USNR, Naval Liaison Medical Officer, participated daily in medical supervision of the volunteers. In addition, the pre-exposure and postexposure physical examinations were conducted cooperatively by most of the Medical Officers stationed at these Laboratories. The laborious task of maintaining a well-functioning wind tunnel was admirably accomplished by PFC Paul L. Paquette. Analyses of the aerosol concentrations were performed by Mrs. Ethyl Hackley and Mr. Jack C. London; other laboratory data were furnished by Mr. William A. Groff and Major Mary E. Sicks. Mr. William P. McShane aided in the overall smooth functioning of the program. The large amount of secretarial assistance required was ably given by Mrs. Martha Langan, and the statistical evaluations were computed by Dr. John Atkinson. Administrative duties were accomplished through the efforts of Lt. Joseph T. McCullen and M/Sgt I. Ditchkus. Finally, we must acknowledge all the Army Chemical Center personnel who volunteered to be exposed to CS and without whom the program could not have been accomplished.

DIGEST

The object of the work reported herein was to determine the effects on man of CS aerosols in order to be able to standarize CS as a riot-control agent.

On the basis of the work done it is concluded that:

1. CS is a relatively nontoxic harassing agent and is stable and effective over a wide temperature range.

2. It is effective at very low concentrations and produces incapacitation either by affecting the eyes, the respiratory tract, or both.

3. It acts rapidly at first but is not persistent.

4. It has produced no adverse effects when used repetitively or on persons afflicted with mild hypertension, bronchial asthma, hay fever, hepatitis, or peptic ulcers.

5. The effects are the same in both elderly and young persons.

6. If it is used against subjects who are hyperventilating, its effectiveness is greatly accentuated.

7. Therapy has not been found effective or necessary at this time. Talking with a person with severe chest symptoms is sufficient to give him rapid relief.

8. There has been little tolerance developed to this agent.

CONTENTS

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I. INTRODUCTION.

The possibility of using CS to replace CN and DM as a riot-control agent necessitated a detailed study of the effectiveness of this compound on man.

Crichton,[1] Gongwer. et al.,[2] and Weimer et al.[3] reported that the toxicity of CS is of a low order in all species studied. Autopsies performed on animals either dying or sacrificed after administration of CS revealed a minimal amount of pathology. The salient finding was an increase in the number of goblet cells found in the respiratory tract and conjunctiva following exposure to high airborne doses (20,000 to 30,000 mg min/cu m).

Since CS has a very low degree of toxicity and a high degree of potency as a sternutator and lacrimator, it was deemed important to pursue an intensive study of the effects of this compound on man.

II. EXPERIMENTAL PROCEDURE.

This study used both military and civilian personnel as volunteers. Each volunteer's medical history was taken and he was given a pre-exposure and postexposure examination. Appropriate tests, such as chest X-ray, electrocardiogram, urinalysis, or liver-function studies, were performed at the discretion of the examining medical officer. Volunteers were rejected, accepted as normal, or placed in one of four special exposure categories.

Normal subjects were divided into four groups to establish baseline exposure data for comparison with other results. In the first group were untrained men who did not have protective masks, in the second were untrained men with masks available, in the third were trained men without masks, and in the fourth were trained men with masks available. The trained volunteers had previous experience with the agent; the untrained volunteers had never had a previous exposure. When a protective mask (M9A1 or M17) was available, it was carried in its closed carrier by the subject, who was instructed to use it upon noting any effects of the agent. At no time were possible effects discussed with the volunteers. Prior to exposure, all men received instructions in the use of protective masks.

Normal subjects under climatic conditions of 0°F and 95°F were exposed (10 exposures) while hyperventilating to CS combined with DM. Before the exposure, the subjects were instructed to tolerate the CS as long as possible. Time to incapacitation was measured as the time at which a subject could no longer tolerate the agent and was allowed to leave the chamber. Naturally, this varied with individuals and was related to the person's threshold of pain and his motivation. These are variables that could not be controlled. All subjects were examined and interviewed by a medical officer immediately after the exposure and again 2 to 4 days later.

In the first of the special categories were placed subjects who showed hypertension with a diastolic pressure between 80 and 110 mm Hg or normotension with a history of of hypertension. These subjects had a pre-exposure EKG, Chest X-ray, NPN, and urinalysis, all of which were within normal limits. In the second category were those subjects liable to hay fever, drug sensitivity, or bronchial asthma. Those with asthma had a chest X-ray that was interpreted as normal. In the third category were placed subjects who had a history of jaundice or hepatitis (sulfobromophthalein retention considered normal at 45 minutes) along with those having a history of peptic ulcers unaccompanied by gastrointestinal bleeding. Subjects between 50 and 60 years of age were placed in the fourth category.

Four subjects at a time were exposed in a wind tunnel[2] (working-enclosure section 8 x 8 x 8 feet) at a fixed wind speed of 5 mph.

Airborne samples of CS were collected isokinetically at nine points spaced equidistantly over the cross-sectional area of the wind-tunnel exposure section. The sampling cycle was continuous; that is, it was started before the dissemination of the agent and terminated 1 minute after dissemination was completed. Samples for particle-size estimation were collected with a six-stage, modified-cascade impactor during the exposures. Estimation of the airborne concentrations was made by ultraviolet-light absorption at 260 mu using a Beckman DU Spectrophotometer. CS was disseminated from a 10% solution in acetone, from a 10% solution in methylene dicholoride, or from a miniature M18 thermal grenade.

Spray nozzles (Spraying Co., Type J) placed at the air intake of the tunnel were used to disseminate the CS from the solution.

III. RESULTS AND DISCUSSION.

A. General.

The mass-median diameters of the particles produced were 3.0, 1.0, and 0.5 microns from the CS-acetone spray, the CS-methylene dichloride spray, and the miniature M18 CS thermal grenade, respectively. Particles of this size should penetrate into and deposit along all regions of the human respiratory tract.[4]

The data listed in table 1 show the results of exposures of untrained men without protective masks to CS dispersed from a CS-acetone solution.

TABLE 1

EFFECTIVENESS OF CS AEROSOLS ON UNTRAINED SUBJECTS WITHOUT PROTECTIVE MASKS

Concentration	Number of men	Time to incapacitation
mg/cu m		sec
5	4	43 - 48 - 48 - F*
12	4	19 - 22 - 24 - 43
23	3	21 - 21 - 21
32	3	21 - 21 - 21
35	2	17 - 18
40	3	11 - 20 - 20
59	3	14 - 25 - 25
60	8	10 - 11 - 11 - 12 - 17 - 18 - 19 - 21
61	3	15 - 15 - 15
66	6	10 - 13 - 14 - 14 - 15 - 20
69	2	17 - 18
83	5	13 - 14 - 21 - 22 - 30
94	6	12 - 13 - 14 - 15 - 20 - 33
111	3	20 - 21 - 21
112	6	7 - 8 - 8 - 9 - 10 - 10
138	6	3 - 3 - 4 - 5 - 6 - 7
201	4	7 - 8 - 10 - 20
442	3	5 - 5 - 5

*F = able to tolerate agent longer than 120 seconds

Figure 1, appendix, shows expected response times for untrained men exposed to CS. Times for 1%, 16%, 30%, 50%, 84%, and 99% of the men to leave the chamber were estimated using the results of 146 exposures. The curves shown in figure 1, appendix, were calculated and drawn according to the method of Bliss [Bliss, C. I., The Statistics of Bioassay with special reference to the vitamins, Academic Press Inc., New York, 1952, pp 536-549]. Using 30 seconds to incapacitation as a criterion for an effective agent, it can be seen from this figure that 50% of the exposed subjects left the chamber at a concentration of 7 mg/cu m and that 99% left at approximately 70 mg/cu m. According to table 1, however, approximately 99% of the subjects left the chamber for all concentrations above 12 mg/cu m. If we assume that our volunteers were from a "normal population," there must be some variable that caused the discrepancy between the data and expected results. An explanation of this discrepancy may be found in the fact that a large percentage of people, during their first exposure, develop a panic reaction, especially at higher concentrations where respiratory symptoms predominate. All the symptoms and signs produced will be discussed later in this paper.

Many untrained persons having masks were unable to don and retain their masks at low concentrations of CS. Some men exposed to high concentrations, however, were able to mask well enough to remain in the contaminated atmosphere. It is known that the protective mask, when properly fitted, will protect fully against CS. If the men were unable to mask rapidly, panic was evident. Even though a large number of men were able to mask rapidly, they were forced to leave the chamber and remove their masks. Data for untrained men with masks available are listed in table 2.

The data listed in table 3 show the results of exposures of trained men without protective masks. Figure 2, appendix, shows expected response times for trained men exposed to CS. The curves in this figure were drawn using the method of Bliss referred to above. Again using 30 seconds to incapacitation as a criterion for an effective agent, it can be seen from this figure that a concentration of 9 to 10 mg/cu m forced 50% of the subjects to leave the chamber and that 99% of the subjects left at approximately 400 mg/cu m. The data in table 3 reveal, however, that 40 mg/cu m or greater were sufficient to incapacitate 100% of the subjects. In this case the explanation of the discrepancy may be found in the fact that persons who had been exposed to a high concentration at the time of their first exposure developed a fear of the agent. Even though the concentrations at a later exposure might be low, the time to incapacitation for trained men was shorter than expected. The airborne concentration during the sensitizing exposure apparently was one of the most important factors in determining how the volunteer would react to a subsequent exposure.

NOTE: Appendices are not included with this report.

TABLE 2

EFFECTIVENESS OF CS AEROSOLS ON UNTRAINED SUBJECTS WITH PROTECTIVE MASKS AVAILABLE

Concentration	Number of men	Time to incapacitation
mg/cu m		sec
13	6	F - F - F - F - F - F*
20	6	21 - 30 - F - F - F - F
33	7	10 - 10 - 10 - 20 - 41 - F - F
47	6	F - F - F - F - F - F
48	2	40 - 51
52	2	21 - 31
64	2	24 - 24
89	5	78 - 83 - 95 - F - F
124	3	11 - F - F
165	2	20 - 28
179	6	15 - 15 - 15 - 20 - 20 - 30

*F = able to tolerate agent longer than 120 seconds

TABLE 3

EFFECTIVENESS OF CS AEROSOLS ON TRAINED SUBJECTS WITHOUT PROTECTIVE MASKS

Concentration	Number of men	Time to incapacitation
mg/cu m		sec
4	4	37 - 46 - F - F*
5	1	F
10	6	18 - 20 - 22 - 31 - 40 - 41
17	6	23 - 25 - 27 - 27 - 30 - 47
40	3	11 - 21 - 21
49	3	6 - 7 - 7
61	6	13 - 15 - 16 - 18 - 19 - 30
64	1	15
76	2	4 - 12
83	2	14 - 16
92	7	7 - 10 - 11 - 14 - 15 - 17 - 18
108	2	21 - 21
141	3	12 - 14 - 25

*F = able to tolerate agent longer than 120 seconds

The data in table 4 show that there was no correlation between the concentration of CS and the time to incapacitation if a protective mask was available. The data do show, however, that a protective mask will protect the person if used correctly and rapidly. Figure 3, appendix, shows that there was no significant difference at low and medium concentrations between a group of trained and untrained men with protective masks available. At high concentrations not enough points of comparison between trained and untrained men were available to make a valid statistical judgment concerning significant differences, although past experience with the agent makes it doubtful whether any difference exists.

TABLE 4

EFFECTIVENESS OF CS AEROSOLS ON TRAINED SUBJECTS WITH PROTECTIVE MASKS AVAILABLE

Concentration	Number of men	Time to incapacitation
mg/cu m		sec
12	3	F - F - F*
26	3	41 - F - F
28	3	F - F - F
29	2	14 - 16
31	3	14 - F - F
39	3	50 - F - F
59	8	F - F - F - F - F - F - F - F
61	6	F - F - F - F - F - F
63	5	35 - 35 - 35 - 35 - F
82	3	46 - 50 - F
95	2	90 - 90
112	6	20 - 22 - 23 - 30 - 30 - F
128	4	15 - 19 - 25 - 30
135	5	25 - 28 - 43 - F - F
136	6	69 - F - F - F - F - F
146	4	14 - 35 - 40 - F
149	4	12 - 12 - 13 - 14
155	6	10 - 20 - 21 - 70 - F - F
164	6	16 - 20 - 49 - 58 - F - F
165	2	24 - F

*F = able to tolerate agent longer than 120 seconds

There were no significant differences noted in the time to incapacitation in those subjects exposed to CS at 0° F and 95° F. When higher temperatures were used (95° F, RH of 35% and 97%), the men appeared unable to tolerate the agent as well as persons exposed to it at ambient temperature. However, the decreased tolerance was not great. It is uncertain whether this was because of the agent, the uncomfortable climate, or a combination of both. Certainly, skin-burning symptoms were much more prominent and this was because of excessive diaphoresis. The data for these exposures are reported in table 5.

TABLE 5

THE EFFECT OF TEMPERATURE ON THE INCAPACITATION TIME OF CS AEROSOLS ON UNTRAINED SUBJECTS

Temp	RH	Concentration	Number of men	Time to incapacitation
° F	te %	mg/cu m		sec
		8	3	20 - 24 - 24
95	35	11	2	4 - 4
		40	3	4 - 5 - 5
95	97	36	1*	12
		5	4	11 - 19 - 21 - 30
0	—	36	3	22 - 25 - 27

* Trained volunteer without a protective mask

To test the ability of men to work in a CS-contaminated atmosphere, subjects were given 50 simple addition problems to solve before, during, and after exposure to a low concentration of CS (4 to 5 mg/cu m). Since most of the men could not remain in the atmosphere long enough to complete the problems, the time for completion was extrapolated from the number of problems completed in the measured time. As can be seen from table 6 there was a significant difference in time to complete the problems since the least difference to be significant is 1.17 minutes. Accuracy was not impaired except in one individual, who was unable to tolerate the agent and had lingering conjunctival aftereffects; he was able to complete only four problems during exposure. Protective masks were not used in this phase of the experiment.

TABLE 6

EXTRAPOLATED TIME TO COMPLETION AND ACCURACY FOR FIFTY ADDITION PROBLEMS BEFORE, DURING, AND AFTER CS EXPOSURE

Subject no.	Before		During		After	
	Time	Accuracy	Time	Accuracy	Time	Accuracy
	min.	no. wrong	min	no. wrong	min.	no. wrong
1	8.0	0	12.0	0	7.5	0
2	9.2	2	12.0	0	7.0	2
3	7.0	1	7.5	0	6.0	2
4	9.9	1	12.5	36*	8.3	16*
5	11.5	1	13.5	4	9.2	3

Note - Least significant difference in time was 1.7 min.

* Too few problems were solved to be significant.

In another group of subjects, a test of visual acuity consisted of "dry firing" (triangularization) a rifle before and during CS exposure. In this phase, protective masks could be worn as soon as any indication of the aerosol was present. These data are summarized in table 7. Several men could not finish the task since the signs that persisted after donning the mask precluded any visual test. Measuring accuracy from the area of the triangle formed indicated that there was no significant difference before and during exposure.

Hypertensive individuals (table 8) reacted similarly to and were able to tolerate CS as well as normotensive subjects. However, as can be seen in table 9, their blood pressures had a greater elevation and were sustained for a longer period of time than the normotensive persons. This probably resulted more from the stress engendered by the situation than from the agent. There was no symptomatology that could be ascribed to the sudden rise in blood pressure, and these men recovered from the effects of CS as rapidly as a "normal" group.

TABLE 7

TIME AND ACCURACY OF TRIANGULARIZATION FIRING TESTS DURING CS EXPOSURE
(Untrained subjects)

Run no.	Concentration	Subject no.	Control (no CS)		Exposure to CS
			Without mask	With mask	Without mask
	mg/cu m				sq mm*
		1	–	–	**
1	25	2	12	14	23
		3	9	18	10
		4	–	–	**
		1	15	16	152
2	20	2	–	–	**
		3	23	4	27
		1	252	70	76
		2	6	4	168
3	5.1	3	162	15	25
		4	63	11	6
		1	–	–	**
4	70	2	–	–	**
		3	450	55	45

* Area of triangle formed by three shots

** Unable to complete task because of effects of CS

TABLE 8

THE EFFECT OF CS AEROSOLS ON-UNTRAINED SUBJECTS WITH A HISTORY OF HYPERTENSION, JAUNDICE, HEPATITIS, OR PEPTIC ULCER, OR OVER THE AGE OF 50

Description of subjects	Concentration	Number of men	Time to incapacitation
	mg/cu m		sec
History of hypertension	31	3	11 - 12 - 20
History of jaundice,	33	3	13 - 13 - 14
hepatitis, or peptic ulcer	64	3	9 - 15 - 18
	5	5	16 - 18 - 20 - 48 - F*
Over the age of 50	35	4	18 - 22 - 24 - 29

*F = able to tolerate agent longer than 120 seconds

TABLE 9

THE EFFECT OF CS AEROSOLS ON BLOOD PRESSURE IN NORMAL AND HYPERTENSIVE SUBJECTS

(Untrained subjects)

Blood pressure of subjects	Subject no.	Pre-exposure blood pressure	Immediate post-exposure blood pressure	Time for blood pressure to return to normal
				min
	1	134/88	170/120	3
	2	118/76	124/80	–
	3	120/85	120/85	–
Normal	4	120/90	120/90	–
	5	124/90	138/90	3
	6	128/84	138/92	2
	1	146/106	168/108	15
	2	138/100	130/98	–
	3	120/70	180/120	11
Elevated	4	140/80	160/110	17
	5	140/110	182/118	8
	6	130/98	158/132	6

Subjects with a history of peptic ulcer, jaundice, or hepatitis and those between the ages of 50 and 60 reacted similarly to normal subjects. These data are summarized in table 8.

Persons with a history of drug allergy, hay fever, asthma, or drug sensitivity were able to tolerate the agent as well as the "normal" population with respect to ability to remain in the atmosphere. It was noted, however, that a higher percentage of this group had more severe chest symptoms than would have been expected from the "normal" group exposed to a similar concentration. Many of them lay prostrate on the ground for several minutes. At no time were any wheezes or rhonchi heard on auscultation. The breathing of one volunteer was marked by a prolonged expiratory phase that disappeared after coughing. The recovery time was as rapid as for any other group of individuals similarly affected (table 10).

TABLE 10

THE EFFECT OF CS AEROSOLS ON UNTRAINED SUBJECTS WITH A HISTORY OF BRONCHIAL ASTHMA

Concentration	Number of men	Time to incapacitation
mg/cu m		sec
14	6	10 - 13 - 15 - 16 - 21 - 24
21	7	40 - 50 - 52 - 53 - 55 - F - F*
22	3	14 - 17 - 20
39	5	12 - 13 - 14 - 17 - 57
61	5	13 - 14 - 22 - 56 - 56
73	7	8 - 9 - 9 - 10 - 11 - 13 - 14

*F = able to tolerate agent longer than 120 seconds

Hyperventilating subjects, with or without masks available, were incapacitated at much lower concentrations than normally breathing subjects. Their recovery time was slightly prolonged, but this was only in the range of 1 to 2 minutes. Eye symptoms were negligible, possibly because the time of exposure was short and the chest symptoms were severe enough to mask any eye effects that were present. These data are presented in table 11.

TABLE 11

THE EFFECT OF CS AEROSOLS ON UNTRAINED SUBJECTS HYPERVENTILATING

Protective mask	Concentration	Number of men	Time to incapacitation
	mg/cu m		sec
Yes	10	3	23 - F - F*
	18	4	13 - 41 - 55 - F
	33	4	10 - 11 - 20 - 22
	89	4	17 - 20 - 22 - 24
No	10	3	12 - 13 - 13
	13	3	9 - 12 - 13
	39	3	6 - 9 - 9

* F = able to tolerate agent longer than 120 seconds

The data reported in table 12 indicated that the subjects exposed to CS disseminated from a CS-methylene dichloride solution could tolerate the agent for a slightly longer period than those subjected to CS-acetone solution. However, this should not be considered a significant difference.

Time to incapacitation in subjects exposed to CS disseminated from the miniature M18 CS smoke grenade was not significantly different from the incapacitation time of subjects exposed to CS dispersed from a solvent (table 13).

Table 14 summarizes the data obtained from subjects who were exposed to combinations of DM and CS. It can be seen that if the CS was potent enough to be effective in less than 30 seconds, the effects of DM were negligible. On the other hand, most men exposed for a period longer than 30 seconds (groups 4 and 5) developed symptoms and signs referable to both agents, and these were apparently severe enough to discourage any further volunteering by these same men. Invariably, all men developed symptoms because of CS regardless of concentration or length of exposure. For DM to be effective, however, the concentration had to be fairly high and the length of exposure greater than 30 seconds. It was deemed inadvisable to further increase the dose of DM because of possible toxic hazards.

TABLE 12

THE EFFECT ON MAN OF CS AEROSOLS DISSEMINATED FROM A CS - METHYLENE DICHLORIDE SOLUTION

Subjects	Concentration	Number of men	Time to incapacitation
	mg/cu m		sec
Trained	6	2	50 - F*
	12	4	15 - 19 - 23 - 25
	43	2	31 - 32
	117	2	23 - 26
Untrained	5	2	F - F
	9	5	20 - 20 - 24 - 32 - 35
	28	2	24 - 33
	71	3	10 - 30 - 41
	143	5	10 - 10 - 10 - 10 - 12
	118	5	10 - 11 - 13 - 15 - 21

*F = able to tolerate agent longer than 120 seconds

TABLE 13

THE EFFECT ON UNTRAINED SUBJECTS OF CS AEROSOLS DISSEMINATED FROM A MINIATURE M18 SMOKE GRENADE

(Burning time of grenades: 15 or 30 seconds)

Concentration	Number of men	Time to incapacitation
mg/cu m		sec
11	3	36 - 36 - 64
38	3	10 - 14 - 14
64	3	10 - 14 - 14

TABLE 14

THE EFFECT ON UNTRAINED SUBJECTS OF COMBINATIONS OF CS AND DM AEROSOLS

Group no.	Number of men	Concentration		Time to incapacitation	Comments
		DM	CS		
		mg/cu m		sec	
1	5	4.0	4.0	30	Mild to no conjunctivitis; one man had nausea and vomited after lunch but retained his appetite. The same man had "butterflies" in his stomach for several hours.
2	4	5.3	5.3	60	Allowed to mask upon first symptom after entering the chamber that was filled with the agent; all men were hyperventilating and masked immediately upon entering the chamber; no symptoms or anoxia.
3	5	7.2	7.2	20-60	One man had diarrhea twice; one had slight nausea before lunch (about 2 hours after exposure) and found relief by eating.
4	2 1 3	60.0	21.0	30 50 60	Severe conjunctivitis - 6/6; blepharospasm - 3/6; unable to function adequately for 1 hour - 5/6; stuffed nose - 2/6; aching gums - 1/6; irritating frontal headache - 4/6.
5	5	109.0	18.0	38-60	Severe eye burning and conjunctivitis - 5/5; burning of nose - 5/5; nausea - 5/5; vomiting - 0/5; headache - 3/5 (remained 2 hours in one person); discomfort in teeth and gums - 2/5; diarrhea - 5/5; sneezing - 2/5. All felt very bad for 15 to 30 min and four were not fully recovered for 2 hours.

A group of seven men given 10 exposures to concentrations of up to 13 mg/cu m of CS (table 15) in a period of 15 days revealed no clinical abnormalities except for a rising value of the thymol turbidity in one volunteer. It is interesting to note that whichever symptom, i. e., chest or eye, predominated in any one individual in the initial exposure remained the dominant symptom upon repeated exposures. No volunteers appeared able to develop a tolerance to this agent during these 10 exposures.

Throughout these studies many persons tried to "beat" the agent by holding their breaths, closing their eyes, breathing quietly, or opening their belts (to allow for more shallow breathing). None of these acts were successful in allowing them to tolerate the agent indefinitely. Some persons, however, tolerated very low concentrations (1 to 3 mg/cu m) for as long as 4 minutes. At no time were there any positive physical findings other than those noted from intolerable exposures, and there was no indication that any subject had suffered adverse effects.

The symptoms and signs produced by exposure to CS aerosols remained remarkably constant; only the duration and severity varied during different phases of this study. Symptoms can be classified as major and minor as follows:

B. Major Symptoms.

1. Eyes.

Eyes were affected by instantaneous and severe conjunctivitis accompanied by burning and pain that persisted 2 to 5 minutes and usually disappeared abruptly rather than gradually. The conjunctivitis itself remained intense for periods up to 25 to 30 minutes, but the volunteer was asymptomatic after 45 minutes. Erythema of the eye lids was generally present and persisted for an hour. Erythema was occasionally accompanied by blepharospasm. Lacrimation was invariably present and, at times, tended to be profuse, lingering for as long as 12 to 15 minutes. Occasionally, the volunteers complained of a "tired feeling" in their eyes lasting about 24 hours. At times, photophobia occurred and remained up to 1 hour; this was quite marked in about 5% to 10% of the volunteers. One person noticed poor dark-adaptation in the evening following exposure. These eye symptoms were regularly reproduced with repeated exposures.

2. Respiratory Tract.

The symptoms referable to the respiratory tract were potentially the most capable of causing incapacitation. The symptoms and signs generally varied directly with length of exposure and depth of respiration.

TABLE 15

CLINICAL LABORATORY FINDINGS IN MEN AFTER REPEATED EXPOSURES TO CS AEROSOLS

(A = control values; B = postexposure values; C = 2 - month postexposure values)

Subject no.	Electrolytes*				Liver - function studies **								Urinalysis				Chest X-ray	
	Sodium		Potassium		BSP		Alkaline phosphatase			Thymol turbidity			Albumin		Sp gr			
	A	B	A	B	A	B	A	B	C	A	B	C	A	B	A	B	A	C
	meq/el				% reten in 45 min		Bodansky units											
1	139	140	3.7	4.2	–	–	–	0.43	2.0	1.7	4.6	4.0	neg	neg	1.018	1.020	neg	neg
2	139	135	4.6	4.5	0.0	2.1	3.54	0.84	1.2	1.4	0.4	3.8	neg	neg	1.017	1.024	neg	neg
3	135	139	4.3	4.5	–	–	3.12	1.19	5.0	3.6	9.0	4.8	neg	neg	1.019	1.022	neg	neg
4	130	141	4.0	4.5	3.5	2.3	3.02	0.22	–	0.6	4.3	–	neg	neg	1.020	1.015	neg	neg
5	131	139	3.9	4.6	2.3	2.3	4.06	0.75	2.6	2.3	4.8	4.5	neg	neg	1.022	1.014	neg	neg
6	126	137	3.9	4.4	0.0	2.6	3.02	0.97	2.5	0.0	3.3	2.0	neg	neg	1.016	1.023	neg	neg
7	131	142	5.3	4.8	7.0	3.5	2.60	0.97	3.8	0.9	5.2	15.6	neg	neg	1.018	1.023	neg	neg

* Normal values: sodium - 135 to 145 meq/el; potassium - 3.5 to 4.5 meq/el

** Normal values: sulfobromophthalein - 0% to 6% retention in 45 min; alkaline phosphatase - 1 to 4 Bodansky units; thymol turbidity - 1 to 5 units

Usually the first symptom noted was "burning" beginning in the throat and progressing down the respiratory tract; this was sometimes associated with coughing. As the exposure continued, this burning became painful and was rapidly followed by a "constricting sensation" throughout the chest. This latter symptom, if present, invariably produced incapacitation for several minutes. Panic usually accompanied and accentuated this symptom and persons so affected appeared unable to either inhale or exhale. No therapy other than fresh air and encouragement was necessary. Auscultation of the chest immediately after exposure never revealed wheezes, rales, or rhonchi. Air-way resistance, as measured by the Asthmometer, developed by Dr. J. Clements of these Laboratories, showed no significant change (table 16); however, this measurement could not be made until the volunteer was breathing adequately (usually 2 to 4 minutes after the exposure). A Portable Breath Recording Apparatus as used by Dr. F. Craig to measure the breathing patterns of exposed persons verified the clinical observations that persons involuntarily gasped when the aerosol was inhaled and then held their breath or breathed slowly and shallowly. This frequently was followed by short paroxysms of coughing that forced the individual to leave the cloud. An irregular rhythm of respiration was noted for several minutes after exposure was terminated. A large percentage of individuals were aphonic for 1 to 2 minutes post exposure and several persons were hoarse for 24 hours.

TABLE 16

THE EFFECT OF EXPOSURE TO CS AEROSOLS ON AIRWAY RESISTANCE*

Subject no.	Control	After 4th exposure	After 10th exposure	24 hr after last exposure
		cm H_2O**		
1	1.94	1.80	2.01	1.99
2	4.38	3.11	2.67	3.28
3	2.50	1.16	–	1.79
4	3.61	2.96	2.91	3.04
5	2.50	2.68	4.23	2.78
6	2.85	2.64	2.41	1.83
7	3.32	3.29	2.97	3.32

* These measurements were made on seven subjects exposed repetitively (10 exposures) to CS aerosols.

** The normal range is from 1 to 3 cm H_2O but occasionally goes up to 3.5 cm H_2O.

C. Minor Symptoms.

1. Ear, Nose, Throat.

Usually there was mild to moderate burning of the nares and throat. This was more irritating than incapacitating and disappeared readily in fresh air. Rhinorrhea and salivation were profuse and at times persisted for 12 hours. The nasal mucosa occasionally appeared mildly erythematous. Several persons working with this agent developed minor epistaxis that was self-limited and nonrecurring. One individual who had partial deafness for over 30 years had remarkable subjective improvement in hearing; audiometry revealed no objective improvement.

2. Taste.

There was some taste perversion for substances such as cigarettes and carbonated beverages. This remained for about 30 minutes after exposure; the taste of food usually remained unaltered.

3. Sinuses.

Persons with a long history of sinusitis invariably felt relieved after exposure; at times this was dramatic and many such afflicted persons volunteered for additional exposures. This relief was possibly caused by the expulsion of a large amount of secretion from the sinuses. In line with this, many persons with "head colds" obtained immediate prolonged relief of symptoms.

4. Cardiovascular Changes.

Hypertensive changes in hypertensive volunteers exposed to CS have been discussed above. One man developed acute auricular fibrillation that lasted about 4 hours and reverted without therapy. This individual had a 20-year history of arrhythmia following stress situation, and this apparently was the first time it had been documented by an EKG. (He would have been automatically rejected as a volunteer had he mentioned this fact during his pre-exposure examination.)

5. Gastrointestinal Symptoms.

Nausea was a minor symptom and did not occur with regularity; it was most prevalent when the exposure closely followed food ingestion and was rapidly alleviated by fresh air. Vomiting did not occur. Diarrhea occurred in a very small group of men (about 1%) and was severe in one individual, lasting about 8 hours. This person was well the

following day. Six individuals developed eructation lasting from 1 to 7 days; this was not associated with food ingestion, and there was no accompanying gastrointestinal symptomatology.

6. Genitourinary Symptoms.

Occasional burning of the external genitalia was noted during micturition, probably resulting from residual amounts of the compound coming in contact with a moist area.

7. Central Nervous System.

Generalized headache and lethargy occurred rarely, and these symptoms were never severe enough to incapacitate the individual or prevent him from returning to his normal duties. Several men did develop malaise for 24 hours after exposure.

8. Skin.

Burning occurred on exposed areas and was greatly accentuated by moisture such as perspiration, lacrimation, rhinorrhea, or sialorrhea. The burning remained for several hours and recurred upon washing the exposed areas or the hair. Heavy exposure (for example, in personnel working in the manufacturing plant) produced vesiculation and erythema on exposed areas that at times resembled second-degree burns. Patch tests were made on volunteers using CS, EA 2078 (decontamination product of CS and Clorox), 10% CS in methylene dichloride, and 20% CS in methylene dichloride. These results are summarized in table 17. Both CS and EA 2078 are potentially severe skin irritants.

D. Therapy.

No therapy has been necessary, and it is difficult to visualize any therapy that would be as effective as fresh air. Merely talking with a subject with severe chest symptoms seemed sufficient to bring rapid relief. It is not known at present how long these persons would have remained casualties if they were left to themselves. If the respiratory disability were secondary to reflex laryngospasm, it is possible that this reflex could be maintained by panic until cerebral anoxia produced unconsciousness and perhaps death. Drugs such as epinephrine and isoproterenol did not relieve the respiratory signs. Prophylactic atropine (P.O.) had no effect on the onset of persistence of symptoms. No drugs were used to treat the conjunctivitis, blepharitis, or pain in the eyes; probably any anesthetic ointment, such as tetracaine, would be entirely effective, if needed. Decontamination of the skin with such agents as Clorox (a commercial bleach), alcohol, and sodium bicarbonate paste were all unimpressive. In fact, as noted before, when Clorox is combined with CS, the "decontamination" product is quite irritant to the skin.

TABLE 17

THE EFFECT OF VARIOUS COMPOUNDS ON THE SKIN OF MEN

No. of men	Compound	Results
3	Malononitrile	No reaction
3	o-Chlorobenzylidene	2/3 – pruritus without objective signs
3	10% CS-methylene dichloride	No reaction
4	20% CS-methylene dichloride	2/4 – slight erythema
11	CS (protected from air)	5/11 – no reaction; 2/11 – slight erythema; 4/11 vesicle formation with erythema and sloughing
4	CS (porous gauze covering)	4/4 –vesicle formation surrounded by erythema
4	EA 2078* (protected from air)	4/4 – severe reaction with vesicle formation, erythema, sloughing, and induration; actual second - to third - degree burn
4	EA 2078 (porous gauze covering)	4/4 – same as above, more extensive

* "Decontamination" product formed by combining CS with Chlorox (a commercial bleach), alcohol, and sodium bicarbonate paste were all unimpressive. In fact, as noted before, when Chlorox is combined with CS, the "decontamination" product is quite irritant to the skin.