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AN IMPROVED AGENT FOR RIOT CONTROL: COMPARISON OF THE EFFECTIVENESS OF CR AND CS AS "TEAR SMOKES"

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by

M.A.P. Hogg

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CDE TECHNICAL PAPER NO 62

DATE: APRIL 1971

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"TEAR SMOKES"

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SUMMARY

All available UK data on human exposures to aerosols of CS and CR has been collated and reviewed, in order to provide the best estimate of the difference in the effectiveness of the two compounds as riot control agents.

Probit analysis was used to obtain this estimate, and the results show that CR is about ten times more potent than CS in that a concentration of 1 mg/m^3 of CR will produce effects equivalent to those produced by a concentration of CS of 10 mg/m^3 , which is that normally considered appropriate for riot control.

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INTRODUCTION

CR was first tested as a riot control agent in 1961(1). These preliminary tests, done in comparison with CS, suggested that a given concentration of CR was "commensurate in physiological activity with a concentration of CS one order greater". The results of further, more complete comparative trials of the two agents were published in 1965(2). It was concluded, from the information gained in this series of trials that qualitatively there was little to choose between the two compounds as respiratory irritants, but that quantitatively CR was far superior to CS, in that "to get the same subjective effects as a given concentration of T 2806 (CR), a concentration of CS six times as high is required".

This report collates all the available UK data on chamber exposures of human subjects with CR in order to present a definitive comparison of the relative effectiveness of CR and CS as riot control agents, and to make the best possible estimate of the numerical factor which expresses the difference in their effectiveness.

METHOD

The limited availability of physiological test subjects prevented the undertaking of complete series of comparative trials of CS and CR on a statistically adequate scale, so that exposures to these agents have tended to be a somewhat piecemeal process, spread over a considerable period of time. This has led to inevitable variations in test technique and motivation of the subjects, with generally rather small numbers of individuals engaged in any particular experiment.

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The approach to the problem of reviewing this existing chamber exposure data was to calculate, for each test, in the conventional manner (3), the straight lines relating probits of the percentages of the men forced to leave the agent cloud with the logarithms of the concentrations of the agents. This approach, which has not been used before for evaluating the results of chamber exposures of riot control agents, has two advantages: (a) given the appropriate probit lines, the difference in the effectiveness of the two agents could be compared over a range of concentrations, and (b) computer calculation of the possible probit lines, using a standard programme, automatically ensured that the data were tested for statistical significance.

To analyse the data in this way it was necessary to adopt one (or more) criteria for defining the "end point" of the men's exposures. All the trials to be taken into consideration were of the type in which volunteer service men were exposed to the agents in gas chambers, the men being encouraged to stay for as long as possible, but allowed to leave whenever they felt they could withstand the agent no longer. It was clear, therefore, that the necessary criteria would have to be based upon the time for which men could withstand the agent exposure, and the most appropriate time criterion to use, was judged to be one minute: i.e. agent concentrations forcing men to leave the chamber in times of one minute or less would be those most appropriate for comparison. The use of higher concentrations, with the production of much more severe symptoms and shorter tolerance times, would have added greatly to the experimental difficulties without necessarily improving the precision.

PRELIMINARY ANALYSIS

Preliminary calculations using an unsorted combination of all available data give significant probit lines for both CR and CS based on the one minute criterion. Comparison of these lines showed that though the ratio of the effectiveness of the two agents at the 50% response level might be somewhat lower than the figure of 6.8 derived in PTP 930(2), the slope of the CR

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line was appreciably steeper than that for CS, so that the ratio would become significantly greater at the higher concentrations more appropriate for riot control.

These results were interesting and unexpected, but are not quoted, because data used for this preliminary comparison were unsorted in that, although only trials which were roughly comparable in procedure had been included, no attempt was made to "balance" the number and type of exposures used to derive the probit lines for each agent.

For a first check on the validity of the apparent variation in relative effectiveness with concentration, the "raw" experimental data of PTP 930(2) were used. From these the overall means were calculated of the concentrations to which each man leaving the chamber in a given time bracket was exposed. This gave the figures in Table 1.

TABLE 1

| (No. of men in brackets) | <u>MEAN CONCENTRATION (mg/m³)</u> | | <u>RATIO</u> |
|-------------------------------------|--|-----------|--------------|
| | <u>CS</u> | <u>CR</u> | <u>CS/CR</u> |
| Men leaving in 1st half minute | 5.4 (20) | 0.88 (16) | 6.2 |
| Men leaving in 1st minute | 4.7 (36) | 0.92 (39) | 5.1 |
| Men leaving in 2nd & 3rd minutes | 4.4 (12) | 0.79 (21) | 5.6 |
| Men staying for 4 minutes or longer | 2.5 (27) | 0.79 (10) | 3.2 |

These figures tended to confirm that the variation in effectiveness ratio suggested by the preliminary probit line analysis was real, and a more detailed analysis was therefore proceeded with.

DETAILED ANALYSIS

Firstly, probit lines were calculated, using the PTP 930 data only, for the following "end point" criteria.

- a. Men leaving in $\frac{1}{2}$ minute or less.
- b. " " " 1 " " "
- c. " " " 3 " " "
- d. " staying for 4 minutes or longer.

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It was found that no statistically significant comparisons could be made using this data alone, so that it became essential to take into consideration not only this homogeneous set of data, but all available data that could be regarded as appropriate for this analysis.

Additional data were selected, from the UK trials itemised below.

CS Exposures PTP 930(2), PTP 903(4). Two additional trials reported in PTP 651(5) and reference (6) respectively. Trials to Programmes 3/66 and 21/66(7).

CR Exposures PTP 813(1), PTP 930(2) and additional data, obtained under conditions closely similar to those of PTP 930(8). Trials to Programme 21/66(7).

In considering such an inhomogeneous collation of data it was obvious that at least three important experimental variables would be uncontrolled:-

- a. The form in which the agent was dispersed.
- b. The motivation of the men, which would be expected to differ according to the "task" that they had to perform during their exposures.
- c. Whether or not the men exposed had previous experience of exposure to one of the two agents in question.

Although the variation in all three of these within the trials quoted may still be appreciable, the selection has eliminated other trials in which it was almost certainly even larger. Thus data from PTP 776(9) has been omitted, and data from the exposures to Programmes 3/66 and 21/66(7), in which rifle-firing was the "task", were given as little weight as possible in the analyses because it was recognized that the nature of the task involved would be likely to give a higher than average level of motivation.

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Of the three variables, (c) may be regarded as the important. Thus, for example, PTP 930(2) gives data for 49 man-exposures to CS in which the men had had a previous exposure (to CR), but only 26 man-exposures to CR, in which the men had had a previous exposure (to CS).

In view of this overall variability in the data, every effort was made to make the comparisons with data populations that were as homogeneous as possible. In all, 26 probit analyses were carried out, using various "end point" criteria and sets of data. Many of these analyses had no statistical significance, but those giving, it is suggested, the best available estimate of the difference in the effectiveness of the two agents are described below.

RESULTS

The "Best Possible" Comparison between the Agents

This comparison uses probit lines based upon the one minute "end point" criterion. The main sources of data for the comparison were the CR exposures described in PTP 813(1) and PTP 930(2) with the additional data already referred to (8). This gave a total of 98 man-exposures, of which 78 were first-time exposures, but in 20 of which, the men had had a previous exposure to CS. Comparable CS data could only be obtained from the exposures of PTP 930(2), with the first-time exposures of PTP 903(4) and the two additional trials already mentioned. This gave a total of 127 man-exposures, 78 being first-time, and 49 involving previous exposures to CR. To "balance" the comparison as far as possible there were added to the CR data the results of 15 man-exposures from the first CR exposure in the Programme 21/66 trials (7): before this exposure the men had had a previous exposure to CS, so that the results are comparable with the extra 29 man-exposures in the CS data.

The probit lines computed from these data are shown in Figure 1, and the actual figures used for the computations are given in the Appendix, together with the parameters defining the probit lines.

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From the probit lines, the IC50's and IC75's for the two agents may be read, and these are compared in Table 2 below.

TABLE 2
COMPARISON OF EFFECTIVENESS OF CS AND CR

| | IC50 (mg/m ³) | IC75 = RIOT CONTROL CONCENTRATION (mg/m ³) |
|-----------------------|------------------------------|--|
| CS | 3.60 | 10.0 |
| CR | 0.66 | 1.1 |
| Ratio $\frac{CS}{CR}$ | 5.5 | 9.1 |

The ratio between the IC50's is therefore about 5, but the fact that the probit line for CR is appreciably steeper than that for CS means that the difference in effectiveness is greater at higher concentrations. Thus at the concentration levels which would normally be considered appropriate for riot control (ie the IC75's), CR is about ten times more effective than CS, since a concentration of CR of about 1mg/m³ will produce effects equivalent to those produced by a CS concentration of 10mg/m³.

CONCLUSION

Detailed analysis of the results of chamber trials involving the comparison of data from about 250 man-exposures, have shown CR aerosol to be about 10 times more potent than CS, as a riot control agent, since a concentration of 1mg/m³ of CR aerosol will produce effects equivalent to those produced by a CS concentration of 10mg/m³, which is that normally considered appropriate for riot control.

ACKNOWLEDGEMENT

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APPENDIX

Data used for Calculation of Probit Lines

| <u>CS Exposures</u> | | | <u>CR Exposures</u> | | |
|---|--|------------|---|--|------------|
| <u>Conc.</u> <u>mg/m³</u> | <u>No. of men out in</u> <u>1 min/</u> <u>No. of men exposed</u> | <u>Ref</u> | <u>Conc.</u> <u>mg/m³</u> | <u>No. of men out in</u> <u>1 min/</u> <u>No. of men exposed</u> | <u>Ref</u> |
| 0.26 | 0/6 | (6) | | | |
| 0.52 | 0/4 | (2) | 0.27 | 0/15 | (7) |
| 0.67 | 0/4 | (2) | 0.30 | 0/3 | (1) |
| 0.80 | 1/6 | (2) | 0.53 | 3/6 | (2) |
| 1.20 | 0/6 | (4) | 0.56 | 2/4 | (2) |
| 1.50 | 5/6 | (2) | 0.60 | 3/6 | (2) |
| 1.70 | 0/2 | (2) | 0.62 | 5/5 | (8) |
| 2.70 | 1/4 | (2) | 0.72 | 5/6 | (2) |
| 2.80 | 4/6 | (2) | 0.75 | 3/3 | (8) |
| 3.40 | 2/4 | (2) | 0.80 | 0/2 | (2) |
| 4.00 | 4/5 | (4) | 0.83 | 3/4 | (2) |
| 4.10 | 8/11 | (2) | 0.86 | 4/4 | (8) |
| 4.30 | 4/6 | (2) | 0.90 | 2/3 | (8) |
| 4.80 | 1/6 | (2) | 0.92 | 7/10 | (2) |
| 6.00 | 9/10 | (2) | 0.93 | 5/6 | (2) |
| 6.60 | 4/6 | (4) | 0.97 | 2/3 | (8) |
| 6.80 | 1/6 | (4) | 0.98 | 2/6 | (2) |
| 6.85 | 4/6 | (4) | 1.10 | 2/4 | (1) |
| 6.90 | 2/6 | (4) | 1.17 | 2/4 | (2) |
| 7.80 | 6/6 | (5) | 1.18 | 3/4 | (8) |
| 8.90 | 4/5 | (2) | 1.20 | 0/4 | (2) |
| 9.00 | 2/6 | (2) | 1.40 | 5/5 | (1) |

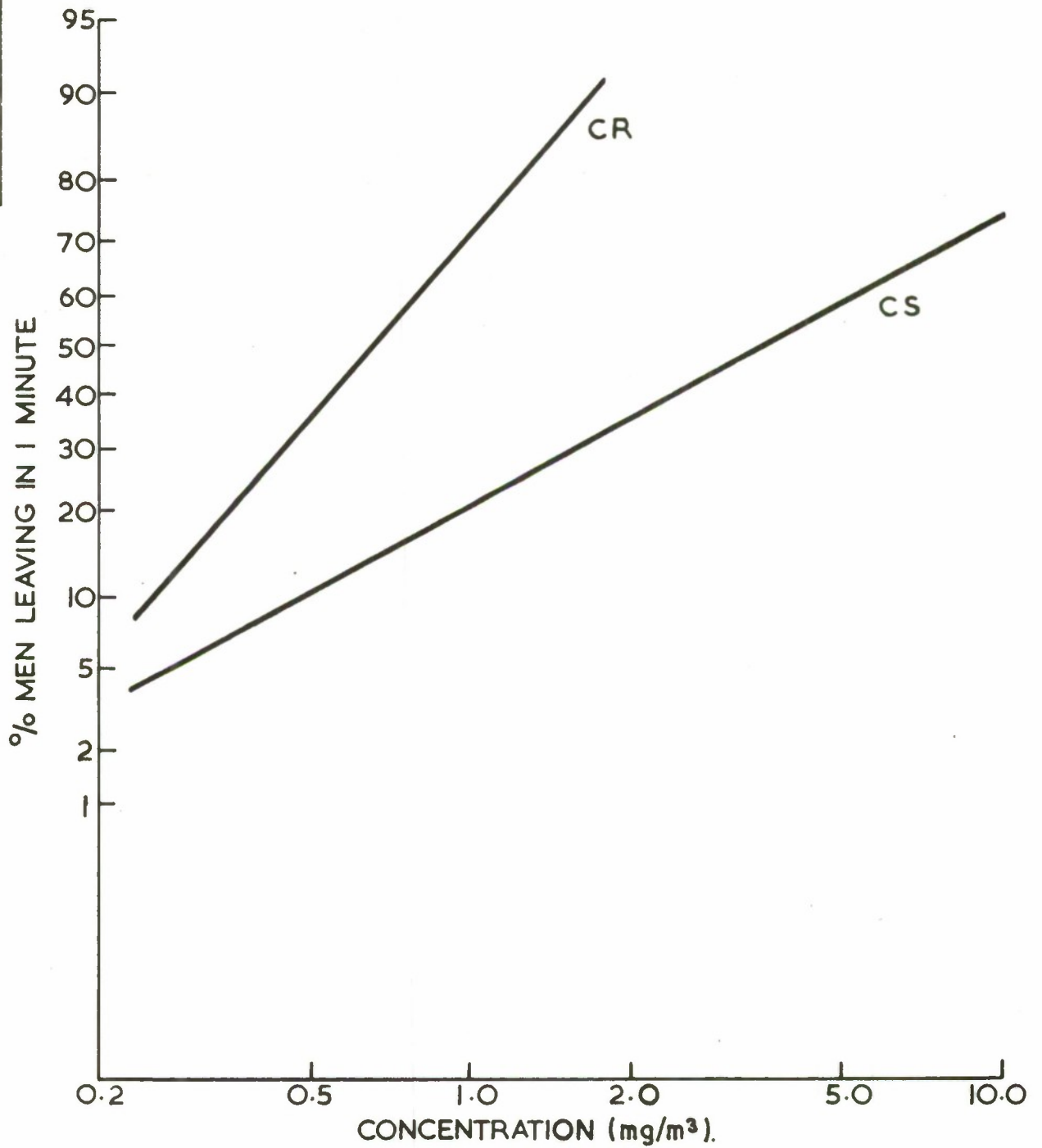
Parameters characterising Probit Lines:

| | <u>IC 50 (mg/m³)</u> | <u>95% Conf. Limits</u> | <u>Slope</u> | <u>SE of Slope</u> |
|----|---------------------------------|-------------------------|--------------|--------------------|
| CS | 3.60 | 7.74 - 1.64 | 1.47 | 0.48 |
| CR | 0.66 | 0.89 - 0.39 | 3.09 | 0.94 |

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PROBIT LINES FOR COMPARISON OF
EFFECTIVENESS OF CR AND CS.

FIG. I.

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