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For the Professional in Government, Industry and Academia with an interest in Nuclear, Biological and Chemical Defense, Disarmament and Verification; Chemical and Biological Terrorism; Emergency and Disaster Medical Planning; Industrial Health and Safety; and Environmental Protection.

Because of recent events and the fact that there is so much misinformation being provided to the public from all sources, ASA suggested to Prof. Meselson that we reprint this article with an update from him to precede the reprint. The original article received outstanding comments from scientists around the world.

Note Regarding Source Strength

by Professor Matthew Meselson

The "Note Regarding Source Strength" reproduced below is the same as that published in the ASA Newsletter of June 8, 1995, except for the correction of a typographical error (the omission of "pi") in the equation for dose in Table 1.

Note that source strength is defined as "the number of viable spores released at the source that travel in the atmosphere as particles small enough to initiate inhalation anthrax". Using this definition, the source strength estimates in Table IV are given in milligrams, taking the number of spores per milligram, as stated, as 10^9. The question of whether the aerosol released at Sverdlovsk consisted only of viable spores or also contained inviable spores and other material is obviously not addressed in the present estimates. These estimates should be regarded only as what they are: estimates of source strength, as defined in the note, that follow from the stated assumptions regarding atmospheric dispersion and regarding dose-response relations for the infectious aerosol and the human population exposed to it.

Although the present estimates follow from the assumptions made, the most relevant dose-response data available are for non-human primates, not for any human population, and none of it is for the low attack rates observed in the Sverdlovsk outbreak. Neither do we know if the virulence of anthrax spores in the aerosol released at Sverdlovsk was like that in aerosols employed in published experiments with monkeys. And even the well done experiments at Fort Detrick and Porton with monkeys gave ID_{50} values covering a more than twenty-fold range -- from 2,000 to 45,000 respirable spores. These uncertainties are only imperfectly addressed by considering a number of different dose-response relations, as is (cont. p. 10 - Source Strength)

From the ASA House in beautiful Maryland all of us wish for all of you a very successful and happy New Year 2002

We note with sadness that for many of our closest friends in the US and throughout the world, this past year 2001 has been most tragic. For all that have been touched by these events, and that does include almost all, our hearts and our minds are with you. We stand as one.

The ASA family of professionals can be found in 115+ countries and they are what the ASA Newsletter is all about. Have a great and have a safe 2002

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S. Registration Forms can be found at the web site: http://www.asanltr.com/cbmts/cbmts/IV/regform.htm and are to be completed/returned by e-mail or website before 28 February 2002. Pre-registration notification to include name, organization, address and tel/fax/e-mail numbers plus Abstract title, should be completed *as soon as possible*. Payment of fees by credit card (MC, VISA, Amex, Diners) is acceptable.

•• Note. The following is the priority for Dormitory rooms:
1. all individuals receiving assistance from the CBMTS Organizing Committee will stay at the Dormitory;
2. individuals from developing countries or from countries with economies in transition, who are paying their own registration, may stay at the Dormitory.
3. all other CBMTS participants on space available basis.

Note. The Dormitory will have separate areas for male and female participants and will have separate space for participants with their accompanying person.

T. Fellowships: Assistance for individuals to attend CBMTS IV. Limited to support of professionals from developing countries and countries with economies in transition. The requirements for fellowship consideration are that the individual submit a paper to be presented at the CBMTS IV and that the paper be approved by the Science Review Committee. The goal for the CBMTS Organizing Committees are to be able to provide:

- Registration Fee
- Accommodations at the Spiez Laboratory Dormitory
- Return fare to Zurich or Geneva and train to Spiez.

Recognizing that available funds for Fellowships will be very limited, the CBMTS Organizing Committee will more favorably consider specific requests for lesser amounts from individuals wishing to attend. Ask ASA for added details.

U. Information on Sponsors/Sponsorship:

Crucial to the success of the CBMTS IV are sponsorship by Government Organizations, Institutions and Industries. Sponsorship funding provides the revenue used to assist many CBMTS professionals to attend the CBMTS meetings. To date, these funds have only been used to assist participants from developing countries and countries with economies in transition. The CBMTS IV is hosted and in part sponsored by the Spiez Laboratory with the Government of Switzerland. The CBMTS International Organization with the CBMTS series originator, Applied Science and Analysis Inc., work in partnership with the host to ensure the symposium meets the goals and objectives of the Swiss Laboratory and the CBMTS.

There are three sponsorship levels for CBMTS meetings:
a. Sponsor (minimum $8K). Includes up to three industry registrations plus full page advert space in the Program and Proceedings plus one full page space in the ASA Newsletter. Includes a booth furnished by the CBMTS Spiez Laboratory.
b. Co-sponsor (min. $5K). Includes up to two industry registrations plus half page advert space in the Program and Proceedings plus half page space in the ASA Newsletter. Includes a booth furnished by the CBMTS Spiez Laboratory.
c. Supporter (min. $2k) Includes one industry registration plus quarter page advert space in the Program, Proceedings, and ASA Newsletter.

Note 1: Please contact ASA for Sponsor letter which outlines the many benefits of sponsoring the CBMTS.

Note 2: To be fair to our Sponsors, Co-sponsors and Supporters, these three categories will be the only participants permitted to import and display their product.

V. General Interest Items

To date, representatives from the following countries have provided information on their proposed papers:

1. Albania	2. Argentina	3. Brazil
4. Bulgaria	5. Canada	6. Croatia
7. Czech Republic	8. Ethiopia	9. Finland
10. France	11. Germany	12. Hungary
13. Iran	14. Italy	15. Japan
16. Macedonia	17. Malaysia	18. Russia
19. Singapore.	20. South Africa	21. Sweden
22. Switzerland	23. Turkey	24. Ukraine
25. UK	26. US	27. Yugoslavia

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(Source Strength - from p. 1)
done in Table IV.

It may be of interest that the estimates presented here have an antecedent in an April 1980 memorandum I wrote for the US Interagency Sverdlovsk Working Group. We had no reliable information about the geographical distribution of attack rates. So we could only estimate what dose would be inhaled at a given downwind and crosswind distance from an aerosol release of a given number of spores under given atmospheric conditions. My estimates of dose as a function of source strength, based on a Gaussian plume model for a moderately stable atmosphere, were, as to be expected, in good agreement with those in the present Table II. Some members of the Working Group, apparently unfamiliar with atmospheric dispersion models, thought my estimates of source strength were far too low. The following month we received a memorandum from Dugway Proving Ground with estimates in essential agreement with those in my memorandum and in the present Table II. By then, however, a very much higher estimate had already been briefed to President Carter by Admiral Stansfield Turner, then Director of Central Intelligence.

(The reprinted article)

Note Regarding Source Strength

by Professor Matthew Meselson

In November 1994, Prof. Meselson described the size and source of a plume of anthrax spores in Sverdlosk in 1979. The model employed and calculations performed to estimate the concentration of spores is presented here.

Cambridge, Massachusetts. This note provides background information regarding the estimate of Meselson et al. (Science 266: 1202-1208, 1994) that the aerosol that caused the Sverdlovsk anthrax outbreak of 1979 contained between a few milligrams and nearly a gram of anthrax spores. Figure and reference numbers correspond to those in the Science article.

Estimating source strength. We define the source strength as the number of viable anthrax spores released at the source that travel in the atmosphere as particles small enough to initiate inhalation anthrax. Source strength may be estimated from knowledge of: (i) the attack rate among people at a particular location; (ii) the dose D (number of spores inhaled) corresponding to the attack rate, obtained from the dose-response relation; (iii) the ratio R of the dose at the particular location to the source strength, computed from the applicable atmospheric dispersion model and the breathing rate of the exposed population. The source strength is then D/R.

Atmospheric dispersion model. The Gaussian plume model used in the article to compute dose as a function of source strength at any downwind distance (x) from the source and crosswind distance (y) from the cloud centerline is given in Table I. The model employs sigma-x and sigma-y values given by Briggs (21) for an atmosphere of neutral stability (stability "D") on open terrain. The breathing rate is taken as 30 L/min, as for a man engaged in light work (33).

TABLE I
BASIS OF DOSE CALCULATIONS
in Meselson et al.

Atmospheric stability "D"
Wind speed = u = 5 m/sec at 10 m
Release height = 10 m
Source strength = Q spores
Deposition negligible
Infectivity independent of travel time
No mixing layer
Breathing rate = B = 5 X 10^{-4} m^3/sec (= 30 L/min)

$$\text{Dose} = [QB][\pi u \sigma_y \sigma_z]^{-1}\exp[-(1/2)(y/\sigma_y)^2]\exp[-(1/2)(10/\sigma_z)^2]$$
$$= [3.18\text{X}10^{-5}Q][\sigma_y \sigma_z]^{-1}\exp[-(1/2)(y/\sigma_y)^2]\exp[-(1/2)(10/\sigma_z)^2]$$
$$\sigma_y = [0.08][x][1+0.0001x]^{-1/2}$$
$$\sigma_z = [0.06][x][1+0.0015x]^{-1/2}$$

Downwind (x) and crosswind (y) distances are in meters.

Comparison with other dispersion models.

Table II gives centerline doses for a source strength of 10^{10} spores calculated from the atmospheric dispersion model and the breathing rate used in the article and given in Table I. For comparison, Table II also gives centerline doses calculated from three other atmospheric dispersion models: Gaussian plume with sigma values given by Briggs (21) for a slightly stable atmosphere (stability "E") on open terrain; POINT V Gaussian puff model for stability "D" with sigma values given in Table 2, page 17 in "Methodology for Chemical Hazard Prediction" (Department of Defense Explosives Safety Board, Washington DC, 1980); and the TNO "Yellow Book" Gaussian puff model for stability "D" (TNO Defence Research, Rijswijk, The Netherlands). For each model, it is assumed that there was no limit to vertical mixing. Depending on the actual height of the mixed layer, the tabulated doses may be subject to upward revision at large downwind distances.

Attack rates. As described in the article, the attack rate at the ceramics factory, ca 2.8 km downwind of the source and apparently intersected by the cloud centerline, was about 2% (10/450) for pipe shop workers and 0.8% (8/1,050) for those who worked in buildings west of the pipe shop. The latter include anthrax patients who worked in the tile shop, maintenance shop, and cafeteria. The overall rate was therefor 1-2%. To calculate source strength, the article takes the attack rate 2.8 km directly downwind of the source as 2%.

Attack rates may also be estimated for two other locations, not considered in the article. These are a residential section and an automotive maintenance and repair center located, respectively, upwind and downwind of the ceramics factory. The residential section had a population density of 10,000/km^2. The part of it within the outermost constant dosage contour of Figure 2 and bounded by the ceramics factory and Compound 32 covers 0.7 square kilometers. If 10% of the adult population were at home at the time of cloud passage (including absentees, night workers, pensioners, sick, unemployed, and vacationers), about 500 adults would have been present. Ten patients were mapped within the area in question (Figure 2), for an average attack rate of 2% or somewhat higher close to the cloud centerline. An additional 8 patients resided in the area but were mapped at their (cont. p. 12)

TABLE II
CENTERLINE DOSE (SPORES) FROM FOUR MODELS
WIND SPEED CA 5 m/sec
BREATHING RATE 30 L/min
SOURCE STRENGTH 10^{10} SPORES

Downwind distance	Briggs "D"	Briggs "E"	POINTV "D"	TNO "D"
1 km	106	219	317	281
2 km	36	75	109	91
3 km	20	42	46	46
4 km	13	28	28	29
10 km	3.7	9.9	5.6	6.3
50 km	0.6	2.8	0.3	0.7

note: Stability "D" is neutral. Stability "E" is slightly stable.

(cont. from p. 11)

workplaces. If some of them were actually at home when exposed, the average attack rate for the area could have been about 3%.

The automotive maintenance and repair center, located about 3.9 km directly downwind of the source, had three anthrax patients (Figure 2, patients 45, 46, and 62). From a cursory tour of the center, I estimate that it had 200-300 employees. The corresponding attack rate would be about 1%, subject to errors of sampling and ascertainment.

It appears from the above that the attack rate of 1-2% recorded at the ceramics factory is consistent with the rates estimated for locations upwind and downwind of it, providing some assurance that the ceramics factory rate used in the article for source strength estimation is not anomalous.

Dose-response relation. The largest uncertainty in estimating the source strength is not in the model of atmospheric dispersion or in the estimate of the anthrax attack rate but in the relation between the number of viable spores inhaled and the probability of contracting inhalation anthrax. Even if there were an agreed dose-response relation for non-human primates, which there is not, there would remain uncertainty regarding the relation applicable to the actual population at risk and the particular aerosol encountered at Sverdlovsk.

In order to reflect the uncertainty, the article employs two different dose-response relations. These are described in the text and in Table III:

(i) Log-normal with a human LD_{50} of 8,000 spores (8) and a slope of 0.7 probits per log dose (26,35). The LD_{50} comes from a U.S. Department of Defense estimate that the human LD_{50} is 8000-10,000 spores (8). The probit slope is that reported by Glassman (26, 35) for a large-scale experiment with cynomolgus monkeys.

(ii) Independent spore action (38) with LD_{50} = 45,000. The LD_{50} is that reported by Druett et al. for rhesus monkeys (37).

A log-normal relation allows for heterogeneity in susceptibility among individuals in the exposed population. This is particularly important at low attack rates, as at Sverdlovsk, since the more susceptible members of the population will be over-represented among those who contract anthrax.

The independent action relation is based on the reasonable assumption that spores act independently, not cooperatively, in the initiation of inhalation anthrax. But the model assumes that there is no heterogeneity of susceptibility in the population. At low attack rates, the neglect of heterogeneity will cause the dose to be overestimated. The estimate from the independent action dose-response relation, with a high LD_{50} (45,000 spores) and no allowance for heterogeneity, is included in the Science article in order to present an extreme high-end estimate.

Source strength. Table IV gives source strengths, in milligrams, calculated from three different dose-response relations and two different atmospheric dispersion models for an attack rate of 2% at a distance of 2.8 km directly downwind of the source and a breathing rate of 30 L/min.

In addition to the two dose-response relations used in the article, the Table gives source strengths estimated on the basis of independent spore action with LD_{50} = 8,000. The doses for a 2% attack rate, calculated dose-response relations A, B, and C, are 9.3, 230, and 1300 spores, respectively. The number of spores per milligram is taken as 10^9 (39).

The two estimates given in the Table for dose-response relations A and C with the Briggs "D" atmospheric dispersion model are those given in the Science article.

Matthew Meselson

TABLE III
DOSE-RESPONSE RELATIONS

LOG-NORMAL	INDEPENDENT ACTION
LD_{50} = 8,000 spores,	LD_{50} = 45,000 spores
Slope = 0.7 probits/log dose	Att.Rate = $1-(1/2)^{dose/LD50}$
	$= 1-\exp[-0.69(dose/LD_{50})]$

The tabulation below is of the form [dose],[attack rate]

8000,.500	8000,.115
4000,.417	4000,.059
2000,.337	2000,.030
1000,.264	1000,.015
500,.200	500,.008
250,.146	250,.004
125,.103	125,.002
60,.068	
30,.045	
15,.028	
8,.018	
4,.011	
2,.006	
1,.003	

TABLE IV
SOURCE STRENGTH ESTIMATES

A: LOG NORMAL WITH LD_{50} = 8,000, SLOPE 0.7.
B: INDEPENDENT SPORE ACTION WITH LD_{50} = 8,000.
C: INDEPENDENT SPORE ACTION WITH LD_{50} = 45,000

DISPERSION MODEL	RELATION A DOSE = 9.3	RELATION B DOSE = 230	RELATION C DOSE = 1300
BRIGGS "D"	4 mg	110 mg	600 mg
BRIGGS "E"	2 mg	50 mg	280 mg

Editor's Note: Prof. Meselson has been at Harvard long enough to be classified a true New Englander and this evening his true New England spirit was tested to the max. ASA cajoled the Professor into going over this paper until almost 0200 hours on 12/17 (we had to be at the printer at 0800). Matt - many thanks.