December, 1966

DETECTION OF REMOTE BIOLOGICAL WEAPONS FIELD TESTS

- A Preliminary Assessment

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SUMMARY

1. An estimate based on incomplete information indicates that it may be feasible to detect the field testing of biological weapons at stations remote from the test site. There are serious uncertainties in the estimation.

2. A brief discussion is given of various arms-control benefits and risks which could accrue at various stages in the development of a test detection capability. Substantial benefits might be obtained even at an early stage.

3. It is proposed that a rapid detection capability may be less effective for over-all arms control purposes than a slow one. In any case, rapidity is not needed for test detection.

I. THE FEASIBILITY OF REMOTE TEST DETECTION

In order to be detected, particles from a remote biological weapons field test must arrive at the sampling station in sufficient concentration to be distinguished from the naturally occurring background of micro-organisms in the air.

Two atmospheric processes, deposition and diffusion will act to reduce the concentration at the sampling station.

A. Deposition

The problem here is to determine whether test particles will remain airborne long enough to be transported by wind to the sampling station.

Particles released by a biological weapon are likely to have diameters of less than 5 microns. Larger particles become trapped in the upper respiratory passages, preventing them from reaching the pulmonary spaces of the human lung, (Hatch, 1961). Penetration to the pulmonary spaces is necessary to initiate most infections of potential military interest.

Particles with diameters in the micron range and possessing a density characteristic of biological materials can remain suspended in the atmosphere for many days. Atmospheric turbulence tends to keep particles from settling. If turbulence and settling are taken into account but washout and coagulation are neglected, it may be estimated that test particles will remain suspended for many weeks, long enough to be blown beyond

10,000 km from their release point (Schrödter, 1960). Turbulent vertical transport is so much more rapid than settling that the height of release may be neglected in this estimate.

Coagulation can probably be ignored (Green and Lane, 1964) but washout due to rain and snow and removal by water condensation on test particles could be important. To my knowledge, there are no fully adequate observations of depletion under natural conditions of precipitation. An average residue time of 30 days has been reported for tropospheric radioactive debris from nuclear weapons tests (Stewart et al, 1955). The bulk of such radioactivity is thought to reside on micron size particles. There is some evidence that 1-10 micron salt particles reside in the atmosphere for 5-10 days on the average (Junge, 1963, 1964). The efficiency of washout by rain decreases with particle density and decreases abruptly with decreasing particle size in the 1-10 micron range (Mason, 1962). Because of their somewhat smaller mean size and lower density, test particles should remain suspended for longer times than salt particles. A mean suspension time of 20 days would result in 50% depletion 5,000 km away from the source if the transport speed from source to sampler were 10 km per hour. (Transport speeds will be greater than ground wind velocities because of vertical mixing into the faster winds found a few hundred meters above ground).

This tentative estimate of deposition places its magnitude just in the most critical range. If deposition is much greater than estimated, remote test detection will not be feasible. If deposition is only slightly less than estimated, it may be neglected. For purposes of the ensuing discussion, I assume that deposition is negligible out to 5,000 km along the average direction traveled by the test particles.

B. Diffusion

Atmospheric turbulence will act to diffuse a particulate cloud. As a result, the peak concentration in the cloud will steadily decrease. Diffusion may be considered to occur in three directions: vertical, cross-wind, and along-wind.

After travelling several days, particles will have diffused to the top of the layer within which there is good mixing - i.e. the troposphere. This places a cieling of 2-10 km on the eventual height of the test cloud. Vertical mixing within the troposphere should distribute particles rather smoothly below this cieling (Pasquill, 1962). Injection into the stratosphere will be neglected. Cross-wind and along-wind diffusion for long distance travel has not been adequately studied so far as I know. Over distances of about 100 km, Pasquill (1962) finds 97% of a released cloud of test particles to be included within a horizontal angular spread of about 0.2 radians subtended from the source and within an along-wind distance equal to about 0.3 of the distance traveled. At a distance of 5,000 km from the source, these relations predict a cloud 97% contained within a volume approximately 1,000 km X 1,500 km X the troposphere height This gives a volume of 7.5 X 10^6 km^3 for a 5 km troposphere. It is reasonable to assume that half of the material is contained in a volume of about 10^6 km^3 or 10^{15} m^3. This value rests on the unproven assumption that cloud behavior out to 100 km may be extrapolated to much greater distances.

C. Concentration of Particles at the Sampling Station

If a field test of a biological weapon releases 10^{15} particles (about 1 kilogram) in the micron size range, the above diffusion estimate shows that a sampling station located 5,000 km from the test site and within a few hundred km of the center of a passing cloud should experience a concentration of about 1 particle per m^3. The concentration should remain at this value for a number of days during passage of the cloud.

D. Detection and Identification

There is no hope of detecting concentrations so low as one particle per m^3 by means of long path light scattering. Even over a 10 km path there would be only one particle per cm^2. In order to be detected, the particles must be collected and concentrated. There is available from Litton Industries (USA) a device which collects 10 m^3 of air per minute and efficiently concentrates particulate matter into a liquid flowing out of the instrument at 10 ml per minute. Thus, with one test organism per m^3 of air, one would obtain an effluent of 10 organisms per minute at a concentration of 1 organism per ml. If each test particle contained several separable organisms, a correspondingly higher number would be found in the effluent. This high degree of concentration is desirable, but the sampling rate of the Litton instrument is far higher than needed for sampling the slowly passing particulate cloud envisaged here. A much simpler instrument might therefore be used.

Various means are available for detecting and identifying micro-organisms with concentrations as low as a few per ml. After several days of travel, many organisms of possible military interest would not be viable, although certain ones might be. Nevertheless, no general detection scheme can be based on procedures in which the test organisms must reproduce.

In connection with its recent discussions of the rapid detection of air-borne micro-organisms, the Biological Warfare Study Group has outlined several methods which should be considered for use in test detection. These include acridine orange staining, dielectric particle counting, and fluorescent antibody labeling. Because of the long period of exposure expected at the sampling station, several methods might be used in rotation. Although no detection and identification technique has been brought to a point of generality and sensitivity satisfactory for use in long-range test detection, it is likely that adequate methods can be developed. No detailed discussion of detection and identification procedures will be given here inasmuch as meteorological factors and the level of natural background are likely to be overriding in deciding whether long-range test detection of the sort under consideration here is feasible at all. If the natural background of insoluble micron size particulate matter is sufficiently low, a test cloud might initially be detected by particle counting alone. Suitable filters could be employed to remove particles with diameters outside the range of interest. Particles larger than 0.5 micron can be counted and sized by a dielectric counter manufactured by Coulter Electronics (USA). Means can almost surely be devised for counting and sizing smaller particles, such as most viruses.

Discrimination could be increased by the use of optical counting of particles stained with nucleic acid or protein stains. If initial detection could be based on such relatively non-specific counting, samples obtained during periods of high counting rate could be taken from the sampling station to a central facility for specific identification. This would reduce the level of instrumentation and operator sophistication needed at sampling stations.

If the natural concentration of airborne micro-organisms in the micron size range is comparable to the concentration in the passing test cloud, specific detection methods must be used at the outset. Fluorescent antibody staining seems to be the most promising of these. Its use would require some knowledge of the types of organisms likely to be encountered in test clouds.

So far as I know, there are no suitable estimates of the natural background of airborne micro-organisms in the micron size range. However, the results of some very limited investigations leave open the possibility that in certain places the natural background is less than 10 organisms per m^3, possibly much less. It is important to know not only the average natural concentration but the nature, frequency and intensity of fluctuations in the natural background.

E. Tracing

If a test cloud can be positively identified, it may be possible to locate the approximate source of the material by consideration of synoptic meteorological information and relevant geographic factors.

II. ARMS CONTROL ASPECTS

Efforts to develop a biological weapons test detection capability could have several arms control effects - some beneficial, and some detrimental.

Under certain conditions even preliminary studies of the feasibility of biological weapons test detection could have a beneficial effect. If such studies are conducted by competent, responsible, and respected individuals or institutions, they can act to reinforce worldwide concern with the need to prevent biological warfare and may stimulate various other developments and measures aimed at maintaining the barriers to the use of biological weapons. Especially if it can be determined that test detection is ultimately feasible, it may be advantageous to publicize development efforts at a relatively early stage. However, if it should turn out that detection is not possible, premature publicity might lead to disappointment and disillusionment later on. At present, care should be exercised not to give the impression that the problem is definitely soluble. Instead, overall concern with the problem of preventing biological warfare and sustained effort towards its prevention should be emphasized in public statements.

If a detection capability of even modest performance can be developed and deployed on a limited scale, a strong inhibition against biological weapons field testing can result. It is reasonable to suppose that some political leaders may be under pressure from their military advisors to authorize field testing of biological weapons. Even if the natural inclinations of an official or his close advisors are against authorizing such testing, it may be difficult for them to resist continued requests from weapons laboratories wishing to obtain information from field tests. The existence in the world of even a rather modest detection capability could influence this situation. Within governments, opponents of testing could cite the increased hazard of public disclosure brought about by the existing detection capability and made likely by possible future strengthening of such capability. Furthermore, it could be argued that the political liabilities of public disclosure would be increased in the environment of worldwide opposition to weapons testing generated by respected individuals and states cooperating in a limited detection effort.

A limited detection capability might be deployed cooperatively or in parallel by a number of states with different political alignments who have agreed among themselves not to test. Participating states might be expected to urge their non-participating military allies to refrain from detectable testing.

Even a rather modest detection capability might create an environment in which nations would participate in an international agreement to forego certain types of tests. This could occur even though the test detection capability may not be adequate to detect all violations of such an agreement.

A very effective test detection capability might lead to the conclusion of a treaty similar to the limited Nuclear Test Ban Treaty. However, such a capability must at present be considered very remote. Nearer term arms control benefits should be pursued as indicated above.

It is very likely that all nations have more to lose than to gain from the general introduction of biological weapons into warfare. It should constantly be emphasized that the long term hazard to the security of whole populations far outweighs any likely military gains to be obtained by the introduction of biological weapons. Unless this emphasis is maintained, a concentration on the dangers of biological warfare might unnecessarily stimulate the interest of some nations in producing and possibly using such weapons. Furthermore, all efforts to develop a test detection capability should be scrutinized to make sure that they do not contribute needlessly to the technology of biological warfare itself. For example, the development of a very slow acting test detection capability would have much less military applicability than would a fast reacting system. The fast reacting system could be used in actual military operations, albeit for defensive purposes. It has sometimes been argued that the availability of rapid detection equipment could discourage the use of biological weapons. I believe this argument should be carefully reexamined. Meanwhile, until a convincing case can be made, it is probably better to steer clear of any development with direct military application.

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