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THE SENSITIVITY, IN VITRO, OF BACTERIA TO THE BETA AND GAMMA RAYS OF RADIUM

By R. R. SPENCER, *Surgeon, United States Public Health Service*

It is generally agreed among radiologists that the young and actively growing cells of the human body are more radiosensitive than old or adult cells, the metabolism of the latter being very much slower. It is further recognized that cells of one type vary in radiosensitivity from cells of another type. Thus, for example, the lymphocytes, whose metabolic cycle among human cells is the shortest, are also the most radiosensitive, and the nerve cells, whose life cycle is the longest, are the most resistant to radiation.

In view of these observations (6) one would expect not only the radiosensitiveness of bacterial species to vary a great deal but that the rapidly multiplying cultures would be more sensitive than cultures at rest. However, according to the observations recorded here, it is the rapidly multiplying cultures that are least sensitive to the beta and gamma rays of radium, while resting bacteria, in contrast with the least active human cells, are the most sensitive.[1]

Review of the literature.—The earliest report of the effect of the radiation from radioactive substances upon bacteria seems to be that of Pacinotti and Parcelli (16). In 1899 Pacinotti and Parcelli exposed various bacteria (*B. proteus, Vibrio cholerae, B. typhosus,* and *B. diphtheriae*) to preparations of powdered uranium and found that the organisms were killed. At that early date, of course, they did not test separately the effect of the alpha, beta, and gamma rays.

[1] It should be recalled that the radiant energy emanating from radium consists of the alpha, the beta, and the gamma rays.

The alpha rays consist of a stream of material particles which are projected at high speed from radioactive substances. The alpha particles from all types of radioactive matter are identical in mass and consist of charged atoms of helium projected at velocities of about 10,000 miles a second. The alpha particles are expelled with a characteristic speed from each radioactive substance and have a definite distance of travel or range in matter before they are stopped. The range of the alpha particles for different radioactive substances varies between about 3 and 11 centimeters in air at atmospheric pressure and temperature. Most of the energy emitted from radioactive bodies is in the form of alpha rays. The alpha rays are easily absorbed and are stopped by a sheet of paper or a few centimeters of air.

The beta rays consist of a stream of electrons which are projected at high velocities approaching in some cases that of light. Unlike the emission of alpha particles, a radioactive body emits beta particles over a considerable range of velocity.

The gamma rays, which are of very penetrating character, have been shown to be a type of X-rays of very high frequency. Usually the gamma rays accompany the emission of beta rays. Unlike the alpha and beta particles, the gamma rays are undeflected by a magnetic field.

Henri and Mayer (11) found that radium rays rapidly destroy the activity of the ferments, invertin emulsin, and trypsin.

Dauphin (5) concluded from his tests that the rays of radium stop the growth of mycelium of the Mortierella (mold) and prevent germination of the spores. The action is considered as paralyzing, causing the appearance of real cysts in the interior of the filaments, and the cysts were considered as organs of defense. He also concluded that spores and mycelium submitted to the action of radium are not killed but remain in a latent state of life and when replaced in a normal condition can once more germinate or continue to develop afresh.

Bouchard and Balthazard (1) exposed *B. pyocyaneus* to the emanations from radium (randon gas) and produced a reduction in virulence and an increase in involution forms. When exposed to larger doses over a longer period, the organisms were destroyed, as shown by failure of growth when irradiated cultures were transplanted.

Iredell and Minett (12) exposed plates inoculated with *B. pyocyaneus* for 10, 20, and 60 minutes to radium rays. The radium salts were applied directly to the surface of the media. Transfers were made from exposed and unexposed cultures (controls) and from exposed and unexposed areas on the same plates. The capacity for staining, growth, and reproduction was unimpaired and no differences could be detected. The quantity of radium employed was not stated, and the only observation made was a slight increased tendency to spore formation after 60 minutes' exposure. *Staphylococcus aureus* and *B. megatherium* were also unaffected. *B. coli* exposed for 17 hours was unaffected and grew normally on Conradi-Drigalski medium.

Hans Jansen (13) found that *B. prodigiosus* was killed when the air above the culture on a slant agar surface contained at least 345 Mache units of emanations per cc over a period of 48 hours. He concluded that the effect was not due to changes in the media and that the bactericidal effect was due to the alpha rays.

Fabre (7) found that anthrax organisms spread on plates and exposed to alpha, beta, and gamma rays of radioactive substances always gave a smaller number of colonies than the control plates not irradiated. When fresh plates were planted from the colonies developed under irradiation, only slight differences were observed in the number of colonies appearing on control plates and on the plates seeded from the irradiated colonies. With gonococcus, however, transplants from the colonies developing under irradiation gave no growth at all.

Chambers and Russ (3) state that it is the alpha and beta rays that have the bactericidal effect. These rays from a comparatively small quantity of radium, a few milligrams, have a direct bactericidal effect; but exposure of a suspension of *Staphylococcus aureus* to the gamma rays only, 7 milligrams of radium bromide, gave no evidence of any effect after an exposure of one week. When the beta rays from the same source were utilized, a completely lethal effect was obtained in 6 hours.

Mottran (15) states that both animal and vegetable cells show a disturbance of normal growth when submitted to the gamma and beta rays of radium. This disturbance is more marked if the cells are in active division. Dividing ova of *ascaris* are at least 8 times as vulnerable as resting ova. The most vulnerable stage in division is the metaphase. Beta and gamma radiation is followed by profound nuclear changes affecting the chromatin, and such changes are less marked if the cells have been irradiated in a resting condition.

Lequeux and Chomé (14) state that the action of radium salts varies with the microbe and the salts employed and that the gamma rays have only a questionable effect.

Cluzet, Rochaix, and Kofman (4), using 50-milligram tubes of radium bromide employed in radium therapy, found no effect upon *B. pyocyaneus* after 24 hours' exposure. Even after 3 days' and in another experience after 5 weeks' exposure, transfers from irradiated cultures showed no differences in abundance of growth or in morphology. They did note, however, that when cultures of *B. pyocyaneus* were irradiated in the ice box for 7 days and then incubated they were destroyed, while control cultures developed abundantly when placed in the ice box for the same period and then incubated. Typhoid bacilli were destroyed after 12 days' irradiation in the ice box. The action was not due to the irradiation affecting the broth media, since media irradiated 7 days and then planted with organisms gave good growth. The dose of irradiation which is bactericidal varies with the species and the strain of the same species. The authors gave no explanation for the marked difference in results with the same organism irradiated in the ice box and in the incubator. (See p. 190.)

Bruynoghe and Mund (2) state that the gamma rays are without action on bacteria but that the alpha and beta rays are distinctly bactericidal. According to the same authors, the bacteriophage of typhoid after 3 days' contact with 7 to 8 millicuries of radium emanation was unaffected.

It is generally agreed that the X-rays and the radium rays have the same general effect upon living tissue. Young or immature cells are more radio-sensitive than old or adult cells, and this has been generally recognized as the essential foundation of radiotherapy. According to Desjardins (6), "each variety of cell in the body has a specific sensitiveness or rather a specific range of sensitiveness to radiation." Further, "The specific sensitiveness of each kind of cell looms up as the dominant single fact of radiology and deserves to be recognized as a law * * *. Although the factors responsible for such specificity have not yet been determined, the sensitiveness peculiar to each kind of cell appears to be related chiefly to the natural life cycle. Thus the lymphocytes, whose metabolic cycle among human cells is the shortest, are also the most radio sensitive, and the nerve cells, whose life cycle is the longest, are also the most resistant to radiation."

Gurwitsch (8, 9, 10) has observed that dividing cells (onion roots) emit a radiation of a frequency in the ultraviolet of 2,000 to 2,400 Ångstrom units, and that this radiation has the property of stimulating the process of cell division in neighboring cells.

DESCRIPTION OF RADIUM NEEDLES EMPLOYED

(a) *Monel metal needles.*—Length 14.5 mm; external diameter 1.25 mm; wall thickness 0.25 mm. Each of these needles has a gamma radiation equivalent approximately to that from 5 milligrams of radium element, according to the United States Bureau of Standards certificate, when corrected to allow for the wall absorption. The Monel metal of which the needles are made is an alloy containing 28 percent copper, 67 percent nickel, and 5 percent iron, silica, and other impurities. It screens off 85 percent of the primary beta radiation and has a density of 8.7.

(b) *Platinum-iridium needles.*—Length 44.0 mm; external diameter 1.65 mm; wall thickness 0.5 mm. These needles have a gamma radiation equivalent to that from 10 mg of radium element according to the United States Bureau of Standards certificates when corrected to allow for the wall absorption. The platinum-iridium has a density of 21.5 and screens off approximately 99 percent of the primary beta radiation.

EXPERIMENTAL DATA

When one loop of a 24-hour broth culture of *B. typhosus*, *Streptococcus scarlatinae*, or *B. proteus* X_{19} is planted in a broth tube with one or as many as seven 5-milligram radium needles and incubated at 37° C. a decided retardation of growth takes place during the first 6 or 8 hours when compared with a similarly inoculated nonirradiated control. After 24 hours, however, there may be no marked differences in the density of growth, especially if only one or two needles are employed. If transfers are continued daily in two series, one being irradiated and the other serving as control, frequently but not invariably a denser growth will be observed in the tubes of the irradiated series after 8 or 10 transfers. Accompanying the heavier growth one will notice that there is a tendency to longer chain formation in the case of the irradiated streptococci and to the formation of long filamentous forms in the case of the irradiated typhoid and proteus organisms. Furthermore, the organisms seem to stain more deeply and generally appear more vigorous. Motility is not apparently affected.

On the other hand, if these organisms are irradiated in the ice box at about 0° C., at which temperature metabolism, growth, and multiplication have been brought practically to a standstill, the organisms are gradually killed.

TABLE 1.—*Irradiation of B. typhosus. Colony counts of duplicate sets of broth suspensions of B. typhosus stored at 0° C.*

Tube number and contents	Amount of inoculum	After 7 days' storage	After 14 days' storage	After 18 days' storage
	cc			
1. 5 cc broth	0.1	Innumerable colonies in 1/10 cc.	Innumerable colonies in 1/10 cc.	Innumerable colonies in 1/10 cc.
1A. 5 cc broth, 5 mg radium	.1	0	0	0.
2. 5 cc broth	.2	Innumerable colonies	Innumerable colonies	Innumerable colonies.
2A. 5 cc broth, 5 mg radium	.2	0	0	0.
3. 5 cc broth	.3	Innumerable colonies	Innumerable colonies	Innumerable colonies.
3A. 5 cc broth, 5 mg radium	.3	0	0	0.
4. 5 cc broth	.4	Innumerable colonies	Innumerable colonies	Innumerable colonies.
4A. 5 cc broth, 5 mg radium	.4	0	0	0.
5. 5 cc broth	.5	Innumerable colonies	Innumerable colonies	Innumerable colonies.
5A. 5 cc broth, 5 mg radium	.5	71 colonies in 1/10 cc	3 colonies in 1/10 cc	0.
6. 5 cc broth	.6	Innumerable colonies.	Innumerable colonies	Innumerable colonies.
6A. 5 cc broth, 5 mg radium	.6	59 colonies in 1/10 cc	5 colonies in 1/10 cc	0.
7. 5 cc broth	.7	Innumerable colonies	Innumerable colonies	Innumerable colonies.
7A. 5 cc broth, 5 mg radium	.7	98 colonies in 1/10 cc	5 colonies in 1/10 cc	0.

From table 1 it may be seen that when as much as 0.4 cc of a 24-hour broth culture is placed in 5 cc of broth with one 5 mg radium needle (Monel metal) and stored at 0° C., the organisms are killed within 7 days. When as much as 0.7 cc of the same culture is planted in a similar tube of broth and irradiated at 0° C. the number of living organisms gradually decreases and all are killed within 18 days. In all the nonirradiated control tubes there was no evidence of either a reduction or multiplication of the bacteria.

A study of table 2 reveals the fact that when 0.1 cc and 0.2 cc of living typhoid organisms are inoculated into autoclaved suspensions of the same strain and irradiated at 0° C., the organisms survive 14 days but are killed in 21 days. When this result is compared with that recorded in table 1 it will be seen that the presence of the dead suspensions tends to protect the living organisms from the rays of radium.

TABLE 2.—*Irradiation of B. typhosus. Colony counts of duplicate sets of suspensions B. typhosus planted in a killed broth suspension of B. typhosus tubes stored at 0° C.*

Tube number and contents	Amount of inoculum	After 7 days' storage	After 14 days' storage	After 21 days' storage
	cc			
1. Killed suspensions of *B. coli*.	0.1	Innumerable colonies in 1/10 cc.	Innumerable colonies in 1/10 cc.	Innumerable colonies in 1/10 cc.
1A. Killed suspensions of *B. coli* and 5 mg radium.	.1	200+colonies in 1/10 cc.	Growth in water of condensation only.	No growth.
2. Killed suspensions of *B. coli*.	.2	Innumerable colonies in 1/10 cc.	Innumerable colonies in 1/10 cc.	Innumerable colonies in 1/10 cc.
2A. Killed suspensions of *B. coli* and 5 mg radium.	.2	200+colonies in 1/10 cc.	14 colonies	No growth.

Table 3 likewise shows that 0.15 percent agar and 12½ percent gelatine have a decided protective effect against the rays of radium. There was no perceptible decrease in organisms in the irradiated tubes containing agar and gelatine when compared with the control tubes containing these substances but not irradiated. A suspension of kaolin, however, did not protect as well as the gelatine or agar.

TABLE 3.—*Irradiation of B. typhosus. Colony counts of duplicate sets of broth suspensions of B. typhosus stored at 0° C.*

Tube number and contents	Amount of typhoid inoculum	After 7 days' storage	After 14 days' storage
	Cc		
1. 5 cc of 0.15 percent agar	0.1	Innumerable colonies in 1/10 cc.	Innumerable colonies in 1/10 cc.
1A. 5 cc of 0.15 percent agar, 5 mg radium	.1	do	Do.
2. 5 cc of 12½ percent nutrient gel	.1	do	Do.
2A. 5 cc of 12½ percent nutrient gel., 5 mg radium.	.1	do	Do.
3. 4 cc broth, 1 g kaolin	.1	do	Do.
3A. 4 cc broth, 1 g kaolin, 5 mg radium	.1	10 colonies in 1/10 cc	No growth.
4. 5 cc broth	.1	Innumerable colonies	Innumerable colonies.
4A. 5 cc broth, 5 mg radium	.1	No growth	No growth.

In table 4 is recorded the results of irradiating a gram-negative nonmotile bacillus at 37° C. rather than at 0° C. This organism was carefully tested a number of times and always failed to grow at 37° C. Good growth was obtained, however, at room temperature and in the ice box at about 10° C. It was recovered as a contaminant from a commercial antiserum but was not further identified.

The table shows that when 0.1 and 0.2 cc of a 48-hour broth culture of this organism were planted in 5 cc of broth and irradiated at 37° C. the organism was killed. Nonirradiated controls were not killed. When a single loop-full of a broth culture (grown at room temperature, 25° C.) was planted in 5 cc of fresh broth and irradiated at 10° C. a good growth was observed within 48 hours.

When the results of irradiating this organism, which does not grow at 37° C., are compared with the irradiation of *B. typhosus* one obtains the impression that the metabolic condition or state of an organism is a most important factor in its vulnerability to the rays of radium, while the temperature *per se* at which the organism is irradiated does not seem to play an important role. But temperature, of course, largely controls metabolism when other conditions are favorable for growth and thus indirectly influences the vulnerability of organisms to radium.

TABLE 4.—*Irradiation of a bacillus that does not grow at 37° C. Colony counts of duplicate sets of broth suspensions stored at 37° C.*

Tube number and contents	Amount of inoculum	After 4 days' storage	After 7 days' storage
	Cc		
1. 5 cc broth	0.1	Innumerable colonies in 1/10 cc.	Innumerable colonies in 1/10 cc.
1A. 5 cc broth, 5 mg radium	.1	No growth in 1/10 cc.	No growth in 1/10 cc.
2. 5 cc broth	.2	Innumerable colonies in 1/10 cc.	Innumerable colonies in 1/10 cc.
2A. 5 cc broth, 5 mg radium	.2	Growth in water of condensation only.	No growth in 1/10 cc.

In table 5 evidence is submitted which we believe shows conclusively that it is the beta rays rather than the gamma which possess predominantly the killing effect. It will be noted that in tube no. 2, in which *B. typhosus* was irradiated with 5 milligrams of radium, the organisms were all killed within 1 week, whereas in tube no. 3, in which a corresponding suspension was irradiated with a 10-milligram needle, 300 colonies were obtained from 1/10 cc of the irradiated suspension. However, only 1 percent of the irradiation from the 10-milligram platinum-irridium needle was the beta rays while 15 percent of the radiation from the 5-milligram Monel metal needle was of the beta variety. In other words, there was 7½ times as much beta radiation emanating from the 5-milligram needle as from the 10-milligram needle.

TABLE 5.—*Irradiation of B. typhosus. Colony counts of broth suspensions stored at 0° C., showing killing effect of the beta rays*

Tube number and contents	Amount of inoculum	After 7 days' storage	Remarks
	Cc		
1. 5 cc broth	0.1	Innumerable confluent colonies in 1/10 cc.	Control not irradiated.
2. 5 cc broth, 5 mg. radium in Monel metal needle.	.1	No growth in 1/10 cc.	Needle emanates 85 percent gamma rays and 15 percent beta.
3. 5 cc broth, 10 mg. radium in platinum-irridium needle.	.1	300+ colonies	Needle emanates 99 percent gamma and 1 percent beta rays.

We have also studied the effect of radium emanations upon *S. scarlatinae* and *B. proteus* X_{19} with practically identical results as those recorded above for *B. typhosus*.

DISCUSSION

In previous studies referred to, it is claimed that both the alpha and the beta rays are bactericidal, but that the gamma rays have no appreciable effect upon bacteria. Neither of the two varieties of needles that we have used in this study permit the passage of the alpha particles. Our needles are essentially similar to those usually employed in the treatment of cancer and in other radio-therapeutic procedures, and unfortunately no needle is manufactured, so far as we are aware, which completely excludes all of the beta rays.

The brief study of Cluzet, Rochaix, and Kofman (4) is the only reference in the literature, so far as we have been able to find, in which a difference was noted between the sensitivity of bacteria to radium when irradiated at 37° C. and at ice box temperatures. These authors gave no explanation for their findings. Our studies, on the other hand, seem to connect definitely the degree of sensitivity of bacteria to irradiation with the degree of metabolism, growth, and reproduction of the organisms.

While our studies support the view expressed by many previous workers that the beta rays are bactericidal, they also suggest that bacteria in an optimum media and temperature, and where growth and multiplication are rapid, are not perceptibly injured, but their growth may, on the other hand, be stimulated.

These results fit in with what is known regarding the sensitivity of animal tissue cells to radium in that the sensitivity seems to be related to the metabolic rate. However, the statement of radiologists that the most active cells in the human body are the most sensitive to radium and that cells with a low metabolic or reproductive rate are less sensitive seems to be the exact opposite of our results upon bacteria.

Since our work was completed we have seen a recent editorial in the Lancet (Sept. 9, 1933) discussing the work of Crabtree and Cramer (Proc. Roy. Soc. B. 1933, CXIII, 226). These authors found that "low temperatures which retard all cell processes, including respiration, hydrocyanic acid in suitable dilution, and simple Ringer's solution (nonoxygenated and lacking glucose and bicarbonate) markedly increased radiosensitivity as measured on thin sections of Jensen's rat sarcoma."

This observation upon the sensitivity of rat sarcoma cells seems contrary to the generally accepted idea regarding the radiosensitivity of tissue cells, but it is in complete accord with our observations upon the radiosensitivity of bacteria.

The results that we have obtained so far in the irradiation of bacteria can all be attributed to the effect of the beta rays; and we have no conclusive evidence that the gamma rays affect bacteria in any way, despite the fact that some of our needles emanate 99 percent gamma and only 1 percent beta rays. This result is in accord with the work of previous investigators and, in addition, suggests that the sensitivity of bacteria to irradiation varies inversely with the metabolic rate.

These results have also suggested to us the use of radium in the production of bacterial variants or mutants. Our observations in this field will be the subject of a future communication.

SUMMARY

The effect of radium rays (beta and gamma) upon broth cultures of actively multiplying bacteria is first manifested by a retardation of growth within the first 6 hours after planting. When observed after 24 hours there may be no perceptible difference between the gross appearance of irradiated and nonirradiated cultures.

After several transfers the continuously irradiated cultures may be stimulated to a more vigorous growth, and the organisms tend to display pleomorphism and stain more deeply.

Bacteria kept at sufficiently low temperatures to prevent multiplication are gradually killed by the irradiation. The lethal effect appears to be due to the beta rays.

These experiments suggest rather strongly that the sensitivity or vulnerability of bacteria to radium rays is in some way associated with the activity of the cell.

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LIQUID SULPHUR DIOXIDE AS A FUMIGANT FOR SHIPS

By C. L. WILLIAMS, *Senior Surgeon, United States Public Health Service*

Part I. Advantages, Methods, Apparatus, and Costs

Since the development of hydrocyanic acid for fumigation purposes, sulphur dioxide has largely passed out of use in the United States. The change of procedure is clearly shown in the number of ships fumigated for quarantine purposes by the two methods. Prior to 1914, practically 100 percent of vessels fumigated were treated with sulphur, while in 1932 this figure had dropped to 6.5 percent for ships fumigated at continental United States ports; and at insular ports hydrocyanic acid had largely displaced sulphur, except in the Philippines.

The absolute figures for the fiscal year ended June 30, 1932, as taken from the annual report of the Surgeon General, are as shown in table 1.

TABLE 1.—*HCN and sulphur fumigations during fiscal year ended June 30, 1932*

Ports	Number using HCN	Number using SO_2	Percent using SO_2
Continental United States ports	1,321	93	6.5
Insular United States ports:			
Philippine Islands	72	500	89.2
All others	46	8	17.4

Despite this obvious trend, however, it does not appear at the present writing [1] that HCN will entirely displace SO_2 for the fumigation of ships for quite some years to come. At the smaller quarantine stations, where only a few ships are fumigated each year, there are obvious economic objections to maintaining crews of highly trained cyanide fumigators when these vessels can be fumigated with reasonable effectiveness with SO_2 in the hands of relatively untrained station laborers.

[1] May 1933.

DISADVANTAGES OF BURNING SULPHUR

There is no point in reciting here the numerous advantages that HCN holds over SO_2 as a fumigant. Discussion will, therefore, be restricted to methods of using the latter material. In different parts of the world, these include:

1. Burning sulphur in pots or pans in the spaces to be fumigated.
2. Burning carbon disulphide ("Salforkose" process) in the spaces to be fumigated.
3. Burning sulphur in special furnaces and pumping the fumes, by means of blowers, into the ship (Clayton apparatus).
4. Passing liquid SO_2 through a furnace to convert it into a gas, and blowing it into the ship (Marot process).
5. Introducing liquid SO_2 into the ship and permitting it to evaporate therein.

The first of these procedures involves the use of a large amount of material and apparatus, innumerable pots and pans of water, inflammable material for igniting sulphur, scales for weighing it, etc. After the fumigation, all of the apparatus must be gathered and removed. The operation itself involves a distinct fire hazard.

The Salforkose method involves the use of less apparatus, but somewhat increases the fire hazard.

All methods wherein SO_2 is produced outside the ship and blown in involve the use of heavy, cumbersome apparatus, specially constructed for the purpose.

Of all the methods listed above, the first named—that is, burning sulphur in pots—is by far the least accurate. There are two main causes for this: One is that, in a considerable proportion of the pots, some of the sulphur remains unburned; the second is that, as a rule, burning requires several hours, the result being that the theoretical concentration of SO_2 is never reached, the quantity actually produced varies greatly, and maximum concentration appears late. In the Salforkose process the material is rapidly and completely burned, making it a procedure of greater accuracy. In all methods whereby the gas is produced outside the ship and blown in, in order to secure accurate dosage it is necessary actually to make tests of the concentration produced in the various compartments fumigated.

LIQUID SULPHUR DIOXIDE

The advantages of liquid SO_2 directly applied are that accurate doses may be introduced, fire hazard is obviated, and much cumbersome apparatus is eliminated. Its disadvantages are that it is at present supplied to the market in relatively heavy units and its cost is relatively high.

Liquid SO_2 is a highly volatile fluid, with a boiling point of 11° F. It is stored and shipped in heavy steel cylinders or strong tanks, in which at ordinary temperatures the material is kept liquid through a self-generated gas pressure of from 50 to 100 pounds.

Liquid SO_2 is on the market in quantity in two grades. The cheaper, which is quite satisfactory for fumigation, is described as anhydrous liquid SO_2 containing less than 0.1 percent water. This grade is at present supplied in cylinders holding 150 pounds each (tare approximately 130 pounds, total weight approximately 280 pounds), and in drums holding 1 ton each (tare 1,000 pounds). It may also be purchased in tank-car lots. The higher and more expensive grade of SO_2, generally supplied for refrigeration purposes, may be obtained in cylinders holding 35, 10, 5, and 2 pounds.

HANDLING SULPHUR-DIOXIDE CYLINDERS

A steel cylinder of SO_2 with a total weight of 280 pounds cannot be handled by one man; it is a heavy load for two men, but not too heavy for manipulation once it is on the deck of the ship. The points at which any material lifting must be done are in loading it onto a truck or boat at the quarantine station and in removing it from the truck or boat to the ship. At the quarantine station this difficulty should be overcome by the use of an inclined way or small hoist. At the ship it is practically necessary to secure the assistance of the crew. The cylinders may be hoisted to the ship's deck by swinging out one of the boat davits.

The handling of the heavy cylinders may be obviated by transferring the liquid from the large cylinders into small cylinders at the quarantine station. This involves an initial outlay for a supply of small cylinders, some 40 or 50 of which (35-pound size) would be required for fumigation of the average cargo vessel; it also involves considerable time to effect the transfer. It hardly seems to offer sufficient advantages to be worth while except at stations where the volume of fumigation is sufficient to warrant purchasing liquid SO_2 in 1-ton drums.

Liquid SO_2 in drums may be transferred into cylinders for use. The drums are fitted with a tube inside leading from the outlet valve to the periphery of the drum so that by rolling the latter into suitable position (indicated by the position of the valve), the contents may be drawn off either as gas or liquid.

This piping arrangement of the drum also permits that it be mounted on a truck or boat, taken to the ship's side, and the liquid SO_2 delivered directly into the ship through long delivery tubes. Used in this manner, in cold weather a provision would have to be made for pumping in air pressure or for heating the drum. Where a truck is assigned exclusively to fumigation, this provision may be met by building into the body a sheet metal bed with double walls, between which the exhaust gases from the motor may be passed.

RELEASING LIQUID SULPHUR DIOXIDE

Liquid SO_2 may be taken from the cylinders in either of two ways. If the cylinder is placed upright—that is, with the valve at the top—and the valve opened, the accumulated gas under pressure will be blown off and can be led with a tube into the space to be fumigated. On the other hand, if the cylinder is inverted or tilted so that the valve is at the lowest point, and the valve opened, the contents will be forced out as a liquid, which, if sprayed, evaporates very rapidly. In use, of course, the outlet is connected with a delivery tube ending in a sprayer, which is carried into the compartment to be fumigated.

The first procedure is quite limited in its application, owing to the fact that as soon as the accumulated gas in the top of the cylinder has blown off, the rate of delivery is markedly reduced, becoming progressively less and less until at ordinary temperatures it reaches a minimum of about 3½ pounds per hour. From the 150-pound cylinder, about 25 pounds of gas can be obtained in the first half hour; thereafter the outflow will be at the minimum rate. The reason for this is that SO_2 has a sufficiently high latent heat of vaporization so that evaporation results in marked chilling, which, in turn, slows the rate of evaporation. This becomes readily apparent, in about one half hour after the valve has been opened, through the appearance of a heavy frost on the outside of the cylinder, which stops at the level of the liquid. Evaporation may be hastened by heating or, to a limited extent, by agitation.

On the other hand, introduction of the SO_2 by inverting the cylinder and forcing it out as a liquid through a sprayer can be accomplished quite rapidly. The gas pressure already in the cylinder is quite sufficient completely to empty the 150-pound size in 20 minutes. If sprayed into the top of a hold, it will appear as a heavy mist, which evaporates before it sinks to the bottom.

MEASURING LIQUID SULPHUR DIOXIDE

If it is desired that the amount of fumigant introduced be quite accurately measured, it is necessary to put the cylinder on its cradle on platform scales, note the progressive loss of weight, and close the valve when the desired amount has been introduced. For practical fumigation, however, this can be obviated by determining the discharge rate of the sprayer or sprayers used. This is accomplished by completely discharging a cylinder through the sprayer and noting carefully the time intervals for each 5 pounds of weight lost. With this rate once established, a very considerable amount of bother incident to the carting around of the heavy platform scales can be eliminated, the amount of SO_2 introduced being calculated on the basis of the length of time it is permitted to flow. As the contents of the cylinder are discharged, evaporation within is sufficient to maintain pressure so that the rate of outflow is remarkably uniform.

APPARATUS REQUIRED

In addition to the cylinders of the fumigant, the only necessary apparatus includes wrenches to open and close the valve and to tighten the hose connections, a reducing connection to fit over the ¾-inch outlet of the cylinder at one end and receive the ¼-inch outlet hose coupling at the other, a 20-foot length of ¼-inch pressure tubing with ¼-inch pipe-thread couplings at either end, a sprayer to be attached to the end of the delivery tube, and a cradle for placing the cylinder in a tilted position. Introduction can be materially speeded by supplying several outlet tubes, sprayers, and connections, as well as several cradles (or a cradle holding 2, 3, or more cylinders), so that as many cylinders as desired may be operated at one time.

SPRAYERS

Any type of sprayer may be used, but for practical fumigation it is necessary to adopt a type which will permit of a rapid flow. The one illustrated in figure 1, B and C, was constructed and used at the New York Quarantine Station, where it proved to be quite satisfactory. The rate of delivery was almost exactly 10 pounds per minute. Figure 3 shows the type of spray produced.

It is absolutely essential that the sprayer and the inside of the delivery tube be free from water. If even comparatively small amounts of water are present, the chilling caused by evaporation of the SO_2 will freeze the water in the narrow outlet of the sprayer and block it. If the tube and sprayer are dry, however, it will function perfectly.

AMOUNT OF GAS AND PERIOD OF EXPOSURE

For fumigation by burning sulphur, the United States quarantine regulations prescribed that 3 pounds of this material be used for every 1,000 cubic feet of space, with exposure of 6 hours. The burning of this amount theoretically should produce a concentration in the air of 3 percent by volume. As a matter of fact, it is doubtful that it ordinarily produces a concentration higher than half of this figure. Furthermore, on account of its slow burning it seems reasonably clear that the maximum concentration does not appear until near the end of the prescribed period of exposure.

As opposed to these conditions, when liquid SO_2 is used the amount introduced into the fumigated space is accurately gaged and maximum concentration produced at the beginning of the period of exposure. It would appear to be entirely logical, therefore, when this substance is used, to reduce either the prescribed amount of fumigant or the prescribed exposure, or possibly both. If a concentration of 3 percent by volume, as prescribed in the quarantine regulations, were to be used, it would be necessary to introduce approximately 6 pounds of liquid SO_2 for every 1,000 cubic feet of space. If thereafter the exposure should be 6 hours, as prescribed in the regulations, we would have, in actual fact, about twice the concentration that would be secured by burning sulphur, applied over the same length of time. It would appear reasonable, therefore, either to reduce the time of exposure by half—that is, to 3 hours—or to reduce the amount of gas by half—that is, to 3 pounds per 1,000 cubic feet.

The cheapest procedure would be to reduce the amount of gas, but there are a number of reasons for not reducing this below the amount that will produce a concentration of 2 percent by volume. One important one is that this is the standard that has generally been settled upon by investigators using SO_2 as a fumigant in foreign countries; another is that it has been determined (1) that this is the lowest concentration that will actually kill rats rapidly (within 5 to 10 minutes). Furthermore, it is known that SO_2 penetrates into enclosed spaces rather slowly. It does not, therefore, seem wise to reduce too much the period of exposure.

With these considerations in mind, it is recommended that 4 pounds of liquid SO_2 be used per 1,000 cubic feet, and that the exposure—counting from the moment when the full charge of gas has been introduced—be 4 hours. In an experimental fumigation with this standard at the New York Quarantine Station it was found through actual titration of samples that, 1 hour after the gas was introduced, the concentration in a hold was 1 percent by volume, which progressively dropped until at the end of 5½ hours it was 0.6 percent by volume, while at the same periods the concentration in a relatively tight pipe casing in the same hold was 0.5 percent and 0.4 percent by volume, respectively.

TOXICITY OF SULPHUR DIOXIDE

Sulphur dioxide kills rats and other warm-blooded animals through local irritation of the tissues of the lung. In concentrations of 2 percent by volume and higher, it will produce death in rats in from 5 to 10 minutes through causing edema of the lung (1). In tests carried out at the New York quarantine station it has been determined that approximately 0.1 percent by volume causes death of exposed rats in 2 to 4 hours; 0.2 percent causes death in 1 to 2 hours; 0.3 percent causes death in 1 hour or less; and 0.5 percent by volume kills rats in ½ hour.

Applying these figures to the experimental ship fumigation cited in the preceding section, it will be seen that, during the period actually under test—that is, from 1 hour after introducing the gas until 5½ hours after introducing the gas—there was present in the hold a sufficient concentration to kill rats in less than ½ hour, and in the pipe casing sufficient concentration to kill rats in 1 hour or less.

ABSORPTION OF SULPHUR DIOXIDE

Sulphur dioxide is readily absorbed by water, which takes up about 30 times its volume of the gas. This is a matter of importance in ship fumigation, since the great majority of ships' holds are decidedly damp. In the experimental fumigation cited above, the drop of concentration from 2 percent by volume, as actually introduced, to 1 percent, as actually found on test 1 hour later, is ascribed to absorption on wet surfaces in the hold. In the experiment, the ship's hold used was a thoroughly tight one, and during the course of the experiment no appreciable leakage through the tarpaulin over the hatch could be detected.

FUMIGATION OF LOADED SHIPS

The principal problem in the fumigation of loaded ships is to introduce the gas into all levels of loaded holds. When sulphur is burned, it is possible to fumigate holds so loaded that the hatchway is left clear from the weather-deck through into the lower hold. With such an arrangement, the gas will pass fairly equally into all of the various levels. When, however, the hold is completely loaded so that the hatchways leading from shelter-deck to 'tween-deck and from 'tween-deck to lower hold are filled with cargo, it is not possible adequately to fumigate them by this method. The best that can be done in such a case is to remove sufficient of the cargo from the upper level to put the sulphur pots in place, and fumigate the upper level. A small amount of gas will penetrate by way of the ventilators into the lower levels, but not in sufficient amounts to kill rats.

With the various methods in which sulphur is burned outside the ship and the fumes blown into it, it is possible, of course, to blow the gas down the ventilators and thereby introduce it into the various levels. This method is probably not highly accurate, because obstruction to air currents is greater on the lower levels than on the upper levels. In consequence, one would expect the greater portion of the gas blown down a ventilator to pass into the highest level, a lesser portion into the intermediate levels, and the least into the lower hold. However, this tendency can be overcome by passing the tube from the blower down the ventilators directly into the lower hold and thereafter into the various levels in turn.

Liquid SO_2, of course, can be readily sprayed into any desired level in a loaded hold by lowering the delivery tube, with the sprayer at the end, down the ventilator and guiding the sprayer into the lower hold and into the various levels in turn, spraying into each the amount of gas calculated for each level. The difficulty incident to such a procedure is that there appears at present to be little, if any, data available as to what damage may be done to the cargo by spraying directly on it some 100 pounds or so of liquid SO_2. With many types of cargo it can be reasonably stated that no material damage would ensue. These types include many of the bulk cargoes such as bulk grain, bulk linseed, ore, paper pulp, and similar materials. With various other cargoes, however, it seems likely that considerable damage might be done, although there is at present little data to show that such damage actually would occur. It is probable, however, that such commodities as coffee, rubber, flour, colored materials, and fabrics would be injured.

The only alternative to spraying the SO_2 as a liquid into loaded holds is to heat it in the container and blow it in as a gas. For reasonably accurate work, this entails apparatus for heating, as well as either an arrangement whereby the gas introduced might be weighed or the use of some type of gas meter that will indicate the number of cubic feet delivered.

The problem of metering the gas should not be too difficult; in fact, there are several types of gas-flow meters on the market that can be used for this purpose. The problem of supplying sufficient heat to vaporize the large amount of SO_2 required is a real one. In the Marot process the liquid is passed through a copper coil heated in one form of the apparatus by the exhaust from a gasoline motor.

Partly loaded holds in which the hatchway is clear down to the lower hold may be fumigated by spraying liquid SO_2 at the top of the hatchway without greater damage to cargo than is incident to burning sulphur in the hold.

In view of the small number of ships at continental United States ports required to be fumigated with SO_2 when fully loaded, it is believed that, in the cases that do occur, the most practical procedure would be to discharge cargo from the hatchways until these are clear and then fumigate. Since when using SO_2 there is no particular objection to permitting exposure to continue through the night, it would appear that there should be little, if any, additional delay to the ship incident to such a procedure.

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COSTS

At present writing, liquid SO_2 (commercial anhydrous containing less than 0.1 percent of water) is obtainable in 150-pound cylinders at 7 cents per pound f.o.b. A deposit of $20 is required on each cylinder, which is refunded on return of the cylinder. In 1-ton drums, the present price is 6 cents per pound f.o.b., with a deposit of $200 on each drum. This grade of liquid SO_2 is not at present supplied in small-size containers; but, should a sufficient demand appear, it can probably be obtained in cylinders containing 35 pounds each, at a price of about 10 cents per pound. Deposits on this size cylinder are $10 each. The prices quoted are for Norfolk, Va.

The average cargo ship is about 3,500 tons net. To fumigate such a ship with liquid SO_2, using 4 pounds per 1,000 cubic feet, would require very nearly 1,500 pounds. Purchased in 150-pound cylinders, this would cost, including freight, probably between $125 and $150.

REFERENCE

(1) Clark, G. A.: Rat destruction by sulphur dioxide. Journal of the Royal Naval Medical Service, April 1932.

Part II. Experimental Tests of Liquid Sulphur Dioxide[1]

THE EXPERIMENTS

The objects of the experiments were as follows:

1. To determine the time required to spray liquid sulphur dioxide.
2. To determine concentrations of the gas produced at various levels in the hold.
3. To determine concentrations produced in enclosed spaces.
4. To determine rate of flow of sulphur dioxide when delivered from the cylinders as a gas.

Location.—The experiments were conducted in holds no. 1 and no. 6 on the American S.S. *President Fillmore* and at the New York quarantine station.

Material.—The material used in these experiments was commercial anhydrous liquid sulphur dioxide, specified to contain not more than 0.1 percent water.

METHODS

Object 1.—A steel cylinder containing approximately 150 pounds of liquid sulphur dioxide was connected with an air pump, and air pressure was brought to 150 pounds per square inch. (At the start of this operation it was noted that the gas pressure already in the cylinder was 50 pounds.) The cylinder was then disconnected from the air pump and placed on a cradle so that it was inclined, with the

[1] Communication to the Permanent Committee of the International Office of Public Hygiene at the meeting in May 1933; published in the Bulletin Mensuel for August 1933.

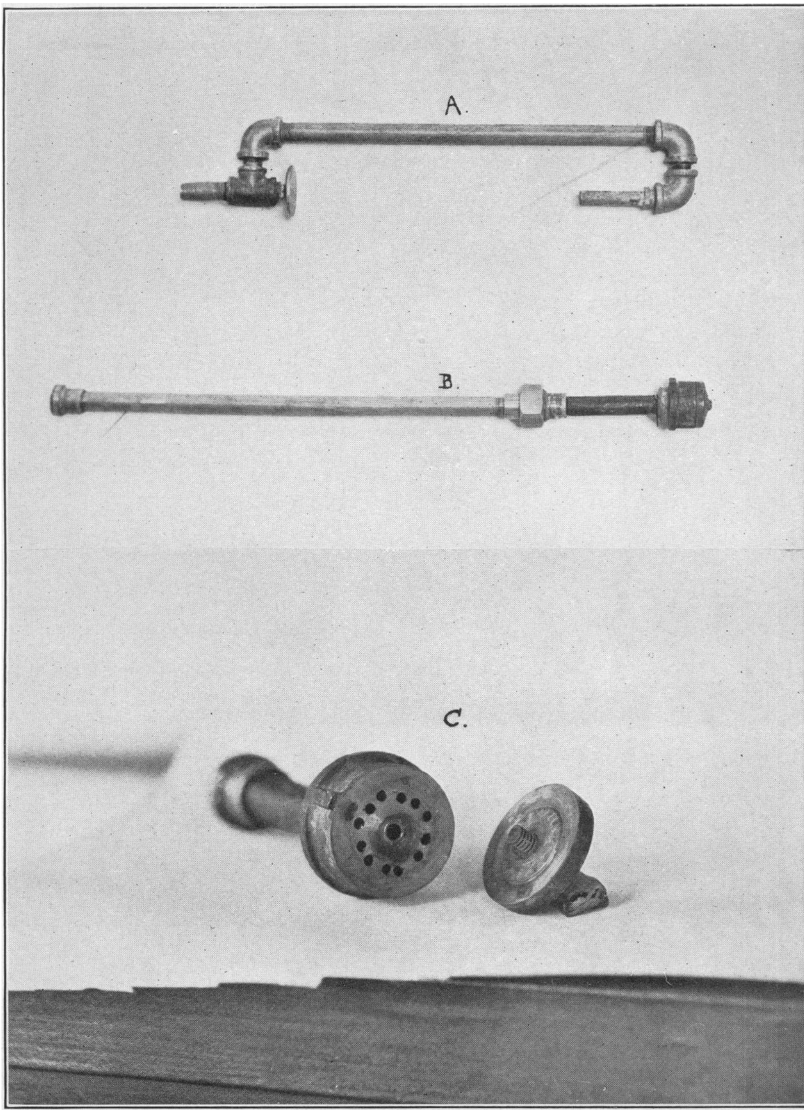

FIGURE 1.—The sprayers used. A, The stream of liquid SO_2 is directed against the disk; B, in this sprayer the liquid sprays out through a narrow slit near the end of the sprayer, shown taken apart in C; around the screw (in C) is a shoulder 1/64 inch high, which sets the outlet at that width.

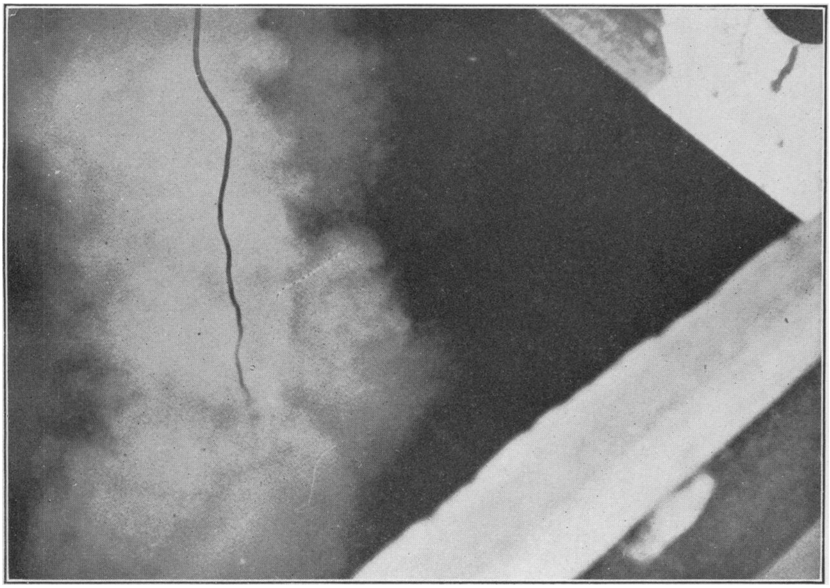

FIGURE 2.—Spray produced by the jet sprayer A, figure 1.

FIGURE 3.—Spray produced by sprayer B, figure 1.

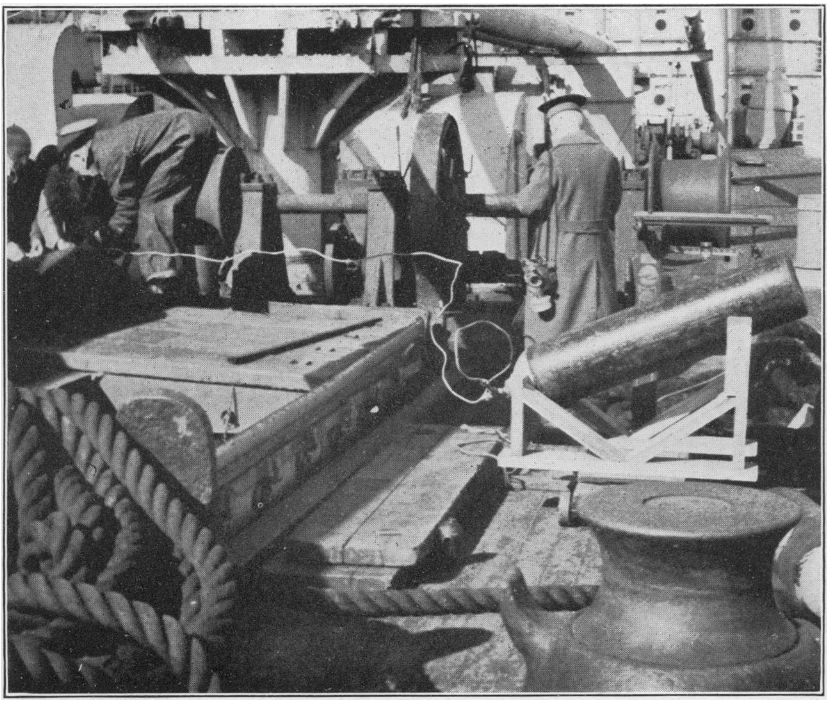

FIGURE 4.—The cylinder of liquid SO_2 shown on its cradle on the platform scales; the delivery tube has been attached and the fumigators are attaching a spray nozzle.

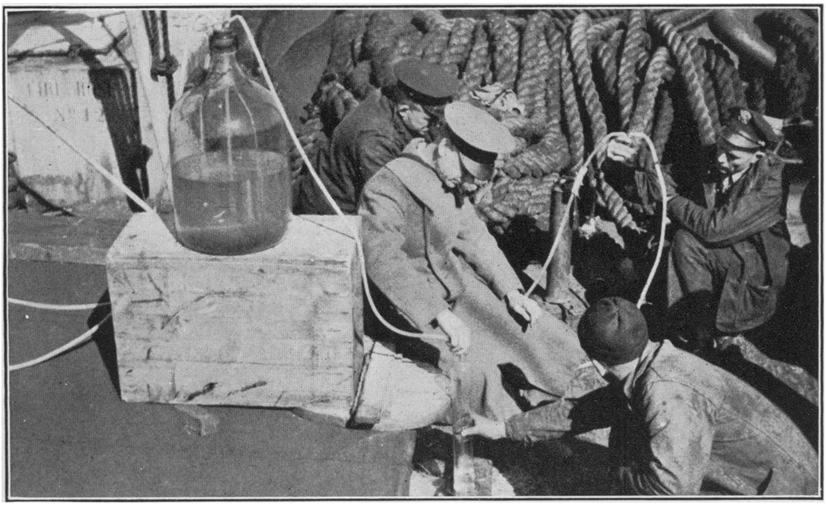

FIGURE 5.—Aspirating bottle and sampling tubes in operation.

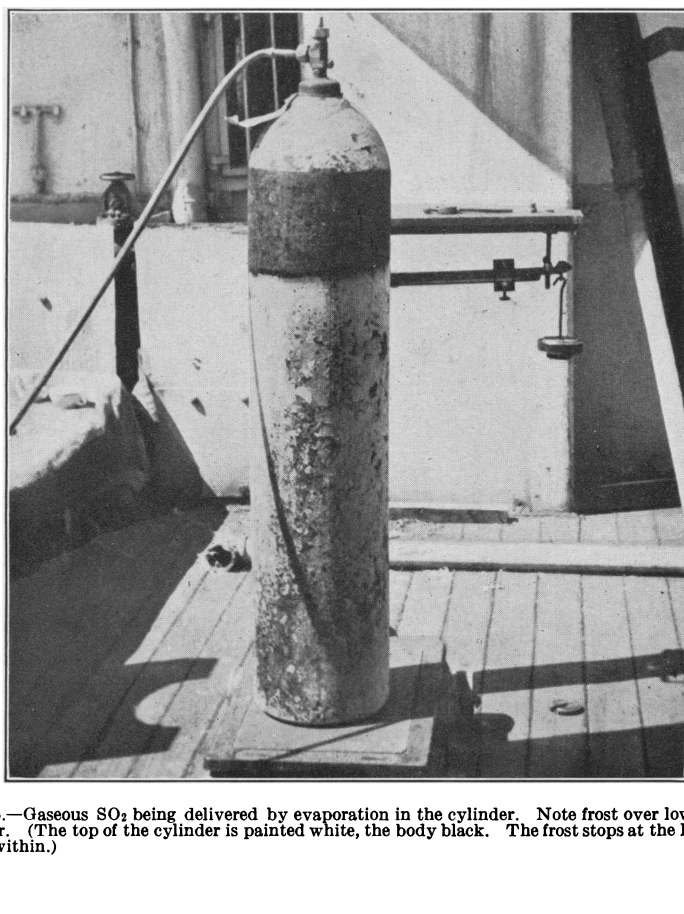

FIGURE 6.—Gaseous SO_2 being delivered by evaporation in the cylinder. Note frost over lower part of cylinder. (The top of the cylinder is painted white, the body black. The frost stops at the level of the liquid within.)

valve at the bottom, and the cradle and cylinder were then placed on platform scales. A ¼-inch flexible copper tubing was connected to the cylinder and a sprayer connected with the far end of the tubing, which was introduced into the hold. The valve of the cylinder was then opened wide. Progressive loss of weight was noted on the scales, and the time required to deliver the gas was noted (fig. 4). This procedure was later repeated without adding any air pressure.

Two types of sprayer were tested. One directed a jet against a flat surface (fig. 1A); the other was a disk sprayer (fig. 1B). In operation, both of these sprayers broke the liquid sulphur dioxide up into a heavy mist (see figs. 2 and 3).

Objects 2 and 3.—Prior to beginning fumigation, sampling tubes of rubber were introduced at various locations into the two holds fumigated (figs. 7 and 8), the free ends of the tubes being brought through the hatches onto the deck. On the deck was set up an aspiration bottle, by means of which measured quantities of air were drawn through 0.1 normal iodine solution in order to titrate the SO_2 content. The apparatus and its operation are shown in figure 5.

Hold no. 1 consisted of a shaftway the size of the hatch, passing down through two decks, below which it expanded into two 'tween-decks and a lower hold. The total capacity was 41,000 cubic feet. The total depth of the hold from the hatch coaming to the top of the deep tank was 58 feet. Over the top of the deep tank, however, was 8 feet of dirt ballast, in the center of which was built a well 3 feet square, which gave access to the manhole on top of the deep tank. This well was covered with loose boards, between which there were several cracks approximately one-half inch wide. One sampling tube (no. 4) was introduced to the bottom of this well. A second sampling tube (no. 3) was introduced into the lower hold 4 feet above the level of the ballast. A third sampling tube (no. 2) was at the first 'tween-deck, 20 feet from the top of the hatch. A fourth sampling tube (no. 1) was in the shaftway 6 feet from the top. A fifth sampling tube (no. 5) was in a relatively tight pipe casing on the second 'tween-deck at a point 30 feet below the hatch coaming. This pipe casing had a hole about 1½ inches square near the bottom, and two small openings about ½ inch square each near the top.

Hold no. 6 was blocked off by closing the hatchway between the first and second 'tween-decks, so that, for the purposes of this fumigation, it consisted of a shaftway similar to the one in hold no. 1 through two decks, below which it expanded into a series of cold-storage holds, the arrangement of which is shown in figure 8. Sampling tubes were placed in three of these cold-storage holds and in the open hold 25 feet below the hatch. None of these sampling tubes were in enclosed spaces, the object being to determine to what extent the gas would diffuse through the relatively small doors into these compartments. In one compartment a tube was placed near the top and another one near the bottom.

Object 4.—To determine the rate of flow when delivered as a gas, a steel cylinder containing approximately 150 pounds of liquid sulphur

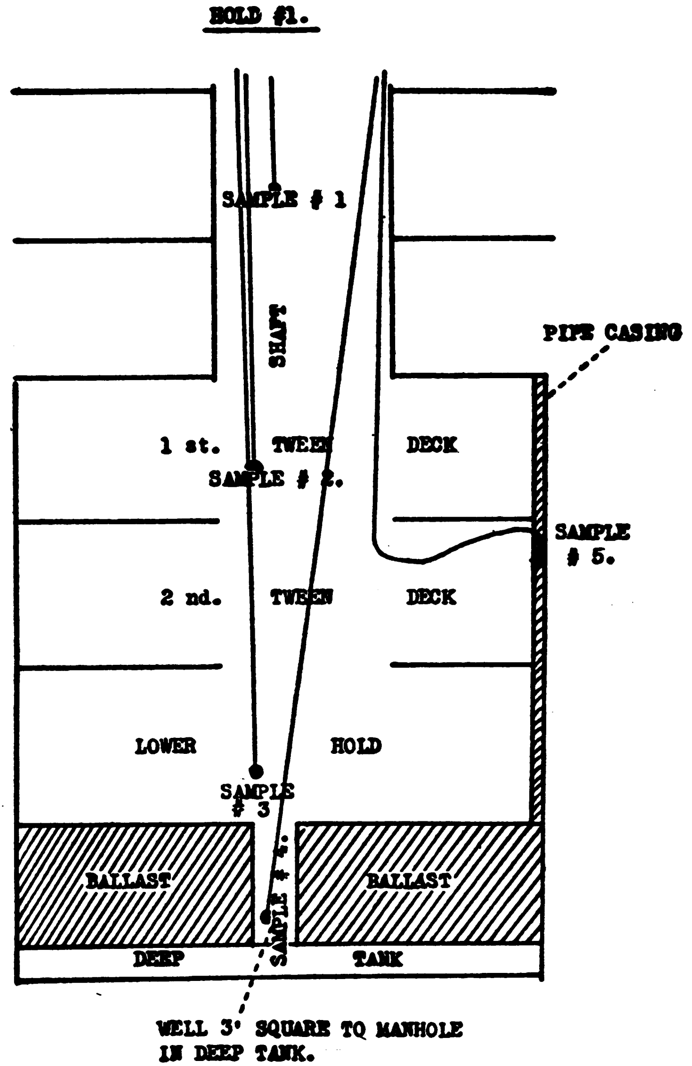

FIGURE 7.—Longitudinal section through hold no. 1, showing locations from which air samples were drawn.

dioxide was placed upright on the platform scales. A 20-foot length of rubber tubing was led from the outlet of the cylinder into the hold. The valve was then opened and the gas permitted to flow. The amount of gas delivered was checked by the progressive loss of weight. The time required was noted.

RESULTS

Object 1.—With the jet sprayer, 50 pounds of liquid sulphur dioxide were delivered in the first 4 minutes of operation, 50 additional pounds in the next 5 minutes, and 45 additional pounds in the suc-

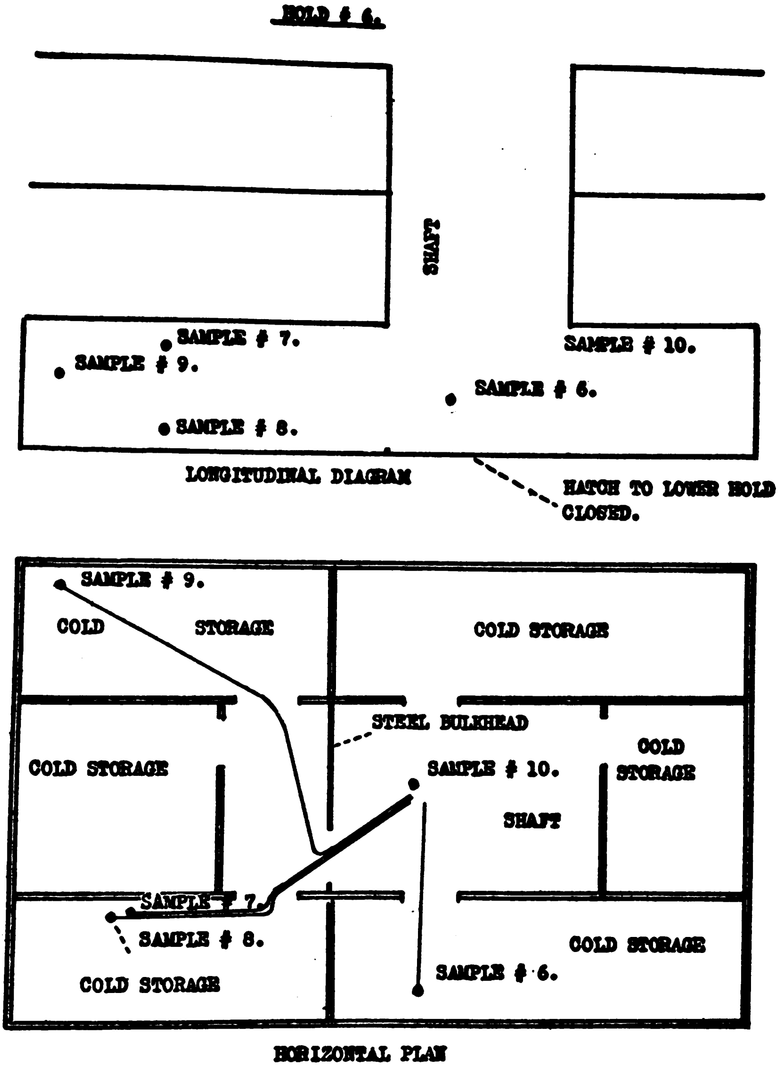

FIGURE 8.—Longitudinal diagram and horizontal plan of hold no. 6, showing locations from which air samples were drawn.

ceeding 6 minutes—a total of 145 pounds in 15 minutes. At this point, loss of weight ceased, showing that the tank was empty. After permitting the pressure to blow off, the delivery tube was disconnected and was placed on a second full cylinder. The jet sprayer was replaced by the disk sprayer. Air pressure of 150 pounds had been let into the cylinder prior to connecting the delivery tube. When all was ready, the valve was opened and 25 pounds of liquid sulphur dioxide were sprayed into the hold in 3 minutes, when the valve was closed.

The total time for delivering 170 pounds of liquid sulphur dioxide into this hold was 28 minutes. Since the capacity of the hold was 41,000 cubic feet, this was over 4 pounds per 1,000 cubic feet and should, theoretically, have produced a concentration of 2.27 percent by volume.

The cylinder with the disk spray attached was removed to hold no. 6, where it was set up in the same manner as before. The valve was opened, and the remaining amount of liquid was sprayed in.

The time intervals and amounts delivered were as follows: In 2 minutes after starting, 20 pounds had been introduced; in the next 2 minutes, 20 additional pounds; in the third 2 minutes, 20 additional pounds; in the fourth 2 minutes, 20 additional pounds; in the ensuing 4 minutes, 43 additional pounds. The entire 123 pounds were delivered in just 12 minutes from the time the valve was opened.

In hold no. 6, there was introduced an additional amount of 31 pounds of liquid sulphur dioxide in a manner that will be explained later. This makes a total of 154 pounds in this hold, the capacity of which was 32,000 cubic feet—a theoretical concentration of 2.63 percent by volume.

At no time was there any material slowing of the rate of delivery with either of these sprayers. There was apparently no tendency for either sprayer to freeze, although both were found frosted over the surface when taken from the hold.

Summarizing, it will be noted that, using cylinders containing 150 pounds of liquid sulphur dioxide under an initial pressure of 150 pounds per square inch and with the types of sprayers used, the liquid was sprayed out at the rate of about 10 pounds per minute. The spraying apparatus was changed from one cylinder to another in 10 minutes. The essential point in manipulation, of course, was that the cylinders were inclined so that the delivery valve was at the bottom, and the air and vapor under pressure at the top. This accomplished two objects: One was rapid ejection of the sulphur dioxide as a liquid; the other was prevention of evaporation of any considerable amount until after the liquid had been projected from the sprayer, thereby preventing excessive cooling of the apparatus.

At a later date a full cylinder was set on a cradle, valve down, the disk sprayer attached and the valve opened. No air pressure was added. Progressive loss of weight was not noted, but the time of opening the valve and the moment when the spray ceased were taken, giving the total time required to empty the cylinder. This was 18 minutes. The cylinder was weighed before and after the test, the loss of weight being 149 pounds. Atmospheric temperature during the period of this test was 58° F.

While the time required to empty the cylinder under its own pressure was a few minutes longer than under 150 pounds air pressure, the time required to introduce air pressure was eliminated along with the labor, inconvenience, and apparatus necessarily incident to such an operation.

By way of comment, two improvements are suggested. One is the use of smaller containers; the other, the use of additional delivery tubes and spray nozzles so that two, three, or more cylinders may be emptied at the same time. As to the size of cylinders, those containing not more than 50 pounds liquid sulphur dioxide would be very much more convenient than the cylinders used. The total weight of one of the latter was close to 300 pounds.

Object 2.—In hold no. 1, object 2 (which was to ascertain varying concentration at different levels) was determined by comparison of concentrations in samples 1, 2, and 3, at levels of 6 feet, 20 feet, and 46 feet, respectively, below the hatch coaming, and, consequently, in reverse at levels of 4 feet, 30 feet, and 44 feet above the level of the ballast in the lower hold. The results of tests of these samples at periods of 1 hour, 3½ hours, and 5½ hours after introducing the gas are given in table 1. Briefly, they show very much the same concentration at different levels, unexpectedly a trifle lower at the deeper levels.

TABLE 1.—*Comparative concentration of SO_2 at different levels in hold no. 1*

[Calculated concentration (basis of amount of SO_2 introduced), 2.27 percent by volume]

Number and location of sample	Concentration, percent by volume		
	After 1 hour	After 3½ hours	After 5½ hours
No. 1, 6 feet below hatch, 44 feet from top of ballast	1.09	0.67	0.51
No. 2, 20 feet below hatch, 30 feet from top of ballast	1.08	.63	.50
No. 3, 46 feet below hatch, 4 feet from top of ballast	1.04	.61	.45

In hold no. 6, samples were taken 1 hour after the gas had been introduced. The results are presented in table 2, and show about the same concentration in the various cold-storage compartments, and a somewhat lower concentration in the hatchway. In one compartment where samples were taken at different levels, concentration was decidedly higher near the floor than near the top.

TABLE 2.—*Concentrations of SO_2 in various compartments on same level*

[Samples taken 1 hour after introduction of gas. Calculated concentration, 2.63 percent by volume

Number and location of sample	Concentration, percent by volume
No. 6, cold-storage space on port side	1.86
No. 7, cold-storage space, port side, forward, near top	1.32
No. 8, same as no. 7, but near floor	2.19
No. 9, cold-storage space on starboard side	1.94
No. 10, in hold 25 feet below hatch	1.03

It will be noted that the concentration shown in hold no. 1 one hour after introduction of the gas was only about one half of that calculated on the basis of the amount of gas introduced. In the succeeding 4½ hours it was progressively reduced an additional 25 percent. Since very little leakage was noted, it is believed that most of this reduction was due to absorption on the surfaces of the hold, particularly in the lower hold, where both steel and wood surfaces were distinctly moist.

In hold no. 6 the concentrations found more nearly approached the calculated figure. It is believed this is largely accounted for by the fact that the lower hold, containing most of the moist surfaces, was blocked off. The compartments actually fumigated were at a warmer level above the water line.

Object 3.—The purpose here, to determine the amount of gas penetrating into enclosed spaces, was accomplished, in hold no. 1, through samples 4 and 5 in the partially closed well passing through the ballast in the bottom of the hold, and in the pipe casing on the second 'tween deck. The results of these tests appear in table 3, where it is shown that the amount of gas was at each period (with one exception) less than half of that in the hold. The more rapid disappearance of gas in sample 4 is presumably explained by the presence of a pool of water at the bottom of the well from which it was taken. It will be noted that in both these locations, for a period of at least 3½ hours the concentration was higher than that which had previously been determined, in experiments at this station, as necessary to kill rats in 1 to 2 hours, that is 0.2 percent.

TABLE 3.—*Concentrations of SO_2 in two enclosed spaces in hold no. 1*

Location of sample	Concentration, percent by volume		
	After 1 hour	After 3½ hours	After 5½ hours
No. 2 (from table 1; control) in hold 20 feet below hatch, 30 feet from top of ballast	1.08	0.63	0.50
No. 4, near bottom of well, 8 feet deep, through ballast in bottom of lower hold	.45	.21	.09
No. 5, in casing on second 'tween-deck, 28 feet below hatch, 22 feet from top of ballast	.48	.54	.21

Object 4.—The purpose here was to determine the rate of delivery of the gas when allowed to vaporize in the cylinder. A cylinder containing approximately 150 pounds of liquid sulphur dioxide was placed upright on platform scales, and the pressure of the vapor in the top of the cylinder was determined to be almost exactly 50 pounds. A 20-foot length of rubber tubing was then connected to the outlet, passed into hold no. 6, and the valve opened wide. During the first 6 minutes, 4 pounds were delivered; during the next 6 minutes, an additional 4 pounds were delivered; during the following 16 minutes, an additional 5 pounds were delivered; and during the ensuing 30 minutes, an additional 5 pounds were delivered. The valve on the cylinder was then closed and the cylinder was allowed to stand for 30 minutes. The valve was then again opened. During the following 30 minutes, 10 pounds were delivered; in the next 12 minutes, 2 pounds additional were delivered; in the ensuing 8 minutes, 1 pound more was delivered.

At the end of the first period of observation the liquid remaining in the cylinder had become so chilled that the surface of the cylinder was frosted to the height of the liquid inside. This frost disappeared during the half-hour interval, but had reappeared at the end of the second period of observation (fig. 6).

It is quite obvious from this test that once the gas already vaporized in the cylinder was blown off, the ensuing delivery of vaporized SO_2 was dependent upon the heat intake. During the period of this experiment, the atmospheric temperature rose from 50° to 55° F. Furthermore, the cylinder, which was painted black, was directly in the sunlight.

It is roughly calculated from the data given—that is, the delivery of a total of 31 pounds of gas in approximately 2 hours' total elapsed time—that it would require some 10 hours to deliver 150 pounds from a single cylinder. While it is obvious that the amount of gas delivered in a given period of time can be increased by using several cylinders, it is equally obvious that unless the amount of gas in each individual cylinder is quite small, a very extended time must be allowed for introducing gas by this method.

This test was repeated a few days later, when a cylinder containing 120 pounds of liquid SO_2 was set upright on platform scales on the open dock and the valve opened wide. During the first half hour it lost in weight 23 pounds. During the next hour it lost 8 pounds. During the following hour it lost 6 pounds. During the following 3 hours it lost 11 pounds, and thereafter 3½ pounds an hour on the average day and night until a constant weight was reached more than 30 hours after beginning the test. The progressive lowering of the level of the liquid inside the cylinder could be followed by observing the slow lowering of the frost covering on the outside. Atmospheric temperature varied during the test from 42° to 58° F. The weather was clear. During the period of this test, 22 hours after the start, the cylinder was moved a distance of 500 feet. The consequent agitation caused a loss in the ensuing hour of 12¼ pounds.

The results of these experiments are of extreme interest in view of the use of liquid sulphur dioxide introduced by such a method at some seaports. It would appear that its use in this manner in the past may have been largely empirical and not controlled by exact measurements. One would not expect that the results obtained were of the highest order.

FREEZING OF SPRAYERS

Because there have been reports of sprayers for liquid sulphur dioxide freezing during the introduction of the fumigant, so that the gas could not be passed through until they had been thawed, an experiment was conducted with liquid sulphur dioxide to which approximately 5 percent of water was added. When attempts were made to spray this through the disk type nozzle, a sufficient amount of the water froze in the narrow outlet to completely block the sprayer. This occurred when only some 5 or 6 pounds had been delivered. It would appear from this that freezing of the sprayers occurs when there is an appreciable amount of water in the fumigant.

COURT DECISION RELATING TO PUBLIC HEALTH [1]

City ordinance, making vaccination a prerequisite to admission to a public school, upheld.—(Mississippi Supreme Court; *Hartman* v. *May et al.*) An ordinance of the city of Biloxi made it unlawful for any child of educable age to attend any school in the city to which the public generally was admitted unless the child, previous to the date of his or her application for admission, had presented to the superintendent, principal, or teacher in charge of such school a certificate from the city health officer or some other reputable physician of the city showing that the child had been successfully vaccinated against smallpox or was immune to the danger of contracting the disease. A resolution on the subject, adopted by the board of trustees of the city schools, was in accord with the requirements of the ordinance. The governing authorities of municipalities were empowered by section 2396 of the Code of 1930 "to make regulations to secure the general health of the municipality" and by section 2417 "to make regulations to prevent the introduction and spread of contagious or infectious diseases" and "to make quarantine laws for that purpose".

An injunction was sought to restrain the defendants, the superintendent and board of trustees of the city schools, from refusing to

[1] This abstract was prepared from a mimeographed copy of the decision furnished to the Public Health Service by the Mississippi State Board of Health.

permit the appellant, an 8-year old child, to enter school. The bill of complaint alleged that the child was excluded from school because he had not been vaccinated, that there was no epidemic of smallpox in the city, that the said child had not been exposed to smallpox or other communicable disease, and that he had violated none of the valid school rules. A demurrer to the bill of complaint was sustained by the lower court, and an appeal was taken to the supreme court.

On appeal it was contended that, in the absence of an express statutory requirement of vaccination against smallpox as a prerequisite to a child's right to enter the public schools, a municipality had no power to require vaccination as a condition precedent to the right to attend its schools, or, in other words, that the general statutory grant of authority to municipalities to make regulations to prevent the introduction and spread of contagious or infectious diseases did not empower municipal authorities to exclude children from the public schools because of failure or refusal to be vaccinated. The further contention was made that, in the absence of an epidemic of smallpox in the city, the vaccination ordinance was arbitrary and unreasonable and, therefore, void. After detailing the statutory provisions quoted above, the supreme court went on to say:

> * * * The medical profession generally recognize vaccination as an effective means of prevention of the disease [smallpox], and we do not think that the ordinance, requiring children to be vaccinated as a condition to their admission to a public school, is an arbitrary and unreasonable exercise of the power "to make regulations to prevent the introduction and spread of contagious or infectious diseases." The power granted is not only to make regulations to prevent the "spread" of such diseases but to prevent the "introduction" thereof. The argument of counsel that the unreasonableness and invalidity of the ordinance is emphasized by the fact that there was no case of smallpox in the municipality or surrounding territory and no threatened outbreak of the disease is not supported by the averments of the bill of complaint. The bill merely charged that there was at the time no epidemic of smallpox in the said city.
>
> In the exercise of the power and authority granted to make regulations to secure the general health and prevent the introduction and spread of contagious or infectious diseases much must be left to the judgment and discretion of the municipal authorities, and the presumption is in favor of the reasonableness and propriety of regulations enacted in pursuance of such grant of power. The ordinance here in question was intended and reasonably calculated to prevent the introduction or spread of contagion and bears a direct and intimate relation to the maintenance of the health of the inhabitants of the municipality, and we are unable to say that, in the enactment thereof, there was an unreasonable or arbitrary exercise of power. * * *
>
> While there is authority in other jurisdictions for the view that a general legislative delegation of power to make regulations for the preservation of the public health does not confer on municipal or school authorities the power to require children to be vaccinated as a condition to their admission to a public school, there is also ample authority supporting the views herein expressed. * * *

The appellant also contended that, in view of a constitutional provision requiring the legislature to establish "a uniform system of free public schools by taxation or otherwise for all children between the ages of 5 and 21 years" and of a statutory provision making school attendance compulsory, the municipal and school authorities of the city had no power to refuse him admission to school because of his refusal or failure to submit to vaccination. Concerning this the court said:

> * * * The same contention and argument was presented in the case of *McLeod* v. *State*, *supra*, and, while the validity of health regulations was not there presented, the principle involved was the same, and the language of the court in disposing of the point is applicable and controlling here. In that case it was held that "Section 201 of the constitution does not deprive the legislature of the power to pass laws authorizing trustees of public schools to make reasonable rules and regulations for the government and conduct of such schools." In passing upon the apparent conflict between regulations excluding certain classes of minors from the public schools and the compulsory education provisions of the school code, the court there held that the compulsory education provision of the school code and other provisions of the code authorizing reasonable regulations for the management, conduct, and control of schools should be construed together, the court saying: "So construed, they do not mean that a child is entitled to attend a public school regardless of his conduct, but on the contrary that it is subject to such reasonable rules for the government of the school as the trustees thereof may see fit to adopt."

The court concluded its opinion as follows:

> * * * It having been determined in the case at bar that the ordinance requiring vaccination as a condition to admission to the public schools was a reasonable and valid exercise of the power granted to the municipality to make regulations to prevent the introduction and spread of contagious or infectious diseases, it follows that the appellant was not entitled to admission to the schools in violation of the provisions of the ordinance.

DEATHS DURING WEEK ENDED JAN. 20, 1934

[From the Weekly Health Index, issued by the Bureau of the Census, Department of Commerce]

	Week ended Jan. 20, 1934	Corresponding week, 1933
Data from 86 large cities of the United States:		
Total deaths	8,859	9,224
Deaths per 1,000 population, annual basis	12.3	12.9
Deaths under 1 year of age	573	705
Deaths under 1 year of age per 1,000 estimated live births	53	[1] 60
Deaths per 1,000 population, annual basis, first 3 weeks of year	12.7	13.3
Data from industrial insurance companies:		
Policies in force	67,487,068	69,051,695
Number of death claims	16,515	17,168
Death claims per 1,000 policies in force, annual rate	12.8	13.0
Death claims per 1,000 policies, first 3 weeks of year, annual rate	10.9	11.5

[1] Data for 81 cities.

PREVALENCE OF DISEASE

No health department, State or local, can effectively prevent or control disease without knowledge of when, where, and under what conditions cases are occurring

UNITED STATES

CURRENT WEEKLY STATE REPORTS

These reports are preliminary, and the figures are subject to change when later returns are received by the State health officers

Reports for Weeks Ended Jan. 27, 1934, and Jan. 28, 1933

Cases of certain communicable diseases reported by telegraph by State health officers for weeks ended Jan. 27, 1934, and Jan. 28, 1933

Division and State	Diphtheria		Influenza		Measles		Meningococcus meningitis	
	Week ended Jan. 27, 1934	Week ended Jan. 28, 1933	Week ended Jan. 27, 1934	Week ended Jan. 28, 1933	Week ended Jan. 27, 1934	Week ended Jan. 28, 1933	Week ended Jan. 27, 1934	Week ended Jan. 28, 1933
New England States:								
Maine	2	1	2	700	1	1	0	0
New Hampshire			1	1	67		0	0
Vermont		1			35		0	0
Massachusetts	18	30		111	1, 521	130	0	3
Rhode Island	3	5	1	71	2	1	0	0
Connecticut	6	6	40	270	14	67	1	0
Middle Atlantic States:								
New York	59	71	[1] 25	[1] 138	629	1, 550	1	1
New Jersey	25	31	30	230	135	413	1	1
Pennsylvania	81	121			1, 667	564	3	2
East North Central States:								
Ohio	44	61	8	375	263	784	0	2
Indiana	36	50	55	107	220	6	4	3
Illinois	38	63	56	158	214	147	11	21
Michigan	11	28	1	64	47	492	2	2
Wisconsin	13	4	46	1, 522	299	164	0	2
West North Central States:								
Minnesota	7	8	3	2	137	610	1	0
Iowa [2]	7	10	18		80		0	1
Missouri	63	40	39	21	785	164	1	2
North Dakota	5		3	655	166	112	1	1
South Dakota		5		17	317	11	0	0
Nebraska	11	12		132	78	9	0	1
Kansas	13	24	6	350	61	104	0	2
South Atlantic States:								
Delaware	5	2		14	87		0	0
Maryland [2]	7	8	33	434	48	1	1	7
District of Columbia	11	6	5	5	156	2	0	1
Virginia	26	28			570	329	2	1
West Virginia	19	14	63	253	27	333	0	1
North Carolina	41	21	109	827	2, 423	334	1	1
South Carolina	13	10	744	3, 092	336	35	0	0
Georgia [2]	19	7	134	676	1, 271	1	1	0
Florida	15	7		183	43	18	1	0

See footnotes at end of table.

Cases of certain communicable diseases reported by telegraph by State health officers for weeks ended Jan. 27, 1934, and Jan. 28, 1933—Continued

Division and State	Diphtheria		Influenza		Measles		Meningococcus meningitis	
	Week ended Jan. 27, 1934	Week ended Jan. 28, 1933	Week ended Jan. 27, 1934	Week ended Jan. 28, 1933	Week ended Jan. 27, 1394	Week ended Jan. 28, 1933	Week ended Jan. 27, 1934	Week ended Jan. 28, 1933
East South Central States:								
Kentucky	18	22	7	395	68	17	0	2
Tennessee	16	15	141	467	772	6	3	6
Alabama [3]	42	15	161	312	240	5	1	2
Mississippi	9	1					0	0
West South Central States:								
Arkansas	7	7	25	645	461	8	1	1
Louisiana	26	16	20	124	41	24	0	0
Oklahoma [4]	34	29	89	554	580		2	1
Texas [3]	179	107	234	448	741	73	5	1
Mountain States:								
Montana	2	1	4	832	11	152	0	0
Idaho		7	1	1	45	9	0	0
Wyoming	1				79	17	0	0
Colorado	5	3	10	65	14	2	0	1
New Mexico	7	7		3	133	8	0	1
Arizona	3	12	15	22	11	1	2	0
Utah [3]		6		2	777	2	0	0
Pacific States:								
Washington		14		6	425	2	0	0
Oregon	1	5	40	243	35	34	0	1
California	32	46	32	312	763	233	3	5
Total	980	987	2,201	14,839	16,895	6,965	49	76

Division and State	Poliomyelitis		Scarlet fever		Smallpox		Typhoid fever	
	Week ended Jan. 27, 1934	Week ended Jan. 28, 1933	Week ended Jan. 27, 1934	Week ended Jan. 28, 1933	Week ended Jan. 27, 1934	Week ended Jan. 28, 1933	Week ended Jan. 27, 1934	Week ended Jan. 28, 1933
New England States:								
Maine	0	4	19	24	0	0	0	0
New Hampshire	0	0	26	51	0	0	0	0
Vermont	0	0	10	16	0	0	2	0
Massachusetts	1	0	265	378	0	0	0	5
Rhode Island	0	0	17	34	0	0	1	0
Connecticut	1	0	53	117	0	2	1	1
Middle Atlantic States:								
New York	2	3	715	823	0	0	5	8
New Jersey	0	0	201	307	0	0	8	3
Pennsylvania	1	0	775	961	0	0	15	2
East North Central States:								
Ohio	1	0	461	689	0	1	5	12
Indiana	0	1	181	129	3	5	0	5
Illinois	1	1	552	523	1	17	7	3
Michigan	0	0	463	476	0	0	4	2
Wisconsin	1	0	206	172	31	7	0	3
West North Central States:								
Minnesota	1	0	63	82	3	0	6	2
Iowa [2]	0	0	102	36	4	31	2	4
Missouri	0	0	144	88	17	0	2	1
North Dakota	0	5	39	11	0	1	0	0
South Dakota	1	0	29	19	1	4	0	11
Nebraska	1	0	32	38	1	39	1	1
Kansas	0	1	156	64	1	0	4	0
South Atlantic States:								
Delaware	0	0	13	10	0	0	0	1
Maryland [3]	0	0	98	81	0	0	2	1
District of Columbia	0	0	18	23	0	0	0	1
Virginia	0	2	99	55	1	0	13	14
West Virginia	0	0	79	41	0	0	7	5
North Carolina	2	0	89	40	1	2	2	4
South Carolina	0	0	17	3	1	4	4	6
Georgia [3]	0	0	16	16	5	1	6	6
Florida	0	0	9	8	0	0	3	2

See footnotes at end of table.

Cases of certain communicable diseases reported by telegraph by State health officers for weeks ended Jan. 27, 1934, and Jan. 28, 1933—Continued

Division and State	Poliomyelitis		Scarlet fever		Smallpox		Typhoid fever	
	Week ended Jan. 27, 1934	Week ended Jan. 28, 1933	Week ended Jan. 27, 1934	Week ended Jan. 28, 1933	Week ended Jan. 27, 1934	Week ended Jan. 28, 1933	Week ended Jan. 27, 1934	Week ended Jan. 28, 1933
East South Central States:								
Kentucky	1	1	74	54	0	0	3	0
Tennessee	1	1	55	51	0	0	9	2
Alabama [3]	1	2	24	28	0	0	11	0
Mississippi	0	0	18	16	0	2	3	3
West South Central States:								
Arkansas	0	1	15	27	22	13	0	8
Louisiana	0	2	37	7	3	8	7	8
Oklahoma [4]	0	1	23	27	2	17	2	5
Texas [3]	0	0	104	68	14	32	11	8
Mountain States:								
Montana	0	0	25	7	0	0	2	1
Idaho	0	0	4	3	7	15	0	0
Wyoming	0	0	7	8	0	0	0	0
Colorado	0	0	38	25	1	0	0	0
New Mexico	0	0	71	12	0	0	13	1
Arizona	1	5	17	10	1	0	0	0
Utah [2]	0	0	13	9	0	0	0	0
Pacific States:								
Washington	2	0	52	32	4	15	2	5
Oregon	0	0	56	17	5	6	1	4
California	4	3	292	204	11	23	7	9
Total	23	33	5,872	5,920	140	245	171	157

[1] New York City only.
[2] Week ended earlier than Saturday.
[3] Typhus fever, week ended Jan. 27, 1934, 23 cases, as follows: Georgia, 13; Alabama, 6; Texas, 4.
[4] Exclusive of Oklahoma City and Tulsa.

SUMMARY OF MONTHLY REPORTS FROM STATES

The following summary of cases reported monthly by States is published weekly and covers only those States from which reports are received during the current week:

State	Meningococcus meningitis	Diphtheria	Influenza	Malaria	Measles	Pellagra	Poliomyelitis	Scarlet fever	Smallpox	Typhoid fever
November 1933										
Colorado	1	31	--------	--------	12	--------	1	139	60	23
Massachusetts	4	98	--------	4	1,085	--------	6	694	0	4
Wisconsin	6	65	135	--------	372	--------	12	469	130	20
December 1933										
California	11	144	177	2	1,223	3	19	859	34	154
Colorado	--------	50	--------	--------	27	--------	0	109	29	22
Georgia	3	134	565	147	1,683	14	5	105	1	44
Indiana	7	292	187	--------	248	--------	3	870	15	13
Massachusetts	4	94	--------	2	2,251	--------	4	843	0	14
Mississippi	--------	68	3,367	2,680	1,284	170	1	114	9	7
Montana	3	13	90	--------	6	--------	0	42	20	12
Nevada	--------	1	10	--------	--------	--------	0	5	4	0
New Mexico	3	38	5	[1] 23	269	1	1	117	0	33
New York [2]	18	218	--------	9	2,245	--------	26	1,953	0	38
Oklahoma [3]	13	271	318	37	284	6	--------	188	1	29
Oregon	--------	18	75	--------	87	--------	4	187	37	13
Puerto Rico	--------	59	263	6,036	188	--------	0	1	0	49
Virginia	8	324	390	3	439	8	1	605	0	55
Washington	4	23	88	--------	940	--------	10	145	17	14
Wisconsin	7	49	117	--------	653	--------	5	428	153	3

[1] 8 carriers included.
[2] The report for New York for December published herein is a correction of an erroneous report published in Public Health Reports of Jan. 20, 1934, pp. 122 and 123.
[3] Exclusive of Oklahoma City and Tulsa.

November 1933

	Cases
Chicken pox:	
Colorado	426
Massachusetts	772
Wisconsin	2,290
Dysentery:	
Colorado	4
Massachusetts	12
German measles:	
Massachusetts	28
Wisconsin	29
Impetigo contagiosa:	
Colorado	25
Lead poisoning:	
Massachusetts	4
Lethargic encephalitis:	
Massachusetts	3
Wisconsin	2
Mumps:	
Colorado	48
Massachusetts	253
Wisconsin	61
Ophthalmia neonatorum:	
Massachusetts	36
Paratyphoid fever:	
Colorado	1
Septic sore throat:	
Massachusetts	20
Trachoma:	
Massachusetts	1
Wisconsin	1
Trichinosis:	
Massachusetts	4
Tularaemia:	
Wisconsin	12
Undulant fever:	
Colorado	1
Massachusetts	2
Wisconsin	9
Vincent's infection:	
Colorado	3
Whooping cough:	
Colorado	226
Massachusetts	1,308
Wisconsin	1,493

December 1933

	Cases
Actinomycosis:	
California	1
Anthrax:	
Massachusetts	2
New York	1
Beriberi:	
California	1
Chicken pox:	
California	1,599
Colorado	475
Georgia	86
Indiana	741
Massachusetts	1,028
Mississippi	593
Montana	322
Nevada	25
New Mexico	83
New York	3,405
Oklahoma [3]	96
Oregon	251
Puerto Rico	31
Virginia	400
Washington	511
Wisconsin	1,913
Conjunctivitis:	
Georgia	1
Dengue:	
Georgia	1
Mississippi	2
Diarrhea and dysentery:	
Virginia	44
Dysentery:	
California (amoebic)	39
California (bacillary)	47
Colorado	4
Georgia (amoebic)	7
Georgia (bacillary)	6
Massachusetts	9
Mississippi (amoebic)	92

December 1933—Continued

	Cases
Dysentery—Continued	
Montana (amoebic)	2
Nevada	1
New Mexico	2
New York (amoebic)	49
New York (bacillary)	21
Oklahoma [3]	5
Oregon	2
Puerto Rico	171
Virginia (amoebic)	6
Washington	10
Washington (amoebic)	2
Filariasis:	
Puerto Rico	7
Food poisoning:	
California	203
German measles:	
California	41
Massachusetts	30
Montana	2
New Mexico	5
New York	42
Washington	11
Granuloma, coccidioidal:	
California	5
Hookworm disease:	
California	1
Georgia	119
Mississippi	224
Impetigo contagiosa:	
Colorado	14
Oregon	50
Jaundice—epidemic:	
California	1
Lead poisoning:	
Colorado	2
Massachusetts	2
Leprosy:	
Puerto Rico	1
Lethargic encephalitis:	
California	3
Indiana	2
Massachusetts	1
New York	3
Oregon	2
Virginia	3
Washington	3
Wisconsin	1
Mumps:	
California	1,164
Colorado	66
Georgia	55
Indiana	38
Massachusetts	367
Mississippi	115
Montana	1
New Mexico	75
Oklahoma [3]	17
Oregon	4
Puerto Rico	43
Virginia	104
Washington	294
Wisconsin	71
Ophthalmia neonatorum:	
California	3
Massachusetts	65
New York	3
Puerto Rico	3
Paratyphoid fever:	
California	4
Georgia	2
New York	2
Virginia	4
Psittacosis:	
California	1
Puerperal septicemia:	
Mississippi	22
New Mexico	1
Puerto Rico	2
Washington	1
Rabies in animals:	
California	61
Indiana	27
Mississippi	3
New York [4]	1

December 1933—Continued

	Cases
Rabies in animals—Con.	
Oregon	1
Washington	13
Rabies in man:	
Oklahoma [3]	1
Rocky Mountain spotted fever:	
Montana	1
Scabies:	
Montana	8
Oklahoma [3]	1
Oregon	23
Septic sore throat:	
California	8
Georgia	35
Massachusetts	15
Montana	2
New Mexico	1
New York	30
Oklahoma [3]	31
Oregon	7
Virginia	48
Washington	4
Tetanus:	
California	9
Georgia	1
Massachusetts	1
New York	3
Oklahoma [3]	1
Puerto Rico	14
Tetanus, infantile:	
Puerto Rico	4
Trachoma:	
California	13
Massachusetts	2
Mississippi	5
Oklahoma [3]	4
Puerto Rico	27
Trichinosis:	
California	2
Massachusetts	1
New York	16
Tularaemia:	
Georgia	5
Virginia	28
Wisconsin	3
Typhus fever:	
Georgia	69
Massachusetts	1
New York	1
Undulant fever:	
California	12
Georgia	3
Massachusetts	1
Mississippi	2
New York	22
Oklahoma [3]	2
Oregon	2
Virginia	1
Wisconsin	4
Vincent's infection:	
Montana	3
New York [4]	79
Oklahoma [3]	2
Oregon	7
Whooping cough:	
California	928
Colorado	194
Georgia	154
Indiana	199
Massachusetts	1,144
Mississippi	1,039
Montana	130
Nevada	2
New Mexico	120
New York	1,577
Oklahoma [3]	40
Oregon	74
Puerto Rico	380
Virginia	276
Washington	302
Wisconsin	909
Yaws:	
Puerto Rico	1

[3] Exclusive of Oklahoma City and Tulsa.

[4] Exclusive of New York City.

WEEKLY REPORTS FROM CITIES

City reports for week ended Jan. 20, 1934

[This table summarizes the reports received regularly from a selected list of 121 cities for the purpose of showing a cross section of the current urban incidence of the communicable diseases listed in the table. Weekly reports are received from about 700 cities, from which the data are tabulated and filed for reference.]

State and city	Diphtheria cases	Influenza		Measles cases	Pneumonia deaths	Scarlet fever cases	Smallpox cases	Tuberculosis deaths	Typhoid fever cases	Whooping cough cases	Deaths, all causes
		Cases	Deaths								
Maine:											
Portland	0		0	1	5	1	0	0	0	10	27
New Hampshire:											
Concord	0		0	2	3	4	0	0	0	0	13
Manchester	0		0	0	4	0	0	1	0	0	25
Nashua	0		0	0	0	6	0	0	0	0	
Vermont:											
Barre	0		0	5	0	0	0	0	0	0	3
Burlington	0		0	0	0	2	0	0	1	0	15
Massachusetts:											
Boston	1		0	344	29	73	0	10	1	80	247
Fall River	2		0	0	3	0	0	0	0	0	34
Springfield	0		0	0	3	3	0	0	0	21	35
Worcester	0		0	190	7	7	0	3	0	9	51
Rhode Island:											
Pawtucket	0		0	0	0	0	0	0	0	0	20
Providence	1	1	0	1	11	14	0	3	0	16	69
Connecticut:											
Bridgeport	0		0	4	4	25	0	1	0	1	32
Hartford	0		0	0	6	12	0	1	0	3	55
New Haven	0		0	0	8	2	0	0	0	10	57
New York:											
Buffalo	2	1	1	190	14	27	0	6	0	15	138
New York	39	22	11	32	167	207	0	69	2	117	1,520
Rochester	0		0	2	2	15	0	0	0	9	62
Syracuse	0		0	0	7	9	0	2	0	60	64
New Jersey:											
Camden	1		0	12	5	8	0	1	0	0	42
Newark	0	2	2	1	10	16	0	2	1	26	98
Trenton	0		0	3	7	17	0	3	0	4	44
Pennsylvania:											
Philadelphia	4	10	7	669	44	84	0	27	1	53	548
Pittsburgh	6	9	6	18	26	33	0	5	1	62	163
Reading	0		0	13	4	4	0	1	0	7	30
Scranton	1		0	0	0	7	0	0	0	7	
Ohio:											
Cincinnati	3	2	0	375	12	21	0	5	0	8	139
Cleveland	9	52	4	2	21	64	0	10	0	74	186
Columbus	12		0	3	13	32	0	9	0	10	94
Toledo	2	3	1	63	5	38	0	3	0	36	63
Indiana:											
Fort Wayne	9		0	1	2	9	0	1	1	0	30
Indianapolis	2		0	65	20	20	0	1	0	13	
South Bend	0		0	0	3	10	0	0	0	0	24
Terre Haute	0		0	54	3	6	0	0	0	1	18
Illinois:											
Chicago	0	9	1	15	72	209	0	34	2	153	722
Springfield	1	1	0	0	7	7	0	0	0	15	28
Michigan:											
Detroit	3	1	4	7	30	97	0	14	0	69	256
Flint	2		2	7	7	60	0	0	0	6	33
Grand Rapids	0		2	1	3	11	0	1	0	0	29
Wisconsin:											
Kenosha	0		0	0	0	41	0	0	0	6	7
Madison	0			3		3	0	2	0	17	23
Milwaukee	0	3	3	1	6	39	0	2	0	77	102
Racine	1		0	3	0	21	0	0	0	5	14
Superior	0		0	1	3	2	0	0	0	0	11
Minnesota:											
Duluth	0		0	0	3	2	0	1	0	0	24
Minneapolis	1		2	1	13	26	0	2	0	20	125
St. Paul	0	1	1	1	16	7	0	3	2	4	81
Iowa:											
Des Moines	3			0		21	0		0	0	39
Sioux City	1			2		2	0		0	0	
Waterloo	0			0		1	0		0	4	
Missouri:											
Kansas City	3		1	4	18	18	0	11	1	1	114
St. Joseph	5		0	1	15	5	0	1	0	0	47
St. Louis	29	1		504	16	25	1	9	2	54	295

City reports for week ended Jan. 20, 1934—Continued

State and city	Diphtheria cases	Influenza Cases	Influenza Deaths	Measles cases	Pneumonia deaths	Scarlet fever cases	Smallpox cases	Tuberculosis deaths	Typhoid fever cases	Whooping cough cases	Deaths, all causes
North Dakota:											
Fargo	0	------	0	122	0	0	0	0	0	3	6
Grand Forks	0	------	0	0	0	0	0	0	0	0	------
South Dakota:											
Aberdeen	0	------	0	0	0	0	0	0	0	0	------
Sioux Falls	0	------	0	72	0	0	0	0	0	0	6
Nebraska:											
Omaha	0	------	0	39	5	0	0	1	0	17	63
Kansas:											
Topeka	0	------	2	0	2	8	0	0	0	8	16
Wichita	2	------	0	1	2	5	0	1	0	12	21
Delaware:											
Wilmington	0	------	0	14	9	4	0	1	0	0	41
Maryland:											
Baltimore	2	13	2	13	23	37	0	13	1	108	223
Cumberland	1	------	0	0	0	2	0	0	0	7	15
Frederick	0	------	0	0	0	2	0	0	0	0	4
District of Columbia:											
Washington	20	3	2	137	29	18	0	13	0	28	202
Virginia:											
Lynchburg	2	------	1	0	1	3	0	0	0	1	9
Norfolk	0	------	0	42	10	11	0	8	1	0	46
Richmond	2	------	1	3	3	11	0	1	0	2	62
Roanoke	1	------	0	1	5	4	0	1	0	0	20
West Virginia:											
Charleston	2	2	0	0	1	5	0	1	0	0	12
Huntington	0	------	0	0	0	13	0	0	0	0	------
Wheeling	0	------	0	0	2	9	0	0	0	2	22
North Carolina:											
Raleigh	0	------	0	14	1	1	0	0	0	11	12
Wilmington	0	1	0	0	2	0	0	1	0	3	13
Winston-Salem	2	------	0	273	7	3	0	1	0	0	25
South Carolina:											
Charleston	0	37	0	0	6	2	0	1	0	0	30
Columbia	0	------	0	0	0	0	0	0	0	0	3
Greenville	1	------	0	2	1	0	0	0	0	1	2
Georgia:											
Atlanta	12	40	2	63	14	4	0	7	0	4	83
Brunswick	0	1	1	27	0	0	0	0	0	0	2
Savannah	5	4	0	19	2	5	0	0	0	0	33
Florida:											
Miami	1	------	0	0	1	0	0	2	1	4	30
Tampa	4	------	0	3	2	1	0	3	0	2	21
Kentucky:											
Ashland	0	------	------	0	------	1	0	------	0	5	------
Louisville	1	------	0	0	8	19	0	1	0	7	79
Tennessee:											
Memphis	0	------	0	111	6	6	0	6	0	10	79
Nashville	0	------	1	51	1	8	0	2	0	12	50
Alabama:											
Birmingham	4	6	0	2	0	10	1	0	0	1	53
Mobile	0	------	0	0	0	1	0	1	0	1	27
Montgomery	0	------	------	0	------	1	0	------	0	4	------
Arkansas:											
Fort Smith	0	------	------	40	------	2	0	------	0	0	------
Little Rock	2	------	0	59	1	1	0	2	0	4	3
Louisiana:											
New Orleans	20	3	4	5	12	0	0	15	2	0	177
Shreveport	1	------	0	0	3	4	0	0	0	0	33
Texas:											
Dallas	10	1	1	0	16	6	2	5	1	5	73
Forth Worth	8	------	4	0	9	8	1	1	0	0	41
Galveston	0	------	0	0	1	1	0	2	0	0	14
Houston	10	------	1	0	7	3	2	6	0	0	75
San Antonio	2	------	5	0	11	7	0	5	0	0	57
Montana:											
Billings	0	------	0	0	0	3	0	0	0	0	11
Great Falls	0	------	0	1	1	0	0	0	0	1	10
Helena	0	------	0	1	0	0	0	0	0	0	0
Missoula	0	------	0	0	0	0	0	0	0	0	9
Idaho:											
Boise	0	------	0	0	1	0	0	0	1	0	7
Colorado:											
Denver	2	29	0	0	8	12	0	4	0	63	77
Pueblo	0	------	1	0	0	1	0	0	0	10	10

City reports for week ended Jan. 20, 1934—Continued

State and city	Diphtheria cases	Influenza		Measles cases	Pneumonia deaths	Scarlet fever cases	Smallpox cases	Tuberculosis deaths	Typhoid fever cases	Whooping cough cases	Deaths all causes
		Cases	Deaths								
New Mexico:											
Albuquerque	1	------	0	2	0	3	0	1	0	2	13
Utah:											
Salt Lake City	0	------	1	626	3	6	2	1	0	31	39
Nevada:											
Reno	0	1	0	0	1	0	0	0	0	0	4
Washington:											
Seattle	0	------	------	1	11	19	0	6	0	63	99
Spokane	0	------	------	406	------	1	0	2	0	5	30
Tacoma	0	------	0	1	5	0	0	1	0	18	41
Oregon:											
Portland	1	------	0	7	3	22	0	2	0	5	72
Salem	0	1	0	0	0	0	0	0	1	6	------
California:											
Los Angeles	18	25	0	7	24	106	14	17	1	74	235
Sacramento	1	------	0	1	3	5	0	2	0	0	34
San Francisco	1	1	1	4	9	18	0	6	0	8	186

State and city	Meningococcus meningitis		Poliomyelitis cases	State and city	Meningococcus meningitis		Poliomyelitis cases
	Cases	Deaths			Cases	Deaths	
Massachusetts:				Georgia:			
Boston	1	0	0	Atlanta	2	0	0
New York:				Tennessee:			
New York	2	1	0	Memphis	3	2	0
Syracuse	0	1	0	Louisiana:			
Pennsylvania:				New Orleans	0	1	0
Pittsburgh	0	1	0	Texas:			
Ohio:				Fort Worth	1	2	0
Cleveland	1	0	0	Nevada:			
Illinois:				Reno	0	0	1
Chicago	5	5	0	California:			
Michigan:				Los Angeles	1	0	1
Detroit	0	0	1				

Lethargic encephalitis.—Cases: Bridgeport, 2; New York, 1; Philadelphia, 1; Detroit, 1; St. Louis, 1; Memphis, 1; Portland, Oreg., 1.

Pellagra.—Cases: Charleston, S.C., 1; Savannah, 1; Memphis, 2; Birmingham, 1.

Typhus fever.—Cases: Savannah, 1.

FOREIGN AND INSULAR

CANADA

Provinces—Communicable diseases—2 weeks ended December 30, 1933.—During the 2 weeks ended December 30, 1933, cases of certain communicable diseases were reported by the Department of Pensions and National Health of Canada as follows:

Disease	Prince Edward Island	Nova Scotia	New Brunswick	Quebec	Ontario	Manitoba [1]	Saskatchewan	Alberta	British Columbia	Total
Cerebrospinal meningitis				1	1					2
Chicken pox		4	1	278	383	39	115	41	98	959
Diphtheria		4	6	35	20	29	4			98
Dysentery							1			1
Erysipelas				11	4	3		1	6	25
Influenza		6		12	10	3			114	145
Lethargic encephalitis					1					1
Measles		1		29	19	11	3	3	14	80
Mumps					90	2			60	152
Paratyphoid fever					1					1
Pneumonia		3			18		7		18	46
Poliomyelitis				1	1					2
Scarlet fever	1	17	8	125	317	21	12	6	87	594
Smallpox								1		1
Trachoma						7	1		3	11
Tuberculosis		2	12	80	76		1	2	22	195
Typhoid fever			2	22	8			2		34
Undulant fever					2					2
Whooping cough		14	2	226	94	6	10	8	16	376

[1] No report was received from Manitoba for week ended Dec. 23, 1933.

CZECHOSLOVAKIA

Communicable diseases—November 1933.—During the month of November 1933 certain communicable diseases were reported in Czechoslovakia as follows:

Disease	Cases	Deaths	Disease	Cases	Deaths
Anthrax	4	1	Paratyphoid fever	11	2
Cerebrospinal meningitis	10	4	Poliomyelitis	13	1
Chicken pox	443		Puerperal fever	45	14
Diphtheria	3,585	203	Scarlet fever	3,678	23
Dysentery	24	1	Trachoma	238	
Influenza	71	2	Typhoid fever	501	48
Lethargic encephalitis	2	1	Typhus fever	12	
Malaria	54				

ITALY

Communicable diseases—4 weeks ended August 20, 1933.—During the 4 weeks ended August 20, 1933, cases of certain communicable diseases were reported in Italy as follows:

Disease	July 24-30		July 31-Aug. 6		Aug. 6-13		Aug. 14-20	
	Cases	Communes affected	Cases	Communes affected	Cases	Communes affected	Cases	Communes affected
Anthrax	41	33	27	27	28	27	31	28
Cerebrospinal meningitis	5	5	6	6	5	5	6	4
Chicken pox	184	98	122	79	91	66	85	54
Diphtheria and croup	351	203	356	197	355	259	342	202
Dysentery	37	25	31	18	25	20	22	17
Lethargic encephalitis			2	2	1	1	1	1
Measles	976	240	898	234	797	212	659	196
Poliomyelitis	11	11	14	13	15	15	9	9
Scarlet fever	222	109	270	126	241	122	258	118
Typhoid fever	645	359	873	472	1,005	513	1,119	543

VIRGIN ISLANDS

Notifiable diseases—November-December 1933.—During the months of November and December 1933, cases of certain notifiable diseases were reported in the Virgin Islands as follows:

Disease	November 1933	December 1933	Disease	November 1933	December 1933
Filariasis	5	7	Pellagra		2
Gonorrhea	2	4	Syphilis	12	11
Hookworm disease		2	Tuberculosis	5	2
Leprosy	1		Typhoid fever		1
Malaria	13	81	Uncinariasis	2	

CHOLERA, PLAGUE, SMALLPOX, TYPHUS FEVER, AND YELLOW FEVER

(NOTE.—A table giving current information of the world prevalence of quarantinable diseases appeared in the PUBLIC HEALTH REPORTS for Jan. 26, 1934, pp. 128-139. A similar cumulative table will appear in the PUBLIC HEALTH REPORTS to be issued Feb. 23, 1934, and thereafter, at least for the time being, in the issue published on the last Friday of each month.)

CHOLERA

Philippine Islands.—During the week ended January 27, 1934, cholera was reported in the Philippine Islands as follows: Bohol Province—Antequera, 5 cases, 5 deaths; Balilihan, 1 case, 1 death; Calape, 2 cases, 1 death; Carella, 2 cases, 1 death; Clarin, 2 cases, 1 death; Cortes, 1 case, 2 deaths; Inabanga, 8 cases, 5 deaths; Loon, 12 cases, 5 deaths; Maribojoc, 1 case, 2 deaths; Tagbilaran, 4 cases, 2 deaths; Talibon, 13 cases, 5 deaths; Tubigon, 7 cases, 8 deaths. Cebu Province—Argao, 1 case; Carcar, 1 case, 1 death; Sibonga, 2 cases, 2 deaths. Occidental Negros Province—Calatrava, 6 cases, 4 deaths; San Carlos, 4 cases, 4 deaths. Oriental Negros Province—Ayuquitan, 1 case; Bais, 6 cases, 2 deaths; Tanjay, 8 cases, 6 deaths.

YELLOW FEVER

Senegal.—On January 14, 1934, 1 imported case of yellow fever with 1 death was reported in Kaolack, Senegal. On January 22, 1934, 1 imported case of yellow fever was reported in Podor, Senegal.

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