THE ALLEGED PURIFICATION OF AIR BY
THE OZONE MACHINE*

W. A. SAWYER, M.D.

Director of the Hygienic Laboratory of the California State
Board of Health

HELEN L. BECKWITH, B.L.

AND

ESTHER M. SKOLFIELD, A.B.

Assistant Bacteriologist in the Hygienic Laboratory of the California
State Board of Health

BERKELEY, CAL.

The experiments of a number of careful investigators have discredited the claims made for ozone as a purifier of air. Largely on the basis of claims already disproved, several manufacturers are so successful in introducing ozone machines into public buildings that this purposeful adulteration of the air with ozone and its accompanying impurities threatens to become a public health problem.

Ohlmüller¹ demonstrated that ozone in considerable strength was incapable of killing dry bacteria within the time-limits of his tests. Erlandsen and Schwarz² showed the falsity of the claim that the presence of free ozone means the absence of organic impurity in the air. They demonstrated, through careful analyses, that ammonia and hydrogen sulphid were not diminished in amount by the presence of ozone. They showed also that the deodorizing property of ozone consisted of the masking of one odor with another. In their experiments with a number of odorous substances, the masked odors again became evident when the odor of the ozone had diminished. Filipow³ demonstrated that strong concentrations of ozone in respired air caused a marked irritation of the mucous membranes. Hill and Flack⁴ showed that a concentration of ozone as small as one part per million was irritating to the respiratory tract and that exposure for two hours to fifteen or twenty parts per million was not without risk to life. They demonstrated that the respiratory metabolism was reduced by the inhalation of ozone.

In September, 1912, the fifteenth annual convention of the League of California Municipalities and the fourth annual conference of state, county, and municipal health officials were held on the campus of the University of California. In connection with these meetings there was a "Public Welfare Exposition" consisting chiefly of the exhibits of manufacturers. An attempt was made by the agent for an ozone machine (designated in this paper as "Machine A") to display his apparatus and literature in that part of the exhibit which was devoted chiefly to foods and was under the supervision of M. E. Jaffa, director of the State Food and Drug Laboratory. Jaffa refused to permit the ozone machine to be exhibited, on the ground that the advertising circulars made claims which could not be true. The decision was protested and was referred to the director of the Hygienic Laboratory of the California State Board of Health, who sustained it, laying special stress on the false claims of bactericidal efficiency for ozone. This

action was repeatedly protested, and requests were made that the machine be given a laboratory test. As a result the few simple experiments reported in this paper were performed with the ozone machines of two well-known companies. It was proposed to show the relative killing power for animals and bacteria. No attempt was made to measure the quantities of ozone, oxids of nitrogen, or other gases, which may have been included in the composition of the "ozone" produced by the machines.

The machines examined were loaned for our tests by the local agents of the manufacturers, and we wish to express our appreciation of the uniform courtesy which was extended to us.

Machine A was intended for use in a large room containing about fifteen people. Unlike Machine B, it had no attached apparatus for agitating the air. Circulars put out by the manufacturers state that ozone is a "necessity" for the destruction of infectious germs and bacterial life, for the sterilization of air in operating-rooms, for the purification of the air in homes of persons suffering from contagious diseases, and for giving to offices and homes the invigorating air of the country, seashore and mountains.

Machine B also was intended for purifying the air of a large room. The machine included a motor and fan for blowing air through the apparatus and out into the room. A well-illustrated advertising pamphlet from the manufacturers includes the statement that ozone cannot exist except momentarily in air containing organic matter, and that therefore the presence of ozone is an indication that the air is sterile and devoid of organic matter. In a quoted article the pamphlet asserts that ozone is unique as a germicide by reason of the fact that it has no deleterious effect on the higher forms of animal life, owing to the low percentage of carbon contained in their structure.

For our experiments a tight wooden cabinet with a capacity of 1 cubic meter was constructed. The door of the cabinet had a glass window which permitted a view of the interior. The ozone machine under test stood in the middle of the cabinet. The humidity was indicated by wet- and dry-bulb thermometers. In some of the experiments the humidity of the air was increased by pouring hot water through a tube into a dish standing in the cabinet. The guinea-pigs which were subjected to the "ozone" were placed in a small wire cage where they could be seen through the glass door. The bacterial cultures used were grown for a day on meat-extract broth. Sterile glass rods were dipped into the cultures and the broth was dried on them in an almost invisible film. These rods were fixed in large corks and were inserted into the cabinet through holes drilled near the top. After exposure to the "ozone" the rods were withdrawn and their ends were dipped into tubes of broth. After forty-eight hours of incubation, the clouded cultures were tested to find whether or not the growth was due to the organism originally placed on the rod. The streptococcus and staphylococcus cultures in all instances showed organisms of the characteristic morphology. The typhoid cultures were tested by agglutination with anti-typhoid serum. The cultures of *Bacillus subtilis* were sufficiently identified by the appearance of the scum growing on the surface of the broth. In the tables the plus sign denotes that the organism exposed in the test grew in the subculture. The minus sign signifies that the subculture was sterile.

The experiments with Machine A were made in several separate tests, and the results are brought together in Table 1. The cultures which were dried on threads

* From the Hygienic Laboratory of the California State Board of Health and the Laboratory of Hygiene of the University of California.

1. Ohlmüller: Ueber die Einwirkung des Ozons auf Bakterien, *Arch. a. d. k. Gsundtsamte*, 1893, viii, 220.

2. Erlandsen, A., and Schwarz, L.: Experimentelle Untersuchungen über Luftozonisierung, *Ztschr. f. Hyg. u. Infektionskrankh.*, 1910, lxvii, 391.

3. Filipow, M.: Zur therapeutischen Bedeutung von Sauerstoff und Ozon, *Arch. f. d. ges. Physiol.*, 1884, xxxiv, 335.

4. Hill, L., and Black, M.: The Physiologic Influence of Ozone, *Proc. Roy. Soc., London, Series B*, 1912, lxxxiv, 404.

were placed in open Petri dishes on the bottom of the cabinet. The control cultures were exposed to the air in a locker in the laboratory.

Guinea-pig 1 seemed sluggish and was breathing rapidly at the end of an hour. In two hours and forty minutes it was dead. Necropsy showed marked edema of the lungs.

The tests with Machine B were carried on both with and without added moisture. The various cultures and the guinea-pig were put into the cabinet and the machine was started at the time of beginning each experiment. The door was not opened until the test was finished.

Guinea-pig 2 showed labored breathing twenty minutes after the machine was started. Twenty-five minutes after beginning, it began rubbing its nose with its fore feet; after forty-five minutes it was drowsy; at the end of an hour its eyes were watery and almost closed,

TABLE 1.—MACHINE A. FULL STRENGTH.

Cultures: 24-hour. Dried on glass rods and silk threads. Extract broth, 1 per cent. acid.
Date: February and March, 1913. Moisture added to air. Humidity not measured.

Length of exposure to "ozone," hours	1/2	1	2	3	4	5	6	7	8	Controls in Air
Cultures on rods:										
<i>Staphylococcus aureus</i>	+	+	+	—	—	—	—	—	—	+
<i>Staphylococcus aureus</i>	+	+	+	+	—	—	—	—	—	+
<i>Bacillus typhosus</i> ..	+	+	+	+	+	+	+	+	+	+
<i>Bacillus typhosus</i> ..	+	+	+	+	+	+	+	+	+	+
<i>Bacillus subtilis</i> ..	+	+	+	+	+	+	+	+	+	+
<i>Bacillus subtilis</i> ..	+	+	+	+	+	+	+	+	+	+
Cultures on threads:										
<i>Staphylococcus aureus</i>	+	+	+	+	+	—	—	—	—	+
<i>Bacillus typhosus</i> ..	+	+	+	+	+	+	+	+	+	+
<i>Bacillus subtilis</i> ..	+	+	+	+	+	+	+	+	+	+
Guinea-pig 1.....	Sick			Dead						

TABLE 2.—MACHINE B. STRENGTH 3.

Cultures: 19-hour. Dried on glass rods. Extract broth, 1 per cent. acid.
Date: May 27, 1913. Time: Started 10:40 a. m. Moisture added to air.

Length of exposure to "ozone," hrs.	0	1/2	3/4	1	2	3	4	6	8	12	12	Controls in Air
Temperature, centigrade...	18	21	22	22	25	22	22	21	21	20	18	
Relative humidity, per cent.	74	70	77	80	77	87	84	86	86	85	..	
Cultures:												
<i>Streptococcus pyogenes</i> ..	+	+	+	+	—	—	—	—	—	—	+	
<i>Staphylococcus aureus</i> ..	+	+	+	+	+	—	—	—	—	—	+	
<i>Bacillus typhosus</i> ..	+	+	+	+	+	—	—	—	—	—	+	
<i>Bacillus typhosus</i> ..	+	+	+	+	+	—	—	—	—	—	+	
<i>Bacillus subtilis</i> ..	+	+	+	+	+	+	+	+	+	+	+	
Guinea-pig 2, 314 gm.	Sick				Dead							

and its nose was wet. After an hour and a half its breathing was irregular and spasmodic. A little later there were convulsive movements. After an hour and forty minutes it was struggling for air and in an hour and fifty-five minutes it died. Necropsy showed marked edema of the lungs. They did not collapse and were filled with foamy fluid.

As all the guinea-pigs showed similar symptoms during life and marked edema of the lungs on necropsy, details will be omitted in the subsequent experiments.

Guinea-pig 3 died four hours and thirty-three minutes after the machine was started.

Guinea-pig 4 died one hour and thirty-five minutes after the machine was started.

In a fourth test of Machine B the conditions were the same as those shown in Table 4, except that the machine was run at strength 1, instead of at the highest strength. The experiment was begun at 9:40 a. m., June 2. No moisture was added to the air, and the average of the

humidity estimations was 62.9 per cent., which is lower than the average (73 per cent.) of the readings in Table 4. The average temperature was 20.3 C. (68.5 F.), which is two degrees lower than the average during the previous test. A table of the results is not presented as the four kinds of bacteria withstood the entire twelve hours of exposure. The guinea-pig (weight, 325 gm.) died in less than one-eighth of that length of time. It showed disturbance of respiration almost immediately after the machine started and died one hour and twenty-five minutes later.

The agents for Machine B sent us another machine (C), which was similar to the other, although of lower capacity. When it was run at the greater of its two possible strengths, without the addition of moisture to the air of the cabinet, the results were similar to those presented in Table 3 for Machine B. This showed that

TABLE 3.—MACHINE B. STRENGTH 1.

Cultures: 24-hour. Dried on glass rods. Extract broth, 1 per cent. acid.
Date: May 28, 1913. Time: Started 9:45 a. m. Moisture added to air.

Length of exposure to "ozone," hrs.	0	1/2	3/4	1	2	3	4	6	8	12	12	Controls in Air
Temperature, centigrade...	18	19	21	21	23	24	24	24	25	25	18	
Relative humidity, per cent.	81	75	76	85	82	80	80	80	77	77	..	
Cultures:												
<i>Streptococcus pyogenes</i> ..	+	+	+	+	+	+	+	+	+	—	+	
<i>Staphylococcus aureus</i> ..	+	+	+	+	+	+	+	+	+	—	+	
<i>Bacillus typhosus</i> ..	+	+	+	+	+	+	+	+	+	—	+	
<i>Bacillus typhosus</i> ..	+	+	+	+	+	+	+	+	+	—	+	
<i>Bacillus subtilis</i> ..	+	+	+	+	+	+	+	+	+	+	+	
Guinea-pig 3, 712 gm.	Sick									Dead		

TABLE 4.—MACHINE B. STRENGTH 3.

Cultures: 19-hour. Dried on glass rods. Extract broth, 1 per cent. acid.
Date: May 29, 1913. Time: Started 9:40 a. m. No moisture added to air.

Length of exposure to "ozone," hrs.	0	1/2	3/4	1	2	3	4	6	8	12	12	Controls in Air
Temperature, centigrade...	18	20	21	23	23	23	23	23	24	24	20	
Relative humidity, per cent.	70	66	74	61	69	75	75	80	80	80	70	
Cultures:												
<i>Streptococcus pyogenes</i> ..	+	+	+	+	+	+	+	+	+	—	+	
<i>Staphylococcus aureus</i> ..	+	+	+	+	+	+	+	+	+	—	+	
<i>Bacillus typhosus</i> ..	+	+	+	+	+	+	+	—	—	—	+	
<i>Bacillus typhosus</i> ..	+	+	+	+	+	+	+	—	—	—	+	
<i>Bacillus subtilis</i> ..	+	+	+	+	+	+	+	+	+	+	+	
Guinea-pig 4, 277 gm.	Sick			Dead								

the results obtained were not due to individual imperfections in one machine.

Comparison of the tables shows that the addition of moisture to the air in the cabinet increased the slight bactericidal effect of the "ozone." In every test in which the guinea-pig and the bacteria were in the cabinet together, the bacteria outlived the guinea-pig.

Additional tests of the bactericidal power of the "ozone" were performed in two bedrooms in a dwelling-house. A room containing 730 cubic feet of air-space was prepared by packing the spaces about the windows and doors with cotton. A similar room was used for exposing control cultures to the drying influence of air. In testing the ozone machines in the room the same varieties of bacteria were exposed as in the tests with the corresponding machines in the cabinet, and the cultures were dried on glass rods in the same manner. Machine A was run at its maximum strength for sixteen hours in the closed room. Subcultures were made when the room was

opened, and the organisms grew in all instances. Machine B was run at its maximum strength (No. 3) for sixteen hours in the same room. The cultures all survived the test, but a guinea-pig (weight, 213 gm.), which had been put in a cage in the room, was found dead when the door was opened. Necropsy showed edema of the lungs. The humidity of the air in the room at the beginning of the test was 61 per cent. of saturation and the temperature was 22 C. (71.6 F.). When the room was opened in the morning a faint haze was visible in the air.

During these tests certain physiologic effects of the "ozone" were noticed by the experimenters after they had been working around the machines. The immediate effect of inhaling the diluted gas was a feeling of dryness or tickling in the nasopharynx, and sometimes the irritation was felt in the chest. If the exposure was prolonged, watering of the eyes, and occasionally a slight headache, resulted. The smell of the "ozone" and its irritation was much more noticeable to persons who came suddenly under its influence than to those who were continuously exposed. This shows the disadvantage of entrusting the regulation of an ozone machine to persons who are constantly breathing its products.

CONCLUSIONS

1. The gaseous products of the two well-known ozone machines examined are irritating to the respiratory tract and, in considerable concentration, they will produce edema of the lungs and death in guinea-pigs.

2. A concentration of the gaseous products sufficiently high to kill typhoid bacilli, staphylococci and streptococci, dried on glass rods, in the course of several hours, will kill guinea-pigs in a shorter time. Therefore these products have no value as bactericides in breathable air.

3. Because the products of the ozone machines are irritating to the mucous membranes and are probably injurious in other ways, the machines should not be allowed in schools, offices or other places in which people remain for considerable periods of time.

4. The ozone machines produce gases which mask disagreeable odors of moderate strength. In this way the machines can conceal faults in ventilation while not correcting them. Because the ozone machine covers unhygienic conditions in the air and at the same time produces new injurious substances, it cannot properly be classed as a hygienic device.

CAUSES, TYPES AND TREATMENT OF DIARRHEA IN ADULT LIFE*

RICHARD C. CABOT, M.D.

BOSTON

AND

HAVEN EMERSON, M.D.

NEW YORK

We have undertaken a fresh study of this ancient problem, beginning with the necropsy records of Bellevue Hospital in New York and the Massachusetts General Hospital in Boston. In each of these institutions we examined three thousand necropsy records, searching for lesions ordinarily supposed to produce diarrhea. We then traced the cases showing these lesions back to the

clinical records, trying to ascertain first whether the lesions actually produced diarrhea, and if so, in what proportion of cases; secondly, whether any special type of symptoms or of discharges was associated with any special lesion of the intestine, the endeavor being to mark out clinical types so far as this was possible. Finally, we reviewed the results of treatment both in necropsy cases and in a considerable series of cases which did not come to necropsy, and endeavored to estimate the value of the different methods used.

For various reasons we have excluded from this study certain diseases often associated with diarrhea. We have taken no account of the cases of typhoid fever, partly because the relation of this disease to diarrhea has already been thoroughly studied in large groups of cases, and, secondly, because we were anxious to get some idea of the relative frequency of the different cases with this symptom, and we are well aware that the number of persons sick with typhoid in these two hospitals was not a fair sample of the number of cases of this disease existing in the community outside, since cases of typhoid are quite abnormally collected from large areas in hospitals such as those in which we have pursued our studies. The parasitic diarrheas have also been excluded because of

TABLE 1.—RELATIVE FREQUENCY OF DISEASES CAUSING
DIARRHEA IN ADULTS—MASSACHUSETTS GENERAL
HOSPITAL, 1905-1912

Acute enteritis and unknown (acute) causes—clinical cases.	244
Acute enteritis—necropsied cases:	
"Primary"	9
Secondary with and without intestinal lesions:	
Nephritic	10
Cardiac	2
Cardiorenal	2
Arteriosclerotic	3
Acute infectious	5
Various acute and chronic conditions	10
Intussusception	1
	42
Acute enteritis total	286
Chronic enteritis and unknown (chronic) causes—clinical cases	130
Chronic enteritis, necropsied cases:	
Primary	8
Cardiac	7
Renal	1
Cardiorenal	1
Various chronic conditions	2
	19
Chronic enteritis total	158
Cancer of bowel	52
Pernicious anemia	34
Mucous colitis	32
Exophthalmic goiter	25
Nervous diarrhea	17
Tuberculosis of bowel	15
Amebic dysentery	14
Fat intolerance	7
Total	640

the small number of these cases available in Boston or New York. We have made no effort to study the cases of mercurial or arsenical poisoning or cases of dysentery due to organisms of the Shiga type, or other organisms closely allied to it. We have also excluded all cases occurring in persons under 16 years of age. Leaving out the types just mentioned, we have studied 640 cases of the varieties ranged in Table 1.

DIFFICULTY OF DISTINGUISHING ACUTE FROM CHRONIC ENTERITIS AND COLITIS

It would have been desirable to distinguish clearly the acute from the chronic cases, but this we found unexpectedly difficult. The intestine is like the kidney in that a long-standing disease may show clinical symptoms only now and then, presenting itself suddenly under the guise of an acute disease.

* Because of lack of space, this article is abbreviated in THE JOURNAL. The complete article appears in the Transactions of the Section and in the author's reprints.

* Read in the Section on Practice of Medicine of the American Medical Association, at the Sixty-fourth Annual Session, held at Minneapolis, June, 1913.