GAS HAZARDS IN SEWERS AND SEWAGE-TREATMENT PLANTS [1]

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Gas hazards in sewers and sewage-treatment plants are those due to inflammable and poisonous gases and to oxygen deficiency. Inflammable and poisonous gases may be derived from three general sources: Low volatile liquids which enter as part of the sewage, leakage from gas mains into the sewers, or the products of fermentation or digestion of sewage.

The inflammable or poisonous gases usually found in treatment plants are methane, hydrogen, carbon dioxide, and possibly carbon monoxide and hydrogen sulphide. Mr. G. W. Jones, chemist, Pittsburgh Experiment Station, United States Bureau of Mines, has summarized the composition and inflammable limits of gases from sewage sludge digestion tanks,[2] and his summary is presented in the accompanying table.

TABLE 1.—*Composition and inflammable limits (in percent) of gases from sewage sludge digestion tanks*

Source	Imhoff tank		Septic tank		Imhoff tanks				Imhoff tank				Range
					Foaming		Non-foaming		Lower compartment		Upper compartment		
Sample number	*a*	*b*	*c*		*d*	*e*	*f*	*g*	*h*	*i*	*j*	*k*	
Reference	(1)	(1)	(2)	(2)	(2)	(2)	(2)	(2)	(3)	(3)	(3)	(3)	
Carbon dioxide	4.4	5.2	13.6	17.0	19.8	29.4	3.3	28.5	11.8	9.6	20.0	23.4	3.3 -29.4
Oxygen	0.6	0.5	0.0	0.0	0.3	0.0	0.0	0.0	1.2	1.0	-----	-----	0.0 - 1.2
Hydrogen sulphide	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	-----	-----	0.0 - 0.1
Hydrogen	7.9	8.2	3.5	0.0	0.0	0.0	0.0	0.0	4.6	0.0	1.8	1.7	0.0 - 8.2
Methane	84.2	82.8	72.5	78.0	68.7	66.6	78.2	63.0	70.2	66.1	70.0	67.5	63.0 -84.2
Nitrogen	2.9	3.3	10.4	5.0	11.2	3.9	18.5	8.5	12.2	23.3	8.2	7.4	2.9 -23.3
Inflammable limit:													
Lower	5.30	5.30	6.55	6.70	7.40	7.80	6.40	8.30	6.55	7.80	7.55	7.80	5.30- 8.30
Upper	16.00	16.10	17.90	16.65	18.25	18.35	16.85	19.15	18.45	19.25	18.45	18.50	16.00-19.25

References: (1) Gas from Imhoff Tank. By C. C. Mommon. Eng. News, **71**, 1914, p. 760. (2) Some Observations on Sewage Tank Gases. By A. M. Buswell and S. I. Strickhouser. Ind. Eng. Chem., **18**, 1926, p. 407. (3) Results of Sewage Treatment. By H. E. Babbitt and H. E. Schlenz. Univ. Illinois Bull. no. 198, 1929, pp. 88 and 92.

The tabulation gives the analyses of typical sewage gases. It will be noted from a study of this table that the oxygen varies from 0 to 1.2 percent, carbon dioxide from 3 to 30 percent, hydrogen sulphide from 0 to 0.1 percent, hydrogen from 0 to 8.2 percent, methane from 63 to 84.2 percent. Jones calls attention especially to the explosion hazards and gives four factors as essential.

[1] Presented before the Illinois Society of Engineers, at Chicago, Jan. 23, 1933.

[2] Jones, G. W.: Explosion and Health Hazards in Sewage Works Operation. 1933.

Katz, in his paper on Gas Hazards in Street Manholes,[3] states that the following are the principal gases found:

Poisonous and explosive gases found in manholes

Gas	*Source*
Ammonia, explosive	Refrigerating plants.
Benzol, explosive	Motor vehicles, storage tanks.
Carbon dioxide, nonexplosive	Products of combustion, sewer gas.
Carbon monoxide, explosive	Manufactured fuel gas, flue gas, products of combustion, exhaust gas from motors.
Ethane, explosive	Natural gas, manufactured fuel gas.
Gasoline, explosive	Motor vehicles, storage tanks.
Hydrogen, explosive	Artificial fuel gases, electrolysis of water.
Hydrogen sulphide, explosive	Sewer gas, coal gas.
Methane, explosive	Natural gas, manufactured gas, sewer gas.
Sulphur dioxide, nonexplosive	Burning insulation.
Unsaturated hydrocarbons, explosive	Manufactured fuel gases.

It will be noted that only a few of the gases mentioned by Katz come from sewage itself. It will be noted also that a number of those gases are both explosive and toxic. This applies to all but methane, ethane, hydrogen, and carbon dioxide, although carbon dioxide is of low toxicity. Carbon monoxide is the poisonous gas most frequently found in manholes and may occasionally occur in treatment plants. Although reported by Hallé[4] as early as 1785 as having caused deaths due to gases from sewers in Paris, according to Katz hydrogen sulphide has not been found in manholes in dangerous concentrations and it probably does not occur in dangerous concentrations in treatment plants.

PROPERTIES OF GASES FOUND IN SEWERS AND TREATMENT PLANTS[5]

AMMONIA, NH_3

Inflammable limits in percentage by volume: Lower, 16; upper, 27.
Boiling point, −35.5° C.
Percentage causing dangerous illness in ½ to 1 hour, 0.25 to 0.45.
Percentage that can be borne without severe effects for ½ to 1 hour, 0.03.
Maximum safe concentration, 0.01 percent.

Ammonia is a colorless gas of sharply penetrating odor. The symptoms of poisoning are acute inflammation of the respiratory organs, cough, edema of the lungs, chronic bronchial catarrh, redness of the eyes, increased secretion of saliva, and retention of urine.

[3] Katz, S. H., Meiter, E. G., and Blcomfield, J. J.: Gas Hazards in Street Manholes. Report of Investigations, Serial No. 2710, U.S. Bureau of Mines, October 1925. 20 pp.

[4] Hallé, M.: Recherches sur une espèce de méphitisme des fosses d'aisance. 1785.

[5] Unless otherwise indicated, the inflammable limits of the various gases are taken from Bureau of Mines Bulletin No. 279, Limits of Inflammability of Gases and Vapors, 1931, and the toxicl imits from International Critical Tables, vol. II, 1927, pp. 318-320.

BENZOL, C_6H_6

Inflammable limits in percentage by volume: Lower, 1.4; upper, 8.
Boiling point, 80.2° C.
Percentage that can be borne without severe effects for ½ to 1 hour, 0.31 to 0.47.
Maximum safe concentration, 0.15 to 0.31 percent.

Benzol is an extremely volatile, colorless fluid. As a vapor it enters the body through the respiratory organs and by reabsorption through the skin. Symptoms of poisoning are headache, vertigo, anemia, muscular tremor, scarlet lips, spots of extravasated blood in the skin, irritant cough, and fatty degeneration of the liver, kidneys, and heart.

CARBON DIOXIDE, CO_2

Boiling point, −78.2° C.
Percentage fatal in 30 minutes or less, 30.
Percentage causing dangerous illness in ½ to 1 hour, 6 to 8.
Percentage that can be borne without severe effects for ½ to 1 hour, 4 to 6.
Maximum safe concentration, 2 to 3 percent.

Carbon dioxide affects the respiratory rate according to its concentration in the air. It has been found that men can breathe air containing many times the amount of carbon dioxide found in our worst ventilated theaters and assembly halls, which, according to Rosenau, do not contain above 0.5 percent carbon dioxide. One half of 1 percent of carbon dioxide in normal air causes a slight and unnoticeable increase in the ventilation of the lungs; that is, a man exposed to one half of 1 percent of carbon dioxide will breathe a little deeper and a little faster than when in pure air. With 2 percent of carbon dioxide in the air the lung ventilation will be increased about 50 percent; with 3 percent to about 100 percent; with 5 percent to about 300 percent, and the breathing will be laborious; and 10 percent cannot be endured for more than a very few minutes. According to Sollmann, if oxygen deficiency is excluded by inhaling gas mixtures containing 20 percent of oxygen, no effects occur until the concentration of 3 percent by volume of carbon dioxide is reached. With this concentration there is some hyperpnea and discomfort; 8½ percent produces in a few minutes distinct dyspnea, rise of blood pressure, and congestion which become insupportable in 15 or 20 minutes; but these symptoms disappear promptly in fresh air. The symptoms increase with 15 percent, but even 20 percent is not dangerous in an hour to animals and probably not to man. With 25 to 30 percent the stimulant phenomena pass into depression, with diminished respiration, fall of blood pressure, coma (generally without convulsions), loss of reflexes, anesthesia, and gradual death after some hours, the heart outlasting the respiration. With higher concentrations, the stimulation is still briefer. With pure carbon dioxide, death may

occur in a few minutes as a mixed effect of carbon dioxide and anoxemia.

The air in manholes and sewage-treatment plants may be deficient in oxygen owing to the oxidation of organic material or to dilution by inert gases from outside sources, such as natural gas (methane). Although oxygen is not usually considered toxic or noxious, a variation in its concentration cannot be neglected, as untoward effects develop if the variation is marked. Man is so made that he breathes easily and works best when the air contains about 21 percent of oxygen, the amount usually in air; but he is able to live and work, although not so well when there is less oxygen. When about 17 percent of the air is oxygen, a man at work will breathe a little faster and a little deeper, about the same as when he first goes from sea level to a height of 5,000 feet. Men breathing air that has as little as 15 percent of oxygen usually become dizzy, notice a buzzing in the ear, have a rapid heartbeat, and often suffer from headache. Very few men are free from these symptoms when the oxygen in the air falls to 10 percent. Haldane, the English physiologist, says that under certain conditions men may be conscious even with as little as 3½ percent of oxygen in the air they are breathing. However, under other conditions men faint or become unconscious when the air contains 9 percent of oxygen or more.

ETHANE, C_2H_6

Boiling point, −93° C.
Inflammable limits in percentage by volume: Lower, 3.2; upper, 12.5.

METHANE, CH_4

Boiling point, −164° C.
Inflammable limits in percentage by volume: Lower, 5.0; upper, 15.

Ethane and methane, or natural gas, may be present. Their importance is not due to physiological or noxious action, but to the fact that they form explosive mixtures with the oxygen of the air, and this may result in disaster. Furthermore, the methane may dilute the oxygen of the air to such an extent as to produce the effects of low oxygen mentioned above.

GASOLINE, C_6H_{14} TO C_7H_{16} [6]

Inflammable limits in percentage by volume: Lower, 1.4; upper, 6.
Boiling point (boiling range), 50° to 140° C.
Percentage causing dangerous illness in ½ to 1 hour, 2.0 to 2.5.
Percentage that can be borne without severe effects for ½ to 1 hour, 0.1 to 0.3.
Maximum safe concentration, 0.1 percent.

Gasoline vapors, when inhaled, cause headache, nausea, delirium, vertigo, and unconsciousness. Burning pains in the chest and irrita-

[6] The toxic limits for gasoline are taken from Bureau of Mines Technical Paper 272, Permeation of Oxygen Breathing Apparatus by Gases and Vapors. 1921.

tion which cause coughing are experienced when the concentration is moderately high—0.7 percent. In some studies carried out by the Bureau of Mines it was found that exposure of men to 0.1 percent of gasoline vapor caused dullness, unsteadiness, and giddiness in 50 minutes; 0.3 percent caused slight irritation of the eyes and moderate symptoms of dizziness in 30 minutes; and 0.7 percent caused coughing, marked irritation of the eyes and nose, numbness of the legs, and unsteadiness in 10 minutes; 1 percent is about the maximum concentration that a man can stand, owing to the irritating effect on the skin as well as on the mucous membrane. The above symptoms were observed in men who had not been exposed to gasoline fumes in such concentrations regularly before the experiments were carried out. Tolerance to gasoline develops to some extent after repeated exposures. In some studies conducted by Mr. A. C. Fieldner, it was found that 2 to 2.5 percent gasoline vapor, when breathed, even though the body was unexposed, rendered a man dizzy and soon became intolerable.

In a study carried out by Dr. Howard W. Haggard for the Bureau of Mines, unconsciousness occurred in dogs when exposed to slightly more than 1.5 percent concentration, signs of discomfort appeared at about 0.8 percent, convulsions usually occurred at about 1 percent, complete surgical anesthesia at about 2.3 percent, and death at about 2.4 percent.

Hydrogen Sulphide, H_2S

Inflammable limits in percentage by volume: Lower, 4.3; upper, 46.
Boiling point, −60.2° C.
Percentage fatal in 30 minutes or less, 0.06 to 0.1.
Percentage causing dangerous illness in ½ to 1 hour, 0.05 to 0.07.
Percentage that can be borne without severe effects for ½ to 1 hour, 0.02 to 0.03.
Maximum safe concentration, 0.005 to 0.01 percent.

Hydrogen sulphide has a very repulsive odor in low concentrations that may serve as a warning. Its presence in sewers and treatment plants has been attributed to the decomposition of sewage. Its toxicity is comparable to that of hydrogen cyanide.

Poisoning by hydrogen sulphide is of two types, namely, acute and subacute, causing asphyxiation and irritation (conjunctivitis, bronchitis, pharyngitis, and depression of the central nervous system), respectively. Death from asphyxia is caused by paralysis of the respiratory center, while death from subacute poisoning is associated with edema of the lungs. The exact low limit of hydrogen sulphide concentration at which it ceases to act as a poison has not as yet been determined, but is evidently below 0.005 percent; 0.06 to 0.1 percent is sufficient to cause serious symptoms within a few minutes.

In low concentrations hydrogen sulphide produces symptoms of headache, sleeplessness, dullness, dizziness, and weariness. Pain in the eyes, followed by conjunctivitis, is fairly constant, while bron-

chitis and pains in the chest are frequent. Further poisoning produces depression, stupor, unconsciousness, and death. The heart continues to beat after respiration has ceased.

Sulphur Dioxide, SO_2

Boiling point, −10° C.
Percentage fatal in 30 minutes or less, 0.2.
Maximum safe concentration, 0.01 percent.

Sulphur dioxide has a pungent odor and suffocating effect. It usually comes from the burning of insulation containing sulphur. It is very irritating to the eyes and respiratory passages, 1 part in 500 being almost intolerable to breathe; there is occasionally sufficient concentration in the atmosphere to be dangerous. It is easily recognized by its characteristic odor, and it causes choking when breathed, as do fumes from burning sulphur. Symptoms of poisoning are spasmodic cough, bronchial catarrh, digestive disturbances, and blood-tinged mucous.

Carbon Monoxide, CO

Inflammable limits in percentage by volume: Lower, 12.5; upper, 74.
Boiling point, −192° C.
Percentage fatal in 30 minutes or less, 0.5 to 1.0.
Percentage causing dangerous illness in ½ to 1 hour, 0.2 to 0.3.
Percentage that can be borne without severe effects for ½ to 1 hour, 0.05 to 0.1.
Maximum safe concentration for long exposures, 0.02 percent.

Carbon monoxide is a colorless, tasteless gas, and odorless in diffused state. It burns with a blue flame in air. It exerts its extremely dangerous action on the body by displacing the oxygen from combination with the hemoglobin. Hemoglobin, the coloring matter of the blood, normally absorbs oxygen from the air and delivers it to the tissues through the blood. The affinity of carbon monoxide for hemoglobin is about 300 times that of oxygen. Because of this, even when only a small amount of the poisonous gas is present in the air breathed into the lungs, much of the hemoglobin is locked up in combination with carbon monoxide and so cannot keep up its usual work of carrying oxygen to the tissues. These, because of lack of oxygen, cannot do their work properly. If they are smothered long enough, the tissue cells become damaged, and the injury to the cells may be permanent even if the patient survives.

With increasing concentrations of carbon monoxide, the time required for a given amount of hemoglobin to combine with carbon monoxide decreases very rapidly, until with 1 percent concentration it may require only time enough to take a few breaths to produce a saturation of 60 to 80 percent, which may be fatal.

The symptoms of carbon-monoxide poisoning may be divided into two stages, the first covering the period beginning with normal and

ending in syncope, and the second a depression of the central nervous system beginning in syncope, extending through coma, and ending in apnea.

Stage 1. Tightness across forehead, dilatation of cutaneous vessels, headache (frontal and basal), throbbing in temples, weariness, weakness, dizziness, nausea and vomiting, loss of strength and muscular control, increased pulse and respiratory rates, collapse. All of these effects are greatly increased and accelerated with exercise, because of the additional need of oxygen in the tissues. Men at rest have often been exposed to carbon monoxide all day without noticing any marked ill effects, but on walking home or exercising have experienced severe symptoms, even to unconsciousness.

It is seldom that all of these symptoms are experienced by the same individual. Also, in some cases the poisoning may proceed to the stage of syncope without the victim's feeling any of the subjective symptoms. This frequently occurs when the poisoning has been rapid.

Stage 2. Increased pulse and respiratory rates, fall of blood pressure, loss of muscular control, especially sphincters, loss of reflexes, coma, usually with intermittent convulsions, Cheyne-Stokes' respiration, slowing of pulse, respiration slow and shallow, cessation of respiration, death.

With a given blood saturation the character and severity of symptoms acquired during exposure depend upon the time required to attain that saturation and the degree of muscular activity—in other words, the extent of oxygen deprivation. The number of symptoms decreases with the rate of saturation. With high concentrations the victim may experience but few (weakness and dizziness) of those symptoms given under stage 1. If a given saturation has been acquired by a long exposure to a low concentration, the symptoms and after-effects will be a great deal more severe than if the same saturation has been acquired by a short exposure to a high concentration. Muscular activity increases the number and accentuates the character of the symptoms during exposure, and will bring out latent symptoms after exposure. A person at rest may pass into a state of dizziness and unconsciousness without experiencing any marked previous effects.

PREVENTION OF POISONING BY GASES FOUND IN SEWERS AND TREATMENT PLANTS

The National Electrical Safety Code states that a manhole should never be entered "until you have assured yourself that it is free from dangerous gases, by testing with an approved safety lamp, by ventilation, or by other adequate methods." Tests may be made to determine the presence of poisonous or explosive gases. Odors are

important indicators of the presence of many such gases. However, some of them have little or no odor, such as carbon monoxide and hydrogen. Inflammable gases may be detected by the Burrell methane indicator, the Martienssen methane detector, and the U. C. C. methane detector.

Deficiency in oxygen and the presence of poisonous gases may be detected by the use of small animals, especially birds. Canaries have been found to be best of the live detectors, as they usually show symptoms of distress sooner than other small animals. Yant [7] found that Japanese waltzing mice were of value for this purpose. This same investigator [8] also called attention to the defects of a flame safety lamp for the detection of gasoline fumes, and it would, therefore, not be universally suitable for the detection of gases in sewers and possibly not in sewage-treatment plants. A portable apparatus [9] has been developed which will indicate whether an atmosphere is explosive above the explosive limit, deficient in oxygen, or, if below the explosive limit, the approximate percentage of combustibles present. The apparatus is operated, however, so as to give an analysis showing the percentage of the various gases, such as carbon dioxide, oxygen, ethylene, carbon monoxide, hydrogen, methane plus ethane, and nitrogen. This apparatus would not necessarily indicate the toxic properties of the atmosphere. Satisfactory apparatus has been developed especially for detecting small quantities of carbon monoxide, such as the iodine pentoxide indicator, pyrotannic acid apparatus, and palladium chloride ampoules or paper.

Jones (see footnote 2) recommends that sewage tanks be well ventilated before workmen are allowed to enter them for making inspection or repairs. This reason is evident, as the lower inflammable limit may be reached when the concentration of sewage gas is about 5 percent. (See table 1.) There are several types of portable blowers with explosion-proof motors which may be used satisfactorily for ventilating sewage tanks before making inspection or repairs. Jones strongly emphasizes that the ventilation should be continued during the time the workmen are in the tanks, as gases are given off and may reach the lower inflammable limit unless continuously diluted with air. Jones makes the following additional recommendations:

"(1) If illumination is required in the tanks, only flashlights approved by the Bureau of Mines should be used.

"(2) At many sewage-disposal plants the gases are collected and used for heating purposes. The utilization of these gases is attended

[7] Yant, W. P., Patty, F. A., Schrenk, H. H., and Berger, L. B.: The Response of Japanese Waltzing Mice and Canaries to Carbon Monoxide and to Atmospheres Deficient in Oxygen. R.I. 3040, U.S. Bureau of Mines, Oct., 1930, 12 pp.

[8] Yant, W. P., Berber, L. B., and McCaa, G. S.: A New Flame Safety-Lamp Testing and Demonstration Apparatus. R.I. 3017, U.S. Bureau of Mines, July, 1930, 10 pp.

[9] Jones, G. W. and Perrott, G. St. J.: Gases in Manholes: A Survey of a Utility in Boston, Mass. R.I. 3109, U.S. Bureau of Mines, May, 1931, 16 pp.

with some hazards. Very little trouble should be experienced when the plant is in continuous operation, because the pure gas contains very little oxygen and should be as safe to use as ordinary manufactured gas. However, if the plant is shut down or gas generation stopped, then air may leak into the distribution system and thus produce explosive mixtures.

"Of chief importance to prevent the infiltration of air is to keep the entire system under a few inches of water pressure so that leakage will be from the system rather than into it. If air can be kept out of the system then explosions will not be possible.

"Even under the best operating conditions there may be times when the system will contain some air, especially when first put into operation. Then precautions must be taken to prevent flames from traveling through the distribution mains and causing bad explosions. Sir Humphrey Davy, over a hundred years ago, discovered that fine meshed screens placed around the flame of a miner's lamp would prevent the flame on the inside of the lamp from igniting explosive mixtures of methane in air on the outside. Since that time many uses have been made of this discovery, more especially the arresting of the flames in pipe lines. Personally, I think the safety features claimed for screens in systems containing large volumes of gas have been overrated. They are excellent protection for 'stationary' flames as found in a safety lamp or even for flames moving at a slow speed; but for flames given a sufficient length of travel, which in pipes of sufficient size may travel 1,000 feet a second and develop high pressures, several screens in tandem will be required, and even then if the flame has been arrested the high pressure is still present and must be eliminated if damage to the flame trap is to be prevented. Our experience gained last year on another problem, whereby means of preventing damage to industrial equipment from explosive mixtures were investigated, led to the conclusion that release diaphragms are the most satisfactory method of protecting systems containing explosive mixtures. Release diaphragms properly placed and of the right size augmented by water seals and screens should give satisfactory protection to sewage-gas systems. On account of a lack of information on the flame speeds and pressures developed when explosive mixtures of sewage gases are ignited in pipes or other chambers, it is not possible to state definitely how and where the diaphragms should be placed. Information on other explosive mixtures in general permits us to reason by analogy what might be adequate for sewage gases. I might say as a mere speculation that, if release diaphragm openings are installed on the flame trap of a sewage pipe system so that there are 3.5 square feet of release opening per 100 cubic feet of gas, the release opening be 6 inches or larger in diameter, aluminum, lead, or tin foil be used for diaphragm mate-

rial and not over 0.002 inch in thickness, then the pressure in the flame trap caused by the explosion of any sewage gas-air mixture should not exceed 12 pounds per square inch above atmospheric pressure. The installation of two flame traps close together and at the delivery end of the sewage gases, so assembled that the traps may be connected in series or parallel, and each equipped with the proper diaphragm releases, water seals, and screens, should safely prevent flames from traveling through the piping system to the sewage tanks. The traps should be equipped with suitable gauges to give the pressure of the gas in the traps and height of the water above the water seals.

"Two flame traps are recommended so that in case of trouble in either the gas may be passed through one while the other is being cleaned. During normal operation both may be used as an added protection.

"It is very important that the water in the seals should be kept at the proper height at all times and screens kept clean, the flame traps be placed in a heated and well ventilated part of the building and protected by an enclosure so the diaphragms are not damaged and that employees may not be burned by flames issuing through the diaphragm openings should an explosion occur."

If it is necessary to enter an atmosphere containing any of the above noxious gases with insufficient ventilation, Katz [10] has recommended the hosemask, especially for manholes. The type N canister mask is also satisfactory when the air contains only a small proportion of poisonous gases and sufficient oxygen to support life. The hosemask has the advantage that there is nothing to be changed until the parts become worn out. It may be used to a distance of 100 feet. Longer hose, however, is not usually practicable. The hosemask with a hand-operated rotary blower delivers the air at the face piece in excess of that necessary to be breathed. It further has the advantage that, should the hose leak, the leak will be outward rather than into the hose. It is obvious that the intake end of the hosemask should be in fresh air.

TREATMENT OF POISONING BY GASES FOUND IN SEWERS AND TREATMENT PLANTS

The steps in effective treatment of acute poisoning by poisonous and noxious gases in sewers and treatment plants are as follows:

1. The victim should be removed to fresh air as soon as possible.
2. If breathing has stopped, or is weak and intermittent, or present in but occasional gasps, artificial respiration by the Schaefer method should be given persistently until normal breathing is resumed, or until after the heart has stopped.

[10] See footnote 3.

3. Circulation should be aided by rubbing the limbs and keeping the body warm with blankets, hot-water bottles, hot bricks or other devices, care being taken that these are wrapped or do not come in contact with the body and produce burns. This aids in tiding the body over a period of low vitality. Other stimulants, such as hypodermics of caffein, sodium benzoate, or camphor in oil, should not be administered except by a doctor after he has considered the possibility of overstimulation and consequent collapse.

4. The patient should be kept at rest, lying down in order to avoid any strain on the heart. Later, he should be treated as a convalescent and given plenty of time to rest and recuperate.

5. After-effects of poisoning by such gases should be treated symptomatically.

6. It should be emphasized that inhalation, for a period of 20 to 30 minutes, of oxygen, or a 5 percent mixture of carbon dioxide in oxygen if available, will, when given immediately, greatly lessen the number and severity of symptoms of carbon monoxide poisoning, as well as decrease the possibility of serious sequelae. All industries in which this type of poisoning commonly exists should provide apparatus (inhalers) for the efficient administration of these treatments. This apparatus should be placed at points most convenient for treating carbon monoxide poisoning, and employees should be trained in its use so that resuscitation may be effected immediately.

CITY HEALTH OFFICERS, 1933

Directory of Those in Cities of 10,000 or More Population

Directories of the city health officers in the cities of the United States having a population of 10,000 or more have been published in the Public Health Reports [1] for each year from 1916 to 1931 for the information of health officers and others interested in public-health activities. These directories have been compiled from data furnished by the health officers. The cities included in this directory are those having populations of 10,000 or more according to the 1930 census.

The asterisk (*) indicates that the officer before whose name it appears has been reported to be a "whole-time" health officer. For this purpose a "whole-time" officer is defined as "one who does not engage in the practice of medicine or in any other business, but devotes all his time to official duties."

[1] Reprints nos. 346, 416, 494, 539, 599, 702, 767, 876, 930, 1025, 1103, 1177, 1257, 1333, 1426, and 1521 from the Public Health Reports.