Health Hazards in Greenhouses Using Carbon Dioxide Generating Equipment*

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Editor's note—We work with many dangerous chemicals and sometimes become very blase about normal safety precautions. To our knowledge there have been no "accidents" with the CO_2 burners, however, it is obvious the gas burning equipment should be kept in a good state of repair and adjustment.

The purpose of reprinting this article is to have you recognize some of the problems associated with this new practice. R. W. L.

Since 1961 there has been a rapid increase in the practice of adding carbon dioxide (CO_2) to greenhouse atmospheres, to promote plant growth (14). Current sources of carbon dioxide include pure liquid carbon dioxide, "dry ice", and the combustion products from burning kerosene, propane or natural gas in commercially-distributed burners designed for this application. Pressurized pure CO_2 is admitted to the greenhouse atmosphere at a controlled rate through pressure regulators and gas flow meters. The hydrocarbon fuels are burned at a controlled rate depending on the volume of the greenhouse. Burners and CO_2 flow rates are designed to maintain an atmosphere containing approximately 1000 parts per million (p.p.m.) CO_2 during the daylight hours (14).

Combustion Products

Products from combustion of hydrocarbon fuels include the following gases (3, 6, 10) (Table I): 1. unburned fuel gases or vapors such as propane, ethane, or methane; 2. intermediate products, unsaturated hydrocarbons, such as ethylene and propylene; 3. intermediate products, partially oxidized, such as aldehydes; 4. water vapor; 5. oxides of nitrogen, principally nitrogen dioxide; 6. oxides of sulfur, principally sulfur dioxide; 7. carbon monoxide and carbon dioxide.

The amount of unburned fuel gases depends on the degree of mixing of fuel gas of vapor and air (6). Intermediate products are indicative of incomplete combustion (11). Water vapor content of combustion effluent gases varies from 44% to 56% of the weight of carbon dioxide produced. The amount of nitrogen oxides increases with flame temperature and with the rate of cooling of the effluent gases. The sulfur oxide content depends on the amount of the sulfur in the fuel. Carbon monoxide production varies inversely with the air supply, and is increased by flame chilling.

Suppliers of combustion CO_2 generators have provided data on the amount of combustion products in the effluent from their generators (2, 13). One of the suppliers (13) provides an analytical service for growers giving the amounts of unburned fuel, unsaturated hydrocarbons and carbon dioxide in samples collected at the burner flue.

The sulfur content of hydrocarbon fuels in relation to sulfur dioxide production is specified in the operating instructions for the CO_2 generators (7, 11, 13). Fuels having 2000 p.p.m. sulfur yield 0.7 p.p.m. sulfur dioxide in 1000 p.p.m. CO_2 which can cause plant damage (11).

Physiological Effects of Combustion Products

Carbon dioxide—In man, carbon dioxide regulates the activities of the heart, blood vessels and the respiratory system. Carbon dioxide concentrations of 1000 to 10,000 p.p.m. (1%) can cause headaches and listlessness (4) while 8 to 10% can be fatal (4). Other symptoms of carbon dioxide narcosis are: mental disturbance, confusion, drowsiness, perspiring, muscle twitching, intra-cranial pressure, pounding pulse, low blood pressure and low body temperature (4).

Carbon Monoxide—Carbon monoxide combines with the hemoglobin of the blood, reducing the ability of the red corpuscles to transport oxygen from the lungs to the brain and other tissues of the body. Prolonged lack of oxygen in the brain can result in permanent brain injury (4). For each one p.p.m. of carbon monoxide, 0.16% of the blood's hemoglobin is inactivated (8). After exposures to low concentrations of carbon monoxide, it may be several hours before effects are detectable. The earliest symptoms are headaches, nausea, and dizziness. Exposure to 30 p.p.m. for four to six hours may be sufficient to pose a serious risk to the health of sensitive persons, while a four-hour exposure to 250 p.p.m. of carbon monoxide can be fatal (10).

Although the effects of severe exposures may be cumulative, the gas itself is not cumulative, but is released from the blood at the rate of half every three or four hours in a non-polluted atmosphere (8).

Sulfur Dioxide—Concentrations from 1 to 5 p.p.m. cause proliferation of the mucous glands, cough, expectoration, wheezing and chronic bronchitis (8).

Nitrogen Dioxide—Nitrogen dioxide may irritate the lungs, with the development of bronchopneumonia following severe exposure (8). Low concentrations react with hydrocarbons in sunlight to yield oxidants (smog) which irritate the eyes and may cause plant injury (4).

Aldehydes—Increasing aldehyde concentrations from about 0.1 p.p.m. are associated with increased eye irritation in smog-polluted atmospheres (8).

Measurement of Combustion Products—Commercially distributed CO_2 generators have been perfected to the extent that even with excessive CO_2 enrichment of the greenhouse atmosphere the emission of other gases is usually below the threshold for conspicuous injury to plants and humans (Table I). How far the concentrations of CO_2 and other gases can vary with respect to greenhouse size and construction, weather conditions, mechanical variability of the apparatus, human error, air supply and fuel composition is unpredictable. For this reason it is desir-

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Table 1. The gases produced by various CO_2 generators and the levels of toxicity to plants and humans (figures given in parts per million, p.p.m.).

	LEVELS OF TOLERANCE[1]		GASES PRODUCED BY PROPANE BURNERS[2]	
	Plant	Human	Outdoor Type	Indoor Type
Methane	*	*	.645	*
Ethane	*	*	.028	*
Propane	*	*	.145	.20
Ethylene	.01 – .1	*	.0085	.10
Propylene	.01 – 50	*	.0095	.05
Aldehydes	.01 – .1	5	*	*
Sulfur Dioxide	.15 – .4	5	*	*
Nitrogen Dioxide	.50 – 25	5	"several p.p.m." (3)	*
Carbon Monoxide	500	100	50 – 100 (5)	50
Carbon Dioxide	20,000	5,000	80,000	7,700

*No information available
[1]This information from references 1, 3, 11, and 14
[2]This information obtained from references 2, 3, 5, 9, 12 and 13

Table 2. GAS DETECTORS, SUPPLIERS AND APPROXIMATE PRICES

Detector*	Gases Detected	Approx. Price
Scott-Draeger (16, 17)	Carbon Dioxide Carbon Monoxide Nitrogen Dioxide Sulfur Dioxide Aldehydes	$ 85.00
Davis (18)	Same as above	$ 9.95 (incl. 12 tubes)
MSA (25)	Same as above plus Ethylene and Propylene	$ 80.00
Kitagawa (21)	Similar to above	$100.00
Dioxor (15)	Carbon Dioxide only	$ 78.50
Monoxor (22)	Carbon Monoxide only	$ 42.50
Saf-CO (26)	Carbon Monoxide only	$ 25.00
MSA (25)	Carbon Monoxide only	$ 45.00
Unico carbon monoxide alarm (24)		$125.00
"Fyrite" (20, 23, 27)	Carbon Dioxide, 0.5 – 20%	$ 38.80 to $63.60
Dwyer (19)	Carbon Dioxide, 0.5 – 20%	$ 37.75

*The numbers refer to the list of manufacturers and distributors found under "Reference to Gas Measuring Apparatus."

able for the grower to be able to measure at least the CO_2 and preferably carbon monoxide as well.

For crop safety as well as the welfare of greenhouse workers it may be desirable for the growers to measure, periodically, the concentrations of several gases (Table 2). Several companies (16, 17, 18, 21, 25) offer gas detectors consisting of a pump which draws a measured volume of air through an expendable glass tube containing a chemical indicator for each of several gases. The range of measurement of gas concentration depends on the volume of air sampled as well as the reaction range of the tube. Thus it is possible to relate gas measurements in the greenhouse air with those taken at the burner exhaust.

The glass tubes may be used only once or twice and cost from $5.00 to $7.90 per dozen, so the frequency of their use is limited. Low levels of gases in the greenhouse can be correlated with high levels of CO_2 in the effluent from some of the burners by other instruments (19, 20, 23) which can be used repeatedly. A carbon monoxide alarm which is sensitive to low levels (50 p.p.m.) of the gas, is available (24).

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15. Ball, George J., West Chicago, Ill.
16. Clougherty Co., Inc., Charles H., 39 Miller St., Medfield, Mass.
17. Deane, David G., 104 Washington Rd., Springfield 8, Mass.
18. Davis Emergency Equipment Co., Inc., 130 W. Emerson St., Melrose 76, Mass.
19. Dwyer, F. W., Mfg. Co., P. O. Box 373, Michigan City, Ind. 46360
20. Fisher Scientific Co., 461 Riverside Ave., Medford, Mass. 02155
21. General Dynamics Corp., Liquid Carbonic Div., 136 Broadway, Cambridge, Mass.
22. Howe and French, Inc., 99 Broad St., Boston 02110
23. Hub Safety Equipment Co., 88 Wales St., Dorchester, Mass.
24. Matheson Co., Inc., P. O. Box 85, E. Rutherford, N. J. 07073
25. Mine Safety Appliances (C. S. Riley, Rep.), 2 Esmond St., Esmond, R. I. 02917
26. United States Safety Service Co., 5 Lawrence St., Bloomfield, N. J.
27. Bacharach Industrial Instruments, 200 North Braddock Ave., Pittsburgh 8, Pa. 15208