Carbon monoxide poisoning is preventable. Reasons why it is not detected more often are offered, and control measures that can be applied are presented. Examples of successful control programs are described, as is the Public Health Service Program to assist communities in reducing the hazards of accidental carbon monoxide poisoning.

CARBON MONOXIDE POISONING: A PREVENTABLE ENVIRONMENTAL HAZARD

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The Problem

Uncertain Diagnosis

ONE of the outstanding medical examiners of the nation has described carbon monoxide poisoning as "a condition rarely diagnosed by the physician even when the manifestations are present."[1] Even a cursory review of the literature reveals the background for such a statement. Carbon monoxide victims have been diagnosed and treated for varied ailments such as food poisoning, influenza, sinusitis, pneumonia, typhoid fever, or meningocephalitis.

All too frequently, after recovery from the immediate symptoms, such patients may return to the carbon monoxide-producing environment. Thereafter, their symptoms of chronic illness and debilitation return or, through further deterioration of the environmental situation, a higher build-up of carbon monoxide occurs, sometimes with fatal results.[2] If, however, a diagnosis is made with awareness of the possibility that there may have been extended exposure to carbon monoxide, a blood test for carboxyhemoglobin can confirm the physician's suspicions, and the living or working environment can be inspected to determine the source. Where such cooperation has been fostered beween the physician and the engineer or sanitarian, corrective action has been followed by dramatic improvement of the health of entire families.[2-4]

A case reported from Savannah, Ga., in 1968, is an example of such a fortuitous ending. Three residents of a small home awoke one cold morning with feelings of extreme distress. One by one, they became incapacitated. Discovered in this state by neighbors, they were rushed to a hospital. Their physician suspected botulism and ordered extensive laboratory tests. As a precaution, pending results of the tests, botulinum antitoxin was administered and severe reactions resulted.

As the laboratory work proceeded, blood tests indicated a suspiciously high carboxyhemoglobin level in one patient. There was an immediate investigation of the home environment by engineers from the State Department of Public Health. They found two unvented gas heaters, burning at a high rate in a small, tightly constructed home, produced a carbon monoxide concentra-

tion that would have been fatal to three persons, if their exposure had continued only a brief period longer.

The epidemiologist's report concludes with a single sentence: "Three persons originally suspected of having botulism were shown to have carbon monoxide poisoning."[5]

Incomplete Morbidity and Mortality Data

Since nonfatal carbon monoxide poisoning is not a reportable disease and since diagnosis is difficult, it is understandable that there is a dearth of reliable morbidity data. Based on the scant evidence available, the Injury Control Program of the Public Health Service has estimated that each year at least 10,000 persons suffer chronic ill effects from exposure to sublethal but debilitating levels of carbon monoxide.

If behavioral impairment (including judgment) and perceptual impairment are considered, the extent of the problem may be much greater. Observations on responses of human volunteers and animals exposed to low levels of carbon monoxide at the Stanford University School of Medicine led the investigators to conclude that the methods of setting standards of air quality need improvement. Deterioration of subjects' performance was demonstrated after continued exposure to carbon monoxide levels as low as 50 ppm.[6]

Mortality data for carbon monoxide poisoning is collected from death certificates and reported annually by the National Center for Health Statistics. Total accidental deaths attributed to this cause in 1966 numbered about 1,500; of these, almost 900 were in homes, more than 100 were in industrial places, and less than 200 were reported to have occurred on streets or highways (presumably from motor vehicle exhaust inhalation). It is not unreasonable to assume that more precise reporting on death certificates would result in higher figures. A recent revision of the International Classification definition for this cause of death undoubtedly will lead to more precise appraisal of the problem in the years ahead.

Sources

Since carbon monoxide is produced whenever a carbonaceous fuel is incompletely burned, potential sources of hazardous concentrations are legion. Epidemiologic studies are scanty, but enough evidence exists to direct attention for control measures toward two broad areas: automobile exhaust systems and heating installations. Standards for motor vehicle combustion and exhaust systems are rapidly being upgraded by the Public Health Service and the Department of Transportation. Carbon monoxide control in industrial situations is a subject of joint cooperation by federal and state (or government) regulatory agencies and industrial safety leaders. Despite a number of progressive steps by regulatory authorities, utility companies, equipment manufacturers, standards-setting groups, and public health agencies, carbon monoxide control in the home environment lags far behind its potential.

Of all forms of accidental death, carbon monoxide poisoning is most senseless. Application of existing technical knowledge to the installation and maintenance of home heating appliances and systems would save 800 to 900 people from untimely death each year. Recent evidence, even though scanty, indicates that thousands more would be spared frustrating, baffling health impairments.

Control Measures That Can Be Applied Now

1. National voluntary standards for heating equipment and installations have materially contributed to reducing the

carbon monoxide hazard. However, there is room for further improvement. The technical requirements and laboratory testing procedures frequently do not allow for a normal amount of hard use and deterioration during the life of the equipment. The safety of unvented gas burning heaters, which are still covered by USASI, is predicated on ample air infiltration and natural ventilation in the rooms where they are installed. In too many instances, this is a false premise. The example cited earlier is only one of many in our files. Health departments can be a major influence in stimulating revision of inadequate standards. When factual epidemiological evidence is presented that links illness and deaths with equipment deficiencies, standards committees listen and act.

2. Every community needs the protection of special code provisions governing installation of heating equipment. These codes should, and frequently do, recognize hazards of the products of combustion as well as fire hazards. Some cities have learned through experience those aspects of national standards that provide less than optimum safety, whereupon they then develop their own requirements.

3. Despite the protection afforded by standards for original equipment and local codes governing its installation, many factors such as deterioration, misuse, and mistakes by home handymen contribute to the creation of dangerous situations. In Memphis, Tenn., 327 random residential inspections, primarily of space heaters, water heaters, and gas cooking ranges, were made.[2] Of slightly more than 1,000 appliances tested, 25 per cent were found to be contributing measurable amounts of carbon monoxide to the home interior. About one-fourth were emitting between 200 ppm and 2,500 ppm of carbon monoxide. Similar situations have been found elsewhere, when concerned health departments have undertaken special surveys.

Colonel Finck of the Armed Forces Institute of Pathology reviewed 567 cases of carbon monoxide deaths in the files of the institute.[7] He found that "the majority (297) of the deaths occurred within buildings such as tourist cabins, hotels, apartments, garages, or barracks. Fumes from coal or kerosene heaters or stoves and from illuminating gas accounted for 51 per cent of the accidental deaths."

These findings suggest that some form of periodic selective inspection of residential heating equipment would pay dividends in lives saved and illnesses averted.

4. Health agencies, cooperating with medical societies, can suggest that physicians consider the possibility of carbon monoxide poisoning when patients come to them with certain kinds of symptoms. They also can suggest the desirability of blood tests for suspected cases. Physicians should feel free to call on the health department or other appropriate agency to investigate the home environment, when evidence of carbon monoxide has been found in a patient's blood.

5. The best defense against accidental carbon monoxide poisoning is an informed public. There have been scattered, sporadic public education campaigns on this subject. They have been sponsored by health agencies, public utilities, or medical societies—frequently as a joint venture. Much more effort, on a continuing basis, would be valuable.

Examples of Successful Control Programs

1. New York City, some years ago, used epidemiological methods to pinpoint problem areas, and then proceeded with intensive inspection and correction actions in blocks identified as having high and repeated carbon monoxide death records. Concurrently, public information on hazards and how they

could be corrected was disseminated through all forms of news media. Substantial and continuing declines in deaths from this cause were noted.

2. Columbus, Ohio, found that carbon monoxide deaths could be reduced when the physicians, the health department, and the building inspectors worked together on the problem. Certain areas with high hazards were given intensive coverage. The effort was rewarded with reduced deaths in subsequent years.[8]

3. Before national standards had been revised to require that all space heaters in mobile homes and camping trailers be vented, there was a series of carbon monoxide deaths in travel trailers reported from widely scattered areas of the country. Brilliant detective work by two state health departments identified the agent as a particular model of unvented gas burning heater. By a chance change in the production dimensions, this model had become a generator of carbon monoxide, even under ideal conditions of use. When all windows and doors were closed, this model was deadly in its effects.

Through the coordinated efforts of industry, health, police, and motor vehicle authorities, the 2,000 dangerous units known to have been produced were traced to their points of distribution. Owners and dealers were warned to replace the defective equipment. As a result of this episode, standards for trailer heating systems were completely overhauled. Reports of carbon monoxide asphyxiation in trailers that meet the new standards are relatively rare.

4. The special short-term control projects in the Memphis-Shelby County area in Tennessee and in Talladega County, Ala., have been mentioned earlier. In both places it was shown that residential carbon monoxide hazards are unduly high in many locations. It also was shown that when corrections are made, family health frequently improves. Unfortunately, despite the demonstrated value, these cities apparently have not had the resources to continue the work.

5. The most recent example of a cooperative attack on a special heater hazard of potential danger to thousands of families started with investigation of a single carbon monoxide death by a county sanitarian. It was followed by state health department laboratory tests of the suspected agent—a self-contained, baseboard-type gas burning heater. When this appliance was found faulty, the Public Health Service joined the state health agency in discussions with the principal distributor (a national retail corporation), and with the American Gas Association Laboratories. The manufacturer of the item had become bankrupt and had suspended business. Nevertheless, records were found that indicated at least 8,000 units of the potentially deadly models of this appliance had been sold, 6,000 to the major distributor. That firm immediately undertook its own investigation of the potential hazard and then, by national advertising and aid from its store managers, undertook an intensive recall and replacement campaign. Simultaneously, both the company and the Public Health Service alerted the public by news release and requested assistance from utility companies, health agencies, and building departments in locating the defective units. Responses from areas where these models had been installed were excellent. A large proportion have been identified and replaced. The episode indicates the high degree of concern for user safety exhibited by responsible retail distributors.

Public Health Service Program

The Public Health Service is launching an intensive, broad-scale program to assist communities in reducing the hazards of accidental carbon monoxide poisoning. Components will include:

1. Studies in selected areas and population groups to assist in analyzing par-

ticular problems, in implementing prevention activities, and in continuing and evaluating program efforts.

2. Recommendations to national code making organizations that higher safety factors be incorporated in heating equipment and heating installation standards.

3. Assistance to state and local regulatory agencies in the adoption and strengthening of their codes on this subject.

4. A program kit for use by health departments. The kit will contain informational materials developed to give the public a better understanding of the causes and prevention of carbon monoxide poisoning. Supportive program materials will include radio and television spots, press releases, brochures, visual aids, and a demonstration script.

5. Informational material directed to physicians to call their attention to the confusing similarity between symptoms of carbon monoxide poisoning and those of certain other conditions.

Summary

Carbon monoxide poisoning, both fatal and nonfatal, is more prevalent than is generally recognized. There is increasing evidence that its chronic, low-level form may be a cause of much ill health. Accidental carbon monoxide poisoning in the residential environment could be almost totally controlled if existing standards were improved, if effective codes were enforced, and if the public had a better understanding of how to avoid this hazard. Some communities have made special efforts to control the hazard and they have succeeded. Unfortunately, there is too often a slackening of attention, after an immediate situation has been controlled. The Public Health Service is now undertaking a comprehensive national program to assist communities in sustained prevention programs. Cooperation of environmental health personnel will be essential to success.

REFERENCES

1. Forensic Casebook: Autopsy Leads to Source of Leakage of CO. Medical Tribune 7,13:17 (Jan. 29-30), 1966.
2. Yates, M. W. A Preliminary Study of the Occurrence of Carbon Monoxide Gas in the Home Environment. Memphis and Shelby County Health Department, Memphis, Tenn. (Aug.), 1965.
3. Rayfield, John D. Field Testing Program for Carbon Monoxide. J. Alabama M. A. 36,12:1494-1502 (June), 1967.
4. McElwee, Kenneth N. Report of Tests for Carbon Monoxide Gas in Home Environment 1965-1966. Unpublished report, Office of Housing Code Enforcement, Talladega County Health Department, Sylacauga, Ala.
5. Eichner, E. R.; Gangarosa, E. J.; and Eickhoff, T. C. Epidemiology Program Unpublished Memorandum (Jan. 23), 1967.
6. Beard, Rodney, R., and Wertheim, George A. Behavioral Impairment Associated with Small Doses of Carbon Monoxide. A.J.P.H. 57,11:2012-2022 (Nov.), 1967.
7. Finck, Pierre A. Exposure to Carbon Monoxide: Review of the Literature and 567 Autopsies. Military Med. 131,12:1513-1539 (Dec.), 1966.
8. Disease Control Prevention: Prevention of Carbon Monoxide Poisoning. Bull. Ohio Department of Health (June 26), 1961.

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