Residential Carbon Monoxide Detector Failure Rates in the United States

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There are more than 38 million residential carbon monoxide detectors installed in the United States. We tested 30 detectors in use and found that more than half failed to function properly, alarming too early or too late. Forty percent of detectors failed to alarm in hazardous concentrations, despite outward indications that they were operating as intended. Public health professionals should consider community education concerning detector use and should work with stakeholders to improve the reliability and accuracy of these devices. (*Am J Public Health.* 2011; 101:e15–e17. doi:10.2105/AJPH.2011.300274)

There are about 450 deaths in the United States each year from unintentional carbon monoxide (CO) poisoning and 15 000 hospital emergency department visits for this cause.[1] According to the 2007 American Housing Survey for the United States, there are more than 38 million residential CO detectors installed in the United States.[2] During the 8-year period of 1998–2005, motor vehicle accidents were directly responsible for 17.3% of all line-of-duty deaths in the fire service.[3] Although it is not possible to determine the extent to which CO callouts were responsible for these deaths, it is compelling that almost 1 of every 5 firefighter deaths is caused by the act of response alone. Thus, as a result of the large number of CO units installed and their relatively high false alarm rate, the volume of emergency runs directly resulting from CO alarm incidents is elevated, as is the potential for injury to first responders.

Consumers expect that CO will be detected at unsafe concentrations and that the alarm will sound. Most CO detectors have a "push to test" feature incorporated into their design so that they can be tested on a regular basis. Data on alarm owners' frequency of use of this test function are nonexistent, but it is likely such testing is not performed as often as recommended by manufacturers, if at all. More problematic, however, is that many detector "push to test" buttons determine only whether power is reaching the detector or whether the audible alarm operates and not whether the CO sensor is functioning as intended.

Voluntary performance standards exist for the performance of CO detectors, most notable among them being Underwriters Laboratories (UL) 2034 in the United States.[4] It must be noted that UL 2034 does not wholly protect all members of the US population, especially at its lowest alarm test level. For example, the current Occupational Safety and Health Administration permissible exposure limit for CO is 50 parts per million as an 8-hour time-weighted average concentration, but the UL lower alarm limit is 70 parts per million. The National Institute for Occupational Safety and Health has established an even lower recommended exposure limit for CO of 35 parts per million on the basis of the risk of cardiovascular effects at higher concentrations.[5] These differences aside, UL 2034 is the only standard with which most US manufacturers seek to comply. This standard prescribes that manufacturers meet 3 concentration plus response time windows of operation (Figure 1) to earn the UL designation. Briefly, low levels of CO should not result in alarms. More specifically, units should not alarm before 60 minutes but before 240 minutes when exposed to 70 parts per million of CO. Conversely, immediately dangerous or life-threatening CO levels should rapidly result in alarms; UL specifies alarming within 4 to 15 minutes at concentrations of 400 parts per million. An intermediate test window mandates that CO detectors alarm in no less than 10 minutes at concentrations of 150 parts per million. Detectors that alarm too early (fail safe) may result in first responder and public risk from unnecessary emergency response actions, whereas detectors that alarm late (fail unsafe) risk CO poisoning to building occupants.

Purchasers of CO detectors typically pay more for more features, one of which is an end of service life signal or indicator. Not all units have this feature, and so it is likely that some CO detectors remain in use long after they are no longer capable of detecting hazardous concentrations of CO. In this preliminary survey, we examined the CO detector infrastructure in a single US community.

METHODS

Members of the community voluntarily provided CO detectors in response to public notices in local newspapers, on the radio, and in a large local employer's newsletter. For inclusion in the study, we selected detectors that had been in active use immediately before testing. We provided certified working loaner detectors to participants during the testing of their units (about 2 weeks). We ascertained visual and audible indicators of proper functioning for each unit before sensor testing and recorded key information, including UL listing, manufacture date, years in service, manufacturer, and model number.

We performed precision testing of detectors in the laboratory in an exposure test chamber housed within a certified laboratory fume hood. Using a custom-built gas-mixing manifold system, we mixed stock CO (Linde Gas; product No. 100111873) at 3.98% volume per volume purity with grade D breathing air and room air in the test chamber. Grade D air is certified to contain 10 or less parts per million CO.[6] We determined concentrations with a factory-calibrated infrared spectrophotometer (Sapphire; Thermo Scientific, Waltham, MA), which we checked for zero before each use and randomly bump tested with a known gas concentration (26.8 ppm CO; Scott Specialty Gases, Plumsteadville, PA).

We tested detectors at each of the 3 concentration plus response time windows, beginning with the lowest CO concentration (70 ppm) first. We did not further test units that failed safe in this test (i.e., alarmed too early), and we considered them to have failed to perform properly. We subsequently tested detectors passing the lowest-level test at 150 parts per million and 400 parts per million levels. We deemed detectors that did not alarm at these concentration plus response time criteria to have failed unsafe. We kept detector units in CO-free air between testing according to UL

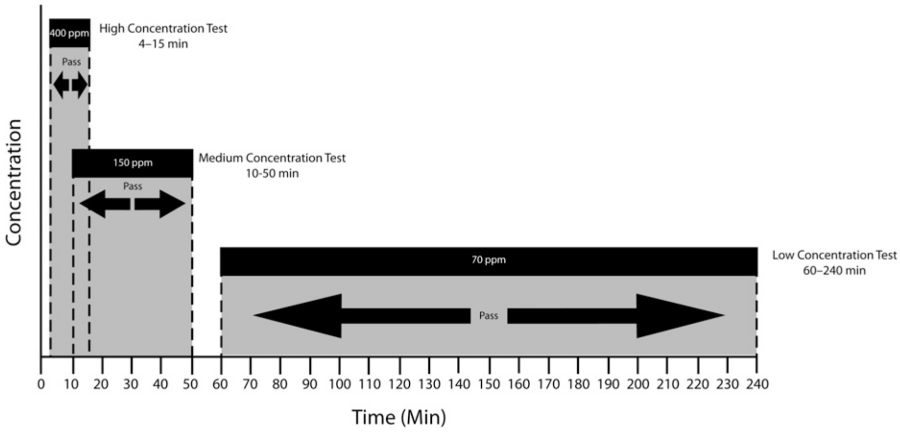

FIGURE 1—The 3 time and concentration test windows for Underwriters Laboratories–listed carbon monoxide detectors: residential carbon monoxide detector failure rates in the United States: Athens, OH, 2010.

2034 requirements. We captured all sampling runtime and concentration data with a data logger.

RESULTS

Observed failure rates were statistically significant at the 95% confidence interval (CI) level. The overall failure rate for all 30 detectors of all ages was 57% (17/30; 95% CI=39%, 74%), which included 40% (12/30; 95% CI=22%, 58%) that failed unsafe (black bars, Figure 2) and 17% (5/30; 95% CI=3%, 30%) that failed safe (gray bars, Figure 2). Although detectors 10 years old or older made up only 40% of the detectors tested, they disproportionately represented 66% (8/12) of the failed unsafe units. Despite the small number of units tested, there was a clear trend toward age-related failures. Contrary to manufacturers' advice to replace alarms after 5 to 7 years, several homes were relying on CO detectors that were 14 or 15 years old.

DISCUSSION

All CO detectors recruited for this study were in use at the time of their selection, a fact of key importance to the implications of these study findings. We determined a statistically significant unsafe failure rate of 40%: of every 5 homes sampled, 2 were in fact not protected by the installed detector. Despite visual assurances such as CO detector indicator lights or digital numeric readouts, toxic yet unannounced concentrations of CO would be entirely possible in such locations. A rate this high is of great concern and has serious public health repercussions in that it portends an unacceptably high national failure rate of the US CO detector infrastructure.

Of all detectors tested, 17% alarmed prematurely. Although such failures may initially seem of little importance, or perhaps even beneficial to the occupant, this failure rate must be deemed as unacceptable as the unsafe failure rate of 40%. Because emergency first responders are often summoned by community members in response to a CO alarm, both the public and first responders are at increased peril because of these fail safe alarms. Traffic accidents involving both groups are the most obvious directly related problem, but wasted resources and possibly diminished municipal response capacity are recognized and well-documented issues.[7]

Public health agencies involved with CO control programs, such as the US Consumer Product Safety Commission, the Centers for Disease Control and Prevention's Healthy Homes Program, and the US Department of Housing and Urban Development's Healthy Homes Initiative, should note these findings and consider educating the public concerning CO alarm limitations.[8,9] City and county health units can become engaged in recommendations for user testing or removal of older and non-functioning CO detectors.

The number of units tested in this study was small, but we saw a clear trend toward age-related failures (Figure 2). Further work should be conducted to better characterize this age relatedness and to discern failure types (safe vs unsafe) on the basis of manufacturer variables such as internal means of detection, electronics, and battery versus line voltage operation. The basic questions of how long CO alarms stay in use in the field and what the performance of CO alarms is after several years of use remain unanswered.[8] UL 2034 only requires that listed units function as required for 3000 hours (i.e., 4 months), or about 1 heating season.[4]

Selection of study objects by convenience sampling as used here deviates from the tenets of statistical sampling, but the practice is also noted to be useful in pilot studies.[10] Random sampling was not practical in this pilot study, and

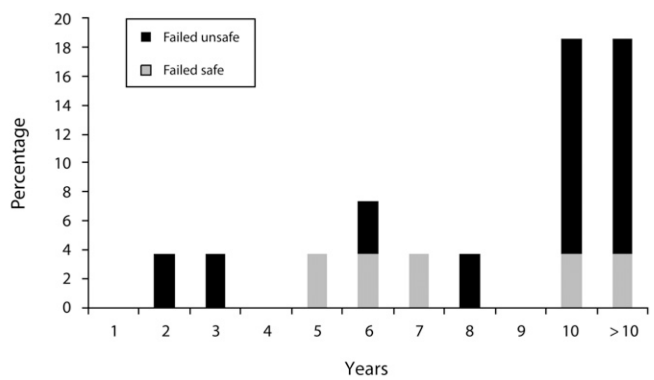

FIGURE 2—Failure rates of carbon monoxide detectors since manufacture: residential carbon monoxide detector failure rates in the United States: Athens, OH, 2010.

there may have been selection bias in that only persons with "working" CO detectors were included. In addition, some CO detector users may have elected not to participate, believing that their units were functioning properly owing to a relatively recent date of purchase or visual indicators (e.g., light-emitting diode readout, green light) displaying on the units. There is no compelling reason to expect that our results would differ greatly from a random sample of the same population, but future studies of CO detectors should involve a more robust sampling design.

We provided loaner detectors to study participants while their units were tested. It is remarkable that of 4 newly purchased, UL-listed loaner detectors, 1 was found to fail unsafe in repeated testing. (Testing outcomes of loaner detectors were not included in these study results because such units did not meet the selection criteria.) This single occurrence does suggest an area for further study. Such future work should examine failure rates of new detectors before they are placed into service and should entail collaboration with governmental agencies and standard-setting bodies (e.g., the Consumer Products Safety Commission and UL) to ensure CO detector quality for the expected life of the unit. ■

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Contributors

T.J. Ryan was the principal investigator of this project and provided all equipment design, construction, testing protocols, logistics, and manuscript preparation. K.J. Arnold served as the research technician; she tested the CO units under the protocols described and maintained the results database.

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Human Participant Protection

This project was declared exempt from full approval requirements by the Ohio University institutional review board because it did not involve human participants (only environmental data were used).

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