

before the measurements are determined. *Analytic methodology* is defined as measurement technology itself.

It would thus be impossible for an independent team to try to precisely reproduce the results obtained by Deitchman et al.¹ It is well known that false CO hemoglobin results can be obtained by using a CO oxymetry analytic methodology in patients with mixed intoxications or in dead patients.^{2,3} For example, in the case of a CO plus hydrogen cyanide mixed intoxication, some CO oxymeters may not be able to distinguish cyanide hemoglobin from O₂ hemoglobin.^{3,4} It cannot therefore be excluded that the real cause of the clinical intoxications described by Deitchman et al¹ is not CO. Why could it not be hydrogen cyanide, which is much more toxic than CO,⁴ for example?

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In reply:

We appreciate Dr. Watine's concern because combined carbon monoxide (CO) and cyanide intoxications can occur in victims of fire smoke inhalation. Like CO, hydrogen cyanide (HCN) is often a product of combustion in fires and is a hazard to firefighters and fire victims. HCN in structural fires typically is produced by the combustion of synthetic polymers, such as plastics; natural polymers, such as wool, can produce HCN, but the primary toxicant generated by combustion of natural polymers is CO.¹

Indeed, during the initial response to this incident, there was confusion among responders and health care personnel regarding possible toxic exposures incurred by victims

and rescuers. For example, victims and rescuers underwent decontamination for possible exposure to sulfur dioxide because that gas was indicated by a direct-reading gas analyzer used by the fire department. No sulfur dioxide was detected in laboratory analysis of atmospheric samples from the manhole, however, and the gas analyzer's manufacturer subsequently told us that sufficiently high levels of CO will cross-react with the sulfur dioxide detector to cause a false reading.

Perhaps because of this initial uncertainty regarding possible exposures, both survivors received amyl nitrate and sodium nitrate for treatment of possible cyanide intoxication. When we reviewed the medical records, we did not see reports of detected cyanide. Methemoglobin levels were 1.9% in the 45-year-old patient after treatment and 0.7% in the 32-year-old patient; timing of this measurement was uncertain. Blood gas samples in the hospital caring for the 45-year-old patient were analyzed with a Ciba-Corning 2500 co-oximeter, which the hospital reported was sensitive for methemoglobin. The manufacturer of this instrument has been sold to another firm (Bayer Diagnostics, Medfield, MA), which has discontinued the instrument. The firm kindly supplied relevant pages from the instrument's operating manual. The manual noted that the instrument measured carboxyhemoglobin, but said nothing about whether it detected cyanmethemoglobin or distinguished that from carboxyhemoglobin or oxyhemoglobin. No other information was available.

There was no structural fire in the incident we reported. The only combustion was the detonation of explosives that produced the CO. As a result, analysis for cyanide was not conducted in the analysis of environmental air samples from the manhole, the post-mortem toxicology conducted on the deceased worker, and environmental samples from the test blast of the explosive that we reported to confirm CO production.

Although the explosives laboratory has since disposed of its samples of this explosive, which contains 61% ammonium nitrate, after receiving Dr. Watine's letter, a test blast was conducted by using an available explosive composed of 94% ammonium nitrate and 6% fuel oil. Length-of-stain detector tubes were used to measure HCN in the test cham-

ber atmosphere (Dräger cyanide detection tube #2/a; Drägerwerk Sicherheitstechnik GmbH, Lübeck, Germany). Information about this explosive would predict about 2 mg/m³ HCN for the detonation of 4.5 kg of explosive in the chamber. No HCN was detected on a stain tube with a minimum sensitivity of 2 mg/m³ (personal communication, Michael Sapko, National Institute for Occupational Safety and Health, Pittsburgh Research Laboratory, Disaster Prevention and Response Branch, Pittsburgh, PA, January 10, 2000), although it is possible that the cyanide level was below the detection limit or that HCN was combusted or reacted with other gases in the chamber.

Indeed, HCN is a predicted product from the detonation of most explosive formulations that contain some form of nitrates, but HCN is very water soluble and has very wide flammable limits. CO produced from the detonation of explosives underground (no excess O₂) will trap the detonation products within the voids of the expanded rock. The CO is not very water soluble, fairly stable, and will stay within the soil for quite some time (several days or weeks). HCN, in contrast, is rapidly absorbed by any moisture present within the expanded rock. HCN is also very reactive with sulfides and other dolomitic materials containing metals, such as iron, sulfides, and pyrites (personal communication, Michael Sapko, National Institute for Occupational Safety and Health, Pittsburgh Research Laboratory, Disaster Prevention and Response Branch, Pittsburgh, PA, January 3, 2000).

If the mechanism of exposure to the victims in our report involved gas diffusion through 50 feet of soil, this raises the question of whether any HCN produced would have reacted in the soil during passage and therefore not be free to accumulate in the manhole. Since the publication of our report, the diffusion of CO through soil from an underground explosion has been confirmed by an additional publication.² In this later report, CO percolated through soil and accumulated in basements of homes near the blasting site and resulted in nonfatal CO intoxications of several residents. The second description of CO intoxication after blasting confirms our initial report and reinforces the need to consider CO intoxication in this setting.

Dr. Watine reminds us that cyanide intoxication should be considered in patients with smoke inhalation undergoing treatment for CO intoxication. We believe the circumstances of the exposure we reported, with its absence of a likely exposure to cyanide, make cyanide intoxication unlikely in the patients we described. However, we would welcome environmental cyanide data and cyanide toxicity information from clinicians who care for other victims of blasting-related CO exposure.

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