MERCURY VAPORIZATION FROM RADIOACTIVE CHLORMERODRIN SOLUTIONS

Philip C. Johnson, Leo Wade, Cheryl Mitchell, and O. L. Pirtle*

Methodist Hospital and Baylor University College of Medicine, Texas Medical Center, Houston, Texas

From an industrial-health standpoint, mercury is well known because simple mercury compounds volatilize at room temperature (*1–3*). Chlormerodrin, the most commonly used radioactive mercury compound, is not generally recognized as a volatile substance. Yet, the pharmacological activity of a mercurial diuretic depends on the lability of the carbon-mercury bond. Therefore, solutions of chlormerodrin might be expected to contain free radioactive mercury and to release mercury vapors into the air because both elemental mercury and mercuric chloride vaporize slowly. Our study shows that radioactive chlormerodrin releases radioactivity into the air at room temperature, producing a contamination in the rooms where it is used. This radioactivity has a tendency to adsorb to glassware and to amalgamate into gold jewelry. Although ^{203}Hg levels have not been sufficient to pose a health hazard in our laboratory, a slow buildup of contamination could occur. This problem warrants consideration because of the long physical and biological half-life of ^{203}Hg.

METHOD

In these studies, pharmacologically prepared ^{203}Hg and ^{197}Hg chlormerodrin were used as they were received from multiple suppliers. Chlormerodrin was shipped in rubber-stoppered multi-injection bottles containing 5 or 15 mc radioactive mercury in about 10 ml of solution. We determined release of radioactive vapor by placing each bottle in separate 400-ml glass chambers (beakers) containing an open well in which 2 ml of 40% trichloracetic acid solution (TCA) had been pipetted. The chambers were sealed with Parafilm and masking tape and left at room temperature in subdued light for 24 hr.

At that time 1.0 ml of trichloracetic acid solution was removed, and its gamma activity was determined in a scintillation well counter. Sufficient counts were obtained to result in a 5% average statistical counting error when radioactivity was measurable (detection limit is about 5.0×10^{-6} μc). Contamination by other isotopes was checked for in each case with a 400-channel analyzer. The valence state of the mercury absorbed by the TCA solution was checked qualitatively by using dithizone dissolved in carbon tetrachloride. This green solution turns yellow when mercurous ions are present and orange when mercuric ions are present. It does not react with elemental mercury. In addition, an open vial of ^{203}Hg chlormerodrin was placed in a chamber containing an open well of dithizone. After 24 hr the color and radioactivity of the dithizone was recorded before and after the addition of TCA.

To study the effect *p*H has on the release of radioactivity, we injected 1-mc amounts of ^{203}Hg chlormerodrin into three 30-ml multi-injection rubber-stoppered vials (sodium chloride injection, USP-Cutter Labs, Berkeley) in which the *p*H of the saline had been adjusted to 2, 7 and 10. Each bottle was placed in a test chamber for 24 hr.

The continued release of ^{203}Hg was followed for one 5-mc bottle which was placed in a new chamber at the end of the 24 hr period. At the end of the second day, the bottle was washed in TCA and rinsed in tap water before being placed in a new chamber for an additional 24 hr.

To show that the mercury contamination we found was not surface contamination but was actually a continuous release of mercury vapors from within the bottle, we washed a 5-mc bottle of ^{203}Hg chlormerodrin in 40% trichloracetic acid solution for 1 hr, rinsed it in running distilled water for 1 hr and then placed it in a chamber. Each day 1 ml of the TCA in the chamber well was removed and the gamma activity was determined. The TCA that was removed was replaced with fresh TCA.

Laboratory surface contamination was measured by wipe samples taken from a room where medical mercury doses are prepared and from another room where our hot storage hood for empty mercury bottles is located. This was accomplished by rubbing a 1-in. square of absorbent paper towel over a 6-in.^{2} surface area. Several gold rings were checked for ^{203}Hg contamination by placing them on an open-

Received Oct. 6, 1966; revision accepted Oct. 20, 1967.

* Hastings Radiochemical Works, Highway 35, Houston, Texas.

TABLE 1. ABSORPTION OF RADIOACTIVE MERCURY VAPORS RELEASED FROM UNOPENED CHLORMERODRIN BOTTLES

Activity in bottle (mc)	Activity in well (μc)	Date of shipment
5 ^{203}Hg	11×10^{-3}	Feb. '66
5 ^{203}Hg	8.5×10^{-3}	Apr. '66
5 ^{203}Hg	9.8×10^{-3}	May '67
15 ^{197}Hg	32×10^{-3}	Mar. '66

faced shielded scintillation crystal. In each case pulse-height analysis ruled out contamination from other frequently used radioisotopes.

RESULTS

Table 1 shows the results of the studies done on the stock bottles of ^{203}Hg and ^{197}Hg chlormerodrin. Three representative shipments of ^{203}Hg from a single manufacturer are shown. In each case radioactive mercury was absorbed into the solution. One shipment of ^{197}Hg chlormerodrin was tested for ^{203}Hg contamination. Although only 0.5% of the total radioactivity in chlormerodrin solution was found to be from ^{203}Hg, the radioactivity released from the bottle contained equal amounts of ^{203}Hg and ^{197}Hg. This would seem to indicate that the outside of the ^{197}Hg bottle had been contaminated with ^{203}Hg not contained within the bottle before shipment to us.

The radioactive TCA solutions as well as both commercial chlormerodrin and radioactive chlormerodrin gave the color reaction for mercurous. Solutions of elemental mercury in TCA also gave mercurous reactions while elemental mercury and TCA independently gave no reaction. When dithizone solution was placed in the well of a closed chamber containing chlormerodrin, radioactivity appeared in the dithizone solution, although it had not changed color. Since chlormerodrin gives a mercurous reaction but elemental mercury does not react, it seems most likely that elemental mercury is released by the chlormerodrin solution. Adding TCA to the dithizone causes a color change which probably indicates oxidation of elemental mercury to mercurous.

TABLE 2. INFLUENCE OF pH ON MERCURY VAPOR RELEASE FROM DILUTE CHLORMERODRIN SOLUTIONS

pH	Activity in well (μc)
2	14×10^{-6}
7	24×10^{-6}
10	86×10^{-6}

In a study of the effect of *p*H on the volatilization of chlormerodrin solutions (Table 2), we found that the greatest amount of mercury was released at *p*H 10. Chlormerodrin is known to be soluble in alkali and stable at *p*H 10 (*4*) which indicates further that elemental mercury and not chlormerodrin is volatilizing into the air above the chlormerodrin solutions.

Our study of the continued release of radioactive mercury using a different chamber each day showed that 9.8×10^{-2} μc were released on the first day, 4.0×10^{-2} μc on the second day and 3.6×10^{-2} μc on the third day. The well continued to collect radioactivity even after the bottle was washed and rinsed with acid on the second day, indicating that the ^{203}Hg was not surface contamination. The results of the second continued release study are shown in Table 3.

TABLE 3. CONTINUED RELEASE OF MERCURY VAPOR FROM UNOPENED BOTTLE OF ^{203}Hg CHLORMERODRIN

Day	Activity in well (μc)
1	3.7×10^{-2}
2	2.1×10^{-2}
3	1.9×10^{-2}
4	1.3×10^{-2}
5	1.3×10^{-2}

When the bottle was washed in acid before being placed in the chamber, 8.1 μc appeared in the TCA wash. The well continued to collect radioactivity for the 5 days tested. If mercury vapors were not continually released from the chlormerodrin bottle, only half of the radioactivity would be expected to remain in the well each day because fresh TCA was added to replace that which was removed. However, the amount of radioactivity present in the well on the fifth day was greater than predicted from dilution. At the end of the fifth day the bottle was placed in a new chamber but the old chamber was also resealed. As predicted from dilution the radioactivity in the chamber without a bottle in it dropped to one half of its original value. The radioactivity in the well of the new chamber with the bottle increased to 2.5×10^{-2} μc. These two studies indicate that radioactive vapors are continuously released from ^{203}Hg chlormerodrin bottles probably by passing through or around the rubber stoppers.

There are two areas in our laboratory where ^{203}Hg is found in appreciable quantities. The first of these is a small room where doses for brain scans and renal scans are prepared. The second is the hot stor-

age hood where all radioisotopes are stored before use and all empty bottles which have contained radioactive material are stored for initial decay after use. The bottle tops are left intact when multi-injection bottles are placed in the hood for decay. Wipe samples taken from the two walls of the hood contained the same amount of mercury contamination as those taken from the walls of the dose-preparation room. Widespread low-level contamination of this type suggests release of radioactive vapors. No other contamination was found in these samples.

The results of the tests for contamination of gold rings are shown in Table 4. Ring A is the wedding ring of one of our technicians who has worked in the laboratory for about 4 years. Ring B is the wedding ring of another technician who has worked there for 6 months. Both technicians frequently injected ^{203}Hg chlormerodrin into patients. Ring C belongs to a secretary who has never worked near or with radioactive materials. Ring D is a gold ring that was placed on a wall in the dose-preparation room for 2 weeks. It contained no detectable radioactivity before being placed in the room. The fact that the ring was contaminated indicates that while spills may account for some of the mercury on technicians' rings, contact with mercury vapors also causes contamination.

TABLE 4. RADIOACTIVE MERCURY AMALGAMATED TO GOLD RINGS

Ring	Activity (μc)
A	5×10^{-3}
B	1×10^{-3}
C	$< 5 \times 10^{-6}$
D	2×10^{-4}

DISCUSSION

It has been known for many years that mercury compounds vaporize producing mercury poisoning (*1–3,5,6*). The results of this study suggest that solutions of ^{203}Hg chlormerodrin also release mercury vapor probably as elemental mercury. Mercury contamination was present even though the bottle stoppers had not been punctured, indicating that mercury vapor can pass around or through the rubber stopper in multi-injection bottles.

We have reported elsewhere that some degree of mercury contamination is present on the outside of chlormerodrin stock bottles from all suppliers tested (*7*). Because of the tendency for mercury vapors to escape from a stoppered bottle, the contamination on the stock bottles may not take place during the manufacturing process; volatilization during shipping can also explain these results. If the ^{203}Hg chlormerodrin solutions are stored by the manufacturer, cross contamination of bottles can occur before shipment. Cross contamination is the best explanation for the high ^{203}Hg-to-^{197}Hg ratio present on the outside of the stock bottle of ^{197}Hg chlormerodrin tested in our study.

We have found no literature evidence that chlormerodrin volatilizes at room temperature, but both elemental mercury and mercuric chloride do vaporize and could be contained in the chlormerodrin solution. In the presence of light, mercurous chloride is converted into a mixture of mercuric chloride and elemental mercury. Thus all valence states of mercury are potentially volatile. The data presented here suggests that the mercury released from chlormerodrin is elemental mercury.

Released ^{203}Hg vapors have produced detectable contamination of laboratory walls and of gold rings. In our laboratory, the levels of ^{203}Hg found are not sufficient to pose either a health hazard (determined by monthly urine assays for ^{203}Hg) or an increase in the background of our counting instruments. However, with continued use a slow buildup of contamination will occur. When radioactive mercury contamination becomes a hazard it can be controlled by: (1) Acid washing the outside of ^{203}Hg chlormerodrin bottles to remove mercury contamination temporarily (*7*) and (2) spreading elemental sulfur in areas where chlormerodrin is spilled or used.

SUMMARY

1. ^{203}Hg chlormerodrin solutions in the concentrations used by pharmaceutical suppliers release radioactive vapors into the air.

2. This tendency to volatilize causes contamination of the outside of chlormerodrin bottles, laboratory walls and gold jewelry worn in the vicinity.

REFERENCES

1. NOE, F. E.: Mercury as a potential hazard in medical laboratories. *New Engl. J. Med.* **261**:1,003, 1959.

2. STECHER, P. G., ED.: The Merck index of chemicals and drugs, 7th ed., Merck and Co., Rahway, N.J., 1960, p. 655.

3. NEAL, P. A.: Mercury poisoning from the public health viewpoint. *Am. J. Public Health* **28**:907, 1938.

4. ANGHILERI, L. J.: A study of the stability of neohydrin (3-acetoxy-mercuri-2-methoxypropylurea) labeled with mercury-203. *J. Nucl. Med.* **4**:410, 1963.

5. TURNER, J. A.: Mercurial poisoning—a report on poisoning from small quantities of mercurial vapor. *Public Health Rep.* **39**:329, 1924.

6. ROESMER, J. AND KRUGER, P.: The radiochemistry of mercury, Nuclear Science Series, National Academy of Sciences—National Research Council, 1960.

7. JOHNSON, P. C., WADE, L., PIRTLE, O. L.: Radiation safety hazard of chlormerodrin. To be published.