RADIATION SAFETY HAZARD OF CHLORMERODRIN

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Abstract—Elemental mercury is a well known occupational hazard which vaporizes slowly at room temperature permitting inhalation of toxic quantities. Not usually appreciated is the tendency of organic compounds containing radioactive mercury to release mercury vapor in amounts large enough to cause significant radioactive contamination of laboratory areas and to pose a possible radiation hazard to employees working in these areas. This is a particular hazard in medical radioisotope laboratories where chlormerodrin, ^{203}Hg, is used in large quantities for scanning of the brain and kidneys.

At room temperatures, release of mercury occurs continuously from commercial solutions of radioactive chlormerodrin prepared for human use. While the release rate is variable from bottle to bottle, we have found multi-injection bottles containing 5–15 mCi of chlormerodrin which release, even before the top has been punctured by a needle, 22.5 $\mu\mu$Ci ^{203}Hg/24 hr. Release was measured by placing a beaker of trichloracetic acid into a closed jar containing a vial of radioactive chlormerodrin. Release of mercury vapor could be increased by alkalinization. Vaporization was decreased by acidification and the addition of weak protein solutions to the bottle of chlormerodrin. Areas in which this compound are used or prepared show significant contamination with mercury not only in areas accessible to liquid spillage but also in exhaust ducts and on ceilings.

Because of its long half-time, progressive build-up of ^{203}Hg was found to occur in our radioisotope laboratory. This occurs particularly on containers used to store chlormerodrin bottles and in the storage hood. The high absorption of mercury into glassware sets the stage for later release of mercury from bottles during storage for radioactive decay. The methods we developed for controlling this hazard will be discussed.

In a recent discussion of the properties of ^{203}Hg labeled Chlormerodrin, it was suggested by one of us that the use of this compound might result in the contamination of radioisotope laboratories because of the ease with which elemental mercury and certain mercury compounds vaporize if exposed to the atmosphere.[1-3] We thought it might be advisable to determine whether ^{203}Hg Chlormerodrin would volatize and whether this could result in a radiation health hazard. This seemed particularly pertinent because of the long physical half-life of ^{203}Hg and because of the long biological half-lives of mercury compounds.

Our investigation showed that pharmaceutically prepared solutions of ^{203}Hg Chlormerodrin do volatize at room temperature. We believe this explains our finding radioactive mercury as a contaminant on the outside of bottles containing millicurie amounts of Chlormerodrin.

METHOD

In this study bottles of ^{203}Hg Chlormerodrin were used as soon as they were delivered. With the exception of one local company, these bottles were sent by air express, leaving the manufacturing plant about 18 hours before being tested. Chlormerodrin from various United States suppliers was used. Several of the studies were done using Chlormerodrin obtained from firm A because their bottles had the highest amount of contamination and because they were our primary supplier of Chlormerodrin at the time of these tests. In addition, the

Chlormerodrin bottles of firms B, C, D, and E were used. Hereafter, each company product will be referred to by these letters to indicate common origin of some of the samples.

Each Chlormerodrin stock bottle was removed from the outer cardboard protective container and was immediately placed in a 400-ml glass beaker which contained an open-topped glass vial into which 1 ml of 15% trichloracetic acid solution had been pipetted. The beaker was sealed with Parafilm M* and masking tape. The beaker remained at room temperature in subdued light or darkness. After 24 hr, 0.5 ml of the trichloracetic acid solution was removed and its gamma activity was determined in a scintillation well counter by its pulse height analyzer. Enough counts were accumulated to obtain a 5% average statistical counting error. ^{203}Hg was proved to be the only contaminant by the use of spectrum analysis with a 400-channel analyzer and by the estimation of the rate of decay. In the laboratory in which these studies were performed, ^{131}I is the only other radioisotope which is used in large enough quantities to make it a potential contaminant.

Another phase of the study consisted of testing the effect of pH on the release of ^{203}Hg from Chlormerodrin. One-millicurie amounts of ^{203}Hg Chlormerodrin (A) were injected into each of three 30-ml, multi-injection, rubber-stoppered vials (sodium chloride injection, U.S.P.—Cutter Labs., Berkeley, Calif.). The pH of the normal saline had been adjusted with NaOH and HCl to pH 2, 7, and 10. These bottles were placed in 400-ml beakers with vials of TCA solution in the manner already described. After 24 hr the gamma activity of the TCA solution was determined.

* Marathon Division, American Can Company, Neenah, Wisconsin.

RESULTS

Table 1 shows the mercury contamination found from the bottles obtained from the various suppliers of radioactive pharmaceuticals. Each determination represents a separate shipment. This table also contains the results obtained during a period between February and June 1966.

During that time, two of the suppliers learned of our study and we discussed the amounts of contamination with them. Evidently the contamination is difficult to remove since both suppliers continued to have mercury contamination on the outside of their bottles four months later. One supplier (B) furnished us a single shipment of ^{203}Hg Chlormerodrin which did not

Table 1.

Supplier	mCi in stock bottle	% trapped × 10^5
A	5.15	46.8
A	10.30	22.4
A	5.15	17.3
B	3.00	12.2
A	5.15	9.2
E	15.00	0.2
D	5.00	0.1
C	5.00	0.1
4 months later		
B	5.00	8.7
A	5.00	13.5
5 months later		
B	5.00	0.1

contain contamination. After questioning this supplier, we learned that these bottles had been washed with acid prior to shipment.

To determine if acid washing the bottles was a practical way to prevent this problem, one of two bottles which were received at the same time from a single manufacturer was washed with 0.1 N HCl. Both bottles had been shipped by air express in the same cardboard container. Bottle 1 was placed in a beaker as it was received from the manufacturer. Bottle 2 was immersed once in 0.1 N HCl and placed in a separate beaker. The trichloracetic acid placed in the beaker with bottle 1 contained 455 mμCi. The trichloracetic acid placed in the beaker with bottle 2 contained 5 mμCi of ^{203}Hg, and the wash water from the bottle contained 625 mμCi of ^{203}Hg. This was good evidence that most of the contamination existed on the outside of the bottle since these bottles had never been opened.

The results of the effect of pH on the release of ^{203}Hg from Chlormerodrin are shown in Table 2.

Table 2.

pH	% × 10^5
7	0.12
2	0.07
10	0.43

The highest amount of mercury was released at a pH of 10. Neohydrin is known to be soluble in alkali and stable at pH 10.[4] Therefore the released radioactive mercury is probably not Chlormerodrin but elemental mercury. The release of ^{203}Hg from these bottles would indicate that the release of mercury vapor is not prevented by the rubber stopper of the multi-injection vials used here.

DISCUSSION

It has been known since antiquity that mercury compounds vaporize producing industrial poisonings.[5] Both elemental mercury and mercuric chloride are known to vaporize slowly at room temperatures. Mercurous chloride, in the presence of light, will be converted to mercuric chloride and elemental mercury. Thus, all valence states of mercury are potentially volatile.[2] We have found no literature evidence that Chlormerodrin will volatize at room temperature. Radioactive neohydrin has been reported to be stable up to 60 days.[4] However, the study which reported this was not designed to detect the small amounts of volatilization found here. It has been our experience that alkali added to Chlormerodrin will at times produce a black precipitate characteristic of elemental mercury.[6] Commercial preparation of radioactive Chlormerodrin consists of refluxing mercuric acetate, sodium acetate, and allyurea in a methanol solution. The addition of sodium chloride causes the precipitation of the Chlormerodrin. An alternate route of production might be by an isotope exchange method. Both techniques are ordinarily followed by chromatography to produce a pure Chlormerodrin. It is likely that the manufacturing process eliminates free mercury from the final product. However, during each of these steps volatilization of the radioactive mercury is potentially possible. This might result in contamination of the equipment, bottles, etc. in the near vicinity.

The results of the study reported here suggest that solutions of Chlormerodrin release mercury vapors in small amounts. This was shown by the presence of mercury in the trichloracetic acid solution when it was placed in a beaker which also contained a rubber stoppered container in which a dilute solution of chlormerodrin had been placed. It would seem that the mercury vapor is capable of passing around the rubber stopper and into the air contained within the beaker. Volatilization during shipment with subsequent contamination of the bottle would explain the results obtained here. It is possible that the bottles were shipped by the manufacturer without contamination.

Thus it is not surprising that bottles containing radioactive Chlormerodrin are contaminated with mercury on the outside surface when they are received from the manufacturer. We have found some degree of contamination on the bottles of all suppliers tested. The degree of contamination is greater with some suppliers than with others which may relate to the volume of Chlormerodrin produced by each and to

differences in manufacturing techniques. The long half-life of ^{203}Hg makes it probable that manufacturers store the Chlormerodrin for periods prior to shipment. During this time cross contamination among bottles could occur.

Acid washing of the outside of these bottles seems to be an adequate method for removing most of this surface contamination. It does not prevent further volatilization of the mercury, however, and the results show that prolonged storage of Chlormerodrin would probably result in further release of radioactive mercury vapors.

The amounts of mercury contamination found in our tests are not very great and probably do not present a radiation health hazard by themselves. However, the long half-life of ^{203}Hg would allow gradually increasing levels to accumulate in the laboratory. The released mercury vapor is in constant equilibrium with the air breathed by the personnel allowing continuous inhalation of radioactive mercury. Even though large amounts of ^{203}Hg have been used in this laboratory over the past two years, no personnel have been found who have detectable amounts of ^{203}Hg in their urine or in the kidney area. Thus to date, this has not proven to be a radiation safety hazard to our personnel.

SUMMARY

1. Chlormerodrin manufactured with ^{203}Hg volatilizes in the concentrations used by pharmaceutical manufacturers.

2. This tendency to volatize causes contamination of the outside of containers even though these containers are sealed.

3. Acid washing of the bottles removes much of this contamination.

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