REUSABILITY STUDY WITH ORGANIC VAPOR AIR-PURIFYING RESPIRATOR CARTRIDGES

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ABSTRACT

The question often arises about the reusability of organic vapor adsorption beds, such as air-purifying respirator cartridges, after periods of storage without use (airflow). The extremes of practice are: 1) use once and discard or 2) reuse multiple times assuming the protection is still afforded. Our goal is to develop data and a model to provide guidance to decide when reuse is acceptable. We have studied the loss of protection of a commercial organic vapor cartridge after storage for varying periods of time. Three vapors (ethyl acetate, methylene chloride, and hexane) were individually loaded onto test cartridges using a breathing pump. Extents of loading, times of loading, and vapor concentrations were varied. After selected periods of storage the cartridges were again challenged with the same vapor concentration. The increases in concentration of a vapor in the effluent air (simulated breaths) from a cartridge immediately upon reuse depended on the storage period, the extent of loading during initial use, the volatility of the vapor, and the water vapor adsorbed, but not much on the vapor concentration.

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INTRODUCTION

The purpose of this two-year study is to develop data to define the conditions, if any, under which an industrial organic vapor air-purifying respirator cartridge or military gas mask canister can be reused. One of the organic vapor air-purifying respirator cartridges used at the Los Alamos National Laboratory, MSA GMC-H, was used in these first studies. In the absence of information on their reusability, the best practice has been to use such cartridges only once before disposing of them. However, does this mean only for one work shift? Or, does it mean for one work period between breaks? Or, can they be used for one workweek? Are there storage conditions that could extend the number of times a cartridge can be used?

Improved user protection and cost savings are the potential benefits from understanding the effects of usage breaks and storage conditions on the remaining OV cartridge or military canister service life. There is a tendency to reuse OV cartridges as a matter of convenience and cost savings. In industrial operations, such as paint shops, excessive reuse of cartridges may be a serious problem. As we generate appropriate data and disseminate it, whatever the conclusion, it will help in training and supervision and could reduce exposures to solvents and other organic vapors and gases. An obvious, though secondary, benefit of demonstrating the reusability of cartridges or canisters is cost savings. Fewer may need to be purchased, stored, distributed, and disposed of as waste.

The objectives of this work are: a) to develop experimental data on vapor migration within OV cartridges used at Los Alamos after single or multiple uses and storage at various conditions; and b) to prepare a mathematical model and computer program that will provide guidance as to the reusability of these and other cartridges and canisters at actual use and storage conditions (vapor, concentration, humidity, temperature, times, etc.

EXPERIMENTAL

We set up and calibrated an experimental apparatus for loading respirator cartridges with organic vapors and measuring vapor breakthrough before and after periods of storage. The cartridge study system was set up in a ventilation hood. A syringe pump was calibrated and used for generating vapors in flowing air for cartridge exposures. A breathing simulation pump generated cyclic airflow. We used a photoacoustic infrared analyzer to measure (at approximately one-minute intervals) the vapor concentrations exiting the test cartridges. The test system was automated for timed starts, stops, and analyses. Analyzer output was collected on a computer for further treatment. Cartridge storage was in sealed plastic bags at ambient temperatures and pressures.

The usual procedure was to seal a freshly opened, weighed respirator cartridge into the airflow manifold between the point of vapor generation and the analyzer. The breathing pump and syringe pump were preset to deliver the desired average volumes of air (25 L/min) and liquid, respectively, to give the desired vapor concentration (usually 1000 ppm). To begin an experiment the pumps and analyzer were started simultaneously. Any vapor breaking through the test cartridge was monitored with the analyzer for a simulated initial use period (0.5 – 2 hours). Then we removed the cartridge, reweighed it, and sealed it in a plastic bag for a selected time. After this storage period the cartridge was reinstalled in the test manifold and rechallenged with vapor at the same concentration. The vapor breakthrough was monitored to the point of cartridge saturation, where it reached a maximum. The final step was to again weigh the cartridge to determine the vapor saturation capacity at the test concentration.

RESULTS

Our first accomplishment was to demonstrate that there really is a problem with reusability of organic vapor respirator cartridges after a period of storage. Figure 1 shows an example of this effect with ethyl acetate. The continuous breakthrough curve is the vapor effluent from a GMC-H cartridge for a continuous challenge of 1000 ppm for six hours. The other curve has a "step" change, which corresponds to the effect of 63 hours (long weekend) of storage without airflow after two hours of initial simulated use (at 990 ppm). The first five measurements after the storage period averaged 200 ppm, as compared with an average of 2 ppm just before the end of the initial simulated use.

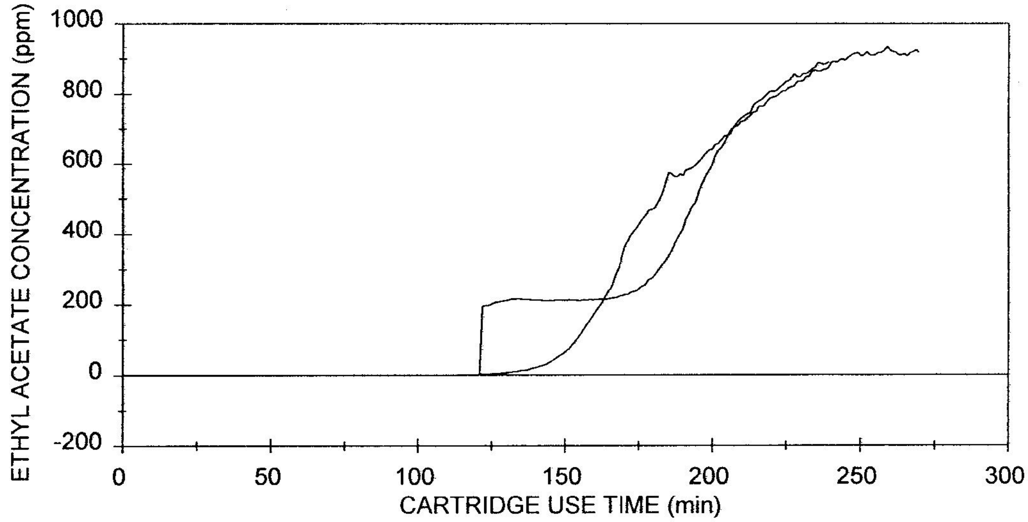

Figure 1. An example of the effect of storage on the concentration of vapor in the effluent with and without a storage period between uses. The challenges were about 1000-ppm ethyl acetate with a GMC-H cartridge. The storage time was 63 hours.

Ethyl acetate was the first vapor we used to study the effect of storage times and initial vapor loadings on reusability. Figure 2 shows averages of changes of vapor concentrations after various storage periods. The last five measurements before storage were averaged and subtracted from the average of the first five after storage to get each change. The initial simulated uses were for 2 hours at 990-1026 ppm (upper curve) or 1 hour at 1008-1077 ppm. After 4 hours of storage with the higher loadings (longer initial use) there was a rapid increase in concentration of vapors released. For the lower loadings significant changes in simulated exposure occurred after 16 hours of storage and rose much more slowly.

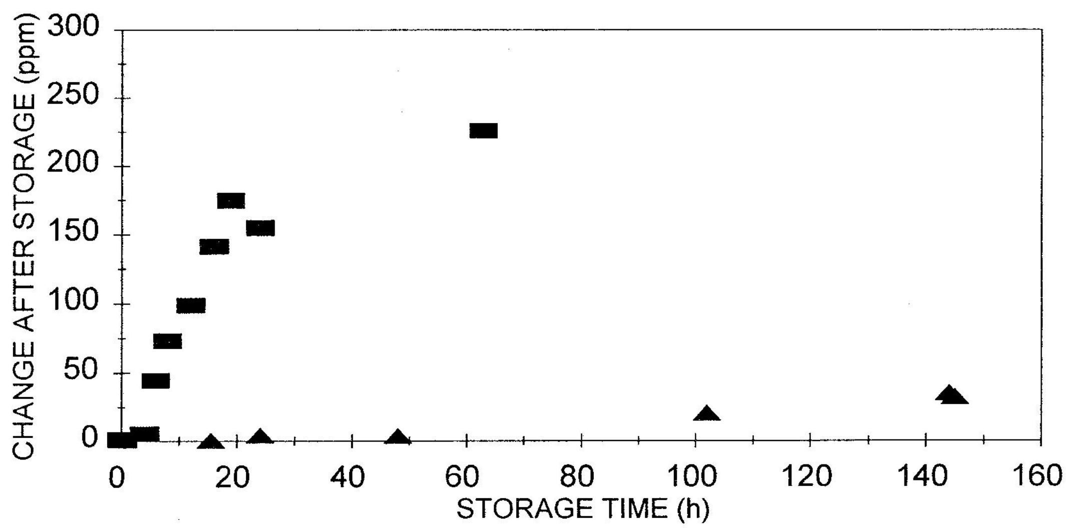

Figure 2. Ethyl acetate vapor. Effects of storage times and extents of loading on the changes in effluent vapor concentration. Squares = 2 hour challenges at about 1000 ppm before and after storage. Triangles = 1 hour challenges before storage.

Methylene chloride was the second vapor we studied. It has a molecular weight similar to ethyl acetate, but is more volatile. It is a commonly used solvent. The OSHA PEL was reduced from 500 ppm to 25 ppm on April 10, 1997, making the possibilities of excessive exposures on cartridge reuse more significant.

The effect of methylene chloride concentration during the initial use period was studied. Figure 3 shows two sets of experiments with about the same (30000 ppm-min) loadings, but at 1000 or 2000 ppm for 30 or 15 minutes, respectively. Challenge vapor concentrations after storage were kept the same as before storage. The first observation is that the initial loading concentration did not affect the concentration changes up to 72 hours storage. Beyond that, the differences in the changes can be attributed to different challenge concentrations during the simulated reuse period. Second, significant vapor changes upon reuse occurred after only 2 hours of storage. Experiments at twice these loadings (i.e., about 2000 ppm for 30 min) also showed rapid (1 hour), but higher storage changes (about 800 ppm at 24 hours).

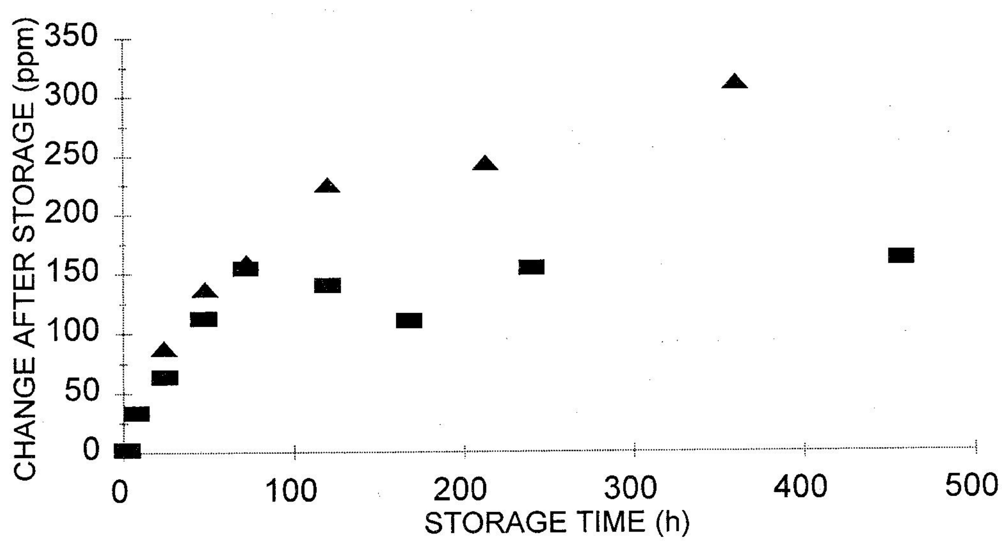

Figure 3. Methylene chloride vapor. Effects of storage times and challenge concentrations on the changes in effluent vapor concentration. Squares = 30-minute challenges at about 1000 ppm before and after storage. Triangles = 15-minute challenges at about 2000 ppm. Both initial loadings were about the same.

Hexane was the third vapor we studied. Figure 4 shows the results for 0.5- or 1-hour simulated initial use at about 1000 ppm. Storage times lasted up to 14 days. In these cases, no changes in effluent vapor concentrations were observed within 2 or 3 days, respectively.

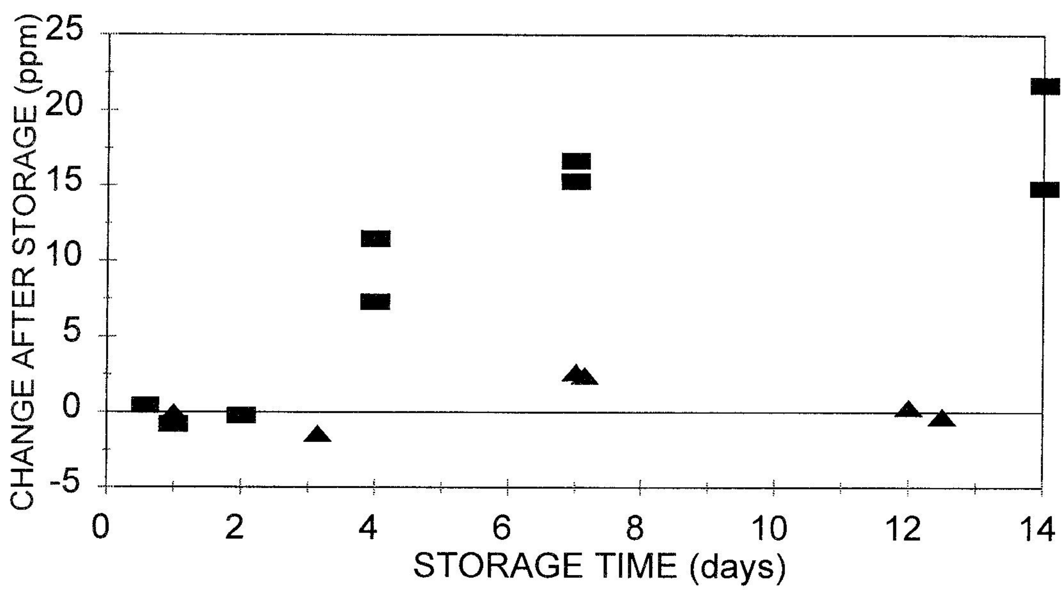

Figure 4. Hexane vapor. Effects of storage times and extents of loadings on the changes in effluent vapor concentration. Squares = 1-hour challenges at about 1000 ppm before and after storage. Triangles = 0.5-hour challenges at the same conditions.

We also did some preliminary studies of effects of water vapor pre-loading and concurrent loading in humid air situations. Two cartridges were preloaded with water by flowing humid (63 – 68 % relative humidity) air through them for one hour before introducing the hexane vapor at 1000 ppm for one hour. Two other cartridges were also run with 1000 ppm of hexane in humid (53 – 55 % relative humidity) air, but not preloaded. After 3 days of storage the vapor concentration changes upon simulated reuse averaged 32 ppm for the preloaded cartridges and 11 ppm for the fresh cartridges run in humid air. These compare with an interpolated value of 4 ppm for the same vapor concentration in dry air (Figure 4).

CONCLUSIONS

We have demonstrated increases in breathed vapor from simulated once-used cartridges upon reuse. This has been shown with three chemical vapors at a variety of conditions. After an initial period of storage the breathed vapor concentration changes increased with time of storage (Figures 2-4). The type of vapor and extent of loading, but not so much the loading concentration (Figure 3), affected the length of this initial period and the rate and extent of breathed vapor changes.

The vapor effluent changes upon storage were greatest for methylene chloride, the most volatile chemical, and least for hexane, the least volatile.

Water vapor co-adsorption (hexane vapor in humid air exposure) resulted in higher storage effects for 3 days of storage. Water vapor pre-adsorption (humid air exposure before and during hexane vapor challenge) resulted in even higher effects.

Qualitatively, the observed effects of loading during the initial cartridge use, storage time, vapor type, and water vapor are what we expected. However, what we now have are quantitative measurements of these effects for three different chemical vapors. With the data accumulated we can begin to model the adsorbed vapor migration. This will be the next phase of the study. Then we can begin to investigate these effects at other storage conditions that may mitigate them.

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