

Letters to the Editor

SOME FURTHER THOUGHTS ON Xe-133 ADSORPTION IN CHARCOAL TRAPS

A letter published in the December 1976 issue of the *Journal of Nuclear Medicine Technology* by Mr. G. Tempe of Radx Corporation contained some incorrect assumptions and information.

These errors are: (1) the type of charcoal used by various manufacturers; (2) the principle of entrapment; (3) an incorrect value for "minute respiratory volume"; (4) the need for "expandable interfaces" on gas traps; and (5) the regeneration and reuse of a charcoal charge.

The following notes should clarify these points and others of interest.

The use of charcoal media to *adsorb* inert radioactive gases has been in common use in the nuclear industry for many years. The adsorption principle is well related in the literature (the "BET" theory, Van der Wall's equation, and constants for gases).

Not all trap manufacturers use NACAR G210. Some use proprietary grades manufactured for them and typically these materials have a dynamic adsorption coefficient (K_d) of 1170–1230 cc/g for xenon. Since charcoal cannot differentiate between isotopes of xenon, it will *adsorb* all radioxenons with the same effectivity. Additionally, since the charcoal is key activated for inert gases, it will also adsorb *all* other inert gases in the effluent stream. Its adsorption capability varies inversely as the atomic weight of the noble gas; in effect, charcoal will adsorb less helium than xenon.

It is the inert gases in the effluent stream that "poison" the charcoal. This accounts for 70% of the "load" on the adsorptive media. There is some oxygen effect, but, owing to its high chemical activity relative to the noble gases, its presence is transitory.

Typically, minute respiratory volume for a standard man is 6 l/min, matching trap flow rates of 5–10 l/min. Mr. Tempe stated that, "people breathe at a rate of 15 liters per minute...." We feel this is incorrect, and that an expandable interface is not required if a throughput flow of 5–10 l/min is maintained by the trap.

A monitor on the output of a xenon trap, although good in principle, is an after-the-fact confirmation of a leak situation. When a trap cartridge saturates, be it a single or serial cartridge system, its effluent concentration of xenon (both radioactive and inert) increases drastically in a short period of time. Typically, empirical monitoring of output concentrations may go from $5 \times 10^{-6} \mu\text{Ci}/\text{cm}^3$ to $10\text{--}20 \mu\text{Ci}/\text{cm}^3$ in 2–3 min at a flow of 5–10 l/min. This "falling off the cliff" effect is common to any charcoal adsorbent upon saturation. A better, safer

method to monitor xenon gas trap exhaust effluent using the gamma camera in a department, is the following:

1. Remove the collimator from the camera.
2. With a 5% window calibrate for Xe-133.
3. Fill a large plastic bag with a known volume of air, typically 50 l.
4. Inject a known quantity of Xe-133 (such as $100 \mu\text{Ci}$) into the bag. Allow the xenon to mix with the air in the bag. The concentration will be $2 \times 10^{-3} \mu\text{Ci}/\text{cm}^3$.
5. Place the bag in front of the crystal and count for a known period of time. The c/m obtained is a standard measure of the efficiency of the camera for this concentration of Xe-133.
6. Collect the exhaust of a typical study in another bag of the same volume (50 l) and count as defined in Step 5.
7. Ratio the test count to the standard to determine exhaust concentration.

For example, if $2 \times 10^{-3} \mu\text{Ci}/\text{cm}^3$ yielded 600,000 c/m above background, and the collected effluent from the patient study was 150 c/m above background, then:

$$\text{Ratio} = \frac{1.5 \times 10^2 \text{ c/m}}{6 \times 10^5 \text{ c/m}} = 2.5 \times 10^{-4} = R;$$

$$\begin{aligned} \text{Exhaust concentration} &= R (2 \times 10^{-3} \mu\text{Ci}/\text{cm}^3) \\ &= (2.5 \times 10^{-4}) (2 \times 10^{-3}) \\ &\quad \mu\text{Ci}/\text{cm}^3 \\ &= 5 \times 10^{-7} \mu\text{Ci}/\text{cm}^3*. \end{aligned}$$

A regular check of trap performance in this manner will ascertain correct operation. If the exhaust concentration approaches $1 \times 10^{-5} \mu\text{Ci}/\text{cm}^3$, the trap cartridge or pack should be changed.

Our theoretical and empirical studies initiated in 1972 have shown that, since a charcoal trap is neutralized by the inert gases in the effluent air stream, reuse of that pack is negated, because the system is saturated. The radioactive xenon in the delivered gas charge comprises only 0.1–0.2% of the total and its decay will not "regenerate" a cartridge or pack.

Reclamation of the charcoal can be affected by heating to 410–430°F in a laminar flow oven and passing dry nitrogen over the charcoal charge to prevent recombination of released gases. Unfortunately, this technique far exceeds the cost of a replacement charcoal charge.

*MPC Xe-133, controlled area: $1 \times 10^{-5} \mu\text{Ci}/\text{cm}^3$, according to 10 Code of Federal Regulations 20 Table 2, Appendix B.

It is also worthy to note that any radioactive noble gas may be adsorbed on media of this type. As other noble gases find use in nuclear medicine studies, an activated charcoal gas trap will serve to contain their release.

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A REPLY

I appreciate Mr. Panetta's interest in my letter on xenon traps and must apologize for one error in the letter, that is, the use of the word "absorb" instead of "adsorb." Being a chemist by education, this is an unforgivable error but I must confess that I never could get it right, even in college. *Webster's New Collegiate Dictionary* also led me astray since it gives "charcoal-gas" as an example of absorption.

With regard to the other errors he alludes to, I must take exception and suggest that he reread my letter more carefully because some of the "errors" attributed to me were neither stated nor implied. In order to clarify the situation, I will discuss them in the order in which he presents them.

The type of charcoal used by various manufacturers. My letter does not state that all manufacturers use type G210. It very clearly says, "the activated charcoal used in most units is type G210..." Further, his statement concerning proprietary grades manufactured for them is misleading. Nuclear Associates has used the following types of charcoal in their traps (in chronological sequence); G210 from North American Carbon; AK from Barnebey Cheney; 727 from Barnebey Cheney; and 617 from North American Carbon.

None is a proprietary product and all are available commercially from the companies indicated. It is commendable that they use a charcoal with a K_d of approximately 1200 cc/g, although without giving the rest of the specification, this number has little significance. Assuming that the K_d was determined at the same temperature, concentration, and velocity as G210, their charcoal would adsorb 1.35 billion Ci/kg as opposed to 856 million Ci/kg for G210 of Xe-133. Since we both use multiple kg cartridge packs, both numbers are ridiculous and that was part of the purpose in writing my letter—to demonstrate that Xe-133 adsorption capacity has little or no bearing on the life of the trap. It is impossible to saturate either trap with Xe-133; however, it is inevitable that all traps will saturate so that they can no longer adsorb Xe-133.

The principle of entrapment. My letter does not disagree with Mr. Panetta's on the principle of entrapment. I clearly state "It is important to note that

this activated charcoal will not only adsorb radioactive xenon, but also a tremendous amount of airborne contaminants." Further, "It has no capacity to selectively adsorb xenon in the presence of contaminants..." In this sense, other inert gases would be considered contaminants since the sole purpose of the xenon trap we both supply is to adsorb radioactive xenon.

I must take exception with his statement that other inert gases "poison" the charcoal. Even the novice environmentalist will tell you that the amount of air pollution (hydrocarbons from auto emissions, etc.) far exceeds in g/l the amount of inert gases in the atmosphere. Charcoal traps will be "poisoned" by these pollutants and moisture long before they saturate with inert gases.

An incorrect value for "minute respiratory volume" (MRV) and the need for "expandable interfaces" on gas traps. Classic pulmonary function textbooks list normal minute respiratory volume as approximately 5.9–7.8 l (1); however, these normal values were determined on water spirometers which were in common usage at the time the textbooks were written. A water spirometer for measuring tidal volumes (TV) has the same effect as measuring cardiac output with a highly dampened rate meter. Modern-day spirometers have demonstrated minute respiratory volumes closer to 9 l (2). It should be stressed that all of these normal values are determined at rest. Normal walking can increase this to over 12 l/min.

There are several other aspects that require consideration. The classic textbooks on lung function state that the MRV increases with age, size, and also during illness. During respiratory illness, MRV can exceed 20–25 l/min (3). Since many of the patients subject to this procedure have respiratory illness, what happens to the additional 15–20 l/min if an expandable interface is not used? A third consideration is the momentary volume differences between the patient and the trap. A normal expiration takes approximately 2 sec, and at a TV of 0.5 l the expiration rate is 0.25 l/sec. A pump moving air through a trap at 5 l/min (the specification on the Nuclear Associates Nonex Trap) is moving it at a rate of 0.08 l/sec. Thus, for 2-sec intervals the patient is attempting to put three times as much air through the trap as the trap is capable of receiving. Resistance would rise appreciably unless an expandable interface is used. That Mr. Panetta has overlooked sick people and momentary volume differences is quite significant.

I do apologize for the statement "People normally breathe at a rate of 15 l/min..." It is in error; however, it would be safe to say that people undergoing a lung ventilation study with suspected disease breathe at a rate in excess of 15 l/min, on the average, and that therefore an expandable interface is required. Mr. Panetta's statement that no expandable interface is required indicates a lack of understanding of what lung ventilation is all about.

The regeneration and reuse of a charcoal charge. I do agree, at least in part, with Mr. Panetta on the reuse of charcoal packs and this was clearly stated in my article.