

RADIOCHEMICAL PURITY OF ^{99m}Tc -PERTECHNETATE

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The radiochemical purity of ^{99m}Tc -pertechnetate obtained from an automated methyl-ethyl-ketone extraction system is compared with that obtained from a commercial generator. The parent ^{99}Mo used in both systems was produced by neutron irradiation of ^{98}Mo . The principle contamination in the product from the extraction system is shown to be ^{186}Re . A study of the amount of ^{186}Re in successive extractions shows that whereas submicrocurie amounts are present in the initial extraction, the amount of contamination drops rapidly to zero after the third extraction. In a similar study of the commercial generator, the principle contaminant is shown to be ^{134}Cs . The amount of this ^{134}Cs contamination is shown to increase with each elution of the generator.

The increasing use of ^{99m}Tc in a wide variety of "kit" or on-site prepared radiopharmaceuticals has led to a very large demand for this isotope. In response to this demand, an increasing number of facilities are turning to liquid-liquid extraction systems which may be designed to meet the production capacity needed. In other institutes, the ^{99m}Tc production capacity of the larger commercially available generators is extended as far as possible by routinely eluting twice and sometimes three times a day in the latter part of the week. Thus it is necessary not only to know what the contaminants are but also the amount of radioactive contamination as a function of repeated elutions or extractions.

A number of publications (1,2) have pointed out that the pertechnetate obtained by liquid-liquid extraction from the parent isotope, ^{99}Mo , has a significantly lower amount of chemical contamination than the eluants of most of the commercially available ^{99}Mo - ^{99m}Tc generators. The only radioactive impurity other than ^{99}Mo which has been reported to be present in the pertechnetate obtained from liquid-liquid extractions is ^{124}Sb (1). The authors

(1) make no direct comment with respect to the amount of contamination in successive extractions although the spectra shown indicated that less ^{124}Sb was present in the terminal than in the initial extraction.

There have been a number of reports in the literature concerned with the radioactive impurities of generator-produced ^{99m}Tc (3-6). From these reports it is clear that one or more of the isotopes ^{134}Cs , ^{86}Rb , ^{60}Co , ^{95}Zr , and ^{124}Sb may be observed in the eluant of any specific generator prepared with ^{99}Mo obtained by neutron activation of ^{98}Mo whereas the eluant from fission-produced ^{99}Mo generators has been shown to contain ^{131}I and ^{103}Ru (6). The only one of these reports which attempts to relate the amount of radioactive contaminant present to the number of times the generator has been eluted is that of Wood and Bowen (3) who showed that the amount of ^{95}Zr and ^{124}Sb obtained per elution decreased with each elution. Each report of the contaminants from neutron activation produced ^{99}Mo - ^{99m}Tc generators has reported the presence of ^{134}Cs with the exception of Wood and Bowen (3) who later in reply to Barrall (5) confirmed that they had also observed this isotope. Yet to date there has been no information published relating to the amount of ^{134}Cs observed with the number of times the generator has been eluted.

This paper reports contamination versus elution data for both a liquid-liquid extraction system and a commercial neutron activation produced ^{99}Mo - ^{99m}Tc generator.

EQUIPMENT

The various ^{99m}Tc samples were examined 2-3 weeks after production using a coaxial Ge(Li) detector coupled to a 512-channel analyzer. From the

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spectra obtained it was possible to determine the energies of the gamma rays originating from the radioactive nuclides in these samples.

RESULTS

Pertechnetate obtained by the liquid-liquid extraction. The ^{99m}Tc -pertechnetate obtained from our automated methyl-ethyl-ketone extraction system has been shown to contain no detectable traces of ^{99}Mo , aluminum, or methyl-ethyl-ketone. The spectrum obtained with the Ge(Li) detector showed that there were no gamma rays with energies above 140 keV. Gamma-ray peaks were observed at approximately 63, 123, and 140 keV. A consideration of the initial radioactivity of the sample and the time allowed for the ^{99m}Tc to decay immediately suggested that the approximate 140-keV peak was not solely due to the ^{99m}Tc . The absence of any gamma rays which could be assigned to ^{99}Mo ruled out the possibility of regeneration of ^{99m}Tc from its parent. A literature search showed that ^{186}Re had been reported to be present in some "instant" ^{99m}Tc (7). Rhenium-186 has gamma rays with energies of 137 and 123 keV as well as an x-ray with an energy of 63 keV from the daughter ^{86}Os (7). The fact that the 63, 123, and 137-keV energies and their relative properties fitted extremely well with those observed in our samples suggested that all the observed gamma rays could be assigned to ^{186}Re .

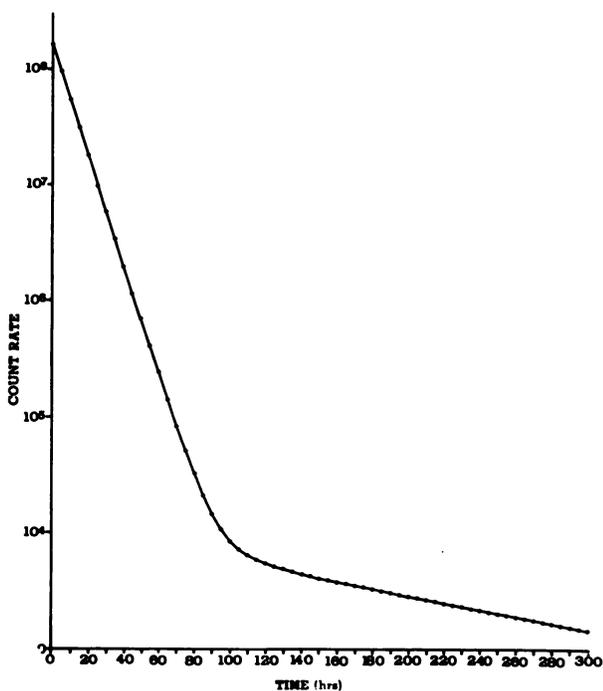


FIG. 1. Decay curve of ^{99m}Tc sample obtained from methyl-ethyl-ketone extraction system.

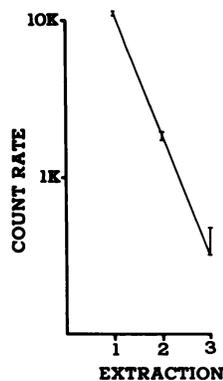


FIG. 2. Amount of ^{186}Re in successive methyl-ethyl-ketone extractions. Error bars show standard deviation of each assay.

To confirm the presence of ^{186}Re , a half-life study of the gamma ray at approximately 140 keV was undertaken. The 512-channel analyzer was set up in the scaler mode for serial counts with this peak in the center of a 20-keV window. The decay curve obtained is shown in Fig. 1. This curve clearly demonstrates the half-lives of the two isotopes contributing to this combined peak. The 6-hr half-life of the ^{99m}Tc is clearly observed in the early section while the final section indicates a half-life of approximately 91 hr. It is interesting to note that in the central portion where the semilog plot is curved an addition of the theoretical counts from the ^{99m}Tc and from the ^{186}Re obtained by projection of their linear decay lines accounts for the total observed counting rate. This emphasizes the complete absence of ^{99}Mo in the product obtained from the system.

Having shown that the only detectable contaminant in the pertechnetate obtained from this automated liquid-liquid extraction system was ^{186}Re , we then proceeded to study the level of contamination in successive extractions. The extraction system is emptied and reloaded each Monday. For several weeks the daily extractions were stored for 2 weeks before being counted on the Ge(Li) detector, then for several weeks twice daily extractions were performed and analyzed in the same manner. Each week the pattern observed was the same, the first extraction showed a small amount of ^{186}Re whereas the second showed a much smaller amount, and the third was barely detectible. When corrections were made for variations in the amount of ^{99}Mo loaded into the system, the observed ^{186}Re counting rates in corresponding extractions were within one standard deviation of each other. Figure 2 shows the observed decrease in ^{186}Re radioactivity as a function of the number of extractions. From the photon yields of ^{99m}Tc and ^{186}Re , and the counting rate observed on a 1- μCi sample of ^{99m}Tc , the initial ^{186}Re yield was

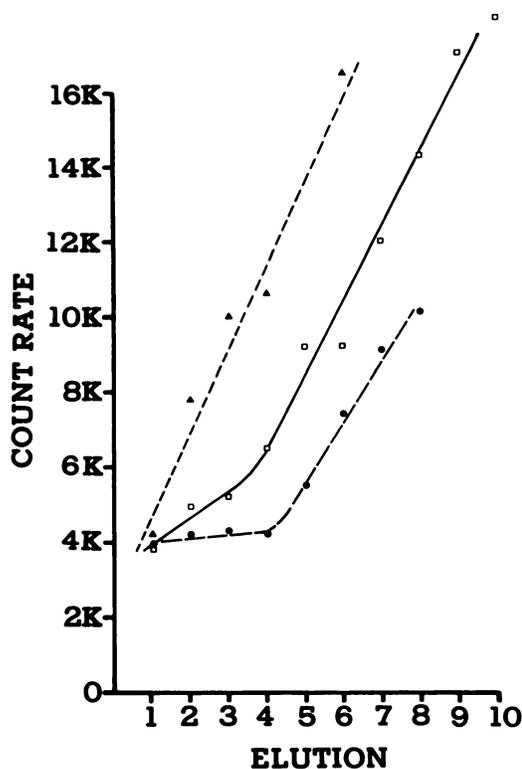


FIG. 3. ^{134}Cs contamination of three commercial generators as function of successive elutions. Δ generator eluted once a day for 1 week. \square generator eluted once a day for 2 weeks. \bullet generator eluted twice a day for 1 week.

estimated at $0.003 \mu\text{Ci}/\text{mCi}$ of $^{99\text{m}}\text{Tc}$. This is in good agreement with General Electric Company's radiopurity analysis of $0.0035 \mu\text{Ci } ^{186}\text{Re}/\text{mCi } ^{99}\text{Mo}$ (8).

Neutron-activation-produced ^{99}Mo - $^{99\text{m}}\text{Tc}$ generator eluant. Four-hundred-millicurie generators are obtained on a basis of two per week from a commercial supplier. Each of these over the past 4 months has been subjected to an "after the fact" examination for trace contamination with long-lived gamma emitters. One week after the initial delivery, the generator was eluted for a final time and the eluant set aside for a further week to allow the $^{99\text{m}}\text{Tc}$ to decay. The gamma-ray spectrum was then obtained with a Ge(Li) detector. With every generator so studied, we have found that the principle contamination is ^{134}Cs . Four incidents of other long-lived radioactive contaminants were observed. One week the eluants of both generators were observed to contain some ^{60}Co , while on another week a small quantity of ^{124}Sb was observed in the eluants of both generators. However, both the ^{60}Co and the ^{124}Sb were of less significance than the ^{134}Cs in the same samples. Throughout the study the level of contamination observed in the two generators obtained on the same week has been comparable although the amount of

contamination from week to week has varied by a factor of approximately ten; that is to say that the final eluant contained between approximately 0.1 and $0.01 \mu\text{Ci}$ of ^{134}Cs . In all cases, these final elutions were the sixth time the generators had been eluted after delivery. To obtain data on the amount of ^{134}Cs contamination as a function of a number of elutions, 2 ml of each elution from one of the cows was set aside and allowed to decay. In the collection of these samples three different elution patterns were used on different generators; one generator was eluted once a day for 1 week, a second generator was eluted twice a day for 1 week, and a third was eluted once a day for 2 weeks. The samples were all counted 3 weeks after the generator was delivered. The results are shown in Fig. 3. These results clearly show that the amount of ^{134}Cs obtained per elution increases with each elution. It appears that in some cases the initial rate of increase is slow. After this initial period the rate of increase is approximately 2,000 counts/hr in the 605-keV peak per elution or correspondingly $0.01 \mu\text{Ci}$ per elution.

DISCUSSION

These results show that the liquid-liquid extraction system gives $^{99\text{m}}\text{Tc}$ -pertechnetate with very little radioactive contamination. The principal radioactive contaminant, ^{186}Re , is present in very low concentration in the initial extraction but disappears completely after the third extraction. On the other hand, although the ^{134}Cs contamination which is observed in the eluant of the commercially available ^{99}Mo - $^{99\text{m}}\text{Tc}$ generators is initially very low, it shows an increase with each elution. Thus, as the $^{99\text{m}}\text{Tc}$ assay decreased, the ^{134}Cs assay would be increasing, and conceivably a patient late in the week could receive a significant dose of ^{134}Cs . However, the maximum permissible total-body burden of $20 \mu\text{Ci}$ of ^{134}Cs (9) appears to be well outside that which could be conceivably administered even with several repeat scans. However, it must be realized that not all generators may show as little leakage as those we have examined. In fact, the variation shown by those examined here suggests that there may be considerable variability and that routine checks should be made on all commercial generators. Fortunately, this may be easily included in routine ^{99}Mo breakthrough tests as long as the technique used for the ^{99}Mo breakthrough does not incorporate an upper level cutoff. Normally ^{99}Mo breakthrough tests use the high-energy gamma rays emitted by the molybdenum, primarily those at 740 and 778 keV which have photon efficiencies of 12 and 4%, respectively. Cesium-134 has gamma rays with energies of 605 and 796 keV which have photon efficiencies of 98 and 99%, re-

spectively. Thus, as long as there is no upper level cutoff set, at least the 796-keV gamma will show up in the ^{99}Mo breakthrough test. From the photon efficiencies this test would be expected to be more sensitive to the presence of ^{134}Cs than to ^{99}Mo . However, the much larger half-life of ^{134}Cs would suggest a lower allowable contamination level than for ^{99}Mo .

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