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STATUS OF PRODUCT MONITORING BY HEALTH-PHYSICS SECTION

by - H. M. Parker
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STATUS OF PRODUCT MONITORING BY THE HEALTH PHYSICS SECTION

By - H. M. Parker

Introduction

A program of health monitoring instruments for product activity was not scheduled before the start of operations at Clinton Laboratories. The Instrumentation has developed largely without consultation with the Health Physics section. The Pluto detector for surface contamination and the Sneezy apparatus, which was planned to give a warning of gross atmospheric activity, have been developed by the Instrument section of the Physics Division of the Metallurgical Laboratory. Both instruments fill an important need in the program.

Special alpha counting equipment of high quality has been designed by S. G. English and collaborators at Clinton Laboratories. These developments, some of which are still in the experimental stage, have been followed with interest by the Health-Physics Section. This Section has studied the technique of measurement of alpha activity in the air by precipitron measurements, and has formed the opinion that this is a convenient, sensitive, and sufficiently quantitative method for routine use. The Section has also experimented with techniques of drawing air through large ion chambers in which beta and gamma activity have been balanced out and also with the possibilities of zinc sulphide screens and the scintillation method. Neither of these investigations was particularly fruitful.

Tolerance Levels

The hazard arising from the deposition of product in the bones can be estimated by analogy with the case of radium poisoning. One microgram of radium fixed in the bone is a long-range lethal dose. As approximately one-half of the radon formed by disintegration of the radium escapes rapidly from the bone, the available alpha ray energy in the bone per disintegration of radium is about 16 Mev. The energy per disintegration of product is approximately 5 Mev. In round numbers, 16 micrograms of product will give the same number of disintegrations as one microgram of radium, and one deduces that approximately 50 micrograms of product fixed in the bone will be a lethal dose. One-tenth of this amount can reasonably be considered to be a tolerance level and the resulting figure of 5 micrograms of product fixed in bone is becoming rather widely accepted. (See appendix)

The amount that can be ingested without risk is much greater than this on account of the fortunately low transfer from the gut to the blood supply and hence to the bone. More or less direct transfer to the blood system through an open wound is a cause for more worry.

The hazard of inhalation of product is perhaps the greatest problem in product monitoring. If product settling on the linings of the lungs remains there permanently then it can be shown that 0.64 micrograms of product in the lungs will produce the alleged tolerance dose of 0.01 rep per day. Since the activity is here built up steadily day by day, it is felt that one could work for two years in a concentration such that the lung deposition at the end of the first year produced a nominal tolerance dose. On this assumption, the permissible tolerance concentration of product in air is 5×10^{-10} micrograms per cc. (CH 1433)

The contrary view that all product is transferred from the lung linings to the bone has been used elsewhere for the basis of a supposed tolerance dose. This limits the permissible intake of product to 5 micrograms, and with a permissible period of 2 years the tolerance concentration in the air is 2×10^{-9} curie per cc. It is quite remarkable that the figures agree to within a factor of four on the basis of such opposing theorem. In this laboratory the more conservative figure has been accepted as the tolerance concentration. If 50% of the deposited material in lung were absorbed, the tolerable intake would be doubled, as there is no connection between the postulated causes of damage in the lung itself and in the bone.

Tolerance concentration of product on the hands is a problem that this writer is incompetent to solve. There is good evidence that all parts of the body are covered by a thin horny layer, the so-called "layer of passive absorption" which should act as a convenient filter for the protection of structures beneath it. This layer is at least 0.1 mm thick and on the hands it is many times thicker. Therefore, there should be zero penetration from alpha particles to significant structures. There would then be no radiation hazard per se in having the alpha activity on the hands. The writer has some reservations about the validity of this proposition. Early writers (Lacassagne - J. de Radiologie - Vol. IX, No. 2, Feb. 1929, p. 73), in the field have mentioned the alleged caustic effects of alpha particle radiation on the hands. If the concentration is large enough, one can almost literally burn off the horny layer. In general, however, one would feel that the risk of hand contamination is two fold (1) if a cut or abrasion occurs, product may enter the tissue and be carried eventually to bone, (2) the contamination may be transferred either to the intestinal tract or through the nose. No tolerance limit for hand contamination has been set to date, but as a working policy, one attempts to remove contamination whenever it is detected by the most sensitive instrument currently available. The tolerance concentration on laboratory benches and floors falls into the same category. There is the additional risk of scuffing up some of the activity to form a dust hazard in the air. Again if the benches or floors have been found demonstrably contaminated, as much as possible has been removed by wet mopping, followed in convenient cases by lacquering or varnishing of the surface.

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Monitoring of Contaminated Surfaces

The Pluto instrument which has been adequately described elsewhere is the most convenient tool for the rapid testing for contamination on approximately flat surfaces whenever extreme sensitivity is not required. Pluto samples an area of approximately 80 cm^2 and since the time constant of the circuit is rather low it is possible to pass the meter fairly quickly over the surface to be tested. Pluto gives a half-scale reading in the presence of 0.1 microgram of product and will give some indication of the presence of as little as 0.02 micrograms. The behavior of Pluto at Clinton on many occasions has been found to be erratic, but provided the readings are assessed in a qualitative rather than quantitative sense the instrument will fill its function.

A sawn-off Lauritsen electroscope with a screen window is about 10 times more sensitive than Pluto (CH 1470). 0.01 micrograms gives a rate of deflection of approximately 50 divisions per 100 seconds. The Lauritsen electroscope used had a sampling window of 20 square centimeters in area, which is inconvenient for the sampling of a large surface. It has been used at infrequent intervals for the testing of surfaces that give no significant indications on Pluto. A redesign of ion chamber with a surface area of about 100 square centimeters and with an optical projection system instead of the microscope on the Lauritsen electroscope would have considerable value for sensitive monitoring.

An alpha particle counting chamber with a screen window is to be preferred for sensitivity and ease of operation. Such a chamber is approximately one hundred times more sensitive than Pluto. However, in the designs to date there has been considerable trouble due to microphonic effects. Recently S. G. English's section has designed a unit in which the counting area is divided up into cylindrical elements in such a way that the microphonic disturbance has been reduced to acceptable levels. This equipment has not yet been tested for a sufficient length of time, but it seems to present the best solution for the monitoring of flat surfaces and also for hand counting which is the same problem.

No convenient direct test for activity on curved surfaces or in other locations inaccessible to Pluto or the Lauritsen electroscope is at present available. Monitoring of such parts is done by a smear test, in which a piece of paper is wiped over the area to be tested and inserted in a regular alpha counting chamber. Interpretation of the results is qualitative.

The activity on hands has been estimated either by exposure to Pluto or to the Lauritsen electroscope. A more sensitive test of at least the finger tips can be made by inserting them in the regular alpha counting chamber.

A test has been made of the efficiency of zinc sulphide screens for the rapid testing of bent surfaces for coveralls and gloves. The method is as sensitive as any other method, but requires careful adaptation to darkness and as a working procedure this method has been discarded. For good observation of scintillations the incidence side of the screen has to be observed, and this brings in inconvenient optical arrangements.

Monitoring of Product in the Air

1. Sneezy

The principle of the Sneezy apparatus is that air is pulled through a special filter paper, the surface of which is continuously exposed to an ion chamber connected to an amplifier circuit. When the ion current exceeds a predetermined value an alarm system is energized. In this manner, exposure to concentrations in the air of quite high degrees relative to tolerance concentrations for a considerable period of time could be avoided. Only one model of Sneezy has been available at Clinton and the electronic circuit of this model has never operated. Practical experience has, therefore, not been obtainable. The suction part of the Sneezy apparatus has been used to collect samples which can be measured in an alpha-counter chamber. The number of counts available in a given collection time is lower than that obtained by precipitron methods, due to the decreased rate of flow through the filter paper.

2. Precipitron Measurements

The precipitrons used here were modified from the industrial MSA Cottrell precipitator by increasing the air flow from 3 cu. ft. per minute to 11½ cu. ft. per minute. This was done primarily in order to obtain high counting rates with short exposure times to investigate the nature of the short-life active deposits found in the samples. For routine measurements in the laboratory, it is sufficient to use the industrial precipitator with the collection rate of 3 cu. ft. per minute and a sampling time of approximately 30 minutes. Measurements of precipitator efficiency have not been made frequently enough to justify authentic statements, but the work done indicates that at the flow of 3 cu. ft. per minute the collection is virtually complete, that at 6 cu. ft. per minute the collection is 83%, and that at the top speed of 11½ cu. ft. per minute, the collection efficiency is approximately 70%. There is some reason to believe that the collection efficiency may vary but certainly not by a factor as large as 2. Measurements of the concentration of radon and thoron in the atmosphere have been given in CH-1619 and CH-1649 and these have been amplified by some unpublished values. At the present time, the measurements

of radon concentration range between 10^{-17} curie per cc and 5×10^{-16} curie per cc. The accepted values by standard methods range between 2×10^{-17} curie per cc. and 10^{-15} curie per cc. The same range is covered with a factor of 2 difference. The measurement of short-life activity as in this active deposit is less accurate than in that of a long-life product. Quantitative results with product should, therefore, not be wrong by a factor of 12.

The sample is obtained by precipitations on the aluminum foil liner in the metal collecting tube of the precipitron. The foil is a cylinder of $1\frac{1}{2}$ in. in diameter and 7 in. long. At the end of the collecting time (30 minutes is the standard time) the foil is transferred to a special alpha-counting chamber which gives an estimated 45% geometry. Normally, the initial count falls with an effective period of 35 to 40 minutes, due to parent-daughter relations in the radium A, radium B, and radium C series with modifications produced by the collection of thorium active deposits and possibly product or uranium dust. If the initial count were large and did not fall it would be an indication of high product contamination. No such count has yet been obtained at Clinton Laboratories. The counting procedure used is to make an initial count as soon as collection is stopped and to observe the decay after about 20 minutes, to check that the initial activity is largely due to active deposit of short-life. The sample is then left for 6 hours at the end of which time the radium active deposit will have disappeared. A count of C_1 counts per minute is obtained at this time. The sample is counted again T hours later, where T is approximately 24, giving C_2 counts per minute. The number of counts per minute due to product activity or to other long-lived alpha activity is then

$$A = \frac{C_2 - C_1 \; e^{-0.0855\,T}}{1 - e^{-0.0855\,T}}$$

This formula takes care of the correction for the thorium active deposit of half-life 10.6 hour.

At an air flow of 11.5 cfm per with exposure time t min., the product concentration is

$$M = 4.4 \times 10^{-16} \times A/t \text{ c-dis/cc}$$

$$\text{or } 7 \times 10^{-11} \times A/t \; \mu\mu\text{g/cc}$$

A count of A = 0.5 min is measurable. In a collection time of t = 30 min., a concentration of about 10^{-12} $\mu\mu$g/cc can be measured. For record purposes, a precipitron run continuously over an 8 hour period would give results down to

approximately 10^{-13} μg/cc.

Appendix

After this report was written, private communication with Dr. J. G. Hamilton indicated that the 5 microgram figure was considered to be unreasonably conservative in some quarters. It has to be strongly emphasized that the figure refers to the amount fixed in bone, not the initial amount that may be present. Both in radium poisoning and product poisoning, the initial amount is higher. The rate at which Ra is eliminated from the bone is rather well known. The figure for product is at best an estimate from short-term animal experimentation.

Until more is known about this elimination, it is proper to assume that the picture for Ra and product will be approximately the same. In this case, the final fixed amount will be the determining factor. So far as this writer knows, it is not known whether the damage due to radium poisoning is initiated mainly in the early stages after the deposition in the bone or is due to the prolonged insult to the bone-marrow extending over a period of several years. The more nearly the caut lies to the second factor, the better will the translation from Ra to product be made.

The distribution of deposited active material throughout the cross section of bone may be different in the two cases. This could alter the tolerable amount.

Apart from these two points, there is agreement on the estimation of product hazard, to whit that 50 μg product is equivalent to 1 μg of Ra so far as energy from disintegration is concerned. Differences then hinge on (1) interpretation of the radium data (2) safety factor required.

Results of R. D. Evans indicate that 1 to 2 μg of Ra have eventually produced lethal damage in some observed cases. It is irrevelant that other cases have been known to continue in good health with amounts of perhaps 5 - 10 μg. It would be hazardous, in the opinion of this writer, to ignore Evan's figure unless a specific error in calculation or interpretation can be demonstrated.

The question of a safety factor is less clear cut. The history and literature of tolerance dose indicate in a general way that it has been planned at all times to have a safety factor of the order of 10 in the published tolerance dose. It has then been common experience to find that the hazard has been under-estimated. Thus, for the external tolerance dose of 100 mr per day, there is certainly not a safety factor of 10. Nevertheless, the present uncertainties in the product hazard, which is evaluated entirely by analogy with radium call for a factor of 10. The contrary view would be that the limiting amount of radium in the skeleton is so well known that there is no need for an additional safety factor. On this basis, the tolerable amount of radium would be just under 1 μg and therefore that of product would be as high as 25 to just under 50 μg.

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Experimental [illegible] measuring the amount of product in the body will be limited to quantities of the order of 3 to 5 μg or more. If this proved to be a very safe figure, protection against product hazard would be simplified

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