MONITORING OF RADIATION WORKERS HANDLING RADIOLUMINOUS PAINTS

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1. Introduction

Radioluminous paint is being consumed by various agencies such as watch manufacturing, telephone and defence. These paints are activated either with tritium (H-3) or promethium-147. The watch industries consume about 37 TBq of H-3 activated paint and the others use 2TBq of Pm-147 activated paint yearly. Earlier, Ra226 was in use as a luminous paint but by the end of 1969, the use of this paint was abandoned completely and H-3 and Pm-147 activated paints were introduced. This has resulted in a significant reduction in external exposure to workers. Because H-3 and Pm-147 are pure beta emitters, the assessment of internal exposure in workers poses many problems. Considerable data are available on the behaviour of H-3 inside the human system, using which it is possible to estimate the H-3 burden from bioassay results. However the Pm-147 burden is difficult to determine as the metabolic behaviour of Pm-147 activated paint is not fully understood. The published literature by Palmer(1), Arndt(2), Shipler(3) and others indicate that the inhaled activity is slowly taken by the liver and finally deposited in bone and this distribution takes years for completion. Therefore, in case of Pm-147, determination of organ activity provides additional information over the bioassay and both these results can be taken into account while determining the internal contamination in a radiation worker. Fourteen radiation workers have been monitored for Pm-147 in their livers and lungs. Bioassay was also carried out for all of these workers. Ten workers were monitored for H-3 burden by urinalysis.

2. Equipment and methods

In order to count the Pm-147 in-vivo, an attempt was made to determine the external bremsstrahlung (EB) coming out. For this purpose a phoswich detector consisting of a NaI (Tl) crystal (20 cm dia x 0.3 cm thick) backed and optically coupled to a CsI (Tl) crystal (20 cm dia x 12.7 cm thick), mounted in a 20 cm thick steel room and operating with the pulse shape discrimination technique was employed(4).

An EB spectrum includes all energies from zero to the maximum beta ray energy of Pm-147 and the percentage yield of low energy photons in 12-75 keV energy is comparatively higher than the high energy component. The counting system was calibrated in the 12-75 keV region and a minimum detectable activity of 1.11 KBq was found in liver for 40 mins counting time (fig.1). The radiation workers were counted with the system for organ activity. Simultaneously the fecal as well as urine activity of these workers were also determined. Radiation workers handling tritium activated paint were monitored on a fortnightly interval by urinalysis.

3. Results and discussion

Three workers showed significant Pm-147 uptake in liver and lung (Table I). An EB distribution obtained from one of the workers is shown in fig.2, along with the background distribution from a normal subject. The natural background count-rate in the steel room used to vary between 30 to 60 cpm in the energy band of 12-75 keV. The counts obtained with the subject in the same energy band are 194 cpm yielding 26.6 KBq of Pm-147 in liver. In the other two cases also the counts observed are quite significant and found to be 10.7 KBq and 27.4 KBq of Pm-147 in their liver. These three workers with internal contamination belong to the same

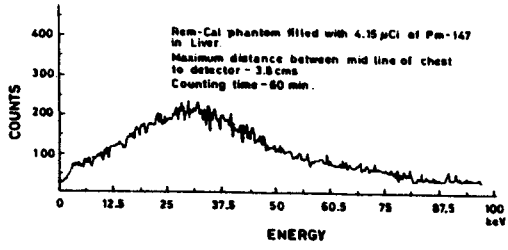

Fig.1 Bremsstrahlung spectrum of Pm-147 obtained with phoswich detector

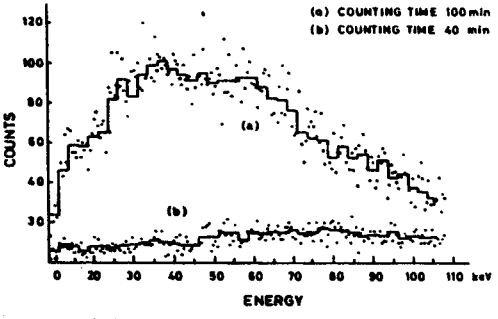

Fig.2. (a) EB detected from radiation worker'A'(b) background distribution from a normal subject of same H/W

institution where air contamination of 2.32 x 10^2 Bq/m^3 was determined in the workshop.

Bioassay results indicated no Pm-147 activity in urine. However, fecal activity was observed in the three workers. In order to compare the results, the liver and lung burdens were estimated from fecal results. ICRP-30 lung model was used for lung burden estimation and the model suggested by Palmer (1) was used for liver burden estimation. For both lung and liver, extreme values were calculated assuming each organ to be the sole source of fecal elimination independent of the other. Lung burden was calculated with biological half-life (Tb) of 50 to 500 days (5). Liver burden was evaluated with Tb of 660 to 1000 days (1).

The estimated organ burdens are given in brackets beneath the external counting results in Table I. Organ burdens are found to be lower than the values measured by external counting.

Since these persons were working regularly with radioactive paint, they were subjected to chronic exposure through inhalation. For calculation of dose, the chronic exposure is averaged to a single intake in the middle of the working

Table I: Results of Pm-147 monitoring of radiation workers

Radiation workers	Duration of work(months)	Time elapsed (days)	Fecal activity (dpm)	Lung activity (KBq)	Liver activity (KBq)
A	8	69	45.9	5.9 (0.08 to 0.8)	26.6 (0.7 to 1.1)
B	1	39	249.6	-	10.73 (3.9 to 6)
C	6	3	5th day 1.23×10^4	12th day 237.6	5th day 7.3 / 12th day 0.5	27.4 (3.8to5.7)

period (6) and lung burden is extrapolated to that point. Pulmonary deposition at the time of exposure is calculated from fecal elimination and external lung counting and are given in column 3 & 4 of Table II. Intakes in the pulmonary region are also calculated from the liver burden values of external counting, assuming

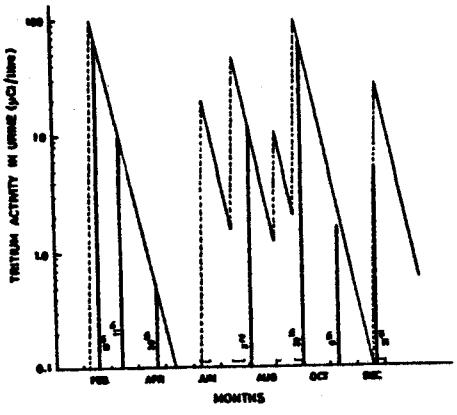

Fig 3. Estimation of H_3 intake in worker III

that 20% of pulmonary activity is transferred to blood with Tb of 50 to 500 days (5), 50% of activity is transferred to liver in 24 hrs[4] and the liver activity is eliminated slowly with a Tb of 660 - 1000 days. The long lived component of intakes evaluated from liver counting data are given in column 5 of Table II. The computed intakes from fecal results are very much less than the intakes computed from external counting. But the results computed from the individual organ activity are falling within agreeable limits.

The same workers used to handle Ra-226 paint also before the introduction of the Pm-147 paint. Therefore, they were monitored for Ra-226 burden by counting in an arc geometry with NaI(Tl) crystal detector (20.3 cm dia x 10.1 cm thick). There was no detectable activity. However, the bioassay results showed lung burden in all of the workers and it was less than 148 Bq.

Table II Estimated intake of Pm-147 in three workers

Radiation worker	Intake occured before monitoring (days)	Estimated intake from		
		Fecal KBq	Lung KBq	Liver KBq
A	160	12.3	90.3	202.9
B	50	19.4	-	123.9
C	120	64.2	131.9	216.0

Table III Results of H-3 monitoring for 4 workers

Radiation Workers	Annual intake MBq	Annual Dose mSv
I	11.3 (305.4 uCi)	12.22
II	12.9 (348.6 uCi)	13.2
III	11.1 (300.0 uCi)	11.8
IV	6.3 (170.3 uCi)	6.0

Ten radiation workers who are actively engaged in dial painting with H-3 activated paint were monitored at fortnightly intervals. The H-3 contamination in urine vary between 3.7 to 370 KBq. In one or two instances the urine concentration exceeded the limit of 1.85 MBq per litre in 1981 and 1982. The maximum concentration which was detected at any time in any subject was 2.5 MBq. These high activities were due to the reason that the exhaust system which is connected to workboxes was occasionally switched 'off' by workers during working hours, resulting in the air concentration upto 118 KBq/m^3. After restoring the normal air flow in the workshop the urine activity in workers dropped to the order of 66.6 KBq per litre.

A typical example of a subject who had exceeded the limit of 1.85 MBq per litre of urine twice in year 1982 has been represented in fig.3. The annual intake of activity and the dose for the worker is calculated from the bioassay results. Since the actual time of intake of activity was uncertain in all the cases, the annual intake was calculated on three main assumptions i) the biological half-life of H-3 in all the workers is 7 days, ii) intakes in workers occur in the middle of their working period, iii) the maximum activity in the workers at any time can never exceed 4.44 MBq (120 μCi)/ litre (as it is observed from the monitoring results). The amount of intake is determined from the urinalysis by extrapolating the elimination rate to the middle of the working period. The six peaks in the figure 3 represents the possible amount of intake while working. The Annual Intake in this case is determined by adding up the corresponding values of activity. The table III gives the annual intake as well as the calculated annual dose of four radiation workers for 1982. The results indicate high Annual Dose but well within the permissible limit.

4. Conclusion

The monitoring of radioluminous paint workers has shown that the radiation risk from working with tritium activated paint is higher than that of handling Pm-147 activated paint. The body monitoring of promethium workers by liver and lung counting provides a complementary method to bioassay, for the estimation of body burden of workers handling Pm-147 radioactive paint. The Pm-147 activity found in fecal samples indicate the slow clearance of lung activity, determination of which may provide effective means of estimating the internal contamination of workers handling Pm-147 activated paints. Workers handling H-3 activated paint need a regular programme of monitoring at short intervals. The excretion rate of tritium has been assumed to be represented by a single exponential curve for the purpose of dose calculation. Theoretically it will be wrong to consider single compartment model for a long term clearance due to two reasons i) tritium is the constituent element of body tissue and therefore, it exchanges with organically bound hydrogen and ii) the paint is an organic polymer which is insoluble in body fluid. The errors in assuming a single compartment model is yet to be evaluated. According to ICRP-30, this is not likely to be more than 10%. The annual dose calculated for H-3 workers were found to be significant even though scheme of rotation of workers was put in action. It requires continuous vigilance on the part of the health physicist to control the working conditions and ensure safe levels of body burden.

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