A STUDY OF INHALED SODIUM-22

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Abstract

This is a study of small intakes by inhalation of ^{22}Na which occurred during the machining of an irradiated target. The arrangements for handling and machining the targets are described. Measured levels of surface contamination and airborne activity, together with particle size data, are given. Whole body counting results, and measurements of the distribution of activity in the body and its variation with time are presented. The information obtained is considered in relation to predictions based on the models of the I.C.R.P. Task Group on Lung Dynamics, and the data given in I.C.R.P. Publication 10.

Introduction

^{22}Na is produced on the Nuffield Cyclotron at the University of Birmingham by bombarding magnesium targets with deuterons. At the end of the irradiation, during which about 50 mCi of ^{22}Na is normally produced, the target is removed from the cyclotron and stored for several weeks to allow short-lived activity to decay. The ^{22}Na is present in a thin layer on the surface of the target, and this active layer has to be removed so that the ^{22}Na can be recovered and processed.

This paper reports studies made to estimate the radiation dose resulting from intakes of fine dust produced during the machining of an irradiated target. The intakes were accidental and the bulk of the activity taken into the body is considered to have been inhaled due to the failure to wear a breathing mask.

Target Machining

Using long handling tongs, the irradiated target is transferred from the storage facility to a shielded enclosure within which is a scraping machine. The walls of the enclosure are made of interlocking lead bricks and a lead-glass window is included to allow the machining process to be observed. Access to the enclosure is via a two part perspex lid, one part of which can be moved. At the time of these intakes, the lead enclosure itself was not ventilated but the room in which the equipment is housed has extract ventilation. The general layout of the room and equipment is shown in Fig.1.

The active layer is removed from the surface of the target by a scraping tool which traverses its face and removes a thin strip of metal. The scraping process is carried out dry without the use of a cutting fluid. The scrapings fall down an inclined trough into a can which is capped and then manually removed using tongs. For the whole operation the operator spends a total of about an hour in the room.

Surface Contamination Levels

When this scraping facility was originally designed it was not thought that contamination outside the lead enclosure would be significan However when the facility was brought into use, surveys revealed that loo activity was escaping from the enclosure. Typical levels of loose surfac contamination at the end of a scraping run, at the positions indicated in Fig. 1., are given below i.e., much of the room was found to be contamina to quite significant levels.

Position (See Fig.1)	Surface Activity Level ($\mu Ci/cm^2$)
S1	6×10^{-4}
S2	1×10^{-3}
S3	5×10^{-4}
S4	5×10^{-4}

Air Contamination Levels

Air samples have also been run during the target loading, machin and can removal stages of the operation. Samples have been taken using st samplers positioned as shown in Fig.1., these positions being close to the positions occupied by the operator. Typical levels of airborne activity a shown below and these should be compared with the 40 hour week $^{m.p.c}$air va of 2×10^{-7} $\mu Ci/cm^3$ and 9×10^{-9} $\mu Ci/cm^3$ for 'soluble' and 'insoluble' materials as given by I.C.R.P.[1].

Position (See Fig.1)	Air Activity Level ($\mu Ci/cm^3$)
A1	1×10^{-8}
A2	2×10^{-7}

Size Selective Sampling of Airborne Activity

In order to obtain information required for specifying the requirements of filters to remove this airborne activity, size selective sampling has been carried out using a cascade centripeter of the type described by Hounam[2] and calibrated by O'Connor[3]. Samples were taken at th positions shown in Fig. 1 during target loading, machining, and can removal and results typical of those obtained are shown below. This distribution i very close to a log-normal distribution with an activity median aerodynamic diameter of 2.7 μ and a geometric standard deviation of 1.9.

Aerodynamic diameter (microns)	Percentage of particles less than stated diameter
12.5	99.3
4.0	69.4
1.5	19.6

Whole Body Counting after Accidental Intake

On one occasion the target scraping machine operator failed to wear thing mask. When this was known it was realised that an inhalation had probably occurred, so it was decided to carry out whole body ıg in order to investigate the distribution of activity and its variation ıme and to estimate the dose.

Strictly speaking the intake was not a single well-defined intake but mall intakes over a period of some hours. The first whole body count .e 2 days after the estimated mid-point of the intake and a further 7 were made, the last being 67 days after intake. Counting was in the V photopeak, and the results obtained have been corrected for normal und and ^{40}K contribution by using data from an uncontaminated person of build to the person concerned.

At the first count, a total count of 22,680 was recorded, corres- to 0.4μCi of ^{22}Na activity in the body at that time. The results of le body counts were plotted to estimate the count and activity on the the intake (t=o), and the results were then normalised to the result at these are plotted in Fig. 2.

Distribution of Activity in the Body

The whole body counter used for this study has four large sodium letectors. Two are above the subject and positioned at the chest and and the two below the subject are at the head and knees. For all the hat were made, the distribution of counts among the four detectors was lly constant and not significantly different to the distribution found jection of ^{24}Na into a human subject.

As well as counts made using the whole body counter, checks were also ng a collimated sodium iodide detector which could be accurately ed over various parts of the body. Counts were made 2, 11, and 18 days take with the detector positioned over each lung and the lower part of ς on each occasion. These measurements showed no significant change in ribution of activity at these three positions over the time interval l above.

:cted Behaviour of Inhaled ^{22}Na and Comparison with Recorded Data

From the size selective air sampling data, the amounts of activity at various sites can be predicted using the Deposition Model of the Task Group on Lung Dynamics[4]. This model gives the following depositions.

Region	Percentage of Inhaled Activity Deposited
Nasopharynx	60 - 65
Tracheo-bronchial	8
Pulmonary	15 - 20

The I.C.R.P. Task Group on Lung Dynamics also proposes a clearance model and suggests clearance times and routes from various regions for several categories of inorganic compounds. In the case of this study, the radioactive material was sodium, but most of the original magnesium was also present and it was of interest to know how the active sodium would behave in this situation. In contact with moisture and body fluids the hydroxides of these metals would form. Sodium hydroxide is listed by the I.C.R.P. Task Group as a Class D material exhibiting rapid clearance from the lung, whereas magnesium hydroxide is a Class W material exhibiting intermediate clearance. For the radioactive sodium hydroxide, the Task Group's Clearance Model predicts clearance as below.

Region	Clearance percentage, route, and biological half-life
Nasopharynx	50% to systemic blood, 4 mins 50% to G.I. tract, 4 mins
Tracheo-bronchial	50% to systemic blood, 10 mins 50% to G.I. tract, 10 mins
Pulmonary	80% to systemic blood, 30 mins 20% to lymph, 30 mins, and then all to blood, 30 mins

Therefore if the sodium quickly separates from the magnesium, within a few hours of the inhalation all the activity will have been transferred to the G.I. tract and systemic blood. That transferred to the G.I. tract will also quickly transfer to the blood[5] so the behaviour after that time would be expected to be identical to that of orally administered ^{22}Na. Confirmation that this is effectively so from two days after the intake is given in Fig. 2 where the normalised whole body counts are compared with the data given in Publication No. 10 of I.C.R.P.[6], in which the clearance of ^{22}Na is described by a three component exponential derived from whole body counting studies of orally administered $^{22}NaCl$. It is seen that there is quite good agreement between the measured whole body activity and that predicted by the I.C.R.P. clearance formula, particularly bearing in mind the reported variability[7] in biological elemination rate that can occur as the stable sodium intake is varied. Unfortunately no data is available to confirm the predicted very rapid clearance from the lung, but the data from 2 days after the exposure confirm that no translocation of activity from the lung occurred after that time. This is in accord with the findings of similar studies made from 9 to 285 days after the inhalation of another Class D material (^{137}Caesium sulphate) by Miller[8].

Dose Estimate

From the I.C.R.P. Task Group on Lung Dynamics deposition model, of he total initial deposit of 0.5 μCi, the deposits in the nasal, tracheo-ronchial and pulmonary regions are expected to be 0.34, 0.046, and 0.114 μCi espectively. For the nasal and tracheo-bronchial regions it has been assumed n each case that the activity has been uniformly deposited over an area of 00 cm^2, cleared according to the biological half-times of 4 and 10 minutes, nd the resulting doses have been calculated to be 3.3 and 1.1 mrem espectively. Using the data given by I.C.R.P.[1] the average dose to the lung, ssuming a biological half-time of 30 minutes, has been calculated to be 0.14 rem, and from the data given in I.C.R.P. Publication 10, the whole body dose as been estimated to be 10 mrem.

Conclusion

From the above evidence it is concluded that the 0.5 μCi ^{22}Na inhaled as rapidly cleared from the lung and thereafter exhibited the same behaviour s does orally administered ^{22}Na. The most significant dose was the whole ody dose of 10 mrem, the estimated additional doses to the nasal, tracheo-ronchial, and pulmonary regions being only 3.3, 1.1 and 0.14 mrem respectively.

Acknowledgements

I am pleased to acknowledge the help of Dr. H. James, Experimental athology Department, who carried out the whole body counting, and of r. R.G. Harris of the Physics Department. The co-operation of the person nvolved in this study is also greatly appreciated.

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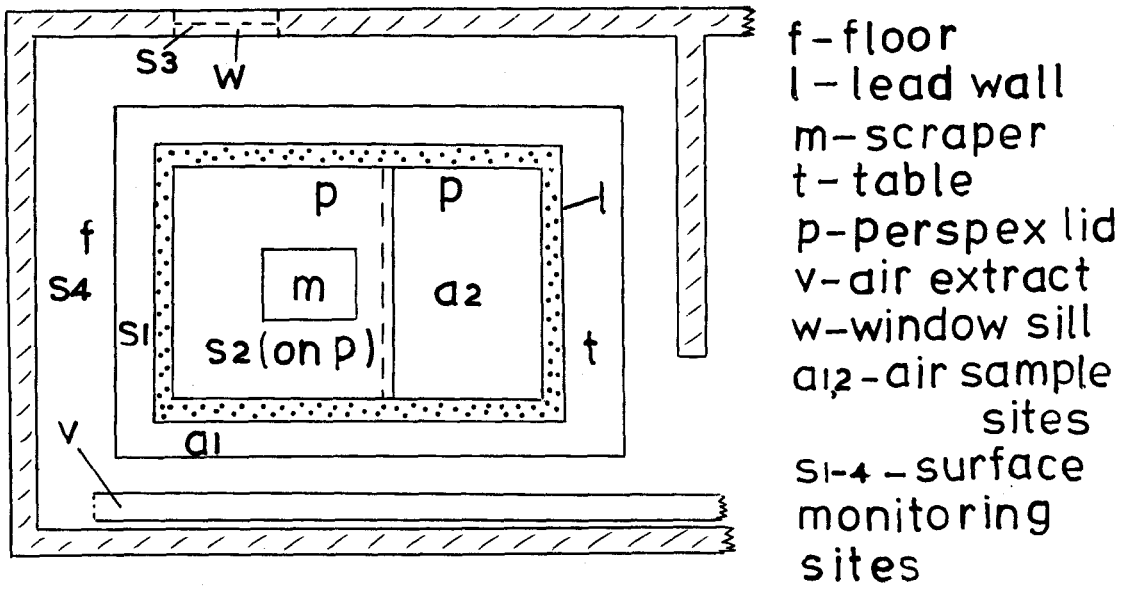

Fig.1. Layout of scraping facility.

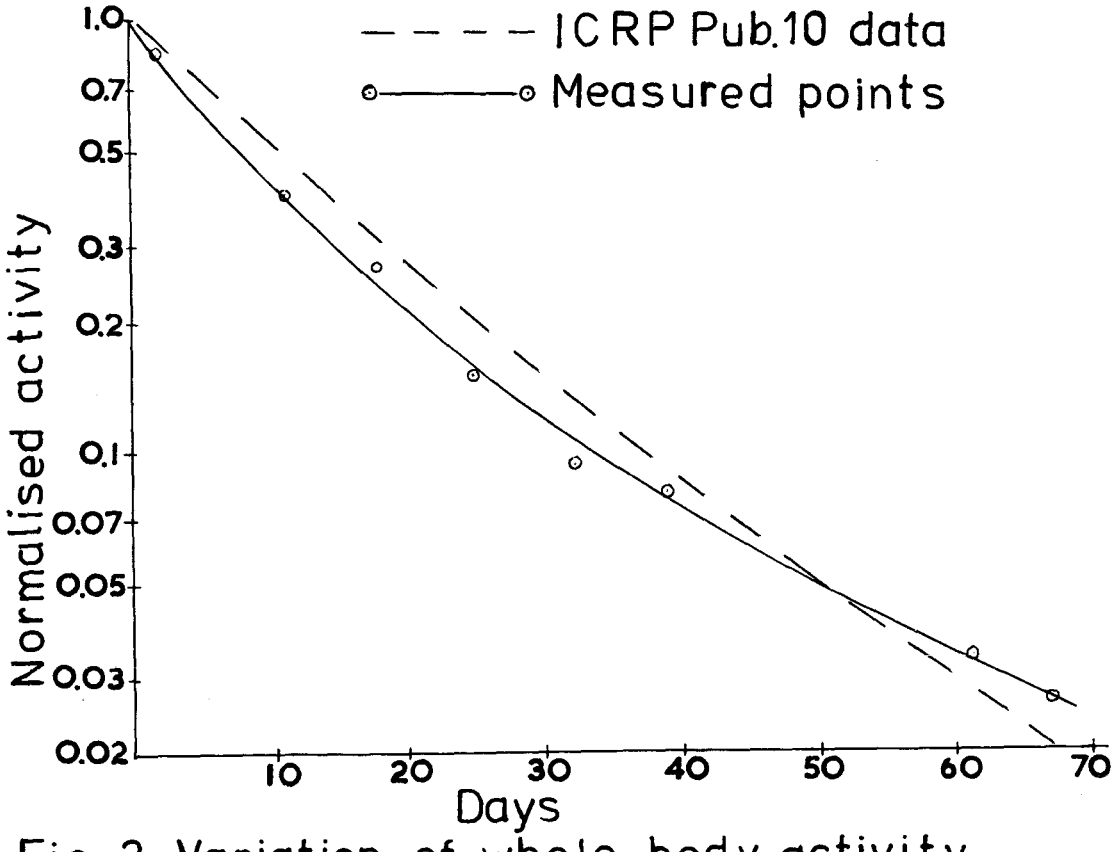

Fig. 2. Variation of whole body activity.