HASL CYCLONE AS AN INSTRUMENT FOR MEASURING AEROSOL PARAMETERS FOR NEW LUNG MODEL

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Abstract

Recently proposed ICRP Lung Model stipulates that a knowledge of an aerosol parameter, activity median aerodynamic diameter (AMAD) is essential to predict the fractional depositions in various parts of the respiratory tract. It is shown that this method of determining AMAD does not reflect significant error in the estimation of pulmonary deposition over a size range of 1.5 to 8.0 µm. Results of a large number of measurements made in Trombay Fuel Reprocessing Plant are reported. Results compare well with similar measurements made by other techniques such as Centripeter and Autoradiography. Significance of the measured AMAD is discussed with respect to maximum permissible concentrations (MPC) in air.

Introduction

Currently used MPC[1] values in air for radioactive nuclides assume that 25% of whatever inhaled goes to pulmonary region of the lung and 12½% undergoes long term retention for insoluble aerosols. This is assumed with no regard to the particle size distribution of the inhaled aerosol. In reality this assumption is not valid and hence ICRP constituted a Task Group[2] to evolve deposition and clearance models taking into account among other parameters, the particle size distribution of the inhaled aerosol. After considerable deliberation Task Group came to the conclusion that the deposition fractions in various parts of the respiratory tract can be predicted fairly accurately, if one knows a particle size parameter, activity median aerodynamic diameter (AMAD). Task Group further states that the spread in particle size distribution (the geometric standard deviation) does not have significant effect on the deposition fractions.

The popular instruments among others[3] available for the measurement of AMAD are cascade impactor[4] and cascade centripeter[5], which have severe limitations with the loading and wall losses respectively. In the present work an approach of using the fraction penetrating the HASL cyclone[6] at a particular flow rate as a measure of AMAD is presented.

Penetration Characteristics of HASL Cyclones

Health and Safety Laboratory of USAEC developed miniature cyclones[6]. These have penetration characteristics matching the so called Los Alamos Respirable Curves, when operated at a particular flow rate. Half inch cyclone[7] is operated at 9 litres/min and one inch cyclones[8] at 68 litres/min. Therefore penetration characteristics of these cyclones can be taken identical to Los Alamos Respirable Curve. Lynch[9] fitted an analytical expression for this penetration curve and worked out mass penetrations for different particle size distributions. He gives a table in which mass penetrations are listed for a given count median aerodynamic diameter and a given geometric standard deviation, assuming that the distribution is log-normal. We have taken this data and computed mass penetration fractions with respect to AMAD for various geometric standard deviations using Hatch and Choate equation[10]. The data thus calculated was fitted to a least squares line on a semilog graph paper. Fig.1 gives such lines for geometric standard deviations between 1.5 and 3.0. A master line given in the figure is a computer fitted least squares line taking into account the entire set of data points used for drawing various lines.

Moss and Ettinger[11] have plotted penetration curves on a linear graph sheet for slightly different penetration curves (ACGIH Criterion).

Mass Penetration Fractions and AMAD

If one measures mass penetration fractions through a cyclone at proper flow rates, one can find AMAD using the master line in Fig.1. As can be seen, the value of AMAD depends to some extent on the geometric standard deviation. Aerosol normally encountered in field conditions has a GSD between 1.5 and 3.0 and the situations giving rise to distributions outside these limits are rare (see Table-III). In the absence of the knowledge of GSD, lines corresponding to GSD of 1.5 and 3.0 enveloping the master line are taken to provide uncertainty in AMAD. For example, if penetration fraction is 0.70, AMAD is 2.3 μm $^{+0.12}_{-0.30}$ μm.

Pulmonary Deposition Fractions and AMAD

The object of measurement of AMAD is to predict the pulmonary deposition fractions. We can now examine whether the possible errors in cyclone measurement of AMAD have significant influence on the estimated pulmonary deposition fractions. ICRP Task Group[2] gives curve between AMAD and the pulmonary deposition fractions. A part of it is reproduced on the left half of Fig.1 for the size range of 1.5 μm and 10.0 μm. Table-I gives for various AMADs, the errors involved in the estimation of pulmonary deposition fractions because GSD is not known. It is also indicated by error bands on the curve in Fig.1. It can be seen that the error is minimum in the size range of 4 μm (AMAD) and is less than 10% for the size range of 1.5 to 7.0 μm. It is therefore concluded that for the size range of interest, the error in estimating the pulmonary deposition fraction is not significant.

Table-I

Errors Associated with the Estimation of Pulmonary Deposition by Cyclone Method for Various Particle Size(AMAD)

Particle size (AMAD) μm		1.5	2.0	3.0	4.0	5.0	6.0	7.0	8.0
% Pulmonary		19.7	17.6	14.9	13.0	11.4	10.3	9.2	8.2
Deposition	+	1.5	+ 1.3	+ 0.1	+ 0.5	+ 1.1	+ 1.2	+1.7	+2.0
with errors	-	1.2	- 0.6	- 0.1	- 0.6	- 0.9	- 1.5	-1.9	-2.1

Field Measurements of AMAD Using Cyclones

Measurements

Fig.2 shows experimental arrangement for cyclone air sampling. Flow rates were set at 9 litres/min for a half inch cyclone using a wet-test meter and also a soap bubble flow meter. Whatever penetrates the cyclone gets collected on an air sampling filter paper (Whatman GF/A glass fibre paper). Other sampling head collects a gross sample. The ratio of the activity on the filter paper following the cyclone and the filter paper from gross sample, provides fractional penetrations. Samples are generally taken over a period of 6 to 8 hours at a location close to breathing zone of workers. Cyclone is thoroughly cleaned before using for a subsequent measurements. Such determinations are made in different operating areas of Trombay Fuel Reprocessing Plant.

Discussion of Results

Number of measurements are made at each of the locations mentioned in Table-II. These measurements are grouped as shown in Table-II. Mean per cent penetrations and the corresponding AMAD are also listed in the table. It can be seen that AMAD does not stay constant from day to day or from one operation to the other. However a mean AMAD can be associated with each location. First three areas are the areas normally used for handling Plutonium and the other areas mostly fission products. It is of interest to compare our results with the AMAD reported in the literature. Table-III lists the range of values obtained by various investigators, using different techniques. Our values compare well with the values shown in Table-III.

Table-II

Results of Measurements of AMAD by Cyclone Method Measurements in Various Areas of Trombay Fuel Reprocessing Plant

Per cent Penetration / Sampled Areas	10 to 20	21 to 30	31 to 40	41 to 60	61 to 80	Weighted mean per cent penetrations	AMAD (μm)
	Number of Measurements						
Crane Space	12	3	5	1	-	22.9	7.5
Pu-Lab	4	4	3	2	-	28.1	6.8
Pu-Lab Maintenance	1	4	1	6	-	37.5	5.2
Operating Gallery	-	1	5	6	7	52.1	3.6
Control Lab	3	3	2	10	2	41.5	4.7
Service Corridor	1	-	2	3	1	43.6	4.4

Note: First three areas give aerosol data for Pu and the subsequent four for fission products.

Revision of MPC_a Values

In light of the actual field measurements described above, we can examine the currently used MPC_a values. Currently used MPC_a values assume that 12½% of the inhaled undergoes long term retention in the pulmonary region for relatively insoluble isotopes. According to the proposed Lung Model, this percentage depends upon AMAD. Table-IV gives the per cent undergoing long term retention with respect to AMAD. It is seen that we are under-estimating the hazard if AMAD is greater than 1.5 μm. Therefore for Fuel Reprocessing Plant, we are over-estimating the hazard by a factor of 2.0 in using the current MPC_a values for insoluble aerosols.

Table-III
AMAD Measurements Available in Literature

Author	AMAD (µm)	GSD	Comments
Andersen[12]	3.4 to 7.2	2.0 to 2.3	Autoradiographic method. Pu aerosols covering different operations.
Sundararajan[13]	2 to 6	1.7 to 2.3	-do-
Stevens[14]	3.5 to 6.0	2.0 to 3.4	Centripeter technique for Pu-aerosols.
	4.7 to 7.0	2.6 to 3.4	Centripeter technique for fission product aerosols.
Langmead[15]	4.3	1.9	UF_4 aerosol. Centripeter technique.
	5.33 ± 1.39	2.46 ± 0.62	Pu-aerosols. Centripeter technique.
	2.5 to 11.0	-	-do- (Windscale)
	5 to 6.0	-	-do- (Springfield)

Table-IV
Ratios of MPC_a (for Insoluble Aerosols) for Old and New Lung Models

Particle size, AMAD (µm)	1.0	1.5	2.0	3.0	4.0	5.0	6.0	7.0	8.0
% long term pulmonary retention	14.4	11.8	10.6	9.0	7.8	6.9	6.2	5.5	4.9
$\frac{(MPC)_a \text{(Old model)}}{(MPC)_a \text{(New model)}}$	1.15	0.94	0.85	0.72	0.62	0.55	0.50	0.41	0.39

Conclusion

Cyclone method of measuring AMAD provides an acceptable method as long as we intend to use the information for estimating inhalation hazards. The method does not provide geometric standard deviation. The basic assumption used in this method, viz. that the penetration characteristics are identical to the Los Alamos Respirable Curve, should be borne in mind. Proper flow rates must be employed. The method is simple and operational health physicists can adopt this method without needing additional skills. The measurement incidentally provides respirable fractions. Recent trend in defining TLV[7] (Threshold Limit values) for Silica and such other particulates, is to define TLV in terms of the respirable fractions. The method has a much wider applications.

Acknowledgements

Our sincere thanks are due to Dr.A.K.Ganguly and Shri S.D.Soman for the helpful discussions and to Shri A.N.Prasad and Shri M.N.Nadkarni for providing facilities for the studies.

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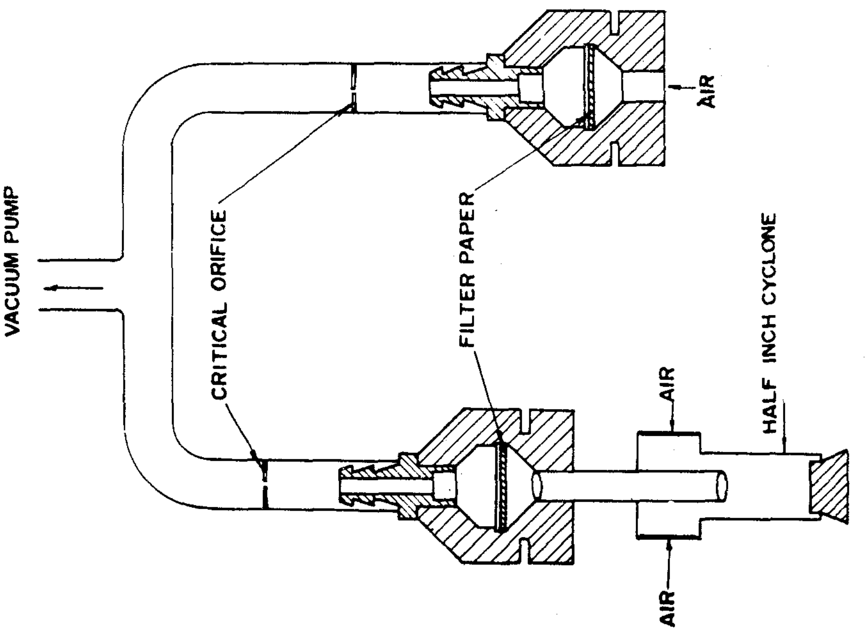

CYCLONE SAMPLING ASSEMBLY