Human Biokinetics of Nasal Clearance by Particle Transport

A compilation of experimental data

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ABSTRACT

This report provides a comprehensive compilation of the data on extra-thoracic (ET) retention and ET clearance from a human volunteer study of nasal clearance conducted at HPA. A summary of the experimental methods and programme of the study is given. It is not intended to review the results of the study but rather provide a complete set of data in one publication. References are given to published work in which results are analysed.

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1 INTRODUCTION

A volunteer study on the clearance of inhaled particles from the human nasal passage has been conducted at HPA (Smith et al., 2011). This report provides a summary of the experimental methods and programme of the study and a compilation of the measurements of extra-thoracic (ET) retention, lung retention and gastro-intestinal (GI) tract contents as a function of time after inhalation and ET clearance by nose blowing. Data from all the main inhalation experiments and for three of the pilot experiments are presented, and uncertainties considered. Breathing parameter measurements, nasal passage measurements and information on the site of retention of particles in the nose are also presented. This report does not review the results, as this has been done elsewhere (Smith et al., 2011). The function of the report is to enable the experimental data to be fully available to the research community.

The study focused on occupational exposure as inhalation is the major route of intake of radioactive material for workers. Under default occupational exposure conditions, most inhaled material deposits in the nose, typically > 40% for particles of aerodynamic diameter (d_{ae}) > 2 µm. It investigated the effects of particle size and breathing pattern on the pattern of aerosol deposition in the respiratory tract and particle clearance from the nasal passage over ranges typical of occupational exposure. The study was conducted because the International Commission on Radiological Protection (ICRP), in its publication on the Human Respiratory Tract Model, HRTM (ICRP, 1994), had identified that there was little information on the clearance from the human nasal passage of particles deposited during breathing for the 12 h following exposure (Fry and Black, 1972, Fry and Black, 1973; Lippmann, 1970) and none on the clearance of the significant fraction that remains in the nasal passage at longer times. The study aimed to address this lack of information and to address uncertainties in the relative sizes of the fractions of inhaled particles that deposited in the unciliated anterior and ciliated posterior of the nasal passage, and in the size of the deposition fraction that subsequently cleared by nose blowing. In addition the study assessed the magnitude of intra- and inter-subject variation and the efficiency of nose blow sampling.

It was not an objective of the study to make precise measurements of nasal deposition as a fraction of intake, as that had been measured by several previous studies (ICRP, 1994), nor was the study intended to investigate the small fraction of deposited particles that is sequestered into the cell wall of the ET airways.

This report contains a compilation of the results of the measurements made in the form of tables and figures, focusing mainly on the retention of particles deposited in the extra-thoracic airways and the lungs, in transit through the GI tract, and the clearance of particles by nose blowing. Some information is also presented that is indicative of the site of deposition within the nasal passage. Additionally, information is given about the volunteer subjects who took part in the study and their breathing parameters and nasal dimensions in specific experiments. It also contains information on some aspects of the experimental method that it was not possible to include in other published papers but which it is useful to record.

2 EXPERIMENTAL DESIGN AND METHOD

2.1 Subjects and ethical approval

Nine subjects (Table 1) volunteered to take part in the study. All were healthy with no history of any serious lung disorder. One subject was a light smoker, smoking less then a packet of 20 cigarettes a week, two were ex-smokers who had stopped smoking in excess of ten years before the study, and the rest were non-smokers. Internal approval for the study was obtained from the National Radiological Protection Board (NRPB, now Health Protection Agency Centre for Radiation, Chemical and Environmental Hazards, CRCE) Volunteer Studies Advisory Committee. External ethical approval for the study was obtained from the Oxford Research Ethics Committee (OxREC: references: C95.289: Study of the deposition and clearance of inhaled particles in the nasal passage and C00.038: Study of the deposition and clearance of inhaled particles in the nasal passage: Part 2. An independent medical examiner established the medical fitness of the volunteers and that their willingness to participate in the study was based on free and informed consent. Inhalation of the radio-labelled aerosols by the subjects was carried out under a certificate issued by the Administration of Radioactive Substances Advisory Committee (ARSAC certificate numbers: RPC 530-1114 (9080) issued 14 December 1995, extended 24 November 1997 and RPC 530-2417 (13912)). Subjects were excluded from taking part in specific inhalation experiments if they had had symptoms of a respiratory tract infection in the ten days before the experiment.

2.2 Method

The study comprised a series of experiments in which volunteers inhaled, through the nose, an insoluble, stable, non-toxic, non-irritant, radio-labelled, monodisperse polystyrene latex (PSL, ρ = 1.05 g cm^{-3}) aerosol in the size range 1.5 µm to 6 µm d_{ae}. The particles were generated using either a spinning top aerosol generator (STAG Mk II, Research Engineers, London, U.K.: 1.5 µm and 3 µm) or a vibrating orifice aerosol generator (VOAG, model 3450, TSI Inc., St. Paul, MN, U.S.A.: 6 µm) (Smith et al., 2011). Subjects, wearing a nose mask, breathed naturally through the nose to inhale the aerosol, either while sitting at rest or while exercising at a workload of 80 watts, which is defined as "light exercise" by the HRTM (ICRP, 1994). The two regimes are representative of typical occupational breathing conditions. As “sitting at rest” takes 30 watts of work, for the "light exercise" experiments the subjects sat on an ergometric bicycle and pedalled at a work rate of 50 watts. Pilot experiments using particles labelled with ^{99m}Tc (half-life: 6.02 h) were performed with 3 µm and 6 µm aerosols for both breathing regimes, but not for the experiments in which 1.5-µm particles were inhaled as the higher surface/volume ratio of these particles causes too much ^{99m}Tc to leach from them. Main experiments, using ^{111}In (half-life: 2.83 days) labelled aerosols, were conducted on at least three volunteers for each combination of particle size and work rate, so enabling inter-subject variation to be determined. Main experiments using a ^{111}In labelled 1.5-µm aerosol could be conducted as indium binds with the polystyrene matrix in a different manner to technetium, causing significantly less leaching. To assess

fully the degree of inter-subject variation, all nine subjects took part in main experiments in which they inhaled 3-µm particles while sitting at rest. Information on the radio-labelling of the particles is given in Smith et al. (2008). The use of ^{99m}Tc and ^{111}In radio-labels meant that ET retention could be measured for up to 1 day after inhalation in pilot experiments and for about 5 days for the main experiments. The retention of the deposited particles was determined from in vivo measurements of the activity in the ET airways, lungs and GI-tract that detected the gamma-rays emitted by the radio-labelled particles. Additional information on nasal clearance was gained from nose blow samples. On occasion, subjects provided 24 hour urine samples that were measured to check the insolubility of the radiolabel. The activities of these biological samples were measured using a United Kingdom Accreditation Service (UKAS) accredited gamma-ray spectrometry system, with all calibrations being traceable back to national standards. All samples were bagged to prevent cross-contamination, and uniquely labelled.

To inhale the aerosol, the subject sat within the five detector array of the Rapid Particle Clearance Detector Array (RPCDA, Figure 1). The aerosol inhalation system was positioned in front of the subject (Figure 2). If the subject was to inhale the aerosol while sitting at rest, the subject sat on a chair. For the light exercise experiments, the subject sat on the ergometric bicycle and pedalled at a work rate of 50 watts. The subject's pulse rate was monitored and when the rate had stabilised the subject was assessed to have fully adapted to the work rate. The cross-sectional area of the nasal passages as a function of depth was then measured using non-invasive acoustic rhinometry (NADAR) (Hilberg et al. 1989). Typically, the right and left nasal passages were each measured three times to reduce measurement uncertainties. The subject then donned the nasal mask, ensuring an air-tight fit and, when a steady pulse rate showed the desired work rate had been re-established, commenced the aerosol inhalation.

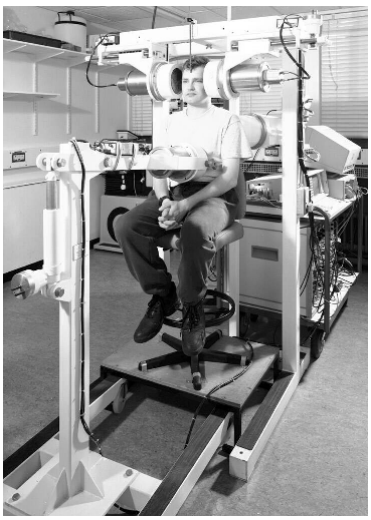

Figure 1: Rapid Particle Clearance Detector Array (RPCDA)

The administration of the radio-labelled aerosol to the volunteer was controlled to give an initial extra-thoracic deposit (IETD) of about 500 Bq ^{99m}Tc for pilot experiments and 1 kBq ^{111}I for main experiments. The required intake was determined from the activity of the aerosol particles and the fraction of inhaled particles expected to deposit in the ET airways. The deposition fraction was calculated using LUDEP 2.0 (Jarvis et al., 1996), a

PC program which implements the ICRP (1994) human respiratory tract model, using the volunteer's tidal volume and respiratory frequency for the required breathing regime.

The aerosol was inhaled from the chamber through computer controlled valves, which automatically switched as the volunteer inhaled and exhaled (Figure 2). A 100 ul aliquot of the radio-labelled particle suspension was dispersed into the chamber using a compressed air nebuliser. Following resuspension the volunteer inhaled the aerosol from the chamber at the start of the next inhalation. The aerosol concentration was controlled so that the administration took approximately four breaths. The laser photometer (Figure 2) measured the concentration of the inhaled aerosol, while the pneumotachograph measured the volunteer's flow rate. Thus the number of particles inhaled was determined and the administration automatically stopped once the required activity has been inhaled.

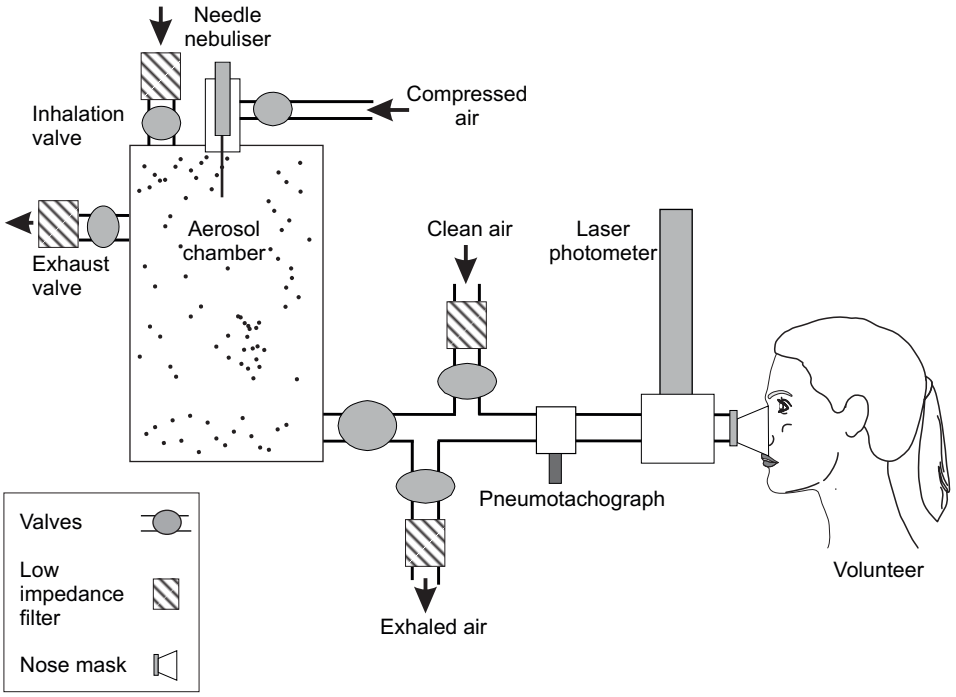

Figure 2: Aerosol inhalation system

As the intensity of laser light reflected by the particles varied with their size, and the inhalable fraction of the aerosol varied with the subjects' breathing patterns, the system was calibrated for inhaled aerosol for each experiment. Particles from the batch of particles to be used for the subject inhalation were nebulised and a simulated subject inhalation performed. This was done using a sinusoidal breathing machine that matched the subject's typical tidal volume and breathing rate for the work rate to be investigated. A plaster-of-Paris cast of the face of Subject 3, including nose holes and a nose mask attached to it with an airtight seal, was used to simulate the physical conditions of subject inhalation. On the posterior side of the mask tubing connected the nose holes to a holder containing a micropore filter and then to the breathing machine. The activity of the particles collected on the filter in the course of the calibration run, which represents the inhalable fraction, was measured using the UKAS accredited gamma-ray spectrometry system. The integrated intake assessed from the laser photometer and

pneumotachograph signals measured during the calibration run was equated with the activity of the particles collected on the filter to give the calibration factor used to set the desired intake for the subject experiment.

When the subject had inhaled the desired amount of aerosol, aerosol inhalation was automatically stopped. The aerosol inhalation system was shut down and removed from the laboratory so that the activity still present in it would not interfere with subject measurements. The subject's nose mask was removed and the area around the nose and mouth wiped to clean it of any deposited activity. The wipes and nose mask were bagged, uniquely labelled and measured for activity using the UKAS accredited gamma-ray spectrometry system.

The study measured ET and lung retention and GI tract contents using two different detector arrays. The inhalation laboratory's Rapid Particle Clearance Detector Array (RPDA, Figure 1) measured changes in retention during the forty-five minute period after intake. At later times it was possible to make longer, higher accuracy measurements using the Low Background In vivo measurement Detector Array (LBIDA, Figures 3 and 4).

The RPCDA in vivo measurements were synchronised to start at the same time as the aerosol inhalation. The subject inhaled the aerosol while seated within the array of five 110 mm diameter sodium iodide [NaI(Tl)] detectors, collimated with lead side shields. Two detectors measured activity in the head, two positioned against the upper back measured lung activity, and a fifth was positioned in front of the stomach (Figure 1). A sixth collimated detector measured the background gamma radiation level in the laboratory. This sixth detector's measurement was used to correct the RPCDA background measurements of a non-exposed colleague of the same build as the subject if it showed that the background radiation rate had changed significantly between the subject and background measurements.

Simultaneously with the start of aerosol inhalation, the RPCDA's computer controlled data acquisition system began a sequence of twelve one-minute and six five-minute measurements. This measured any initial rapid particle clearance during a period of approximately 45 minutes. Time of intake for each experiment was defined as the mid-time of aerosol inhalation by the subject. Typically, the first three to five RPCDA one-minute measurements occurred while the aerosol inhalation system was still present in the laboratory and affecting the detector measurements. Therefore, these measurements are discounted. The first useable set of RPCDA measurements was typically made about 5 minutes after the time of intake; that is five minutes after the mid-point of aerosol inhalation by the subject (see Table 7).

Following aerosol inhalation, subjects were free to blow their noses at will, and were provided with a kit of tissues, bags and uniquely identified labels to collect, bag, and label such samples with the time of collection. The activities of these samples were measured as soon as reasonably practicable. The subject was also asked to keep a diary of events that might affect nasal clearance (for example eating, drinking, and bathing). Subjects were asked not to swim on the day of the inhalation but were otherwise asked to maintain their usual routine.

The low background in vivo measurement detector array (LBIDA), housed in a steel room (Sumerling et al., 1985), was used to make high accuracy measurements of the activity in the head (nasal passage), chest (lungs) and abdomen (GI tract) of the subjects from approximately 1 hour after intake. Each measurement was made using four 150 mm diameter NaI(Tl) detectors collimated with lead side shields, two above and two below the bed, each collimated with a cylindrical lead side shield. The four detectors were arranged in ring geometries for the head (Figure 3) and chest measurements and in a linear geometry for the abdomen measurements (Figure 4). The head, chest and abdomen measurements were made sequentially, and then, on the first day, a second head measurement was usually made. Measurements were repeated at intervals for several hours after administration and then at about 24 hours after intake and, for the main experiments, over several days following until the activity could not be measured with sufficient accuracy.

For the head measurements, those subjects who did not find it too uncomfortable wore a vest of lead-impregnated rubber to reduce the contribution to the activity measured by the head detector array from the activity in the lungs and the GI tract.

Figure 3: Low Background In vivo Detector Array (LBIDA) using Sodium Iodide detectors to measure head activity

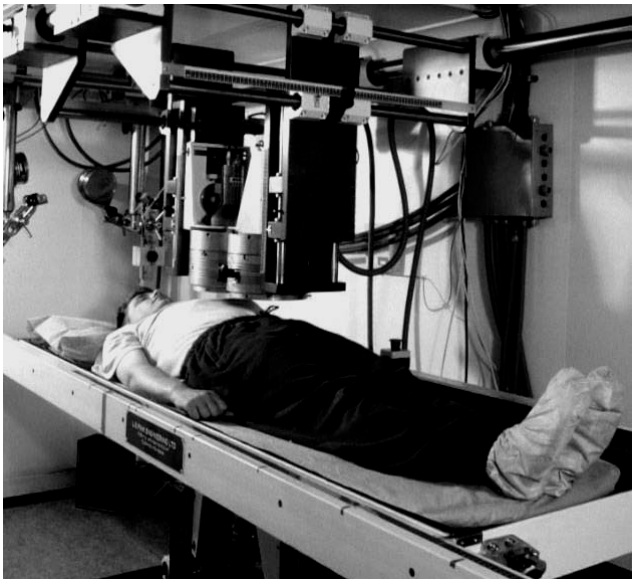

Figure 4: Low Background In vivo Detector Array (LBIDA) using Sodium Iodide detectors to measure GI tract activity

The location of retained particles in the nasal passage was assessed using a Small Sodium Iodide Detector Array (SSIDA). This consists of two 19-mm diameter x 40-mm long NaI(Tl) detectors within cylindrical 8-mm thick lead collimators, positioned as shown in Figure 5. The site of retention was determined from the ratio of counts measured by the side detector divided by the counts measured by the front detector and comparing that to the ratios measured from calibration sources positioned in either the anterior or posterior of the nasal passage of the tissue equivalent head phantom (see Technical Annex, Smith et al., 2011). Measurements of count rate were background subtracted and for corrected for radioactive decay since the time of intake. Eight of the subjects were measured using this array on the first two days after inhaling 3-µm aerosols while at rest. Typically, the first SSIDA measurement was made after the first LBIDA head measurement with further measurements made in the following 24 hours. In two cases measurements continued for two or more days.

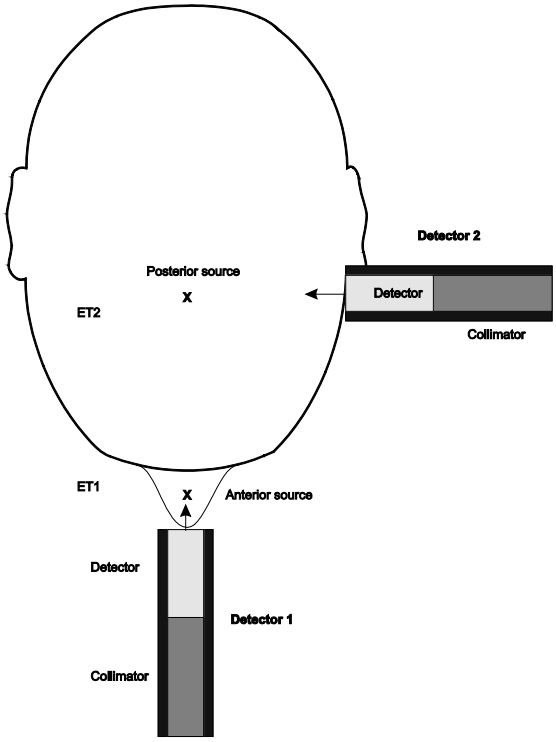

Figure 5: Small Sodium Iodide Detector Array (SSIDA)

The calibration of these three in vivo detector arrays is described in the Technical Annex of reference Smith et al. (2011). For the LBIDA, the head, chest, and abdomen activities were determined from the background subtracted spectra using a multiple linear regression program (Nuclear Data Inc., 1978). For the RPCDA and SSIDA, activities were determined using standard peak area determination. All measured activities were then corrected for radioactive decay since the time of inhalation. For the RPCDA and LBIDA measurements corrections were also made for contributions from activity present in the other two organs by use of 3 × 3 matrix manipulation of calibration factors (Annex, Smith et al., 2008). The calibration matrix used to correct head measurements differed depending on if the subject had or had not worn the lead impregnated vest for that measurement. All calibration factors were derived from phantom calibration

measurements of lung, stomach, and ET sources whose activities were traceable back to national standards.

3 RESULTS

3.1 Retention and clearance measurements

Tables 2-6 list the measurements of ET retention and ET clearance by nose blow of the deposited aerosol (Tables 2A-6A) and of lung retention and the GI tract content (Tables 2B-6B) for the pilot experiments for 3-µm particles inhaled at rest and for all the main experiments. No results are given for the other pilot experiments (6-µm particles inhaled at rest and 6-µm and 3-µm particles inhaled while performing light exercise) as the analysis of these data focused on ensuring that inhalation conditions were correct for conducting the main experiments.

For reasons discussed below, caution should be employed when using the tabulated data. Inappropriate use could lead to erroneous conclusions. The numerical values are given to a higher degree of precision than usual to prevent rounding errors causing artefacts in any analysis of the data. Hence, times after intake are given to three significant figures and ET retention, lung retention, GI tract content and clearance by nose blow fractions are all given to four decimal places as fractions of initial extra-thoracic deposition (IETD) or initial lung deposition (ILD). ILD is also given as a multiple of IETD to four decimal places in Tables 2B-6B. Sources of uncertainty for each type of measurement are discussed below.

3.1.1 Determination of IETD and ILD

In Tables 2-6, ET retention, clearance from ET by nose blowing, and GI tract contents are all reported as fractions of IETD. Lung retention is reported as a fraction of ILD, with ILD given as a multiple of IETD.

In Smith et al. (2011), IETD is defined as the sum of the first valid RPCDA measurements of ET retention and GI tract contents after inhalation. The activity in the GI tract at the time of this first measurement is dominated by particles deposited in the airways ET that clear almost immediately to the stomach by, for instance, swallowing. However, use of the term “first measurement” in this definition is a simplification.

The first twelve RPCDA sets of ET, lung and stomach measurements were made for live count times of one minute. The first measurement started at the same time as the beginning of the aerosol intake. The set of twelve measurements took approximately 15 minutes to complete, due to system dead time between measurements while the measured spectra were being saved. Table 7 shows these sets of measurements for the three “1.5-µm aerosol inhaled at rest” experiments. The one minute measurement time was chosen to enable rapid changes in head, chest or stomach activity to be measured, and to minimise the amount of initial data that had to be discarded due to the

presence of the aerosol inhalation system. The measurements discounted due to interference from the aerosol inhalation system are shown in italics in Table 7.

The one minute measurements have large counting uncertainties because of their brevity. Therefore, IETD and ILD would have large uncertainties if they were assessed just from the first valid set of one minute RPCDA measurements. In most experiments rapid ET clearance was not recorded by the one minute RPCDA measurements and the values of successive RPCDA measurements show little statistical difference. Therefore, IETD was estimated as the sum of the average of all the initial ET measurements that were statistically similar plus the average of all the initial GI-tract measurements that were statistically similar. If the number of relevant ET and GI-tract measurements differed then both averages were taken over the lower number of measurements. Therefore the number of measurements used to estimate IETD varied between experiments. ILD was estimated in the same way using the lung measurements.

In Tables 2-6 these one minute measurements are represented by the first three values given for ET and lung retention and the GI-tract contents. As the one minute counts had large counting uncertainties, and large changes in activity were not generally observed between successive one minute measurements, the sets of seven to nine useable one minute measurements were combined to give sets of three measurements of two to three minutes duration. These are the values that were used in the subsequent analysis of the data.

In Tables 2-6, for most experiments, the first pair of RPCDA values for ET retention and the GI-tract contents do not sum to 1, because the IETD value was typically derived from the average of more measurements than those summed to give that first pair of values.

3.1.2 ET retention

Tables 2A – 6A indicate which ET retention measurements were made using the RPCDA and which were made using the LBIDA. Those LBIDA measurements for which the subject chose to wear the lead impregnated rubber vest are indicated by the superscript ^{3} following the measurement time given in column 1.

Figures 6a-f show plots of total ET retention data (solid diamonds), the ET retention fraction that subsequently cleared by nose blowing (solid line) and the ET retention fraction that subsequently cleared to the GI tract (open squares). The derivation of the ET nose blow clearance fraction and the ET clearance to the GI-tract fraction is given in Smith et al. (2011). In Figures 6a-f ET retention in the eight hours following intake is shown using a linear vertical scale to display the RPCDA measurements and first few LBIDA measurements, and for 100 hours following intake using a logarithmic vertical scale.

3.1.3 ET clearance by nose blowing

The activities of the bagged nose blow sample tissues where measured in a calibrated counting geometry and were decay corrected to the time of inhalation. They are presented in Tables 2A-6A as fractions of the initial extra-thoracic activity. Nose blow

samples collected within a two minute interval of each other were treated as one event and their summed ET clearance fractions given as one value.

3.1.4 Lung retention and GI-tract content

Tables 2B – 6B indicate which lung retention measurements and GI tract content measurements where made using the RPCDA and which were made using the LBIDA. Lung retention is expressed as fractions of ILD to enable easy assessment of clearance from the lung. To compare these values with those of ET retention and GI tract content they should to be multiplied by the value of ILD as a multiple of IETD given at the top of each table, bearing in mind the uncertainties discussed below.

No figures of lung retention and GI tract content are given.

3.1.5 Small Sodium Iodide Detector Array measurements

Table 8 presents the results of SSIDA measurements of count rate per Bq for the calibration source positioned in the tissue equivalent head (Figure 5), the subjects' count rate measurements, and the ratios of those count rates (side detector/front detector). Plots of the count rate ratios are shown in Figure 7. The count rate ratios from the subject measurements are all similar to that measured for the anterior source calibration and significantly different from the ratio measured for the posterior source calibration, indicating that at times of one hour or more after intake particles are predominately retained in the anterior of the nasal passage. The uncertainties of these measurements are discussed below.

3.1.6 Retention uncertainties

The uncertainties given for the ET, lung and GI tract measurements in Tables 2-6 are those due to counting statistics. For the RPCDA measurements this is the uncertainty associated with the counts in the gamma-ray photo-peaks present in the subject and background measurements and the uncertainties of the background subtracted calibration measurements. For the LBIDA measurements the uncertainty was assessed from the subject and background spectra by the maximum likelihood fitting routine used to analyse the measurements (Nuclear Data Inc., 1978) which also takes into account the counting uncertainties of the calibration spectra used by the fitting routine. For both types of measurements these uncertainties were propagated through correction for radioactive decay, correction for contributions to the measured activity from activity in the subject's lung and GI-tract, and conversion into a fraction of IETD.

The other sources of uncertainties for the in vivo measurements that have not been included in the quoted 95% uncertainties include:

- The uncertainties of the activities of the ET, lung and GI-tract calibration sources.
- Uncertainties associated with decay correction of measurements from the uncertainty of the time of measurement, time of intake and of the reference values of the radioactive half-lives of ^{99m}Tc and ^{111}In.

- Uncertainties associated with the emission abundances of the gamma-rays from ^{99m}Tc and ^{111}In.

- Co-incidence summing of gamma-rays.

The uncertainties associated with calibration source activities, decay correction of measurements, emission abundances and co-incidence summing are all small, and combined amount to less than ± 2% of measurement values.

More significant sources of uncertainty, which are also more difficult to assess are:

- Differences in the self-attenuation of the signal for individual subjects compared to that for the humanoid calibration phantoms due to variations in physique.

  - Type: Systemic uncertainty

    RPCDA and LBIDA: This causes a systematic bias to ET, lung and GI tract measurements for each subject, which in turn affects the estimate of IETD, and of ILD as a fraction of IETD. The measurement biases will be the same throughout the study so long as subjects do not significantly change weight, of which there is no indication in this study.

    The magnitude of these uncertainties are difficult to assess, but estimates made using very simple Monte Carlo modelling suggests biases of ± 20% or less to the measured activities.

    SSIDA: The effect of the physical differences between the heads of subjects and the tissue equivalent head phantom are greatest for these measurements.

- Uncertainties caused by variations in the positioning of subjects relative to the detectors.

  - Type: Random uncertainty

  - General: The methodology used to position subjects and detectors limits the variation in their relative positions to less than a centimetre. The uncertainties arising for this source do not exceed a few percent of the measured activities.

- Uncertainties due to movement of subject during measurement.

  - Type: Random uncertainty

  - General: Subjects are encouraged to stay as still as possible during measurements and are prompted to return to the correct position if they move significantly.

    RPCDA: Seated subjects may sway, move their head and neck, and/or relax and extend the spin in the course of the 45 minutes of measurement.

- ET airways: Swaying forward significantly reduced the counting efficiency of activity in the anterior nasal passage, potentially reducing the measured activity by 10% (see Table 3Aiv). In most experiments a thin plastic bar was placed to restrict forward movement of the head and minimise the uncertainty to a few percent. It was not used for the first six experiments (3-µm sitting pilots and the 3-µm sitting main experiments for subjects 2, 3 and 6) which used other means to minimise head movement that was found to be inadequate and hence, replaced.

- Lungs: Subjects tended to rest against the lung detectors, minimising movement so it did not make a significant contribution to measurement uncertainties so it is taken to be less than 2% of measured activities.

- GI tract: Subjects may relax and stretch during the course of such measurements, but such movement did not make a significant contribution to measurements uncertainties so it is taken to be less than 2% of measured activities.

LBIDA: Supine subjects may shift position slightly during the course of measurements. Moving legs and arms, while discouraged, has little or no effect on measured activities.

- ET airways: First order effects of small head movements are countered by the ring counting geometry of the head detectors. Head movement did not make a significant contribution to measurements uncertainties so it is taken as less than 1% of measured activities.

- Lungs: There tended to be minimum movement of the torso with first order effects of any movement being counted by the ring count geometry of the lung detectors. Chest movement did not make a significant contribution to measurement uncertainties so it is taken as less than 1% of measured activities.

- GI tract: There tended to be minimum movement of the lower torso. Torso movement did not make a significant contribution to measurements uncertainties so it is taken as less than 1% of measured activities.

SSIDA: The nature and short duration of these measurements meant that there was no significant subject movement during measurement.

- Uncertainties due the variation in the site and/or distribution of particles within the organ of interest

  – Type: Random

  – General: All lung calibrations were made assuming uniform distribution of activity. This is a reasonable assumption as deposition should be

predominantly in the alveolar interstitial region. There is no indication in either the RPCDA or LBIDA measurements that the redistribution of activity caused by particle clearance effected detection efficiency.

RPCDA

- ET airways: Subject measurements suggest that small changes particle location in the anterior nasal passage soon after deposition can change detection efficiency by as much as 15% of the measured activities (See Table 3Axii).
- GI tract: The measurement was calibrated for activity concentrated in stomach. This distribution is not likely to change over the period of the RPCDA measurements. However, the calibration is unlikely to be accurate for measurements made at times significantly greater than a couple of hours after intake as the activity will then have entered the colon and be distributed through it (see GI tract content at 26.8 hours in Table 3Bv).

LBIDA

- ET: There is no indication of significant redistribution of deposited particles within the nasal passage at times greater than an hour after intake. The uncertainty due to particle movement will be from the small fraction that clears from the nose in the course of a measurement and will cause an uncertainty of the order of a percent or less of the measured activity.
- GI tract: The measurement was calibrated for activity concentrated in the stomach. Detection efficiency may therefore vary as activity transits through and around the GI tract despite the detector counting geometry of two sets of two parallel detectors above and below the subject being designed to minimise this. The magnitude of this uncertainty is difficult to estimate as it will vary with subject physique and the pattern and time of transit of the activity through the GI tract. However, this uncertainty has only a small, second order effect on the estimates of nasal retention and clearance.

SSIDA: This source of uncertainty is not relevant to the SSIDA measurements as the function of these measurements was to determine the distribution of activity in the nasal passage.

The total additional uncertainty associated with in vivo measurements is therefore variable, covering a probable range of ± 5% to ±50%, depending on the measurement. The magnitude of this additional uncertainty varies between the ET, lung and GI tract measurements of a specific subject, between measurements of the same subject, and between subjects. For these reasons caution should be employed when interpreting the data. For ET retention measurements, it would be reasonable to assume an additional uncertainty of ±15% of their quoted values.

3.1.7 Uncertainties of nose blowing measurements

The reported uncertainties for the ET retention fractions cleared by nose blowing are those calculated by the analysis software used by the UKAS accredited gamma-ray spectrometry system. The uncertainties of the sample activities reported by the software are based on two standard deviations, corresponding to a confidence interval of +/- 95%. The components of uncertainty that are taken into account include those associated with the radionuclides' gamma-ray emission abundances; the efficiency calibration, including the uncertainty on the cascade summing correction but not run-to-run variation of the efficiency calibration; peak area; and decay correction. In addition to these uncertainties an additional component of uncertainty is added to allow for all other sources of uncertainty such as run-to-run variations from sources such as sample positioning, run-to-run uncertainty on efficiency calibration, sample self attenuation, uncertainties in the radionuclide decay rate and in the counting time. The combination of additional uncertainties from all the sources considered is approximately 15% (95% confidence interval).

3.2 Breathing parameters

Table 9 lists the subjects' breathing parameters during aerosol inhalation for each experiment. In the main, values are similar to those predicted by the ICRP HRTM for given work rates. Note that the average flow rate is for inhalation only, which typically occupied less than 50% of the breathing cycle. Therefore, flow rate averaged over both inhalation and exhalation is lower. Volunteers were asked to breath at will while aerosol inhalation was taking place. However, given the experimental conditions such as the wearing of a nose mask and the pressure exerted on the face, breathing through the dead space of the administration system and the knowledge that one is inhaling a radioactive aerosol, these measured parameters may well not be comparable to those for people working at the same work rate on a routine task. The standard deviations given provide an indication of the variability of the subject's breathing pattern, both in terms of the flow rate and the tidal volume of individual breaths.

3.3 Nasal dimensions

Table 10 lists the depths and cross-sectional areas of the nasal valve and second nasal minimum of the right and left nasal passages determined by acoustic rhinometry measurements for those experiments for which results are available. Typically, the values are the averages of three measurements of each nasal passage. As discussed in Smith et al. (2010), evidence suggests that a second nasal minimum occurs at the anterior edge of the turbinates. Variations in the degree of congestion of the nasal epithelium changes both the measured cross-sections and also the position of these features in the nasal passage. Results are not available for all experiments mainly because the subject must not inhale or exhale during the measurement. In some cases, subjects were not able to achieve this and hence no usable data was obtained.

As with the retention data, the values in Table 10 are given to a higher number of decimal places than usual to prevent rounding errors causing artefacts in any analysis of

the data. Note that the acoustic rhinometer samples the cross-sectional area in depth increments of 0.345 cm. The uncertainty associated with inserting the nose piece into the nose means that depth measurements will typically cause an uncertainty of ± 0.1 cm. The standard deviations quoted for the areas are derived from the same measurements from which the average areas were obtained.

4 DISCUSSION

The purpose of this report is to provide a compilation of the data obtained from the nasal clearance study. Analysis and interpretation of the data is described in peer reviewed journal reports and conference proceedings (Smith et al. 1997a, Smith et al. 1997b, Smith et al. 2002, Smith 2003, Smith et al. 2011).

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7 TABLES

TABLE 1 Subject characteristics

Subject ID:	Sex (male/female)	Age (y)	Weight (kg)	Height (m)	Smoking status
01	Male	44	71	1.75	Ex-smoker for last 11y
02[1]	Male	37	70	1.76	Non
03	Male	26	81	1.79	Non
04	Male	48	70	1.70	Non
05	Male	38	90	1.77	Non
06	Male	51	96	1.86	Non
07	Male	34	77	1.79	Light Smoker[2]
08	Female	52	57	1.66	Non
09	Male	56	97	1.77	Ex-smoker for last 23y
Mean		**43**	**78**	**1.76**	
± SD[3]		**±10**	**±14**	**±0.06**	

1. Volunteer regularly used Beconase (™ GlaxoSmithKline group of companies) nasal spray (active component Beclometasone dipropionate) to counter chronic allergic rhinitis

2. Light Smoker: smoked less than 1 pack of 20 cigarettes per week.

3. SD: Standard deviation

TABLE 2Ai ET retention: Main experiment: Subject 1, 1.5-µm particles inhaled at rest

Time since intake (hours)	ET retention IETD fraction	± 95% uncertainty[1] IETD fraction	Nose blow clearance IETD fraction	± 95% uncertainty[2] IETD fraction
		RPCDA measurements		
0.106	0.9133	± 0.0246		
0.166	0.9044	± 0.0247		
0.227	0.8928	± 0.0303		
0.282	0.8966	± 0.0192		
0.372	0.8931	± 0.0193		
0.462	0.9069	± 0.0192		
0.553	0.8879	± 0.0192		
0.643	0.8708	± 0.0193		
0.733	0.8102	± 0.0193		
		LBIDA measurements		
1.09[3]	0.7915	± 0.0186		
2.54[3]	0.7580	± 0.0151		
4.59[3]	0.7225	± 0.0159		
5.79[3]	0.7198	± 0.0159		
18.1			*0.0223*	*± 0.0014*
20.0[3]	0.1457	± 0.057		
41.6			*0.0027*	*± 0.0002*
43.4[3]	0.1154	± 0.0092		
57.3			*0.0195*	*± 0.0012*
72.4[3]	0.0521	± 0.0053		

The following footnotes apply to all Tables 2A, 3A, 4A, 5A and 6A of ET retention and ET clearance by nose blowing:

1. The 95% uncertainties given for ET retention are due to counting statistics, taking into account correction for radioactive decay since intake and activities in the lung and gastrointestinal tract, and their counting uncertainties. See section 3.1.6

2. The 95% uncertainties given for the ET retention fractions cleared by nose blowing are those reported by the UKAS accredited gamma-ray counting software (see section 3.1.7)

3. Subject wore lead impregnated vest for LBIDA head measurement

TABLE 2Bi Lung and GI tract retention: Subject 1; 1.5-µm particles inhaled sitting

Lung	ILD = 1.7633 IETD		GI tract		
Time since intake	Lung retention	± 95% uncertainty[1]	Time since intake	GI tract content	± 95% uncertainty[1]
Hours	ILD	ILD	Hours	IETD	IETD
RPCDA measurements					
0.106	0.9997	± 0.0327	0.106	0.0863	± 0.0135
0.166	1.0194	± 0.0329	0.166	0.0925	± 0.0137
0.227	1.0002	± 0.0403	0.227	0.1124	± 0.0169
0.282	1.0000	± 0.0255	0.282	0.1287	± 0.0107
0.372	0.9878	± 0.0256	0.372	0.1426	± 0.0109
0.462	0.9629	± 0.0255	0.462	0.1550	± 0.0109
0.553	0.9705	± 0.0256	0.553	0.1366	± 0.0108
0.643	1.0257	± 0.0257	0.643	0.1272	± 0.0108
0.733	1.0426	± 0.0258	0.733	0.1214	± 0.0108
LBIDA measurements					
1.51	0.9752	± 0.0156	2.06	0.1268	± 0.0108
5.03	0.9527	± 0.0140	5.39	0.1872	± 0.0095
20.4	0.9682	± 0.0130	20.9	0.3279	± 0.0086
43.8	0.9538	± 0.0110	45.3	0.1043	± 0.0072
73.0	0.9597	± 0.0077	73.4	0.0691	± 0.0100

The following footnotes apply to all the Tables 2B, 3B, 4B, 5B and 6B of lung retention and gastro-intestinal tract content:

1. The 95% uncertainties given for lung retention and GI tract retention are those due to counting statistics, taking into account correction for radioactive decay and activity in the lung and gastrointestinal tract, and the counting uncertainties of those activities. See section 3.1.6

TABLE 2Aii ET retention: Main experiment: Subject 4, 1.5-µm particles inhaled at rest

Time since intake	ET retention	± 95% uncertainty[1]	Nose blow clearance	± 95% uncertainty[2]
Hours	IETD fraction	IETD fraction	IETD fraction	IETD fraction
RPCDA measurements				
0.074	0.4322	± 0.1122		
0.134	0.4195	± 0.0920		
0.194	0.4344	± 0.1127		
0.249	0.4242	± 0.0713		
0.338	0.4404	± 0.0712		
0.427	0.4422	± 0.0713		
0.516	0.4205	± 0.0711		
0.605	0.4225	± 0.0714		
0.694	0.4186	± 0.0715		
LBIDA measurements				
1.02[3]	0.4487	± 0.0122		
2.14			*0.0374*	*± 0.0024*
2.21[3]	0.3664	± 0.0139		
3.39			*0.0407*	*± 0.0026*
4.92[3]	0.2813	± 0.0125		
6.06[3]	0.2867	± 0.0139		
6.47			*0.0208*	*± 0.0014*
7.69			*0.0158*	*± 0.0011*
9.14			*0.0114*	*± 0.0009*
16.7			*0.0281*	*± 0.0019*
17.2			*0.0040*	*± 0.0004*
18.6[3]	0.1217	± 0.0106		
28.4			*0.0071*	*± 0.0006*
30.5			*0.0020*	*± 0.0003*
32.9			*0.0022*	*± 0.0003*
40.9			*0.0022*	*± 0.0003*
42.1[3]	0.0541	± 0.0116		
44.0			*0.0005*	*± 0.0002*
46.8			*0.0017*	*± 0.0003*
50.1[3]	0.0727	± 0.0116		

See Table 2Ai for footnotes 1,2 and 3

TABLE 2Bii Lung and GI tract retention: Subject 4; 1.5-µm particles inhaled at rest

Lung	ILD = 2.4242 IETD		GI tract		
Time since intake	Lung retention	95% uncertainty[1]	Time since intake	GI tract content	95% uncertainty[1]
Hours	ILD	ILD	Hours	IETD	IETD
RPCDA measurements					
0.074	0.9607	± 0.1109	0.074	0.5907	± 0.0717
0.134	0.9964	± 0.0910	0.134	0.1793	± 0.0172
0.194	1.0090	± 0.1114	0.194	0.1758	± 0.0210
0.249	1.0380	± 0.0705	0.249	0.1743	± 0.0132
0.338	1.0022	± 0.0704	0.338	0.1542	± 0.0132
0.427	1.0409	± 0.0704	0.427	0.1551	0.0132
0.516	0.9495	± 0.0703	0.516	0.1576	± 0.0132
0.605	1.0000	± 0.0706	0.605	0.1765	± 0.0132
0.694	0.9843	± 0.0707	0.694	0.1657	± 0.0133
LBIDA measurements					
1.42	0.9935	± 0.0121	1.84	0.0839	± 0.0033
5.32	0.9915	± 0.0116	5.67	0.0969	± 0.0030
20.1	0.9144	± 0.0102	20.9	0.1267	± 0.0034
42.7	0.9084	± 0.0085	43.4	0.0723	± 0.0037

See Table 2Bi for footnote 1

TABLE 2Aiii ET retention: Main experiment: Subject 6, 1.5-µm particles inhaled at rest

Time since intake	ET retention	± 95% uncertainty[1]	Nose blow clearance	± 95% uncertainty[2]
Hours	IETD fraction	IETD fraction	IETD fraction	IETD fraction
RPCDA measurements				
0.100	0.9015	± 0.0434		
0.160	0.9008	± 0.0435		
0.221	0.9184	± 0.0435		
0.295	0.9029	± 0.0336		
0.384	0.9006	± 0.0337		
0.474	0.9283	± 0.0337		
0.563	0.8804	± 0.0337		
0.652	0.8850	± 0.0337		
0.741	0.8821	± 0.0336		
LBIDA measurements				
1.17[3]	0.4953	± 0.0059		
1.92			*0.2215*	*± 0.0134*
2.42			*0.0845*	*± 0.0051*
2.45[3]	0.3042	± 0.0047		
3.17			*0.0275*	*± 0.0017*
6.67			*0.0059*	*± 0.0004*
6.72[3]	0.0815	± 0.0024		
7.88[3]	0.0938	± 0.0024		
9.67			*0.0074*	*± 0.0006*
21.8			*0.0012*	*± 0.0001*
22.2[3]	0.0267	± 0.0029		
23.4			*0.0009*	*± 0.0001*
25.7			*0.0002*	*± 0.0001*
45.6[3]	0.0045	± 0.0012		
53.0[3]	-0.0028	± 0.0012		

See Table 2Ai for footnotes 1,2 and 3

TABLE 2Biii Lung and GI tract retention: Subject 6; 1.5-µm particles inhaled at rest

Lung	ILD = 1.1455 IETD		GI tract		
Time since intake	Lung retention	± 95% uncertainty[1]	Time since intake	GI tract content	± 95% uncertainty[1]
Hours	ILD	ILD	Hours	IETD	IETD
RPCDA measurements					
0.100	0.9998	± 0.0887	0.100	0.0909	± 0.0257
0.160	0.9855	± 0.0889	0.160	0.1165	± 0.0259
0.221	0.9835	± 0.0889	0.221	0.1102	± 0.0258
0.295	0.9570	± 0.0687	0.295	0.0951	± 0.0199
0.385	0.9668	± 0.0689	0.385	0.1043	± 0.0200
0.474	0.9340	± 0.0688	0.474	0.1087	± 0.0200
0.563	0.9277	± 0.0689	0.563	0.1123	± 0.0200
0.652	0.8834	± 0.0689	0.652	0.1352	± 0.0202
0.741	0.8252	± 0.0687	0.741	0.1320	± 0.0201
LBIDA measurements					
1.60	0.9573	± 0.0239	1.97	0.1968	± 0.0072
7.12	0.8694	± 0.0274	7.48	0.3206	± 0.0075
23.7	0.8167	± 0.0138	24.8	0.2634	± 0.0087
46. 3	0.8344	± 0.0174	46.9	0.0375	± 0.0070

See Table 2Bi for footnote 1

TABLE 3Ai ET retention: Pilot experiment: Subject 1, 3-µm particles inhaled at rest

Time since intake	ET retention	± 95% uncertainty[1]	Nose blow clearance	± 95% uncertainty[2]
Hours	IETD fraction	IETD fraction	IETD fraction	IETD fraction
RPCDA measurements[4]				
0.105	0.9418	± 0.2462		
0.165	0.9844	± 0.2071		
0.215	0.9991	± 0.2588		
0.279	0.9349	± 0.1642		
0.368	0.9274	± 0.1637		
0.456	0.9174	± 0.1656		
0.545	0.8754	± 0.1666		
0.633	0.9246	± 0.1697		
0.722	0.8907	± 0.1712		
LBIDA measurements				
1.29	0.8979	± 0.0352		
1.73	0.8704	± 0.0341		
3.51	0.8790	± 0.0345		
4.59	0.7534	± 0.0295		
6.26	0.6709	± 0.0263		
9.96			*0.0161*	*± 0.0045*
19.3			*0.0275*	*± 0.0027*
22.6	0.0499	± 0.0049		

See Table 2Ai for footnotes 1,2 and 3

4: Plastic bar to limit forward movement of subject's head not implemented.

TABLE 3Bi Lung and GI tract retention: Pilot: Subject 1: 3-µm particles inhaled at rest

Lung	ILD = 0.9067 IETD		GI tract		
Time since intake	Lung retention	95% uncertainty[1]	Time since intake	GI tract content	95% uncertainty[1]
Hours	ILD	ILD	Hours	IETD	IETD
RPCDA measurements					
0.105	0.7512	± 0.4787	0.105	-0.0222	± 0.1154
0.165	1.0636	± 0.4029	0.165	0.0745	± 0.1463
0.215	1.0092	± 0.5036	0.215	0.1715	± 0.1227
0.279	1.1684	± 0.3197	0.279	0.1299	± 0.0776
0.368	1.1453	± 0.3186	0.368	0.0531	± 0.0770
0.456	1.0935	± 0.3223	0.456	0.0708	± 0.0780
0.545	0.9481	± 0.3243	0.545	0.0696	± 0.0786
0.633	0.9792	± 0.3304	0.633	0.1190	± 0.0803
0.722	1.1745	± 0.3333	0.722	0.0856	± 0.0807
LBIDA measurements					
2.29	0.8978	± 0.0182	2.93	0.1311	± 0.0059
5.19	0.9929	± 0.0229	5.69	0.1432	± 0.0077

See Table 2Bi for footnote 1

TABLE 3Aii ET retention: Main experiment: Subject 1: 3-µm particles inhaled at rest

Time since intake	ET retention	± 95% uncertainty[1]	Nose blow clearance	± 95% uncertainty[2]
Hours	IETD fraction	IETD fraction	IETD fraction	IETD fraction
RPCDA measurements				
0.094	0.8533	± 0.0552		
0.154	0.8383	0.0552		
0.214	0.8284	0.0554		
0.289	0.8114	0.0430		
0.378	0.7953	0.0431		
0.468	0.8214	0.0431		
0.557	0.8106	0.0430		
0.647	0.7831	0.0432		
0.736	0.7902	0.0432		
LBIDA measurements				
1.13[3]	0.7683	± 0.0182		
2.66[3]	0.7736	± 0.0185		
5.78[3]	0.4249	± 0.0191		
7.05[3]	0.3864	± 0.0193		
20.2			*0.0377*	*± 0.0022*
21.7[3]	0.1950	± 0.0082		
43.7			*0.0065*	*± 0.0005*
44.0			*0.0028*	*± 0.0003*
47.6[3]	0.0721	± 0.0100		
59.5			*0.0004*	*± 0.0001*
70.8[4]	0.0648	± 0.0127		
124.3[3]	0.0486	± 0.0218		

See Table 2Ai for footnotes 1,2 and 3

4. Not clear if lead impregnated vest was or was not worn.

TABLE 3Bii Lung and GI tract retention: Main: Subject 1; 3-µm particles inhaled at rest

Lung	ILD = 1.7181 IETD		GI tract		
Time since intake	Lung retention	95% uncertainty[1]	Time since intake	GI tract content	95% uncertainty[1]
Hours	ILD	ILD	Hours	IETD	IETD
RPCDA measurements					
0.094	1.0046	± 0.0755	0.094	0.1297	± 0.0337
0.154	0.9621	± 0.0755	0.154	0.1698	± 0.0340
0.214	1.0155	± 0.0759	0.214	0.1716	± 0.0341
0.289	1.0534	± 0.0590	0.289	0.1753	± 0.0265
0.378	1.0152	± 0.0591	0.378	0.2321	± 0.0268
0.468	1.0089	± 0.0591	0.468	0.2253	± 0.0267
0.557	0.9342	± 0.0589	0.557	0.2433	± 0.0268
0.647	1.0032	± 0.0593	0.647	0.2562	± 0.0270
0.736	0.9958	± 0.0593	0.736	0.2514	± 0.0269
LBIDA measurements					
1.63	0.9930	± 0.0165	1.95	0.2538	± 0.0285
6.18	1.0072	± 0.0145	6.55	0.3075	± 0.0250
22.1	0.9740	± 0.0148	22.5	0.3097	± 0.0256
48.2	0.9482	± 0.0142	48.6	0.1414	± 0.0244
71.3	0.9252	± 0.0151	71.7	0.0747	± 0.0260
124.8	0.9207	± 0.0174	125.1	0.0923	± 0.0300

See Table 2Bi for footnote 1

TABLE 3Aiii ET retention: Pilot experiment: Subject 2, 3-µm particles inhaled while at rest

Time since intake	ET retention	± 95% uncertainty[1]	Nose blow clearance	± 95% uncertainty[2]
Hours	IETD fraction	IETD fraction	IETD fraction	IETD fraction
RPCDA measurements[4]				
0.115	0.8206	± 0.0935		
0.175	0.7923	± 0.0765		
0.235	0.7492	± 0.0936		
0.289	0.6813	± 0.0600		
0.378	0.6435	± 0.0606		
0.466	0.6051	± 0.0614		
0.555	0.6022	± 0.0616		
0.643	0.5188	± 0.0624		
0.732	0.4618	± 0.0629		
LBIDA measurements				
0.951			*0.1536*	*± 0.0083*
1.33	0.3051	± 0.0120		
1.75	0.3141	± 0.0123		
3.56	0.3151	± 0.0123		
5.12	0.2915	± 0.0114		
17.5			*0.0117*	*± 0.0009*
20.6	0.0706	± 0.0042		

See Table 2Ai for footnotes 1,2 and 3

4: Plastic bar to limit forward movement of subject's head not implemented.

TABLE 3Biii Lung and GI tract retention: Pilot, Subject 2; 3-µm aerosol inhaled at rest

Lung	ILD = 1.1900 IETD		GI tract		
Time since intake	Lung retention	95% uncertainty[1]	Time since intake	GI tract content	95% uncertainty[1]
Hours	ILD	ILD	Hours	IETD	IETD
RPCDA measurements					
0.115	0.9968	± 0.1432	0.115	0.1769	± 0.0373
0.175	0.9650	± 0.1759	0.175	0.1808	± 0.0459
0.235	0.9233	± 0.1436	0.215	0.1705	± 0.0374
0.289	1.0255	± 0.0923	0.289	0.1826	± 0.0240
0.378	1.0190	± 0.0932	0.378	0.1951	± 0.0243
0.466	1.0555	± 0.0945	0.466	0.2120	± 0.0247
0.555	0.9388	± 0.0948	0.555	0.2304	± 0.0250
0.643	1.0160	± 0.0964	0.643	0.2430	± 0.0253
0.732	1.0257	± 0.0972	0.732	0.2356	± 0.0255
LBIDA measurements					
2.25	1.0359	± 0.0138	2.75	0.1213	± 0.0041
3.97	0.9503	± 0.0139	4.65	0.2164	± 0.0061
21.1	0.9527	± 0.0229	22.2	0.2327	± 0.0257

See Table 2Bi for footnote 1

TABLE 3Aiv Main experiment: Subject 2, 3-µm particles inhaled while sitting at rest

Time since intake	ET retention	± 95% uncertainty[1]	Nose blow clearance	± 95% uncertainty[2]
Hours	IETD fraction	IETD fraction	IETD fraction	IETD fraction
		RPCDA measurements[4]		
0.111	0.7721	± 0.0473		
0.171	0.7565	± 0.0388		
0.232	0.6113	± 0.0468		
0.287	0.6130	± 0.0296		
0.377	0.6493	± 0.0296		
0.467	0.6886	± 0.0299		
0.557	0.6041	± 0.0296		
0.647	0.5320	± 0.0296		
0.736	0.5208	± 0.0295		
		LBIDA measurements		
1.45	0.6293	± 0.0141		
4.11			*0.1268*	*± 0.0068*
7.86			*0.0607*	*± 0.0033*
8.04	0.4287	± 0.0151		
18.4			*0.0272*	*± 0.0015*
19.5			*0.0079*	*± 0.0005*
20.0	0.1526	± 0.0172		
28.0			*0.0033*	*± 0.0003*
28.7	0.0707	± 0.0188		
30.8			*0.0117*	*± 0.0006*
43.5			*0.0024*	*± 0.0002*
44.1	0.0530	± 0.0220		
51.0	0.0402	± 0.0235		
68.8			*0.0010*	*± 0.0002*
117.2	0.0718	± 0.0463		

See Table 2Ai for footnotes 1,2 and 3

4. Plastic bar to limit forward movement of subject's head not used.

TABLE 3Biv Lung and GI tract retention: Main: Subject 2; 3-µm particles inhaled sitting

Lung	ILD = 1.6234 IETD		GI tract		
Time since intake	Lung retention	± 95% uncertainty[1]	Time since intake	GI tract content	± 95% uncertainty[1]
Hours	ILD	ILD	Hours	IETD	IETD
RPCDA measurements					
0.111	0.9423	± 0.0831	0.111	0.2332	± 0.0311
0.171	0.9927	± 0.0838	0.171	0.2399	± 0.0382
0.232	0.9746	± 0.0675	0.232	0.1289	± 0.0303
0.287	1.0008	± 0.0427	0.287	0.0922	± 0.0190
0.377	0.9630	± 0.0426	0.377	0.0981	± 0.0190
0.467	1.0464	± 0.0431	0.467	0.1297	± 0.0193
0.557	1.0203	± 0.0427	0.557	0.0586	± 0.0189
0.647	1.0248	± 0.0427	0.647	0.0582	± 0.0189
0.736	0.9948	± 0.0427	0.736	0.0696	± 0.0190
LBIDA measurements					
2.00	1.0177	± 0.0113	2.45	0.0909	± 0.0026
8.54	0.8172	± 0.0096	8.92	0.3177	± 0.0060
20.9	0.8351	± 0.0100	22.0	0.3603	± 0.0068
29.1	0.8329	± 0.0102	29.4	0.4192	± 0.0078
44.8	0.7474	± 0.0098	43.8	0.4983	± 0.0092
51.4	0.8380	± 0.0108	51.8	0.0970	± 0.0036
117.6	0.7805	± 0.0131	118.0	0.0136	± 0.0045

See Table 2Bi for footnote 1

TABLE 3Av ET retention: Main experiment: Subject 3, 3-µm particles inhaled at rest

Time since intake	ET retention	± 95% uncertainty[1]	Nose blow clearance	± 95% uncertainty[2]
Hours	IETD fraction	IETD fraction	IETD fraction	IETD fraction
RPCDA measurements[4]				
0.107	0.9966	± 0.0876		
0.167	0.9450	± 0.0862		
0.227	1.0503	± 0.0868		
0.302	0.9980	± 0.0672		
0.392	0.9187	± 0.0674		
0.481	0.9157	± 0.0675		
0.571	0.8498	± 0.0675		
0.660	0.8537	± 0.0676		
0.750	0.8563	± 0.0675		
LBIDA measurements				
1.35	0.9280	± 0.0177		
RPCDA measurements				
3.86	0.8655	± 0.0485		
LBIDA measurements				
4.22	0.7771	± 0.0141		
8.92	0.8198	± 0.0141		
22.0	0.6598	± 0.0133		
RPCDA measurements				
26.8	0.3069	± 0.0587		
LBIDA measurements				
32.4	0.4890	± 0.0148		
45.7	0.3457	± 0.0169		
48.1			*0.2128*	*± 0.0104*
54.2			*0.0487*	*± 0.0028*
56.0	0.1363	± 0.0188		
71.6			*0.0017*	*± 0.0004*
99.8	0.0258	± 0.0294		

See Table 2Ai for footnotes 1,2 and 3

4. Plastic bar to limit forward movement of subject's head not implemented.

TABLE 3Bv Lung and GI tract retention: Main: Subject 3; 3-µm particles inhaled at rest

Lung	ILD = 1.3423 IETD		GI tract		
Time since intake	Lung retention	95% uncertainty[1]	Time since intake	GI tract content	95% uncertainty[1]
Hours	ILD	ILD	Hours	IETD	IETD
		RPCDA measurements			
0.107	1.0326	± 0.1835	0.107	0.0619	± 0.0658
0.167	0.9485	± 0.1495	0.167	0.0719	± 0.0537
0.227	1.0206	± 0.1504	0.227	0.1250	± 0.0813
0.302	1.0276	± 0.1166	0.302	0.1149	± 0.0420
0.392	1.1244	± 0.1173	0.392	0.1470	± 0.0423
0.481	1.1239	± 0.1173	0.481	0.1404	± 0.0423
0.571	1.1396	± 0.1174	0.571	0.1263	± 0.0422
0.660	1.1902	± 0.1177	0.660	0.1311	± 0.0423
0.750	1.0690	± 0.1175	0.750	0.1584	± 0.0424
		LBIDA measurements			
1.85	1.0965	± 0.0157	2.28	0.0045	± 0.0037
			3.20	0.1539	± 0.0059
		RPCDA measurement			
3.86	1.1391	± 0.1656	3.86	0.1880	± 0.0599
		LBIDA measurements			
5.65	0.9912	± 0.0149			
9.42	0.9377	± 0.0146	9.9	0.0916	± 0.0052
22.6	0.9506	± 0.0156	23.1	0.1894	± 0.0072
		RPCDA measurement			
26.8	1.1625	± 0.2019	26.8	0.1075	± 0.0726
		LBIDA measurements			
33.1	0.9424	± 0.0163	33.5	0.2498	± 0.0086
46.1	0.9139	± 0.0170	46.5	0.3256	± 0.0104
56.6	0.8965	± 0.0178	57.2	0.2167	± 0.0095
100.3	0.9058	± 0.0232	100.8	0.1524	± 0.0121

See Table 2Bi for footnote 1

TABLE 3Avi ET retention: Pilot experiment: Subject 4, 3-µm particles inhaled at rest

Time since intake	ET retention	± 95% uncertainty[1]	Nose blow clearance	± 95% uncertainty[2]
Hours	IETD fraction	IETD fraction	IETD fraction	IETD fraction
RPCDA measurements[4]				
0.088	0.6185	± 0.1593		
0.147	0.6987	± 0.1613		
0.207	0.7290	± 0.1609		
0.281	0.6910	± 0.1972		
0.370	0.6377	± 0.1261		
0.459	0.6812	± 0.1267		
0.547	0.7372	± 0.1286		
0.636	0.6458	± 0.1300		
0.724	0.6133	± 0.1315		
LBIDA measurements				
1.09	0.5175	± 0.2598		
1.82			0.0662	± 0.0037
1.91			0.0320	± 0.0019
2.81	0.3775	± 0.0218		
3.49			0.0143	± 0.0010
4.06	0.3385	± 0.0170		
4.41			0.0106	± 0.0009
7.89	0.2676	± 0.0157		
8.57			0.0166	± 0.0013
8.99			0.0174	± 0.0016
16.8			0.0168	± 0.0015
17.1			0.0156	± 0.0016
17.3			0.0079	± 0.0013
17.5			0.0038	± 0.0016
18.4			0.0021	± 0.0012
18.6	0.1276	± 0.0181		
19.0			AND5	< 0.00386
20.8			0.0052	± 0.0017

See Table 2Ai for footnotes 1,2 and 3

4. Plastic bar to limit forward movement of subject's head not implemented.

5. AND = Activity not detected on nose blow sample

6. There is a 95% probability that sample activity is less than the given minimal detectable IETD fraction

TABLE 3Bvi Lung and GI tract retention: Pilot: Subject 4: 3-µm particles inhaled at rest

Lung	ILD = 1.3990 IETD		GI tract		
Time since intake	Lung retention	95% uncertainty[1]	Time since intake	GI tract content	95% uncertainty[1]
Hours	ILD	ILD	Hours	IETD	IETD
RPCDA measurements					
0.088	1.0199	± 0.1985	0.088	0.2637	± 0.0586
0.147	1.0964	± 0.1160	0.147	0.2871	± 0.0594
0.207	0.8786	± 0.1376	0.207	0.2975	± 0.0595
0.281	0.9577	± 0.1570	0.281	0.3027	± 0.0466
0.370	0.8466	± 0.1578	0.370	0.3117	± 0.0469
0.459	1.0444	± 0.1602	0.459	0.2593	± 0.0472
0.547	0.9190	± 0.1618	0.547	0.3461	± 0.0482
0.636	0.9702	± 0.1639	0.636	0.3603	± 0.0488
0.724	1.0556	± 0.1653	0.724	0.2945	± 0.0489
LBIDA measurements					
1.56	1.0223	± 0.0157	2.06	0.0000	± 0.0039
4.56	1.0109	± 0.0182	5.06	0.0815	± 0.0067
7.4	1.0147	± 0.0216	6.93	0.0514	± 0.0076
19.1	0.9450	± 0.0553	19.6	0.3527	± 0.0347

See Table 2Bi for footnote 1

TABLE 3Avii ET retention: Main experiment: Subject 4: 3-µm particles inhaled at rest

Time since intake	ET retention	± 95% uncertainty[1]	Nose blow clearance	± 95% uncertainty[2]
Hours	IETD fraction	IETD fraction	IETD fraction	IETD fraction
RPCDA measurements				
0.091	0.7116	± 0.0946		
0.151	0.7963	± 0.0953		
0.211	0.8381	± 0.0955		
0.285	0.8068	± 0.0740		
0.375	0.8235	± 0.0741		
0.464	0.8203	± 0.0742		
0.553	0.8006	± 0.0742		
0.642	0.8001	± 0.0742		
0.731	0.7678	± 0.0741		
LBIDA measurements				
1.21[3]	0.6772	± 0.1453		
1.64			*0.0802*	*± 0.0045*
2.61			*0.0915*	*± 0.0050*
2.86[3]	0.4902	± 0.0138		
3.61			*0.0015*	*± 0.0004*
3.94			*0.0848*	*± 0.0047*
5.61[3]	0.3935	± 0.0107		
7.03[3]	0.3458	± 0.0093		
7.11			*0.0292*	*± 0.0018*
8.27			*0.0263*	*± 0.0016*
9.77			*0.0484*	*± 0.0028*
13.8			*0.0507*	*± 0.0029*
16.9			*0.0309*	*± 0.0018*
17.3			*0.0028*	*± 0.0004*
17.6			*0.0045*	*± 0.0005*
18.8			*0.0053*	*± 0.0006*
19.2[3]	0.0923	± 0.0090		
23.1			*0.0037*	*± 0.0003*
26.4			*0.0037*	*± 0.0005*
28.8			*0.0025*	*± 0.0004*
30.3			*0.0048*	*± 0.0006*
31.3			*AND*[4]	*<0.0012*[5]
33.3			*0.0024*	*± 0.0004*
41.9			*0.0006*	*± 0.0003*
43.0[3]	0.0646	± 0.0085		
45.3			*0.0010*	*± 0.0003*
49.5			*AND*	<0.0012
51.4			*AND*	<0.0007
54.3			*AND*	<0.0010
57.3			*0.0001*	*± 0.00004*
57.8			*AND*	*<0.0013*

TABLE 3Avii ET retention: Main experiment: Subject 4: 3-µm particles inhaled at rest

Time since intake	ET retention	± 95% uncertainty[1]	Nose blow clearance	± 95% uncertainty[2]
Hours	IETD fraction	IETD fraction	IETD fraction	IETD fraction
65.7			*0.0013*	*± 0.0001*
67.0[3]	0.0689	± 0.0095		
115.5[3]	0.0290	± 0.0094		

See Table 2Ai for footnotes 1,2 and 3

4. AND = Activity not detected on nose blow sample

5. There is a 95% probability that sample activity is less than the given minimal detectable IETD fraction

TABLE 3Bvii Lung and GI tract retention: Main: Subject 4: 3-µm particles inhaled at rest

Lung	ILD = 1.9369 IETD		GI tract		
Time since intake	Lung retention	± 95% uncertainty[1]	Time since intake	GI tract content	± 95% uncertainty[1]
Hours	ILD	ILD	Hours	IETD	IETD
RPCDA measurements					
0.091	0.9781	± 0.2045	0.091	0.0567	± 0.0599
0.151	0.9133	± 0.2044	0.151	0.1820	± 0.0609
0.211	1.0024	± 0.2044	0.211	0.1877	± 0.0610
0.286	1.0325	± 0.0916	0.286	0.1343	± 0.0471
0.375	0.9981	± 0.0916	0.375	0.1517	± 0.0472
0.464	1.0556	± 0.0917	0.464	0.1092	± 0.0470
0.553	1.0355	± 0.0917	0.553	0.1151	± 0.0471
0.642	1.0040	± 0.0917	0.642	0.1182	± 0.0471
0.731	0.9628	± 0.0917	0.731	0.1475	± 0.0473
LBIDA measurements					
1.83	0.9520	± 0.0032	2.28	0.1993	± 0.0063
6.13	0.9220	± 0.0034	6.51	0.2449	± 0.0065
19.6	0.8734	± 0.0039	20.1	0.2526	± 0.0075
43.4	0.8552	± 0.0049	43.8	0.1558	± 0.0096
67.4	0.8141	± 0.0063	67.9	0.1803	± 0.0122
115.9	0.8039	± 0.0103	116.3	0.1971	± 0.0200

See Table 2Bi for footnote 1

TABLE 3Aviii ET retention: Main experiment: Subject 5: 3-µm particles inhaled at rest

Time since intake	ET retention	± 95% uncertainty[1]	Nose blow clearance	± 95% uncertainty[2]
Hours	IETD fraction	IETD fraction	IETD fraction	IETD fraction
RPCDA measurements				
0.090	0.9060	± 0.0484		
0.150	0.9004	± 0.0395		
0.210	0.8989	± 0.0395		
0.284	0.9124	± 0.0306		
0.374	0.9234	± 0.0308		
0.463	0.9009	± 0.0307		
0.552	0.9042	± 0.0307		
0.641	0.9042	± 0.0306		
0.730	0.8993	± 0.0307		
LBIDA measurements				
1.11[3]	0.6413	± 0.0120		
2.63[3]	0.5293	± 0.0120		
4.09			*0.1523*	*± 0.0081*
6.21[3]	0.2900	± 0.0127		
7.78[3]	0.3095	± 0.0127		
9.17			*0.0646*	*± 0.0035*
17.5			*0.0591*	*± 0.0024*
17.8			*0.0195*	*± 0.0011*
20.2[3]	0.0460	± 0.0074		
28.2			*0.0071*	*± 0.0044*
46.1[3]	0.0190	± 0.0145		
66.7[3]	0.0019	± 0.0235		
142.2[3]	0.0035	± 0.0257		

See Table 2Ai for footnotes 1,2 and 3

TABLE 3Bviii Lung and GI tract retention: Main: Subject 5; 3-µm particles inhaled at rest

Lung	ILD = 0.9900 IETD		GI tract		
Time since intake	Lung retention	± 95% uncertainty[1]	Time since intake	GI tract content	± 95% uncertainty[1]
Hours	ILD	ILD	Hours	IETD	IETD
RPCDA measurements					
0.090	0.9750	± 0.1151	0.090	0.0970	± 0.0281
0.150	0.9742	± 0.0939	0.150	0.0927	± 0.0229
0.210	0.9898	± 0.0940	0.210	0.0905	± 0.0229
0.284	0.9664	± 0.0728	0.284	0.0992	± 0.0178
0.374	1.0308	± 0.0731	0.374	0.0995	± 0.0178
0.463	1.0106	± 0.0729	0.463	0.0951	± 0.0178
0.552	1.0184	± 0.0729	0.552	0.0916	± 0.0177
0.641	0.9690	± 0.0728	0.641	0.1009	± 0.0178
0.730	1.0364	± 0.0730	0.730	0.0950	± 0.0178
LBIDA measurements					
1.63	0.8410	± 0.0028	2.26	0.1142	± 0.0028
6.80	0.7529	± 0.0029	6.50	0.2972	± 0.0029
20.7	0.7339	± 0.0034	20.06	0.2795	± 0.0033
46.5	0.7080	± 0.0044	43.8	0.0475	± 0.0042
67.05	0.7038	± 0.0054	67.8	0.0408	± 0.0054
141.3	0.6573	± 0.0115	141.7	0.0374	± 0.0114

See Table 2Bi for footnote 1

TABLE 3Aix ET retention: Main experiment: Subject 6, 3-µm particles inhaled at rest

Time since intake	ET retention	± 95% uncertainty[1]	Nose blow clearance	± 95% uncertainty[2]
Hours	IETD fraction	IETD fraction	IETD fraction	IETD fraction
		RPCDA measurements[4]		
0.146	0.7635	± 0.0795		
0.207	0.6025	± 0.0791		
0.282	0.6728	± 0.0501		
0.372	0.7306	± 0.0504		
0.461	0.7522	± 0.0503		
0.551	0.8742	± 0.0499		
0.641	0.8742	± 0.0501		
0.652			*0.2355*	*± 0.0127*
0.731	0.6986	± 0.0500		
0.819			*0.0855*	*± 0.0047*
		LBIDA measurements		
1.08	0.5219	± 0.0198		
3.15			*0.0381*	*± 0.0022*
3.57			*0.0453*	*± 0.0025*
3.74			*0.0320*	*± 0.0018*
4.32			*0.0243*	*± 0.0014*
6.69	0.1213	± 0.0123		
8.82			*0.0095*	*± 0.0006*
9.07			*0.0070*	*± 0.0005*
16.9			*0.0086*	*± 0.0006*
17.8			*0.0040*	*± 0.0003*
18.3	0.0526	± 0.0123		
21.6			0.0006	± 0.0002
22.1			*AND*[5]	*<0.0005*[6]
23.1			*AND*	*<0.0004*
23.8			0.0002	± 0.0001
26.0	0.0546	± 0.0129		
26.8			*AND*	*<0.0004*
28.1			*AND*	*<0.0004*
31.8			*AND*	*<0.0004*
32.0			*AND*	*<0.0006*
40.9			*AND*	*<0.0004*
42.44	0.0206	± 0.0153		
66.48	0.0164	± 0.0194		

See Table 2Ai for footnotes 1,2 and 3

4. Plastic bar to limit forward movement of subject's head not implemented.

5. AND = Activity not detected on nose blow sample

6. There is a 95% probability that sample activity is less than the given minimal detectable IETD fraction

TABLE 3Bix Lung and GI tract retention: Main: Subject 6; 3-µm particles inhaled at rest

Lung	ILD = 1.5371 IETD		GI tract		
Time since intake	Lung retention	± 95% uncertainty[1]	Time since intake	GI tract content	± 95% uncertainty[1]
Hours	ILD	ILD	Hours	IETD	IETD
RPCDA measurements					
0.146	1.0079	± 0.0984	0.146	0.2300	± 0.0408
0.207	0.9780	± 0.2954	0.207	0.2686	± 0.0410
0.282	1.0160	± 0.0763	0.282	0.2264	± 0.0316
0.372	1.0713	± 0.0768	0.372	0.2814	± 0.0320
0.461	1.0663	± 0.0766	0.461	0.2522	± 0.0318
0.551	0.9750	± 0.0757	0.551	0.1344	± 0.0311
0.641	0.9460	± 0.0760	0.641	0.2334	± 0.0316
0.731	0.9338	± 0.0762	0.731	0.2720	± 0.0318
LBIDA measurements					
1.58	0.8084	± 0.0109	2.09	0.2310	± 0.0057
6.21	0.4771	± 0.0079	5.39	0.7803	± 0.0137
18.8	0.3809	± 0.0075	19.3	0.9776	± 0.0169
25.4	0.4466	± 0.0084	24.9	0.4833	± 0.0099
43.3	0.4636	± 0.0094	43.7	0.0085	± 0.0037
67.2	0.4885	± 0.0110	67.6	-0.0139	± 0.0043

See Table 2Bi for footnote 1

TABLE 3Ax ET retention: Main experiment: Subject 7, 3-µm particles inhaled at rest

Time since intake	ET retention	± 95% uncertainty[1]	Nose blow clearance	± 95% uncertainty[2]
Hours	IETD fraction	IETD fraction	IETD fraction	IETD fraction
		RPCDA measurements		
0.088	0.7026	± 0.0513		
0.149	0.7169	± 0.0515		
0.209	0.6861	± 0.0517		
0.284	0.6861	± 0.0400		
0.373	0.6646	± 0.0401		
0.461	0.6390	± 0.0402		
0.551	0.6312	± 0.0403		
0.640	0.6444	± 0.0403		
0.729	0.6357	± 0.0403		
		LBIDA measurements		
1.28[3]	0.5437	± 0.0180		
2.59[3]	0.4389	± 0.0100		
6.34[3]	0.3492	± 0.0078		
7.63[3]	0.3391	± 0.0057		
18.3			*0.0045*	*± 0.0003*
19.9[3]	0.1565	± 0.0049		
43.6[3]	0.0483	± 0.0081		
68.3[3]	0.0550	± 0.0095		
165.7[3]	0.0657	± 0.0135		

See Table 2Ai for footnotes 1,2 and 3

TABLE 3Bx Lung and GI tract retention: Main: Subject 7; 3-µm particles inhaled at rest

Lung	ILD = 1.7021 IETD		GI tract		
Time since intake	Lung retention	± 95% uncertainty[1]	Time since intake	GI tract content	± 95% uncertainty[1]
Hours	ILD	ILD	Hours	IETD	IETD
RPCDA measurements					
0.088	0.9717	± 0.0590	0.088	0.2693	± 0.0254
0.149	1.0415	± 0.0727	0.149	0.2585	± 0.0311
0.209	1.0027	± 0.0729	0.209	0.3195	± 0.0316
0.284	1.0113	± 0.0565	0.284	0.3238	± 0.0245
0.373	0.9918	± 0.0567	0.373	0.3630	± 0.0247
0.461	1.0062	± 0.0569	0.461	0.3811	± 0.0249
0.551	0.9945	± 0.0570	0.551	0.4013	± 0.0250
0.640	0.9917	± 0.0571	0.640	0.4161	± 0.0251
0.729	0.9949	± 0.0570	0.729	0.3929	± 0.0250
LBIDA measurements					
1.69	0.8846	± 0.0135	2.16	0.5191	± 0.0071
6.83	0.7697	± 0.0111	7.18	0.7160	± 0.0129
20.3	0.7871	± 0.0127	20.7	0.5579	± 0.0106
44.1	0.7727	± 0.0107	44.4	0.3548	± 0.0102
68.8	0.7255	± 0.0107	69.1	0.2316	± 0.0093
166.1	0.7338	± 0.0220	166.5	0.0411	± 0.0135

See Table 2Bi for footnote 1

TABLE 3Axi ET retention: Main experiment: Subject 8, 3-µm particles inhaled at rest

Time since intake	ET retention	± 95% uncertainty[1]	Nose blow clearance	± 95% uncertainty[2]
Hours	IETD fraction	IETD fraction	IETD fraction	IETD fraction
RPCDA measurements				
0.090	0.8537	± 0.0313		
0.151	0.8403	± 0.0314		
0.211	0.8182	± 0.0315		
0.286	0.8182	± 0.0243		
0.376	0.8117	± 0.0243		
0.466	0.8062	± 0.0243		
0.556	0.7996	± 0.0244		
0.645	0.7934	± 0.0243		
0.735	0.7816	± 0.0243		
LBIDA measurements				
1.47[3]	0.7800	± 0.0096		
3.13[3]	0.7562	± 0.0053		
4.48			*0.2673*	*± 0.0143*
5.85	0.5308	± 0.0041		
6.01			*0.0720*	*± 0.0039*
7.42	0.4042	± 0.0041		
21.3	0.3324	± 0.0049		
22.7			*0.0425*	*± 0.0023*
23.7			*0.0313*	*± 0.0017*
30.1			*0.0261*	*± 0.0014*
46.6	0.1520	± 0.0063		
142.6	0.1072	± 0.0167		

See Table 2Ai for footnotes 1,2 and 3

TABLE 3Bxi Lung and GI tract retention: Main: Subject 8; 3-µm particles inhaled at rest

Lung	ILD = 1.0633 IETD		GI tract		
Time since intake	Lung retention	± 95% uncertainty[1]	Time since intake	GI tract content	± 95% uncertainty[1]
Hours	ILD	ILD	Hours	IETD	IETD
RPCDA measurements					
0.090	0.9845	± 0.0693	0.090	0.1612	± 0.0192
0.151	1.0328	± 0.2090	0.151	0.1713	± 0.0580
0.211	0.9867	± 0.0698	0.211	0.2111	± 0.0196
0.286	1.0026	± 0.0540	0.286	0.1905	± 0.0151
0.376	0.9901	± 0.0539	0.376	0.1932	± 0.0151
0.466	0.9823	± 0.0538	0.466	0.1837	± 0.0150
0.556	1.0078	± 0.0540	0.556	0.2006	± 0.0151
0.645	1.0035	± 0.0540	0.645	0.1996	± 0.0151
0.735	1.0113	± 0.0541	0.735	0.2002	± 0.0151
LBIDA measurements					
2.18	0.9902	± 0.0115	2.43	0.2273	± 0.0038
6.43	1.0149	± 0.0093	6.88	0.1767	± 0.0068
21.7	0.8491	± 0.0109	22.6	0.2220	± 0.0057
46.2	1.0258	± 0.0092	45.9	0.1336	± 0.0054
142.1	1.0004	± 0.0190	141.7	0.0432	± 0.0103

See Table 2Bi for footnote 1

TABLE 3Axii ET retention: Main experiment: Subject 9, 3-µm particles inhaled at rest

Time since intake	ET retention	± 95% uncertainty[1]	Nose blow clearance	± 95% uncertainty[2]
Hours	IETD fraction	IETD fraction	IETD fraction	IETD fraction
RPCDA measurements				
0.086	0.8151	± 0.0351		
0.146	0.8552	± 0.0431		
0.207	0.9035	± 0.0432		
0.282	0.9035	± 0.0336		
0.371	0.9174	± 0.0335		
0.461	0.9556	± 0.0335		
0.550	0.9540	± 0.0336		
0.639	0.9038	± 0.0335		
0.729	0.9345	± 0.0336		
LBIDA measurements				
1.18[3]	0.6945	± 0.0141		
2.66[3]	0.5792	± 0.0078		
5.73[3]	0.4183	± 0.0147		
7.06[3]	0.4096	± 0.0149		
17.6			*0.0452*	*± 0.0018*
19.81[3]	0.0655	± 0.0171		
41.4			*0.0007*	*± 0.0001*
44.6[3]	0.0285	± 0.0220		
68.1[3]	0.0020	± 0.0278		

See Table 2Ai for footnotes 1,2 and 3

TABLE 3Bxii Lung and GI tract retention: Main: Subject 9; 3-µm particles inhaled at rest

Lung	ILD =2.7158 IETD		GI tract		
Time since intake	Lung retention	± 95% uncertainty[1]	Time since intake	GI tract content	± 95% uncertainty[1]
Hours	ILD	ILD	Hours	IETD	IETD
		RPCDA measurements			
0.086	0.9932	± 0.0467	0.086	0.0659	± 0.0290
0.146	0.9881	± 0.0381	0.146	0.0756	± 0.0237
0.207	1.0193	± 0.0382	0.207	0.0675	± 0.0237
0.282	1.0347	± 0.0297	0.282	0.0712	± 0.0184
0.371	0.9926	± 0.0296	0.371	0.0837	± 0.0184
0.461	0.9811	± 0.0295	0.461	0.0765	± 0.0184
0.550	0.9991	± 0.0296	0.550	0.0805	± 0.0184
0.639	1.0031	± 0.0296	0.639	0.0770	± 0.0184
0.729	0.9984	± 0.0296	0.729	0.0921	± 0.0185
		LBIDA measurements			
1.66	0.9739	± 0.0066	2.20	0.1318	± 0.0056
6.16	0.9826	± 0.0054	6.60	0.4301	± 0.0101
20.3	0.8759	± 0.0062	20.7	0.7376	± 0.0083
44.2	0.8646	± 0.0052	50.2	0.5122	± 0.0084
67.7	0.8679	± 0.0052	67.4	0.1536	± 0.0071

See Table 2Bi for footnote 1

TABLE 4Ai ET retention: Main: Subject 1, 3-µm particles inhaled while performing light exercise

Time since intake	ET retention	± 95% uncertainty[1]	Nose blow clearance	± 95% uncertainty[2]
Hours	IETD fraction	IETD fraction	IETD fraction	IETD fraction
RPCDA measurements				
0.107	0.7991	± 0.0360		
0.168	0.8118	± 0.0365		
0.228	0.7579	± 0.0447		
0.248	0.7476	± 0.0282		
0.372	0.7396	± 0.0283		
0.462	0.7283	± 0.0283		
0.552	0.7273	± 0.0284		
0.642	0.7236	± 0.0284		
0.731	0.7196	± 0.0284		
LBIDA measurements				
1.19[3]	0.6041	± 0.0176		
2.70[3]	0.5350	± 0.0161		
5.37[3]	0.3441	± 0.0132		
6.58[3]	0.3453	± 0.0132		
9.10			*0.0158*	*± 0.0010*
17.6			*0.0391*	*± 0.0016*
19.8[3]	0.0749	± 0.0110		
33.9			*0.0066*	*± 0.0005*
41.7			*0.00023*	*± 0.00007*
41.8			*0.00023*	*± 0.00008*
43.7[3]	0.0257	± 0.0088		
54.4			*0.0010*	*± 0.0002*
66.1			*AND[4]*	*< 0.0002[5]*
67.4[3]	0.0156	± 0.0073		
139.4[3]	0.0118	± 0.0059		

See Table 2Ai for footnotes 1,2 and 3

4: AND = Activity not detected on nose blow sample

5: There is a 95% probability that sample activity is less than the given minimal detectable IETD fraction

TABLE 4Bi Lung and GI tract retention: Main experiment: Subject 1; 3-μm particles inhaled while performing light exercise

Lung	ILD =0.6576 IETD		GI tract		
Time since intake	Lung retention	± 95% uncertainty[1]	Time since intake	GI tract content	± 95% uncertainty[1]
Hours	ILD	ILD	Hours	IETD	IETD
RPCDA measurements					
0.107	± 0.9087	0.1285	0.107	0.1808	± 0.0213
0.168	± 1.0913	0.1954	0.168	0.2362	± 0.0218
0.228	± 1.2152	0.1600	0.228	0.2113	± 0.0266
0.248	± 1.0905	0.1011	0.248	0.2328	± 0.0169
0.372	± 1.1416	0.1013	0.372	0.2442	± 0.0169
0.462	± 1.1928	0.1015	0.462	0.2182	± 0.0169
0.552	± 1.1269	0.1017	0.552	0.2705	± 0.0171
0.642	± 1.1488	0.1019	0.642	0.2552	± 0.0172
0.731	± 1.0832	0.1019	0.731	0.2846	± 0.0172
LBIDA measurements					
1.81	± 1.0692	0.0387	2.23	0.2945	± 0.0039
5.80	± 0.8494	0.0285	6.17	0.4705	± 0.0103
19.3	± 0.8823	0.0156	18.9	0.3689	± 0.0047
44.6	± 0.8108	0.0076	45.9	0.1051	± 0.0034
68.5	± 0.7852	0.0077	69.6	0.0275	± 0.0031
140. 5	± 0.7542	0.0037	141.7	0.0238	± 0.0060

See Table 2Bi for footnote 1

TABLE 4Aii ET retention: Main: Subject 4, 3-µm particles inhaled while performing light exercise

Time since intake	ET retention	± 95% uncertainty[1]	Nose blow clearance	± 95% uncertainty[2]
Hours	IETD fraction	IETD fraction	IETD fraction	IETD fraction
RPCDA measurements				
0.100	0.6447	± 0.0366		
0.161	0.6839	± 0.0301		
0.221	0.6833	± 0.0370		
0.277	0.6600	± 0.0233		
0.366	0.6736	± 0.0235		
0.456	0.6738	± 0.0236		
0.546	0.6996	± 0.0235		
0.636	0.6809	± 0.0235		
0.726	0.6556	± 0.0234		
LBIDA measurements				
1.07[3]	0.6736	± 0.0236		
2.19			*0.0747*	*± 0.0043*
2.37	0.4894	± 0.0179		
2.90			*0.1019*	*± 0.0062*
3.90			*0.0564*	*± 0.0033*
5.50[3]	0.2519	± 0.0087		
6.65	0.2797	± 0.0174		
7.04			*0.0188*	*± 0.0012*
7.65			*0.0056*	*± 0.0004*
8.07			*0.0074*	*± 0.0005*
9.24			*0.0301*	*± 0.0018*
16.6			*0.0251*	*± 0.0016*
16.8			*0.0031*	*± 0.0003*
17.4			*0.0015*	*± 0.0001*
19.2			*0.0006*	*± 0.0001*
19.6[3]	0.0547	± 0.0066		
20.7			*0.0015*	*± 0.0001*
23.6			*0.0013*	*± 0.0001*
28.5			*0.0022*	*± 0.0002*
33.2			*0.0005*	*± 0.0001*
41.0			*0.0021*	*± 0.0002*
43.4[3]	0.0315	± 0.0068		
44.2			*0.0002*	*± 0.0001*
46.4			*0.0002*	*± 0.00005*
50.3[3]	0.0220	± 0.0073		
115.3[3]	0.0145	± 0.0131		

See Table 2Ai for footnotes 1,2 and 3

TABLE 4Bii Lung and GI tract retention: Main experiment: Subject 4; 3-µm particles inhaled while performing light exercise

Lung	ILD =1.3242 IETD		GI tract		
Time since intake	Lung retention	± 95% uncertainty[1]	Time since intake	GI tract content	± 95% uncertainty[1]
Hours	ILD	ILD	Hours	IETD	IETD
RPCDA measurements					
0.100	0.9933	± 0.0799	0.100	0.2698	± 0.0277
0.161	1.0218	± 0.0809	0.161	0.3459	± 0.0285
0.211	0.9774	± 0.0661	0.211	0.3752	± 0.0235
0.277	0.9329	± 0.0417	0.277	0.3602	± 0.0148
0.366	1.0904	± 0.0422	0.366	0.3752	± 0.0149
0.456	1.0874	± 0.0423	0.456	0.3628	± 0.0150
0.546	1.1071	± 0.0420	0.546	0.3061	± 0.0145
0.636	1.1289	± 0.0421	0.636	0.2782	± 0.0146
0.726	1.1144	± 0.0419	0.726	0.2701	± 0.0144
LBIDA measurements					
1.50	0.9877	± 0.0228	1.85	0.1475	± 0.0083
5.90	0.8898	± 0.0196	6.27	0.3135	± 0.0055
20.8	0.7708	± 0.0130	21.9	0.2992	± 0.0065
44.5	0.7624	± 0.0123	45.6	0.1237	± 0.0029
116.7	0.7387	± 0.0173	117.6	0.0901	± 0.0078

See Table 2Bi for footnote 1

TABLE 4Aiii ET retention: Main: Subject 7, 3-µm particles inhaled while performing light exercise

Time since intake	ET retention	± 95% uncertainty[1]	Nose blow clearance	± 95% uncertainty[2]
Hours	IETD fraction	IETD fraction	IETD fraction	IETD fraction
RPCDA measurements				
0.089	0.8019	± 0.0484		
0.149	0.7698	± 0.0490		
0.210	0.7447	± 0.0589		
0.285	0.7351	± 0.0373		
0.374	0.6897	± 0.0377		
0.464	0.6852	± 0.0382		
0.554	0.6750	± 0.0376		
0.643	0.6385	± 0.0378		
0.732	0.6140	± 0.0378		
LBIDA measurements				
1.10[3]	0.4425	± 0.0120		
2.28[3]	0.4366	± 0.0100		
5.90[3]	0.3069	± 0.0078		
7.13[3]	0.3054	± 0.0059		
21.4			*0.0053*	*± 0.0004*
22.6	0.0383	± 0.0078		
28.0			*0.0005*	*± 0.0001*
44.6			*AND*[4]	< 0.0003[5]
46.3			*AND*	< 0.0003
46.4[3]	0.0053	± 0.0120		
52.7[3]	0.0024	± 0.0139		
118.3[3]	-0.0078	± 0.0664		

See Table 2Ai for footnotes 1,2 and 3

4. AND = Activity not detected on nose blow sample

5. There is a 95% probability that sample activity is less than the given minimal detectable IETD fraction

TABLE 4Biii Lung and GI tract retention: Main experiment: Subject 7; 3-µm particles inhaled while performing light exercise

Lung	ILD =0.6249 IETD		GI tract		
Time since intake	Lung retention	± 95% uncertainty[1]	Time since intake	GI tract content	± 95% uncertainty[1]
Hours	ILD	ILD	Hours	IETD	IETD
RPCDA measurements					
0.089	0.8393	± 0.1825	0.089	0.2505	± 0.0301
0.149	1.1017	± 0.2782	0.149	0.3444	± 0.0464
0.210	0.9117	± 0.1824	0.210	0.2147	± 0.0299
0.285	1.0968	± 0.1410	0.285	0.1229	± 0.0227
0.374	1.1548	± 0.1428	0.374	0.2363	± 0.0234
0.464	1.1372	± 0.1449	0.464	0.4019	± 0.0244
0.554	1.1110	± 0.1425	0.554	0.2057	± 0.0233
0.643	1.0156	± 0.1435	0.643	0.3133	± 0.0239
0.732	0.9266	± 0.1438	0.732	0.3519	± 0.0241
LBIDA measurements					
1.49	0.8107	± 0.0465	1.86	0.5411	± 0.0081
6.28	0.4758	± 0.0267	6.67	0.8150	± 0.0131
24.3	0.4298	± 0.0147	25.6	0.3508	± 0.0114
47.5	0.4283	± 0.0112	48.6	0.0568	± 0.0052
119.5	0.3786	± 0.0139	120.6	0.0156	± 0.0076

See Table 2Bi for footnote 1

TABLE 5Ai ET retention: Main experiment: Subject 4, 6-µm particles inhaled at rest

Time since intake	ET retention	± 95% uncertainty[1]	Nose blow clearance	± 95% uncertainty[2]
Hours	IETD fraction	IETD fraction	IETD fraction	IETD fraction
RPCDA measurements				
0.095	0.8437	± 0.0452		
0.155	0.8609	± 0.0453		
0.216	0.8810	± 0.0555		
0.236	0.8619	± 0.0351		
0.325	0.8464	± 0.0351		
0.414	0.8330	± 0.0351		
0.503	0.7949	± 0.0352		
0.592	0.7691	± 0.0352		
0.681	0.7419	± 0.0352		
LBIDA measurements				
1.08	0.7021	± 0.0222		
2.25	0.6182	± 0.0150		
3.06			*0.0024*	*± 0.0002*
3.31			*0.0910*	*± 0.0056*
5.42	0.4328	± 0.0180		
6.53	0.4464	± 0.0281		
6.89			*0.0382*	*± 0.0023*
7.56			*0.0239*	*± 0.0015*
9.64			*0.0086*	*± 0.0006*
17.3			*0.0058*	*± 0.0004*
18.8	0.1907	± 0.0216		
22.0			*0.0014*	*± 0.0002*
22.5			*0.0026*	*± 0.0002*
27.2			*0.0022*	*± 0.0002*
28.4			*0.0061*	*± 0.0004*
29.6			*0.0105*	*± 0.0007*
41.6			*0.0070*	*± 0.0004*
42.9	0.0793	± 0.0212		
46.4			*0.0010*	*± 0.0001*
50.0[3]	0.0186	± 0.0073		
50.3	0.0684	± 0.0229		

See Table 2Ai for footnotes 1,2 and 3

TABLE 5Bi Lung and GI tract retention: Main: Subject 4; 6-µm particles inhaled at rest

Lung	ILD =1.2997 IETD		GI tract		
Time since intake	Lung retention	± 95% uncertainty[1]	Time since intake	GI tract content	± 95% uncertainty[1]
Hours	ILD	ILD	Hours	IETD	IETD
RPCDA measurements					
0.095	0.9489	± 0.0824	0.095	0.1534	± 0.0271
0.155	0.9700	± 0.0826	0.155	0.1593	± 0.0272
0.216	0.9484	± 0.1010	0.216	0.1536	± 0.0332
0.236	1.0031	± 0.0640	0.236	0.1300	± 0.0209
0.325	0.9934	± 0.0639	0.325	0.1210	± 0.0209
0.414	1.0196	± 0.0640	0.414	0.1081	± 0.0208
0.503	1.0485	± 0.0643	0.503	0.1242	± 0.0210
0.592	1.0387	± 0.0644	0.592	0.1429	± 0.0211
0.681	0.9670	± 0.0643	0.681	0.1732	± 0.0212
LBIDA measurements					
1.52	1.0494	± 0.0222	1.87	0.3031	± 0.0079
5.80	0.8404	± 0.0157	6.12	0.5819	± 0.0114
19.9	0.6162	± 0.0118	21.0	0.7228	± 0.0131
44.0	0.5361	± 0.0149	45.0	0.1789	± 0.0070

See Table 2Bi for footnote 1

TABLE 5Aii ET retention: Main experiment: Subject 5, 6-µm particles inhaled at rest

Time since intake	ET retention	± 95% uncertainty[1]	Nose blow clearance	± 95% uncertainty[2]
Hours	IETD fraction	IETD fraction	IETD fraction	IETD fraction
RPCDA measurements				
0.100	0.9879	± 0.0197		
0.160	0.9714	± 0.0198		
0.220	0.9530	± 0.0242		
0.241	0.9191	± 0.0153		
0.330	0.9160	± 0.0153		
0.420	0.9240	± 0.0154		
0.509	0.9063	± 0.0154		
0.599	0.8883	± 0.0154		
0.689	0.8872	± 0.0154		
LBIDA measurements				
0.767	0.9110	± 0.0126		
2.2	0.4088	± 0.0042		
4.8	0.3500	± 0.0036		
5.9	0.3275	± 0.0030		
17.1			*0.1013*	*± 0.0038*
20.4	0.0284	± 0.0024		
41.8			*0.0009*	*± 0.0001*
43.4	0.0156	± 0.0022		
67.5	0.0083	± 0.0020		

See Table 2Ai for footnotes 1,2 and 3

TABLE 5Bii Lung and GI tract retention: Main: Subject 5; 6-µm particles inhaled at rest

Lung	ILD =0.2115 IETD		GI tract		
Time since intake	Lung retention	± 95% uncertainty[1]	Time since intake	GI tract content	± 95% uncertainty[1]
Hours	ILD	ILD	Hours	IETD	IETD
RPCDA measurements					
0.100	0.7877	± 0.2084	0.100	0.0031	± 0.0111
0.160	0.9970	± 0.3144	0.160	0.0015	± 0.0167
0.220	0.8909	± 0.2569	0.220	0.0153	± 0.0137
0.241	1.0056	± 0.1631	0.241	0.0179	± 0.0087
0.330	1.0228	± 0.1632	0.330	0.0150	± 0.0087
0.420	0.9090	± 0.1633	0.420	0.0265	± 0.0088
0.509	1.0466	± 0.1637	0.509	0.0163	± 0.0087
0.599	1.1158	± 0.1644	0.599	0.0236	± 0.0088
0.689	1.0796	± 0.1641	0.689	0.0182	± 0.0088
LBIDA measurements					
1.48	1.2009	± 0.0195	1.82	0.4457	± 0.0078
5.18	0.4975	± 0.0128	5.48	0.8029	± 0.0081
19.9	0.5944	± 0.0138	19.6	0.4012	± 0.0098
44.5	0.4168	± 0.0167	45.5	0.0982	± 0.0126
68.5	0.4599	± 0.0206	69.6	0.0235	± 0.0071

See Table 2Bi for footnote 1

TABLE 5Aiii ET retention: Main experiment: Subject 6, 6-µm particles inhaled at rest

Time since intake	ET retention	± 95% uncertainty[1]	Nose blow clearance	± 95% uncertainty[2]
Hours	IETD fraction	IETD fraction	IETD fraction	IETD fraction
RPCDA measurements				
0.098	0.9643	± 0.0432		
0.158	0.9801	± 0.0432		
0.218	0.9681	± 0.0529		
0.238	0.9095	± 0.0335		
0.327	0.8655	± 0.0335		
0.416	0.8280	± 0.0335		
0.505	0.7854	± 0.0335		
0.594	0.7059	± 0.0335		
0.683	0.6631	± 0.0335		
LBIDA measurements				
0.836			0.0136	± 0.0008
1.05	0.4648	± 0.0118		
1.42			0.0110	± 0.0007
2.27	0.2247	± 0.0112		
3.50			0.0172	± 0.0010
3.84			0.0253	± 0.0016
5.75			0.0084	± 0.0005
6.67			0.0020	± 0.0002
6.77	0.0438	± 0.0082		
7.88	0.0361	± 0.0077		
10.5			0.0020	± 0.0002
12.5			0.0003	± 0.0001
20.6			0.0009	± 0.0001
22.0	0.0018	± 0.0029		
22.5			0.0060	± 0.0006
24.3			AND[4]	< 0.0003[5]
25.3			AND	< 0.0003
46.3	0.0089	± 0.0047		

See Table 2Ai for footnotes 1,2 and 3

4. AND = Activity not detected on nose blow sample

5. There is a 95% probability that sample activity is less than the given minimal detectable IETD fraction

TABLE 5Biii Lung and GI tract retention: Main: Subject 6; 6-µm particles inhaled at rest

Lung	ILD =0.5852 IETD		GI tract		
Time since intake	Lung retention	± 95% uncertainty[1]	Time since intake	GI tract content	± 95% uncertainty[1]
Hours	ILD	ILD	Hours	IETD	IETD
RPCDA measurements					
0.098	1.0108	± 0.2595	0.098	0.0226	± 0.0380
0.158	0.9842	± 0.2594	0.158	0.0230	± 0.0380
0.218	0.9073	± 0.2118	0.218	0.0424	± 0.0312
0.238	0.9350	± 0.1342	0.238	0.0465	± 0.0198
0.327	0.9375	± 0.1344	0.327	0.0578	± 0.0199
0.416	0.9737	± 0.1349	0.416	0.0698	± 0.0200
0.505	0.9940	± 0.1349	0.505	0.0604	± 0.0199
0.594	0.9808	± 0.1354	0.594	0.0908	± 0.0201
0.683	1.1151	± 0.1358	0.683	0.0714	± 0.0201
LBIDA measurements					
1.50	0.6828	± 0.0132	1.85	0.9710	± 0.0159
7.18	0.5380	± 0.0122	7.52	0.9839	± 0.0162
23.1	0.2732	± 0.0110	24.1	0.5703	± 0.0106
47.2	0.2658	± 0.0133	48.2	-0.0091	± 0.0028

See Table 2Bi for footnote 1

TABLE 6Ai ET retention: Main experiment: Subject 1, 6-µm particles inhaled while performing light exercise

Time since intake	ET retention	± 95% uncertainty[1]	Nose blow clearance	± 95% uncertainty[2]
Hours	IETD fraction	IETD fraction	IETD fraction	IETD fraction
RPCDA measurements				
0.099	0.9509	± 0.0228		
0.160	0.9501	± 0.0232		
0.220	0.9238	± 0.0284		
0.241	0.8741	± 0.0180		
0.331	0.8153	± 0.0181		
0.420	0.7795	± 0.0182		
0.510	0.7574	± 0.0183		
0.600	0.7419	± 0.0183		
0.690	0.7054	± 0.0182		
LBIDA measurements				
1.03[4]	0.5751	± 0.0057		
2.15[4]	0.4731	± 0.0067		
5.82[4]	0.3310	± 0.0035		
6.95[4]	0.3723	± 0.0063		
8.94			*0.0248*	*± 0.0015*
20.9			*0.0080*	*± 0.0005*
21.3			*0.0119*	*± 0.0007*
23.2[4]	0.1700	± 0.0033		
29.3			*0.1050*	*± 0.0060*
44.8			*0.0003*	*± 0.00004*
46.3[4]	0.0158	± 0.0014		
52.7[4]	0.0149	± 0.0012		

See Table 2Ai for footnotes 1,2 and 3

TABLE 6Bi Lung and GI tract retention: Main experiment: Subject 1; 6-µm particles inhaled while performing light exercise

Lung	ILD = 0.2333 IETD		GI tract		
Time since intake	Lung retention	± 95% uncertainty[1]	Time since intake	GI tract content	± 95% uncertainty[1]
Hours	ILD	ILD	Hours	IETD	IETD
RPCDA measurements					
0.099	0.8732	± 0.3332	0.099	0.0295	± 0.0202
0.160	0.8798	± 0.3397	0.160	0.1208	± 0.0212
0.220	1.0441	± 0.2787	0.220	0.1241	± 0.0174
0.241	1.0761	± 0.1772	0.241	0.1469	± 0.0111
0.331	1.0918	± 0.1789	0.331	0.1920	± 0.0114
0.420	1.0258	± 0.1809	0.420	0.2569	± 0.0117
0.510	0.9424	± 0.1825	0.510	0.3110	± 0.0120
0.600	0.7557	± 0.1824	0.600	0.3276	± 0.0121
0.690	0.4981	± 0.1812	0.690	0.3203	± 0.0120
LBIDA measurements					
1.43	0.5376	± 0.0472	1.85	0.6364	± 0.0112
6.20	0.8237	± 0.0496	6.57	0.5945	± 0.0118
23.9	0.4591	± 0.0733	24.6	0.3511	± 0.0120
47.1	0.2342	± 0.0928	47.4	0.1836	± 0.0152

See Table 2Bi for footnote 1

TABLE 6Aii ET retention: Main experiment: Subject 2: 6-µm particles inhaled while performing light exercise

Time since intake	ET retention	± 95% uncertainty[1]	Nose blow clearance	± 95% uncertainty[2]
Hours	IETD fraction	IETD fraction	IETD fraction	IETD fraction
RPCDA measurements				
0.109	0.9389	± 0.0162		
0.169	0.9222	± 0.0162		
0.219	0.8529	± 0.0206		
0.284	0.8051	± 0.0132		
0.374	0.7670	± 0.0133		
0.464	0.7629	± 0.0134		
0.554	0.7572	± 0.0134		
0.643	0.7332	± 0.0130		
0.733	0.7410	± 0.0126		
LBIDA measurements				
1.27[3]	0.5503	± 0.0077		
2.57[3]	0.4753	± 0.0062		
5.72[3]	0.4694	± 0.0066		
6.95[3]	0.4438	± 0.0066		
11.4			0.0348	± 0.0021
20.4			0.0857	± 0.0054
21.5[3]	0.0607	± 0.0018		
25.4			0.0053	± 0.0003
32.4			0.0057	± 0.0004
35.4			0.0018	± 0.0001
44.4			0.0021	± 0.0001
46.5[3]	0.0236	± 0.0006		
52.6[3]	0.0186	± 0.0012		

See Table 2Ai for footnotes 1,2 and 3

TABLE 6Bii Lung and GI tract retention: Main experiment: Subject 2: 6-µm particles inhaled while performing light exercise

Lung	ILD = 0.2676 IETD		GI tract		
Time since intake	Lung retention	± 95% uncertainty[1]	Time since intake	GI tract content	± 95% uncertainty[1]
Hours	ILD	ILD	Hours	IETD	IETD
RPCDA measurements					
0.109	1.0000	± 0.2007	0.109	0.0770	± 0.0139
0.169	0.7863	± 0.2015	0.169	0.1198	± 0.0144
0.219	0.8393	± 0.1743	0.219	0.3025	± 0.0135
0.284	0.7301	± 0.1125	0.284	0.3914	± 0.0090
0.374	0.8106	± 0.1144	0.374	0.4406	± 0.0093
0.464	0.7892	± 0.1156	0.464	0.4795	± 0.0095
0.554	0.7049	± 0.1155	0.554	0.4850	± 0.0095
0.643	0.6957	± 0.1112	0.643	0.3458	± 0.0088
0.733	0.6694	± 0.1073	0.733	0.2267	± 0.0081
LBIDA measurements					
1.72	0.6857	± 0.0420	2.12	0.5023	± 0.0045
6.14	0.6063	± 0.0469	6.49	0.5179	± 0.0056
24.3	0.4627	± 0.0434	22.7	0.5947	± 0.0071
45.8	0.1137	± 0.0152	47.2	0.6146	± 0.0071

See Table 2Bi for footnote 1

TABLE 6Aiii ET Retention: Main experiment: Subject 4: 6-µm particles inhaled while performing light exercise

Time since intake	ET retention	± 95% uncertainty[1]	Nose blow clearance	± 95% uncertainty[2]
Hours	IETD fraction	IETD fraction	IETD fraction	IETD fraction
RPCDA measurements				
0.108	0.8700	± 0.0277		
0.168	0.8605	± 0.0278		
0.219	0.8502	± 0.0339		
0.283	0.7950	± 0.0216		
0.373	0.7609	± 0.0216		
0.462	0.7494	± 0.0217		
0.551	0.7362	± 0.0217		
0.640	0.7067	± 0.0217		
0.729	0.6486	± 0.0219		
LBIDA measurements				
1.04[3]	0.5519	± 0.0086		
2.32[3]	0.5004	± 0.0100		
3.22			*0.0727*	*± 0.00428*
4.36			*0.0230*	*± 0.00145*
4.69[3]	0.3523	± 0.0053		
5.11			*0.0292*	*± 0.00185*
5.97[3]	0.2321	± 0.0088		
6.52			*0.0103*	*± 0.00065*
7.12			*0.0092*	*± 0.00058*
7.69			*0.0215*	*± 0.00136*
9.52			*0.0306*	*± 0.00193*
16.9			*0.0240*	*± 0.00152*
17.4			*0.0013*	*± 0.00008*
18.2			*0.0016*	*± 0.00010*
18.3[3]	0.0329	± 0.0025		
22.5			*0.0010*	*± 0.00006*
26.8			*0.0018*	*± 0.00012*
28.3			*0.0004*	*± 0.00003*
28.6			*0.0006*	*± 0.00004*
32.0			*0.0009*	*± 0.00006*
41.3			*0.0007*	*± 0.00004*
43.3[3]	0.0152	± 0.0027		
46.4			*0.0001*	*± 0.00001*
47.5			*0.0002*	*± 0.00001*
50.2[3]	0.0067	± 0.0031		

See Table 2Ai for footnotes 1,2 and 3

TABLE 6Biii Lung and GI tract retention: Main experiment: Subject 4: 6-µm particles inhaled while performing light exercise

Lung	ILD = 0.9766 IETD		GI tract		
Time since intake	Lung retention	± 95% uncertainty[1]	Time since intake	GI tract content	± 95% uncertainty[1]
Hours	ILD	ILD	Hours	IETD	IETD
RPCDA measurements					
0.108	0.9781	± 0.0988	0.108	0.1277	± 0.0244
0.168	1.0263	± 0.0992	0.168	0.1255	± 0.0244
0.229	0.9934	± 0.0808	0.229	0.1306	± 0.0200
0.283	1.1090	± 0.0517	0.283	0.1354	± 0.0127
0.373	1.0736	± 0.0518	0.373	0.1655	± 0.0129
0.462	1.0795	± 0.0520	0.462	0.1739	± 0.0130
0.551	1.0777	± 0.0522	0.551	0.1985	± 0.0132
0.640	1.0863	± 0.0524	0.640	0.2065	± 0.0132
0.729	1.1622	± 0.0530	0.729	0.2349	± 0.0134
LBIDA measurements					
1.39	0.9188	± 0.0270	1.39	0.5137	± 0.0200
5.12	0.5917	± 0.0212	5.49	0.9678	± 0.0257
19.0	0.3177	± 0.0120	19.4	0.7107	± 0.0150
42.6	0.2942	± 0.0072	44.0	0.2008	± 0.0046

See Table 2Bi for footnote 1

TABLE 6Aiv ET retention: Main experiment: Subject 5, 6-µm particles inhaled while performing light exercise

Time since intake	ET retention	95% uncertainty[1]	Nose blow clearance	95% uncertainty[2]
Hours	IETD fraction	IETD fraction	IETD fraction	IETD fraction
RPCDA measurements				
0.099	1.0032	± 0.0319		
0.160	0.9874	± 0.0320		
0.220	0.9852	± 0.0393		
0.240	0.9709	± 0.0248		
0.330	0.9621	± 0.0248		
0.419	0.9027	± 0.0249		
0.508	0.8827	± 0.0250		
0.598	0.8733	± 0.0250		
0.687	0.8350	± 0.0251		
LBIDA measurements				
0.967	0.6372	± 0.0059		
2.23	0.4624	± 0.0065		
5.45	0.2782	± 0.0051		
6.70	0.2599	± 0.0051		
17.2			*0.050*	*± 0.002*
20.1	0.0612	± 0.0022		
43.3	0.0109	± 0.0012		
74.3	0.0054	± 0.0012		

See Table 2Ai for footnotes 1,2 and 3

TABLE 6Biv Lung and GI tract retention: Main experiment: Subject 5: 6-µm particles inhaled while performing light exercise

Lung	ILD = 0.1652 IETD		GI tract		
Time since intake	Lung retention	± 95% uncertainty[1]	Time since intake	GI tract content	± 95% uncertainty[1]
Hours	ILD	ILD	Hours	IETD	IETD
RPCDA measurements					
0.099	0.8034	± 0.6649	0.099	-0.0009	± 0.0283
0.160	0.9757	± 0.6666	0.160	-0.0031	± 0.0283
0.220	1.1556	± 0.5464	0.220	0.0030	± 0.0232
0.240	1.0346	± 0.3456	0.240	0.0123	± 0.0147
0.330	0.9320	± 0.3455	0.330	0.0148	± 0.0148
0.419	1.1021	± 0.3485	0.419	0.0537	± 0.0150
0.508	1.0807	± 0.3502	0.508	0.0840	± 0.0152
0.598	0.8429	± 0.3497	0.598	0.0890	± 0.0152
0.687	1.0855	± 0.3516	0.687	0.1010	± 0.0154
LBIDA measurements					
1.37	0.9672	± 0.0625	1.78	0.3573	± 0.0043
5.90	0.3393	± 0.0655	6.43	0.5568	± 0.0045
20.8	0.6317	± 0.0501	21.5	0.5871	± 0.0051
44.0	0.2872	± 0.0634	45.0	0.2055	± 0.0065

See Table 2Bi for footnote 1

TABLE 7: RPCDA 60 second live time measurements for 1.5-µm particle inhalations while at rest

Subject	Time since intake	ET retention	± 95% uncert.	Lung retention	± 95% uncert.	GI tract content	± 95% uncert.
	Hours	IETD fraction		ILD fraction		IETD fraction	
Subject 1[1]	*0.004*[2]	*1.0539*	*± 0.0470*	*1.0574*	*± 0.0630*	*0.7767*	*± 0.0312*
	0.025	*0.8681*	*± 0.0468*	*1.3889*	*± 0.0632*	*0.4836*	*± 0.0289*
	0.045	*0.6951*	*± 0.0426*	*1.0911*	*± 0.0574*	*0.0926*	*± 0.0237*
	0.065	*0.7557*	*± 0.0426*	*1.0626*	*± 0.0570*	*0.0594*	*± 0.0233*
	0.085	0.9199	± 0.0427	1.0129	± 0.0567	0.0843	± 0.0234
RPCDA 1	0.106	0.9120	± 0.0427	0.9851	± 0.0567	0.0944	± 0.0237
	0.126	0.9081	± 0.0426	1.0012	± 0.0566	0.0801	± 0.0233
	0.146	0.9128	± 0.0429	1.0152	± 0.0570	0.0932	± 0.0237
RPCDA 2	0.166	0.9071	± 0.0429	1.0382	± 0.0571	0.0951	± 0.0236
	0.186	0.8933	± 0.0428	1.0047	± 0.0569	0.0893	± 0.0237
	0.206	0.9012	± 0.0429	1.0068	± 0.0570	0.1175	± 0.0239
RPCDA 3	0.227	0.8844	± 0.0428	0.9937	± 0.0569	0.1074	± 0.0239
Subject 4[3]	*-0.026*	*1.4656*	*± 0.1808*	*1.4666*	*± 0.1788*	*2.9757*	*± 0.1305*
	-0.006	*1.2262*	*± 0.1751*	*1.4844*	*± 0.1731*	*2.0766*	*± 0.1214*
	0.014	*0.8538*	*± 0.1777*	*2.1024*	*± 0.1768*	*1.8871*	*± 0.1202*
	0.034	*-0.1417*	*± 0.1570*	*0.9134*	*± 0.1567*	*0.6287*	*± 0.1019*
	0.054	*0.2244*	*± 0.1585*	*1.0625*	*± 0.1572*	*0.5452*	*± 0.1006*
	0.074	0.4415	± 0.1592	1.0108	± 0.1574	0.5631	± 0.1015
RPCDA 1	0.094	0.4229	± 0.1582	0.9105	± 0.1564	0.6182	± 0.1012
	0.114	0.4250	± 0.1592	1.0134	± 0.1575	0.5640	± 0.1016
RPCDA 2	0.134	0.4387	± 0.1593	0.9802	± 0.1575	0.6670	± 0.1021
	0.154	0.3948	± 0.1593	0.9955	± 0.1577	0.6111	± 0.1022
	0.174	0.4299	± 0.1587	0.9813	± 0.1569	0.5758	± 0.1009
RPCDA 3	0.194	0.4388	± 0.1600	1.0368	± 0.1583	0.6278	± 0.1026
Subject 6[4]	*0.020*	*0.9343*	*± 0.0853*	*1.6159*	*± 0.1776*	*1.3001*	*± 0.0598*
	0.040	*0.5708*	*± 0.0797*	*1.4572*	*± 0.1663*	*0.6366*	*± 0.0521*
	0.060	*0.2756*	*± 0.0731*	*0.9301*	*± 0.1524*	*0.0839*	*± 0.0441*
	0.080	0.9151	± 0.0754	1.0385	± 0.1540	0.0837	± 0.0444
RPCDA 1	0.100	0.8957	± 0.0751	0.9663	± 0.1535	0.1013	± 0.0445
	0.120	0.8936	± 0.0752	0.9947	± 0.1536	0.0878	± 0.0444
	0.140	0.9020	± 0.0752	0.9772	± 0.1537	0.0997	± 0.0445
RPCDA 2	0.160	0.9067	± 0.0754	0.9724	± 0.1541	0.1243	± 0.0449
	0.180	0.8937	± 0.0755	1.0069	± 0.1544	0.1255	± 0.0450
	0.201	0.9137	± 0.0753	0.9699	± 0.1538	0.1036	± 0.0446
RPCDA 3	0.221	0.9342	± 0.0759	1.0757	± 0.1551	0.1186	± 0.0450
	0.241	0.9073	± 0.0751	0.9051	± 0.1533	0.1084	± 0.0446

1. See Tables 2Ai and 2Bi

2. Values in italic and smaller font are those measurements that were judged to have been made before aerosol delivery system had been removed and subject and the RPCDA stomach detector correctly positioned.

3.See Tables 2Aii and 2Bii 4. See Tables 2Aiii and 2Biii

TABLE 8 Small Sodium Iodide detector array measurements

Subject/Source	Time since intake	Detector 1 (front)		Detector 2 (side)		Side / front detector counts ratio	
Calibration measurements	Hours	Counts s^{-1} Bq^{-1} (1)		Counts s^{-1} Bq^{-1} (1)			
Anterior source	N/A(2)	3.258 x10^{-3}	± 0.012 x10^{-3}	1.323 x10^{-4}	± 0.029 x10^{-4}	0.0406	± 0.0038
Posterior source	N/A	3.833 x10^{-4}	± 0.044 x10^{-4}	3.531 x10^{-4}	± 4.243 x10^{-4}	0.9212	± 0.0159
Subject measurements		Counts. s^{-1} (3)		Counts. s^{-1}		Ratio	
1	1.39	65.61	± 1.50	0.18	± 0.30	0.0027	± 0.0233
	1.87	65.98	± 1.51	0.09	± 0.30	0.0014	± 0.0233
	5.57	34.43	± 1.14	0.26	± 0.32	0.0077	± 0.0344
	6.27	30.40	± 1.08	0.18	± 0.32	0.0058	± 0.0372
	21.9	9.81	± 0.76	-0.05	± 0.36	-0.0053	± 0.0859
	22.3	10.48	± 0.78	0.03	± 0.36	0.0030	± 0.0824
2	1.85	24.51	± 0.97	1.76	± 0.44	0.0717	± 0.0436
	2.38	28.53	± 1.04	1.21	± 0.42	0.0425	± 0.0394
	2.80	25.83	± 1.00	1.38	± 0.43	0.0535	± 0.0421
	3.68	29.49	± 1.06	1.51	± 0.44	0.0511	± 0.0390
	4.31	14.98	± 0.81	1.31	± 0.43	0.0872	± 0.0613
	5.95	16.36	± 0.85	0.95	± 0.42	0.0579	± 0.0579
	7.88	12.07	± 0.77	0.95	± 0.43	0.0786	± 0.0728
	8.45	14.86	± 0.83	0.44	± 0.41	0.0294	± 0.0623
	9.21	15.82	± 0.85	0.71	± 0.43	0.0452	± 0.0603
	21.4	4.26	± 0.63	0.35	± 0.47	0.0829	± 0.1830
	24.2	3.04	± 0.60	0.33	± 0.48	0.1092	± 0.2524
	24.3	2.71	± 0.59	0.30	± 0.48	0.1107	± 0.2796
	28.5	2.15	± 0.59	0.37	± 0.50	0.1719	± 0.3605
3	1.7	35.05	± 1.12	0.87	± 0.39	0.0249	± 0.0338
	2.2	30.63	± 1.12	0.74	± 0.39	0.0242	± 0.0388
	3.2	32.11	± 1.14	0.86	± 0.39	0.0268	± 0.0374
	3.5	38.71	± 1.14	0.85	± 0.40	0.0219	± 0.0312
	5.0	32.20	± 1.16	0.75	± 0.40	0.0234	± 0.0380
	5.5	27.72	± 1.16	0.67	± 0.40	0.0242	± 0.0443
	8.6	32.43	± 1.20	0.89	± 0.42	0.0275	± 0.0392
	10.3	38.33	± 1.22	0.43	± 0.40	0.0111	± 0.0336
	21.8	19.97	± 1.38	0.73	± 0.47	0.0366	± 0.0727
	26.0	19.76	± 1.44	0.68	± 0.48	0.0342	± 0.0767
	32.8	20.83	± 1.54	0.85	± 0.52	0.0409	± 0.0781
	34.8	17.89	± 1.57	0.92	± 0.54	0.0513	± 0.0928
	45.5	14.53	± 1.76	0.44	± 0.57	0.0302	± 0.1272
	47.2	15.43	± 1.79	0.18	± 0.57	0.0114	± 0.1216
	48.7	7.59	± 1.81	0.47	± 0.59	0.0616	± 0.2514
	51.7	3.93	± 1.87	0.54	± 0.61	0.1372	± 0.5012
	57.6	3.26	± 1.99	0.09	± 0.63	0.0278	± 0.6407

TABLE 8 Small Sodium Iodide detector array measurements

Subject/Source	Time since intake	Detector 1 (front)		Detector 2 (side)		Side / front detector counts ratio	
4	1.43	38.43	± 1.17	1.47	± 0.41	0.0383	± 0.0322
	2.67	23.94	± 1.18	1.02	± 0.40	0.0426	± 0.0521
	3.67	34.49	± 1.19	1.02	± 0.40	0.0296	± 0.0365
	4.67	22.44	± 1.20	0.97	± 0.41	0.0433	± 0.0567
	5.67	24.93	± 1.22	0.93	± 0.41	0.0372	± 0.0515
5	2.39	83.81	± 1.71	0.56	± 0.33	0.0067	± 0.0208
	2.87	66.16	± 1.72	0.63	± 0.34	0.0095	± 0.0265
	3.30	86.18	± 1.73	0.12	± 0.31	0.0014	± 0.0204
	3.87	65.60	± 1.74	0.12	± 0.31	0.0019	± 0.0269
	7.47	32.35	± 1.81	0.10	± 0.32	0.0031	± 0.0567
	8.04	39.82	± 1.82	0.05	± 0.32	0.0014	± 0.0463
	8.50	33.89	± 1.82	0.05	± 0.32	0.0013	± 0.0547
	9.04	36.88	± 1.83	0.00	± 0.32	0.0000	± 0.0505
	21.0	6.15	± 2.08	0.34	± 0.38	0.0556	± 0.3435
	21.5	3.34	± 2.09	-0.01	± 0.37	-0.0031	± 0.6346
	22.4	2.15	± 2.10	-0.01	± 0.37	-0.0049	± 0.9937
6	1.42	23.19	± 0.94	1.34	± 0.43	0.0580	± 0.0445
	1.95	9.16	± 0.94	0.78	± 0.41	0.0854	± 0.1122
	2.49	12.33	± 0.95	0.44	± 0.40	0.0361	± 0.0834
	5.97	4.17	± 0.98	0.14	± 0.40	0.0340	± 0.2540
7	1.5	71.33	± 1.89	0.34	± 0.44	0.0047	± 0.0272
	2.3	101.01	± 2.30	0.01	± 0.51	0.0001	± 0.0233
8	1.18	126.47	± 2.06	5.73	± 0.58	0.0453	± 0.0169
	1.56	124.29	± 2.07	5.50	± 0.58	0.0442	± 0.0173
	2.14	127.91	± 2.08	5.27	± 0.57	0.0412	± 0.0169
	2.63	107.95	± 2.09	4.36	± 0.55	0.0404	± 0.0200
	3.38	141.46	± 2.11	6.83	± 0.62	0.0483	± 0.0155
	6.09	52.77	± 2.17	1.93	± 0.48	0.0365	± 0.0420
	6.66	53.96	± 2.18	1.95	± 0.49	0.0362	± 0.0414
	7.11	48.19	± 2.19	2.06	± 0.49	0.0428	± 0.0465
	21.4	24.93	± 2.54	0.86	± 0.51	0.0346	± 0.1037
	22.3	19.83	± 2.56	0.70	± 0.51	0.0354	± 0.1316
	22.8	16.94	± 2.57	0.86	± 0.52	0.0510	± 0.1549

1. Measured gamma-ray count rate per Bq from ^{111}In calibration source, corrected to reference time.
2. N/A: Not applicable
3. Measured gamma-ray count rate from retained ^{111}In labelled particles, corrected to time of intake.

TABLE 9 Experiment breathing parameters

Subject	Main/Pilot	Work rate	Aero-dynamic diameter, d_{ae}, µm	Geometric standard deviation ±	Average Flow rate, l/min	Standard deviation ±	Average tidal volume Litre	Standard deviation ±	Ventilation rate m^3h^{-1}	Inhale fraction breathing cycle %	Resp.Fr. Breaths /min	Impaction parameter Qd_{ae}^2
ICRP[1]		**Sitting**	**1.5**	**1.2**	**18**		**0.75**		**0.54**	**50%**	**12**	**675**
1	Main	Sitting	1.5	1.2	19.56	3.41	0.9184	0.1337	0.4975	42.4%	9.03	733.3
4	Main	Sitting	1.5	1.2	18.15	2.08	0.6639	0. 0442	0.4850	44.5%	12.18	680.7
6	Main	Sitting	1.5	1.2	23.35	1.98	0.5589	0.0722	0.6618	47.2%	19.74	875.6
ICRP		**Sitting**	**3**	**1.2**	**18**		**0.75**		**0.54**	**50%**	**12**	**2700**
1	Pilot	Sitting	3.1	1.1	18.60	2.61	0.6194	0.1103	0.4471	40.1%	12.03	2978.4
1	Main	Sitting	2.7	1.1	20.09	0.68	0.8768	0.1048	0.4099	34.0%	7.79	2440.7
2	Pilot	Sitting	3.1	1.03	28.62	2.45	0.9094	0.1066	0.6843	39.9%	12.54	4583.3
2	Main	Sitting	3.2	1.1	34.48	1.85	1.0877	0.0981	0.9928	48.0%	15.21	5884.7
3	Main	Sitting	3.3	1.1	32.79	1.31	0.8786	0.0448	0.8110	41.2%	15.38	5950.9
4	Pilot	Sitting	3.1	1.1	23.19	1.91	0.7130	0.0439	0.6408	46.1%	14.98	3713.6
4	Main	Sitting	2.7	1.1	17.98	2.88	0.5272	0.0765	0.4134	38.3%	13.07	2184.8
5	Main	Sitting	2.7	1.1	36.46	3.31	0.9094	0.0163	0.8759	40.0%	16.05	4430.2
6	Main	Sitting	3.2	1.1	35.41	2.14	0.6711	0.0719	0.9533	44.9%	23.67	6042.6
7	Main	Sitting	2.7	1.1	28.89	2.81	0.7882	0.0723	0.6904	39.8%	14.60	3510.6
8	Main	Sitting	2.7	1.1	25.10	0.58	0.9818	0.0615	0.6526	43.3%	11.08	3050.0
9	Main	Sitting	2.7	1.1	21.72	5.57	0.9134	0.3029	0.4681	35.9%	8.54	2638.5
ICRP		**L.E.[2]**	**3**	**1.2**	**50**		**1.25**		**1.5**	**50%**	**20**	**7497**
4	Pilot	L.E.	3.12	1.2	56.25	23.91	3.0543	1.0856	1.9909	59.0%	10.86	9126.0
1	Main	L.E	3.19	1.2	51.56	5.82	1.8230	0.1299	1.2476	40.3%	11.41	8745.2
4	Main	L.E	3.19	1.2	50.79	7.16	1.6849	0.2076	1.3405	44.0%	13.26	8614.4
7	Main	L.E	3.19	1.2	64.31	5.23	2.0640	0.1981	1.7140	44.4%	13.84	10907.7

TABLE 9 Experiment breathing parameters

Subject	Main/Pilot	Work rate	Aero-dynamic diameter, d_{ae}, µm	Geometric standard deviation ±	Average Flow rate, l/min	Standard deviation ±	Average tidal volume Litre	Standard deviation ±	Ventilation rate m^3h^{-1}	Inhale fraction breathing cycle %	Resp.Fr. Breaths /min	Impaction parameter Qd_{ae}^2
ICRP			**6**	**1.2**	**18**		**0.75**		**0.54**	**50%**	**12**	**10800**
2	Pilot	Sitting	5.65	1.2	26.18	6.43	1.2268	0.8483	0.4369	27.8%	5.94	13941.0
4	Main	Sitting	5.8	1.2	19.57	6.71	0.6504	0.1214	0.5317	45.3%	13.62	10971.9
5	Main	Sitting	5.8	1.2	29.65	1.44	0.7553	0.0687	0.7735	43.5%	17.07	16624.3
6	Main	Sitting	5.8	1.2	22.62	1.11	0.6550	0.0528	0.5595	41.2%	14.24	12682.9
ICRP			**6**	**1.2**	**50**		**1.25**		**1.5**	**50%**	**20**	**30000**
3	Pilot	L.E.	5.96	1.2	70.28	5.48	1.8840	0.1291	2.0186	47.9%	17.86	41572.8
1	Main	L.E	6.06	1.2	43.41	3.32	2.1108	0.0832	1.3182	50.6%	10.41	26570.6
2	Main	L.E	6.25	1.2	69.87	3.36	1.4823	0.0561	1.4509	34.6%	16.31	45489.4
4	Main	L.E	6.25	1.2	46.32	17.15	2.0849	1.4584	2.0702	74.5%	16.55	30156.5
5	Main	L.E	6.06	1.2	78.20	3.76	1.5231	0.0902	1.9440	41.4%	21.27	47865.2

1. ICRP Human respiratory tract model default breathing parameters for the stated work rate 2. L.E = Light exercise

TABLE 10 NADAR measurements of the positions and areas of the nasal valves and entrance to

		Right nasal valve		Right second nasal minimum		Distance from valve to 2nd min.	Left nasal valve		Left second nasal minimum		Distance from valve to 2nd min.
Subject	Experiment	Depth[1], cm	Area, cm^2	Depth, cm	Area, cm^2	cm	Depth, cm	Area, cm^2	Depth, cm	Area, cm^2	cm
1	1.5-µm^2 Sitting[3]	3.63	0.803 ± 0.074[4]	6.73	5.133 ± 0.378	3.10	3.09	0.966 ± 0.060	5.84	1.871 ± 0.161	2.76
	Pilot[5] 3-µm Sitting	3.29	1.180 ± 0.053	8.46	4.326 ± 0.236	5.17	3.09	0.936 ± 0.019	5.50	1.631± 0.110	2.41
	3-µm Sitting	3.29	0.914 ± 0.012	6.04	3.397 ± 0.166	2.76	3.09	0.961 ± 0.028	5.50	1.569 ± 0.022	2.41
	3-µm L.E[6]	3.98	1.371 ± 0.072	6.39	11.21 ± 3.05	2.41	3.09	0.935 ± 0.062	5.84	1.681 ± 0.073	2.76
	6-µm Sitting	3.63	0.937 ± 0.034	6.04	5.15 ± 0.512	2.41	3.09	1.044 ± 0.019	5.84	2.139 ± 0.206	2.76
2	Pilot 3-µm Sitting	2.50	0.780 ± 0.033	5.94	1.387 ± 0.047	3.45	2.39	0.713 ± 0.008	4.46	0.786 ± 0.041	2.07
	3-µm Sitting	2.15	0.745 ± 0.045	4.22	2.0286 ± 0.144	2.07	3.08	0.606 ± 0.060	4.80	1.116 ± 0.119	1.72
3	3-µm Sitting	3.53	1.168 ± 0.176	7.32	6.012 ± 1.273	3.79	2.54	0.548 ± 0.031	4.61	1.421 ± 0.232	2.07
4	1.5-µm sitting	2.24	0.860 ± 0.017	5.34	2.710 ± 0.059	3.10	2.24	1.078 ± 0.032	5.00	2.057 ± 0.012	2.76
	Pilot 3-µm Sitting	2.93	0.680 ± 0.012	5.69	2.298 ± 0.114	2.76	2.93	1.064 ± 0.094	5.69	2.012 ± 0.168	2.76
	3-µm Sitting	2.59	0.763 ± 0.004	5.69	2.948 ± 0.171	3.10	2.59	0.889 ± 0.063	9.83	5.477 ± 0.236	5.86
	Pilot 3-µm LE	3.62	0.750 ± 0.005	7.07	3.528 ± 0.002	3.45	2.59	1.207 ± 0.123	3.97	2.074 ± 0.029	1.38
	6-µm Sitting	3.28	0.594 ± 0.042	7.41	2.780 ± 0.681	4.14	2.59	1.158 ± 1.158	5.34	2.168 ± 0.066	2.76
	6-□□ □.□	2.93	0.771[7]	5.69	5.1441[7]	2.76	2.59	0.810 ± 0.004	4.31	1.321 ± 0.017	1.72
5	3-µm sitting	3.23	1.078 ± 0.053	5.64	2.623 ± 0.043	2.41	2.94	0.713 ± 0.025	5.01	1.425 ± 0.076	2.07
6	1.5-µm sitting	3.58	0.602 ± 0.012	7.37	1.620 ± 0.163	3.79	4.02	0.560 ± 0.003	7.81	1.725 ± 0.076	3.79
	3-µm sitting	3.23	0.882 ± 0.055	6.33	2.325 ± 0.267	3.10	3.33	1.028 ± 0.042	5.74	2.463 ± 0.267	2.41
	6-µm sitting	3.58	0.612 ± 0.056	7.37	2.086 ± 0.376	3.79	4.37	0.430 ± 0.038	7.81	1.080 ± 0.269	3.45
7	3-µm sitting	2.45	0.829 ± 0.040	4.52	0.907 ± 0.056	2.07	2.25	0.981 ± 0.076	5.70	2.364 ± 0.230	3.45
	3-µm L.E.	2.80	0.799 ± 0.018	4.87	1.334 ± 0.018	2.07	2.94	0.696 ± 0.021	4.32	1.221 ± 0.184	1.38
8	3-µm sitting	2.60	0.696 ± 0.020	5.70	2.910 ± 0.103	3.10	2.56	0.799 ± 0.071	6.00	2.533 ± 0.206	3.45
9	3-µm sitting	3.18	0.962 ± 0.005	6.28	3.556 ± 0.005	3.10	2.49	0.6784 ± 0.142	5.59	2.8723 ± 0.519	3.10

1. “Depth” is the line of flight distance into the nasal passage travelled by the sound wave from the NADAR equipment

2. Size of aerosol particles inhaled

3. Sitting = subject sitting at rest while inhaling aerosol

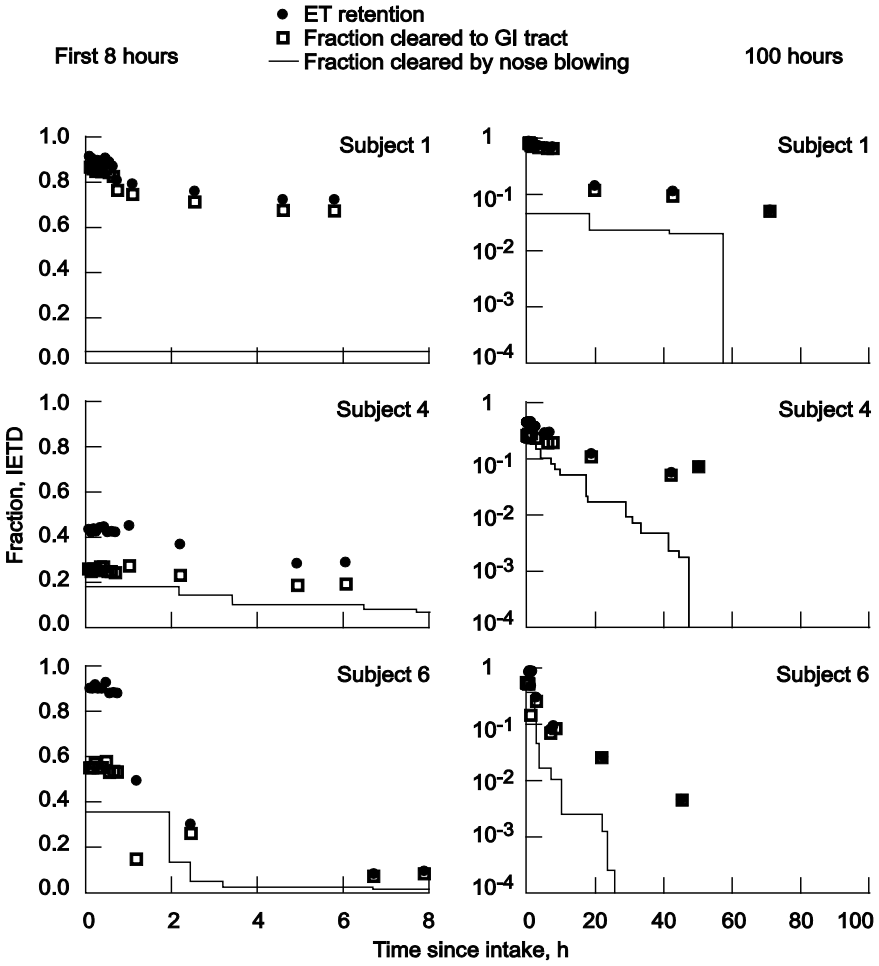
4. Standard deviation of the multiple measurements made of the nasal passage

5:“Pilot” indicates that this was a pilot experiment, all other experiments are main experiments

6: L.E = subject performing light exercise while inhaling aerosol

7: No uncertainty given as only one viable measurement obtained

8 FIGURES



Figures 6a: Retention of 1.5 µm particles inhaled at rest over eight and 100 hours following intake

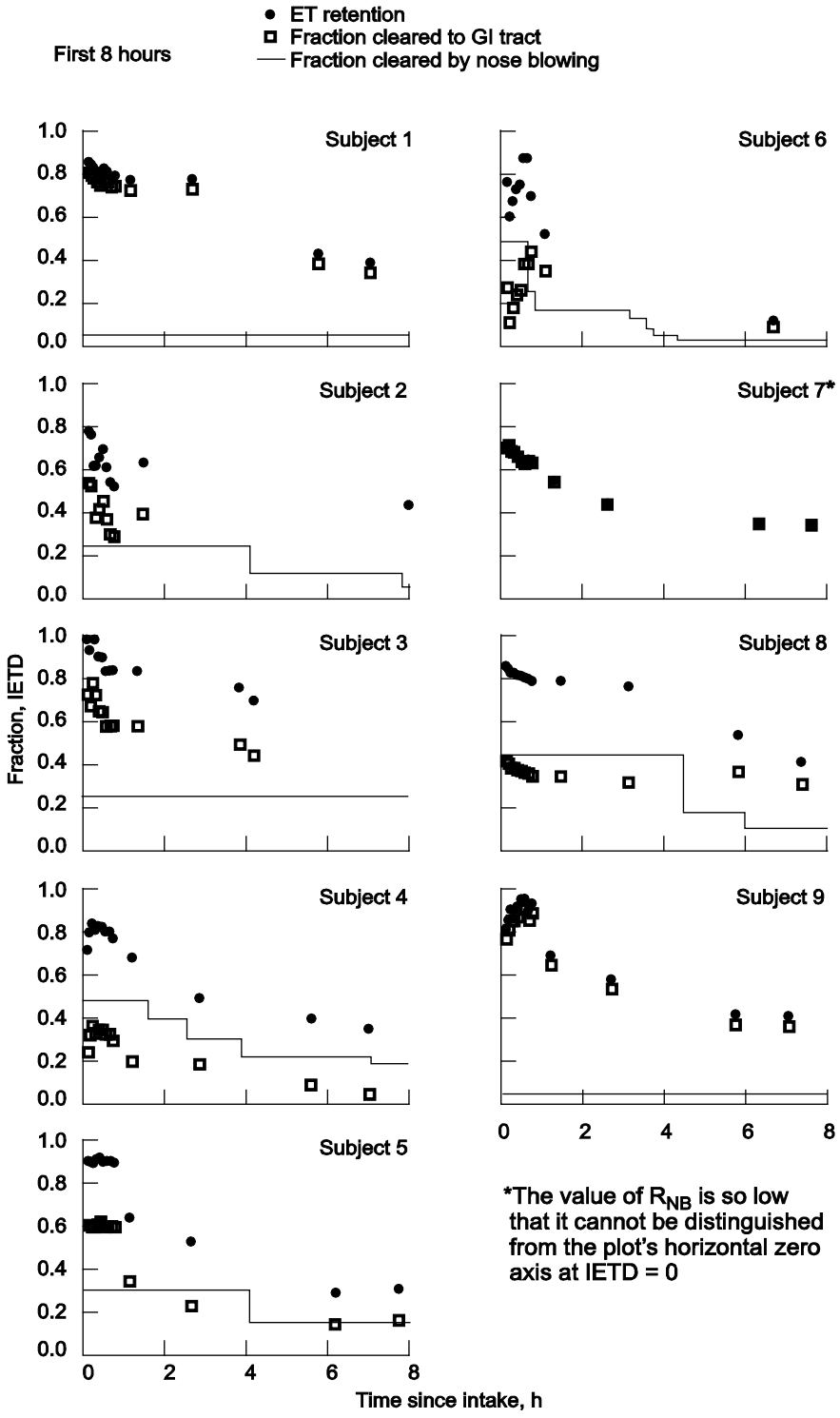


Figure 6b: Retention of 3-µm particles inhaled at rest over eight hours following intake

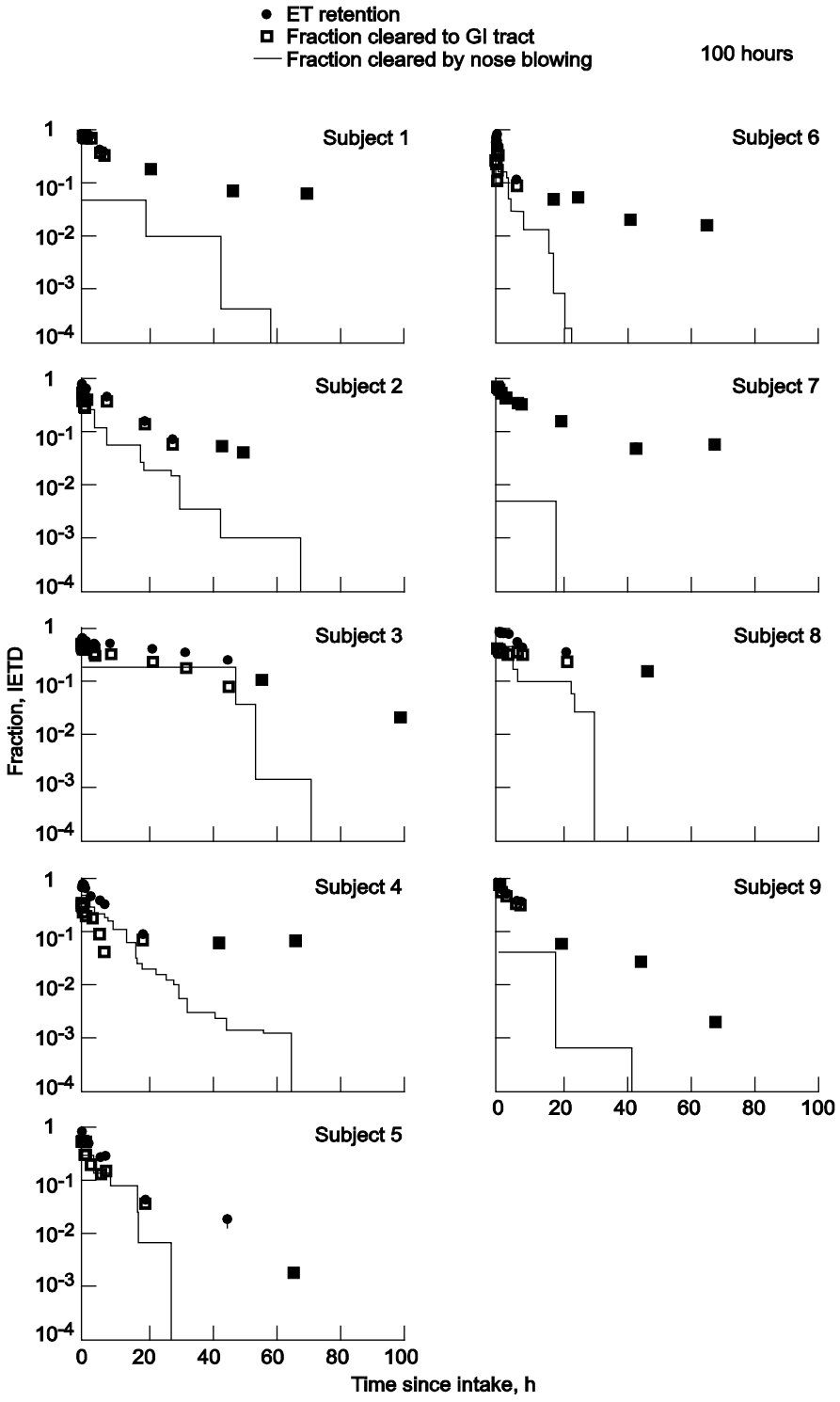


Figure 6c: Retention of 3-µm particles inhaled at rest over 100 hours following intake

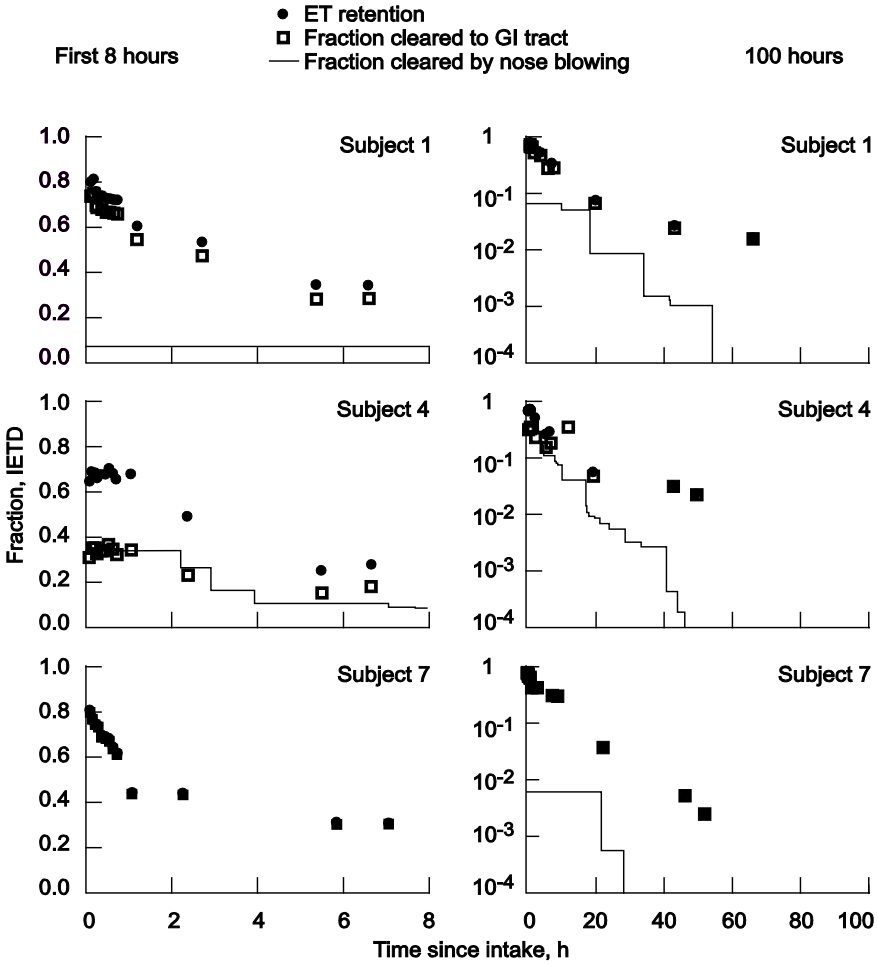
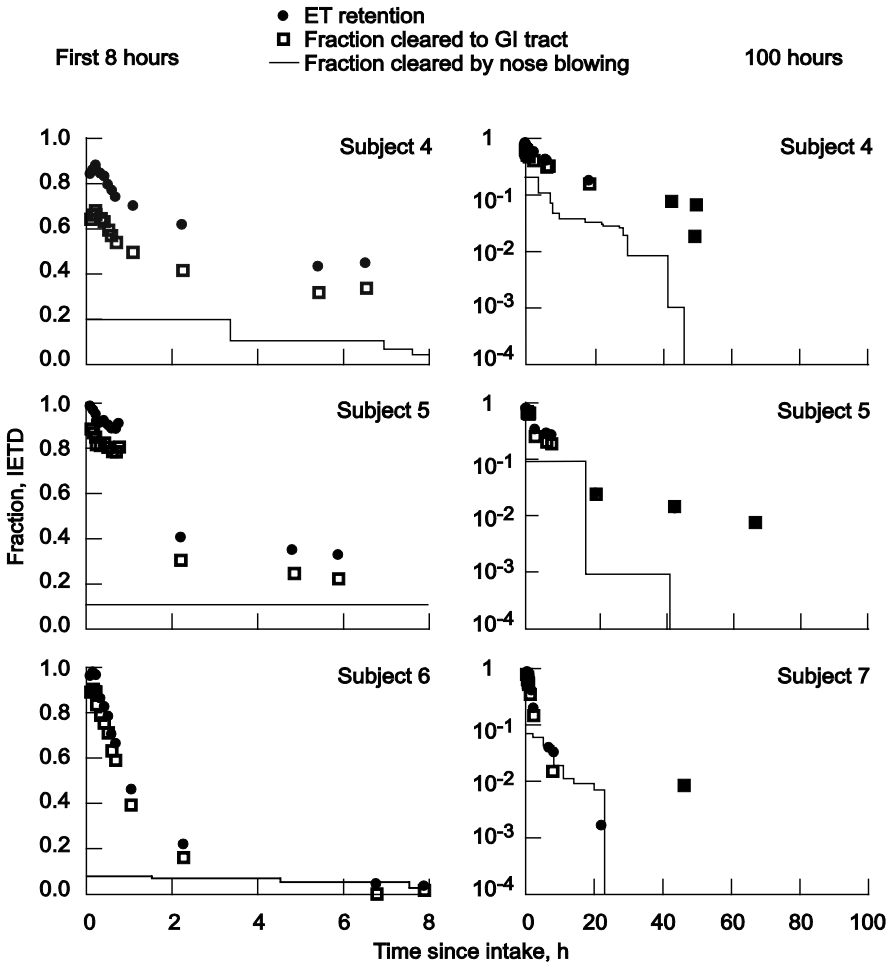
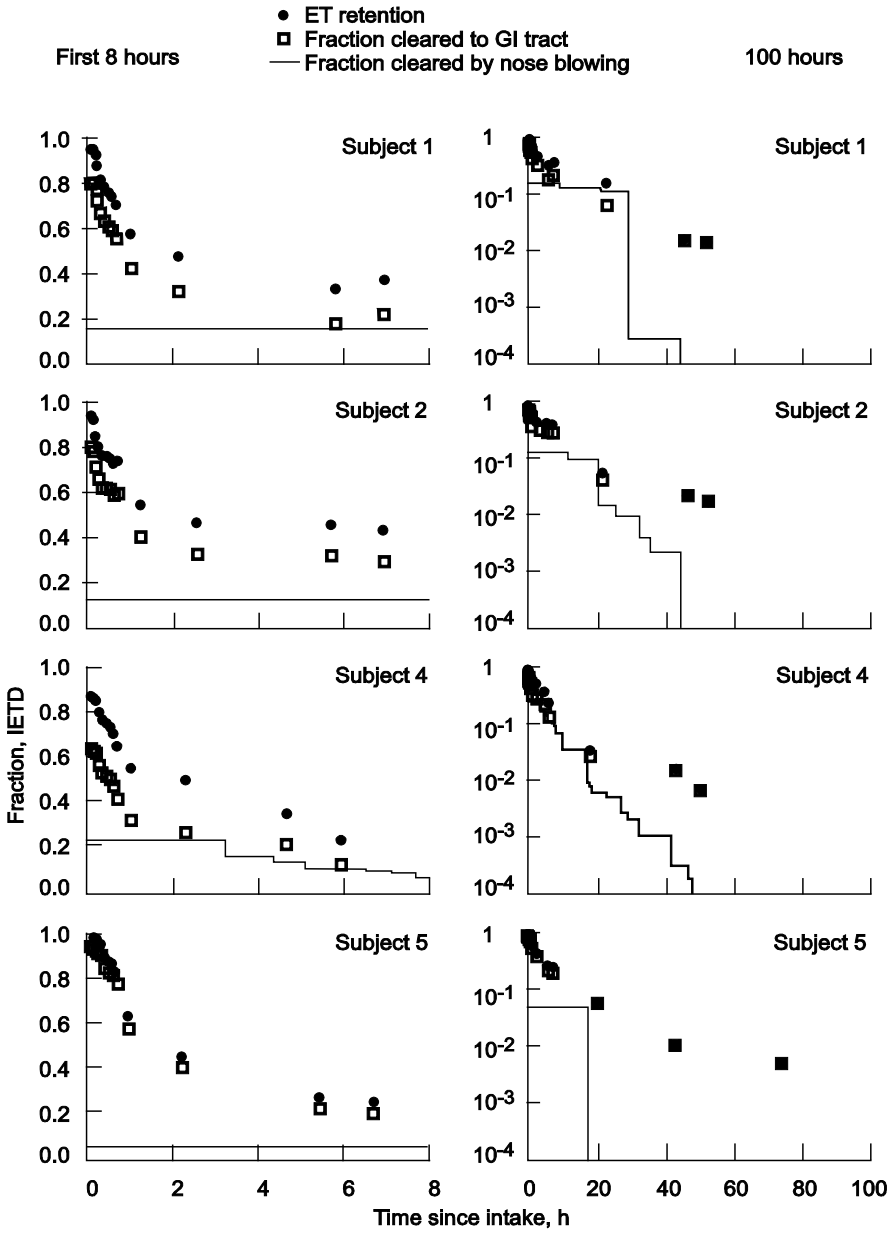


Figure 6d: Retention of 3-µm particles inhaled at light exercise over eight and 100 hours following intake



Figures 6e: Retention of 6-µm particles inhaled at rest over eight and 100 hours following intake



Figures 6f: Retention of 6-µm particles inhaled at light exercise over eight and 100 hours following intake

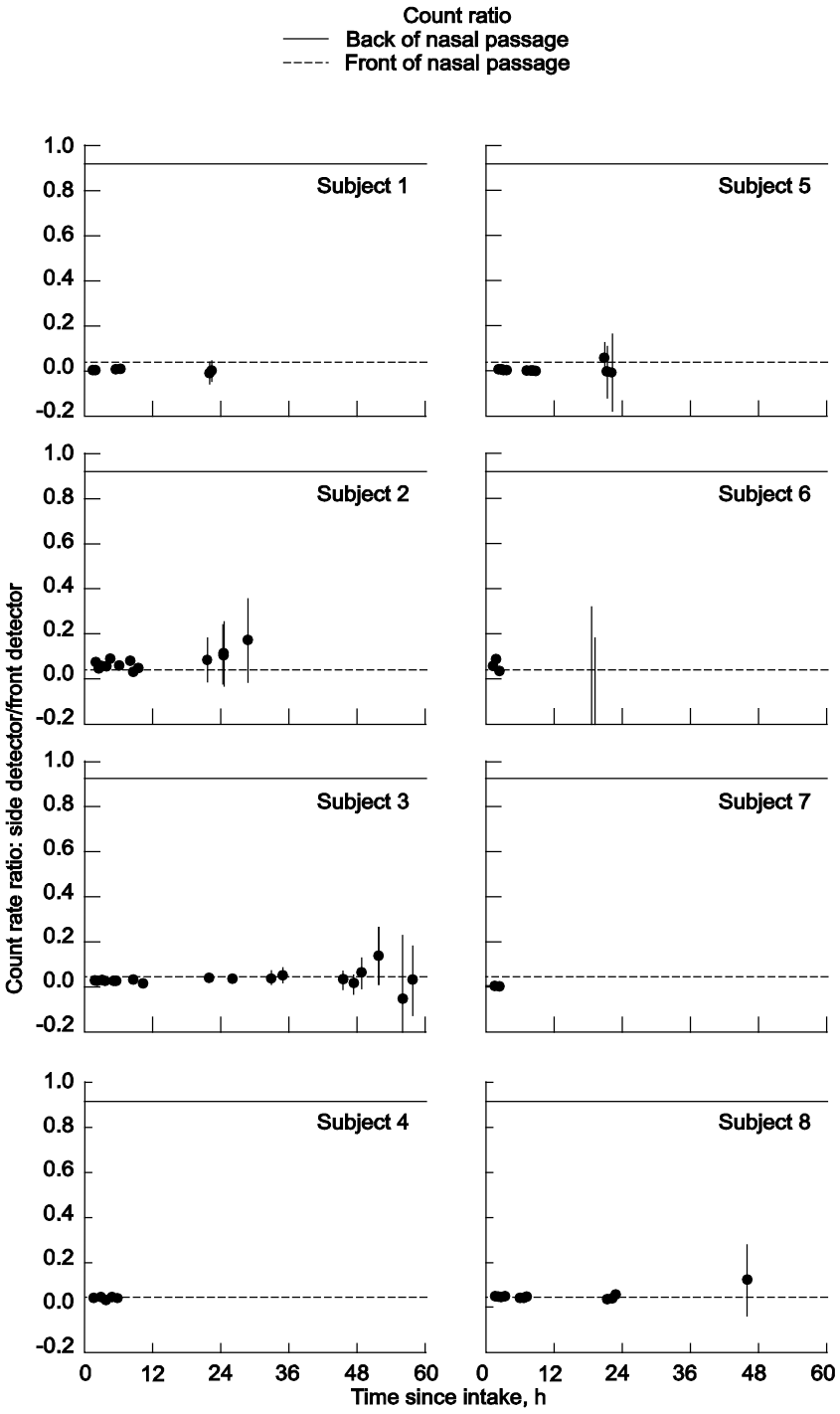


Figure 7: Count ratios measured by SSIDA following inhalation of 3-µm particles while seated at rest

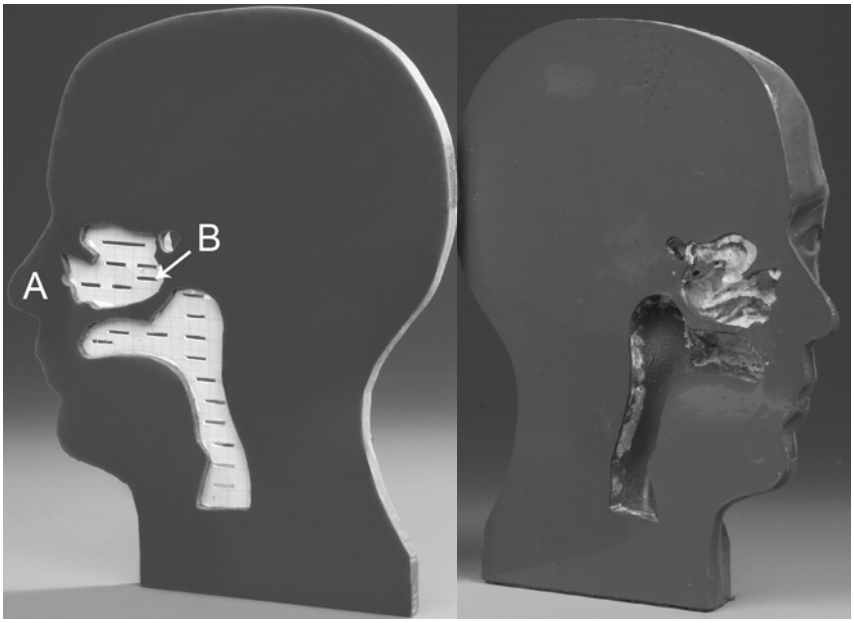


Figure 8 Tissue equivalent head phantom with oral-nasal cavity