



Investigation of Aerosol Mass and Number Deposition Velocity in a Closed Chamber

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ABSTRACT

In the event of a core disruptive accident in a sodium cooled fast reactor, the Reactor Containment Building (RCB) is bottled-up with coolant (sodium), fuel and fission product aerosols. The aerosols suspended in the closed environment undergo coagulation and gravitational settling. Sodium aerosols are generated by combustion, while fission product aerosols are generated by vaporization and condensation, with the resulting particles having two flow regimes. It is expected that the mass concentration of sodium aerosols is relatively high, on the order of a few g/m^3 , while that of the fuel and fission products is only a few mg/m^3 . Taking into account the concentration criteria, experiments are carried out by generating sodium aerosols (mono dispersed) with the concentration of 3.0 g/m^3 , and the deposition velocity over time is determined by mass measurements (concentration and flux). Similarly, non-radioactive species of SrO_2 aerosols are generated (mono dispersed) with a number concentration of $10^9/\text{cm}^3$, and their deposition velocity over time is determined by number measurements (concentration and flux). The mass deposition velocity of sodium aerosols was found to be more than two orders of magnitude greater than the number deposition velocity of SrO_2 aerosols. As the SrO_2 aerosols are generated in the free molecular regime, the depletion pattern of the number concentration of suspended aerosols follows a process of simultaneous coagulation and settling. A theoretical formulation for the rate of depletion of the number concentration is developed, and the rate coefficients of coagulation and deposition velocity are determined from the theoretically fitted equation. The experimental and theoretical results are compared and found to be nearly same. The deposition velocity of sodium aerosols is used to predict the deposition time for the suspended aerosol mass concentration inside the RCB. The mass and number deposition velocities are determined by using a state of art Turn Table Instrument fabricated in our lab.

Keywords: Deposition velocity; SrO_2 aerosol; Sodium aerosol; Depletion rate; Turn table.

INTRODUCTION

In the event of Core Disruptive Accident (CDA), condition of Sodium Cooled Fast Reactor (SFR), fuel and fission product vapors that are released into the Reactor Containment Building (RCB), would condense to form aerosols. In addition, sodium burning would give rise to various compounds of sodium aerosols. Thus, RCB is bottled-up with the large amount of coolant (sodium), fuel and fission product aerosols. Under the bottled-up condition, these aerosols undergo various phenomena like coagulation (thermal and kinematic), gravitational settling, diffusion etc. It is to be noted here that, the particles confined in the RCB have different flow regime and hence different phenomena would dominate. Sodium aerosols are generated by combustion route and hence initial particle size is in the

micrometer range ($1.0 \mu\text{m}$ at 50–65% RH) (Subramanian, *et al.*, 2007), which falls in continuum regime. Further, sodium burning gives large quantity (mass concentration is high) of various compounds of sodium aerosols, hence mass related phenomena dominate. Fission product and Fuel aerosols are generated by vaporization and condensation route and hence initial particle size is in the few tens of nanometer range (about 30 nm in the case of SrO_2 aerosols) (Subramanian *et al.*, 2011), which falls in free molecular regime. The particle distribution is described in terms of number and number related phenomena dominate. In our earlier studies characteristics of sodium and non-radioactive fission product aerosols were studied. The time evolution properties of aerosol mass concentration, number concentration, mass and number size distributions and coagulation rate coefficients were determined for individual aerosols as well as their mixtures (Subramanian *et al.*, 2008, 2011). In addition to the above studies, it is important to know the plated mass of these aerosols on the floor and side walls, for the analysis of corrosion of building material and equipments, and also for the planning of subsequent cleaning inside the containment building. Hence, it is

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important to determine the aerosol deposition rate in a confined environment. The experimental result is used to validate the prediction made by various codes [AEROSIM (Ramsdale, 1986), PARDISEKO, CONTAIN, HAARM, and AEROSOLS/B2] (Lhiaubet, 1991) on deposition velocity.

Studies on gravitational deposition of aerosols and thermal coagulation of various types of aerosols have been conducted elsewhere for the suspended monodispersed and polydispersed aerosols. In these studies different types of aerosols have been used, such as tobacco smoke (Keith, 1982; Morawaska et al., 1997; Robinson et al., 1999), diesel/engine exhaust (Kittelson, 1998; Khalek et al., 2000; Schnell et al., 2004), sodium chloride (Park et al., 2000) etc. All these studies are pertaining to determination of coagulation rate coefficient and deposition rate independently. Interestingly, the simultaneous measurement of coagulation and deposition has been investigated by Schnell et al. (2006), for paper ash and diesel aerosols under still and stirred conditions. They found that, both still and stirred conditions are effective in reducing particles smaller than 0.04 μm in diameter, while stirring additionally reduces the particle concentration above 0.6 μm . The dust deposition on printed circuit boards has been studied for various conditions by Tencer et al. (2008) and it is pointed out that, deposition velocities would be different for particles which are associated with different types of ions viz. sulfate, chloride, sodium etc. A complementary study on particle deposition flux and airborne concentration in the open atmosphere was conducted by Kim et al. (2000) for the particle size between 10 and 1000 μm , and they showed that, with increase in diameter, the dry deposition velocity become larger up to 20 cm/s and it also agrees with some of the models like Schmel et al. (1978). It is noted here that, the above studies are pertaining to particular particle size or range of size and none of the studies have been conducted for the determination of bulk deposition rate in a confined environment. Hence it is imperative to conduct a study on collective aerosol behaviour (in the event of bottled-up condition), in order to ascertain mass or number deposition velocities, which, will be used for aerosol deposition studies. Further, the study is useful to get the deposition coefficient of the aerosols from the plume (total average deposition rate on the ground not the deposition velocity of individual particles), which is released in the open atmosphere from any industry (Safety Reports Series No. 19, 2001).

In order to determine the collective aerosol deposition velocity, experiments are conducted in Aerosol Test Facility (ATF) in our division, by generating aerosols with expected mass concentration prevailed during the event of CDA^a. Sodium aerosols are generated with mass concentration of few g/m^3 and SrO_2 aerosols are generated at a concentration of about 10^6 particles/ cm^3 . Further, it is to be noted that, the particles suspended in the RCB belong to disparate flow regime, hence the aerosol deposition velocity has been studied for two different cases viz. (i) for sodium aerosols – continuum regime and (ii) for SrO_2 aerosols – free-molecular regime. The aerosol deposition velocities in terms of mass or number measurements have been determined by using indigenously developed Turn Table Equipment. A

theoretical formulation of simultaneous coagulation and deposition of aerosols in a confined environment under still air condition is adopted in the case of SrO_2 aerosols; the net coagulation rate and number deposition velocity were calculated. The experimental values and the theoretically estimated results are discussed in this paper. Since the deposition velocity of sodium aerosols is the dominant phenomena in the reduction of suspended aerosol mass concentration in RCB, the experimental value obtained for sodium aerosols is used to predict the time taken for the decay of mass concentration inside the RCB.

MATERIALS AND METHODS

Aerosol Chamber

The experiments were carried out in the ATF (Baskaran et al., 2004) which has been designed and commissioned, for the aerosol safety studies of fast reactors. ATF mainly consists of an aerosol chamber of volume one cubic meter (diameter = 1.5 m, height = 0.6 m and it is made of SS-304L with proper ground), a sodium combustion cell for the production of sodium aerosols, a 25 kW thermal plasma torch for the production of non-radioactive fission product aerosols, aerosol measurement apparatus (Low pressure impactor, Quartz crystal Microbalance, Filter paper sampler, Single particle counter, Differential Mobility Analyser and Ensemble diffraction instrument), humidity and auxiliary systems such as water cooling, air flow, gas flow, pneumatic control, vacuum, material handling systems, and on-line data acquisition system for temperature, pressure and Relative Humidity (RH) during experiments. The chamber is provided with eight numbers of 3" ports, three numbers of 4" ports and one number of 6" port. A vacuum pumping system is connected to 6" port. Sodium combustion cell and a 25 kW Thermal Plasma Torch are connected into two different 3" ports. An integrated view of the aerosol chamber, the sodium combustion cell, plasma torch and the aerosol measurement apparatus is presented in Fig. 1.

Aerosol Diagnostic Equipment

Filter Paper Sampler

A closed face type filter paper sampler (25 mm) and a non-lubricant rotary vane pump with a capacity of 20 L/min coupled with rotameter were used for the measurement of mass concentration. Aerosol sampling was carried out at a flow rate of 10 L/min. The cumulative experimental errors associated with measurement in time, flow rate and mass is estimated to be $\pm 10\%$.

^a In the event of CDA condition in PFBR, it is calculated that, about 350 kg of sodium, 1 kg of non-volatile fission products and 200 g of fuel get transported into RCB (Chellapandi et al., 2002). The expected mass concentration of sodium aerosols would be about few (3–5) g/m^3 , while that of fuel and fission product aerosols are of the order of few mg/m^3 (RCB volume $\sim 70000 \text{ m}^3$) (Subramanian et al., 2011), hence, the total bottled-up mass concentration is of the order of few g/m^3 (Indira et al., 2006).

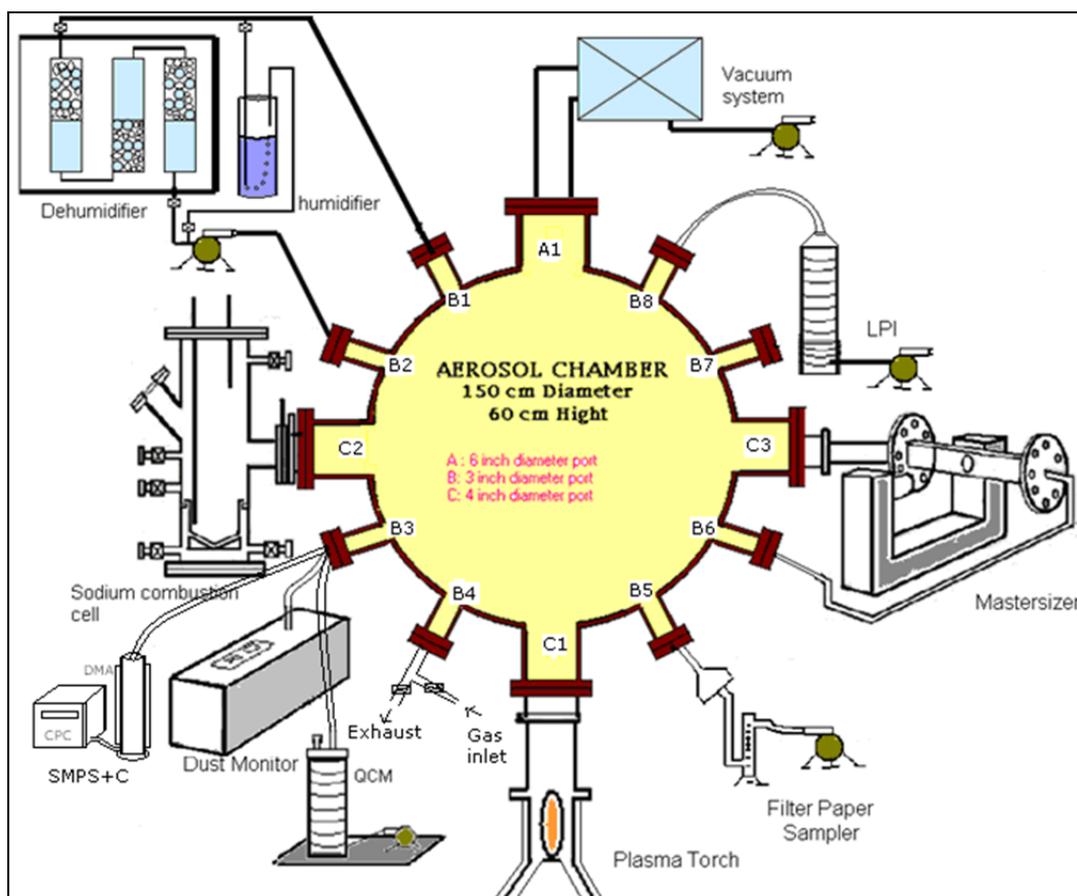


Fig. 1. Schematic diagram of Aerosol Test Facility (ATF).

Aerosol Dust Monitor

Aerosol Dust Monitor (Aerosol Spectrometer) operates by the principle of light scattering by a single particle. The Aerosol Dust Monitor (Model 1.108 of M/s GRIMM Aerosoltechnik, GmbH, Germany) is connected with aerosol chamber in one of the port through a 1:100 dilutor (Model No. 1.159 for 1.2 L/min, M/s GRIMM Aerosoltechnik, Germany). The dilutor is used here to take care of both excess concentration of aerosol and excess pressure of 4 kPa above ambient atmosphere. The monitor gives the spectrum from 0.3–20 μm in 15 channels in terms of Number of particles/liter.

SMPS + C + E

The system is a combination of Differential Mobility Analyser (DMA), (Model: 5.5-900) Condensation Particle Counter (CPC) (Model: 5.403) and 32-bit software program and it is procured from M/s GRIMM Aerosoltechnik, Germany. The system is connected with aerosol chamber through 1:100 dilutor. The system used in our measurement is Universal DMA, where Long-range classifier or Medium range classifier can be mounted on a single bottom base depending upon our requirement. The experiments are conducted with LDMA and it can measure particles (count-size distribution) from 11–1083 nm with a particle concentration up to 10^{10} particles per liter. The sample flow rate of the system is 1.5 L/min and sheath flow rate is 3

L/min.

The SMPS is integrated with aerosol chamber through a 3" port and used for the measurement of particle size distribution and number concentration of SrO_2 aerosols for a longer duration. The software program calculates number-size distribution and displays data online, as $\Delta N/\Delta \ln(d)$ where N is number of particle in that particular effective cut-off diameter 'd'. Also it gives the raw data i.e. number of particles per liter in various size ranges and the total number of particles in each cycle.

Turn Table Instrument

This technique is used for measuring the aerosol deposition flux. The instrument is designed and fabricated indigenously (Baskaran *et al.*, 2009). A photograph of the instrument is shown in Fig. 2. It consists of a circular top plate and a circular collection plate. The collection plate is connected beneath of the top plate on a central axis. The collection plate is provided with 16 numbers of 25 mm diameter slots, on to which, pre-weighed Whatmann filters or glass plates can be mounted. The top plate has got only one opening for the entry of aerosols in such a way that it is aligned in the same vertical line with one of the 16 slots of the collection plate. The collection plate is rotated and aligned to the next slot by using stepper motor and its controller. The controller unit is provided with automatic timer circuit for the rotation of the collection plate. The

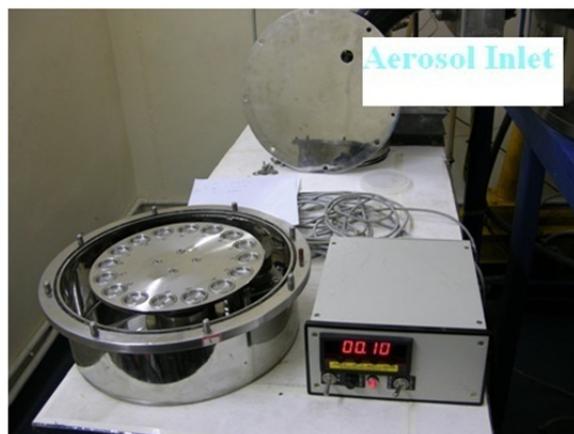


Fig. 2. Photograph of the Turn Table Instrument.

timer can be set up at 30 s and 60 s duration. By collecting a sample on the glass plate or on the filter paper, the number of particles or mass of aerosols deposited on a known area of the substrate at a programmed time interval is determined.

Transmitted Light Scanning Microscope

The system contains compound microscope (Model: Axiostar plus make Zeiss, Germany), with objective of various magnifications (5x, 10x, 40x and 100x), eyepiece with 10x magnification, dark/bright field arrangement, CCD image capturing camera attached on the top and image processing software. It has an additional feature for scanning in the x-y plane with joy stick arrangement. This feature enables to scan object, say on the glass plate, in the x-y plane and its image processing software divided the whole area of glass plate into numerous grids. The area of the whole glass plate and number count in each grid is obtained through particle counting software. In our experiment, the number of particles in each grid, the total number of particles in all the grids and total area of the glass plate are measured by segmenting the area of the glass plate into 3×3 matrix.

Aerosol Generation

Generation of Sodium Combustion Aerosols

About 10 g of sodium is placed in a crucible and mounted on the heater. The sodium combustion cell is isolated, flushed and filled with argon gas, upto a pressure of 10–20 kPa excess over atmosphere. The sodium is heated upto a required temperature (say 550°C, the temperature of the primary sodium in the fast reactor). The hot sodium is ignited by exposing it to air, after flushing out the argon. By combustion, sodium oxide aerosols are formed in the combustion cell. The gate valve is opened and aerosols are get filled into the aerosol chamber and the diagnostic ports immediately. The pressure inside the cell raises upto 70–80 kPa excess over the atmosphere (before opening the gate valve) helps to fill the aerosol chamber and its diagnostic ports with sodium aerosols. The cell is isolated after one minute. During the experiments, the chamber is kept in atmospheric pressure on to which aerosols are injected. The chamber pressure rose up to 4 kPa excess pressure over atmosphere, that enable homogeneous mixing and filling of

aerosols in the chamber and its diagnostic ports. Thus, aerosol chamber is bottled-up with aerosols and samples are drawn through horizontal ports to avoid bias due to gravitational and settling properties (Subramanian *et al.*, 2007).

Generation of SrO₂ Aerosols

The strontium peroxide aerosols were generated using the plasma torch at one atmospheric pressure. Nitrogen is used as both plasma generating gas and the sheath gas. A known weight of SrO₂ powder is palletized. The typical weight of the pellets was 5 ± 0.2 g. The pellet was rigidly fixed in front of the plasma flame. Prior to the generation of fission product aerosols (SrO₂), a study has been conducted in which, the plasma torch parameters were standardized by generating test aerosols of Fe₂O₃ and the characterization of the aerosols were carried out (Subramanian *et al.*, 2009). The torch was operated for two minutes. The pellet was melted and evaporated and the vapours are getting carried into the aerosol chamber with the help of sheath gas. Simultaneously, the vapor is diluted and re-condenses to produce aerosols by homogeneous nucleation or by heterogeneous nucleation on air molecules in the aerosol chamber (Subramanian *et al.*, 2009, 2011). The pneumatic valve separating the torch and the chamber was closed after two minutes operation of plasma torch, such that aerosols are bottled-up inside the chamber.

Sampling

Determination of Deposition Velocity by Mass Measurements for Sodium Aerosols $V_{dep}(m)$

As the production of sodium combustion aerosols has been standardized with our previous experiments, the mass deposition velocity has been determined with few experimental trials and keeping humidity and pressure inside the chamber at atmospheric level, before starting the experiment.

Turn Table Instrument is loaded with glass fiber filter papers of 2.5 cm diameter in all the 16 slots and placed on the floor of the chamber. Timer unit is set for 60 s duration such a way that each paper is exposed to 60 s duration. The sodium aerosols are generated and bottled-up in the chamber. As soon as chamber is isolated, the turn table instrument is started. Simultaneously mass concentration is measured using filter paper sampler at a regular interval of time and a depletion pattern of suspended aerosol mass concentration is obtained by using a graph between aerosol mass concentrations versus time. The mass deposition velocity for the sodium aerosols $V_{dep}(m)$ is determined as follows:

$$V_{dem}(m)(cm/s) = \frac{Mass\ flux}{Mass\ concentration} \quad (1)$$

and the mass flux is obtained as follows:

$$Mass\ flux(g/cm^2/s) = \frac{mass\ collected\ on\ filter\ paper}{Area \times Aerosol\ exposure\ time} \quad (2)$$

It is observed that, the deposited sodium aerosols tend to

coalesce (hygroscopic) (number estimation become difficult), and also, the deposited mass on the filter paper is found to be too less for the weight measurement (< 0.1 mg). Hence a new approach has been evolved to determine the mass of the aerosols deposited on the filter paper by measuring the conductivity of the solution (sodium aerosol dissolved in water).

Procedure for the Determination of Mass Collected on the Filter Paper

A small cut piece of sodium is weighed and dissolved in 100 mL of DM water (Sodium become sodium hydroxide). The conductivity of the solution is measured by using conductometer (Model 856, M/s. Metrohm, Switzerland). Then by making 100 times dilution of the solution (10 mL of solution + 90 mL of water) for 3 more times, the change in conductivity is measured for every dilution. The change in the specific conductivity is measured from 600 $\mu\text{S}/\text{cm}$ to 0.98 $\mu\text{S}/\text{cm}$. (The conductivity of DM water is determined to be 0.90 $\mu\text{S}/\text{cm}$). Then a calibration plot is drawn between change in conductivity and the quantity of sodium. Thus, by dissolving sodium aerosols collected in the filter paper into 100 mL water (becomes hydroxide) and measuring the conductivity of the solution, the deposited mass of the sodium aerosol on the filter paper is determined. By using this technique the deposited quantity of sodium aerosols on the filter paper is measured in the range of 80–157 μg .

The mass deposition velocity of sodium aerosols at various times is obtained by dividing mass flux by the corresponding mass concentration measured at that time from the fitted curve.

Determination of Deposition Velocity by Number Measurements for SrO₂ Aerosols $V_{dep}(n)$

Deposition velocity for SrO₂ aerosols is determined after few trial runs, by standardizing the production of strontium peroxide aerosols with similar count-size distributions by optimizing torch parameters and temperature, humidity and pressure inside the chamber.

Turn Table instrument is mounted with the glass plates having approximately of 1 cm² area in all the 16 slots and placed on the floor of the chamber. The suspended aerosol number concentration is measured by using dust monitor and SMPS. The aerosol dust monitor gives the number-size distribution and number concentration for every 6 s (fast mode operation) while SMPS gives at every 406 s (sweep time). Turn table is operated for 30 s duration by taking care of particle deposition one over the other, which becomes difficult to distinguish while counting. The number of particles deposited on the glass plate is counted by using optical scan microscope and the number flux is determined as described below:

$$\text{Number flux (1/cm}^2\text{/s)} = \frac{\text{Number collected on glass plate}}{\text{Area} \times \text{Aerosol exposure time}} \quad (3)$$

The number flux obtained at various times by the turn

table equipment and corresponding number concentration measured by the dust monitor for the same time, are used to determine number deposition velocity of SrO₂ aerosols. The deposition velocity in this case is defined as:

$$V_{dep}(n) \text{ (cm/s)} = \frac{\text{Number flux}}{\text{Number concentration}} \quad (4)$$

Here, the mass collected on the glass plate was found to be too less for weight measurement and hence, the number flux and the number concentration were used for the estimation of deposition velocity.

RESULTS AND DISCUSSION

Sodium Aerosols

The depletion pattern of aerosol mass concentration is given in Fig. 3. Initial mass concentration of sodium aerosols measured at 0–60 s is 3.0^b g/m³ and at the end of 900s, it is decreased to 0.5^b g/m³. The deposition velocity (by mass measurement) $V_{dep}(m)$ is determined, as per the procedure stated above, at a regular interval of time and the graph showing deposition velocity $V_{dep}(m)$ versus time is also included in Fig. 3. The pattern of deposition velocity curve is explained as follows: The initial deposition velocity for sodium aerosols is found to be 0.08 cm/s when the initial aerosol mass concentration is 3 g/m³. Since mass concentration is high, the aerosols undergo gravitational agglomeration and settling rather than Brownian

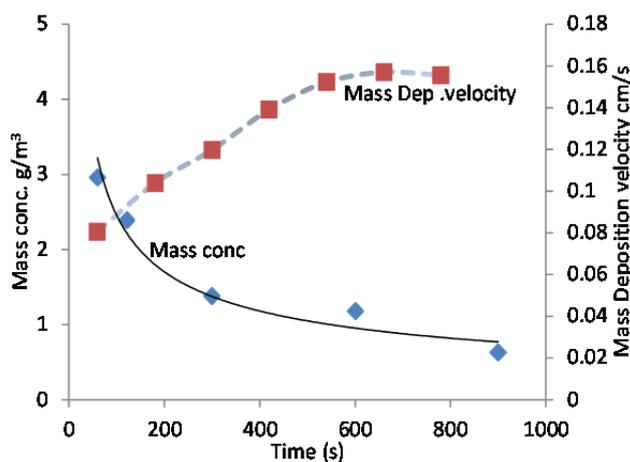


Fig. 3. Depletion pattern of aerosol mass concentration and mass deposition velocity of sodium aerosols in a confined environment.

^b The initial particle size of the sodium compound aerosols was reported to 1.0 μm . Taking sodium compound as hydroxide with density 2.12 g/cm³, the single particle mass is calculated to be 1.17×10^{-9} mg. Hence the total number of particles available for the mass concentration of 3 g/m³ and 0.5 g/m³ would be 2.56×10^6 particles/cm³ and 4.2×10^5 particles/cm³.

agglomeration, hence the deposition velocity progressively increases as more and more settling of agglomerated particles. As the mass concentration reaches a particular stage, the pace at which particle settling rate becomes steady (Bomford *et al.*, 1992) and deposition velocity also becomes steady. It is found from the Fig. 3, the deposition velocity reaches nearly steady value in the range 0.15–0.155 cm/s during 480–840 s when the concentration becomes 1 g/m³ with a peak value at 0.157 cm/s at 720th second.

Further, the final value, 0.170 cm/s (after the peak value) could be the indicator of change from mass phenomena to number phenomena (Brownian agglomeration) as the aerosol mass concentration inside the chamber becomes one order less.

SrO₂ Aerosols

The deposition velocity by number measurement is determined up to 480 s (16 × 30 s), as given by procedure above, and it is shown in Fig. 4. It is observed from the figure that, the initial number deposition velocity is of the order 10⁻⁴ cm/s (particle concentration 8.9 × 10⁵ particles/cm³) and it reduces to 10⁻⁵ cm/s (4.3 × 10⁵ particles/cm³) at the end of 480 s. It is observed that, the initial number concentration favours gravitational deposition upto certain period, hence, particles are seen on the collection plate. Afterwards, as the concentration becomes steady, number deposition velocity becomes individual particle settling velocity which could not be measured using this technique and hence the number of particles settling on the glass plate is too less for counting. (The number of particles deposited on the glass plate is found to be within 3σ_b; σ_b – Standard deviation of background counts). Fig. 5 shows the suspended aerosol number concentration measured by SMPS for a period of 5000 s. The data is re-plotted as Average gas volume per particle (1/N) versus Time (t), which yields a straight line with two different slopes Fig. 6. The first slope lasts upto 2000 s and indicates particle number loss rate due to coagulation^c, while the second slope is very steep and indicates particle number loss rate due to settling beyond 2000 s^d (Harrison, 1996; Subramanian *et al.*, 2011). The experimental net coagulation coefficient is found to be 6 × 10⁻⁹ cm³/s (Hinds, 1982; Subramanian *et al.*, 2011).

Assessment of Simultaneous Coagulation and Settling for SrO₂ Aerosols

In a confined environment, the decrease in total number concentration *N* over time *t* is given in Kim *et al.* (2003) and Kim *et al.* (2000):

^c The initial count-size distribution SrO₂ aerosols is uni-model with CMD = 27 nm and GSD ~1.1, hence monodispersed coagulation theory is applied.

^d The number deposition velocity measurement were not conducted beyond 2000 s during this experiment. The mass and number deposition velocity measurements were conducted for the initial time period of bottled-up condition only, and the results are applied to RCB environment.

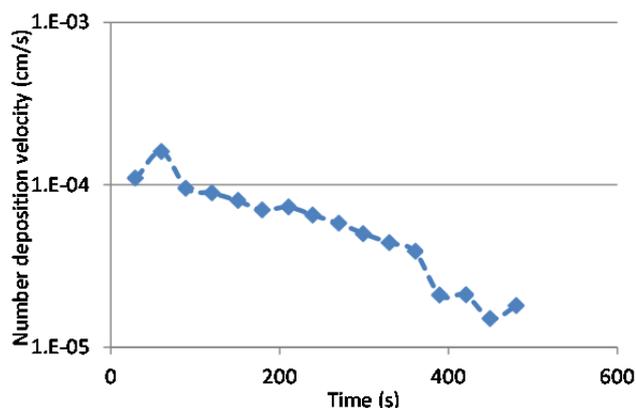


Fig. 4. Variation of number deposition velocity of SrO₂ aerosols with time.

$$\frac{dN}{dt} = -\delta N - \gamma N^2 \quad (5)$$

The terms γ , δ , and N denote the coagulation rate, deposition rate (by number) and number concentration of the suspended aerosols in the chamber at a particular time respectively. The coagulation rate ' γ ' in this equation describes, rather taken as, net coagulation rate for the entire size distribution for a period of time (sampling time), but not the temporal coagulation rate of distribution of aerosol system which is varying with time.

Assuming δ and γ are to be positive and constant over a period of time. Then, the solution of the Eq. (5) gives the decay in total number concentration over a period:

$$\frac{N(t)}{N(0)} = \frac{\delta}{[(\gamma N(0) + \delta) \exp(\delta t) - \gamma N(0)]} \quad (6)$$

where $N(0)$ and $N(t)$, are the measured number concentrations at time $t = 0$ and at time t respectively. By using the value of $N(0)$, as an input parameters in the Eq. (6) and $N(t)$ is estimated theoretically with least-error-square algorithm. Table 1 shows the calculated values against experimental values using the above equation. The fitted curve is also included in Fig. 5. From the fitted equation, the values of δ and γ are evaluated and it is found to be 3 × 10⁻⁴ cm/s and 3.4 × 10⁻⁹ cm³/s respectively. The experimental and theoretical values of coagulation coefficient and number deposition velocity are nearly same. According to Kim, the parameter ' δ ' includes loss of number concentration due to aerosol sampling. The particle loss rate other than deposition and coagulation is mainly due to sampling. But in this case, it is 12% of the volume for the entire period of 5000 s. Hence it is not considered in this calculation.

Assessment of Deposition Velocity by Mass Measurement for Sodium Aerosol inside RCB

The work described in this paper is to understand the aerosol behaviour in a confined environment (RCB) under accidental condition. In this work, settling rate is determined on the basis of concentration of the aerosols reside in the

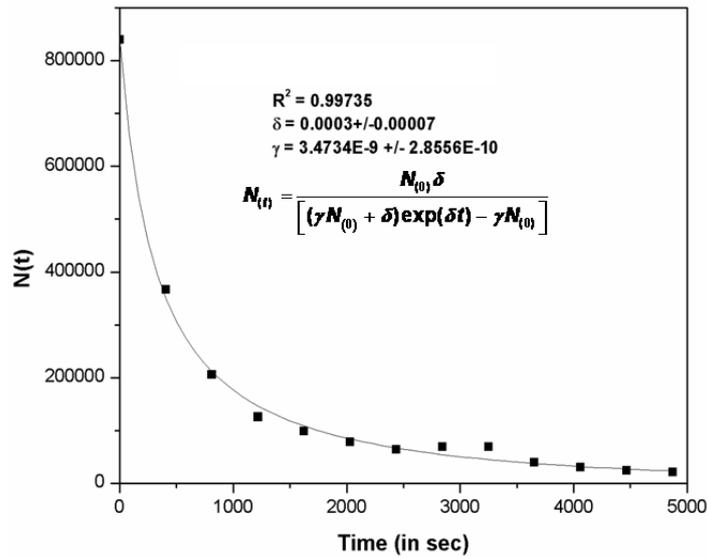


Fig. 5. Depletion rate of suspended number concentration of SrO₂ aerosols.

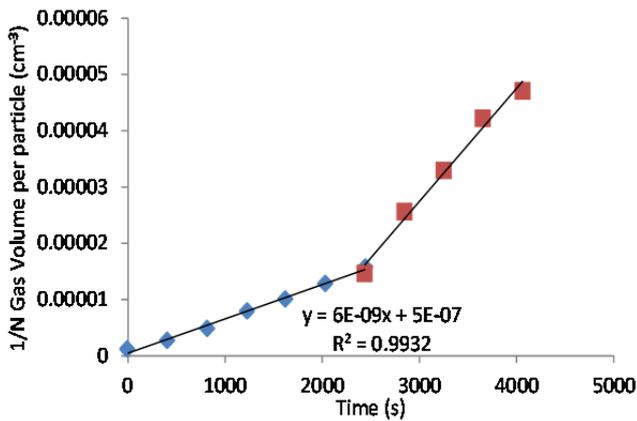


Fig. 6. Average gas volume per particle (1/N) versus Time (t).

Table 1. Experimental and Theoretical values of N_(t) for SrO₂ aerosols.

Time (s)	N _(t)	Fitted values of N _(t)
0	840569.4	840569.4
406	367147.7	351686.4
812	206143.8	212251.9
1218	125437.3	146598.2
1624	98978.4	108641.3
2030	77949.3	84058.1
2436	63406.5	66947.2
2842	68433.1	54431.8
3248	68468.2	44942
3654	39013	37547.8
4060	30362.1	31663.5
4466	23713.3	26901.6
4872	21253.7	22995.3

RCB in a typical accident scenario of fast reactor. In a system of aerosols generated with few g/m³ (in the case of sodium aerosols), the aerosols settling is determined by mass

deposition pattern. It is determined that, the mass deposition velocity of sodium aerosols progressively increases and reaches the steady value. This steady state value is used to predict the reduction rate of suspended aerosol mass concentration inside the RCB.

Let us consider the concentration of aerosols inside the aerosol chamber is uniform at all times. Diffusion, wall deposition and re-suspension if any, are taken to be negligible. The particle settling velocity is superimposed on vertical components of convective velocity and average collective settling velocity is taken as 0.15 cm/s (experimental value). Then fraction of mass removed dm/m , during an interval of time dt is given by (Hinds, 1982).

$$\frac{dm}{m} = -\frac{(V_{dep} \times dt)}{h} \tag{7}$$

and it reduces to

$$\frac{m(t)}{m(0)} = \exp\left[\frac{(-V_{dep} \times t)}{h}\right] \tag{8}$$

where $m(0)$ and $m(t)$ are the mass concentration at time $t = 0$ and t seconds and h is the height of chamber.

By taking $h = 60$ cm (height of aerosol chamber), the time taken for the mass concentration to decay by one order is calculated to be 910 s. This is almost same as shown in Fig. 3. It is also observed that, the wall deposition on the side wall (smooth and polished) of aerosol chamber is practically nil. In a similar way, if we consider the RCB volume ($h = 4200$ cm) and taking initial aerosol mass concentration is 3.0 g/m³, the time taken for the concentration to decrease by one order is found to be 17 hrs. This value is again obtained by neglecting diffusion, wall deposition and particle re-suspension. But this value can be considered as a conservative estimate and gives gross idea on the depletion of suspended aerosol mass concentration inside the RCB in the event of CDA condition.

SUMMARY

Examining the results of this study showed that deposition velocity (cm/s) is more than two orders for sodium aerosols compared to any of the fission product aerosols. The experimental and theoretical values of net coagulation rate for SrO₂ aerosols are in line with literature. The aerosol deposition is mainly dominated by the mass phenomena when the aerosol suspended mass concentration is above 1 g/m³ and it is favoured by the particle size distribution. In the case of CDA condition of fast reactor, the RCB is bottled up with large quantity of sodium aerosols of few g/m³ while fission product aerosols are few mg/m³. Hence the mass deposition velocity of sodium aerosols is the key number for the reduction of aerosol concentration suspended inside RCB, which ultimately reduce the suspended radioactive concentration too. This number can be used for various codes to model the suspended mass/activity concentrations of the aerosols reside inside RCB from time to time and also used to validate the code prediction on deposition velocity.

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