

# Development of exposure assessment method with the chamber

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**Abstract.** This study aims at developing the measurement method of nanoparticle concentration and at getting a representative value of nanoparticle uniform concentration due to chamber ventilation. We conducted a chamber equipped with HEPA filter and control the background nanoparticles concentration by using an adequate ventilation. Then, we used generator to evaluate concentration in the chamber uniformity. We measured background value and source counts at the particle size distribution by SMPS. In addition, we performed numerical analysis with CFD model OpenFoam. As results, we found that there is no aggregate in experimental conditions in this study. Though we confirmed that it is difficult to uniformise nanoparticle concentration, However we also found simulation results showed higher reproducibility. Therefore, we could assess nanoparticle size distribution and concentration in our chamber at this stage.

## 1. Introduction

Nowadays, the nanomaterials are used in various consumer products [1]. A definition of nanoparticles is different from each country. However, those diameters are approximately less than 100 nm. It was reported that impacts on the health and safety depend on the use of a surface treatment and on the diameter of nanoparticles (NPs) [2-3]. One of the exposure routes through human is to breathe airborne NPs. Products containing NPs release various types of NPs (shape, particle diameter and so on).

Therefore, exposure assessment is difficult to define for products emitting NPs [4]. It is very critical issue to estimate NPs exposure when using products containing NPs in general indoor environments as well as in workplaces [5], and it is necessary to standardize an effective and easy to use exposure assessment method of products containing NPs.

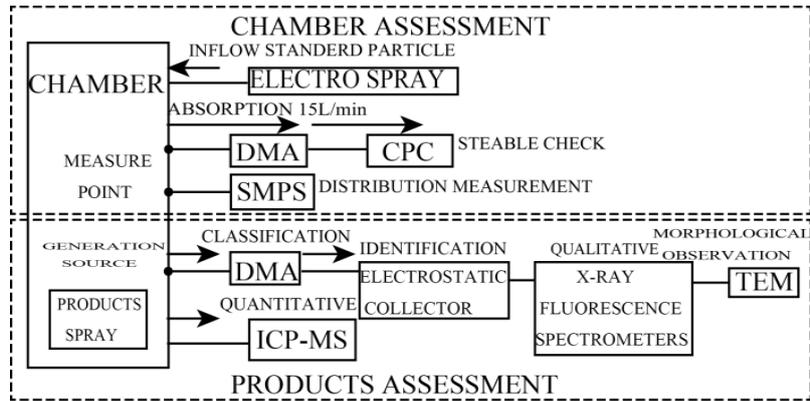
This study aims at developing the exposure assessment method for products containing nanomaterial. Therefore we get a representative value with nanoparticle uniform concentration due to chamber ventilation. We conducted a chamber equipped with HEPA filter and control the background nanoparticles concentration by using an adequate ventilation in the chamber. Then, they become steady state. Thereby, we can obtain the representative value of NPs concentration in the chamber and make an exposure assessment. There are measurement methods which evaluates the quantity of volatile organic chemical substances (VOC) in daily necessities, such as formaldehyde [6-8]. We applied these methods to measure a concentration of NPs. If a ventilation speed is controlled adequately, it is expected that we can measure airborne NPs exposure due to a homogeneous dispersion without aggregate and anybody can measure nanoparticle concentration with ease.



## 2. Methodology

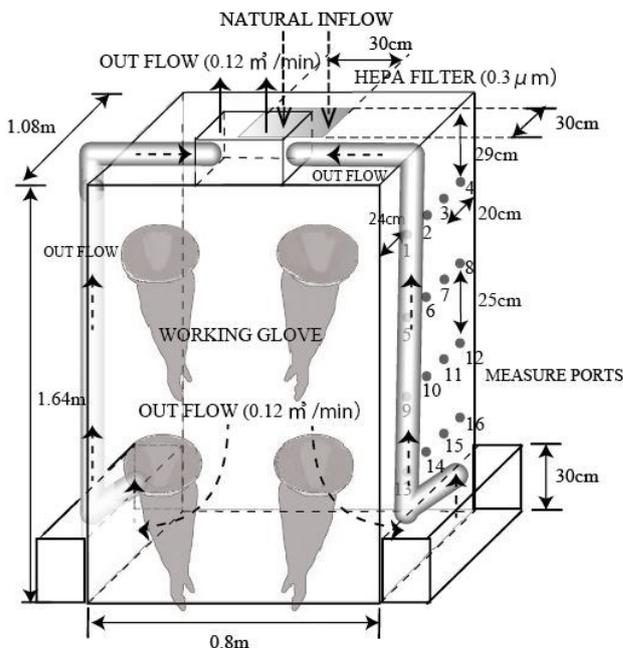
### 2.1. Construction of the chamber

At first, we show outline map of exposure assessment method (Figure 1).

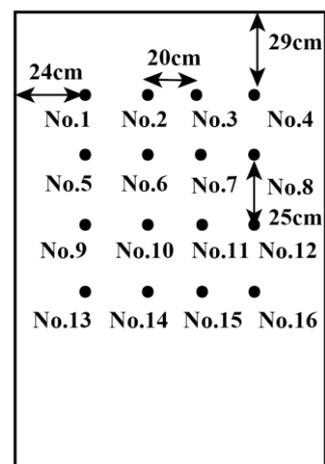


**Figure 1.** Chamber Method Outline Map.

We constructed the chamber equipped with the ventilation (Figure 2). The flames of chamber are stainless steel and inner surfaces are covered with insulating films. There are working glove to work in the sealed state with the front door, a power outlet in chamber and upper window with HEPA filter. Whole inner volume of chamber is ventilated from exhaust pipes on both sides to the upper duct by the airflow for every 12min. In addition, 16 ports for NPs concentration measurement on the right side (Figure 3).



**Figure 2.** Chamber with ventilation and working glove.



**Figure 3.** Chamber on the right side.

Secondly, we evaluated the chamber constructed, then, we practiced exposure assessment of products containing NPs (Figure 1). This study specialized in part of chamber assessment with measurement by devices and numerical analysis.

### 2.2. Assessment of NPs concentration in the chamber by measurement

We ventilated in the chamber sufficiently until background become low. Next, we measured background value of airborne particles at the NPs size distribution with Scanning Mobility Particle Sizer (SMPS, Model 3910, TSI Inc.) from ports on the right side for a few minutes. Then, we generated standard particles (size 70nm) made from sucrose for assessment with the generator (Model 3480, TSI Inc.) continuously at 12cm distance from port No.7 of the right wall (Figure 3), and checked stable condition at particle size distribution with Condensation Particle Counter (CPC, Model 3775, TSI Inc.). After we confirmed that the value is stable, we measured particle size distribution at 24cm distance from each port in rotation with SMPS for a few minutes every minute.

### 2.3. Assessment NPs distribution in the chamber by numerical analysis

We performed numerical analysis by CFD model (OpenFoam [9]). Governing equation shows (1-2). Calculation conditions in this study were incompressible, and a constant temperature is 298[K] at the measurement condition. We show a calculation condition at Table 1. On both sides, we made 16 cell outlet which evacuated 0.45[m/s] continuously and inlet on the top of chamber is pressure gradient is zero. We calculated airflow in conditions.

$$\nabla \cdot \vec{U} = 0 \tag{1}$$

$$\frac{D\vec{U}}{Dt} = -\frac{\nabla p}{\rho} + \nu[\nabla^2 \vec{U}] \tag{2}$$

**Table 1.** Calculation conditions.

head	Conditions
Calculation area	108×102×164 [grid]
Discrete method	Finite volume method
Initial condition	U=0 [m/s](air velocity) p/ρ=0
Boundary condition	U=0.45 [m/s] Pressure gradient = 0
Calculation time	20 [minute]
Temperature	Constant 298 [k]
Kinematic viscosity	0.000015 [m2/s]

After calculating for 20 minutes (flow in the chamber was stable about 10 minutes), particle tracers were generated at the same position with generator. We obtain a trajectory of particle tracer in the stable flow then we confirm whether we get the representative value.

### 3. Results

Background concentration showed much low level by the chamber ventilation (Figure 5). The peak of generating particle size distribution is mainly 48.7-64.9nm (Figure 6), and approximately maintained at each port measure data (Figure 7-9). Based on those results, there was no aggregate on this concentration.

However, the concentration was higher in the bottom of Chamber (Figure 9-10). Results of simulation also showed the same tendency which measure by SMPS (Figure 12). The airflow was much weakest in the chamber (Figure 11-12). We obtained results that the distribution of particles generated from

Port No.7 was not uniform, that is rotating in the chamber (Figure 11).

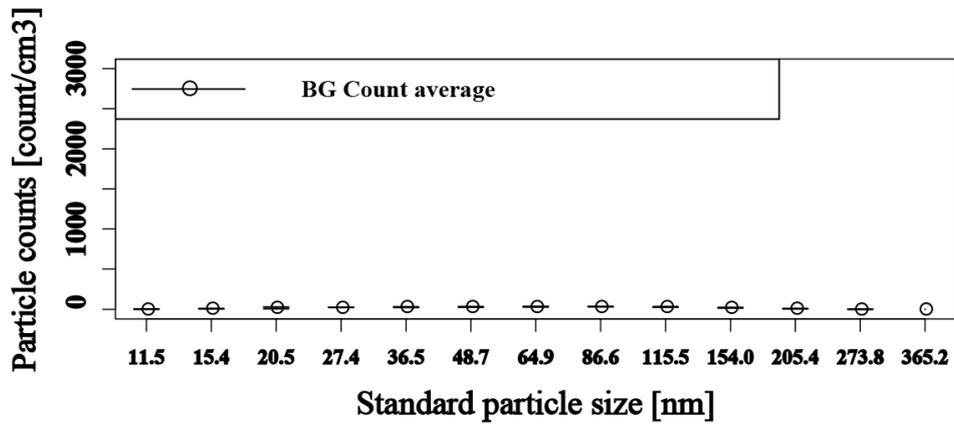


Figure 5. Mean and 95% confidence intervals for particle counts at background (n=5).

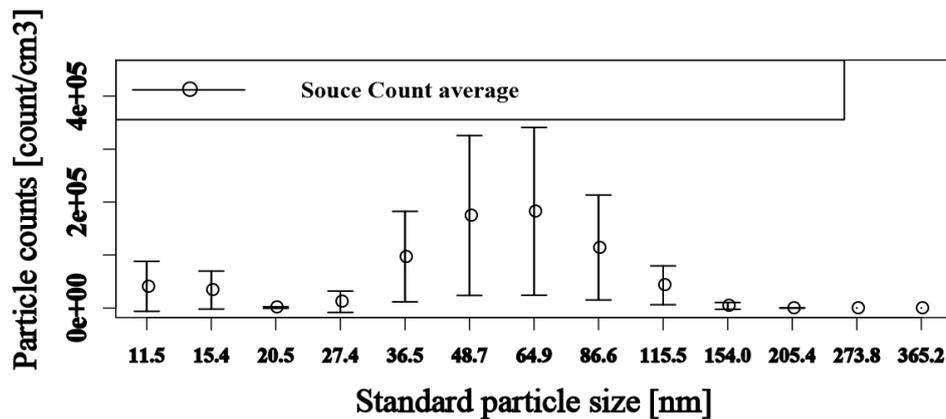


Figure 6. Mean and 95% confidence intervals for standard particle counts into port No.7 (n=3).

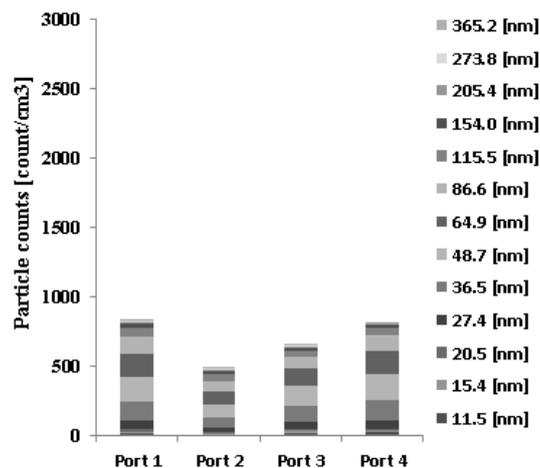
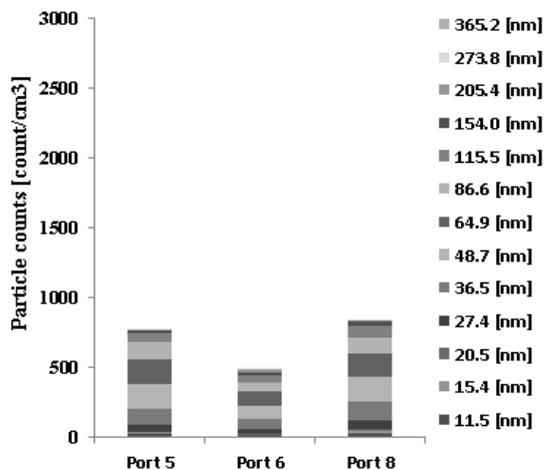
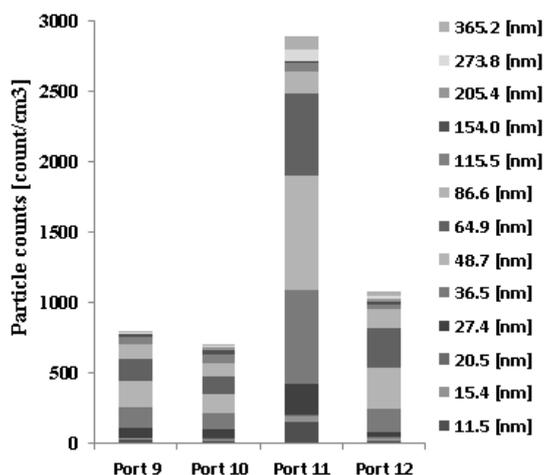


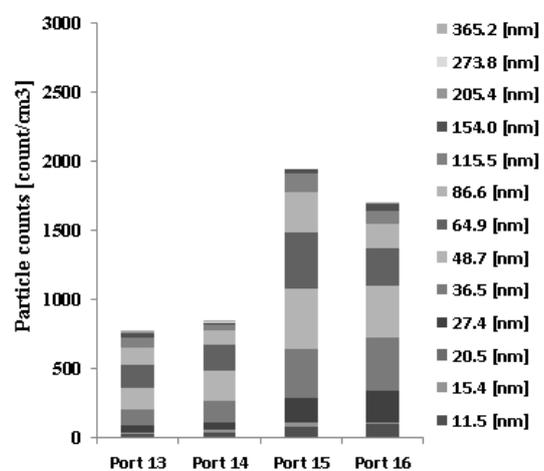
Figure 7. Particle size distribution at Port No.1-4 by SMPS.



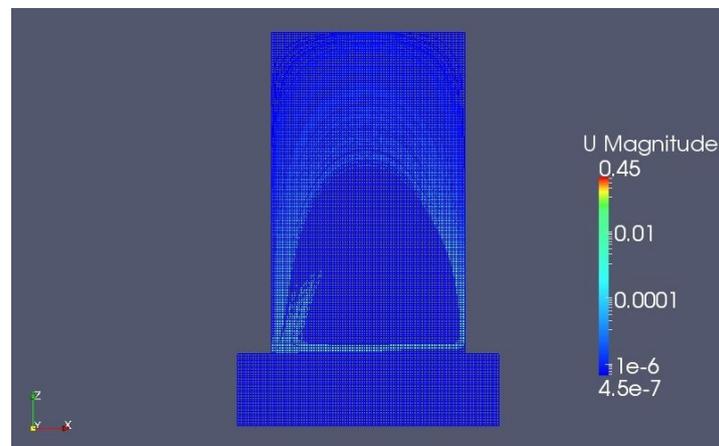
**Figure 8.** Particle size distribution at Port No.5-8 by SMPS.



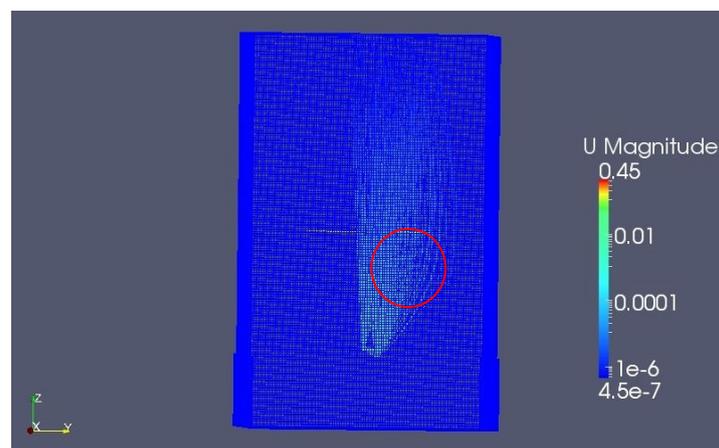
**Figure 9.** Particle size distribution at Port No.9-12 by SMPS



**Figure 10.** Particle size distribution at Port No.13-16 by SMPS.



**Figure 11.** Particles trajectory along air advection in front of the chamber.



**Figure 12.** Particles trajectory along air advection in right side of the chamber.  
The red circle is around Port 11,12,15,16.

#### 4. Conclusion

Results did not show uniform concentration of nanoparticles. However, we found that there was agglutination in these conditions (source of sucrose, velocity, concentration of particle generated, temperature). Moreover, the results of simulation corresponded with measurement data by devices. Figure 12 showed many trajectories around Port No.11, 12, 15 and 16 as well as Figure 9-10 estimated high concentration around same points. To be conclusion, we cannot obtain a representative value in this chamber at this stage. However, we obtained that optimum ventilation conditions and numerical analysis is efficient in this study.

Now, we are improving the chamber. We plan to ventilate in the whole chamber with closing upper wall without aggregate and agglomerate (from bottom part to top part).

Therefore, it is expected that nanoparticle concentration is stable uniformity. In addition, we can obtain a representative value easily for anyone.

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