Size-selective Bioaerosol Sampler Combined with an Adenosine Triphosphate (ATP) Bioluminescence Assay

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Abstract

Airborne biological dust (bioaerosol) is ubiquitous in environments and is found associated with adverse health effects. Their concentration should be measured to assess the exposure and protect workers' health. To measure the concentration, bioaerosols are usually collected in the media and then incubated for >24 hrs. However, this quantification method is time-consuming because of transportation and incubation. In this study, we built a size-selective bioaerosol sampler which combines with adenosine triphosphate (ATP) bioluminescence assay for measuring bioaerosol concentration more rapidly. This sampler consisted of a respirable cyclone, an impactor to collect bioaerosols onto the head of a swab used for ATP assay, a swab holder, and a sampling pump. The performance of the sampler was evaluated and compared with a conventional Andersen impactor in the lab. Concentrations of aerosolized *Escherichia coli* collected using the sampler were highly correlated to those from the Anderson impactor (R^2 = 0.85).

Introduction

What are "Bioaerosols"?

- Airborne (aerosol) particles of biological origins
  - Virus, bacteria, fungal spores, pollen, live or dead organism.[1]
- Bioaerosols found in workplaces
  - Composting sites, waste plants, food industries, livestock facilities, etc.
- Health effects
  - Potentially cause acute and chronic diseases: contagious infectious disease, acute toxic effects, allergies and cancer.[2]

Monitor methods for bioaerosols

- Traditional method: Inertial impactors and impingers
  - Collect particles onto agar plate (media) → Incubate → count colony
  - Limitations: easy to cause overload, time-consuming, not portable

⇒ A more convenient, rapid and portable device is needed!

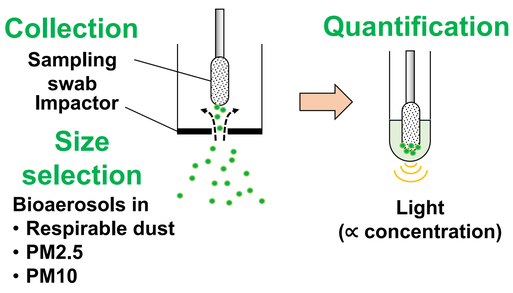
Adenosine triphosphate (ATP) bioluminescence

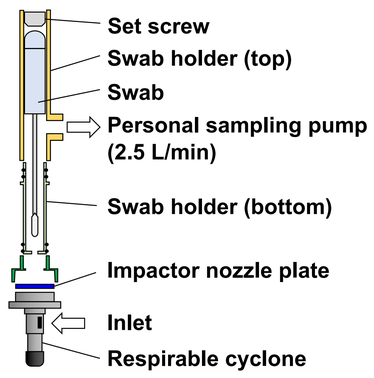
- Alternative Method
- Widely used for rapidly detecting microbial contaminants on surfaces
- Requires a swab to take microbial contaminants
- ATP (from bacteria) + Luciferin (from fire flies) → Oxyluciferin + AMP + Inorganic Pyrophosphate + Light

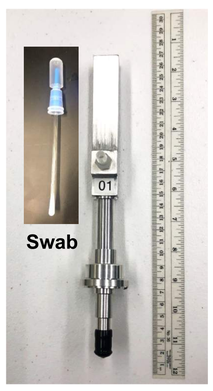
Bioluminometer

How to collect bioaerosols onto "swab"?

- Size-selective bioaerosol sampler was designed and fabricated.







- The sampler consists of:
  - Respirable cyclone (cut-off diameter of 4 μm)
  - Impactor to collect bioaerosols onto the head of a swab used for ATP assay (Experimental cut-off diameter of 0.44 μm)
  - Swab holder
  - Sampling pump

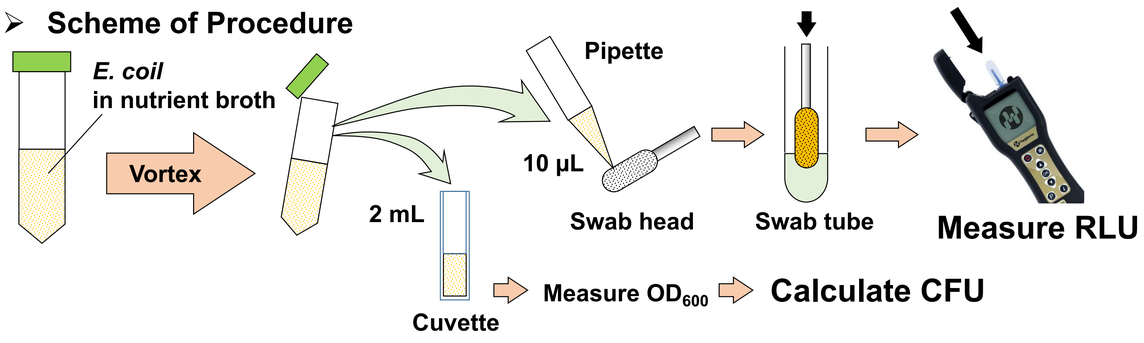
Objectives

- Development of a bioaerosol sampler combined with ATP bioluminescence method for rapid quantification of bioaerosols
  - ✓ Develop a method to convert a relative light unit (RLU) from the ATP bioluminescence assay to a conventional colony forming unit (CFU)
  - ✓ Evaluate the performance of developed method
  - ✓ Compare the developed method to conventional method

Methods

Swab test for developing the conversion method

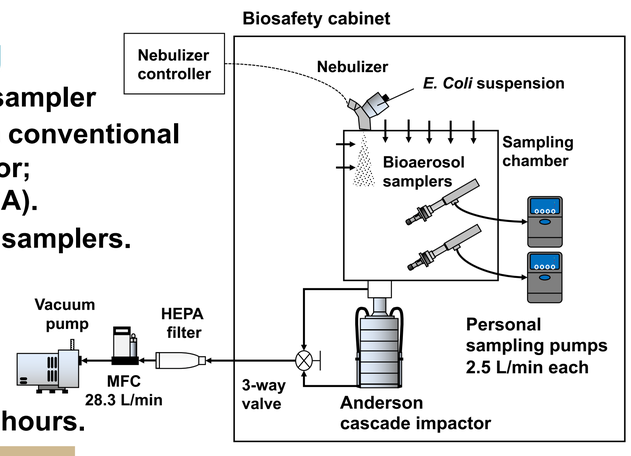
- Scheme of Procedure



- Two swabs were tested using *E. coli* suspension.
  - Test swab: SuperSnap (Hygiena, USA) and UltraSnap (Hygiena, USA)
  - Test bacteria suspension: *E. coli* (ATCC 11775) in nutrient broth (Difco, BD, USA)
- Test procedure
  - Dilute test suspension: 1%, 5%, 10%, 15%, 20%, 30%, and 50%
  - Measure optical density at 600 nm (OD_{600}) of *E. coli* suspensions
  - Calculate cell numbers from OD_{600} using following equation:
    - OD_{600} of 1.0 = 8 x 10^8 cells/mL
  - Pipette 10 μL of suspension onto swab head and measure the RLU value using a bioluminometer (EnSURE, Hygiena, USA)
  - Plot the conversion curve

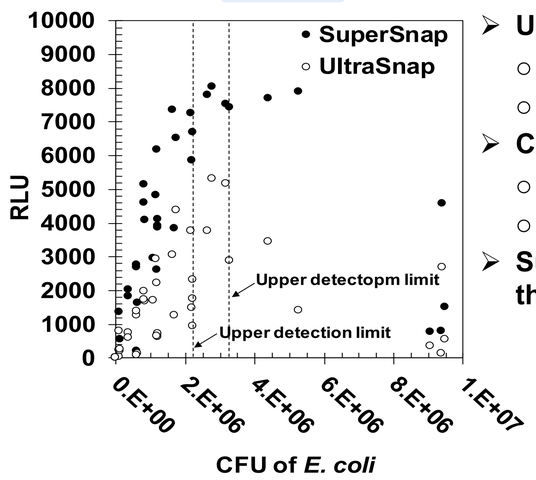
Evaluation by lab sampling

- The performance of the developed sampler was evaluated and compared with a conventional sampler (Andersen cascade impactor; TE-10-800, Tisch Environmental, USA).
- Two different swabs were set in the samplers.
- Aerosolized *E. coli* was sampled.
- RLU values were measured using a bioluminometer.
- CFU values were counted after incubating agar plate in 37°C for 24 hours.



Results and Discussion

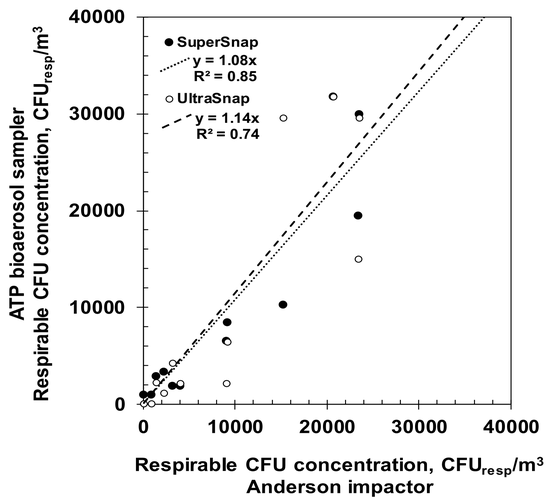
Swab test results and conversion equations



- Upper detection limits of test swabs
  - SuperSnap: ~ 2.2 × 10^6 $CFU_{E. coli}$
  - UltraSnap: ~ 3.3 × 10^6 $CFU_{E. coli}$
- Conversion equations
  - SuperSnap: $CFU_{E. coli}$ = 277.78 × RLU (R^2 = 0.81)
  - UltraSnap: $CFU_{E. coli}$ = 633.60 × RLU (R^2 = 0.53)
- SuperSnap was about 2.3 times more sensitive than UltraSnap.

Evaluation and comparison results

- The CFU concentrations measured using SuperSnap and UltraSnap were Proportional to CFU concentrations measured using the Andersen impactor.
- R^2: SuperSnap (0.85) > UltraSnap (0.74)
- The slopes of both swabs were slightly lager than 1.



Conclusions

- The SuperSnap showed better sensitivity than the UltraSnap.
  - SuperSnap: appropriate for both environmental and occupational samplings
  - UltraSnap: appropriate for occupational sampling (∵ Occupational concentration > Environmental concentration)
- The CFU concentrations measured using SuperSnap and UltraSnap were proportional to those measured using the Andersen impactor.
- In comparison with Andersen impactor, the ATP bioaerosol sampler can overcome the limitations of Andersen impactor.
- Future research will be focused on:
  - Lab test with different aerosolized bacteria (e.g., *S. epidermidis*, etc.)
  - Field test in various occupational settings (e.g., horse barn, hospital, etc.)

References

[1] W.C. Hinds, Aerosol Technology: Properties, Behavior, and Measurement of Airborne Particles, 2nd edition, John Wiley & Sons, New York (1999).

[2] K.-H. Kim, E. Kabir, S.A. Jahan, Airborne bioaerosols and their impact on human health, J. Environ. Sci. 67 (2018) 23−35.

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If you have any questions or want to know more about this study, please scan the QR code!