Potential and control method of bioaerosol emission at composting process in TPST Diponegoro University

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Abstract. Laboratories in university particularly related to biological process have the potential to emit bioaerosol. The composting process in the lab is one of those that produce complex bioaerosol. This study is aimed at analyzing the potential bioaerosol emissions from the composting process at TPST and proposing efforts to reduce emissions toward outside the lab room. To calculate the emission potential of bioaerosol, specific emission factors from the literature are used. The room dimensions for composting are 2.46 x 1.38 x 0.7 m, and there are 18 spaces for the composting process. Based on the measured dust concentration in the composting room were on average above the ambient air quality standard for TSP (230 ug/m³). Hypothetically, emissions from the composting process at TPST reach a highest point of 4x10⁶ CFU/m³, peak at a distance of 7 m from the source of the composting process. However, the health risks associated with bioaerosol emissions are relatively small because the period of exposure to TPST operators near the composting area is quite small. Control efforts by installing a windbreak fence can minimize the amount of emissions that leave the composting area by 80%.

1. Introduction

Bioaerosol or air microorganisms found in the environment in space with a large number [1]. Based on several studies conducted in several countries in the world it was reported tahat bioaerosol contribute to 5 – 10% of total suspended particles and about 24% of the total particles in the atmosphere [2]. Although bioaerosol is present in most of habitat, outdoor/ambient air, housing construction, and maintenance of material, the parameters of air exchange ventilation, human occupancy, and operational activities are the main factors affecting bioaerosol in the room level [3]. Specified bacteria and fungi are bred through humans activities, where humans do not appear to be the place to grow these classifications, human activities play an important role, for example in shedding particles from clothes or scattering dust that sticks to the fabric can contain bioaerosol types of fungi [4]. The characteristic of source, species, relative humidity and aerosolization mechanism will determine the size of particles derived from airborne bacteria and fungi. Around the room, bacteria and fungal particles are in the breathable size range of <5 μm which allows inhalation via the human respiratory tract. Several studies have shown that exposure to aerosol types of bacteria and fungi around rooms is associated with non-communicable diseases, including allergies, respiratory diseases, and immunotoxics [5]. In Indonesia, studies on bioaerosol are mostly carried out by hospitals where there is a lot of potential for microbial scattering in the air in the treatment room, kitchen room, operating room, toilet and laundry room. In public facilities, especially
Integrated Waste Management Site or TPST, where there are activities of collecting, sorting, and processing waste, the it is potent to produce bioaerosol emission continuously in the area of composting process. The Integrated Waste Management Site (TPST) is a place for the collection, sorting, reuse, recycling, processing and final processing of waste. With an increasingly consumptive lifestyle, the amount of waste generated continues to increase, so that management efforts are needed. In the waste management activities at TPST. In the TPST, there are usually process that requires a long period of time, such as composting, but there are also fast processes such as solid waste transfer, solid waste shredding and untreated solid waste transfer to final disposal in landfills. Identification these process will eventually minimize and even prevent hazards particularly related to bioaerosol emission.

Activities in TPST can massively increase the number of pollutants in the environment. This condition causes the risk of exposure to indoor pollutants to humans is getting higher, but this condition is still rarely known by the people. Poor air quality will have a negative impact on workers or employees in the form of complaints of health problems. The impact of indoor air pollution on the body, especially on organs that are in direct contact with the air, namely complaints of diseases related to bioaerosol can be in the form of infectious diseases such as flu, hypersensitivity (asthma, allergies), and toxicoses, namely toxins in contaminated air in the room that become causes of SBS (Sick Building Syndrome) symptoms. SBS is a collection of symptoms of a disease which is also defined as symptoms that occur based on the experience of building users while they are in the building. Symptoms of SBS include headache, loss of concentration, dry throat, eye and skin irritation. Some forms of diseases associated with SBS include irritation of the eyes and nose, skin, and mucous layer of dry, mental fatigue, headache, URI (Upper Respiratory Tract Infection), coughing, sneezing, and hypersensitivity reactions. Thus, this study aims to assess the bioaerosol emission that occurs in the Integrated Waste Processing Site (TPST) and propose mitigation for emission dispersion reduction. With this measure, it is hoped that that bioaerosol dispersion from the Integrated Waste Management Site (TPST) could be minimized.

2. Methodology
The research was carried out in the Diponegoro University (Undip) Integrated Waste Processing Site (TPST), Indonesia. In this TPST, the anorganik solid waste types i.e plastic, styrofoam, bottles, paper types will be selected and resold to collectors. Part of the waste that cannot be resold and composted (for organic types) will be disposed of in the landfill. With this system, it is hoped that only a small proportion of waste will be disposed of in the landfill. We measured ambient air quality (TSP parameter) for short period at two sites in the area and outside composting area. The two measurement sites close to the composting location and the outside/outdoor area as the control location in the TPST field. The sampling was carried out in the morning and during the day. Activities at the TPST are generally congested at 10-11 AM, where many bulky waste collected with vehicles from the Undip area were selected and dumped to the composting area. The TPST condition was abnormal (relatively low load) since it was during the Covid-19 pandemic conditions.

The building characteristic TPST’s composting is the dimension of each composting area 2.4 m x 1.38 m with 1 m height. It consist of 5 composting areas in the right side and and left side and there are 8 composting square in the middle (figure 2). However during sampling event, only two composting area (one in left side and one in right side) were in operation. The main composting material is dry leaves. The composting method is used natural wind with periodical stirring. We estimate the bioaerosol emission from [6] using specific bioaerosol emission rate (SBER).
To quantify and estimate the risk of exposure to bioaerosol, it is necessary to record activity data of the worker at the Diponegoro University Integrated Waste Processing Site (TPST). This record is important because activities in TPST can affect the level of bioaerosol in the area of composting. The data and information needed to calculate intake in order to find a health impact are all variables related to the following equation [7]:

$$I = \frac{C \times R \times t_E \times f_E \times D_t \times W_b}{\text{tavg}}$$

Where:
- $I$ : Intake, mg/kg/day
- $C$ : Concentration risk agent, mg/m$^3$ for air medium, mg/L for drinking water, Mg/kg for food or groceries
- $R$ : Ingestion Rate, m$^3$/hours for inhalation
- $t_E$ : Time of exposure
- $f_E$ : Exposure Frequency (days/yr)
- $D_t$ : Exposure Duration (yr)
- $W_b$ : Body Weight (kg)
- $\text{tavg}$ : Averaging Time (Period over which exposure is averaged) (days)

Time of exposure ($t_E$) was traced by asking how long it the respondent's daily habit of being at the TPST's composting process in hours. Likewise for the Exposure Frequency ($f_E$), what the period they...
are in the area of TPST composting in days. For the Exposure Duration (Dt), it must be known how long the respondent actually was (real time) at the TPST until the time the survey was conducted in years. The body weight is also be estimated by interview.

3. Results and discussion

Based on the monitoring of dust quality at TPST Undip locations in three places, namely locations near composting and control points, the following results were obtained in table 1:

| Location                  | Concentration (µg/m³) | Status   | Description |
|---------------------------|-----------------------|----------|-------------|
| Near Composting (East Side) | 263.4                | >AAQS    | Measurement |
|                           | 335.5                | >AAQS    | 8.30 – 9.30 AM |
| Near Composting (West Side) | 151.9                | <AAQS    | Measurement |
|                           | 303.8                | >AAQS    | 9.35 – 10.35 AM |
| TPST Parking Area          | 135.3                | <AAQS    | Measurement |
|                           | 114.1                | <AAQS    | 10.40 – 11.40 AM |

AAQS of TSP for 24h : 230 µg/m³

Although there is no ambient air quality standard for 1 h, if we compare with 24 h standard, it violated in several occasions. Considering that the bioaerosol component is also present in dust particles, it is likely that bioaerosol emissions are also high around the TPST as there was no specific sources other than composting process. This is quite different from the ambient dust concentration in the parking area where the concentration of dust is still below the threshold value. At the time of the dust measurement, the parking area was relatively quiet and there were no activities. The garbage collection activity in normal conditions occurs at 10-11 am. However, when the research was carried out, there was few activity of unloading garbage from transport vehicles considering the quiet campus conditions due to the impact of the Covid-19 pandemic.

To determine the dust distribution from TPST composting, a SCREEN View model was made by modeling one composting area (size 2.46 x 1.38 m). The assumptions used are:

a. Static composting process with natural wind;
b. Using SBER: AF: 8.3 - 11.1 (x10³ cfu / s), MA: 13.1 - 21.7 (x10³ cfu / s).

![Figure 3. Results of the bioaerosol dispersion model with screen view.](image)

The bioaerosol concentration increases up to a distance of 7 meters from the composting area and begins to decline after that distance. If the control is carried out using the windbreak fence surround the
composting area (figure 4), the dispersion graph will be reduced since this windbreak fence will minimize the wind resuspend the dust emission from the composting process.

Figure 4. Installing wind break fence surrounding TPST’s composting area.

The results of dispersion bioaerosol due to wind break fence installation surrounding the composting facility is as follows:

Figure 5. Results of bioaerosol dispersion model with Screen View with control.

To determine the health impact of bioaerosol, the TPST operator activity data is used with the following assumptions:

a. Body weight average (Wb) = 65 kg
b. Time of exposure (TPST = 2 hours/day)
c. Exposure Frequency (TPST = 260 day/year)
d. Exposure Duration (TPST = 5 year)
e. Ingestion Rate (R) = 0.83 m3/hours

Based on preceeding formula the calculation the parameter I is 0.036 mg/kg/day, thus this is small intake to the person.
4. Conclusion
From the above experiments, several conclusions can be drawn. TPST has the potential for bioaerosol emissions in the range of 1 - 10 x 10^6 CFU/m^3. In an effort to reduce bioaerosol emissions at TPST, it can be reduced by 80% by installing a windbreak fence around the TPST. From the study, the bioaerosol intake of workers at TPST is still low because of activity patterns were unusual operated normally as a result of the Covid-19 pandemic.

Acknowledgment
This study was funded by RKAT Faculty of Engineering, Diponegoro University, Dean Decree No. 145/UN7.5.3.2/HK/ 2020.

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