Potential noise annoyance from ambient air quality measurement using high volume air sampler (HVAS)

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Abstract. One of the benchmarks in air pollution is the quality of ambient air consisting of gas and particulate matter. Measurement of particulates in ambient air can be done using a High-Volume Air Sampler (HVAS). However, in the measurement process it sometimes causes noise annoyance to the community where the measuring instrument is operated, considering that the operating time of the instrument is 24 consecutive hours. This research identifies the value of the sound power level emitted from the several types of HVAS to the surrounding environment. There are two types of HVAS measured in this study consisting of one unit of HVAS with analogue flow control made by Indonesian manufacturer and two units of HVAS with digital flow control made by Japan and United States of America manufacturers. Sound power level is determined using ISO 9614 method with a sound intensity analyzer as the main instrument. The sound power level data for each HVAS were than compared and frequency spectrum distributions are evaluated. Based on the research results, it was found that some sample units emitted sound power levels of more than 90 dBA with dominant noise being at high frequencies starting from 4000 Hz. The results of the research can be used as an early information in the development of the HVAS regarding noise mitigation, because there is different approach for controlling noise specifics in low, mid and high frequencies noise source.

1. Introduction

One of the benchmarks in air pollution is the quality of ambient air consisting of gas and particulate matter that not only effect person health but also non-health as well in example optical, social and economic effects \cite{1}. Measurement of particulates in ambient air can be done using a High-Volume Air Sampler (HVAS). It has the working principle of the vacuum system by pulling environment air through the selective size inlet and through filters at given flow rate \cite{2}. The use of HVAS has grown since 1967 \cite{3}. It provides a measurement of the mass concentration of total suspended particulate matter (TSP) in ambient air for determining compliance with the primary and secondary national ambient air quality standards \cite{4} and requirement for particulate matter \cite{5}.

The volume of air passing through the filter of HVAS is the product of the flow rate and the length of the sampling period \cite{6}. However, in the measurement process it sometimes causes noise annoyance to the community \cite{7} where the measuring instrument is operated, considering that the operating time of the instrument is 24 consecutive hours.

HVAS are instruments used to collect samples of air particle; they draw a large known volume of air through a pre-weighed filter for 24 hours simultaneously (Figure 1). The sampler filter traps the particles as air passes through the instrument. After sampling, the filter is re-weighed and the
difference in filter weight is the collected particulate matter mass. Dividing the mass by the volume of air sampled gives the concentration of total suspended particulate matter. If required, the particulate matter retained on the filter is analysed to determine the concentration of pollutants, such as lead or other metals [8].

![Illustration of a total suspended particulate matter sampler](image)

**Figure 1.** Illustration of a total suspended particulate matter sampler [8].

Regarding airborne noise sources, it is important to determine the sound power and directivity of them to determine their relative contributions to the noise problem. Sound power level information is useful for the following purposes:

a. allows comparison of the noise-producing properties of different machines;
b. allows verification that the noise produced by a particular machine meets specifications for noise-control purposes;
c. provides a means for predicting expected noise levels in reverberant spaces and in the free-field when directivity information is also known.

The sound power level should be characterized in octave or one-third octave frequency bands [9] and dominant single frequencies should be identified [10].

The HVAS can be divided into several type regarding the rotating motor pump used, timed operation and flow regulation and control system. There are HVAS with brush and brushless motor pump for air suction, regarding the flow there are automated regulated flow control using an integrating air flow counter [11] such as differential pressure detection system technology [12] and by manually operated or analog setting using potentiometer to limit the working voltage to the rotating motor which we can found on traditional model.

This research identifies the value of the sound power level emitted from the several types of HVAS to the surrounding environment. The results of the research can be used as an information in the future development of the HVAS regarding noise mitigation technology.

2. Method
The research was conducted in Centre for Research and Development of Quality and Environmental Laboratory (P3KLL), Serpong, Banten, Indonesia in 2021. The scope of the research is limited to \( L_w \) determination using sound intensity analyser refer to ISO 9614-2, which is an appropriate standard for on-site determination of sound power. It is based on measurements where the sound intensity is measured over a surface using the scanning method. With a suitable speed, the probe is simply scanned over the surface of the HVAS, as if the surface were being painted. This gives a single-value spatial average intensity for the surface. Multiplying by the area gives the sound power from this surface. Then the sound power contributions from all the surfaces are added to give the total sound power [13] .

The research steps are literature study, determination of several types of HVAS as the test specimens, measurement using sound intensity analyser, data processing, data analysis, and data interpretation. Literature study was conducted to find out the novelty of research and research preparedness. Determinations of HVAS are based on availability and type of flow controllers.

The sound power measurements used the same measuring instruments and personnel. The specimens tested consisting of HVAS manufactured by Sibata with TSP and PM 2.5 feature, HVAS manufacture by Tisch and HVAS custom made by Indonesian manufacturer. This was quantitative research.

The sound power level of the noise source \( (L_w) \) stated in decibel (dB) on each frequency band follows the equation (1) [14] as follows:

\[
L_w = 10 \log \left( \frac{\sum_{i=1}^{N} P_i}{P_0} \right)
\]

where:
N is the total number of measurement segments
Pi is the partial sound power for segment i
\( P_0 \) is the reference sound power \((10^{-12} \text{ Watt})\).
Figure 2. Measuring the HVAS dimensions.
3. Results and discussion

3.1. Noise consideration of HVAS in the previous study

Previous study found sound level around the HVAS have nonuniform contours indicate that impacts on nearby receptors can be reduced through the choice of the direction in which the HVAS faces [7]. The previous study also have recommendation on noise reduction shelter design for HVAS but the measurements were made in a room whose background noise had a relatively large low frequency component so that the low frequency reduction of the controlled shelter was not precisely quantified [15]. Anthony M. Sacco et al have also proposed noise level reduction using muffler design although yet it cannot give proper information in the low frequency range below 500 Hz [16].
This study tried to give some more information on the low frequency band up to 50 Hz and to take account that sound intensity measurement is relatively annoyed by high background noise. Several national and international standards now exist for the determination of the sound power of sources from sound intensity measurements [17].

3.2. Sound power level distributions over one-third octave frequency spectrum

Figure 5 shows the distribution of sound power level of HVAS in one-third octave frequency spectrum spreading from 50 to 6300 Hz. It is interesting to find that the Sibata TSP give less noise level except in 400 and 500 Hz frequencies.

![Figure 5](image)

**Figure 5.** Sound power level of HVAS in one-third octave frequency spectrums.

A Weighting is a frequency response adjustment of a sound-level meter that makes its reading conform very roughly to human response [18], Figure 6 shows the sound power level of HVAS in A-weighted frequency weighting. The Sibata PM 2.5 has a high value of sound power level above 4000Hz (Figure 6), it is estimated that the HVAS shelter only compensates more on low-frequency bands. It also has the highest noise level value that requires more attention, as The National Institute for Occupational Safety and Health (NIOSH) considers a Noise-induced hearing loss greater than 15 dB at the 500, 1000, 2000, 3000, 4000, and 6000 Hz frequencies to be significant [19].
3.3. Total sound power level of various HVAS under study

On many of equipment standardization required only single value of sound power level that is total A-Weighted sound power level. From Figure 7 it was found that the total sound power level value of the unit under study has different capability in conforming the standard by reducing A-weighted noise source that are sensitive to human response.

To protect the majority of people from being seriously annoyed during the daytime, the sound pressure level on balconies, terraces and outdoor living areas should not exceed 55 dB LAeq for a steady, continuous noise and during night time, sound pressure levels at the outside façades of the living spaces should not exceed 45 dB LAeq, so that people may sleep with bedroom windows open. These values have been obtained by assuming that the noise reduction from outside to inside with the window partly open is 15 dB [20].

Figure 6. Sound power level of HVAS in A-weighted one-third octave frequency spectrums.
4. Conclusion

Based on the research results, it was found that some sample units emitted sound power levels of more than 90 dBA with dominant noise being at high frequencies starting from 4000 Hz to the surrounding environment. The total sound power level for all HVAS is above 70 dBA, different selection of noise mitigation should be used to obtain the desired value of noise level especially at night time that has more stringent tolerance.

The results of the research can also be used as an early information in the development of the HVAS regarding noise mitigation, because there is different approach for controlling noise specifics in low, mid and high frequencies noise source. The noise shelter made from wood and muffler system on the previous research have some opportunity for reducing high frequency noise level. However, the results of this research still require further research regarding the directivity pattern of HVAS noise behaviour.

Acknowledgements

We would like to thank Pramana Budi Purwaka, Hisyam Afilludin and Jamaludin who helped this research. We also give our gratitude to Center for Standardization of Environmental Quality Instruments for providing the opportunity and support to conduct this work.

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