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MEASUREMENT OF AMBIENT OZONE CONCENTRATION USING PASSIVE SAMPLER

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ABSTRACT

Measurement of ozone concentration in ambient air was carried out using the passive sampling method in Cipedes, Bandung, from 2012 – 2020. Sample analysis was done using ICS 1500 Dionex ion chromatography. The results showed a fluctuating concentration from 2012 -2020 with the highest average value in 2015 of 29.94 g/m^3. The monthly pattern shows the highest ozone concentration in September and the lowest in December; this condition was related to the intensity of rainfall that can clean ozone in the atmosphere. The seasonal pattern showed in the dry season ozone concentration is relatively higher than in the rainy season. A comparison of passive and continuous sampling was made to see the performance of the passive sampler showing a similar pattern with a correlation coefficient of r = 0.48. This difference in value was related to the absorption of ozone gas in the passive sampler absorbing filter and the meteorological factors.

Keywords: *passive sampler, Ozone, Concentration*

INTRODUCTION

High concentrations of ozone in ambient air can impact human health and the environment. Tropospheric ozone is a secondary pollutant resulting from a photochemical reaction between nitrogen oxides (NOx) and VOCs [1]. Tropospheric ozone can absorb solar radiation, so it can be a strong greenhouse gas that affects the climate, such as increasing temperature [2]. In addition, ozone can harm human health and ecosystems [3].

One of the ways to monitor tropospheric ozone concentrations is by using the passive sampling method [1]. Research and monitoring of ambient air using the passive sampling method have been widely carried out globally. The ozone troposphere has also been carried out in the tropical regions of Singapore [4] and the United Arab Emirates [5], as well as in Africa [6]. Passive sampling takes gas samples in ambient air without a pump but physically transfers airflow and natural diffusion into a layer of static air or sampling media [7]. Passive sampling equipment is very easy to use, inexpensive, has high sensitivity, does not require calibration, and can be used for monitoring over a long period [5,8].

The concentration ozone troposphere is influenced by many factors, such as the source of the ozone precursor, geographic location, and meteorology [1,9]. Based on research carried out on the European continent using a passive sampler, the average ozone concentration for six months is above 45 ppb. The passive sampler is carried out to complete monitoring points that cannot be reached by automatic monitoring tools [1]. Another study in America, using a passive sampler based on a colorant that faded when reacted with ozone, obtained a detection limit of 30 ppb using a plastic grid and 120 ppb using a Teflon filter [10].

Research and monitoring of ambient air using the passive sampling method have been widely carried out in Indonesia [11,12,13,14]. However, monitoring the ozone concentration using a passive sampler is still rare. This research was conducted to monitor ozone concentration using a Ferm type passive sampler by comparing its concentration with measurements with the Dasibi Ozone Monitor automatic equipment. In the future, the results obtained can be used to complete air quality monitoring points in Indonesia, which are not possible with automated equipment.

METHODS

1. Data and Location

The research was conducted in Cipedes, Bandung. Cipedes is an urban area with the main pollutant source from motor vehicles. Motor vehicles emit pollutants in NOx, which can react with ozone precursors to form tropospheric ozone. The data used was passive sampling ozone concentration from 2012 to 2020.

2. Method

Ozone sampling in ambient air uses a passive method with a passive sampler sampling device according to the CSIRO procedure with a sampling time of every month from 2012 to 2020. The passive sampler is designed based on the principle of molecular diffusion. The gas molecules will diffuse into the sampler and collect in the filter. The filter used is a cellulose filter and has previously been added with K_2CO_3 (potassium carbonate) and $NaNO_2$ (Sodium Nitrite) absorbent materials. The gas inlet on the passive sampler is covered with a fine mesh (stainless steel mesh) that can make air transport convective.

The sampled filter was extracted using demineralized water and left for at least one night or put in an Ultrasonic Cleaner. Extraction results were analyzed using ion chromatography equipment and read as Nitrate (NO_3^-) ions. From the calculation, results will be obtained regarding ambient ozone concentration. The method of calculating ozone concentration can be seen in previous studies [13]. To convert units can use equation [15]:

$$[SO_2] = \frac{C_o \ x \ MW}{1000} \qquad (1)$$

Information:

$[SO_2]$ = concentration (μg m^{-3})

Co = concentration (nmol m^{-3})

MW = molecular weight

To see the performances of the passive sampler, a comparison of the passive sampler's ozone concentration data was carried out with the ozone concentration data from the automatic sampling, namely the Dasibi Ozone Monitor. Data comparison is carried out from 2017-2019 following the availability of data from the automatic monitor.

RESULTS AND DISCUSSION

1. Analysis Of Passive Sampler

Analysis of filter extraction was carried out using ion chromatography equipment type ICS 1500 Dionex. The principle of ion chromatography was the liquid mobile phase is flowed through the column to the detector by a pump. The eluent used was a mixture of Na_2CO_3 and $NaHCO_3$ that had previously been prepared in the laboratory. The stationary phase was a separator column that contained an ion exchange resin. The column was a place for the separation of the sample into ions.

Due to the different interactions between the ions in the sample with the stationary phase, the ions with the small valence will leave the column first. On the other hand, ions with big valence will leave the column longer. Separated ions will leave the column and be detected by the detector and recorded in a chromatogram [16]. Furthermore, the results of the chromato-graphy analysis were calculated for the ozone concentration [13]. The conversion calculation was carried out according to equation (1).

2. Ozone Concentration

Based on Figure 1, it can be seen that the results of monitoring the ozone concentration using the passive sampler method in the Cipedes area, which is an urban area with a busy traffic density every day, the average concentration from 2012 - 2020 is 21.76 g/m3. The lowest concentration was in April 2013 with a concentration of 5.6 g/m3, and the highest concentration was in July 2015 with a concentration of 45.90 g/m3. The Ozone Concentration from 2012-2020 in Figure 2 shows fluctuations in the Ozone concentration every year, with the highest peak concentration in 2015 and a tendency for the ozone concentration to decrease until 2020.

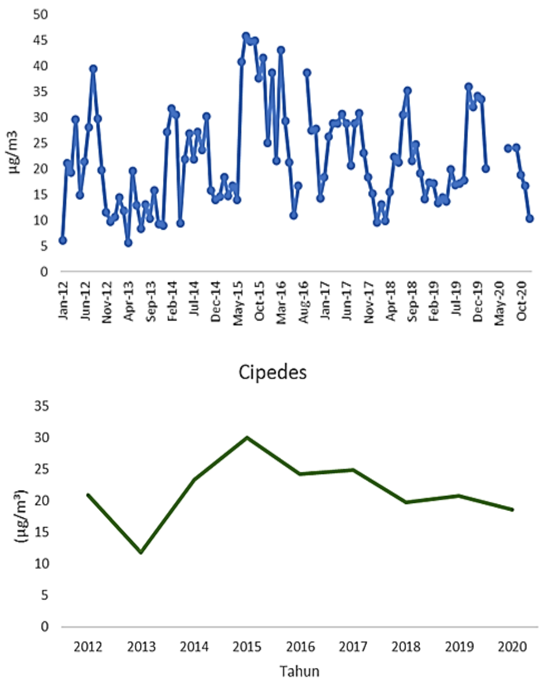

Figure 1. Ozone concentration in Cipedes due to passive sampler sampling in 2012 – 2020. Revise the image according to the writing guide.

Ozone in the troposphere is formed by complex nonlinear photochemical reactions with ozone precursors, such as methane, carbon monoxide, volatile organic compounds (VOCs), and nitrogen oxides (NOx) [17]. VOCs assist the oxidation of primary NO emitted from various sources such as vehicles to form NO_2. NO_2 was photolyzed to produce oxygen atoms and then combined with other oxygens to form ozone in the troposphere [18]. The residence time of the precursors, the rate of formation reactions in the atmosphere, and the residence time of ozone in the troposphere collaborate in forming tropospheric ozone [19].

Several studies reported an increase in ozone concentration in urban areas, which was in line with increased motor vehicle activity [5,20]. The decreasing ozone concentration in the Cipedes area, Bandung, from 2015-2020 is thought to be due to ozone reacting with NO to form NO_2 [21]. Based on previous research on the relationship between ozone and nitrogen oxides, it is seen that when the ozone concentration decreases, there is an increase in the concentration of NO_2 [13].

Similar conditions were also found [22], where a decrease in ozone concentration in urban areas was associated with an increase in NO_2 gas concentration in the Irkutsk area, Russia. In addition, meteorological conditions also directly play a role in forming ozone [22]. Wind speed can carry ozone away from its source to be deposited far from the Cipedes area.

3. Monthly and Seasonal Profile

Based on the monthly profile in Figure 2, it can be seen that in August, the Ozone concentration increased until October and decreased in November to the lowest concentration in December. The highest average ozone concentration from 2012-2020 in August was 29.43 g/m^3, and the lowest was in December 16.28 g/m^3.

The seasonal pattern shows that the ozone concentration increases in the dry season, July-June-August (JJA), by 25.34 g/m3 than in the rainy season December-January-February (DJF) 18.78 g/m^3.

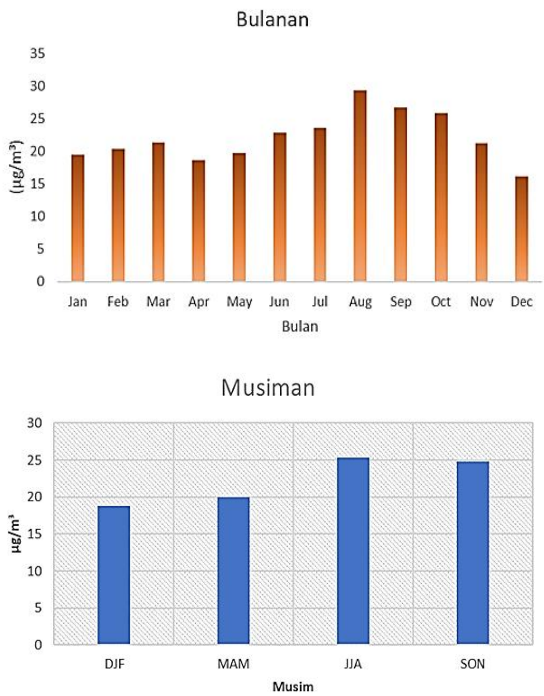

Figure 2. Monthly and seasonal profiles of ozone concentrations in Cipedes from passive sampler sampling in 2012-2020.

Surface ozone concentration is affected by photochemical reactions, which are highly dependent on the amount of solar radiation [23]. The high concentration in the dry season is related to the high solar radiation during the dry season because sunlight can act as the main catalyst to convert the precursor gas in the atmosphere into ozone [24].

The opposite condition occurs during the rainy season when the ozone concen-tration decreases. The ozone in the troposphere is carried away by rainwater and deposited on the surface. So the deposition of ozone in the form of gas is very small in number.

4. Comparison with Active Sampling

In order to see the performance of the passive sampler in measuring ozone concentration, it is necessary to compare the results using the Dasibi Dyle automatic ozone meter. In addition, a comparison of ozone measurements was carried out using data from 2017-2019 due to the availability of existing data. The measurement results show that the ozone concentration produced from the passive sampler has the same pattern as the ozone concentration measured using Dasibi, with a relatively low correlation coefficient of r = 0.48.

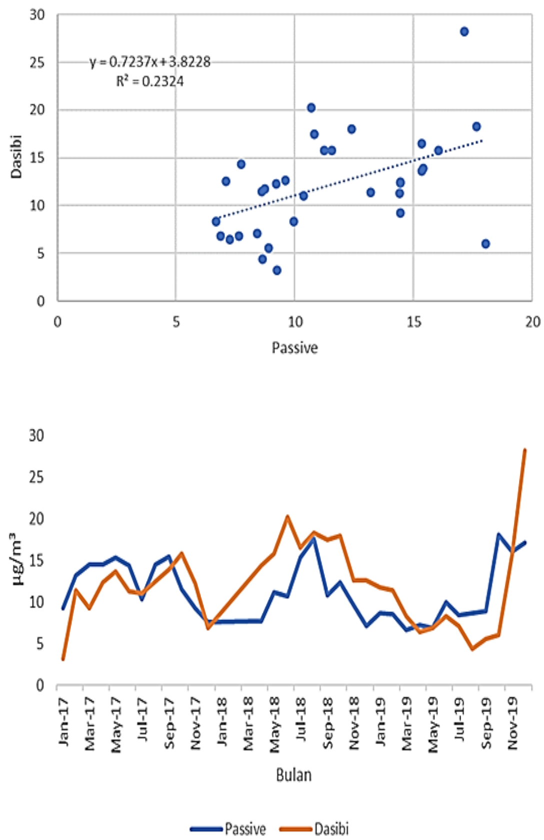

Figure 3. Comparison of ozone concentration data from active sampling and passive sampling.

The difference in value between concentration measurement with active and passive sampling is due to different sampling systems. For example, an automatic ozone monitor requires pump assistance in sampling. In contrast, a passive sampler does not require pump assistance because the sampling is based on gas diffusion or molecular permease through a membrane filter [5].

Sampling with active sampling was carried out by direct measurements of ozone gas in the ambient air. At the same time, passive sampling measurements were based on the accumulation of gas absorbed in the filter during the sampling duration. In this study, the sampling duration was one month.

This condition also affects the ozone concentration because gas absorption in the passive sampler filter depends on gas diffusion, which is strongly influenced by meteorological factors, such as wind speed, wind direction, pressure, temperature, and humidity [15]. One of the weaknesses of the passive method is its inability to perform analyzes with daily variations in ozone [5].

CONCLUSION

Based on the results of monitoring the ozone concentration in Cipedes using the passive sampling method, the average concentration from 2012-2020 was 21.76 µg/m³. Ozone concentration in the Cipedes increases in the dry season, with a peak in August with 29.43 µg/m³. In addition to the solar radiation factor, the absorption process in the passive sampler also affects the ozone concentration obtained. Compared to the passive sampler and automatic measurement, the correlation coefficient value is still quite low, but it is quite close together if you look at the concentration pattern.

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