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Binoculars Modification for Measurement of Smoke Density at Fixed Sources

Modifikasi Teropong untuk Pengukuran Kepadatan Asap pada Sumber Tidak Bergerak

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ABSTRAK

Perubahan kualitas udara yang melebihi nilai ambang batas pada berbagai parameter, baik gas, partikel maupun gangguan akan menyebabkan menurunnya fungsi organ makhluk hidup bahkan dapat menyebabkan kematian. Penggunaan alat ukur kepekatan asap belum familiar untuk diaplikasikan pada pengukuran lingkungan fisik ketika melakukan inspeksi sanitasi di industri. Kondisi ini terjadi karena harga alat yang mahal dan kurangnya sosialisasi untuk menggunakan alat tersebut. Padahal kepekatan asap menjadi salah satu indikator penting pencemaran udara di suatu lingkungan, karena nilai ambang batas yang terlampaui. Tujuan penelitian untuk mengetahui kinerja teropong modifikasi yang digunakan untuk pengukuran kepekatan asap pada sumber tidak bergerak. Teropong ini terbuat dari bahan yang kuat dan mudah untuk dibawa ke lapangan. Pada bagian ujung teropong terdapat kaca yang telah dilengkapi skala Ringelmann untuk membandingkan asap yang diamati dengan standar. Hasil menunjukkan peringkat rata-rata parameter bilangan Ringelmann dan opasitas pada kelompok I dan II memiliki nilai tertinggi. Sig α secara berturut-turut menunjukkan hasil 0,903 pada bilangan Ringelmann, 0,601 pada transmisi cahaya melalui asap dan 0,903 pada level opasitas. Hasil tersebut memiliki arti bahwa tidak ada beda hasil uji efektivitas pada kelompok teropong modifikasi dan opacity meter. Kesimpulan menunjukkan nilai Sig α secara berturut-turut antara kelompok A dan B dengan hasil 0,903 pada bilangan Ringelmann, 0,601 pada transmisi cahaya melalui asap dan 0,903 pada level opasitas. Hasil tersebut memiliki arti bahwa tidak ada beda hasil uji efektivitas pada kelompok teropong modifikasi dan opacity meter. Alat yang dikembangkan memiliki kecenderungan tren yang sama dengan opacity meter yang ada dan digunakan saat ini.

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ABSTRACT

Changes in air quality that exceed the threshold value on various parameters, gases, particles, and disturbances will cause a decrease in the function of living organisms and even cause death. The use of smoke density gauges has yet to be familiar with measuring the physical environment when conducting sanitation inspections in the industry. This condition occurs because the price of the tool is expensive and the lack of socialization to use the tool. The density of smoke is one of the essential indicators of air pollution in an environment because the threshold value is exceeded. The study aimed to determine the performance of modified binoculars used for measuring smoke density at immovable sources. These binoculars are made of solid materials and are easy to carry into the field. At the end of the binoculars, there is a glass equipped with a Ringelmann scale to compare the observed smoke with the standard. The results show the average rank of Ringelmann's number and opacity parameters in groups I and II has the highest value. Sig respectively showed the results of 0.903 on the Ringelmann number, 0.601 on the transmission of light through smoke, and 0.903 on the opacity level. These results mean that there is no difference in the results of the effects test in the modified binoculars and opacity meter groups. The conclusion shows the Sig values between groups A and B with the results of 0.903 on the Ringelmann number, 0.601 on the transmission of light through smoke, and 0.903 on the opacity level. These results mean that there is no difference in the results of the effects test in the modified binoculars and opacity meter groups. The tool developed has the same trend as the existing opacity meter and is used today.

1. INTRODUCTION

1.1 Background

Industrial sector development has increased rapidly in various countries, including Indonesia (Murachman *et al.*, 2013). The consequence of these activities is an increase in waste which is a by-product of the production process carried out in the industry. Air pollution is one of the impacts of these activities that can affect the ambient air quality of the surrounding environment. Changes in air quality that exceed the threshold value on various parameters, gases, particles, and disturbances will cause a decrease in the function of living organisms and even cause death. Increased exposure to air pollution is closely correlated with an increase in the number of hospital stays for respiratory disease conditions (Richa & Sant'Anna, 2022). Air pollution contributes to a large global burden of respiratory and allergic diseases, including asthma, chronic obstructive pulmonary disease, pneumonia, and possibly tuberculosis. (J.Laumbach & M.Kipen, 2012). Ambient air pollution has a significant negative effect on health and is a greater risk factor for individuals living in urban areas (Balasooriya *et al*., 2022).

Waste from combustion consists of combustion gases and vapors, water droplets, and aerosols formed during and after combustion (Guillaume, 2022). Smoke from biomass fuels, industrial smoke, cigarette smoke, and nitrogen oxides is a common cause of air pollution (Qiu *et al*., 2022). Smoke distribution pattern, motion analysis, color, and texture are important characteristics to help identify smoke in ambient air (Chaturvedi *et al*., 2022). Smoke density is a gas containing particles from the combustion products that come from the chimney. The Ringelmann scale is used as the basis for opacity readings on a scale of 1 to five and applies only to black smoke. The relationship between the Ringelmann smoke scale, transmittance, and opacity are described as the ability of smoke to absorb light. If a light cannot penetrate the smoke, the smoke density is included in the 100% category, while the light transmittance is 0% (Badan Standarisasi Nasional), 2005). The use of smoke density measuring instruments has yet to be familiar with measuring the physical environment when conducting sanitation inspections in the industry. This condition occurs because the equipment is expensive and too risky if brought to the field, and the need for more socialization to use the tool.

1.2 Research Purposes

This study aims to determine the performance of modified binoculars used to measure smoke density at immovable sources.

2. METHODS

2.1 Research Stages

This research is a research and development. The product produced in this study is a smoke-density binocular. The stages in conducting research go through five phases: the analysis phase, the design phase, the development phase, the implementation phase, and the evaluation phase. Testing the tools produced in this study is one of the stages in the research and development method. The effectiveness test of the tool was carried out by dividing it into two groups, namely group one for the tool being tested for effectiveness and group two for the opacity meter. The sample test method uses the principle of opacity, namely by comparing the color of the smoke coming out of the chimney with the Ringelmann color scale.

2.2 Smoke Density Measurement and Sampling

Sampling was carried out at an immovable source. The measurement method uses the Ringelmann scale. The way it works is by comparing the smoke that appears with the scale in the image (Badan Standardisasi Nasional, 2005). Using a comparison of commonly used tools, namely an opacity meter and a modified tool as the product being tested. Sampling was carried out 36 times in each group with the same sampling time between groups I and II. Observational data are recorded in the field form or smoke density observation form according to SNI 19-7117.11-2005.

The monitoring location points pay attention to wind direction, land use, chimney height and the distribution area of contaminants. When the wind direction is dominant, monitoring is carried out at two points, but if the opposite occurs, then monitoring is carried out at least at one point. Exhaust emissions from industrial and transportation activities, especially those related to burning fossil fuels, are still a major problem in environmental pollution. The emission results are in the form of thick smoke which is called opacity. The greater the opacity, the greater the effect on the environment (Wahyudi *et al*., 2019).

The chimney, which is the point of emission, has a height of 25–30 m. The distance between the binoculars is three times the height of the observed chimney. No buildings obstruct the view between the chimney and the test equipment in conducting observations. This tool can be used to monitor the environment that produces pollutant emissions from stationary sources, namely chimneys.

2.3 Data Processing

Observational data were then processed statistically. The initial stage is to test the normality of the data. Then proceed with the different test between the two groups in this study.

3. RESULT AND DISCUSSION

The health impact on the community from smoke exposure is not necessarily the same for individuals, but the potential for morbidity and mortality cases due to smoke exposure increases every year (Afrin & Garcia-Menendez, 2021). The description of the emission emitted by the chimney in this study has a black colour of 1. The light transmission by smoke is 80%, while the opacity level is 20%. Observation distance is carried out at three times the chimney's height, at about 75 m. Observations are visible: blue smoke background, white background. Clear skies. The air temperature ranges from 32–34ºC. Humidity in the range of 50–60%. The wind direction when sampling tends to be from East to North with a wind speed of 1.2 m/s. The test equipment is placed 1.2–1.5 m from the ground.

The sample and the data that have been recapitulated are then statistically tested to see the normality of the data in this study. Statistical test results show the value of :

Table 1. Normality test results of research results data

Parameter	Sig α
Ringelmann's Number	0,000
Light Transmission Through Smoke	0,000
Opacity	0,000

The total number of samples is 72 times the results of processing the observation of smoke density divided into two groups. The mean values are respectively according to groups: Ringelmann number group 2.25, light transmission through smoke 56.39%, and opacity 45%. Based on the results of the normality test of the data, it is known that the existing data has a value of sig <0.05, meaning that the data has an abnormal distribution.

3.1 Ringelmann's Number

The value on the Ringelmann scale describes the following conditions (Badan Standardisasi Nasional, 2005):

- Value 0 : 0% density, the background can be seen as proportional to 100%
- Value 1: 20% density, the background can be seen 80%
- Value 2: 40% density, the background can be seen 60%
- Value 3: 60% density, the background can be seen 40%
- Value 4: 80% density, the background can be seen 20%
- Value 5: 100% density, the background can't be seen at all

Table 2. Frequency distribution of effectiveness test results parameter ringelmann numbers groups I and II

Ringelmann's Number	Tool I		Tool II		Total	
	F	%	F	%	F	%
0	2	2.7	1	1.39	3	4.09
1	10	13.88	14	19.44	24	33.32
2	9	12.5	8	11.11	17	23.61
3	9	12.5	4	5.55	13	18.05
4	5	6.95	5	6.95	10	13.9
5	1	1.38	4	5.55	5	6.93
Total	36	50	36	50	72	100

A total of 24 observations, or 33.33%, showed that the Ringelmann number value was 1, i.e., the transmission of visible light through the smoke was 80% while the opacity value was 20%. The test was continued with the Ringelmann number difference test between the two groups of tools being tested. The result was a sig value of 0.904 or more than 0.05. It means that there is no difference in the effectiveness test results for Ringelmann numbers in groups I and II. Descriptively, this condition is also seen with the dominant Ringelmann number percentage in the visible light transmission group through smoke by 80%, while the opacity value is 20% in each test group.

3.2 Light Transmission Through Smoke (%)

The results of the measurement of light transmission through smoke in the two groups are distributed as follows.

Table 3. Frequency distribution of effectivity test results of light transmission parameters through smoke (%) groups I and II

Light Transmission Through Smoke (%)	Tool I		Tool II		Total	
	F	%	F	%	F	%
0	1	1.39	3	4.16	4	5.55
20	5	6.94	5	6.94	10	13.88
40	9	12.5	4	5.55	13	18.05
60	9	12.5	8	11.11	17	23.61
80	10	13.89	14	19.44	24	33.33
100	2	2.78	2	2.78	4	5.56
Total	36	50	36	50	72	100

The results of observations for the transmission of light through smoke from the two devices descriptively showed the dominant category in the 80% group, 13.89% in group I, and 19.44% in group II, respectively. Furthermore, statistical tests were carried out to see the difference in test results on the two groups of tools. The results showed a sig value of 0.605 or more than 0.05. These results indicate no difference in the effectiveness test results for the parameters of light transmission through smoke in both groups I and II. The relationship between Ringelmann's number and the highest level of light transmission through the smoke is at a value of 2 , with a level of light transmission through smoke of 80%, which is 24 times. The results of statistical tests showed a sig value of 0.000. It indicates a significant relationship between Ringelmann number and light transmission through the smoke

3.3 Opacity (%)

The results of observations of smoke are expressed in distributed opacity parameters as follows:

Table 4. Frequency distribution of opacity parameter effectiveness test results (%) groups I and II

Opacity (%)	Tool I		Tool II		Total	
	F	%	F	%	F	%
0	2	2.78	1	1.39	3	4.17
20	10	13.89	14	19.44	24	33.33
40	9	12.50	8	11.11	17	23.61
60	9	12.50	4	5.56	13	18.06
80	5	6.94	5	6.94	10	13.89
100	1	1.39	4	5.56	5	6.94
Total	36	50	36	50	72	100

The observation of opacity showed that, descriptively, the two tools showed an opacity level in the 20% group, which was 33.33%. The results of statistical tests showed a sig value of 0.904 or greater than 0.05. These results indicate no difference in the opacity level measurements using test tools I and II. The relationship between the Ringelmann number and the highest opacity is at value 2 with an opacity level of 20%, 24 times. The results of the statistical test showed a sig value of 0.000. It indicates that there is a significant relationship between Ringelmann number and opacity

3.4 Ringelmann Number Relationship, Light Transmission through Smoke and Opacity

The next step is to see the relationship between Ringelmann Number, Light Transmission through Smoke, and Opacity in the two test groups using the Kruskal-Wallis test. The test results are presented in the following table.

Table 5. Relationship of Ringelmann number, light transmission through smoke, and opacity

Statistical Parameters	Ringelmann's Number	Light Transmission through Smoke	Opacity
N (number of samples)	72	72	72
Mean	2.25	56.39	45.00
Std.Deviation	1.351	26.712	27.011
Minimum	0	0	0
Maximum	5	100	100
Mean Rank Alat I	36.79	35.25	36.79
Mean Rank Alat II	36.21	37.75	36.21
Sig α	0.903	0.601	0.903

The shape and distribution of the data under these conditions have different compositions, so the test results only show the mean value. The average rating of the Ringelmann number and opacity parameters in groups I and II has the highest value. Sig respectively showed the results of 0.903 on the Ringelmann number, 0.601 on the transmission of light through smoke, and 0.903 on the opacity level. These results mean that there is no difference in the results of the effects test in the modified binoculars and opacity meter groups

Emissions released from industrial exhaust gases include CO_2, CO, and HC, which are the most dangerous gases and have the highest percentage. The gas is quite hazardouss for human health and can even cause death if it exceeds the quality standard. In addition to gas, the industry also produces waste heat which is generated by the combustion process of fuel or chemical reactions, which is then discharged into the environment and is not reused for economic and beneficial purposes (Indonesia Environment and Energy Center, 2020)

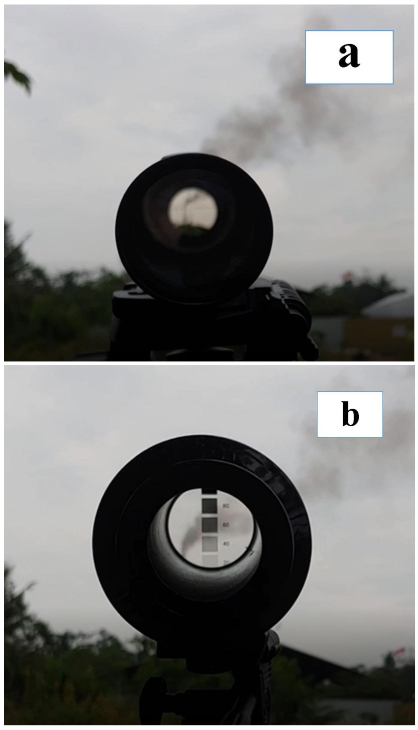

Figure 1. Observation of smoke emission from stationary sources using (a) modified binoculars and (b) opacity meter

3.5 Product Acceptance Test

Measurement of smoke density can be carried out using the principle carried out in a smoke layer using a light source and photo diode located outside the hot environment. In using modified binoculars, a test of the instrument's condition was also carried out. Testing the tools produced in this study is one of the stages in the research and development method. The effectiveness test of the tool is carried out by dividing it into two groups, namely group one for the tool being tested for its effectiveness and group two for opacity meters. The test results show that the modified binoculars are easy to operate and safe to carry into the field. The results of the smoke density reading are no different from the opacity meter that has been used so far. Meanwhile, in terms of cost, this tool is more economical than the price of existing tools. The weakness and correction of the tool are that an autofocus lens can be added, which can be adjusted manually by the sampling officer. The recommendation states that the modified tool is considered good in terms of qualification and is included in the very suitable category for use in the quality category (Parent *et al*., 2016).

4. CONCLUSION

The use of smoke density measuring instruments currently needs to be more familiar for monitoring the physical environment around the industry. This condition can be caused by equipment that is too expensive and a need for more socialization about the importance of observing smoke in the environment. This modification of the smoke binoculars was made and tested with the results of the Sig values between groups A and B, showing the results of 0.903 on the Ringelmann number, 0.601 on the transmission of light through smoke, and 0.903 on the opacity level. These results mean that there is no difference in the results of the effects test in the modified binoculars and opacity meter groups. The tool developed has the same trend as the existing opacity meter used today.

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