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Original Research Article

Performance Test of Environmental Odour Measurement Instrument

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Abstract
Environmental odour assessment is important for evaluating air quality and community amenity; however, conventional dynamic dilution olfactometry requires specialised laboratory facilities and costly equipment, limiting its use for routine field monitoring. This study developed and evaluated a direct-airflow environmental odour measurement instrument that delivers ambient air directly to panellists without dilution. The instrument was designed to operate at an airflow velocity of 1 m/s, selected through climatological analysis, panellist preference testing, and technical verification against ASHRAE Standard 55 and EN 13725:2022. Eight screened panellists assessed ambient air, n-butanol, and ammonia using the Yuwono Hedonic Scale under field conditions. Instrument performance, panellist consistency, and the influence of meteorological conditions on odour perception were evaluated. The selected airflow velocity of 1 m/s yielded the highest ratings for odour detectability, comfort, and ease of assessment. Repeated ammonia measurements (3.4–3.5 ppm) produced highly consistent hedonic scores (–3.2 to –3.0), while ammonia concentration and hedonic scores followed a logarithmic relationship (R^2 = 0.9994). Mean hedonic scores for ambient air (–0.1), n-butanol (–1.3), and ammonia (–3.1) confirmed consistent panellist discrimination of odour characteristics.

Keywords: Direct-airflow olfactometry; environmental odour; hedonic scale; olfactometry; panellists

1. Introduction:

Odour in the environment is one of the parameters of air quality, which is subjective by nature and may be measured using the standard technical measurement methodology (Government of the Republic of Indonesia, 2021). Odour control regulation in Indonesia is provided for in Government Regulation No. 22 of 2021 on the Implementation of Environmental Protection and Management in which odour is listed as one of the parameters of environmental nuisances affecting people's comfort (Government of the Republic of Indonesia, 2021). More specifically, the Decree of the Minister of Environment No. 50 of 1996 on Odour Level Standards establishes the possibility of odour evaluation through the panel technique, which includes no less than eight trained panellists (Minister of Environment, 1996).

One of the main obstacles for the implementation of the described regulation is the scarcity of devices, which allow the measurement of the odour, meeting the technical requirements but at the same time remaining inexpensive and easy to operate independently in Indonesia. At the moment, commercial olfactometers available on the international market work using dynamic dilution olfactometry technique according to EN 13725:2022 standard. It involves determination of the odour concentration in odour units per cubic metre (ouE/m^3) through step-by-step dilution of the air sample up to its detection threshold by a panel of the trained panellists. Thus, it requires the presence of expensive standard odour reference material as well as special laboratory facilities (CEN, 2022). These factors create substantial barriers to the field measurements of the odour in Indonesia (Stuetz & Frechen, 2001; McGinley & McGinley, 2002).

This research aims to develop the environmental odour measuring device, which presents the ambient air samples to the panellists without dilution or addition of any chemical reference substance. This operating principle is easier and more appropriate for the environmental conditions in Indonesia since, according to the data of Indonesian Agency for Meteorology, Climatology, and Geophysics (BMKG), the average ambient wind speed in the major cities of the country equals to about 1.0 m/s (Badan Meteorologi, Klimatologi, dan Geofisika, 2023). This value was chosen as the airflow velocity delivered to the panellists in order to provide the exposure conditions, resembling more the natural environmental ones. Such an approach gives the possibility to introduce some new features, which distinguish it from the existing olfactometric techniques.

Unlike dynamic dilution olfactometry, which provides standardised odour concentration measurements (ouE/m^3) but requires complex laboratory infrastructure, the instrument developed in this study directly evaluates the hedonic responses of panellists to actual environmental odours at the sampling location. The novelty of this approach is reflected in four complementary operational advantages: (1) substantially lower capital and operating costs, as neither a dilution system nor standard reference odours are required; (2) ease of field deployment without the need for specialised laboratory facilities; (3) an airflow velocity calibrated to the typical tropical ambient wind conditions in Indonesia (approximately 1 m/s), enabling odour exposure that more closely represents the conditions actually experienced by communities in affected areas; and (4) direct alignment with the Indonesian regulatory framework, specifically the Decree of the Minister of Environment No. 50 of 1996, which recognises the panel method as a valid approach for odour assessment.

Accordingly, the proposed instrument is not intended to replace dynamic dilution olfactometry for regulatory applications requiring chemically based odour concentration measurements. Rather, it is designed as a low-cost, rapid, and context-specific screening tool based on hedonic perception for assessing the environmental impacts of odours within affected communities. The selection of an airflow velocity of 1 m/s, which constitutes one of the principal advantages of the proposed instrument, is supported by a robust technical justification, as described in the following section.

The selection of an airflow velocity of 1 m/s as the principal operating parameter of the proposed instrument is supported by three complementary quantitative lines of evidence. First, this value represents typical ambient wind conditions in tropical Indonesia. Climatological data indicate that the average wind speed in urban areas such as Jakarta remains close to 1 m/s throughout the year, with daily variations ranging from calm conditions to light breezes of up to approximately 3 m/s (Badan Meteorologi, Klimatologi, dan Geofisika, 2023). Second, this value is broadly consistent with the upper limit of air velocity considered acceptable for naturally ventilated spaces in hot-humid climates under ASHRAE Standard 55. The standard specifies a maximum average air velocity of 0.8 m/s for operative temperatures exceeding 25.5°C (ASHRAE, 2020). Although the airflow velocity adopted in this study is slightly higher, it remains within the range commonly encountered under tropical outdoor conditions and is therefore considered representative of realistic environmental exposure. Third, an airflow velocity of approximately 1 m/s is comparable to the air presentation conditions employed by commercially available standardised olfactometry instruments. For example, the Scentroid SS600 olfactometer operates at a presentation flow rate of 20 L/min, while the Nasal Ranger® Field Olfactometer is calibrated for user inhalation rates of 16–20 L/min (Scentroid, 2023; St. Croix Sensory, 2022). Collectively, these considerations demonstrate that the selected airflow velocity is supported by a robust quantitative basis rather than by panellist opinion alone, thereby strengthening the validity of the exposure conditions adopted in this study. To evaluate the panellists' perceptual responses, this study employed the Yuwono Hedonic Scale, a hedonic assessment instrument specifically developed for application in the Indonesian context.

Panellists' responses were evaluated using the Yuwono Hedonic Scale, a psychometric instrument specifically developed to assess odour quality based on human perception within the Indonesian environmental context (Yuwono, 2008). The scale ranges from +4 (very pleasant) to −4 (very offensive), with verbal descriptors assigned to each rating level to facilitate the standardisation of responses among panellists from diverse backgrounds (Yuwono, 2008).

The testing protocol was designed in accordance with established principles of olfactory psychophysics. Panellists were instructed to inhale the sample air for 1–2 s and were permitted to re-inhale the sample until they were able to assign a hedonic rating, with a maximum evaluation period of 15 s (Pichon et al., 2015). This was followed by a 15 s nasal neutralisation period using clean air before the subsequent assessment. The procedure was repeated three times for each sample to enable the evaluation of score reproducibility and the identification of potential individual response bias (Doty, 2015; Olofsson et al., 2012).

From a physiological perspective, human olfactory sensitivity is influenced by the transport of odour molecules to the olfactory receptors, sniffing behaviour, and sensory adaptation (Doty, 2015; Olofsson et al., 2012). Furthermore, the relationship between the concentration of volatile compounds and perceived odour intensity is non-linear and follows established psychophysical principles, including the Weber–Fechner law and Stevens' power law (Chen et al., 2021). Consequently, controlling airflow parameters and maintaining consistent exposure conditions are essential considerations in the development of panel-based odour assessment instruments.

Previous studies have consistently demonstrated that panel-based assessment remains the primary approach for evaluating the impacts of environmental odours because it directly reflects human perception (Nicell, 2009; Schiffman & Williams, 2005). Although electronic nose technologies and machine olfaction have advanced considerably in recent years, validation against human sensory perception remains essential as the reference standard for interpreting odour quality (Capelli et al., 2014). Nevertheless, an important research gap remains regarding the influence of meteorological conditions on panellists' responses during field-based odour assessments.

The influence of meteorological conditions, particularly air temperature and wind speed, on the dispersion and atmospheric concentration of odorous compounds has been widely recognised in the literature (Stuetz & Frechen, 2001). However, a significant research gap remains regarding how variations in these meteorological conditions directly affect panellists' odour perception when using field-based instruments that deliver ambient air directly to the nose. Most olfactometry studies have been conducted under controlled laboratory conditions, where meteorological variables are either eliminated or tightly controlled (McGinley & McGinley, 2002; Gostelow et al., 2001). Conversely, existing field studies have primarily focused on the macroscopic dispersion of odorous pollutants without quantitatively relating these phenomena to the sensory responses of human panels (Nicell, 2009). Consequently, there is still limited understanding of the extent to which variations in air temperature and wind speed within the ranges commonly encountered under field conditions (particularly in tropical humid environments such as Indonesia) influence panellists' hedonic responses relative to the effects of odour type and odorous compound concentration. This study was therefore designed to address this research gap by directly evaluating the performance of a direct-airflow odour measurement instrument under naturally varying meteorological conditions in the field.

Based on the background and research gap outlined above, this study aimed to: (1) evaluate the performance of direct airflow delivered to the panellists' noses at an airflow velocity of 1 m/s; (2) validate the consistency of panellists' assessments; (3) examine the applicability of the Yuwono Hedonic Scale for environmental odour assessment; and (4) evaluate the influence of meteorological conditions on odour perception.

2. Methods

2.1 Time and Location

This study was conducted over 9 months, from September 2025 to April 2026, at SWAM (School of Waste Management), Margajaya Village, West Bogor, Bogor City, and at PT Unilab Perdana, Jl. Ciledug Raya No. 10, Cipulir, Kebayoran Lama District, South Jakarta City. Device design and panellist screening tests were carried out at SWAM, while device performance testing and environmental odour measurements were conducted at Unilab Jakarta.

2.2 Air Flow Rate Performance on the Nose Panel

The instrument was designed to deliver ambient air from the monitoring location directly to the noses of eight panellists for sensory evaluation. The airflow velocity supplied to the panellists was maintained at 1 m/s, a value established through a stepwise procedure integrating empirical evidence, climatological data, and panellist comfort testing, as summarised in **Table 1**.

Table 1. Procedure for determining the optimum airflow velocity

Stage	Method	Outcome
Stage 1 : Climatological analysis	Analysis of BMKG (2023) surface wind speed data from ten major cities in Indonesia.	Representative wind speed range of 0.5–2.0 m/s, with a mode of approximately 1.0 m/s.
Stage 2 : Selection of candidate airflow velocities	Three candidate airflow velocities were selected for evaluation.	0.5 m/s, 1.0 m/s, and 1.5 m/s.
Stage 3 : Panellist evaluation	Preference assessment using *n*-butanol samples with prospective panellists.	Panellists evaluated odour detectability, comfort, and ease of assessment.
Stage 4 : Technical verification	Comparison with the ASHRAE Standard 55 thermal comfort criteria and commercially available olfactometry instruments.	An airflow velocity of 1.0 m/s was found to be within an acceptable range and comparable to the presentation airflow rates used in field olfactometry instruments.

Wind speed data reported by BMKG (2023) for the ten major cities in Indonesia were examined to identify the typical values of the ambient wind speed. Wind speed data analysis proved that the yearly average wind speed varied within 0.5 and 2.0 m/s range, and the modal value was 1.0 m/s. Therefore, three airflow velocities (0.5 m/s, 1.0 m/s, and 1.5 m/s) were chosen as candidates for evaluation based on this research. Three selected airflow velocities were evaluated employing eight panellists and n-butanol at a 40 ppb concentration under reference conditions described in EN 13725. Each panellist examined all three airflow velocities (0.5 m/s, 1.0 m/s, and 1.5 m/s) with three replications for each velocity. The evaluation of the airflow conditions was made according to three criteria (odour detectability, comfort, and ease of assessment). The results are given in **Table 2**.

Based on these results, an airflow velocity of 1.0 m/s achieved the highest scores across all three evaluation criteria. The airflow velocity of 0.5 m/s was considered suboptimal because fewer odour molecules were expected to reach the olfactory receptors, thereby reducing odour detectability. In contrast, the airflow velocity of 1.5 m/s was perceived as excessively strong and interfered with the panellists' natural sniffing behaviour. Consequently, an airflow velocity of 1.0 m/s was selected as the optimum operating condition, as it most closely represents typical tropical ambient wind conditions while providing the highest levels of comfort and odour detection performance.

Table 2. Results of the candidate airflow velocity evaluation

Airflow velocity (m/s)	Odour detectability	Comfort	Ease of assessment
0.5	0	1	1
1.0	5	5	4
1.5	3	2	3

2.3 Panellist Recruitment and Selection

A total of 18 prospective panellists participated in the selection process, of whom 10 successfully passed the olfactory screening assessment. Subsequently, eight panellists were selected for the main study in accordance with the minimum panel size specified in the Decree of the Minister of Environment of the Republic of Indonesia No. 50 of 1996. This number satisfies the regulatory requirement and was therefore considered sufficient to provide representative odour assessments.

The selection process was designed to ensure that all panellists possessed normal olfactory function and were capable of providing consistent sensory evaluations, as human panellists constitute the primary measurement instrument in olfactometry (CEN, 2022; Zhang et al., 2023). The selection criteria were based on the principles of EN 13725 and included: an age between 18 and 55 years to minimise age-related declines in olfactory sensitivity (Environodour, 2024); non-smoking status, as smoking has been shown to impair olfactory function (Frye et al., 1990; Tobacco Induced Diseases, 2020); no history of olfactory disorders, such as anosmia or hyposmia (Environodour, 2024); no use of medications known to influence odour perception (Dalton, 2003); and successful completion of an olfactory screening test using standard reference odours to verify the consistency of olfactory responses (CEN, 2022; Capelli et al., 2010; Zhang et al., 2023).

Accordingly, the eight panellists included in this study satisfied all predefined eligibility criteria and successfully passed the olfactory screening assessment. Their inclusion complies with the requirements of the Decree of the Minister of Environment No. 50 of 1996, indicating that the panel size was adequate to generate valid, reliable, and scientifically defensible data on human odour perception.

2.4 Field Performance Testing

The field testing of odour performance was achieved through the controlled creation of odours in the set location. The test used three types of odour sources, which were n-butanol, ammonia, and ambient air, each fulfilling a separate and complementing role in the whole experiment.

The choice of n-butanol as the reference stimulus was made due to the extensive use of this substance as the reference odorant in olfactometry. In accordance with the EN 13725 standard, sensory quality criteria are defined by standard values of n-butanol in nitrogen under the assumption that whenever a laboratory satisfies all sensory quality criteria for n-butanol, the same quality level is achieved for other, environmental, odours. Therefore, the selection of the mentioned substance as the test odour allowed for calibration of panellists' sensitivity and served as a chemically defined basis for interpreting responses to more complicated environmental odours (CEN, 2022). Ammonia was chosen as a characteristic compound representing environmental malodour, especially in relation to waste management, wastewater treatment, and agriculture, where ammonia is known to be one of the major odorants (Stuetz & Frechen, 2001). Ambient air was used as the neutral baseline stimulus, which made it possible to define the background odour level and serve as a basis for comparison with active odours. Thus, three such stimuli were sufficient for creating distinct and relevant categories of environmental odours, from the chemically defined one through the biologically relevant pollutant up to the uncontrolled field conditions.

A 25% ammonia solution was used as the odour source. Prior to testing, the solution was diluted by mixing 1 mL of 25% ammonia with 100 mL of distilled water to produce the test solution. Subsequently, 5 mL of the diluted solution was transferred into an open container positioned approximately 2 m above ground level to serve as the odour emission source. During the experiment, the ammonia was allowed to evaporate naturally into the ambient air. The instrument then drew the surrounding air containing the dispersed ammonia vapour and conveyed it to the panellists' noses through the airflow delivery system. This approach was adopted to ensure that the panellists inhaled ambient air containing ammonia vapour under conditions representative of environmental odour exposure, rather than inhaling ammonia directly from the liquid source.

The reference substance chosen was n-butanol as it is the odorant that is recommended for the use in olfactometry according to EN 13725:2022. Before preparing the test solution, 70% ethanol was diluted to make 5% (v/v) solution. Then, the n-butanol was diluted with the 5% ethanol solution in a 1:50 ratio. Five millilitres of the n-butanol solution was put in an open vessel for the evaporation of the substance into the ambient air and further transfer to the panellists' noses via the instrument. N-butanol was used due to its stability and reproducibility and due to the fact that it is widely used as the reference compound for assessing the panellist's olfactory sensitivity (CEN, 2022; Doty, 2015).

Field sampling sessions were conducted between 09:00 and 11:00 local time. This time window was deliberately selected to minimise the confounding influence of extreme or rapidly changing meteorological conditions on odour perception and pollutant dispersal. The morning period prior to midday is generally characterised by relatively stable atmospheric conditions (moderate temperature, low to moderate solar irradiance, and transitional boundary layer development) compared with the more thermally unstable conditions typically observed during the afternoon hours in tropical climates (Turner, 1994).

During each measurement, the panellists stood at the designated sampling location and inhaled the ambient air delivered directly to their noses by the instrument. Each inhalation lasted for 1–2 s, and panellists were permitted to repeat the inhalation within a maximum assessment period of 15 s before assigning a hedonic rating. After each assessment, the panellists moved approximately 10 m away from the sampling location and breathed clean ambient air to minimise olfactory adaptation before the next measurement. This procedure was repeated three times for each assessment condition. The resulting sensory responses were evaluated using the Yuwono Hedonic Scale (**Table 3**).

Table 3. Yuwono hedonic scale

Scale	Odour Perception	Scale	Odour Perception	Scale	Odour Perception
+4	Extremely pleasant	+1	Moderate	-2	Moderately unpleasant
+3	Pleasant	0	Odourless	-3	Unpleasant
+2	Fairly pleasant	-1	Slightly unpleasant	-4	Pungent

Source: *Yuwono (2008)*

2.5 Data Analysis

The data collected in this study comprised odour perception data obtained from panellist assessments of three sample types, namely ambient air, n-butanol, and ammonia. The degree of odour acceptability was evaluated using the Yuwono Hedonic Scale as a subjective measurement instrument for recording panellist responses to olfactory stimuli received. In addition to odour perception data, meteorological parameters encompassing air temperature, wind direction, and wind speed were simultaneously recorded throughout the testing period. The recording of these parameters was grounded in the understanding that atmospheric conditions exert a significant influence on pollutant dispersion processes and odour perception in the open environment (Stuetz & Frechen, 2001; Nicell, 2009). As comparative data, ammonia concentrations were measured directly using an NH_3 detector to validate the reliability and consistency of panellist assessments in relation to the ammonia odour source.

The airflow velocity received by the panellists was maintained at 1 m/s and verified using an anemometer. This velocity value was established to represent ambient airflow conditions commonly encountered in tropical climatic environments, whilst simultaneously ensuring uniformity of odour exposure for each panellist throughout the assessment procedure. Control of airflow rate constitutes a critical variable in olfactometry studies, as fluctuations in airflow may affect the quantity of volatile compounds reaching the olfactory receptors, which in turn influences the intensity of odour perception experienced (McGinley & McGinley, 2002).

The consistency of panellist assessments was evaluated by comparing odour perception values for ammonia against ammonia gas concentration measurements obtained from the NH_3 detector. The relationship between these two variables was analysed using a logarithmic regression approach. The selection of this model was underpinned by the established understanding that the human olfactory system's response to increasing concentrations of volatile compounds is generally non-linear in nature and follows a logarithmic pattern (Schiffman & Williams, 2005). The logarithmic regression approach was employed to quantify the relationship between changes in atmospheric ammonia concentration and changes in odour perception values reported by the panellists.

Meteorological data were analysed descriptively to examine the relationship between environmental conditions and panellist odour responses. Elevated air temperatures are known to promote increases in the vapour pressure of chemical compounds, thereby accelerating the volatilisation process and raising odour concentrations in ambient air, which in turn facilitates detection by panellists (Stuetz & Frechen, 2001). Wind speed, on the other hand, plays a significant role in the dispersion and dilution of pollutants in the atmosphere. Under conditions of low wind speed, accumulation of odorous compounds tends to occur, potentially increasing the intensity of perceived odour, whilst higher wind speeds promote pollutant dilution and consequently reduce odour intensity (Turner, 1994). Accordingly, analysis of meteorological conditions was conducted as an integral component of interpreting the relationship between odour emission sources and panellist responses throughout the testing period.

3. Result and Discussion

3.1 Airflow Performance at the Nose Panel

The performance of the airflow system to the nasal panel is an important aspect of the design of an odour instrument because it directly influences the consistency and accuracy of odour perception by panellists (Doty, 2015). Based on the results of the instrument design, the resulting airflow speed of 1 m/s was determined to be the optimum value. This value was obtained through a combination of empirical approaches, including panellist opinion polls and comparisons with the average ambient wind speed in various cities in Indonesia (Badan Meteorologi Klimatologi dan Geofisika, 2023).

Physiologically, the human odour-detection process is strongly influenced by the pattern of airflow entering the nasal cavity. Excessively low flow velocities can limit the number of odourant molecules reaching the olfactory receptors, reducing detection sensitivity. Conversely, excessively high flow velocities can cause discomfort and disrupt the natural human sniffing pattern (Doty, 2015; Olofsson et al., 2012). Therefore, flow conditions that approximate natural conditions are required to ensure that panellist responses remain representative.

The 1 m/s velocity used in this study aligns with real environmental conditions. Meteorological studies show that surface wind speeds in tropical urban areas generally range between 0.5–2 m/s (Badan Meteorologi Klimatologi dan Geofisika, 2023; Jones et al., 2014). Consequently, the device’s output falls within a realistic range that can represent odour exposure conditions in the ambient environment. Moreover, the perception-based approach, as evidenced by the panellist survey, reinforces that this velocity provides an adequate level of comfort and ease in detecting odours.

In the context of olfactometry, airflow consistency is an important factor in maintaining measurement validity. The international standard EN 13725:2022 emphasises the importance of airflow control when presenting odour samples to ensure the stimulus received by panellists is uniform (CEN, 2022). With airflow control at 1 m/s, the system developed in this study can maintain a stable odourant distribution towards panellists' noses.

Furthermore, from a fluid engineering perspective, air flow at a moderate velocity, such as 1 m/s, tends to be laminar or mildly transitional at small scales, thereby reducing turbulence that causes fluctuations in odour concentration (Turner, 1994). This is important to ensure that panellists receive a stable odour stimulus that is not distorted by flow variations.

The results of this study indicate that a design approach combining empirical data on panellist perceptions with environmental data on ambient wind speed can yield optimal operational parameters. Compared with several previous studies that used static or uncontrolled flow, employing directional flow at standardised speeds offers advantages in terms of reproducibility and measurement accuracy (Stuetz & Frechen, 2001; McGinley & McGinley, 2002).

The consistency of the airflow delivery system was subsequently verified using ammonia (NH_3) gas. Across three repeated measurements, the measured NH_3 concentrations were 3.5 ppm, 3.5 ppm, and 3.4 ppm, while the corresponding mean panellist hedonic scores were −3.1, −3.2, and −3.0, respectively (Figure 1). The very small variation in NH_3 concentration (0.1 ppm) was associated with only a 0.2-point difference in the mean hedonic score, indicating a high degree of consistency in the panellists' perceptual responses to the odour stimulus. This consistency suggests that the instrument was able to deliver the odour stimulus uniformly to each panellist under repeated testing conditions. Consequently, the selected airflow velocity of 1 m/s was shown to provide stable and consistent odour exposure, thereby enhancing the reliability and reproducibility of the sensory assessment.

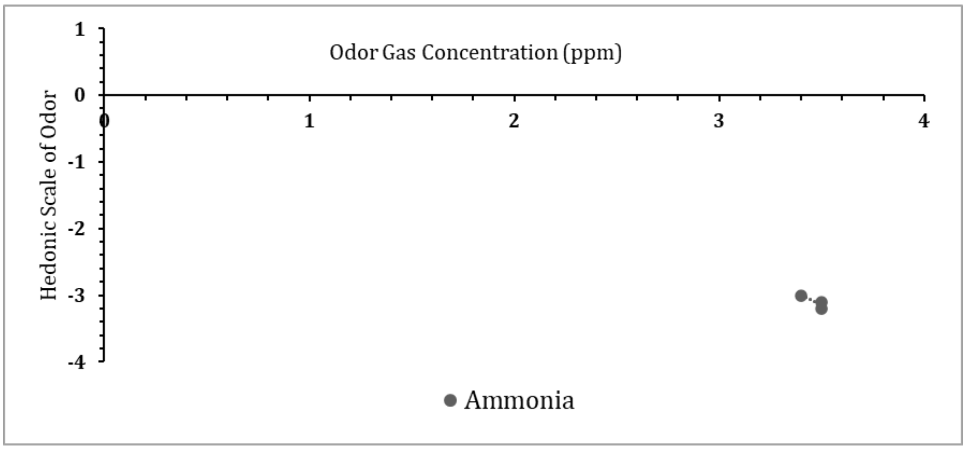

Figure 1. Consistency of the airflow delivery system

3.2 Panel Assessment Consistency

The panellists in this study were individuals who passed the screening test in accordance with ISO 8586:2023 for sensory analysis (International Organization for Standardization, 2023). The selection process considered attendance, communication ability, basic knowledge, and physical and psychological health. Smoking habits were also taken into account, as they can affect olfactory sensitivity (Doty, 2015; Herz, 2002). The minimum number of eight panellists follows the provisions of Kepmen LH No. 50 of 1996, which states that this number is sufficient to obtain representative odour test results (Menteri Negara Lingkungan Hidup, 1996). The screening process aims to ensure the consistency of panellists' sensory capabilities in assessing odour impressions, which is an important prerequisite in olfactometry studies (International Organization for Standardization, 2023; CEN, 2022).

Consistency of values across sessions indicates no significant temporal differences, suggesting stability in panellist assessments. Previous studies have shown that sniffing behaviour tends to be consistent within individuals, although inter-individual variation exists (Olofsson et al., 2012). Additionally, n-butanol is widely used as an indicator of olfactory sensitivity in research and in the diagnosis of olfactory disorders (Hummel et al., 1997). Therefore, consistent results for n-butanol in this study indicate that the panellists possessed adequate detection capacity.

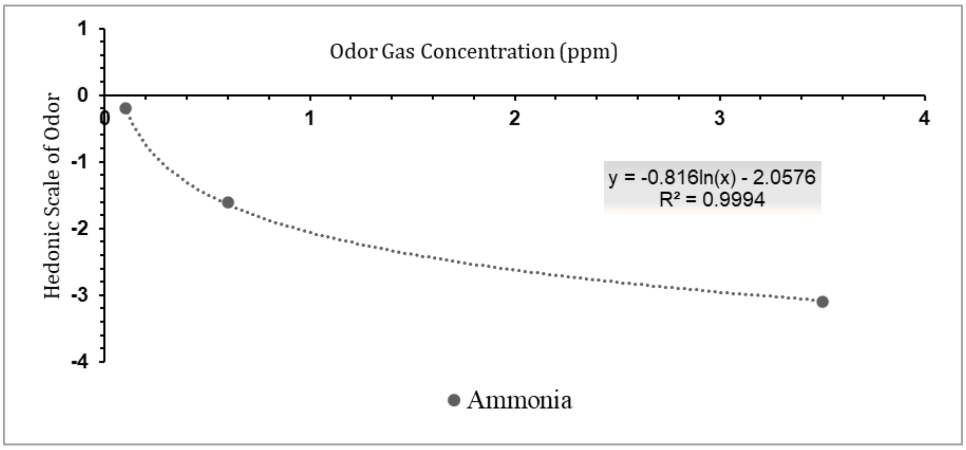

Figure 2. Graph of the relationship between odour hedonic scale and odour gas concentration.

The relationship between ammonia (NH_3) concentration and odour perception followed a logarithmic trend, described by the regression equation $y = -0.816 \ln(x) - 2.0576$, with a coefficient of determination (R^2) of 0.9994 (Figure 2). The high coefficient of determination ($R^2 > 0.75$), which in this study approached 0.9994, indicates a very strong association between the hedonic ratings assigned by the panellists and the NH_3 concentrations measured by the gas detector. This strong relationship suggests that the panellists provided consistent sensory evaluations across repeated measurements, thereby supporting the reliability of the panel-based assessment.

The observed logarithmic relationship is consistent with established psychophysical theories, particularly the Weber–Fechner law and Stevens' power law, which describe human sensory responses to chemical stimuli as inherently non-linear (Chen et al., 2021). Accordingly, increases in odour concentration at relatively low concentration levels produce comparatively large changes in perceived odour intensity, whereas at higher concentrations the perceptual response progressively approaches saturation, resulting in reduced sensitivity to further increases in concentration.

3.3 Yuwono Hedonic Scale: Field Assessment Results

Assessment using the Yuwono Hedonic Scale yielded scores that varied with the characteristics of the odour source (Yuwono, 2008). Test results showed that the mean odour perception values differed significantly across samples: ammonia (-3.1), n-butanol (-1.3), and ambient air (-0.1). These values indicate that ammonia is the least liked, while ambient air approaches a neutral or odour-free condition. The detailed average odour perception ratings provided by the panellists for each session can be seen in **Figure 3**.

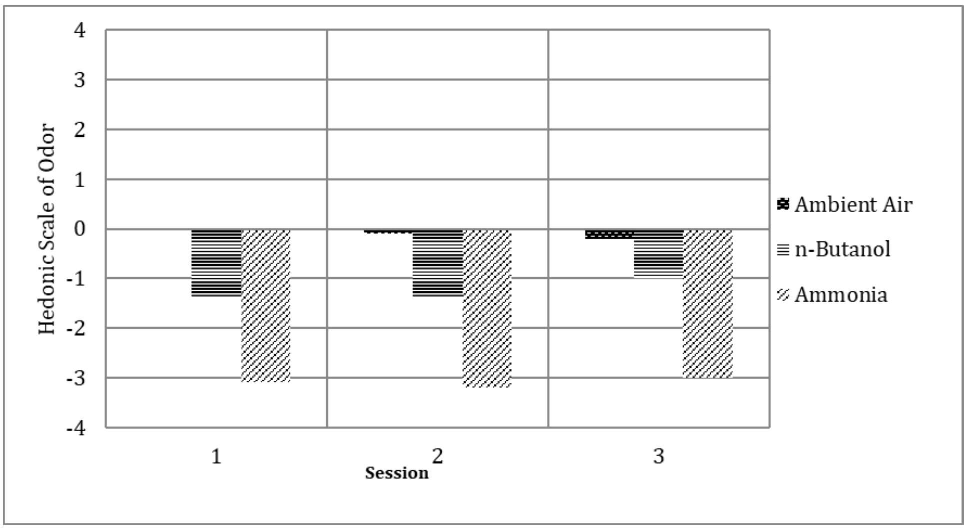

Figure 3. Graph of mean panellist ratings per replicate.

From a physiological perspective, odour perception is influenced by both the concentration of volatile compounds and the sensitivity of the olfactory receptors. The relationship between odour concentration and perceived intensity is inherently non-linear and generally follows a logarithmic function, as described by the Weber–Fechner law and Stevens' power law (Chen et al., 2021). This relationship explains why ammonia can elicit a substantially stronger odour response than other compounds at comparable concentrations. In addition to its odorous properties, ammonia is a potent respiratory and sensory irritant, which contributes to more negative perceptual responses than those typically associated with organic compounds such as n-butanol (Agency for Toxic Substances and Disease Registry, 2004). In this study, the perceived odor scale ranking was ammonia > n-butanol > ambient air. In accordance with EN 13725:2022, n-butanol was used as the reference substance for calibrating panellists' olfactory sensitivity, indicating that the panellists' responses were within the valid range expected under standardised olfactometric procedures (CEN, 2022; Van Gemert, 2011).

The study proves that together with the use of the reliable airflow supply system, the Yuwono Hedonic Scale allows developing an efficient method to assess the community response to environmental smells. Apart from providing objective data on the levels of pollution, the method gives an opportunity to get direct information about comfort and discomfort related to odor exposure. It is especially valuable due to the fact that odour nuisance perception is not always dependent on the concentration of air pollution but is related to physicochemical properties of odors, meteorological conditions, and individual sensitivity to odorants. Thus, combining the objective information on pollution concentration with hedonic measurement is a more complete evaluation of the odours effect on the environment. In such a way, the suggested method can be applied in regular odour monitoring in the area of industrial enterprises, MSW disposal locations, sewage treatment plants, livestock units and other odor producers.

3.4 Effect of Meteorological Conditions on Odour Perception

Table 3 shows that the experiments were conducted under relatively uniform meteorological conditions, with air temperatures ranging from 30 to 32°C and wind speeds between 0.2 and 1.0 m/s. These conditions are representative of typical weather patterns in tropical Indonesia; therefore, the influence of meteorological variability on odour perception was expected to be limited (BMKG, 2023). Maintaining relatively consistent testing conditions was important to ensure that differences in hedonic ratings were primarily attributable to the characteristics of the odour sources rather than to changes in the surrounding environment during the measurements (Brancher et al., 2017).

For the ambient air assessment, air temperatures ranged from 30 to 31°C and wind speeds from 0.6 to 1.0 m/s. The mean hedonic score of –0.1 indicates that the ambient air was perceived as either odourless or only slightly odorous. This finding is consistent with the interpretation of the Yuwono Hedonic Scale, in which ratings close to zero indicate that the odour has little or no adverse effect on olfactory comfort (Yuwono, 2008).

Assessment using *n*-butanol produced a mean hedonic score of −1.3 under air temperatures of 30–32°C and wind speeds of 0.2–0.7 m/s. This score indicates that the panellists perceived the odour as mildly unpleasant. The finding is consistent with the established role of *n*-butanol as the reference compound in olfactometry because of its stable odour characteristics and its widespread use for panellist calibration and selection in accordance with EN 13725 (CEN, 2022; Capelli et al., 2010).

Ammonia produced the lowest mean hedonic score (−3.1) under air temperatures of 30–31°C and wind speeds ranging from 0.4 to 1.0 m/s. This result indicates that ammonia was perceived as distinctly unpleasant and considerably more offensive than the other two odour sources. This observation is consistent with the well-established characteristics of ammonia as a pungent gas with a low odour detection threshold, enabling it to be readily detected by the human olfactory system even at relatively low concentrations (NIOSH, 2019; ATSDR, 2004).

Table 3. Meteorological conditions and panellist assessment results for each odour source

Odour Source	Temperature (°C)	Wind Speed (m/s)	Mean Hedonic	Interpretation
Ambient Air	30–31	0.6–1.0	-0.1	Odourless
n-Butanol	30–32	0.2–0.7	-1.3	Slightly Unpleasant
Ammonia	30–31	0.4–1.0	-3.1	Unpleasant

Source: *processed from environmental odour test results*

Overall, the results presented in Table 3 demonstrate a consistent relationship between odour source and the panellists' hedonic responses. Although the assessments were conducted under relatively uniform air temperature and wind speed conditions, the mean hedonic ratings decreased progressively from −0.1 for ambient air to −1.3 for n-butanol and −3.1 for ammonia. This pattern indicates that the instrument consistently delivered odour stimuli to the panellists, such that the observed differences in hedonic ratings were primarily attributable to the characteristics of the odour sources rather than to variations in meteorological conditions during the experiments.

Furthermore, the ambient wind speeds recorded during the assessments (0.2–1.0 m/s) were broadly comparable with the instrument's operating airflow velocity of 1.0 m/s. This correspondence suggests that the airflow delivery system was capable of reproducing odour exposure conditions representative of those encountered in the ambient environment, thereby supporting the ecological validity of the sensory assessments (BMKG, 2023; Doty, 2015).

4. Conclusions

This study developed and evaluated a direct-airflow environmental odour nuisance measurement instrument designed to deliver ambient air directly to panellists under field conditions. An airflow velocity of 1.0 m/s was selected based on climatological analysis, panellist evaluation, and technical verification, providing the most favourable combination of odour detectability, comfort, and ease of assessment.

The instrument demonstrated consistent airflow delivery under repeated testing, as indicated by the small variation in ammonia concentration (3.4–3.5 ppm) and the corresponding consistency of panellists' hedonic scores. The logarithmic relationship between ammonia concentration and hedonic score (R^2 = 0.9994) further supports the reproducibility of the sensory responses obtained under the experimental conditions.

Under the relatively uniform meteorological conditions encountered during field testing (30–32°C and wind speeds of 0.2–1.0 m/s), differences in hedonic scores were primarily associated with the characteristics of the odour sources rather than with variations in air temperature or wind speed. Ambient air, *n*-butanol, and ammonia produced progressively lower mean hedonic scores (−0.1, −1.3, and −3.1, respectively), indicating that the Yuwono Hedonic Scale was able to distinguish differences in perceived odour unpleasantness across the tested odour sources.

The findings demonstrate the feasibility of combining a direct-airflow delivery system with the Yuwono Hedonic Scale to assess environmental odour nuisance under the field conditions investigated in this study. Further validation under a wider range of odour sources, meteorological conditions, and monitoring environments is required to establish the broader applicability of the proposed instrument.

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Ethics Statement

This study was conducted in accordance with ISO 8586 standards for sensory analysis and with the Minister of Environment Decree No. 50 of 1996 on odour level standards. All participants provided written informed consent before participating in the study, and their privacy and confidentiality were strictly maintained throughout.

CRediT Author Statement

Dede Heri: Idea Development, Investigation, Formal Analysis, Visualization, Manuscript Draft Preparation. **Arief Sabdo Yuwono**: Supervision, Research Design, Resources, Result Verification, Manuscript Review and Revision. **Erus Rustami**: Supervision, Result Verification, Manuscript Review and Revision. **Daranrat Jaitiang**: Supervision, Manuscript Review and Revision.

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