

Determination of the hedonic odour tone in China and the behavior curve of ammonia

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The hedonic tone of 73 panellists is tested with reference to the Guideline VDI 3882 with two standard odorants: vanillin(5 g/L) and guaiacol (5 µg/L). For guaiacol, about 77% of the panellists judged the smell to be unpleasant with the mean value -1.3. For vanillin, about 81% of the panellists observed a pleasant tone with the mean value of 1.2. Based on the data analysis, the domestic screening criteria for the panel of the hedonic tone test (not the individual hedonic tone) is obtained as follows:

vanillin: from+1.1 ~ +2.4

guaiacol from -1.6 ~ -0.4.

Ammonia is presented as an example in this paper. The odour concentration of the original sample was 1713, and it was diluted to 5 concentration gradients which differ by a factor of approximately 3. The result shows that the hedonic tone at different dilution levels all belong to the category of unpleasant. Moreover, the hedonic tone was approximately 0 with an odorant concentration of 26 ppm. In addition, the behaviour curves of the hedonic tone and odour concentrations are plotted. The trend of the behaviour curve demonstrates a multiple nonlinear relationship between the hedonic tone and the odour concentration, and the regression equation is $Y = 3.26 - 3.26 X + 0.42 X^2$ ($R^2=0.99$). The model can reflect the changing tendency of the hedonic tone at different concentrations, which will be helpful for the prediction of the hedonic tone.

1. Introduction

Environmental odour is an important subcategory of perceived air pollution, which is discussed under the common heading of environmental stress together with noise, heat and light (Sucker et al.,2008). With the progress of society, people seem to have become less tolerant to environmental odour (Capelli et al.,2013), and it has become a major environmental problem among neighborhood communities, local municipalities, state agencies and national governments around the world (Carmo et al.,2010). There are great differences in the odour substances and characteristics of different sources. At present, the odour concentration, intensity, odour quality are the most important indicators for the odour impact evaluation, among which the odour concentration is the most widely used (Nicell et al.,2009). However, odour concentration refers to the dilution times of odour samples with clean air to the olfactory threshold, and it has nothing to do with the characteristics of the odour. Therefore, odour concentrations cannot reflect the discrepancy in the effects of different odours.

The hedonic tone is a measurement which can truly reflect the person's "pleasant - unpleasant" psychology. It is contingent on the nature of the odorous substance or mixture of the substances, on the odorous concentration and hence on the perceived intensity of the odour, and on the mental condition of the individual person. Experience

has shown that the hedonic tone can reflect the injury and the psychological influence better than odour concentration (Both et al., 2004). A study on the odour classification was carried out in 2004, it is considered that the hedonic tone is an important dimension of classification for the people with diverse cultural background (Chrea C et al., 2004). Besides, the hedonic tone has been found to affect annoyance and the number of highly annoyed persons (Steunenbergh, 1998), and also to strongly influence associations between odour exposure and symptom reporting (Sucker et al., 2009). A large scale of surveys was executed from 1999 to 2001, the results showed that only the unpleasant and neutral odour would cause the annoyance and complaint, and the pleasant smell almost won't induce annoying reactions (Sucker et al., 2008). In Germany, a standard of hedonic tone determination (VDI 3882, 1994) was published in 1994. It proposed a nine-point scale with values ranging from "-4 - extremely unpleasant" through "0 - neither pleasant nor unpleasant" ("neutral") to "+4 - extremely pleasant". Furthermore, the standard proposed the qualified criterion of the panel as follows:

vanillin: from +1.9 ~ +2.9

guaiacol: from -0.8 ~ -2.0

Currently, the evaluation and management of odour pollution in China is mainly based on the odour concentration, yet the studies and applications on the hedonic tone have not been carried out. In this paper, the panel selection criterion is proposed through the test of two odorous substances referred to VDI3882. Furthermore, ammonia is presented as an example to reveal the relationship between the hedonic tone and the odour concentration, and a mathematical model of the two factors is established.

2. Material and methods

2.1 Method for panel selection

VDI 3882 stipulates the panel selection criterion: vanillin is from +2.9 to +1.9, while guaiacol is from -0.8 to -2.0. However, the psychological feelings for a certain odorant may be different between China and Western countries because of the discrepancy of the cultural background and living habit. So it is necessary to propose a panel selection criterion which will be conform to the actual condition of China.

73 members aged from 18 to 45 participated in the panel screening, including 36 males and 37 females. They are all tested with the reference materials: vanillin (5 g/L, dipropylene glycol), guaiacol (5 µl/L, distilled water). The fresh samples have been prepared each day and have been presented in 500 mL wide-neck bottles with 45 mm standard ground stoppers. Each bottle contained 200 ml of the solution. The assessor was asked to evaluate the hedonic tone one by one. The fixed sequence is as follows:

1. vanillin

2. guaiacol.

The results of the evaluation are given according to the 9 point hedonic scale as shown in Table1.

Before the experiment, the members have been told that there is no "right" or "wrong" answer in the test. They should respond on behalf of their individual feelings. Once the members got the bottle, they should open the stopper immediately, sniff two or three times and then quickly replace the stopper. The decision according to the 9 point hedonic scale should be given as spontaneously as possible, without too much reflection. The evaluation process can be carried out only once.

Table 1: 9 point hedonic scale for odour.

Hedonic Tone	Verbal description
-4	extremely unpleasant
-3	moderate unpleasant
-2	unpleasant
-1	slightly unpleasant
0	neutral
1	slightly pleasant
2	pleasant
3	moderate pleasant
4	extremely pleasant

2.2 Procedure for the hedonic odour tone evaluation

The panel should consist of at least 15 persons to account for the inter-individual differences which may occur when determining the hedonic odour tone. The odour samples to be presented to the panel members consist of several dilution levels according to the method of the triangle odour bag. The lower limit corresponds to the panel threshold. The entire range of concentrations to be presented to the panel members is checked for toxicity, and all possible risks of injury to the panel members must be reliably excluded. In the case of low odorant concentrations, a smaller number of dilution levels may be presented.

The presentation of odour samples is carried out at random. With this method, the dilution levels are presented in any desired sequence for each series of the measurements. Adaptation effects must be minimized by ensuring that an above-threshold odour sample should not be presented for longer than 15 seconds, with an allowance of an additional decision time of 5 seconds. The minimum break between any two stimuli should be at least 1 minute. In order to avoid the phenomenon of guessing by the panellists, additional samples of pure air was offered in a stochastic order.

It is necessary to ask the panel members whether he or she smelled the odour or not. If the answer is "Yes", the hedonic tone of the perceived concentration should be evaluated according to the 9 point hedonic scale. If the answer is "No", then a symbol of " - " will be recorded.

Table 2: Hedonic tone of vanillin and guaiacol.

Hedonic Tone	Vanillin	Guaiacol
+4	1	3
+3	11	6
+2	21	16
+1	26	31
0	3	15
-1	7	0
-2	4	1
-3	0	0
-4	0	1
Average Value	1.3	-1.2

3. Results and discussion

3.1 The criteria of the panel selection

The hedonic tones of vanillin and guaiacol are shown in Table 2. The proportion of the hedonic tones of the two standard materials are presented in Figure 1 and Figure 2, respectively.

For vanillin, nearly 59 (81%) members record a pleasant tone, while about 11 (15%) people feel unpleasant, and 3 (4%) persons consider it neither pleasant nor unpleasant. The results are mainly concentrated in the range of +1 ~+3 with an average value of 1.3, which is lower than the criterion presented in VDI 3882. It means that the psychological impact of vanillin for the Chinese is not as strong as for Germans.

The major proportion of the panel judged guaiacol as unpleasant (56 (77%) persons). About 15 (21%) people, which occupy the second largest rate, feel neither pleasant nor unpleasant, only 2 (2%) members feel pleasant. The results are mainly concentrated in the range of 0 ~-2, with the average value of -1.2, which belongs to the category "slightly unpleasant".

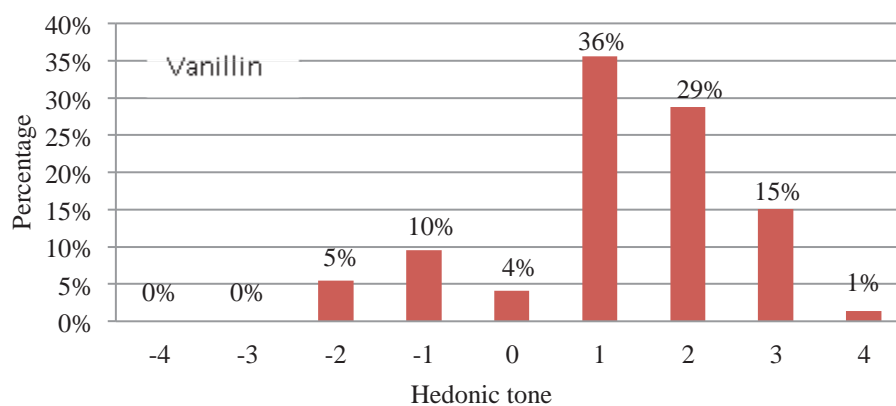


Figure 1. The hedonic tone percentage of vanillin.

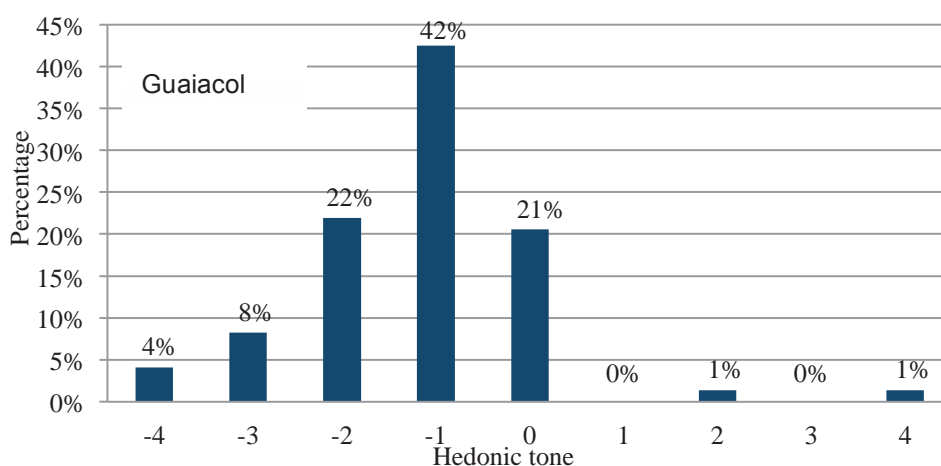


Figure 2. The hedonic tone percentage of guaiacol.

The criterion for panel selection is not the panel member's sensitivity, but the mean value of the whole panel results. The values of the hedonic tone given by the panel

members are subject to the normal distribution, the range of values under different confidence levels can be determined by the formula:

$$[\bar{X} - \frac{\sigma}{\sqrt{n}} Z_{\frac{\alpha}{2}}, \bar{X} + \frac{\sigma}{\sqrt{n}} Z_{\frac{\alpha}{2}}] \quad (1)$$

Where

\bar{X} - mean value,

σ - standard deviation, n quantity of sample

$Z_{\frac{\alpha}{2}}$ - a coefficient that can be obtained by the normal distribution table

From the perspective of statistics, the higher the confidence level, the larger the probability that the sample falls into the interval, and the wider the corresponding interval. However, for the panel selection, the confidence interval is not as wide as possible. It is necessary to exclude the extreme values in order to improve the panel selection conditions. In this study, the hedonic tone samples of vanillin are chosen as {1, 2, 3}, while those of guaiacol are {0, -1, -2}. Through the comprehensive analysis of the range corresponding to different confidence levels and the distribution characteristics of the hedonic tone determined by the panellists, the panel selection criteria are finally put forward as follows:

vanillin: +1.1 ~ +2.4 ,

guaiacol: -1.6 ~ -0.4.

3.2 Determination of the typical odorant hedonic tone

Ammonia (NH₃) is presented as a typical odorant. The original odour concentration of the sample is 1713 ou/m³ (under the assumption that 1 ppm correspond to 1 ou/m³), and it is diluted in steps of three by 0, 3, 10, 30, 100. The hedonic tone at different odour concentrations is determined by 18 qualified panel members.

The results are shown in Table 3. Generally, the hedonic tones are all negative, which means that NH₃ belongs to the range of unpleasant substances. At the concentration index of 3.23, the corresponding hedonic tone is the maximum (-2.89). As the dilution factor increases, the degree of aversion gradually mitigates, until the concentration index declines to 1.23, at which point the average value of the hedonic tone decreases to the minimum of -0.08.

Fig. 3 demonstrates the percentage of the hedonic tone at different concentrations. For the concentration level of Z₁, the level “-3” ranks the first, which accounts for 39%. The levels “-2” and “-4” occupy the second largest proportion with 28% each, and the level “-1” constitutes only 5%. As the dilution factor increases, the proportion of “serious disgust” is gradually reduced, while the percentage of “slight disgust” increases. The odour concentration of Z₅ is the lowest with the concentration index of 1.23. At this point, about 78% of the panellists feel neither pleasant nor unpleasant, which makes up the largest rate, and only 4% persons feel unpleasant.

3.3 Relationship between odour concentration and hedonic tone

A behaviour curve of the hedonic tone in the above-threshold concentration range can provide useful information for the extent to which abatement measurements are necessary. Assuming that the downstream waste gas cleaning process doesn't change the composition of the crude gas with respect of its constituents, the behaviour curve

may serve to determine what odorant concentration of cleaned gas is permissible in order to obtain a gas emission with an acceptable hedonic tone.

Table. 3 Hedonic odour tone evaluation for NH_3 .

Panel member	Blank sample		Concentration steps	Z_1	Z_2	Z_3	Z_4	Z_5
			$\lg Z_k$	3.23	2.76	2.23	1.76	1.23
1	0	-	Hedonic tone	-4	-2	-2	0	0
2	-	-		-3	-2	-1	-1	0
3	0	0		-2	-1	-1	0	0
4	-			-3	-1	-2	-1	-
5	1	1		-3	-1	0	-	2
6	-	-		-4	-2	-1	0	-
7	0	0		-2	-1	-1	0	-
8	-	-		-3	-3	-2	-1	-
9	0	0		-2	-2	-2	-1	0
10	0	0		-4	-2	-1	-2	0
11		0		-2	-2	-2	0	0
12	0	0		-3	-2	-2	-2	-1
13	-	0		-2	-1	0	-2	-1
14	-	-		-4	-2	-4	-3	-1
15	0	1		-1	-1	-1	0	-
16	-	-		-3	-2	-2	-1	-
17	-1	0		-4	-4	-4	-2	0
18	-	-		-3	-2	-2	-1	0
Frequency	+4		0.00	0.00	0.00	0.00	0.00	
	+3		0.00	0.00	0.00	0.00	0.00	
	+2		0.00	0.00	0.00	0.00	0.00	
	+1		0.00	0.00	0.00	0.00	0.00	
	0		0.00	0.00	0.11	0.39	0.78	
	-1		0.06	0.06	0.33	0.33	0.17	
	-2		0.28	0.56	0.44	0.22	0.06	
	-3		0.39	0.33	0.00	0.06	0.00	
-4		0.28	0.06	0.11	0.00	0.00		
Average value			-2.89	-2.40	-1.96	-1.21	-0.08	

The behaviour curve of the hedonic tone as a function of odour concentration index is shown in Fig.4. A significant decrease in the hedonic tone by concentration was found. When the odour concentration index is 1.42 (odour concentration approximately 26 ou/m^3), the corresponding hedonic tone is -0.5. If the concentration index is less than 1.42, people will feel neither pleasant nor unpleasant, which means that the odour will have no influence on persons. In order to prevent from odour pollution of NH_3 , the odour concentration should be below 26 ou/m^3 .

To fit the hedonic tone and the odour concentration index by the data analysis software of Origin, the following regression equation is obtained:

$$Y = 3.26 - 3.26 X + 0.42 X^2 \quad (2)$$

with the hedonic tone Y and the odour concentration index X.

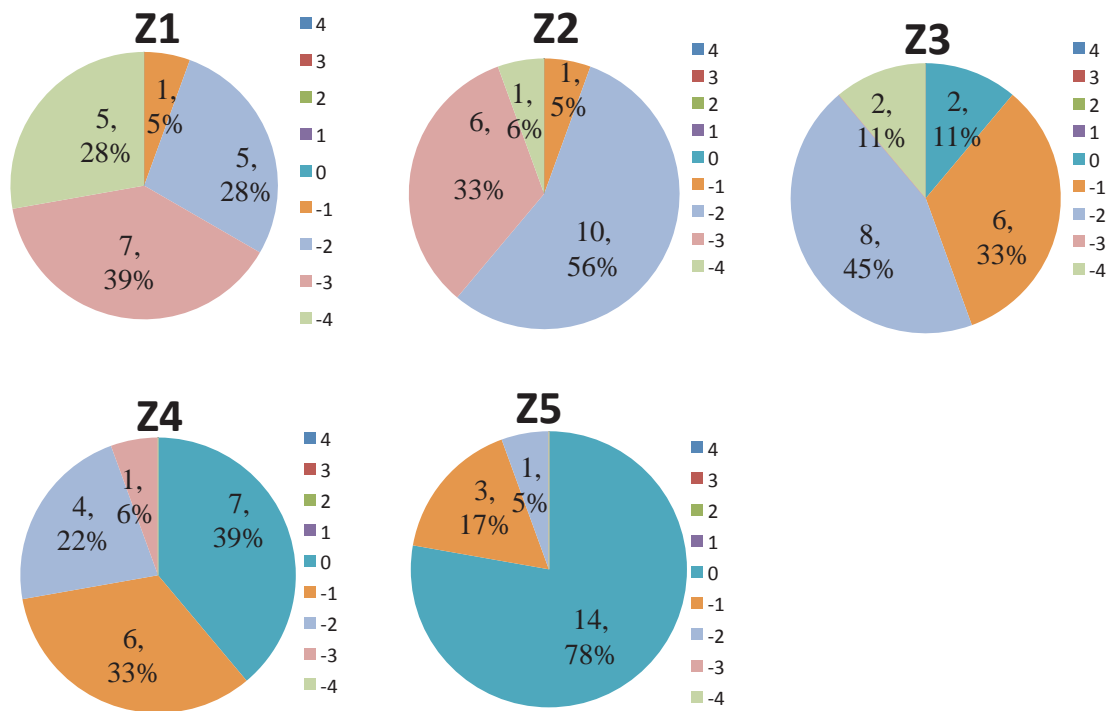


Figure 3: The percentage of hedonic tones at different concentrations.

The correlation coefficient is 0.99, which means a strong correlation between the two factors. The model indicates that there is a multiple nonlinear relationship between the hedonic tone and the odour concentration

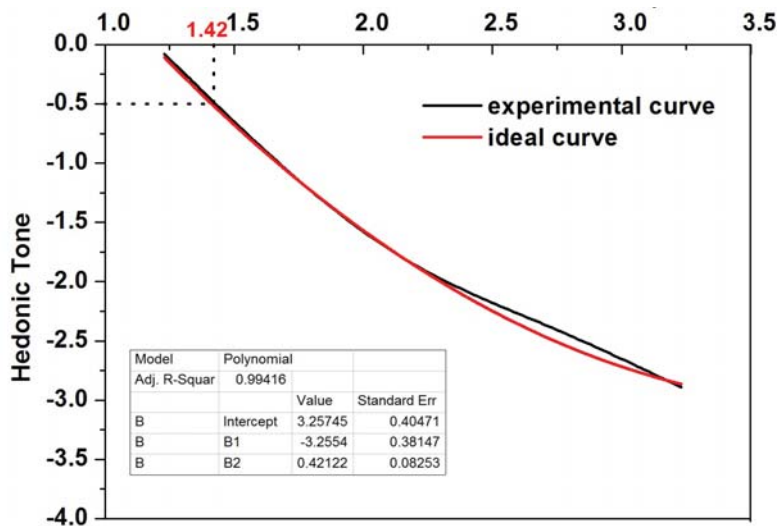


Figure 4: Relationship between the odour concentration index and the perceived hedonic tone of NH₃.

4. Conclusion

The hedonic tone is a measure which can quantify the subjective feeling of individuals (pleasant or unpleasant). In this study, the characteristics of the Chinese hedonic tone are analyzed with the two reference materials according to the method provided by VDI 3882, and a panel selection criterion is proposed. Furthermore, the hedonic tone of NH₃ is determined to study the relationship between hedonic tone and odour concentration. The conclusions drawn from the research are as follows:

- (1) For vanillin, 81% of the members feel pleasant with the average value of 1.3 which is lower than the criterion of 1.9 ~ 2.9 presented in VDI 3882. For guaiacol, 77% of the members feel unpleasant with the average value of -1.2 which conforms to the criterion of -2.0 ~ -0.8 presented in VDI 3882.
- (2) The criterion of panel selection for China is put forward as follows: vanillin: +1.1 ~ +2.4, guaiacol: -1.6 ~ -0.4. The selection of the panel is not based on the individual sensitivity of the olfactory sense, but on the average value of the whole group.
- (3) The hedonic tone of NH₃ belongs to the category of unpleasantness, and the degree of disgust gradually increases with the odour concentration. If the odour concentration is below 26 ou/m³, the humans won't be disturbed by the smell of NH₃ as it is neither pleasant nor unpleasant.
- (4) There is a multiple nonlinear relationship between the hedonic tone Y and the odour concentration X according to $Y = 3.26 - 3.26 X + 0.42 X^2$ with a correlation coefficient of 0.99.

Acknowledgments

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