Pol. J. Environ. Stud. Vol. 31, No. 1 (2022), 979-984
DOI: *10.15244/pjoes/138181* ONLINE PUBLICATION DATE: 2021-11-22

Short Communication

Evaluation of O_3 and NOx Pollution Based on People's Perception

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Received: 31 January 2021
Accepted: 24 May 2021

Abstract

Both NOx and O_3 are irritants and harmful pollutants for human health, and it is very reasonable and important to evaluate their effects by combining public perceptions. Five groups of pollutant concentrations and scores (98 healthy people) were available at the same site. Using the optimal Weber constant and Weber-Fischna-Law (W-F-L) change, the results showed that O_3 and NOx were the main irritants compared with other factors in our experiment, and most assessments were approximately in agreement with the pollution level and people's perception rules. In addition, due to the lack of calculation unity and the essential concept for the present Weber constant, the true value based on real human perceptions was first obtained based on the findings that the exact match between concentrations and score means was the unique breakthrough.

Keywords: air pollution, concentration, score, Weber Fischna Law

Introduction

NOx and O_3 investigations in terms of their physical and chemical properties are currently of great concern. NO_2 is a key precursor for a range of secondary pollutants [1], such as O_3, and can cause damage to humans, animals, vegetation, and materials [2], and increase susceptibility to respiratory infections [3]. A linear relationship between O_3 and mortality has also been found [4], which could be explained by the fact that pollutants are easily absorbed by humans, thereby impairing lung function [5-6]. In addition, O_3 has been increasingly associated with climate change [7]. These two pollutants also produce negative synergistic effects with particulate matter and SO_2 in many diseases in which their relative risks (RRs) are statistically significant and the highest [8]. Although there are some natural emissions of NOx, the majority of emissions are from anthropogenic sources [9], in which coal and biomass are regarded as the major sources of emissions in northeastern China [10], and urban-traffic NO_2 has increased the COVID-19 pandemic fatality rate [11]. O_3 pollution is also serious due to its close relationship with NOx.

Therefore, it is very important to evaluate the effects of O_3 and NOx, especially on human health. In general, large data analyses have been widely used, such as utilizing a Poisson regression model to find the associations between O_3 and NO_2 and disease mortality in Panama City [12] and assessing the effects from PM and NO_2 on health indicators [13]. The large and synergistic effects of O_3, NO_2, and

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other pollutants have also been studied in respiratory and related diseases [14]. In fact, human perception, which combines physiology and psychology, is a part of health or is an indicator. Perception can thus show the influence on health and public satisfaction of air quality, in which perceptions change with the stimulus, which includes pollution according to the Weber-Fischna Law (W-F-L). Unfortunately, relevant research is very scarce. Although a few assessments of gas quality have been reported [15-17], they are only nominal evaluations of people's perceptions. It is still unknown which and how perceptions of a person agree with the law. The only research in recent years has been to accurately perceive indoor formaldehyde pollution through smell, in which perceptions could match the pollutant concentration [18].

Since the harm from O_3 and NOx to humans is attracting increasing attention, people's perception cannot be ignored, especially according to the basic law (W-F-L). Therefore, the aim of this study is to examine the relationship between O_3 and NO_x pollution and human perceptions through the nose, eyes and throat based on the W-F-L. In addition, the true Weber constant based on people's perceptions is obtained.

Materials and Methods

Study Design

O_3 and NOx were determined according to the China environmental standards (HJ 504-2009 and HJ 479-2017, respectively), hourly O_3 and NOx concentration data were available from three simultaneous monitoring recordings at the same site, and the arithmetic mean was selected as the experimental value (shown in Table 1). In addition, for the influence of pollution on the throat, nose and vision, random sampling of a face-to-face questionnaire survey was conducted among 98 effective people who could pass the corresponding health questionnaire test near the monitoring site, in which participants scored their physiological sensations from a range of 1 to 5. The grade of fractions is presented in Table 2. In the experiment, the proportion of males to females was 20:29, and the age distributions, 20.1%, 40.8% and 39.1%, were in the ranges of 20-35, 35-50 and 50-65 years, respectively.

Pollution Assessment

Using the pollutant concentrations and questionnaire scores, conventional assessments were performed. In addition, the data were changed by the W-F-L of Eq. (1):

$$K = \alpha \lg(1 + S) \qquad (1)$$

...where K is the Weber exponent, the intensity of a person's perception; α is the Weber constant, which is only related to the species and property of pollutant and type of perception, but not to concentration; and S is the outer stimulating strength, the pollutant concentrations and questionnaire scores. In this study, the (1 + S) method was used to ensure lg (c + 1)≥0 and did not influence the results of the evaluation.

Table 1. Grade and Measured Value.

<table>
<tr><td>Classification and Measured Content</td><td colspan="6">First grade</td><td>Second grade</td></tr>
<tr><td rowspan="2">Score</td><td colspan="6">≤4</td><td rowspan="2">≤5</td></tr>
<tr><td>The first time</td><td>Second one</td><td>The third time</td><td>The fourth</td><td colspan="2">The fifth</td></tr>
<tr><td>Vision</td><td>3.6</td><td>3.7</td><td>3.2</td><td>3.2</td><td colspan="2">3.1</td><td>----</td></tr>
<tr><td>Nose</td><td>4</td><td>3.8</td><td>3.9</td><td>3.6</td><td colspan="2">3.5</td><td>----</td></tr>
<tr><td>Throat</td><td>3.5</td><td>3.4</td><td>3.3</td><td>3.3</td><td colspan="2">2.8</td><td>----</td></tr>
<tr><td>Average</td><td>3.7</td><td>3.6</td><td>3.5</td><td>3.3</td><td colspan="2">3.1</td><td>----</td></tr>
<tr><td rowspan="5">O_3</td><td colspan="6">Standard (μg m^{-3})</td><td>Standard (μg m^{-3})</td></tr>
<tr><td colspan="6">≤160</td><td>≤200</td></tr>
<tr><td colspan="6">Measured values (μg m^{-3})</td><td>measured values (μg m^{-3})</td></tr>
<tr><td>Second one</td><td>The third time</td><td>The fourth</td><td colspan="3">The fifth</td><td>The first time</td></tr>
<tr><td>90.16</td><td>130.34</td><td>104.08</td><td colspan="3">83.79</td><td>164.67</td></tr>
<tr><td rowspan="5">NOx</td><td colspan="7">Standard (μg m^{-3})</td></tr>
<tr><td colspan="7">≤250</td></tr>
<tr><td colspan="7">Measured values (μg m^{-3})</td></tr>
<tr><td>The first time</td><td>Second one</td><td colspan="2">The third time</td><td colspan="2">The fourth</td><td>The fifth</td></tr>
<tr><td>110.86</td><td>142.10</td><td colspan="2">68.32</td><td colspan="2">91.83</td><td>88.06</td></tr>
</table>

Table 2. Fraction grade.

Physiological perception	A	B	C	D	E
	Weak	Weaker	Strong	Stronger	Strongest
Fraction	1	2	3	4	5

Results and Discussion

The Optimal Weber Constants

According to the China Environmental Standard (GB3095-2012), the 1-hour average limit of O_3 and NO_x is divided into two grades, and the scores are also graded according to the rate of O_3. Combining the measured values, the results are shown in Table 2.

It is necessary for the W-F-L to clearly reflect the difference in degree of different grades and the concentrations in the same grade, in which α is very important. Therefore, using the study method [18], according to Eqs (2) and (3), the α for pollutants, throat, nose, eyes and scores were obtained, as shown in Table 3.

$$\min(\geq 0) = \sum_{i=1}^{4}[\lg(160) - a_c\lg(c_{i,O_3})] + \sum_{i=1}^{5}[\lg(250) - a_c\lg(c_{i,NOx})] + [\lg(200) - a_c\lg(c_{5,O_3})] - [a_c\lg(c_{5,O_3}) - a_c\lg(c_{4,O3})] \quad (2)$$

$$\min(\geq 0) = \sum_{i=1}^{m}[\lg(4) - a_k\lg(f_{ki})] + \sum_{i=m}^{98}[\lg(5) - a_k\lg(f_{ki})] - [a_k\lg(f_{k,m+1}) - a_k\lg(f_{km})] \quad (3)$$

...where 160 and 200, 250, and 4 and 5 are the grade standards of O_3, NOx and the score, respectively; $α_c$ is the Weber constants for pollutant concentrations; $α_k$ is for the different and average pollution irritations in which k is 1, 2, 3, or 4 representing throat, nose, or vision irritation, respectively, and the mean of three perceptions; f_{ki}, f_{km} and $f_{k,m+1}$ are the ith, mth and (m+1) th scores, respectively, for the k pollution irritation, in which f_{km} and $f_{k,m+1}$ are the demarcation values for the score grade.

Table 3. Weber Constant for Different Objects.

Object	α
Pollutant concentration	1.13
Vision influence	1.38
Throat irritation	1.48
Nose irritation	1.35
Perception mean	1.37

Since the specific pollutants were the same, the change in the Weber constant was related to the type of perception and other influencing factors (such as aerosols and psychology). It is interesting that for the real concentration and people's perceptions, the Weber constant distribution is relatively uniform, and every value distance is small, in which their relative mean error is 5.6%. The results show that in the experiment, O_3 and NOx are the main irritation sources compared with the other factors, which also improved the experimental design. In addition, the calculated values are very close to 1, which is the selected level of the constant for different grade standards; thus, selection is important. In our experiment, no influence of K was determined in principle, but there were various ways and a lack of unity.

The Assessment by Pollutant Concentration

Basing on the data and Eq. (1), K could be acquired and is shown in Table 4, including the values according to the arithmetic mean of the two pollutant concentrations.

For the standard and measurement changes, their Weber exponents are in agreement with each other. In addition, due to the property of logarithms, the calculated data are closer to each other than the real concentrations, because the ability for humans to perceive pollution differences is obviously lower than the measurements. All results mentioned above are in accordance with changes in human perception; thus, similar methods are usually used to assess environmental quality through fitting, integration and so on [16, 18].

The Evaluation by Scores

All score assessments in Table 2 were synthetic evaluations corresponding to most pollutant concentrations in the first grade, which show that the evaluation based on human perception can approximately reflect the pollution. Indeed, a similar method, especially direct scoring, is usually used in public participation on environmental problems and is very helpful in assessing and solving the issue. Through logarithmic change, Table 5 also displays the tightness for each value, which are similar to the concentration results mentioned above, which caused the change rate to always be lower than the real scores and concentrations, abiding by the law of people's perceptions. On the other hand, due to physiological

Table 4. Weber Exponent of Pollutant Concentration.

Pollution	K						
	Standard change		Measurement change				
O_3	First grade	≤2.49		Second one	The third time	The fourth	The fifth
				2.21	2.39	2.30	2.17
	Second grade	≤2.60	The first time				
			2.50				
NOx	Grade	≤2.71	The first time	Second one	The third time	The fourth	The fifth
			2.31	2.43	2.07	2.22	2.20
Arithmetic mean	First grade	≤2.62	2.42	2.33	2.26	2.25	2.19
	Second grade	≤2.66	---------				

Table 5. Weber Exponent of Scores.

Perception	K						
	Grade change		Investigation change				
			The first time	Second one	The third time	The fourth	The fifth
Vision	First Grade	≤0.99	0.77	0.78	0.70	0.70	0.68
	Second Grade	≤1.07					
Nose	First Grade	≤0.94	0.81	0.78	0.80	0.75	0.73
	Second Grade	≤1.05					
Throat	First Grade	≤1.03	0.81	0.79	0.77	0.75	0.66
	Second Grade	≤1.15					
Arithmetic mean	First Grade	≤1.03	0.64	0.63	0.61	0.59	0.56
	Second Grade	≤1.15					

and psychological limitations in humans, the sores are not completely in accordance with the real measurement data; for example, in Tables 2 and 5, a single O_3 pollution value (164.67 μg/m^3) in the second grade was not expressed; moreover, most values did not have effective relevance to the measurement data.

The Weber Constant for Real People's Perceptions

In the physiology and psychology experiment, the Weber constant α is obtained using Eq. (4), which unfolds its essential concept and calculation:

$$\alpha = \frac{\Delta I}{I} \tag{4}$$

...where ΔI is the difference threshold for perception related to I (the initial stimulation strength), which is the real concentration in our experiment.

Therefore, the Weber constants enumerated in Table 3 for different objects are only nominal data, which can support the assessment by using complete concentrations but not real human perceptions. The true expression by using people's perceptions must depend on Eq. (4), in which the key was to find the accurate matching between the initial perception data and measured concentrations. Thus, the two kinds of values must have strong and significant correlations based on Pearson and Spearman correlation coefficients (coefficient>0.9, significance<0.05) because the Pearson test can show a close relationship between absolute counts of human perceptions and outer stimulations, the Spearman test display that of data interval. Using SPSS, significant correlations using Pearson tests were first performed, as shown in Table 6, in which only means of the scores and concentrations can satisfy the demand. Then, the two groups of averages also passed the Spearman test, as shown in Table 7. Thus, the minimal distance of the concentration mean (99.33-97.96) and corresponding value (99.33) could be used as ΔI and I,

Table 6. Significant Correlation of the Pearson Test.

		Vision Score	Nose Score	Throat Score	Score Mean
O_3 Concentration	Significance	0.620	0.080	0.216	0.250
NOx Concentration	Significance	0.051	0.766	0.459	0.312
Concentration Mean	Significance	0.063	0.092	0.063	**0.026 (Coefficient = 0.921)**

Table 7. Correlation of the Spearman Test.

		Score Mean
Concentration Mean	Significance	-
	Coefficient	1

respectively, and the real α = 0.014, which is the real Weber constant of people's perceptions combined with nose, vision and throat for NOx and O_3 pollution.

Conclusion

For air pollution, it is very important to use various methods to assess the influence on the public. Although both the initial concentration and the score data could be used to evaluate O_3 and NOx pollution, the assessment through value changes was in agreement with human perception law, using the W-F-L with the optimal Weber constant, in which the Weber constants were relatively uniform and depended on the determining principle. In addition, if the evaluation was closer to true human perceptions, it was more beneficial to health; thus, the study found that the concentration and score means could exactly match each other, which proved that people's perceptions had a comprehensive effect corresponding to O_3 and NOx. Thus, the W-F-L can be used not only in the evaluation of pollutant values but also in the assessment of people's true perceptions regarding pollution.

Acknowledgments

This research was financially supported by the characteristic innovation project of Guangdong Universities (Grant No. 2020KTSCX183) and the science project of Zhanshan City (Grant No. 2019B2015).

Conflict of Interest

The authors declare no conflict of interest.

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