Introduction

NOx and O3 investigations in terms of their physical and chemical properties are currently of great concern. NO2 is a key precursor for a range of secondary pollutants [1], such as O3, and can cause damage to humans, animals, vegetation, and materials [2], and increase susceptibility to respiratory infections [3]. A linear relationship between O3 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, O3 has been increasingly associated with climate change [7]. These two pollutants also produce negative synergistic effects with particulate matter and SO2 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 NO2 has increased the COVID-19 pandemic fatality rate [11]. O3 pollution is also serious due to its close relationship with NOx. Therefore, it is very important to evaluate the effects of O3 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 O3 and NO2 and disease mortality in Panama City [12] and assessing the effects from PM and NO2 on health indicators [13]. The large and synergistic effects of O3, NO2, and

Short Communication

Evaluation of O3 and NOx Pollution Based on People’s Perception

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Abstract

Both NOx and O3 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 O3 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

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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-Fischina 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 O₃ 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 O₃ and NOₓ 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

O₃ and NOₓ were determined according to the China environmental standards (HJ 504-2009 and HJ 479-2017, respectively), hourly O₃ 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):

\[ K = \alpha \lg(1 + S) \]  

(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 \( \lg(c + 1) \geq 0 \) and did not influence the results of the evaluation.

| Classification and Measured Content | First grade | Second grade |
|-------------------------------------|-------------|--------------|
|                                     | ≤4          | ≤5           |
|                                     | The first time | Second one | The third time | The fourth | The fifth |
| Vision                             | 3.6         | 3.7          | 3.2          | 3.2        | 3.1       |
| Nose                               | 4           | 3.8          | 3.9          | 3.6        | 3.5       |
| Throat                             | 3.5         | 3.4          | 3.3          | 3.3        | 2.8       |
| Average                            | 3.7         | 3.6          | 3.5          | 3.3        | 3.1       |

| Standard (µg m⁻³)                  | Measured values (µg m⁻³) |
|-------------------------------------|--------------------------|
| ≤160                                |                          |
| O₃                                  |                          |
| Standard (µg m⁻³)                   | Measured values (µg m⁻³) |
| ≤200                                |                          |
| NOₓ                                  |                          |
| Standard (µg m⁻³)                   | Measured values (µg m⁻³) |
| ≤250                                |                          |
Results and Discussion

The Optimal Weber Constants

According to the China Environmental Standard (GB3095-2012), the 1-hour average limit of O₃ and NOₓ is divided into two grades, and the scores are also graded according to the rate of O₃. 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.

\[
\begin{align*}
\min (\geq 0) &= \sum_{i=1}^{n} \left[ \alpha_i \log(c_{i,0}) \right] + \sum_{i=1}^{n} \left[ \alpha_i \log(c_{i,0}) \right] \\
&= \log(160) \cdot \alpha_i \log(c_{i,0}) + \log(250) \\
&- \alpha_i \log(c_{i,0}) \\
&= \alpha_i \log(c_{i,0}) \\
&= \alpha_i \log(c_{i,0}) \\
&= \alpha_i \log(c_{i,0}) \\
\end{align*}
\]

\[
\begin{align*}
\min (\geq 0) &= \sum_{i=1}^{m} \left[ \beta_i \log(f_{i,m}) \right] + \sum_{i=m}^{n} \left[ \beta_i \log(f_{i,m}) \right] \\
&= \log(4) \cdot \beta_i \log(f_{i,m}) \\
&- \beta_i \log(f_{i,m}) \\
&= \beta_i \log(f_{i,m}) \\
&= \beta_i \log(f_{i,m}) \\
&= \beta_i \log(f_{i,m}) \\
\end{align*}
\]

...where 160 and 200, 250, and 4 and 5 are the grade standards of O₃, NOₓ and the score, respectively; αᵢ is the Weber constants for pollutant concentrations; αᵢ 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; fᵢ, fₘ, and fₘ₊₁ are the ith, mth and (m+1) th scores, respectively, for the k pollution irritation, in which fₘ and fₘ₊₁ are the demarcation values for the score grade.

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, O₃ 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

| Physiological perception | A | B | C | D | E |
|--------------------------|---|---|---|---|---|
| Fraction                 | 1 | 2 | 3 | 4 | 5 |

Table 2. Fraction grade.

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

Table 3. Weber Constant for Different Objects.
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 $\alpha$ is obtained using Eq. (4), which unfolds its essential concept and calculation:

$$\alpha = \frac{\Delta I}{I}$$  \hspace{1cm} (4)

...where $\Delta I$ 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 $\Delta I$ and $I$.

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### Table 4. Weber Exponent of Pollutant Concentration.

| Pollution | Standard change $\leq$2.49 | Measurement change |
|-----------|-----------------------------|--------------------|
| First grade | Second one 2.21 | The third time 2.39 | The fourth 2.30 | The fifth 2.17 |
| Second grade | The first time 2.50 | |

| NOx | Grade $\leq$2.71 | The first time 2.31 | Second one 2.43 | The third time 2.07 | The fourth 2.22 | The fifth 2.20 |
|-----|-----------------|------------------|--------------|----------------|----------------|----------------|

| Arithmetic mean | First grade $\leq$2.62 | 2.42 | 2.33 | 2.26 | 2.25 | 2.19 |
|-----|-----------------|-------|------|-----|-----|-----|

| Second grade $\leq$2.66 |  |
|--------------------------|-----|

---

### Table 5. Weber Exponent of Scores.

| Perception | Grade change $\leq$0.99 | Investigation change |
|------------|-------------------------|----------------------|
| Vision     | First Grade 0.77 | Second one 0.78 | The third time 0.70 | The fourth 0.70 | The fifth 0.68 |
| Second Grade $\leq$1.07 |  |
| Nose       | First Grade 0.81 | Second one 0.78 | The third time 0.80 | The fourth 0.75 | The fifth 0.73 |
| Second Grade $\leq$1.05 |  |
| Throat     | First Grade 0.81 | Second one 0.79 | The third time 0.77 | The fourth 0.75 | The fifth 0.66 |
| Second Grade $\leq$1.15 |  |
| Arithmetic mean | First Grade $\leq$1.03 | 0.64 | 0.63 | 0.61 | 0.59 | 0.56 |
| Second Grade $\leq$1.15 |  |
Table 6. Significant Correlation of the Pearson Test.

|                      | Vision Score | Nose Score | Throat Score | Score Mean |
|----------------------|--------------|------------|--------------|------------|
| O\textsubscript{3} Concentration | Significance | 0.620      | 0.080        | 0.216      | 0.250      |
| NO\textsubscript{x} 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 |

respectively, and the real \( \alpha = 0.014 \), which is the real Weber constant of people’s perceptions combined with nose, vision and throat for NO\textsubscript{x} and O\textsubscript{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\textsubscript{3} and NO\textsubscript{x} 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\textsubscript{3} and NO\textsubscript{x}. 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.

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Conflict of Interest

The authors declare no conflict of interest.

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