International Journal of Occupational Safety and Ergonomics

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/tose20

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Published online: 19 Aug 2015.

International Journal of Occupational Safety and Ergonomics (JOSE), 2015
Vol. 21, No. 2, 193–200, http://dx.doi.org/10.1080/10803548.2015.1029288

Influence of traffic-related noise and air pollution on self-reported fatigue

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A growing body of evidence suggests that exposure to environmental pollutions is related to health problems. It is, however, questionable whether this condition affects working performance in occupational settings. The aim of this study is to determine the predictive value of age as well as traffic related air and noise pollutions for fatigue. 246 traffic officers participated in this study. Air pollution data were obtained from the local Air Quality Control Company. A sound level meter was used for measuring ambient noise. Fatigue was evaluated by the MFI-20 questionnaire. The general and physical scales showed the highest, while the reduced activity scale showed the lowest level of fatigue. Age had an independent direct effect on reduced activity and physical fatigue. The average of daytime equivalent noise level was between 71.63 and 88.51 dB(A). In the case of high noise exposure, older officers feel more fatigue than younger ones. Exposure to PM_{10} and O_3 resulted in general and physical fatigue. Complex Interactions between SO_2, CO and NO_2 were found. Exposure to noise and some components of air pollution, especially O_3 and PM_{10}, increases fatigue. The authorities should adopt and rigorously implement environmental protection policies in order to protect people.

Keywords: subjective fatigue; noise; air pollution; traffic; police officers

1. Introduction

Fatigue indicates a feeling of tiredness, reduced energy levels or muscle strength and cognitive impairments.[1,2] It is an everyday experience that individuals report after inadequate rest or sleep, after exertion of physical power, after mental effort or when they lack motivation to initiate activities.[3]

Fatigue is an important issue, which can strongly interfere with several aspects of daily life and can have a marked negative impact on quality of life in general.[4,5] It can diminish the ability of the individual to perform a particular task by altering alertness and vigilance, together with the motivational and subjective states that occur during this transition.[6] As a consequence, there is reduced competence and willingness to develop or maintain goal directed behavior aimed at adequate performance. It has also been identified as a contributing factor for accidents, injuries and death in a wide range of settings, with the implications that tired people are less likely to produce safe performance and actions.[7] An adverse effect on innovative thinking and flexible decision making, less ability to adjust plans when new information becomes available, tendency to adopt more rigid thinking and previous solutions are some of the important cognitive consequences of fatigue.[8] Motor skills such as co-ordination and timing could be also affected by fatigue. Fatigue can cause poor communication through difficulty in finding and delivering the correct word and decreasing expression of speech. Social outcomes of fatigue include being withdrawn, acceptance of own errors, neglecting smaller tasks, being less tolerant of others and irritability.[8] It should be mentioned that the term fatigue also describes a symptom considered to indicate the presence of somatic diseases (cancer, multiple sclerosis, arthritis, renal disease and HIV infection, ...) and/or psychological disorders (depression, anxiety, ...).[2,9] Besides being a symptom of disease, fatigue can be due to some medical treatments like surgery (abdominal operation), radiotherapy or chemotherapy.[3,10]

Researchers have identified several factors responsible for elevated fatigue. Lifestyle variables such as sleep disorders, nutritional deficiencies, disrupted biological clock, excessive physical activity, dietary habits and satisfaction were found to be significant causes of fatigue.[11–14]

Sociodemographic factors such as age, sex, marital status, education, social class and occupational history are also known to influence fatigue. Many studies have found a higher prevalence or higher mean scores in women whereas others did not report any sex-related difference.[9] Having a partner could also modulate fatigue.[2] Bültmann et al. [15] found single employees were more tired than those who live in a couple. In contrast, David et al. [16] failed to find any relationship between marital status and total fatigue scores. The results on the association between

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age and fatigue are even more contradictory. Some found no associations; some found an increase of fatigue with age; while others found lower levels of fatigue in older people. Generally, higher education and social status was found to be related with less fatigue. However, this has not been confirmed by some studies.[9,17]

Previous studies approved the potential role of occupational conditions on fatigue. Bültmann et al. [15] reported that fatigue prevailed among the working population. Nagashima et al. [18] reported a significantly greater likelihood of 'general fatigue' and 'chronic tiredness' among employees working a longer (65) than shorter (50–64) number of hours per week. Beckerset et al. examined work quality and motivation difference in terms of fatigue. They concluded that fatigued workers reported higher levels of job demand paired with less decision-latitude and less work motivation.[19] A fairly large number of publications have explored the role of shift work in relation to fatigue. The nature of this type of work schedule may disrupt sleeping pattern contributing to increased perceived fatigue level especially during the night shift.[20] Monotony in occupational tasks can also be a causal factor of fatigue due to low arousal, boredom and possibly stress.[13]

The last but not the least variable to introduce is the physical environment that may contribute to fatigue particularly in occupational contexts.[11] Melamed and Bruhis reported a study on textile workers exposed to noise during one week with and one without hearing protectors.[11] They found increased fatigue and irritability as well as a higher cortisol level after the week without hearing protectors.

Moreover, several studies indicated the association between fatigue and air pollution. A questionnaire study conducted in alpine communities investigated the relationship of traffic air pollution, perception of exhaust fumes/soot and behavioral impact or symptoms/illnesses. The results indicated a significant association between feelings of fatigue and air quality.[4] Rahama et al. investigated the effects of exposure to car exhausts on traffic policemen in Sudan. They revealed that 61.29% have various complaints of headache, fatigue and other symptoms, which have a close relationship with the air pollutants' concentration.[4]

As mentioned above, many studies have focused on fatigue in healthy people. However, referring to their findings, it seems difficult to determine the essential predictors of fatigue; especially in populations who are simultaneously exposed to several risk factors. In the present study, we examine the predictive value of principal environmental pollutants (i.e., noise and air pollution which are essentially emitted from traffic resources) for the presence of fatigue in traffic police officers in a crowded, noisy and polluted big city such as Tehran. We have also aimed to investigate the predictive effect of age.

2. Methods and materials

2.1. *Study sample*

A cross-sectional study was performed in the capital of Iran, Tehran. The study was conducted between April 21 and June 29, 2011. Based on the location of the air quality monitoring stations throughout the city, 15 municipalities' districts were selected (see Figure 1). So, all study variables (described below) were collected within these locations. 246 traffic police officers participated in the study by completing questionnaires after the end of their working shift (i.e., 14:00). They were all permanently employed. None worked overtime or had an extra job. Periodic medical examinations showed no diseases or medication use attributed to their fatigue.

2.2. *Exposure measurements*

In each of the 15 selected municipalities' districts (Figure 1), three sites (including main streets or intersections) were chosen. Therefore, the total number of sampling sites – in which the ambient noise levels were recorded – was 45. Three periods of measurement, (i.e., 6:00–9:00, 9:00–12:00 and 12:00–15:00) were planned. In each period, noise levels were recorded in three spots around the selected sampling site. The time interval of at least 5 min was respected. The mean value of these recordings was set as mean noise level (LAeq, dB) for each corresponding site and computed for statistical analysis.

Since the normal working area of subjects were within 100 m of any measurement site, the above-mentioned noise values were taken as representative indicators of work-related noise exposure (LAeq, 8 h) for all traffic police officers in the same intersection or street. A sound level meter CEL-450 'Casella' was used.

Information about air pollution was directly obtained from the records of the local Air Quality Control Company (AQCC). Monitoring stations which were located in multiple points of the city by the AQCC, are fully automated

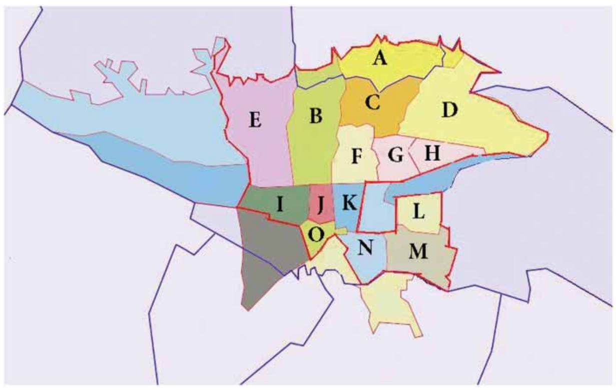

Figure 1. Map of municipalities' districts (selected districts are outlined).

and provided continous readings of sulphur dioxide (SO_2), nitrogen dioxide (NO_2), particulate matter (PM_{10}), carbon monoxide (CO) and ozone (O_3) concentration.

2.3. *Questionnaire*

We used The Farsi version of the Multidimensional Fatigue Inventory (MFI) questionnaire in order to evaluate fatigue sensation among participants. MFI-20 has independently been translated from English to Farsi, standardized for the Iranian population and its validity and reliability have also been confirmed.[21] It comprises five subscales: General fatigue, Physical fatigue, Mental fatigue, Reduced activity and Reduced motivation. General fatigue includes general statements about fatigue and decreased functioning and was designed to encompass both physical and psychological aspects of fatigue. Physical fatigue concerns physical sensations related to fatigue. Mental fatigue pertains to cognitive functioning, including difficulty in concentrating. Reduced activity refers to the influence of physical and psychological factors on the level of activity. Reduced motivation relates to lack of motivation for starting any activity.[22] Each subscale includes four items scored on 5-point Likert scales. Scores on each subscale range from 4 to 20 with higher scores indicating greater fatigue. The fatigue levels in the traffic organizers were measured at the end of the working shift. Close supervision was followed so as to avoid the influence of one's result by another participant.

Respondents were also asked to provide information regarding age, job history, marital status, educational level, smoking habit, drug usage, sport and job history by another questionnaire designed by the authors. They also signed an informed consent.

2.4. *Statistical analysis*

We conducted a multiple linear regression analysis with interaction terms to separate the effect of the different factors from each other. The variables included in the analysis were age (year), ambient noise (LAeq, dB), PM_{10} ($\mu g/m^3$), SO_2 (ppb), NO_2 (ppb), CO (ppm) and O_3 (ppb). All direct effects were kept in the model, but nonsignificant interaction terms were eliminated with an exclusion criterion of $p < .05$. All analyses were performed using SPSS software program version 15.0 for Windows (SPSS Institute Inc.).

3. Results

Between the studied subjects ($n = 246$), we confirmed that there was no difference in baseline characteristics that could yield biased results. Table 1 presents some general characteristics of the participants. The mean age of the officers was 26.37 years ($SD = 3.9$). 76.4% of participants were single and the majority of them (70%) had at least 12 years of formal education.

Table 1. Characteristics of the study group.

Characteristics	Number	%
Age (years)		
20–29	169	68.6
30–40	77	31.4
Marital status		
Single	188	76.4
Married	58	23.6
Education (years)		
≥12	173	70.3
<12	73	29.7
Smoking		
Yes	31	12.6
No	215	87.4
Regular sporting activities		
Yes	106	43.1
No	140	56.9
Job history (years)		
≥3	173	70.3
<3	73	29.7

Note: $n = 246$.

Ambient noise levels (LAeq) in the selected districts are summarized in Table 2. The minimum and maximum noise levels ranged from 71.63 to 88.51 dB (A).

Table 3 shows the average concentration of CO, PM_{10}, O_3, SO_2 and NO_2 in the 15 monitoring stations.

Descriptive analysis showed that General Fatigue and Physical Fatigue had the highest mean scores (15.6 and 13.3, respectively) while Reduced activity had the lowest one (9.2).

To determine the characteristics of the reference group, we used the guidelines recommended by the National Institute for Occupational Safety and Health (NIOSH) [23] and the Air Pollution Control Company (AQCC) [24] for ambient noise and air pollutants, respectively; as well as the minimum of age. Therefore, 20-year-old officers with lower exposure to both noise (<85 for 8 h) and air pollutants ($CO < 4.5$ ppm for 8 h, $PM_{10} < 75\ \mu g/m^3$ for 24 h, $NO_2 < 150$ ppb for 1 h, $SO_2 < 30$ ppb for 24 h and $O_3 < 60$ ppb for 1 h) were set as the reference group.

A multivariate analysis was then performed on data in order to identify fatigue predictors (see Table 4). The regression coefficient estimates the change in score associated with belonging to the relevant category. For age, the regression coefficient estimates the change in score associated with a 10-year increase in age. Interaction terms appear in situations where one variable modifies the effect of another. An estimated score can be constructed for any group by simply adding the terms: for example, 40-year-old officers with exposure to ozone had an estimated Physical Fatigue score of (Intercept $+ \beta_{Age} + \beta_{O3} + \beta_{Age\times O3}$) $= 13.18 + 3.1 + 3.4 = 19.68$.

Table 2. Mean LAeq (*SD*) in each of the 15 district of study.

Municipalities' districts	Sound level, dB(*A*) 6:00–9:00	9:00–12:00	12:00–15:00	Mean (*SD*)
A	74.82	75.51	77.3	75.87(1.2)
B	71.63	73.83	75.00	73.48(1.7)
C	75.47	77.22	77.56	76.75(1.1)
D	76.00	77.12	78.53	77.21(1.2)
E	75.51	**85.00**	**87.34**	82.61(6.2)
F	74.00	76.69	**85.95**	78.88(6.2)
G	72.30	73.22	76.33	73.95(2)
H	73.77	74.35	74.40	74.17(0.3)
I	78.26	78.97	80.12	79.11(0.9)
J	77.01	78.83	**86.24**	80.69(4.8)
K	75.83	76.82	**87.83**	80.16(6.6)
L	72.83	79.51	**87.66**	80.20(7.4)
M	79.53	**85.35**	**86.51**	83.79(3.7)
N	**86.30**	**88.42**	**88.51**	**87.74(1.2)**
O	83.60	**85.83**	**86.82**	**85.41(1.6)**

Note: Noise levels exceeded from the 'occupational noise exposure standard' recommended by the National Institute for Occupational Safety and Health (i.e., 85 dB(*A*) for 8 h) are shown in bold.

Table 3. Concentration of air pollutants in studied municipalities' districts obtained from AQCC.

Municipalities' districts	CO 8 h (ppm)	PM_{10} 24 h (mg/m^3)	O_3 1 h (ppb)	SO_2 24 h (ppb)	NO_2 1 h (ppb)
A	2.5	**150**	**106.8**	18.6	111
B	1.5	**75**	19.2	23.4	**309**
C	1.6	62	47.6	10.8	147
D	2.3	61	30.0	**43.2**	**171**
E	**5.3**	**165**	**78.2**	19.2	**321**
F	2.3	57	**75.8**	**45.4**	**150**
G	**7.7**	65	48.0	25.2	**321**
H	2.7	**156**	**87.6**	**30.0**	**330**
I	2.0	**158**	44.4	19.8	138
J	**5.1**	65	44.6	20.3	**456**
K	2.8	60	30.0	**100.6**	**216**
L	**4.7**	**155**	18.0	23.4	**303**
M	**4.5**	**289**	**78.0**	**87.2**	**330**
N	**7.3**	**170**	**81.0**	12.0	135
O	2.7	**160**	44.2	13.2	**171**

Note: Concentrations exceeded from AQCC acceptable level are shown in bold.
Good concentration of air pollutants according to pollutants standard index (PSI) recommended by air pollution control company (AQCC) are CO (8 h): <4.5 ppm, PM_{10} (24 h): <75 μg/m^3, O_3 (1 h): <60 ppb, SO_2 (24 h): <30 ppb, NO_2 (1 h): <150 ppb.

3.1. Age

In the multiple regression model, Age was significantly associated with Physical Fatigue and Reduced Activity scales. It means that the older the police officers are, the more they physically feel fatigued and the less they are active. No significant trend was found for the other scales.

3.2. Noise

No independent effect of noise was found on any of the five dimensions of fatigue. However, older respondents who were exposed to higher noise levels estimated themselves more fatigued in all dimensions except Reduced motivation. It is notable that Noise has also an additive effect on two fatigue dimensions (Physical and Reduced Activity) which were already significant in older officers compared to the younger ones.

3.3. Nitrogen dioxide

NO_2 had no significant effect on fatigue independently. However, it interacted with Age on General fatigue.

Table 4. Regression coefficients (*SE*) from the multiple linear regression analysis.

	General Fatigue	Physical Fatigue	Reduced Activity	Reduced Motivation	Mental Fatigue
Reference score (intercept)	16.59 (2. 3)	13.18 (2)	9.12 (2. 9)	10.47 (2.5)	13.0 (2.2)
Age	2.20 (1.5)	**3.10 (1.1)**	**2.60 (1.2)**	1.70 (1.2)	1.30 (0.4)
Noise	0.98 (0.4)	0.96 (0.4)	0.47 (0.4)	0.81 (0.4)	0.24 (0.5)
CO	–0.28 (5.7)	–1.70 (6.2)	–2.01 (6.4)	–0.19 (6.9)	–2.40 (7.1)
PM_{10}	**4.12 (0.8)**	–0.29 (0.7)	–2.80 (0.1)	0.90 (0.7)	0.91 (0.8)
NO_2	2.90 (0.9)	0.86 (0.7)	1.80 (0.1)	0.88 (0.2)	2.01 (0.1)
SO_2	0.40 (0. 1)	0.94 (0.1)	–2.90 (0.2)	–0.12 (0.1)	0.13 (0.1)
O_3	1.40 (0.2)	**3.40 (2.7)**	–2.50 (2.7)	–3.20 (0.29)	–1.10 (0.3)
Interactions					
Age × Noise	**3.2 (0.14)**	**4.2 (0.16)**	**3.2 (0.16)**	NS	**4.3 (0.28)**
Age × NO_2	**1.2 (0.10)**	NS	NS	NS	NS
Noise × O_3	NS	**4.6 (0.03)**	NS	NS	NS
CO × SO_2	**3.4 (0.01)**	**3.9 (0.01)**	NS	**2.7 (0.02)**	NS
NO_2 × SO_2	**7.1 (0.01)**	**7.3 (0.02)**	NS	NS	NS
R^2	.26	.25	.19	.23	.20

Note: Only significant interactions are shown ($p < .05$). Coefficients with $p < .05$ are presented in bold. Raw R^2 estimating variance explained by the model; NS = Not significant.

Simultaneous exposure to NO_2 and SO_2 also resulted in increased General and Physical fatigue.

3.4. *Ozone*

High exposure to O_3 was related to higher Physical fatigue. This relationship became more severe in the case of co-exposure to ambient noise. No meaningful trend was found for the other scales.

3.5. *Carbon monoxide*

No meaningful relationship was observed between CO and different aspects of fatigue. However, a significant CO with SO_2 interaction showed that combined exposure to these two pollutants could deteriorate General and Physical status of fatigue and reduce the level of motivation.

3.6. *Particulate matter*

Respondents who were exposed to higher levels of PM_{10} reported more General fatigue than their co-workers who were exposed to lower concentrations. No other significant effect was observed.

Regarding all dependent and integrated effects of variables, our models explain between 19% (Reduced activity) and 26% (General fatigue) of the variance in scale scores (R^2).

4. Discussion

In the present study, we used the multiple regression analysis with an interpretable intercept with regard to five dimensions of fatigue as dependent variables and Age, Noise and Air pollutants as possible predictors. The main outcome of our study was that some aspects of fatigue could be predicted by Age, PM_{10} and O_3 and be aggravated by other environmental pollutants. In the other words, a synergism exists between the factors studied.

Our results revealed that Age could predict Physical Fatigue and Reduced activity. It has been suggested that reduction in physical activity due to fatigue is one of the main outcomes of the aging process.[25] Recently, the American Geriatrics Society and the National Institute on Aging held a research conference for 'Idiopathic Fatigue and Aging' [26] and identified oxidative stress, inflammation, mitochondrial function and energy utilization as likely contributors to Physical fatigue.[27] In regard to energy utilization at the whole body level, there is a fixed, limited level of energy availability based primarily on aerobic fitness. With age, declines in fitness result in reductions in total energy, while completion of daily activities requires greater energy due to changes in biomechanical efficiency.[27] One could therefore conclude that energy imbalance results in higher perception of physical fatigue in older persons, which in turn could result in a reduction of his (her) daily activities.

Our results showed a meaningful interaction between Age and NO_2 on the General scale, indicating that the older respondents exposed to high levels of NO_2 reported more general fatigue. Previously, a Chinese study has demonstrated a significant relationship between NO_2 and neurobehavioral functions (i.e., psychomotor, visual perception, speed and attention, motor coordination) in children.[28] However, the direct effect of NO_2 on subjective fatigue is still unknown in the literature.

Contrary to our hypothesis, we observed no significant independent relationship between noise and multiple dimensions of fatigue. Previous studies showed at least three ways in which noise may have fatiguing effects. Firstly, it may contribute to a general over-stimulation. Secondly, monotonous noise has been found to have sleep-provoking effects.[29] Thirdly, noise may make a task more difficult and tiring to perform. In our study, noise intensity changed from 72 to 88 dB. Therfore, the fact that the minimum ambient noise (i.e., 72 dB) was relatively high, together with the slightly low noise fluctuations (approximately 16 dB) probably made participants unable to subjectively estimate the real intensity of noise. As a consequence, it might be expected that they fail to accurately perceive, determine and judge their real status of fatigue as a function of noise. The lack of noise effect could also be explained by adaptation phenomenon. There is good literature evidence that long-term noise exposure induces habituation.[30,31] So, it is possible that our participants failed to distinguish any noise-related fatigue symptoms because they were habituated to it.

Although a direct effect of noise was not found on fatigue scales, observed Age by Noise interaction supports the fatigue-provoking role of noise. Older officers (30–40 years) who were exposed to >85 dB of traffic noise estimated themselves less active and more fatigued in terms of General, Physical and Mental aspects. In fact, noise exposure produced not only General and Mental fatigue in older officers, but also raised the scores of already existing Physical fatigue and reduced Activity in this group. Our findings are corroborated by a previous study conducted by Saremi and colleagues who reported an increased subjective fatigue in industrial noise exposed older workers compared to the younger ones.[32] In our study, Motivation remained stable whatever the noise level and age of the officers. This finding is in concordance with the study of Whiteet et al., who suggested high stability of motivations among police officers over time, regardless of their race/ethnicity and gender.[33]

In agreement with some previous studies,[34] our results showed a positive relationship between particulate matters and General fatigue. A contributing mechanism can be related to the physical nature of PM_{10}. Since it can easily enter the respiratory system and induce airway inflammation,[35] it could be easily perceived and interpreted as an important cause of fatigue and tiredness.[36]

There is good evidence confirming that exposure to O_3 may induce alterations in the function of many systems.[37–40] For instance, headache, somnolence and fatigue are known to be related to O_3 exposure.[41,42] Our finding is therefore in line with the existing literature on this topic. However, the effect of ozone on Physical fatigue became more intense in the presence of ambient noise, supporting once more the noticed synergic effect of noise and other factors subjected to produce fatigue.

Although our results did not reveal any dependent effect of SO_2, CO and NO_2 on different scales of fatigue, interesting interactions were found. Co-exposure to SO_2 and CO increased the level of General and Physical fatigue and decreased motivation. It is known that exposure to high concentrations of CO reduces the oxygen-carrying capacity of blood resulting in fatigue and impaired central nervous system function.[43,44] With regard to the negative health effects of SO_2, it has been suggested that inhalation of SO_2 may contribute to neurophysiological impairments leading to cerebral ischemic accident. Very little evidence exists for this.

Similarly, co-exposure to SO_2 and NO_2 was also related to an augmentation in perceived General and Physical fatigue. The health effects of combined exposure to NO_2 and SO_2 have been studied by Atari et al., who reported more annoyance among people exposed to high levels of these ambient air pollutants.[45]

Our models explain between 19–26% of fatigue that is confirmatory on the multi-factorial nature of fatigue.[9] This confirms that there are certainly many more factors related to fatigue than we took into account in the present study. Other contributing factors might be regular sporting activities, smoking, satisfaction and lifestyle. Further investigations should, therefore, be conducted in order to examine and introduce the other possible socio-demographic, occupational and environmental predictors of fatigue and to determine their interactive effects.

In conclusion, the present study suggests that continuous exposure to the environmental risk factors of fatigue could result in more tiredness among the outdoor working population. Therefore, it is of vital importance to pay more attention to this link especially in large and polluted cities such as Tehran, where the concentration of these pollutants sometimes exceeds the standard levels. PM_{10} emission must be reduced through managing traffic, as it is the major source of urban aerosols. Another factor directly responsible for fatigue is ozone for which the control process seems to be more complex. However, other environmental pollutants interact with each other to increase fatigue. Responsible authorities should absolutely control air quality by developing appropriate strategies aimed at reducing traffic and industrial emission of air pollutants, as well as improving public culture about air quality and increasing green areas. The next assumption is that working performance would also be reduced in such situations. Further studies are needed to examine this hypothesis.

Acknowledgements

The authors would like to express especial thanks to all persons who agreed to participate in the study.

Disclosure statement

No potential conflict of interest was reported by the authors.

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