VOL. 10, NO 20, NOVEMBER, 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

EVALUATION OF BTEX CONCENTRATION AND INDOOR AIR QUALITY PERCEPTIONS IN PLATFORMS AND TRAIN

Siti Hajar Ya'acob[1], Nor Syazwani Saidin[2], Nor Sayzwani Sukri[1] and Mazrura Sahani[2]
[1]Faculty of Earth Science, Universiti Malaysia Kelantan, Jeli, Kelantan, Malaysia
[2]Faculty of Health Sciences, Universiti Kebangsaan Malaysia, Bangi, Selangor, Malaysia
E-Mail: hajar.y@umk.edu.my

ABSTRACT

Benzene, toluene, ethylbenzene and xylene (BTEX) are compounds that are harmful to health and it exists in the public transportation environment including the railway transportation. This study was conducted to determine the concentration of BTEX in the train and the platform of a railway service provider. Air sampling was conducted to compare the concentrations of BTEX in the train and platform by using activated charcoal sorbent tubes for one hour at Sentul-Klang route during peak hours. Analysis of air samples was done by using Gas Chromatography-Flame Ionization Detector (GC-FID). In addition, questionnaires were distributed to 254 respondents by cluster sampling on weekdays to examine passengers' perception on the indoor air quality (IAQ) of trains and platforms. The results indicated that 70.5% of passengers are aged 21-30 years, 11.8% aged 31-40 years, 10.6% aged 51 years and over, 5.5% aged 41-50 years and 1.6% aged 20 years and less. Majority of the passengers perceived the density of passengers on trains as dense (63.0%) and platform as less dense (49.2%). Passengers mostly feel that ventilation (57.9%), wind quality (66.9%) and IAQ (57.9%) are acceptable in the train. In the platform, passengers mostly choose an acceptable answer to the perception of ventilation (64.6%), air quality (63.0%) and IAQ (70.5%). There were no significant differences in comparison of IAQ in the train and platform by passengers' age range ($p > 0.05$). There is a significant correlation between IAQ and passenger density, ventilation, odor and air quality in the train ($p < 0.01$). However, a significant correlation was only found between IAQ and ventilation and air quality in the platform ($p < 0.01$) and no significant correlation was found between IAQ and the passenger density on the platform ($p > 0.01$). Although the overall passengers' perception of IAQ in the train and platform are acceptable, improvement is required especially regarding to indoor air quality services so that a better indoor environment can be achieved.

Keywords: IAQ, train and platform.

INTRODUCTION

Public transport is a common routine for residents to move from one location to another. Thus, more time is spent by residents which cause a high volume of passengers during peak hours in the public transport. Consequently, the indoor air quality of public transport should be emphasized since users are often exposed to the presence of pollutants that are harmful to health in public transport [11]. Recently, many studies have been conducted regarding public transport user exposure to volatile organic compounds (VOCs) specializing parameter of benzene, toluene, ethylbenzene and xylene [5, 7, 19]. The assessments on the indoor air quality in air-conditioned rail systems have also been carried out [6, 7, 30] to create an internal environment that is healthy and safe.

This study was conducted to measure the concentration of benzene, toluene, ethylbenzene and xylene (BTEX) in the train and the platform, to identify the percentage of passenger perception on indoor air quality (IAQ in the train and the platform, to compare the perception of IAQ trains and platforms in the age range of passengers, and to study the correlation between the passenger IAQ perception with the perception that regarding to each these aspects which are density, ventilation and wind quality in the train and the platform.

METHODOLOGY

Study design

Cross-sectional study was chosen, whereby the measurement has been done at a particular time among train passengers.

Selection of sampling locations at field

Selected sampling locations are categorized as an urban route which is Klang-Sentul as shown in Figure-1. It indicates the sampling location that be utilized in this study.

ARPN Journal of Engineering and Applied Sciences

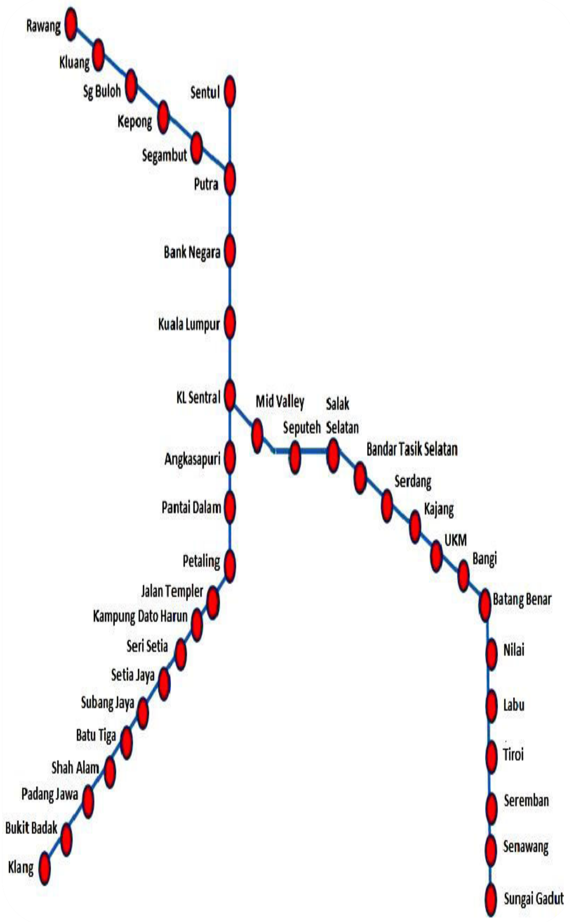

Figure-1. Sampling location.

Sampling point selection in the field

Sampling points chosen are on the platform and in the train [25]. For platform, measurements were carried out in the central platform and 1.5m above the floor [16]. As for the measurement of the train, the study was conducted by moving the passenger holding the adsorbent samplers placed at the height of 1m in the passenger breathing zone [34]. The adsorbent during sampling should be noted in terms of the breathing zone of the passengers in either position of standing or sitting to represent the exposure of the highest BTEX inhaled by the passengers.

Time and duration of sampling in the field

For both sampling points, sampling conducted on weekdays bilaterally during its operational period. Sampling was conducted during peak hours of 7:00 to 9:00 or 17:00 to 19:00 [26] due to the concentration of BTEX is significant during peak hours. In fact, trains are randomly selected without specific criteria. The sampling was carried out for about an hour [35].

Methods of air sampling and analysis in laboratories

Prior to sampling, the sampling pump was calibrated individually. Then, the ends of the sorbent tube were removed and connected to the individual sampling pump. The flow rate was set at 0.2L/min. The sorbent tube was covered with a plastic cover and packed for transport. The sampler was kept at 5˚C until it was analyzed.

Analysis of air samples was performed at NIOSH Industrial Hygiene Analytical Laboratory in Bangi. Prior to the analysis, sample preparation was done by using NIOSH method 1501, Issue 3 [30]. The front sorbent tubes with glass fiber were placed in a vial and back tube was placed in separate vials. About 1.0mL of carbon disulfide was added to each vial. It allowed at least 30 minutes of occasional agitation to occur. Then, Gas Chromatography-Flame Ionization Detector (GC-FID) was used to analyze the samples.

Questionnaire

This research utilizes the MM-40 questionnaire which was adapted from the Department of Occupational Safety and Health (DOSH). However, this questionnaire has been modified to evaluate passengers' perceptions of the quality of indoor air train and platforms. This form contains the perception of passengers on passenger density, aeration, odor, air quality and indoor air quality in the platform and the train. The pilot study was conducted before the questionnaire was distributed to 25 people on a weekday commuter. A number of pilot study sample size was determined by taking 10% of the actual sample size of the study [24]. Reliability analysis was done by acquiring a Cronbach alpha greater than 0.7 [36].

The distribution of the questionnaire was done in cluster sampling of 254 respondents. The questionnaires were distributed to passengers who are waiting for the train on the platform of central stations of both routes from January 2014 until April 2014.

Ethical issues

Ethical considerations were approved by the Research Ethics Committee UKM with project code NN-037-2014.

Statistical analysis

Data were analyzed by using the software Statistical Package for the Social Sciences (SPSS) version 21. The independent t-test is selected to compare the mean concentration of BTEX in the train and the platform. For the survey, the data collected was not normal. Therefore, nonparametric tests were applied. Kruskal-Wallis test was used to compare the median perception of indoor air quality in the age range of passengers on trains and platforms, whereas Spearman correlation was utilized to determine the relationship between indoor air quality and passenger density, ventilation and quality of wind in the train and the platform.

VOL. 10, NO 20, NOVEMBER, 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

RESULTS AND DICUSSIONS

BTEX concentration evaluation in train and platform

The main sources for the presence of BTEX in public transportation are fuel emissions from vehicles [5, 25, 40]. In general, BTEX compounds could not be detected by GC-FID for both locations. Based on these observations, the location of commuter services was found to be quite far from the traffic congestion source. Therefore, the lack of presence of BTEX on the train and the platform has contributed to the very small concentration of BTEX in this study. In [5] indicated that BTEX concentrations were higher in public transportation such as taxis and buses in the path of a motor vehicle against the concentration of BTEX in the train. This is due to the road transport, which is very vulnerable, and almost continuously expose to BTEX emissions from the engines and vehicles' exhaust. Additionally, train in the current study uses electrical energy to move [15]. Therefore, self-contamination by fuel and exhaust emissions leaks into the cabin of the train is not the case [25]. This reinforces that the train itself is not a strong source of BTEX production in its microenvironment. In [32] also found that BTEX resulting from vehicle emissions is weak in the train as it is far away from traffic sources.

On ground track also influences the presence of BTEX in the microenvironment. For example, a study comparing levels of BTEX in the underground railroad and the ground route by [25] found higher levels of TEX in the underground train from TEX levels in above ground train route. It is proven that the source of increased levels of TEX is the environment subway train itself. At the subway environment, the flow of outside air into the underground passage is difficult compared to the route on the ground. Thus, the environment subway has potential to collect more pollutants such as BTEX in it, whereas the environment on the ground rail allows outside air to flow easily into the vicinity of the train.

The concentrations of contaminants such as BTEX can be reduced by promoting the infiltration of outside air moving into the indoor environment [37]. Therefore, the inflow of outside air through the thawing is fundamental to controlling indoor air pollution [10].

Changes in locations pressure, humidity and ambient temperatures during the sampling may interfere with the pump flow rate and efficiency of absorption of adsorbents, thus affecting the readings obtained for BTEX concentrations. According to the [29], adsorption by using activated charcoal tubes, pumps and techniques extraction calibration laboratory should be carefully measured to obtain the right concentration of BTEX. In [3, 4, 9] found that the above factors affect the sampler and the adsorption capacity of sorbent tubes during the sampling process. In addition, factors such as the limitations of GC-FID instrument which leads to the concentration of BTEX were not detected in this study. The GC-FID that was used in this study has a limit of detection (LOD = 0.7ug/Ml) for BTEX. Hence, it is not able to detect very small concentrations in the environment that is less polluted like the train.

Survey of passengers' perception regarding indoor air quality (IAQ) train and platform

In addition to evaluate of the concentration of BTEX in indoor air, the study on the perception of the quality of indoor air passenger trains is conducted to determine more tangible and accurate feedback to ensure that improvement by the service providers can be done in the future.

Age passengers

Based on the available age categories of passengers, the highest category that uses the commuter train service are passengers aged 21 to 30 years (70.5%) as shown in Table-1. This is where most of this age group is consisting of staff and students. Young people are physically stronger to mobile and it causes them to prefer the use of public transport rather than people who are much older. This is supported by the studies conducted by [1], which found that more than 26% of consumers aged 18 to 34 years are using public transport as the method of travelling to work or study in contrast to other users' age.

In fact, the absence of a private vehicle driver's license is also a factor affecting the majority of users to use public transport like train. In [1] also found that consumers aged between 18 to 24 years prefer to use public transport due to the absence of a driver's license and not having the knowledge of how to drive. Moreover, even if they have a driver's license, but the absence of a self-own motor vehicle also contributes to the cause.

Table-1. Frequency and percentage of the age group of passengers.

Age	**Frequency** (n)	**Percentage** (%)
≤ 20	4	1.6
21-30	179	70.5
31-40	30	11.8
41-50	14	5.5
≥ 51	27	10.6
Total n	254	100

Density of passengers in train and platform

Based on Table-2, passengers feel the density in the train is very high (63.0%) as the density of passengers is depending on the current state of operation of the railroad system. This can be seen when there is a delay in the train timetable to pick up and drop off passengers which can cause an increase in passengers in the train. Thus, the imbalance between capacity and demand rail ridership occurs can contribute to a reduction in the level of passenger comfort. The same thing has happened in the study of [6]. In addition, most of the passengers said the platform density is less dense (49.2%). This is caused by an area of the platform that is relatively broad from the train area.

Table-2. Frequency and percentage of passenger density perception by location.

Perceptions	Train, n (%)	Platform, n (%)
Less dense	74 (29.1)	125 (49.2)
Dense	160 (63.0)	119 (46.9)
Overladen	20 (7.9)	10 (3.9)
Total n	254 (100)	254 (100)

Congestion in train microenvironment services can increase the rate of heat released per individual. In the space of a compact passenger, the heat released by a discharge to other passengers can cause an internal environment of space to be hot and uncomfortable. Thus, congestion can increase the level of thermal strain on passengers, blocking mechanisms of heat loss and psychological distress to passengers [28, 38, 14]. This coincided with an incident in which the density is very compact among passenger on the train, and the platform causing many train passengers experiencing shortness of breathing and loss of consciousness [13].

Ventilation

Most of the passengers stated that ventilation in both locations is acceptable, namely 57.9% and 64.6% in the train and on the platform respectively (Table-3). It appears that the situation in the train is equipped with central air-conditioning and the platform is equipped with a wall fan. Both types of ventilation are able to provide a more comfortable environment by providing a fresh outdoor air into the indoor air. In [21] mentioned that system Heating, Ventilation and Air Conditioning (HVAC) are capable to dilute the pollutants contained in the indoor air, bringing out the confined air out, promoting the circulation of air in the indoor environment and the ability to control temperature and humidity levels in indoor environments. Thus, mechanical ventilation is a very practical step to provide a comfortable environment in rail transport.

Table-3. Frequency and percentage of ventilation perception by location.

Perceptions	Train, n (%)	Platform, n (%)
Very stuffy	8 (3.1)	10 (3.9)
Stuffy	43 (16.9)	54 (21.3)
Acceptable	147 (57.9)	164 (64.6)
Fresh	50 (19.7)	20 (7.9)
Very fresh	6 (2.4)	6 (2.4)
Total n	254 (100)	254 (100)

Quality of wind

Table-4 shows that most of the passengers feel that the quality of the wind is acceptable, in the train or on the platform. The result indicated the reading percentage of 66.9% and 63.0% respectively. This is caused by natural occurring wind infiltration into indoor air. The purpose of natural wind infiltration is similar to the mechanical ventilation system to provide a comfortable environment of odor, heat and other contaminants. However, the mechanical ventilation system uses natural wind as the main driving force to further increase the air cycle round into the indoor environment and to provide comfortable conditions for passengers. In conclusion, the use of natural air can improve the air quality in microenvironment [27].

Table-4. Frequency and percentage of wind quality perceptions by location.

Perceptions	Train, n (%)	Platform, n (%)
Very strong	4 (1.6)	2 (0.8)
Strong	41 (16.1)	26 (10.2)
Acceptable	170 (66.9)	160 (63.0)
Weak	33 (13.0)	60 (23.6)
Very weak	6 (2.4)	6 (2.4)
Total n	254 (100)	254 (100)

Indoor air quality

The majority of the passengers stated that IAQ in the train and the platform is acceptable as shown in Table-5; with the percentage are 57.9% and 70.5% respectively. This may be due to the train environment that is much more comfortable compared to the study by [6] in which the passenger is not satisfied with the IAQ train in China due to environmental temperature in the hot train, unpleasant odor, lack of moisture and the quantity of fresh air which is minimum. IAQ could be improved by increasing the thermal comfort and air flow, provide adequate ventilation indoor environment and encourages the use of HVAC capable of controlling humidity of

VOL. 10, NO 20, NOVEMBER, 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

indoor environments. Moreover, the use of coaches must also follow the right schedule. For example, a coach which is lacking in capacity (3 carriages) to accommodate the large number of passengers needs to be avoided especially during peak hours. This will cause passengers on board to feel uncomfortable with the train indoor environment.

Table-5. Frequency and percentage of indoor air quality perception by location.

Perceptions	Train, n (%)	Platform, n (%)
Very stuffy	5 (2.0)	9 (3.5)
Stuffy	37 (14.6)	43 (16.9)
Acceptable	147 (57.9)	177 (70.5)
Fresh	60 (23.6)	19 (7.5)
Very fresh	5 (2.0)	4 (1.6)
Total n	254 (100)	254 (100)

Comparison between perceptions on IAQ with age range

Based on Table-6 and Table-7, there are no significant difference between the perception of IAQ in train ($p > 0.05$) and the platform ($p > 0.05$) with passengers' age range of both locations. It is stated that the perception of IAQ is similar among all ranges of age [12, 18]. However, the study by [22, 23, 33] found that the age factor is related to the level of perception. The study by [17] stated that young people are more concerned about environmental issues than older people who are more stressed on health and safety.

Table-6. Comparison of train IAQ perception between passengers' age range.

	Passengers' Age Range	n	Mean Rank	P-Value
Train IAQ	≤ 20	4	93.00	0.510
	21-30	179	125.82	
	31-40	30	123.42	
	41-50	14	146.39	
	≥ 51	27	138.50	
	Total	254		

Table-7. Comparison of the platform IAQ perception between passengers' age range.

	Passengers' age range	n	Mean rank	P-value
Platform IAQ	≤ 20	4	114.25	0.546
	21-30	179	127.78	
	31-40	30	128.75	
	41-50	14	148.21	
	≥ 51	27	115.46	
	Total	254		

Correlation of IAQ with passenger density, ventilation and air quality

For IAQ in train, there are correlation between IAQ with density of passenger (r_s = -0.23, $p < 0.01$), ventilation (r_s = 0:57, $p < 0.01$) and quality of wind (r_s = -0.28, $p < 0.01$). Meanwhile, for IAQ of the platform, IAQ only has correlation with ventilation (r_s = 0.49, $p < 0.01$) and quality of the wind (r_s = -0.45, $p < 0.01$).

IAQ train and platform will be improved with adequate ventilation. The increased level of comfort among passenger will increase the number of passengers, thus causing them to be satisfied with the overall perception of the environment [20]. Whereby, the complete mechanism of heat release can be utilized with no mass transfer between passengers to other passengers. However, in [34] could not unlock how air temperature affects air quality despite the impact of density with temperature of the internal environment.

The presence of unpleasant odors has made passengers feel uncomfortable to breathe. In [39] concluded that less chemical pollutants emitted could improve the indoor environment satisfaction. Wind infiltration can dilute other indoor air pollutants, thus it can improve indoor air quality especially as ozone, nitrogen dioxide and suspended particulates are being reduced [2].

IAQ platform is not correlated with the density of passengers (rs = -0.08, $p > 0.01$), since the space platform is wider than in the train. Thus, passengers can travel from one place to another if they are not comfortable compared to moving in a train which has limited space. However, IAQ train correlated with the density of passengers because of the smaller space of a train [15].

CONCLUSIONS

For the first objective of this study, it is found that there were low concentrations of BTEX indicated in the train and the platform at the time of sampling. This coincides with the first hypothesis that the concentration of BTEX in the commuter train service is low. In addition, for the second objective, which is to identify the percentage of passenger, perception of the IAQ train and platform, passengers will express the perception of being satisfied with the indoor air quality in trains and platforms surrounding. In fact, for the objective of the third study, it is found that there is no difference between the perception of indoor air quality in trains and platforms with the age range of passengers. For the fourth objective of the study, there was a significant correlation between the perception of train indoor air quality with passenger density, ventilation, and air quality. For the perception of the indoor air quality platform, significant correlation was only found with the perception of ventilation and air quality. Overall, these hypotheses for the study of passengers' IAQ perception regarding to train and the platform are not rejected except for the hypothesis of the indoor air quality perception with the age range of passengers. However, improvement of train service management should be continued to improve indoor air quality commuter to ensure a healthier and safer environment. For example, such improvements can be in the form of providing flexible ventilation systems according to passenger density. Ventilation rates need to be increased during peak hours. Thus, this may allow the train's management to save and optimize the energy consumption according to the needs.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interests regarding the publication of this paper.

ACKNOWLEDGEMENT

Universiti Kebangsaan Malaysia (UKM) financially assisted this study under the research grant incentive, Grant University-Industry Research (INDUSTRY-2013-047). The authors also would like to thank all of the respondents who have provided excellent cooperation during this study.

REFERENCES

[1] Australian Bureau of Statistics. 2008. Public transport use for work and study. http://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/4102.0Chapter10102008.

[2] Barn P. 2010. Infiltration of air pollutants and effectiveness of air cleaners. http://www.ccnse.ca/sites/default/files/INSPQ_2010_Pollutants_and_Air_Cleaners.pdf.

[3] J. Begerow, E. Jermann, T. Keles, U. Ranft and L. Dunemann. 1995. Passive sampling for volatile organic compounds (VOCs) in air at environmentally relevant concentration levels. Fresenius' Journal of Analytical Chemistry. 351(6): 549-54.

[4] R. H. Brown. 2000. Monitoring the ambient environment with diffusive samplers: Theory and pratical considerations. Journal of Environmental Monitoring. 2(1): 1-9.

[5] L. Y. Chan, W. L. Lau, X. M. Wang and J. H. Tang. 2003. Preliminary measurements of aromatic VOCs in public transportation modes in Guangzhou, China. Environment International. 29(4): 429-435.

[6] H. Chen, S. Huang and P. Yang. 2003. Study on indoor environment in air-conditioned trains. International Journal on Architectural Science. 4(2): 60-72.

[7] X. Chen, G. Zhang, Q. Zhang and H. Chen. 2011. Mass concentrations of BTEX inside air environment of buses in Changsha, China. Building and Environment. 46(2): 421-427.

[8] W. K. Chow. 2000. Ventilation of enclosed train compartments in Hong Kong. Applied Energy. 71(3): 161-170.

[9] C. Chung, M. T. Morandi, T. H. Stock and M. Afshar. 1999. Evaluation of a passive sampler for volatile organic compounds at ppb concentrations, varying temperatures, and humidities with 24-h exposures 1. Description and characterization of exposure chamber system. Environmental Science and Technology. 33(20): 3661-3665.

[10] DiNardi S. R. 1994. Exposure and environmental characterization. In: Air pollution and lung disease in adults. P. Witorsch and S. M. Spagnolo (Eds.). CRC Press, Florida, USA. pp. 1-19.

[11] M. R. Dudzińska. 2011. Volatile organic compounds in private cars and public vehicles. Rocznik Ochrona Srodowiska. 13: 101-115.

[12] T. Egondi, C. Kyobutungi, N. Ng, K. Muindi, S. Oti, S. v. d. Vijver, R. Ettarh and J. Rocklöv. 2013. Community perceptions of air pollution and related health risks in Nairobi Slums. International journal of environmental research and public health. 10(10): 4851-4868.

[13] P. D. Ellis. 1998. Chaos in the underground: Spontaneous collapse in a tightly-coupled system. Journal of Contingencies and Crisis Management. 6(3): 137-152.

[14] G. W. Evans and R. E. Wener. 2007. Crowding and personal space invasion on the train: Please don't

make me sit in the middle. Journal of Environmental Psychology. 27(1): 90-94.

[15] W. Fazlina, Y. Jusoh, W. H. W. Zakiyatussariroh and W. M. W. Fauzi. 2010. Customers' perception towards electric commuter train services application of logistic regression analysis. In: Regional Conference on Statistical Sciences. 274-282.

[16] Y. Feng, C. Mu, J. Zhai, J. Li and T. Zou. 2010. Characteristics and personal exposures of carbonyl compunds in the subway stations and in-subway trains of Shanghai, China. Journal of Hazardous Materials. 183(1-3): 574-582.

[17] G. Fischer, M. Morgan, B. Fischhoff, I. Nair and L. Lave. 1991. What risks are people concerned about. Risk Anal. 11(2): 303-314.

[18] Frontczak, M. 2012. Human comfort and self-estimated performance in relation to indoor environmental parameters and building features. Doctoral dissertation, Technical University of Denmark.

[19] R. K. Fujii, P. Oyola, J. C. R. Pereira, A. S. Nedel and R. C. Cacavallo. 2007. Air pollution levels in two São Paulo subway stations. Highway and Urban Environment. 12: 181- 190.

[20] F. Haghighat and G. Donnini. 1999. Impact of psycho-social factors on perception of the indoor air environment studies in 12 office buildings. Building and Environment. 34(4): 479-503.

[21] Health Canada. 2009. Ventilation. http://www.hc-sc.gc.ca/ewh-semt/air/in/tips-trucs/ventilation-eng.php.

[22] K. Krupa, A. Piekut and R. Złotkowska. 2012. Assessment of risk perception connected with exposure to indoor air pollution in the group of inhabitants of Silesian Voivodeship. Environmental Medicine. 15(3): 46-54.

[23] M. Kim, O. Yi and H. Kim. 2012. The role of differences in individual and community attributes in perceived air quality. Science of the Total Environment. 425:20-26.

[24] Lackey N. R. and Wingate A. L. 1998. The pilot study: One key to research success. Advanced design in nursing research. 2nd Ed. Sage Publications, California, USA. pp. 375-384.

[25] W. L. Lau and L. Y. Chan. 2003. Commuter exposure to aromatic VOCs in public transportation modes in Hong Kong. The Science of the Total Environment. 308(1-3): 143-155.

[26] T. T. Li, Y. H. Bai, Z. R. Liu, J. F. Liu, G. S. Zhang and J. L. Li. 2006. Air quality in passenger cars of the ground railway transit system in Beijing, China. Science of the Total Environment. 367(1): 89-95.

[27] Lien J. and Ahmed N. A. 2011. Wind driven ventilation for enhanced indoor air quality. In: Chemistry, Emission Control, Radioactive Pollution and Indoor Air Quality. N. A. Mazzeo (Eds.). InTech, Croatia. pp. 539-562.

[28] D. McFarland, R. A. Karlin, J. R. Aiello and Y. M. Epstein. 1976. Normative mediation of reactions to crowding. Environmental Psychology and Nonverbal Behavior. 1(1): 30-40.

[29] Minnessota Department of Health. 2009. Indoor air sampling at vapor intrusion sites: Introduction, methods, and interpretation of results. http://www.health.state.mn.us/divs/eh/hazardous/topics/iasampling.pdf.

[30] T. Moreno, N. Pérez, C. Reche, V. Martins, E. d. Miguel, M. Capdevila, S. Centelles, M. C. Minguillón, F. Amato, A. Alastuey, X. Querol and W. Gibbons. 2014. Subway platform air quality: Assessing the influences of tunnel ventilation, train piston effect and station design. Atmospheric Environment. 92: 461-468.

[31] National Institute for Occupational Safety and Health (NIOSH). 2003. NIOSH Manual of Analytical Methods 1501 (Issue 3)-Hydrcarbons, Aromatic. http://www.cdc.gov/niosh/docs/2003-154/pdfs/1501.pdf.

[32] M. Ongwandee and O. Chavalparit. 2010. Commuter exposure to BTEX in public transportation modes in Bangkok, Thailand. Journal of Environmental Sciences. 22(3): 397-404.

[33] L. Reinikainen, L. Aunela-Tapola and J. Jaakkola. 1997. Humidification and perceived indoor air quality in the office environment. Occupational and Environmental Medicine. 54(5): 322-327.

[34] O. A. Seppänen and W. J. Fisk. 2004. Summary of human responses to ventilation. Indoor Air. 14(7): 102-118.

[35] N. Shiohara, A. A. Fernández-Bremauntz, S. B. Jiménez and Y. Yanagisawa. 2005. The commuter's exposure to volatile chemicals and carcinogenic risk in Mexico City. Atmospheric Environment. 39(19): 3481-3489.

[36] S. Tongprasert, J. Rapipong and M. Buntragulpoontawee. 2014. The cross-cultural adaptation of the dash questionnaire in Thai (Dash-Th). Journal of Hand Therapy. 27(1): 49-54.

[37] U.S. Environmental Protection Agency. 2011. Indoor air: What are the trends in indoor air quality and their effects on human health? http://cfpub.epa.gov/eroe/index.cfm?fuseaction=list.listBySubTopic&ch=46&s=343.

[38] T. A. Walden and D. R. Forsyth. 1981. Close encounters of the stressful kind: Affective, physiological, and behavioral reactions to the experience of crowding. Journal of Nonverbal Behavior. 6(1): 46-64.

[39] P. Wolkoff and G. D. Nielsen. 2001. Organic compounds in indoor air-Their relevance for perceived indoor air quality? Atmospheric Environment. 35(26): 4407-4417.

[40] Y. Zhang, C. Li, X. Wang, H. Guo, Y. Feng and J. Chen. 2012. Rush-hour aromatic and chlorinated hydrocarbons in selected subway stations of Shanghai, China. Journal of Environmental Sciences. 24(1): 131-141.