Activity pattern of school/university tenants and their family members in Metro Manila – Philippines

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Abstract

Limited studies exist focusing onto personal exposure/deposition dose of particulate pollution in developing regions. In this study, as a first step, we present the results on how people spend their daily time in Metro Manila, Philippines. This information is critical in assessing the personal exposure/deposition dose of particulate pollutants. We found that: people spend less time at home on workdays than weekends (52% versus 70%); the time fraction spent at work/school increased with age until retirement; adult males spend less time at home than females (18% versus 28%); most of their time people spend indoors (84%). The biggest difference from previous studies – people in Metro Manila on average spends 11% of their daily time in transit traffic. This is up to 2.2 times more than in Europe, America, Korea or China. Longer times in transit traffic subjects the population of Metro Manila to a higher

risk of increased exposure to toxic pollutants and adverse health symptoms. The main results of this study will be used in upcoming study on personal deposition dose of soot.

Keywords: Activity survey; Mega-city; Traffic; Exposure.

1. Introduction

Exposure to particulate pollution can be associated with respiratory diseases and adverse health effects (Sorensen et al., 2003; Pope and Dockery, 2006). To assess the health risk due to environmental pollutants, intrinsic biological factors such as genetic susceptibility, general health status, metabolic processes, and pattern of the exposure to those contaminants are needed (Jarabek, 1995). Cohort activity studies were found to be particularly important in pollutant exposure assessment and risk management studies, and are often used in exposure models (e.g. Buonanno et al., 2012; Hussein et al., 2013).

The first use of activity patterns in estimating human exposures to environmental pollutants was registered in the 1980s (Robinson, 1988). McCurdy et al. (2000, 2003) provides a brief review of human activity pattern research methods and the National Exposure Research Laboratory's (NERL's) Consolidated Human Activity Database (CHAD). A large survey of time-activity patterns for four Canadian cities over a nine-month period in 1994-1995 was made by Leech et al. (1996). Xue et al. (2004) summarized a series of sequential activity/location data for 160 children aged 7-12 years in Southern California. In Europe, activity pattern investigations by Hussein et al. (2012), Odeh and Hussein (2016), Schweizer et al. (2007), Brasche and Bischof (2005) were also reported. Activity patterns in Europe were found to be rather similar to those reported in North America.

And while the studies on activity patterns in more developed countries, namely Europe and U.S., are somewhat more adequate, only few studies were reported from Asian countries. For instance, Jim et al. (2009) reported leisure participation pattern from a Zhuhai city in China. People leisure activity patterns in Hong Kong, China, were explored by Chau et al. (2002). From a study in Korea, Yang et al. (2011) concluded that Korean population activity patterns significantly differ from those in Western countries and using it in generalized form would result in high uncertainties.

In this work we present the results of activity pattern study in South East Asia, Philippines, at two main thoroughfare cities in Metro Manila: Quezon City, and Manila City. With the immense population in Metro Manila, the vehicular fleet was found to be rapidly increasing (LTO, 2013). As a result, the mean mass concentration of black carbon can be as high as 57 μg m^{-3} (Kecorius et al., 2017; Alas et al., 2018; supplementary material Fig. S1), which is much higher than those in Europe, U.S., China, and India (Birmili et al., 2015; Chen et al., 2014; Tiwari et al., 2015; Rattigan et al., 2013). Elevated eBC concentrations may contribute to increased personal exposure to environmental pollutants and may be the leading cause for respiratory diseases (Laudico et al. 2010). Based on the authors' knowledge, studies on the relationship between activity patterns and air pollution levels in Metro Manila are non-existing; hence, results of such study will be a basis for future assessment of personal exposure and deposition dose of equivalent Black Carbon (work in preparation).

2. Materials and methods

2.1. The questionnaire of daily activity

A paper questionnaire in English was designed to collect information about daily activity patterns from volunteers. Additionally, an electronic version of the questionnaire was shared online for the convenience of those who had internet access. The time resolution of the reporting was one hour for the time from 6 PM to 5 AM and a half hour from 5 AM to 6 PM. Philippines standard time (PST) was used for the convenience of data interpretation. The survey was constructed to cover activities in three main categories of indoors, outdoors and transportation, which were also divided into subcategories. The indoors category included the subcategories: home, kindergarten/school/university, work, and shopping/restaurant/canteen, which were further divided into sleeping, sitting, walking and heavy activity. The outdoors included the subcategories of work, city, and nature with the same branching as the in the indoors subcategory. Transportation covered the use of a private car/taxi/minivan, *Jeepney*/tricycle, bicycle and train, which were the further specified into sitting, standing and driving categories. All categories and subcategories included an "Other" (with a request to specify) choice for non-categorized activities. Together with the mentioned categories, respondents had to identify their gender, age, occupation, work and residence city, and a short description regarding the activity they were involved in.

2.2. The Study Cohort and Activity Table Data Processing

A total of 339 weekly activity tables were acquired in this study out of which 76% passed a quality check and were further selected for time-use investigation. Based on gender and age,

cohort was divided into 5 age categories which are presented in Table 1. People in this study mainly included school and university students and their family members living in Metro Manila, Philippines. They were asked to fill out weekly activity tables for the period of March to May, 2016. During hot and dry season (April - May), most of the schools and universities are on their long academic break. However, this greatly depends on particular academic institution, meaning that there might be academic summer vacation time in one school/university, while others are still open for classes. This diversity results in an incessant fraction of students being involved in some kind of academic activities throughout the year. Moreover, from the personal conversations with students and their family members it became clear that despite their academic break, the majority of questioned family members remain on their regular daily routines. Taking all this into account, we conclude that our cohort is a random sample of university students still attending the classes, secondary school students on academic break and their family members. Naturally, the differences in time-activity patterns may occur for the subjects from specific schools/universities, however, to determine those differences is beyond the scope of this study.

Table 1. Number of people involved in this study by age and gender.

Group name	**Age interval**	**Number of people**		**Age average (± standard deviation)**	
		Male	Female	Male	Female
Toddlers	1.5 ≤ age < 7	2	7	3±2	4±1
Pupils	7 ≤ age < 12	10	10	9±1	9±1
Teens	12 ≤ age < 18	20	43	16±2	16±2
Adults	18 ≤ age < 64	71	92	33±14	35±14
Elderly	64 ≤ age ≤ 84	no data	3	no data	79±5
Total		103	155		

The paper questionnaires were encoded to digital format for further analysis. Tables with missing respondent age/gender and entries with unexplained overlapping activities were

removed. Further data processing included conjugation of all activities into 6 groups: indoors home sleep; indoors home non-sleep; indoors/outdoors work/school; indoors shop/restaurant/canteen; outdoors city; and transport. Activities such as, cooking, indoors/outdoors other and outdoors nature were excluded from the analysis due to a low number of participants (less than 50% of a total number in given age group). The activities were then converted to normalized time fractions for each age group and gender. Time-use fraction was calculated as the ratio between the number of participants in the activity to the total number of participants in a given age group and gender. This fraction was then normalized to unity. The data evaluation process is illustrated in Fig. 1, which plots the time fractions of 5 normalized hypothetical activities A, B, C, D and E.

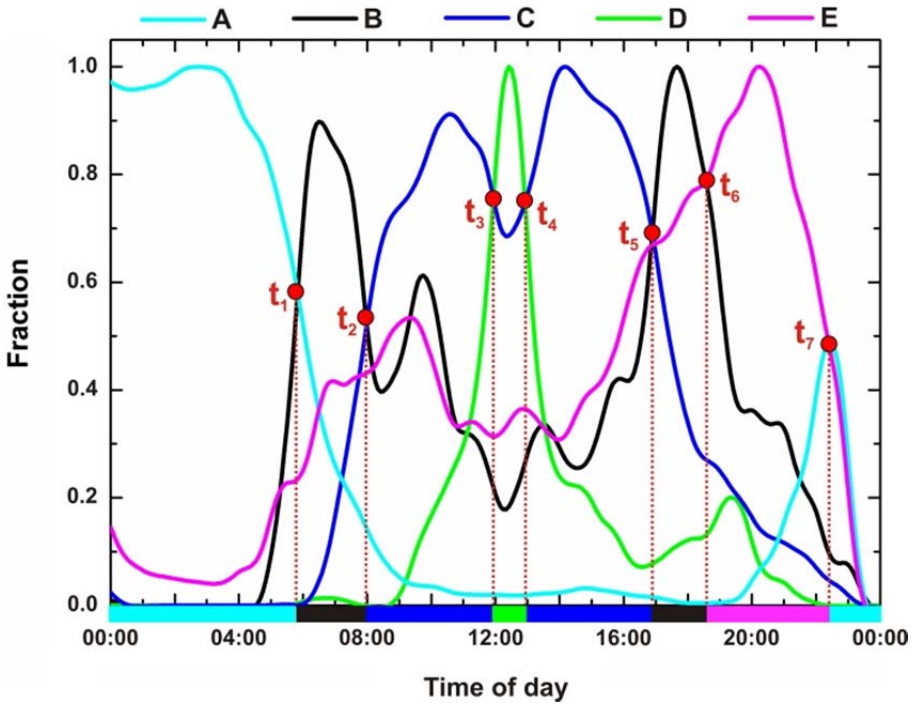
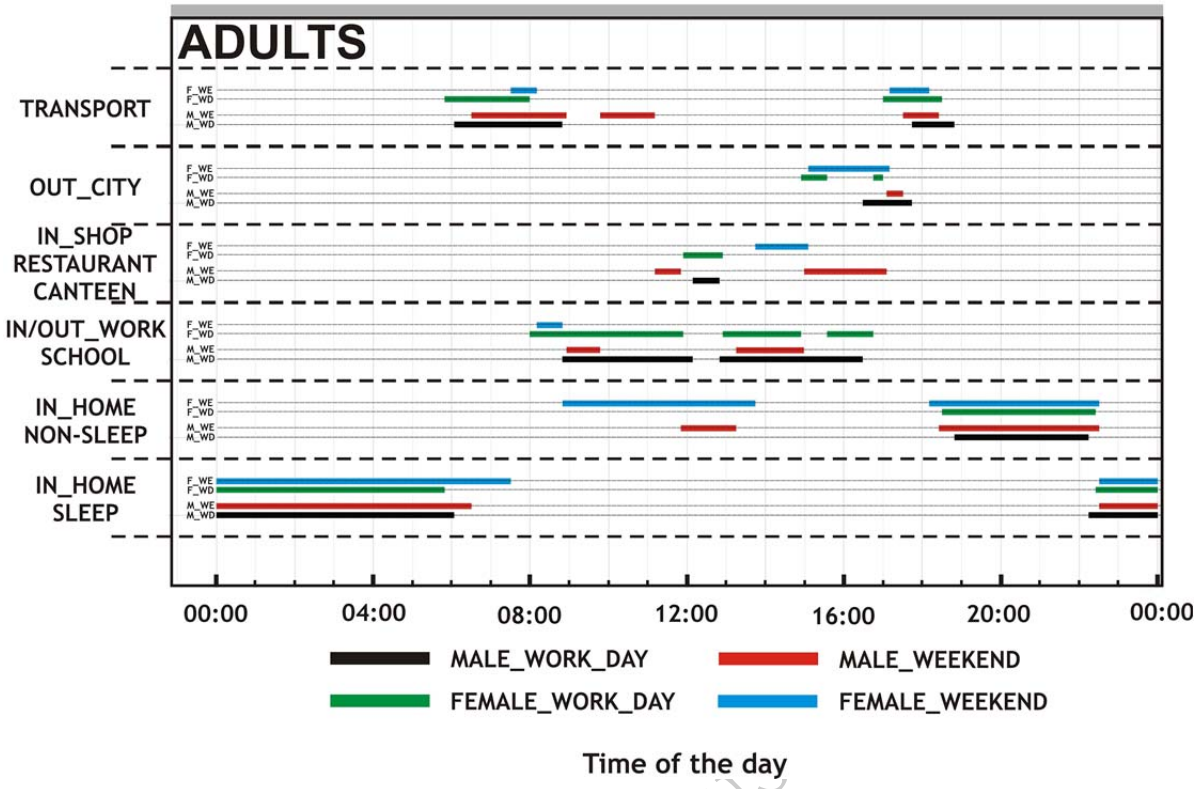


Fig. 1. Example of extracting activity start-end time from normalized hypothetical day time-use pattern.

The fraction of activity A starts to decrease rapidly from around 4 AM to midday, remains constant, and then increases again around 7 PM. Compared to activity A, the time fraction of activity B is much more variable. It starts to increase from around 5 AM, reaches the same fraction as activity A at point t_1 and peaks at the first local maximum between 6-7 AM. t_1 is the transition point where it is assumed that activity A has ended and the activity B has started. This indicates that the highest fraction of participants in activity A is from midnight to t_1 (approx. 6 AM). Likewise, the transition points t_2 to t_7 can be identified to retrieve the start-end times of the remaining activities. From Fig. 2, it can be seen that the fractions of some activities do not drop to zero. In real life situations, this would mean that there will always be a non-zero number of people who are engaged in one or another activity throughout the day. Daily activity patterns were retrieved following this procedure and show not only the duration of the activity for a certain age group or weekday, but also how it is distributed within the day (Fig. 2). The daily activity patterns of the other age groups are available in the supplementary material (Fig. S2-S6).



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146 Fig. 2. Example of activity pattern of adult males and females during workdays and weekends.

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148 It has to be clarified that not all age groups are equally representative in this study. Not
149 more than ten people were registered in the toddler, pupil and elderly age groups. This has to
150 be taken into account when comparing the results as it will lead to elevated uncertainties.
151 Hence, the succeeding discussion utilizes the age groups in which the number of people is
152 more than one standard deviation of the total survey participant number. The only age groups
153 that obey this criterion are teens and adults. The results from these two groups will be used for
154 further discussion in sections 3.1. While in the section 3.2, we will still include the results
155 from different age groups, despite small size of the sample.

2.3. Weather conditions

Two pronounced seasons can be identified in Metro Manila: dry season lasting from December to May, and wet season during the rest of year. December to February and March to May are classified as a cool-dry, and hot-dry season, respectively (Akasaka 2010; Villafuerte et al., 2014). The average temperature, wind speed and rain index during activity survey period is shown in Fig. 3. The temperature maximum was recorded during midday and reached 33±2 °C (± shows standard deviation). The lowest temperature was recorded between 5-6 AM PST, however, it never dropped below 25±1 °C. Wind speed was consistent with temperature. There was basically minimal rainfall from March to April. It became more prominent on May – June, when the wet season started (see Fig. 3).

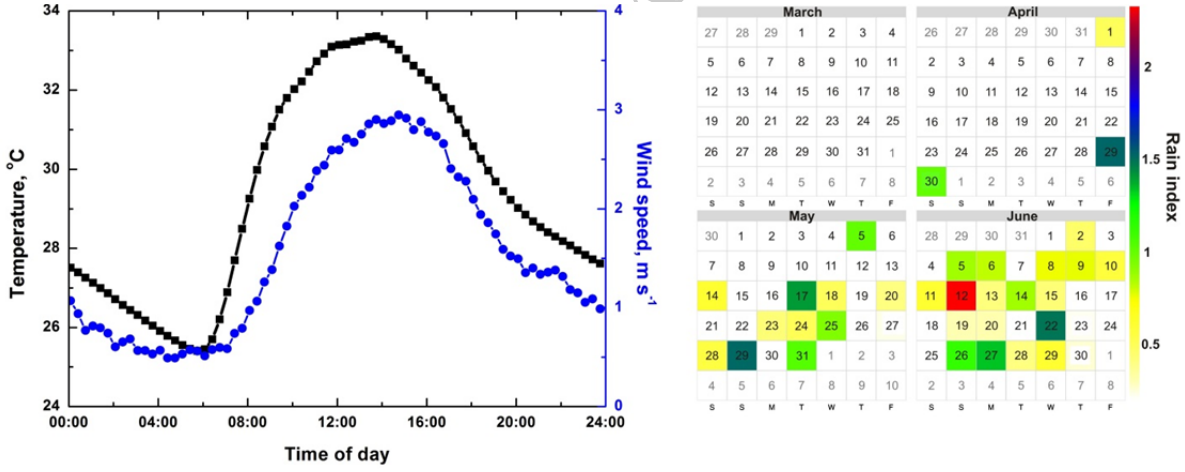

Fig. 3. Average temperature and wind speed variation (left) and rain occurrences (right) during the activity survey period. Rain index here indicates the relative strength of rainfall. White color means no rainfall while red color represents heavy rain.

Extreme meteorological conditions in Philippines, which might influence the times spent indoors and outdoors, are most often associated with tropical cyclones and monsoons. Since our time-use survey questionnaires were mostly responded in March, April and May, the possibility of extreme meteorological conditions, which may affect the results, were minimal. The observed variation in temperature, wind speed and rain occurrences were relatively moderate to influence the activity pattern in this study and will not be discussed further in the text.

3. Results and discussion

3.1. Activity pattern with respect to weekday

A summary of activity pattern by age group, gender and weekday is shown in Table 2 and Fig. S7. Analysis of the questionnaires revealed that regardless of gender and age group, people spent most of the time indoors at home – 52% and 70% on working days (Monday to Friday) and weekends (Saturday and Sunday), respectively (*p-value* < 0.05, Table S1). They spent more time at home during weekends most likely because higher fraction of people does not work on weekends (Table 2). This is confirmed by second most prominent activity – work/school, in which 27% of the respondents' daily time is spent on weekdays, and only 8% on weekends. The time spent at home can be divided into sleeping and non-sleeping activities. Around 32% of time on working days and 38% on weekends was spent for sleeping, while around 20% on working days and 32% on weekends was spent for non-sleeping activities. The fraction of day time spent for shopping and visits to the city was 1.6 times higher on weekend than working day, 13% versus 8%. There was also somewhat difference in time fraction spent for transit traffic. On work days, people spent 3.12 hours, or 13%, of their time

199 in transportation, while on weekends this fraction was lower – 9% (*p-value* < 0.05 for females
200 and *p-value* > 0.05 for males). Higher time fraction on workdays is most likely the result of
201 commuting to work/academic institution.

202

203 Table 2. Summary of activity pattern and number of doers.

Activity	Weekday				Weekend			
	Percent of day time		Number of doers		Percent of day time		Number of doers	
	Males	Females	Males	Females	Males	Females	Males	Females
(a) Time-activity pattern of the toddler group (1.5 - 7 years old) during weekdays and weekends								
Indoors at home sleeping	57	45	2	7	53	46	2	7
Indoors at home non-sleeping	23	19	2	7	37	26	2	7
Indoors/outdoors work/school	12	17	1	3	0	0	0	1
Indoors shop/restaurant/canteen	0	0	0	1	0	9	1	4
Outdoors city	0	8	0	4	3	16	1	4
Transport	8	11	1	3	7	3	1	2
(b) Time-activity pattern of the pupil group (7 - 12 years old) during weekdays and weekends								
Indoors at home sleeping	40	38	10	10	49	48	10	10
Indoors at home non-sleeping	14	18	9	10	25	39	10	10
Indoors/outdoors work/school	30	34	9	9	0	0	1	1
Indoors shop/restaurant/canteen	5	2	7	7	17	0	3	2
Outdoors city	0	0	1	1	0	0	1	0
Transport	12	8	9	8	9	13	7	5
(c) Time-activity pattern of the teen group (12 - 18 years old) during weekdays and weekends								
Indoors at home sleeping	30	33	19	42	41	39	19	43
Indoors at home non-sleeping	34	17	16	36	38	30	17	39
Indoors/outdoors work/school	24	26	16	37	10	7	3	13
Indoors shop/restaurant/canteen	5	5	9	21	0	10	4	17
Outdoors city	2	2	4	5	5	9	2	8
Transport	5	17	14	33	6	5	7	30
(d) Time-activity pattern of the adult group (18 - 64 years old) during weekdays and weekends								
Indoors at home sleeping	33	31	70	90	33	37	68	89
Indoors at home non-	14	16	60	84	23	37	63	83

sleeping								
Indoors/outdoors work/school	29	30	62	74	12	4	29	28
Indoors shop/restaurant/canteen	3	4	30	35	11	6	30	31
Outdoors city	5	4	15	16	2	9	14	20
Transport	16	15	62	72	19	7	49	58
(e) Time-activity pattern of the elderly group (64 - 84 years old) during weekdays and weekends								
Indoors at home sleeping	---	47	---	3	---	45	---	3
Indoors at home non-sleeping	---	53	---	3	---	55	---	3
Indoors/outdoors work/school	---	0	---	1	---	0	---	0
Indoors shop/restaurant/canteen	---	0	---	0	---	0	---	0
Outdoors city	---	0	---	0	---	0	---	1
Transport	---	0	---	0	---	0	---	1

In general, it was found that on average people in Metro Manila spend 84% of their time indoors, 5% outdoor and 11% in transit traffic (Fig. 4). On working days, the people spent more time in transportation, while on weekends higher fractions of time were spent indoors and outdoors. It is important to note that outdoors here refers only to time spent outdoors in the city. Other outdoor activities, such as time spent in nature, were prominent among less than 10% of the respondents. Moreover, time fraction was spread through the day and no conclusive results were evident. Time fraction spent indoors on weekends is mostly determined by time spent at home.

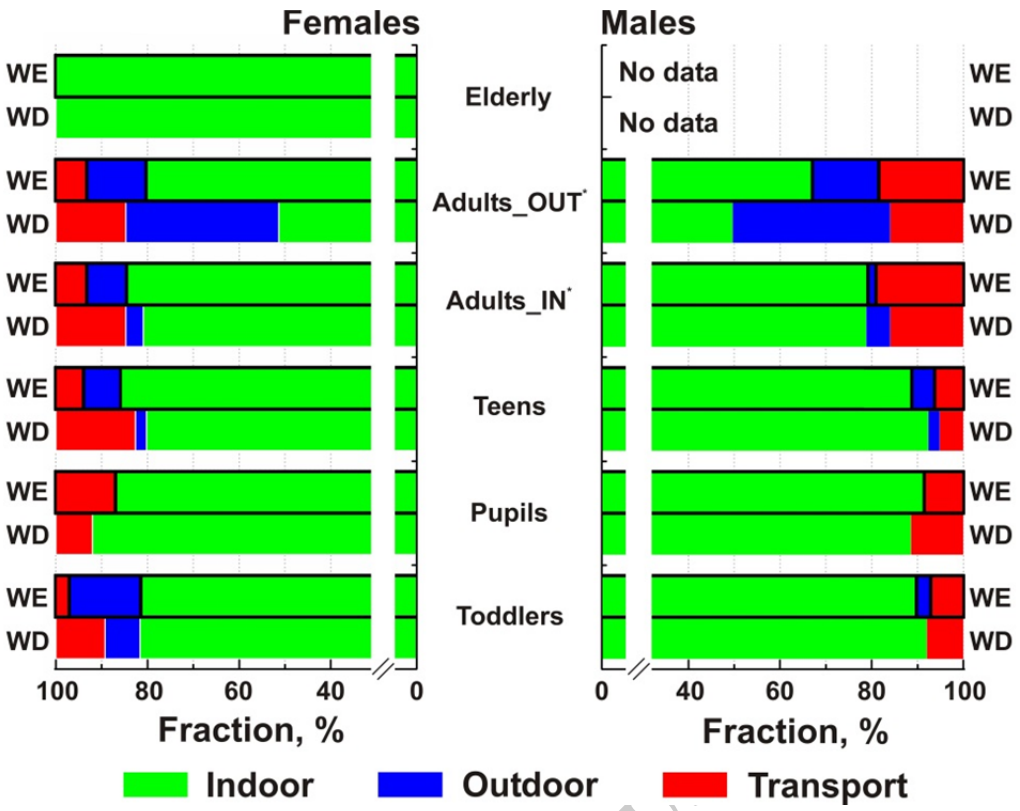

Fig. 4. Fraction of time spent indoors, outdoors and transit traffic by age group, gender and weekday. Adults_OUT* and Adults_IN* indicate individuals working outdoors and indoors, respectively. WE and WD stands for weekends and work days, respectively.

In the studies by Brasche and Bischof (2005), Hussein et al. (2012) and Schweizer et al. (2007) in major cities in Europe people spent from 56% to 66% of their daytime at home. In a study from air pollution hotspot in New Jersey, United States, Wu et al. (2010) reported that time fraction spent at home was from 67% on workdays up to 74% on weekends. In Asia, Chau et al. (2002) found that people in Hong Kong on average spend 58% of their time indoor at home, 44% of which is for sleeping and/or resting. In our study, people spent 52% and 70% of their time at home during workdays and weekends, respectively. On average 35% of this time was spent for sleeping. Thus, time fractions spent indoors at home in our study seemed to be on the lower end of values observed in other studies in both Western and Asian

countries. Although some apparent variability between times spent at home is evident among countries, we did not expect time spent indoors at home sleeping to be largely different because sleeping is a common biological necessity that people share around the world. Regardless of nationality, social status or other uniqueness, people require around 8 hours of sleep per day (Taillard, 1999). The rest time at home is most likely spent as recreational activities after work, spending time with family or preparing for the next day's activities.

Europeans spend on average 25% to 31% of their time indoors at work or school (Schweizer et al., 2007). In our study, this fraction ranged from 8% on weekends to 27% on working days, and while it was comparable with Europeans, it was higher than in Hong Kong where it is reported that people spend around 18% of their time indoors at work or school (Chau et al., 2002). When comparing more general time fractions, in Hong Kong people on average spent 89% and 4% (Chau et al., 2002); in California - 87% and 6% (Jarabek, 1995); in Canada – 82% and 13% (Leech et al., 2002); in U.S. – 83%, 11% (Leech et al., 2002); in Finland – 89% and 7%; and in this study in Metro Manila – 84% and 5% of their day time indoors and outdoors, respectively. It can be seen that time fraction spent indoor are similar in all studies, however, time spent outdoor tend to be shorter in Asia than in Western countries.

People from California, Korea and China spend on average 7% of their time in transit traffic while in Finland people spent from 3% to 5% of their time for the same activity (Jenkins et al., 1992; Yang et al., 2011; Hussein at al., 2012). In the case of Metro Manila, the fraction of time spent in transportation varied from 9% on weekends up to 13% on working days and was found to be considerably larger than observed in other studies. This discrepancy might be the result of high population density in Metro Manila and absence of an extensive and convenient public transport network that would meet the daily commuting needs of the people. A large fraction of the population is commuting by private cars, taxis, busses and *Jeepneys* – a mainstreamed and cheap transport in Metro Manila, all contributing to severe

253 vehicle traffic. This may significantly increase personal exposure to particulate matter and
254 toxic pollutants such as polycyclic aromatic hydrocarbons and heavy metals.
255
256 **3.2. Activity pattern with respect to age and gender**
257
258 Based on the gender of the people, the study revealed that females and males tend to
259 spend most of their time at home, around 60%. This time was split between sleeping (34%)
260 and non-sleeping activities (26%). The least time both genders spent outdoors. However,
261 females spent twice as much time as males – 6% versus 3% (*p-value* < 0.05, Table S1). Time
262 spent in transit traffic for both genders were around 12%. Females spent more time indoors
263 shop/restaurant/canteen and outdoors city. Another only minute difference appears in time
264 spent at school/working place, which is 19% for males and 17% for females (see Table 2 and
265 Fig. S7).
266 When analyzing time-use by age group, time fraction spent indoors at home is highest in
267 the groups of toddlers and elderly – 77% and 100%, respectively. Starting with toddlers, this
268 fraction gradually decreases with increasing age and reaches its minimum of 56% in group of
269 adults, since youngsters tend to spend more time at home while teens and adults have to
270 attend school and/or work. Elderly spend their entire time indoors at home - 46% for sleeping
271 and 54% for non-sleeping activities. In all other groups, the most of day time is spent for
272 sleeping: toddlers spent 50%, pupils – 44%, teens – 36% and adults 34% of their daily time in
273 this activity. Out of all age groups, adults were found to spend highest fractions of day time
274 indoors/outdoors at work/school and transportation activities. However, it is worth to
275 remember that not all age groups share same number of respondents and may be biased
276 towards higher uncertainties. Low number of toddlers, pupils and elderly might be misleading
277 and should be used with great caution. We also distinguished between adults working indoors

and outdoors. As can be seen from Fig. 4, adults working outdoors obviously spend much more time outdoors compared to those working indoors – 24% versus 5%. This also affects time spent indoors – resulting in 62% and 81% for adults working outdoors and indoors, respectively.

The results from our study have same tendencies and in some extent agree with previous studies. For instance, in a study by Hussein et al. (2012), 64 and older people were found to spend more time indoors at home compared with younger age groups. Even though our sample of this age group is scarce, we found that the elderly does spend all of their time indoors at home. Younger age groups tend to spend less time at home and more time at work/school with increasing age. Moreover, adults spend more time in traffic than youngsters and elderly (*p-value* < 0.05, Table S1). Similar results were also reported from U.S. (Leech et al., 2002). We also found that adult females stay longer indoors at home than males, as stated in the studies from Europe and U.S (Hussein et al, 2012; Schweizer et al. 2007; Klepeis et al., 2001; Wu et al., 2010). Moreover, adult females spend less time indoors at work/school – 17% versus 21%, compared to males (*p-value* < 0.05). The reason for this might be that women have to adapt to their young children's schedules by spending more time at home. Buonanno et al. (2012) found that children in Italy (8-11 years old) spend 21-35% of their daily time at school and 59-71% at home, out of which 37% for sleeping. Time spent in transit transport ranged between 2% to 4%. In our study, pupils (7-12 years old) spent on average 16% at school, 68% at home, out of which 44% was for sleeping. In Metro Manila, pupils spent 10% of their time in transit transport, which is considerably higher fraction compared to children in Italy. Comparing with China, in Hong Kong young group (6-18 years old) and adults spent more time at school and work compared with Philippines. However, in the Philippines, both youngsters and adults spent more time in transit traffic than in China.

In previous studies the differences in time fractions spent during the day can be explained by gender, age, specific work, employment and social status, monthly income etc. (Klepeis et al., 2001; Schweizer et al. 2007; Yang et al., 2011; Hussein et al., 2012). In this study we found that the activity pattern mostly occurred individually, however we were able to distinguish the most common factors among people gender, age and type (workday/weekend) of day.

4. Summary and conclusions

This study characterized the activity pattern of school/university occupants and their family members living in Metro Manila, Philippines. The population has a different time patterns not only from Western but also from other Asian countries, with particularly longer time spent in transit traffic. Times spent indoors, outdoors and transit traffic were 84%, 5% and 11%, respectively. With the elevated concentrations of air pollutants and the larger amount of time spent in transit traffic, Metro Manila population is thus at higher risks of increased personal exposure to ambient air pollutants that may lead to adverse health symptoms. As in previous studies - gender, age and type of day were found to be important factors in determining how people spent their day time.

We would also like to emphasize that there are several limitations of the study. First, the cohort is relatively small and may not represent the general population of Metro Manila and its many different social groups. Greater attention should be given to specific groups of the city's inhabitants who spend most of their time in much different environments than the cohort investigated in this study. Different sources estimate that there is more than 4000 homeless street families, including 1 million children, who reside in slums and live on Metro Manila streets. The fraction of time spent in most polluted environments may be much

different than the values reported in this study. Second, there are noticeable differences in the sample type not only in certain age group participant number but also their gender. For example, females were oversampled compared with males and less than 10 people were found in toddlers, pupils and elderly age groups. Additional information is needed to confirm the information about these age groups, which were very limited in this study. Despite these limitations, the provided information is a good starting point for such studies in the Philippines. The results observed in this study will be used to estimate and manage the personal exposure to air pollutants in Metro Manila.

Acknowledgement

This study was supported by the Partnership for Clean Air Inc., the Researchers for Clean Air, Inc., the Metro Manila Development Authority, and the City Office of Manila. Also it would have not been possible without the help of the students from De La Salle-College of Saint Benilde, Ateneo de Manila University and De La Salle University-Manila and their family members. We greatly acknowledge their time and efforts filling activity tables and participating in this survey.

References

Akasaka I. Inter-annual variations in seasonal march of rainfall in the Philippines. Int J Climatol. 2010; 30, 1301–1314.

Alas, H. D., Müller, T., Birmili, W., Kecorius, S., Cambaliza, M. O., Simpas, J. B. B., Cayetano, M., Weinhold, K., Vallar, E., Galvez, M. C., Wiedensohler, A. Spatial Characterization of Black Carbon Mass Concentration in the Atmosphere of a Southeast Asian Megacity: An Air Quality Case Study for Metro Manila, Philippines. Aerosol and Air Quality Research 2018; (doi.org/10.4209/aaqr.2017.08.0281)

Birmili W, Sun J, Weinhold K, Merkel M, Rasch F, Wiedensohler A, Bastian S, Löschau G, Schladitz A, Quass U, Kuhlbusch TAJ, Kaminski H, Cyrys J, Pitz M, Gu J, Kusch T, Flentje H, Meinhardt F, Schwerin A, Bath O, Ries L, Gerwig H, Wirtz K, Weber S. Atmospheric aerosol measurements in the German Ultrafine Aerosol Network (GUAN) - Part III: Black Carbon mass and particle number concentrations 2009-2014. Gefahrst. Reinh. Luft 2015; 75, 479-488.

Brasche S, Bischof W. Daily time spent indoors in German homes - baseline data for the assessment of indoor exposure of German occupants. Int J Hyg Environ Health 2005; 208, 247-53.

Buonanno, G., Marini, S., Morawska, L. and Fuoco, F.C. Individual dose and exposure of Italian children to ultrafine particles. Sci Total Environ 2012; 438, 271-277.

Chau CK, Tu EY, Chan DWT, Burnett J. Estimating the total exposure to air pollutants for different population age groups in Hong Kong. Environ Int 2002; 27, 617-30.

Chen X, Zhang Z, Engling G, Zhang R, Tao J, Lin M, Sang X, Chan C, Li S, Li Y. Characterization of fine particulate black carbon in Guangzhou, a megacity of South China. Atmospheric Pollution Research 2014; 5(3), 361-70.

Hussein T, Paasonen P, Kulmala M. Activity pattern of a selected group of school occupants and their family members in Helsinki-Finland. Sci Total Environ 2012; 425, 289-92.

Hussein, T., Löndahl, J., Paasonen, P., Koivisto, A.J., Petäjä, T., Hämeri, K. and Kulmala, M. Modeling regional deposited dose of submicron aerosol particles. Sci Total Environ 2013; 458, 140-149.

Jarabek A.M. Consideration of temporal toxicity challenges current default assumptions. Inhalation Toxicol 1995; 7, 927–946.

Jenkins PL, Phillips TJ, Mulberg EJ, Hui SP. Activity patterns of Californians: use of and proximity to indoor pollutant sources. Atmos Environ 1992;26A:2141-8.

Jim CY, Chen WY. Leisure Participation Pattern of Residents in a New Chinese City. Ann Assoc Am Geog 2009; 99, 657–673.

Kecorius, S., Madueño, L., Vallar, E., Alas, H., Betito, G., Birmili, W., Cambaliza, M.O., Catipay, G., Gonzaga-Cayetano, M., Galvez, M.C. and Lorenzo, G. Aerosol particle mixing state, refractory particle number size distributions and emission factors in a polluted urban environment: Case study of Metro Manila, Philippines. Atmos Environ 2017; 170, 169-183.

Klepeis NE, Nelson WC, Ott WR, Robinson JP, Tsang AM, Switzer P, et al. The national human activity pattern survey (NHAPS): a resource for assessing exposure to environmental pollutants. J Expo Anal Environ Epidemiol 2001; 11, 231-52.

Laudico AV, Mirasol-Lumague MR, Mapua CA, Uy GB, Toral JA, Medina VM, Pukkala E. Cancer incidence and survival in Metro Manila and Rizal province, Philippines. Japanese journal of clinical oncology 2010; 40(7), 603-12. (doi:10.1093/jjco/hyq034)

Leech J.A., Wilby K., McMullen E., and Laporte K. Canadian human time – activity pattern survey report of methods and population surveyed. Chron Dis Can 1996; 17, 118 – 123.

Leech JA, Nelson WC, Burnett RT, Aaron S, Raizenne ME. It's about time: a comparison of Canadian and American time–activity patterns. J Expo Anal Environ Epidemiol 2002;12, 427-32.

LTO. Philippine Transportation Statistics. Philippine Statistics Authority. Republic of the Philippines: Land Transportation Office; 2013.

McCurdy T, Glen G, Smith L, Lakkadi Y. The national exposure research laboratory's consolidated human activity database. J Expo Anal Environ Epidemiol 2000; 10, 566-78.

McCurdy T, Graham S. E. Using human activity data in exposure models: Analysis of discriminating factors. J Expo Anal Environ Epidemio 2003; 13, 294–317.

Odeh I, Hussein T. Activity pattern of urban adult students in an Eastern Mediterranean Society. International Journal of Environmental Research and Public Health 2016; 13, 960. (doi: 10.3390/ijerph13100960)

Pope III CA, Dockery DW. Health effects of fine particulate air pollution: lines that connect. J Air Waste Manag Assoc 2006; 56, 709-42.

Rattigan OV, Civerolo K, Doraiswamy P, Felton HD, Hopke PK. Long term black carbon measurements at two urban locations in New York. Aerosol and Air Quality Research 2013;13(4), 1181-96+.

Robinson, J.P. Time diary research and human exposure assessment: some methodological considerations. Atmos Environ 1988; 22, 2085-2092.

Schweizer C, Edwards RD, Bayer-Oglesb L, Gauderman WJ, Ilacqua V, Jantunen J, et al. Indoor time–microenvironment–activity patterns in seven regions of Europe. J Expo Sci Environ Epidemiol 2007; 17, 170-81.

Sorensen M, Autrup H, Moller P, Hertel O, Jensen SS, Vinzents P, et al. Linking exposure to environmental pollutants with biological effects. Mutat Res 2003; 544, 255-71.

417 Taillard J, Philip P and Bioulac B. Morningness/eveningness and the need for sleep. J Sleep
418 Res 1999; 8, 291-295. (doi: 10.1046/j.1365-2869.1999.00176.x)
419 Tiwari S, Bisht DS, Srivastava AK, Gustafsson Ö. Simultaneous measurements of black
420 carbon and PM2. 5, CO, and NO x variability at a locally polluted urban location in
421 India. Natural Hazards 2015; 75(1), 813-29.
422 Villafuerte MQ, Matsumoto J, Akasaka I, Takahashi HG, Kubota H and Cinco TA. Long-
423 term trends and variability of rainfall extremes in the Philippines. Atmos Res.2014; 137,
424 1-13.
425 Wu XM, Fan, ZT and Ohman-Strickland P. Time-location patterns of a population living in
426 an air pollution hotspot. J Environ Public Health 2010; 10. (doi: 10.1155/2010/625461)
427 Xue J, McCurdy T, Spengler J, Özkaynak H. Understanding variability in time spent in
428 selected locations for 7–12-year old children. J Expo Anal Environ Epidemio 2004; 14,
429 222–233.
430 Yang W, Lee K, Yoon C, Yu S, Park K, Cho W. Determinants of residential indoor and
431 transportation activity times in Korea. J Expo Sci Environ Epidemiol 2011; 21, 310-6.