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Simonas Kecorius
Leibniz-Institute for Tropospheric Research

Everlyn Gale Tamayo
University of the Philippines Diliman

Maria Cecilia Galvez
De La Salle University, Manila

Leizel Madueño
Leibniz-Institute for Tropospheric Research

Grace Betito
Ateneo de Manila University, gbetito@ateneo.edu

See next page for additional authors

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Authors
Simonas Kecorius, Everlyn Gale Tamayo, Maria Cecilia Galvez, Leizel Madueño, Grace Betito, Mylene Gonzaga-Cayetano, Edgar Vallar, and Alfred Wiedensohler

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Activity Pattern of School/University Tenants and their Family Members in Metro Manila – Philippines

Simonas Kecorius[1*], Everlyn Gayle Tamayo[2], Maria Cecilia Galvez[3], Leizel Madueño[1], Grace Betito[4], Mylene Gonzaga-Cayetano[2], Edgar Vallar[3], Alfred Wiedensohler[1]

[1] *Leibniz-Institute for Tropospheric Research, Leipzig 04318, Germany*
[2] *Institute of Environmental Science and Meteorology, University of the Philippines, Quezon City 1101, Philippines*
[3] *Physics Department, De La Salle University, 1004 Manila, Philippines*
[4] *Ateneo de Manila University, Quezon City 1108, Philippines*

ABSTRACT

Existing studies that focus on personal exposure to or the deposition dose of particulate pollution in developing regions are limited. Hence, in this study, as a first step, we present results on how people spend their daily time in Metro Manila, Philippines. This information is critical to assessing personal exposure to and the deposition dose of particulate pollutants. We found that people spend less time at home on workdays than weekends (52% versus 70%), the fraction of time spent at work/school increases with age until retirement, adult males spend less time at home than females (18% versus 28%), and people spend most of their time indoors (84%). The biggest difference from previous studies is the discovery that people in Metro Manila spend 11% of their daily time on average in transit traffic, which is up to 2.2 times more than in Europe, America, Korea, or China. Longer times in transit traffic subject the population of Metro Manila to a higher risk of increased exposure to toxic pollutants and adverse health symptoms. The main results of this research will be used in an upcoming study on the personal deposition dose of soot.

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

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 (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), and 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 Philippines, South East Asia, 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,

[*] Corresponding author.
E-mail address: kecorius@tropos.de

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 (Rattigan *et al.*, 2013; Chen *et al.*, 2014; Birmili *et al.*, 2015; Tiwari *et al.*, 2015). 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).

MATERIALS AND METHODS

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 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.

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.

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.

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

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	$1.5 \leq age < 7$	2	7	3 ± 2	4 ± 1
Pupils	$7 \leq age < 12$	10	10	9 ± 1	9 ± 1
Teens	$12 \leq age < 18$	20	43	16 ± 2	16 ± 2
Adults	$18 \leq age < 64$	71	92	33 ± 14	35 ± 14
Elderly	$64 \leq age \leq 84$	no data	3	no data	79 ± 5
Total		103	155		

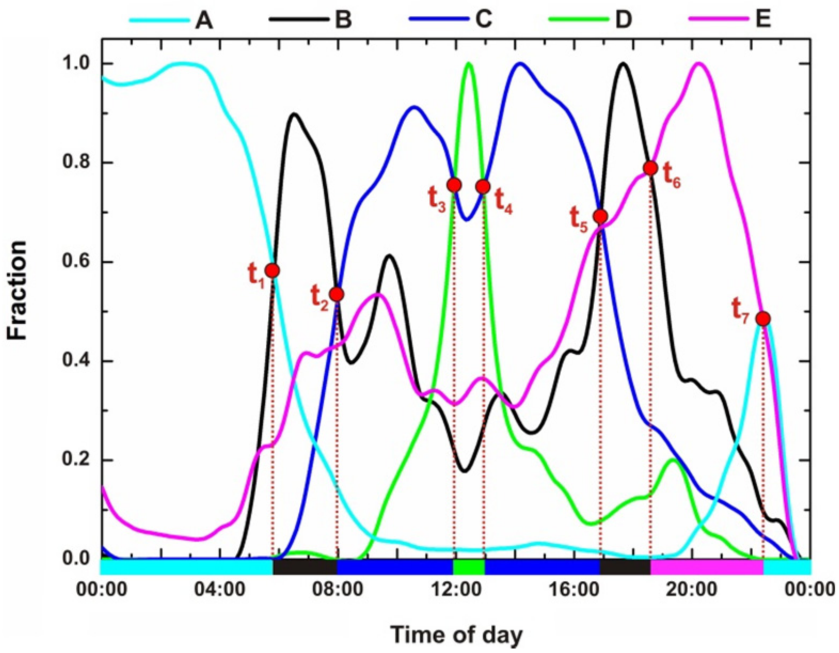

Fig. 1. Example of extracting activity start-end time from normalized hypothetical day time-use pattern.

is assumed that Activity A has ended and 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 (Figs. S2–S6).

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

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).

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.

RESULTS AND DISCUSSION

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

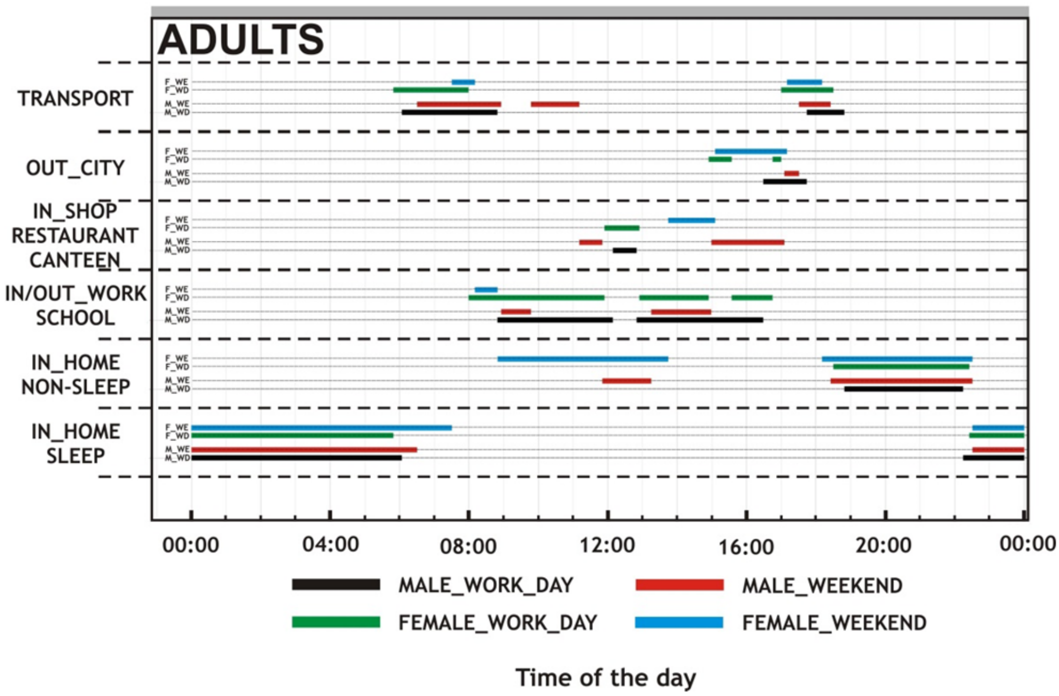

Fig. 2. Example of activity pattern of adult males and females during workdays and weekends.

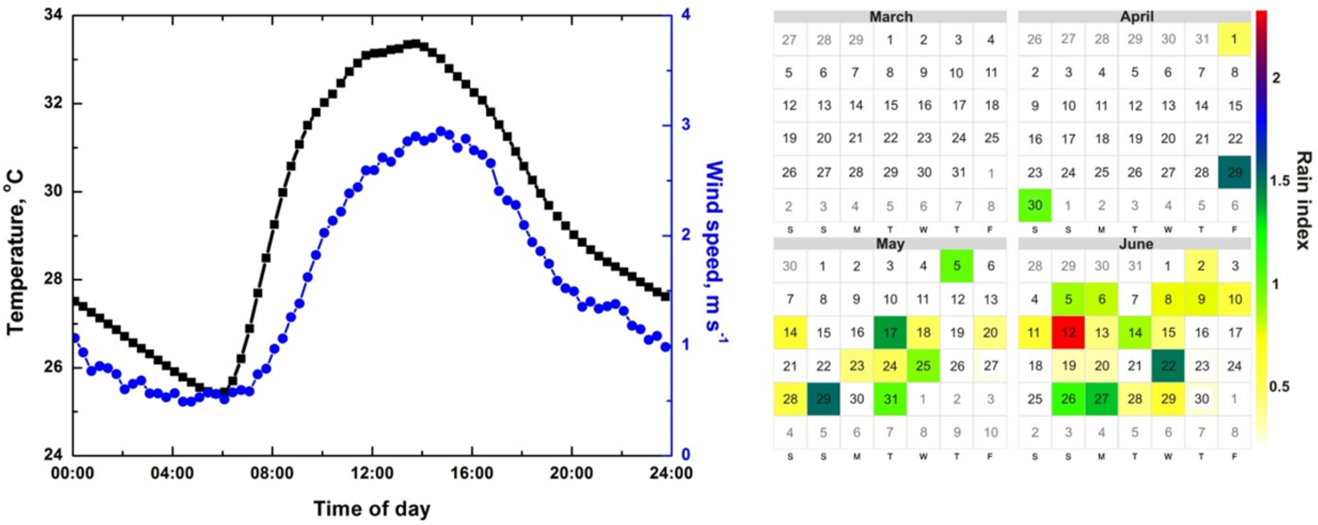

Fig. 3. Average temperature and wind speed variation (left) and rain occurrences (right) during the activity survey period. Rain index here indicates the relative strength of rainfall. White color means no rainfall while red color represents heavy rain.

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

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.

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-sleeping	14	16	60	84	23	37	63	83
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 the studies by Brasche and Bischof (2005), Schweizer *et al.* (2007) and Hussein *et al.* (2012) in major cities in Europe people spent from 56% to 66% of their day time 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% and 11% (Leech *et al.*, 2002); in Finland, 89% and 7%; and in this study in Metro Manila,

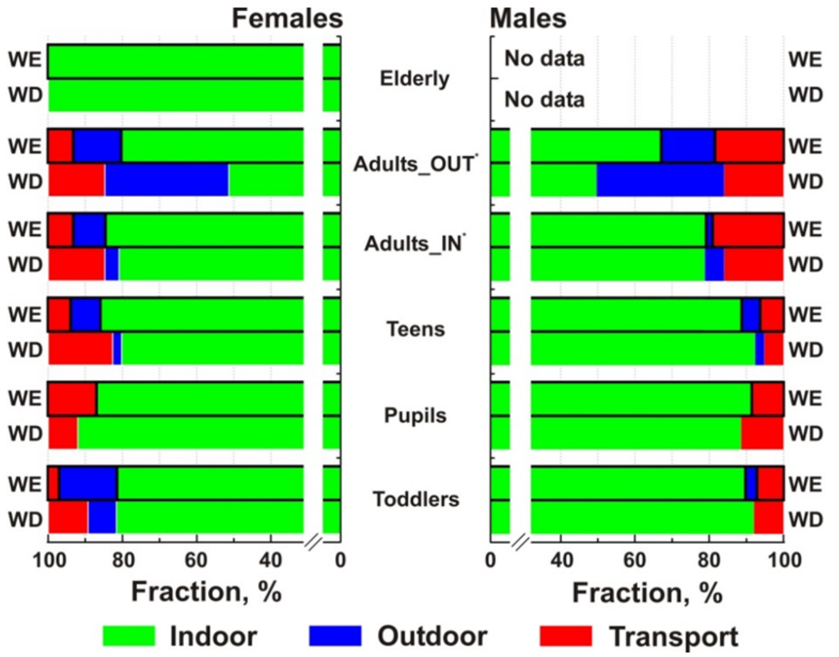

Fig. 4. Fraction of time spent indoors, outdoors and transit traffic by age group, gender and weekday. Adults_OUT* and Adults_IN* indicate individuals working outdoors and indoors, respectively. WE and WD stands for weekends and work days, respectively.

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 *et 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 vehicle traffic. This may significantly increase personal exposure to particulate matter and toxic pollutants such as polycyclic aromatic hydrocarbons and heavy metals.

Activity Pattern with Respect to Age and Gender

Based on the gender of the people, the study revealed that females and males tend to spend most of their time at home, around 60%. This time was split between sleeping (34%) and non-sleeping activities (26%). The least time both genders spent outdoors. However, females spent twice as much time as males—6% versus 3% (p-value < 0.05, Table S1). Time spent in transit traffic for both genders were around 12%. Females spent more time indoors shop/restaurant/canteen and outdoors city. Another only minute difference appears in time spent at school/working place, which is 19% for males and 17% for females (see Table 2 and Fig. S7).

When analyzing time-use by age group, time fraction spent indoors at home is highest in the groups of toddlers and elderly—77% and 100%, respectively. Starting with toddlers, this fraction gradually decreases with increasing age and reaches its minimum of 56% in group of adults, since youngsters tend to spend more time at home while teens and adults have to attend school and/or work. Elderly spend their entire time indoors at home—46% for sleeping and 54% for non-sleeping activities. In all other groups, the most of day time is spent for sleeping: Toddlers spent 50%; pupils, 44%; teens, 36%; and adults, 34% of their daily time in this activity. Out of all age groups, adults were found to spend highest fractions of day time indoors/outdoors at work/school and transportation activities. However, it is worth to remember that not all age groups share same number of respondents and may be biased towards higher uncertainties. Low number of toddlers, pupils and elderly might be misleading 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. (Klepeis *et al.*, 2001; Schweizer *et al.*, 2007; Wu *et al.*, 2010; Hussein *et al.*, 2012). 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 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.

SUMMARY AND CONCLUSIONS

In this study we present the activity patterns of school/university occupants and their family members living in Metro Manila, Philippines. The population exhibits different time patterns not only from Western but also from other Asian countries, particularly the longer times spent in transit traffic. The fractions of time spent indoors, outdoors, and in 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, the population of Metro Manila is thus at higher risk for increased personal exposure to ambient air pollutants that may lead to adverse health symptoms. As in previous studies, the gender, age, and type of day were found to be important factors in determining how people spent their time.

We would also like to emphasize that there are several limitations of this 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 city inhabitants who spend most of their time in very different environments than the cohort investigated in this study. Different sources estimate that there are more than 4000 homeless street families, including 1 million children, who reside in slums and live on the streets of Metro Manila. The fraction of time spent in the most polluted environments may be very different from the values reported in this study. Second, the representativeness of the sampling noticeably varies not only by age but by gender. For example, females were oversampled compared with males, and fewer than 10 participants were toddlers, pupils, or elderly individuals. Additional information is needed to confirm the information about these age groups, which was very limited in this study. Despite these limitations, the current information is a good starting point for such studies in the Philippines. The results obtained in this study will be used to estimate and manage personal exposure to air pollutants in Metro Manila.

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SUPPLEMENTARY MATERIAL

Supplementary data associated with this article can be found in the online version at http://www.aaqr.org.

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