DETERMINING LOCAL EXPOSURE FACTORS OF YOUNG ADULTS IN A NORTHEASTERN UNIVERSITY, THAILAND

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ABSTRACT:

Background: Lack of adequate information on local data for human exposure factors has been problematic for exposure assessment and health risk assessment in Thailand. Data from western countries is often deviated from local situations found in various provinces. This study intended to determine common exposure factors among young adults in university settings in northeastern Thailand.

Method: Questionnaire was used to collect relevant information from the sample groups regarding age, body weight, and daily activity. Daily record and measurement were used to quantify daily water and food consumption over 14 days. Personal air samplers were used to estimate level of total suspended particles (TSP) exposure during commuting on passenger pick-up trucks while ambient air samplers were set to quantify indoor and outdoor fine particulate matter concentrations ($PM_{2.5}$) during January and May 2014.

Results: The participants were 18 to 22 years old (n = 382 persons) having the average body weight of 60.4 ± 9.2 kg and 51.4 ± 8.3 kg for males and females, respectively. Time-activity patterns showed that daily in-class and out-of-class study occupied about 34% daily, almost equally to resting and sleeping. The rest of the time was leisure, exercising, eating and showering. Drinking water consumption was about 883 ± 338 mL/day. Average daily rice consumption was about 357 ± 108 g/day, somewhat less than other foods (424 ± 126 g/day). Meat, consisting of chicken, pork, and fish, were accounted for 36% while egg and vegetable were about 17% of daily weight of total food consumption. Indoor and outdoor $PM_{2.5}$ concentrations were not statistically different with indoor/outdoor ratio of 0.94, lower than the ratios found in colder climates. Chemical analyses of air samples indicated that the potential exposure of arsenic, copper, lead, and nickel was in part per billion ranges, 1.5, 10.4, 27.5, and 7.6 ppb, respectively. Major soluble ions were sulfate and nitrate while ammonium ion was lower.

Conclusion: This type of information is important for health impact assessment at the local level, since observations in this study differed substantially from those commonly reported in the foreign literature.

Keywords: Daily consumption, Exposure factors, Northeastern young adult, Thailand

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INTRODUCTION

Availability of public data on exposure factors among Thai people is relatively rare. Lack of data causes a substantial drawback for evaluating exposure and health impact assessment. Many researchers have inevitability acquired the exposure factors from international literatures [1, 2]. For instant, the Exposure Factors Handbook from the U.S. EPA [3] uses 80.0 kg as the average weight of the adults and used 71.6 kg for 16 - <21 years old as the basis for exposure or dose calculations. These numbers can be wildly found in several reports on environmental and health impact assessment in Thailand despite the average body weight of most Thais is obviously lower. As a result, the conclusions are subjected to mislead or often questionable. Population with age between 16 - <21 years old is a sub-group of population and is recommended by the U.S. EPA [4] as a group with differences in behavior and physiology that may impact exposures. This sub-group starts to have high rate of food consumption in which influence oral and dermal exposure [4] and most of them are in college or university for education. Information of this sub-group, however, is rarely available for the public.

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Another example is the different levels of pollution indoor and outdoor in western countries. Pollution exposure indoor is very critical in many cases [5-8]. Living in cold climate requires a relatively sealed house to conserve the energy and minimize utility cost. Double glass windows and air tight houses are very common. In Thailand and tropical climate countries, the situation is quite difference. Air exchange between outdoor and indoor is encouraged to ventilate or cool down the house. Lifestyle in educational institutions may also differences from the urban resident. Thus, it is important to investigate local situations and establish appropriate exposure factors for the benefit of environmental and health risk assessment. This research aims to quantify the common exposure factors among the young adults living in the university environment. Specific exposure factors would be of benefit for research agencies and governmental organizations to evaluate health impact assessment.

RESEARCH METHOD

Study area

The study area was in a medium size university, located in the northeast region of Thailand in Nakhon Ratchasima Province. The university has the total area of approximately 1,120 hectares (11.2 square km), situated between 14.87N, 102.04E and 14.90N, 102.00E. The surroundings are dominated by agricultural land use, mostly maize, tapioca, and sugar crane plantation.

Study population

The university is considered as a small town with the total population of 11,714 persons, consisting of 10,246 full-time students and 1,468 staffs. This study was interested in determining the common exposure factors of the young adult sub-population group, mainly the undergraduate student. Total population of the undergraduate student was acquired from the university registrar to estimate the number of sample required for body weight and time activities data. The overall enrollment of students (N) for 2013-2014 academic year was 9,439 persons. Estimate sample size was calculated using Cochran formula [9]. A proportion of number population in young adult group (40%), an α of 0.05, and an allowable error of 5% determined that a sample size of 369 participants was necessary in this study. To strengthen this study, the samples was increased to 382 persons.

Data collection

A questionnaire was distributed throughout the campus between January and June 2014. The questionnaire was asked about age, sex, body weight, and daily time activity. Data collection was repeated during this period to obtain the required data with sufficient number of samples. Data on drinking water consumption, food consumption, and level of particulate matter were records or experiments.

Drinking water consumption

Drinking water consumption was estimated from the amount of water remained in containers each day. Drinking water was prepared daily in 650 mL polyethylene (PET) bottles. Each bottled was weighted in a laboratory with an electrical balance, 100 g accuracy (Preica, Switzerland). The weight was recorded prior to distribute in the evening for the next day water consumption. A set of four bottles, the total of 2,600 mL drinking water, was prepared for each student every evening. The bottles were used for the entire next day and were retrieved after daily consumption. The post-weight of the remaining water was recorded and calculated as the volume consumed assuming the water density is 1 g/mL.

Food consumption

Food consumption was determined by personal record and weighting. Foods were exclusively limited to cooked rice as the main component. Other foods that consumed with rice were recorded and weighted separately. Noodle and soup were not included in this study due to difficulty of determining water and food portions prior to consume. Foods were weighted as a wet weight basis with the mechanical balances (Camry, China), 10 g accuracy. Each type of foods was separately weighted and recorded daily.

Air pollution exposure

Levels of particulate matter exposure during commuting by the passenger pick-up trucks between the university and downtown were estimated using to personal air samplers, SKC PCXR8 (SKC, Inc., USA). Pre- and post-weight of 37 mm quartz fiber filters (Pallflex QUATUP, Pall Corp, USA) was determined by 1 µg resolution electronic microbalance, XP26 (Mettler Toledo, USA). All filters were pre-heated at 650 °C in an electronic furnace (Carbolite Ltd., UK) for two hours and equilibrated in humidity control chamber (WELFO, Taiwan ROC). This process was performed to minimize impurities in the filters during chemical analysis. After 24 hours, the filters were weighted and ready for field sampling. Post-weight was performed after the filters were retrieved and equilibrated accordingly. The flow rate of each personal pump was calibrated against the primary standard flow calibrator (4146 TSI, USA). The flow rate was set at 2.0 ± 0.1 L/min and sampling time was accounted for round-trip. The sampling times were recorded during the entire trip including waiting time at passenger stations and walking near busy streets in downtown. It was important to note that irregular schedule of the passenger truck and traffic affecting the sampling time. The sampling times varied from 2.27 to 3.52 hours including waiting and walking. Calculated air volume was the product of flow rate and sampling time. Mass concentrations of total particulate matter were calculated as milligram per cubic meter of air. The sampling was performed on two available routes of the passenger trucks.

Indoor and outdoor relationship of $PM_{2.5}$ concentrations were investigated in regularly used classroom and outside of the building. Two Federal Reference Method (FRM) $PM_{2.5}$ samplers, PQ200 (BGI Inc., USA) were operated concurrently for 24 hours period. The required flow rate was calibrated at 16.7 L/min with a primary standard flow device, Deltacal (BGI Corp., USA) according to the manufacturer recommendations. Quartz fiber filters, with 47-mm diameter, were used to collect $PM_{2.5}$ (Pallflex QUATUP, Pall Corp., USA). The filters preparation procedures were similar to the previous paragraph.

Laboratory analysis of the selected toxic metals component found in the filters was further investigated for arsenic (As), chromium (Cd), copper (Cu), lead (Pb), and nickel (Ni). Filters were extracted with hot acid digestion method according to U.S. EPA Compendium followed by the quantification of Inductively Coupled Plasma with Mass Spectroscopy (ICP-MS), (7700 Agilent Technologies, USA). Major soluble ions were extracted with deionized water and analyzed for sulfate (SO_4^{2-}), nitrate (NO_3^-) and ammonium ions (NO_4^+) by Ion Chromatography (Dionex Inc., USA).

Data analysis

Collected data was analyzed as descriptive statistics using MegaStat® and Microsoft Excel® Data Analysis Package. The t-test was used for evaluating mean differences of the average body weight, indoor and outdoor concentrations of fine particulate matter. All statistics significant was tested at 95% confidence level.

RESULTS AND DISCUSSION

A. Age, body weight, and time activity

This study involved undergraduate students who enrolled in 2013-2014 academic year. The total

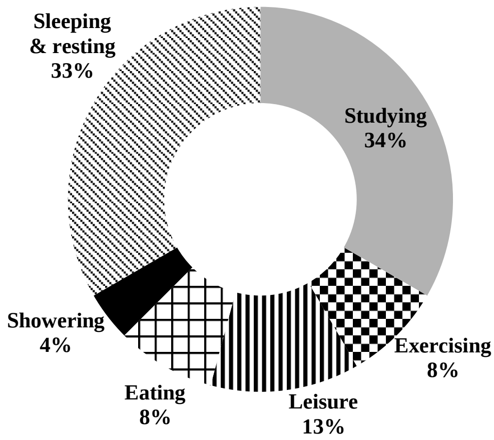

Figure 1 Daily time activity of young adults in the university setting

number of response from the questionnaires was 382 persons (n). The survey showed that the age ranged between 18 and 22 years old. The independent t-test was performed to compare the differences between the averages body weight of male and female. Average body weight of male was higher than female with statically significant ($p<0.05$), 60.4 ± 9.2 and 51.4 ± 8.3 kg, respectively. Overall average body weight of the samples was 52.3 ± 8.8 kg. These numbers were lower than those described by the Exposure Factor Handbook [3]. The Handbook described the average body weight of 71.6 kg for 16 to <21 years old. Some research used 69.0 kg as a mean body weight for adults [11]. Daily time activity was listed to cover the general daily activities. The activities grouped into 6 categories: studying, leisure, exercising, eating, sleeping, and showering. The results indicated that time for studying (both in-class and out-of-class) accounted about 1/3 each day, similar to sleeping and resting (Figure 1). Thus, indoor activities accounted for 1,020 min/day (about 71%). The rest was outdoor related activities, 420 min/day (29%). It should be noted that eating and leisure were in well ventilated areas and in the open-space which indicated the possible intrusion of outdoor pollutants. The Handbook reported about 1,248 and 102 min/day for time spent indoor and outdoor, respectively [3]. In Korea, the average time spent indoor for general population was 1,281.0 ± 125.3 min/day and 76.2 ± 100.9 min/day for outdoor. The rest of the time was in-vehicle, based on 2007 survey [11]. When people spend more time in indoor environment, it is possible that indoor exposure to contaminants may be crucial for evaluating the health impacts [12].

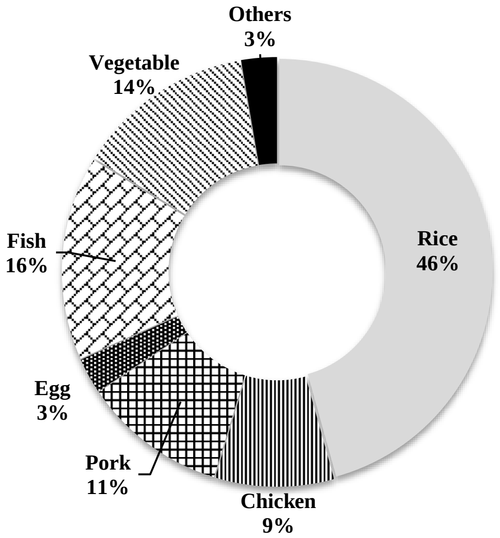

Figure 2 Estimated daily food consumption of students

B. Drinking water and foods consumption

Totally, 502 samples, with repeat measurements over six months, were obtained for drinking water and food consumption determination. The average drinking water consumption was about 883 ± 338 mL/day while a mean value described in the Exposure Factor Handbook was 816 mL/day for 18 – 21 years old [3]. Value in this study was about 100 mL/day higher consumption. Hot and humid climate may contribute to high consumption of drinking water. It was important to note that this study did not account for other beverages, for example, carbonate drink, tea, coffee, etc. Average daily food consumption was estimated at 781 ± 212 g/day. Rice was the main component for each meal at about 357 ± 108 g/day (46%). The samples consumed other foods more than rice or about 424 ± 126 g/day (54%). Main components of the other foods were chicken, pork, egg, vegetables, and fish, accounting for about 9, 11, 3, 14, and 16% of total weight, respectively (Figure 2). It was obvious that the samples had avoided having foods with large amount of liquid due to difficulties in food handling and weighting during data collection.

C. Indoor and outdoor $PM_{2.5}$

Indoor $PM_{2.5}$ measured in the air conditioner operated classroom showed that the average 24-hr concentration (n = 30) was about 47.6 ± 4.9 $\mu g/m^3$. Higher average concentration was found outdoor, 50.6 ± 4.5 $\mu g/m^3$. The independent t-test showed no statistical difference between average indoor and outdoor concentrations of $PM_{2.5}$ ($p>0.05$). Indoor and outdoor ratio (I/O) was approximately 0.94 indicating that both indoor and outdoor $PM_{2.5}$ were equally important. A study in Hong Kong reported I/O ratio measured in houses at 1.4 indicating that indoor environment in household of Hong Kong was an important source of exposure [6]. Similarly, the I/O ratio, in a study in 25 individual living in Boston, USA, was about 1.17 during the winter months [13]. In Scotland [14], I/D ratio varied from 1.4-1.7 depending on the types of buildings. Climate, lifestyle, and local activity may be influential on the level of $PM_{2.5}$. Daily variations between indoor and outdoor $PM_{2.5}$ concentrations were small and no measurement had been performed to determine level of $PM_{2.5}$ in classroom without the air conditioner in this study.

D. Some chemical compositions of personal exposure from TSP during commuting

Chemical analyses of filters (n = 30) exposed during commuting between the university and downtown on selected metals showed that arsenic, cadmium, chromium, copper, lead, and nickel were found at ppb levels. Arsenic concentrations were relatively low, 1.2 to 1.9 ppb (Table 1). Chromium concentrations were found higher than other metals, ranged between 59.8 and 633.4 ppb. Copper concentrations ranged from 8.4 to 13.5 ppb while lead was ranged from 9.3 to 54.4 ppb. In some cases, Cr levels were approached ppm levels. Cu, As, and Ni levels were relatively low compared to other elements. Sulfate was a large contributor for soluble ions found in particulate matter, followed by nitrate.

Table 1 Levels of some observed metals and soluble ions exposed during commuting

Chemical composition	Concentration (ppb) (n=30)			
	Min	Max	Average	SD
Arsenic	1.2	1.9	1.5	0.9
Chromium	59.8	633.4	249.2	387.8
Copper	8.4	13.5	10.4	6.3
Nickel	1.0	19.9	7.6	9.6
Lead	9.3	54.4	27.5	22.3
SO_4^{2-}	231.5	397.6	296.9	125.5
NO_3^-	69.5	192.1	169.9	156.1
NH_4^+	35.0	112.4	77.1	66.2

CONCLUSIONS

Our findings suggested that the actual exposure factors among young adults in a university environment were somewhat differ from widely used U.S. Exposure Factors Handbook [3]. The average body weight was significantly lower than the Handbook. Male had higher average body weight than female, 60.4 ± 9.2 and 51.4 ± 8.3 kg, respectively. Drinking water consumption in the area was slightly higher than in the U.S., possibly the influent of hot and humid climate in Thailand. No other types of beverage were investigated. Food consumption was quite different due to local lifestyle and customary when rice was the main component (46% by weight) but other foods were consumed more on a daily basis. However, foods with the large amount of liquid were avoided by the samples in this study since they had experienced difficulties in weighting. Indoor and outdoor $PM_{2.5}$ levels in the university settings were similar with the mean I/O ratio of 0.94 indicating that indoor and outdoor concentrations were equally important. Sulfate ion had large contribution in particulate matter found during commuting while chromium was surprisingly higher than other measured metals. Overall results indicated that any exposure assessment and environmental health assessment should take into account local conditions when they were selected exposure factors from commonly used references. However, this finding was not extensive and future works are required to better study relevant exposure factors for population in Thailand.

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