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Techno-Science Research Journal

Emission Sources of Air Pollutants in Phnom Penh, Cambodia

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Abstract: *Cambodia is an under developing country and economic development is certainly leading to increase the level of air pollution. In order to keep an economic growth with acceptable environmental loads, the investigations of primary sources are essentially important. This paper discusses a study on Total Suspended Particulate (TSP), Organic Carbone (OC), Elemental Carbone (EC), Char-EC and Soot-EC concentration at the major emission sources, traffic (intensive sampling), construction, brick factory, cooking (Ouressey market), breakfast shop and stove, and also the investigation on daily life of citizens, breakfast shop and generator used at the hotel in Phnom Penh. OC, EC, Char-EC, and Soot-EC were analyzed using the IMPROVE thermal/optical reflectance method with different temperature plateaus and oxidation atmospheres. Referring to our result, 55% of gas using for cooking and 68% of people going to work by motorbike. Breakfast shop generally used 12kg of charcoal per day. The consumption of diesel for generator in hotel, was around 30L/h, when electricity cut of. TSP concentration at traffic side was between 72.55 and 1091.06 μg/m^3 with the average 580.08 μg/m^3 and the linear correlation between TSP and traffic amount is R^2 = 0.77. The average value of OC and EC was 41.25 μg/m^3 and 21.59 μg/m^3 respectively. Amount 5 others sources, stove showed the highest concentration of TSP, OC and EC, 2789.82 μg/m^3, 1454.87 μg/m^3 and 796.45 μg/m^3,while TSP in, breakfast shop, cooking, brick factory, construction were 1210.38 μg/m^3, 454.20 μg/m^3, 380.07 μg/m^3, 266.47 μg/m^3, respectively. These pollutants will give many adverse effects on public health and climate change.*

Keywords: Emission Sources, Air pollutant, TSP, OC, EC, Char-EC, Soot-EC

1. INTRODUCTION

After 1993, Cambodia economy has been increase rapidly and the scale of the city also expended but at the same time it leads to level up of air pollution (Furuuchi et al., 2006). Many emission sources of air pollution from anthropogenic are concerned, especially the rising number of vehicles has resulted in even greater pollution and growth in the population, resulted in a large amount of energy consumption: electricity, automobiles, household, field burning etc. (Furuuchi et al., 2009). Most of the air pollution came from the traditional energy and commercial or modern energy. Modern energy was classified as petroleum products, ignites and coal, and was used in the transport, household sectors and industrial sectors whereas traditional energy was identified from the burning of fuel wood, paddy husk, and charcoal, significant energy sources for households, which commonly are charcoal and wood. Cambodia is not heavily industrialized country but most of the factories still use old technology and not paid attention on the environmental pollution as well as air pollution and never conducted environmental impact assessment and they are located in the Capital City of Phnom Penh. Most of them are garment factory (Ministry of environment, 2004). Anyway electricity supply in Cambodia is not enough so many service sectors use their proper generator, especially the hotels. Generators are not only exhausting the pollutantsin the atmosphere but also the noise. Moreover Phnom Penh is the capital city of Cambodia with highest population and the number of

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vehicles increases day by day, so the traffic jams has been occurred frequently. Most of vehicles are second hand imported and some illicit traffickers continue to import low quality gasoline contains highly sulfur, lead and other substances which banned by the government and restrict by national standards. On the other hand, dust on the road that generate from poor management of construction material due to improper transportation of sand, soil, cement, etc., also concerned (Ministry of environment, 2004). In Cambodia, biomass fuel particularly firewood and charcoal were the main source of energy for cooking (93.1%) and use for small industries. The demand of charcoal and firewood for a domestic using in Phnom Penh was evaluated in 2003/04, 26 000 tons/year for charcoal and 100 000 tons/year for firewood (Aurélien, 2006). From these activities, the dispersion of air pollutants will largely determine the rout of pollution and its degree of severity. The increase of air pollution can cause the adverse effects on public health, including respiratory diseases such as asthma or lung cancer, and environment quality. Specially, soluble organic fraction or Organic Carbone (OC) gives many effects negative like mutagens and carcinogens. OC contains polynuclear aromatic hydrocarbons such as Benzo[a]pyrenes that came from the incomplete combustion of fuel and lubricant (Hisashi et al., 2003). EC also give many impact negative to global warming, carries carcinogenic compounds, and causes serious health risks. Char-EC and Soot-EC are the two mains parts of carbon contents of EC. Char formed at relatively low combustion temperatures from the incomplete biomass burning by heating organicsubstances with limited access of air and it is defined as carbonaceous material or as a difference form of graphitic carbon obtained as a combustion residue. Soot was form by incomplete fossil fuel and wood combustion at higher temperature from the condensation of hydrocarbons in the vapor phase. The different between char and soot is chemical and physical properties. Char is weak light absorption with a strong spectral dependence while Soot is strong light absorption characteristics with little spectral dependence (Han et al., 2010). By the way, Particle matter (PM) was associated with cardiovascular mortality and morbidity. Spontaneous Hypertensive Rate was the effect of single intrataracheal of $PM_{2.5}$, it increased the parasympathetic nervous activity and decreased the heart rate (Ryoko, 2008). PM consists of a complex mixture of solid and liquid particles of organic matter, mineral dust, secondary inorganic aerosols and trace metals, as well as water and unspecified compounds (Katarzyna et al., 2011). In order to avoid the impact negative on public health, climate change and keep an economic growth with acceptable environmental loads, the investigations of emission sources of air pollutants are essentially important.

The objective of this study was to investigate the possible sources and measure the air-pollutants by conducting air monitoring. This research work was captured two mains points: (1)-Survey on possible sources in city area: daily life, breakfast shop and hotel's generators. (2)-Measurement of Total Suspended Particulates (TSP), OC and EC in locations affected by a typical source such as traffic (intensive sampling), stove, cooking (Ouressey Market), brick factory, construction, breakfast shop.

2. METHODOLOGY

2.1 Materials

Portable high volume air sampler (SIBATA, HV-500F, 500 L/min), in purpose for short-time (1 to 24h) TSP sampling for chemical analysis or battery pump (SIBATA, 3L/min), short-time TSP sampling by using battery, used with quartz fiber filter, was installed to collect the samples at each sources of sampling side. In order to conservation and stabilisation, freezer at ITC was used to keep filters for chemical analysis after sampling.

2.2 Methods

TSP, OC and EC have been sampled simultaneously on the at six different sources in Phnom Penh by using high volume air samplers (SHIBATA, HV-500F) for traffic, construction and pumping battery (SHIBATA) for brick factory, breakfast shop, cooking (Ouressey market), stove and construction. After having done the sampling in Phnom Penh, all the filters are returned and analysis at the Kanazawa University, Japan. Before and after sampling, Quartz Fibers Filters (ADVANTEC QR-110 and 47) were stored in a constant humidity and temperature for 72 hours in chamber , after weighing them to determine the concentration of TSP and analyse the chemical pollutants component.

IMPROVE (Interagency Monitoring of Protected Visual Environment) Thermal/Optical Protocol were used to determine the concentration of OC and EC. A 0.5 cm^2 sample punch taken from a quartz-fiber filter is subjected to different temperature and oxidation environments. Carbonaceous materials are volatilized, pyrolized, and combusted to gas-phase compounds that leave the sample and are converted to carbon dioxide as they pass through an oxidizer (manganese dioxide [MnO_2] at 912 °C), then reduced to methane (CH_4) as the carrier gas passes through granulated firebrick impregnated with a nickel catalyst at ~420 °C. The CH_4 is then quantified by a flame ionization detector (FID). A helium-neon (He-Ne) laser (633 nm, red light) is directed at the deposit side of the sample punch, and the R (Reflectance) from and with the Model 2001, T (Transmettance) through the filter is monitored throughout the analysis.

The nominal IMPROVE temperature plateaus in pure He are 120 °C, 250 °C, 450 °C, and 550 °C, and the corresponding thermal carbon fractions are called OC1, OC2, OC3 and OC4. Temperature is ramped to the next step when the FID response returns to baseline or remains at a constant value for more than 30 seconds; the residence time at each plateau is longer for more heavily loaded samples. The analysis atmosphere is then switched to 2% O_2/98%He. Temperature plateaus in the 2% O2/98% He atmosphere are 550 °C (EC1), 700 °C (EC2), and 800 °C (EC3). TC, OC, and EC are calculated from the eight carbon fractions as:

$$TC = OC + EC \quad \text{(Eq. 1)}$$

$$OC = OC1 + OC2 + OC3 + OC4 + OP \quad \text{(Eq. 2)}$$

$$EC = EC1 + EC2 + EC3 - OP \quad \text{(Eq. 3)}$$

3. RESULTS AND DISCUSSION

3.1 Survey on daily life

The human activities is a kind source of air pollution in the large urban area, such as the operation of the city, the density of the population, the development, the travels, the fuels burning for cooking, without carful of air quality, so the amount of air pollutants from these emission sources have increased significantly (Furuuchi et al., 2007). In order to understand this situation clearly, two main activities was investigated. The fuels consumption for cooking and the transport mean of people. Amount seven transport mean, most of citoyen are going to work by motobike (68 %) and a some by car (7 %) as shown in Fig. 1 (a). Furthermore, biomass burning include firewood, charcoal, kerosene andfuel gas used for cooking purpose has caused immense indoor air pollution. Firewood burning produces a large quantity of CO_2, CO, CH_4, N_2O, $SO_2$and TSP (MoE). As shown in Fig. 1(b), generally they use gas (55 %), electricity heater (26 %), and the charcoal (16 %) and a part of wood for cooking.

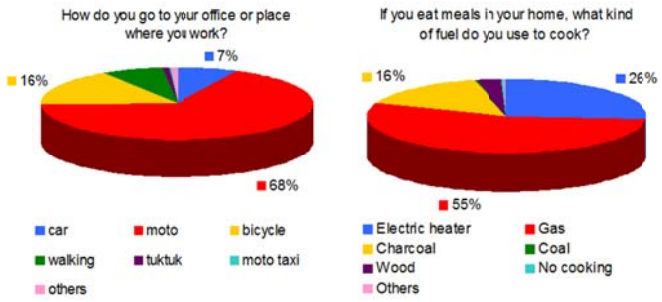

Fig.1.Resuls of 446 data, (a) Transport means, car, motorbike, bicle, walking, tuktuk, moto taxi and other, (b) Fuels consumption, electricity heater, gas, charcoal, coal, wood, no cooking and other.

3.2 Survey on breakfast shop

In Cambodia, a part of people have their breakfast at the restaurant (breakfast shop) before they go to work and and the number of restaurant also increase day by day. After the result of survey as shown in Table 1, generally breakfast shop work from 4am to 10am by using charcoal as fuel around 12 kg/day and they used the quantity of meat around 11kg/day for preparing the food and selling, but the duration of cooking by using the charcoal was mostly from 5:30am to around 9am. Quantity of port used can predict the charcoal using according to the seller's estimation. Two type of stove was used for cooking, iron and traditional lao stove in different size. These activities are the main source that leads to the level up of air pollutants at the early morning.

3.3 Survey on hotel's generators

The hotels in Phnom Penh are still widely use their own generator to support the energy when the electricity supplied by Electricité Du Cambodge (EDC) cut off. But sometime, they also used the generator to support their own business. As the result shows in Table 2, hotel uses generator which has the puissance between 250 to 450 KVA, nearly every day at the morning around one to tree hours per day, depend on the region of electricity supply. It was found that maybe 30 L/h of diesel was used.

3.4 Traffic analysis

During our sampling, in order to make a correlation between the concentration of particles and the traffic activities,camera video was used to record the car, motorbike, bicycle, truck, walker and bus passed through the road (Russian federation Blvd., near Century market) every hour in 5min (24h) (Zhenxing et al., 2010). There was no traffic jam on this road during sampling but it is also a busy road. After taken, the number of the traffic activities was count, as the result in the figures below. Fig. 2 shows the percentage of differences types of vehicles passed throught the road. Motorbikes were the large number of vehicles (71 %) and some other was the car (23 %). On this way, truck also presented (1 %). Truck was not proper and it carried a lot of dust and also emit large of particles from their machine. Fig. 3 show the number of vehicles crossed the road during 24 h. The number of traffic peaked in morning around 7am then decreased till 10 am but it increased again at 11 am and then decreased. It continued to plot again during the evening then decreased to the lowest at 2 am and from 4 am, it continued to increase, so this activity was contributed to the level up of particles during the early morning. According to the survey result, most of citizens go to work

at 7 am (33 %) and back home at 5 pm (30 %). So during these time the particles pollutants represents the highest level compared with the other time.

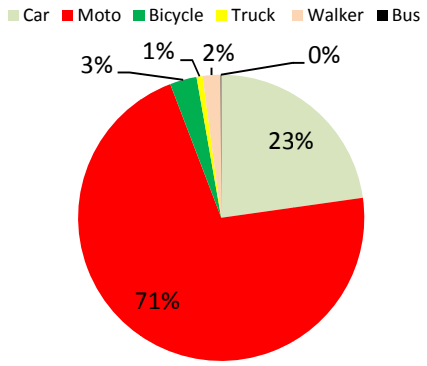

Fig.2.Percentage of traffic activities cross the road, 24h (5 min/hour). Number of car, motorbike, bicycle, truk, walker and bus every hours during 5min recording per day.

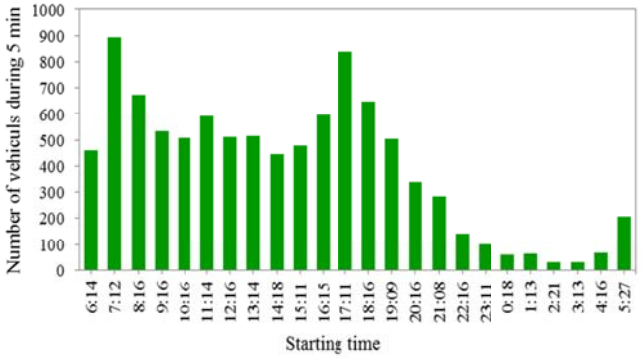

Fig.3. Variation of traffic activities, 24h (5 min/hour). Total of vehicle cross the road every hours during 24h.

, number,

3.5 Traffic

Fig. 4 shows the concentration of TSP at traffic side every 2h during 24h. TSP concentration was in the range 72.55 to 1091.06 µg/m^3. It has level up in the morning. It was 873.95
µg/m^3 during 6 to 8am and it was a little decreased from 8 to 10 am but it continued to increase a little to 843.46 µg/m^3

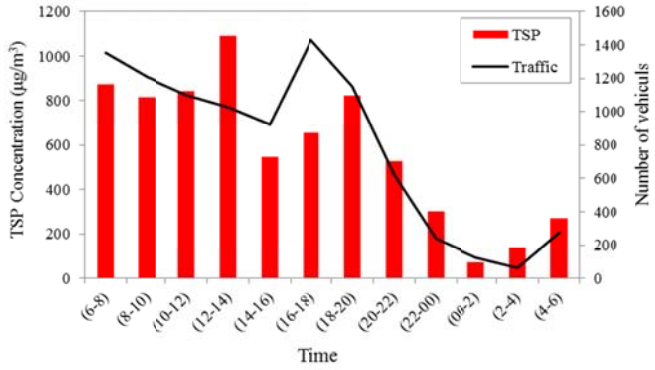

Fig.4. TSP concentration at traffic side (µg/m^3). Evaluation of Total Suspended Particulate (TSP) during 2h.

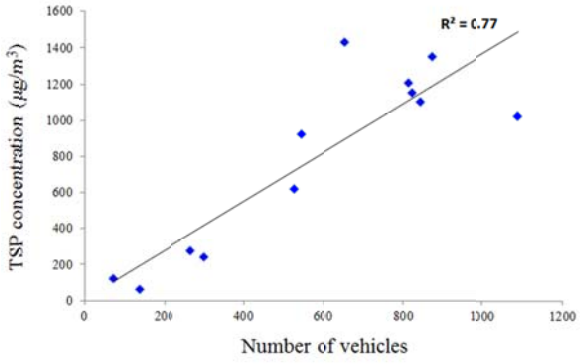

Fig.5. Correlation between TSP and traffic. The linear regression was 0.77 between number of vehicles and TSP concentration.

between 10 to 12am. Then, it peaked during 12 to 14 pm to 1091.06 µg/m^3, because of the activity of road cleaner, but after that it declined to 545.38 µg/m^3 during 14 to16pm. It is continued to increase during 16 to 18 pm and 18 to 20pm to 656.97 µg/m^3 and 824.18 µg/m^3 respectively. And then it was decreased again during 20 to 22pm, 22 to 00 pm and 00 to 2am to 527.17 µg/m^3, 304.04µg/m^3, 72.55 µg/m^3 respectively. But it started increasing in the early morning, to 138.18µg/m^3 during 2 to 4am and continues up to 269.56µg/m^3 during 4 to 6am. This variation depends on the activity of traffic along the road. The results obtained in our study show good correlation between TSP concentration and number of traffic, R^2 = 0.77 but it was also contributed by road dust as shown in Fig. 5.

Fig. 6 shows the different concentration of OC, EC, Char-EC and Soot-EC. The concentration of OC and EC for this intensive sampling varies from 19.60 µg/m^{3}to 66.44 µg/m^3 and 1.93 µg/m^3 to 46.11 µg/m^3 respectively for the same duration, 00 to 2 pm and 6 to 8pm. The result of OC and EC were similar to the result of TSP, they were also high during the morning. But the concentration of OC was large higher than EC from 20 to 22pm. The concentration of OC and EC was low during 2 to 4 am and 00 to 2am and the concentration of EC was also low during 20-22pm and 22-24pm. But the concentration of OC and EC started to increase in the early morning. The average value of OC and EC was 41.25 µg/m^{3}and 21.59 µg/m^3 respectively, was lower than the average value of OC and EC, 53.0 µg/m^3 and 17.0 µg/m^3 respectively in Xi'an, China but higher than the average value of OC and EC in the Birmingham, 4.6 µg/m^3 and 3.8 µg/m^3 respectively (Zhenxinget al., 2010). Whereas Soot-OC was always higher than Char-EC because most of particles was came from the gasoline and diesel combustion of vehicles. Soot-EC and EC showed a good correlation with the traffic activity, R^2 = 0.80 and R^2 = 0.78, while OC and Char-EC was less correlation, R^2 = 0.61 and R^2 = 0.69, respectively, compared to EC and Soot-EC as shown in Fig.7.

As Cambodia is a developing country, dust generated from the street was occurred, and it has been identified the more air pollution concerns because of poor management of material (Ministry of environment, 2004). Fig.8 shows the concentration average of TSP, OC and EC every 2h during 24h. TSP concentration was large higher nearly 14time than OC and 28time than EC because of the dust generated from the street and the dust from the vehicles non proper.

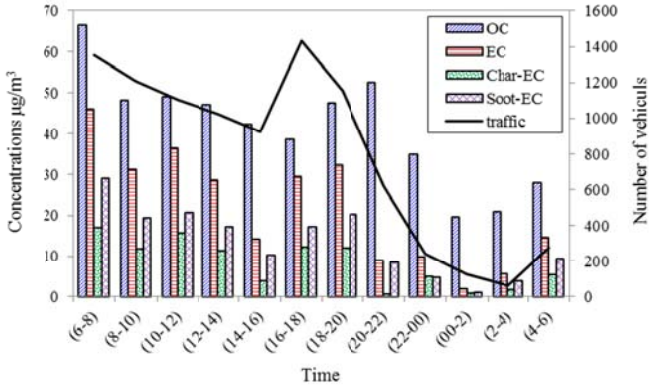

Fig.6. OC, EC, Char-EC, Soot-EC and Char-EC at traffic side (µg/m^3). Intensive sampling of Organic Carbon (OC) Elemental Carbon (EC), Soot-EC and Char-EC concentration during 24h.

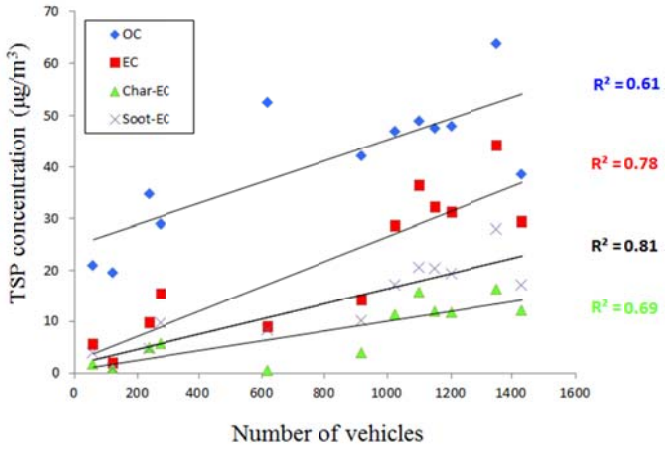

Fig.7. Correlation between OC, EC, Char-EC, Soot-EC and traffic.

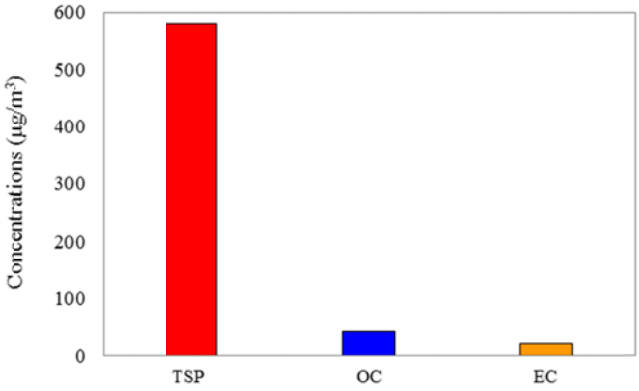

Fig.8. Average concentration of TSP, OC and EC (µg/m^3). Total Suspended Particulate (TSP), Organic Carbon (OC), Elemental Carbon (EC).

3.5 Others 5 sources

These 5 emission sources, traffic, construction, brick factory, cooking, breakfast shop and stove, shows the different levels of TSP. The sampling side of stove has the highest concentration of TSP, 2789.82 µg/m^3, while the sampling side of construction presented lowest of TSP, 266.47 µg/m^3. The sampling side of breakfast shop was also represent a high level of TSP, 1210.38 µg/m^3 but the sampling side of Ouressey market and brick factory were relatively low level of TSP, 454.20 µg/m^3, 380.07 µg/m^3, respectively, compared to stove, as presented in Fig.9.

Fig.10 shows OC and EC of each sample from emission sources of air pollutants have been determined by using the method thermal/optical. The concentration of OC and EC varied in the 5 sources of emissions from 89.70 to 1454.87 µg/m^3 and from 0.56 to 796.45 µg/m^3 respectively. The highest concentration of OC and EC was found at the sampling side of stove. But the lowest concentration of OC was found at the construction while the lowest concentrationof EC has been identified at Ouressey market. But the sampling side of construction, breakfast shop was also low the concentration of EC, 3.91 µg/m^3 and 18.15 µg/m^3 respectively.

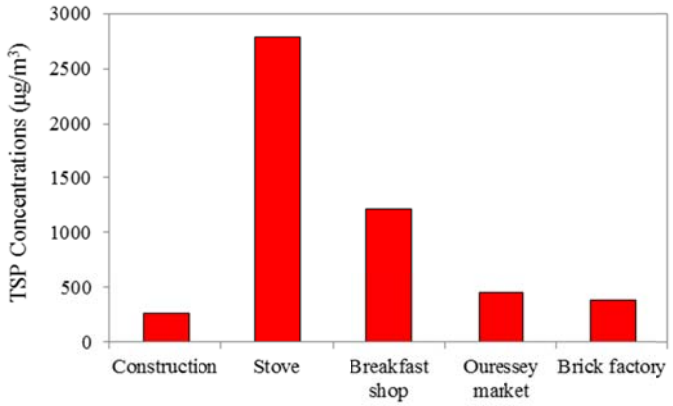

Fig.9. TSP Concentration at 5 others differences sources (µg/m^3). Comparing the TSP of construction, stove, breakfast shop, cooking and brick factory.

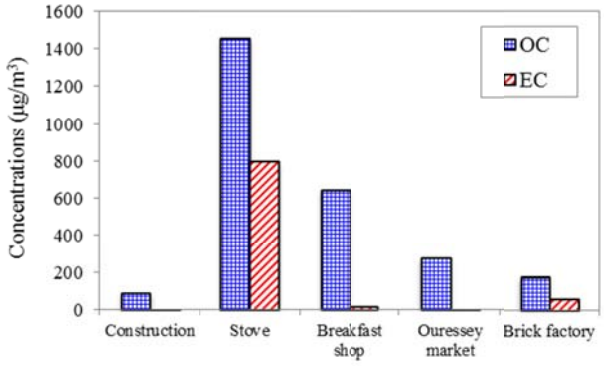

Fig. 10. OC and EC concentration at 5 others differences sources (µg/m^3), construction, stove, breakfast shop, cooking and brick factory.

In fact, the concentration of OC was always higher than the concentration of EC and the concentration of TSP. OC and EC concentrationsfromthe stove was higher than other because of fuel consumption, wood was using for cooking. The wood contains high moisture and cellulose, so when the wood was burned, it'll break out more fume and concentration of carbon into the atmosphere.

4. CONCLUSIONS

According to the results of the investigation, the more part of citizens activities contributed to the air pollution are cooking by using charcoal, and wood and the transport

means. The main sources that lead to level up the concentration of pollutants in the early morning are the breakfast shop and the traffic activities. The hotels in Phnom Penh are stillwidely using their own generator to support the energy when the electricity cut. The concentration of pollutants increased in the morning and increased again at the evening at the traffic side with the average of TSP, 580.08 μg/m^3. Soot-EC is always higher than Char-EC. These pollutants were showed a good correlation with traffic activities. Anyway the five others sources, TSP, OC and EC were highest at the stove, while TSP and OC were low at the construction but EC was low at the Ouressey market and also at the construction. These primary pollutants for each source of pollution will also disperse and transform to secondary pollutants in the atmosphere by the condition of the wind, temperature, pressure, and precipitation, which give the adverse effects on public health and the climate change.

ACKNOWLEDGMENTS

This study was sponsored by School of Environmental Design, College of Science and Technology, Kanazawa University. We would like to acknowledge Prof. Masami FURUUCHI, administrator of this project, for his support and Dr. Mitsuhiko HATA, assistance of Prof. Masami FURUUCHI, for his explanation and helpful during our work although he was busy.

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