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Preparing emission factors of carbon dioxide, carbon monoxide, hydrocarbons and nitrogen oxides for cigarette

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ABSTRACT:

Introduction: Thousandths dangerous chemicals are found in cigarette smoke. Each day millions cigarettes are consumed and its smoke is emitted in the atmosphere. Although several studies have been carried out on cigarette smoke, there is no reliable emission factor for pollutants emitted from burning cigarette. The aim of this study is to prepare four emission factors to estimate amount of carbon dioxide, carbon monoxide, total hydrocarbons and nitrogen oxides per each cigarette.

Materials and methods: In this study a set of experiments was designed to achieve this aim. Different brands of cigarettes were prepared and then they was burned by a vacuum pump. Their cigarettes smoke was analyzed by a gas analyzer to find the concentration of carbon dioxide, carbon monoxide, total hydrocarbons and nitrogen oxides in the cigarettes smoke. Next, the average emission factor for complete burning of a cigarette was calculated.

Results: High amount of pollutants could be found in cigarette smoke. The results revealed that 0.01 mg of hydrocarbons, 0.13 mg of carbon monoxide, 0.5 mg of carbon dioxide and 0.01 mg of nitrogen oxides are emitted during complete burning of each cigarette.

Conclusion: If the number of consumed cigarettes was available, these emission factors can be used to understand the share of cigarette smoke in air pollution of large cities to understand whether cigarette consumption is effective on air pollution.

Introduction

Air pollution phenomenon occurs when dangerous chemicals such as gases, particulates, and biological molecules are entered into atmosphere. There are a large number of anthropogenic activates that can emit air pollutants [1]. Transportation systems and industries are known as the most important sources of air pollutants [2]. However, there are many other sources of air pollutants such as cigarette consumption which no enough study has been done on them. The cigarette consumption have started since 5000 to 3000 BC in Mesoamerica and South America. Initial cigarettes were imported to Eurasia in the late 17th century by European colonists. Nowadays, cigarette can be easily found world-

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wide. During burning cigarettes over 4000 various chemicals including carbon dioxide, carbon monoxide, hydrocarbons, and nitrogen oxides are emitted in atmosphere [3-5]. A large number of organic chemicals have been categorized as hydrocarbons [6]. Several hydrocarbons are found in smoke of cigarettes [7]. Nearly seventy of the chemicals in cigarettes including vinyl chloride, formaldehyde, acetaldehyde, acrylonitrile, 1-aminonaphthalene, 2-aminonaphthalene, benzo[a]pyrene and benzene are known to cause cancer [8-10]. Also, some heavy metals such as cadmium, chromium and arsenic are found in cigarette smoke [11]. Recent studies showed that many radioactive chemicals such as Lead-210 and polonium-210 are presented in cigarette smoke [12].

Smoking increases human health risk [13]. Nearly one in five deaths in the United States causes by cigarette consumption. It is reported that each 10 min one person in Iran is died due to cigarette consumption [14]. Stroke and coronary heart diseases in smokers are 2 to 4 times more than nonsmokers [15]. Lung cancer for smokers is 25 times more than nonsmokers [16]. Furthermore, smokers are around 12 times more predicted to die from chronic obstructive pulmonary disease than nonsmokers. Cigarette consumption not only can increase the risk of various diseases for consumers, it is a serious indoor air pollution source that cause many diseases for nonsmokers. Therefore, nonsmokers who are exposed to cigarette smoke, are in the health risk. It seems that there is no significant difference between health risk of men and women how consume cigarette [13].

Millions of cigarettes are consumed daily worldwide, resulting in the release of a large amount of different pollutants in the atmosphere [17]. There is no exact information on the share of smoking on air pollution in Iran since the lack of a reliable emission factor for smoking. Although several researches have been carried out on detecting compounds in cigarette smoke, no study has yet been made to determine the emission factor for carbon dioxide, carbon monoxide, total hydrocarbons and nitrogen oxides emitted by cigarettes. Therefore, the aim of this study was to provide pollutants emission factors for smoking. A series of experiments were designed and implemented to determine the emission factor for carbon dioxide, carbon monoxide, hydrocarbons and nitrogen oxides.

Materials and methods

Since all pollutants of carbon monoxide, total hydrocarbons, carbon dioxide and nitrogen oxides can be found in cigarette smoke, a set of experiments was designed to find their amount. For this aim a small system to burn cigarette was made (Fig. 1). In this study, 3 different famous brands of cigarette were selected. Then, cigarettes were installed according to Figure 1 on a peristaltic pump with a flow rate of 7.14 mL / s. The cigarettes were burned and the sucked gases were transferred to a small chimney with a diameter of 0.05 m. In the chimney, a QROTECH gas analyzer model QRO-401 was installed to measure concentrations of carbon monoxide, total hydrocarbons, carbon dioxide and nitrogen oxides. This gas analyzer was used under humidity less than 85 % and it was setup at least 25 cm from the ground surface. Since the flow rate of gases in the chimney is important to find the emission rate of them, a flowmeter was used to measure the sucked gases flow rate. Finally, Eq. (1) was used to determine the emission rate of pollutants. Then using Eq. (2), the emission rate of the pollutants was converted to emission factor.

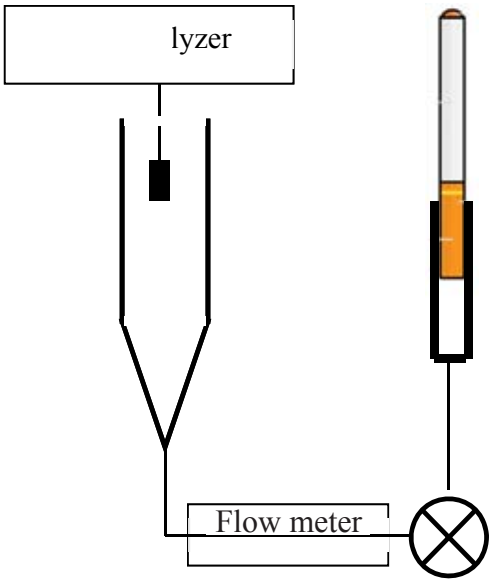

Fig. 1. Schematic of experimental equipment to measure emission rate of pollutants for cigarette

Where ER is emission rate of pollutants in mg / s, Q is gas flow rate in the chimney in m^3 / s, D is diameter of chimney in m and C is concentration of pollutants in chimney in mg / m^3.

$$ER = \left[\frac{4Q}{\pi D^2}\right] \times C$$

Where EF is emission factor of pollutants in kg per each cigarette and t is average time of each cigarette burning.

Results and discussion

The results of this study showed that hydrocarbons, carbon monoxide, carbon dioxide and nitrogen oxides could be found in cigarette smoke (Table 1). The amount of total hydrocarbons was 0.01 mg / cigarette. It was also found that 0.13 mg of carbon monoxide, 0.5 mg of carbon dioxide and 0.01 mg of nitrogen oxides are emitted during complete burning of each cigarette. Charles et al. (2008) reported an emission factor of 3644 mg for volatile organic compound per each cigarette, which is very higher than emission factor that reported in this study [18]. These researchers reported that there are also particular matters (PM) in the cigarette smoke. They stated an emission factor of 18 mg / cigarette for PM.

Table 1. Emission factors of different pollutants during burning a cigarette

No.	Pollutant	EF (mg / cigarette)
1	HC	0.01
2	CO	0.13
3	CO_2	0.50
4	NO_x	0.01

Based on occupational safety and health administration, the maximum exposure limits for carbon monoxide, carbon dioxide and nitrogen oxides are 64.5, 6465 and 1.29 mg / m^3, respectively [19, 20]. If it is assumed that a cigarette was consumed in a room with length of 8 m, width of 5 m, height of 3 m and volume of 120 m^3, it is estimated that the concentration of carbon monoxide, carbon dioxide and nitrogen oxides will be increased up to 0.00108, 0.00416 and 0.00008 mg / m^3, respectively. As can be seen the concentration of carbon monoxide, carbon dioxide and nitrogen oxides in the assumptive room is less than the recommended maximum exposure limits. Hydrocarbons are a large number of organic compounds that several of them are carcinogen even in very low concentrations. These results showed that the important pollutants in cigarette are hydrocarbons. Unfortunately, in this study the concentration of different hydrocarbons emitted from cigarette consumption were not determined. Therefore, we were not able to say toxic and carcinogenic hydrocarbons can be more than maximum exposure limit due to consumption of a cigarette in assumptive room or not.

It is necessary to prepare an emission inventory of pollutants for each city or country [21]. Since millions of cigarettes are consumed in cities every day, smoking can be considered as a source of pollutants in each area. If the number of cigarettes consumed in each country, city or area is determined, using Eq. (3) the emission rate of the pollutants given in Table 1 can be easily calculated.

$$E_{pollutant} = AR \times EF$$

Where $E_{pollutant}$ is rate of pollutants emission in kg / year and AR is number of consumed cigarette.

Conclusion

In this study four emission factors were introduced to estimate amount of carbon dioxide, carbon monoxide, total hydrocarbons and nitrogen oxides for burning each cigarette. This study showed that 0.01 mg of hydrocarbons, 0.13 mg of carbon monoxide, 0.5 mg of carbon dioxide and 0.01 mg of nitrogen oxides are emitted during complete burning of each cigarette. These emission factors can be used for understanding the share of cigarette smoke in air pollution in large cities.

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Competing interests

The authors declare that there is no conflict of interest that would prejudice the impartiality of this scientific work.

Author's contributions

It is certified that all of the authors have made the same contribution in the experiments and manuscript writing.

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Ethical considerations

Authors are aware of, and have complied with, best practices in ethics, specifically with regard to authorship (avoidance of guest authorship), dual submission, manipulation of figures, competing interests and compliance with policies on research ethics. Authors adhere to publication requirements that the submitted work is original and has not been published elsewhere in any language.

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