ARTICLE
ESTIMATING METHANE EMISSIONS FROM DIFFERENT LAND-USE TYPES IN THE URBAN AREA

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Abstract: *In the recent decades, greenhouse gas (GHG) emissions increased considerably; due to the remarkable growth in anthropogenic activities. These gasses have potential warming effects on the atmosphere as long as they accumulate in the atmosphere.*

Methane (CH_4) as a GHG has very high radiative forces, with a short lifetime of approximately 10 years. Therefore, targeting CH_4 emissions would bring immediate climate benefits in the short-term. Land-use changing policies in the urban area decrease CH_4 sinks and affect the urban contribution in CH_4 budget. However, the uncertainty of CH_4 emissions in the urban area is very high, so that estimating CH_4 concentration is important to take appropriate mitigation measures.

In our study, we estimated street-level CH4 concentrations in the following four urban areas: the city center (CC), the central park (CP), a residential area (RA), and a commercial area (CA). An Enhanced Portable Fluxmeter device with a precise measurement of 0.1 parts per million (ppm) was used to perform these CH4 estimations between 10:00 and 12:00 am (EEST), from 20-30 March.

The results showed that the CC and CA have an elevated contribution in CH4 concentration with more than 2.3 ppm. The RA recorded the least as hypothesize. Surprisingly, the CP which was supposed to have the least contribution in CH4 concentration from the anthropogenic perspective, was estimated to have ascending records. These findings demonstrate the remarkable contribution of the urban area in influencing CH_4 concentration, and recommend further CH4 investigation in the urban area and to identify its potential sources.

Keywords: greenhouse gas, methane concentration, urban area, land-use, pollution

INTRODUCTION

In the recent decades and since 1850, emissions of greenhouse gas (GHG) such as: carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) increased considerably; due to the remarkable growth in anthropogenic activities(IPCC 2014). These gasses have significant warming effects on the atmosphere as long as they accumulate in the atmosphere. However, their lifetime in the atmosphere is different, their harmful climate effects vary as well (EPA 2022).

The effects of GHGs range from extreme phenomena of climate change, lack of potable water, loss of species, to increase in death rates (CDC 2022a; EPA 2022; Portier et al. 2010), in addition to mental health, respiratory difficulties and cardiovascular diseases (Luber et al. 2014; WHO 2022). These effects will mostly put the lives of old people, children and women under risk (CDC 2022b; Portier et al. 2010; WHO 2003). Therefore, acting fast in reducing GHG emissions would help in reversing this climate crisis (Klenske 2021).

Methane has extreme radiative forces, but at the same time its lifetime is quite short of approximately 10 years (IPCC 2013). For this reason, targeting CH_4 emissions would bring climate benefits in the short-term (Maazallahi et al. 2020).

Methane come from incomplete burning of organic matter (IPCC 2013), the transformation process of organic matter into fossil fuels (IPCC 2013; Kulongoski et al. 2018), from deep soil layers of high temperature and pressure (Kulongoski et al. 2018), wetlands, sea, rice paddies, combustion of biomass and fossil fuels (IPCC 2013), and it can also be produced in the soil rhizosphere from microbial activities (Kulongoski et al. 2018).

The potential sinks of CH_4 are its oxidation by soil methanotrophic in aerobic conditions (IPCC 2013; Kevin R. Tate 2015) and in the atmospheric layers of troposphere and stratosphere by OH radicals (IPCC 2013).

In Romania, energy and agriculture are primarily contributing to CH_4 emissions on the national level. Methane emission estimates between 1989 – 2000 showed that CH_4 emissions declined by more than 30%; due to the decrease in emissions from these two sectors (ANPM 2020).

In the urban area, CH_4 emissions come from industry, traffic, combustion of fossil fuels and wastewater treatment facilities (Barhoumi et al. 2019; Takano et Ueyama 2021). Also, leaks from natural gas networks in the urban area are other sources of environmental pollution, besides representing a loss of energy sources and a potential contributor in CH_4 fluxes in the urban atmosphere (von Fischer et al. 2017; Zazzeri et al. 2015).

Moreover, land-use policies in the urban area decrease CH_4 sinks and affect the urban contribution in CH_4 emissions (Kevin R. Tate 2015; K.R. Tate et al. 2007).

Von Fischer et al. (2017) stated that there is a high degree of uncertainty in CH_4 emissions in the urban area and therefore, it is important to quantify these emissions and to identify urban areas with high CH_4 concentrations, in order to take the appropriate mitigation measures.

In the current study, we aimed to investigate the influence of land-use policies on the concentration of atmospheric CH_4. To this extent, we conducted street-level CH_4 estimations in the following four urban areas: a highly congested area of the city center (CC), a green area with less human influence of the central park (CP) to represent as a background source for concentration, a residential area (RA) with low traffic density, and commercial area (CA) with high traffic density.

The selection of these four urban areas aimed to measure the difference of gas emission. The objectives of this study are to establish a better understanding of the correlation between land-use types and CH_4 concentration, to point out the importance for further investigation in the urban area in case of significant CH_4 concentrations and different variations, to reduce the degree of uncertainty regarding CH_4 emissions in the urban area and to give decision-makers indicators to potential CH_4 sources for applying appropriate mitigation measures.

Figure 1. The location of the study area in the city of Cluj-Napoca, Romania and the four land-use types, and the location of the measuring points in the commercial and the residential areas as illustrated in the legend.

MATERIALS AND METHODS

The first step of this study was the preparation of a map for field work by identifying the locations of the main four sites, in order to estimate street-level CH_4 concentration in these different land-use sites. The four land-use locations are city center (CC), central park (CP), residential area (RA), and commercial area (CA) which differ in their land-use and human activities supposing different sources of CH_4 fluxes. The field map produced by utilizing online Google Map (Google, USA, 2022).

The measurements in these four sites were divided into two sections. The decision for doing such division aimed for targeting potential sources of CH_4. The first section included one single strategy in both RA and CA by placing the device of the Enhanced Portable Fluxmeter (Westsystems, Italy) at specific locations identified in Figure 1, by carrying the portable device on a human back and holding the inlet tube at approximately 1.5 m height; for estimating street-level concentrations caused by traffic flow or other potential sources. This portable device measures CH_4 and CO_2 simultaneously per second in parts per million (ppm) with a high measuring precision of 0.1 ppm. The second section was performed in CC and CP by walking around and within these two areas in order to cover any possible potential source of CH_4 within the identified areas in (Fig. 1).

The average CH_4 concentration in ppm was estimated at each second between 10:00 and 12:00 am (EEST), from 20-30 March 2021 for one time at each location, according to its specified method. The obtained data from each area was saved on-site and then extracted in the laboratory for further statistical and spatial analysis, by using Microsoft Excel and Word (Microsoft, USA, 2022).

RESULTS AND DISCUSSIONS

In this study, we demonstrated the estimation of street-level CH_4 concentration in four urban areas as part of estimating the influence of urbanization on CH_4 budget. The current estimations were performed in four main land-use areas of city center (CC), central park (CP), residential area (RA), and commercial area (CA) (Figure 1). The atmospheric CH_4 concentrations in each area were plotted in ppm against the recording time (Figure 2).

In our study, we found out that CH_4 atmospheric concentration in CC has high records as observed in Figure 2. The mean value of all records in this area was 1.8 ppm. In addition, the maximum value was estimated at 2.8 ppm and the minimum value was 1.7 ppm, with 0.2 ppm standard deviation. Concentrations were changing in regard to traffic flow. At some point, concentrations hit 2.7 and 2.8 ppm as a truck vehicle passed by.

The CH_4 concentrations in the CP had 1.9 ppm for the mean value, and 2.2 ppm, 1.8 ppm and 0.1 for the max, min, and the standard deviation values, respectively. Concentrations of CH_4 seemed to be steady around 1.9 and 2.0 ppm. These numbers were aimed to be used as indicators to CH_4 background.

Moreover, the mean CH_4 concentration in RA was estimated at 1.6 ppm. Also, the minimum, the maximum, and the standard deviation values are 1.5 ppm, 1.7 ppm, and 0.1ppm, respectively. The values of CH_4 in this area fluctuated between 1.5 ppm and 1.6 ppm in a regular rhythm.

Also, the minimum and the maximum values of atmospheric CH_4 concentration estimated in CA were 1.7 ppm and 2.3 ppm, respectively. The mean value of these concentrations was 2.0 ppm with 0.1 ppm standard deviation. This area observes two steady stages of concentration, one between 1.9 and 2.0 ppm, and another between 2.0 and 2.1 ppm. High concentrations were recorded during the time when big vehicles were passing. These fluxes can be related to gas emissions released from vehicles and particularly from big trucks.

However, Table 1 summarizes all statistical findings in the four areas.

In CC and CA, records showed that land-use type can influence CH_4 concentration, but not in a considerable way as the maximum values in these two areas didn't exceed 2.8 ppm confirming what was stated in (EC. JRC. 2021) that agriculture and energy sectors have a considerable influence.

The low emissions in RA can be referred to the absence of traffic, as proposed at the beginning of this study. However, winddirection fluctuated the emissions from time to time and these might be referred to some sources from household activities or from nearby sources.

These results confirm the suggestions of diversity in CH_4 concentrations according to the land-use type. It seems clear that concentrations of CH_4 in the urban area differ according to the type of use of this area. However, at some points of field work the device measured high concentrations of CH_4 which gives an indication towards the presence of a potential source.

In contrast, the results don't go along with what was hypothesized at the beginning for CP to have the lowest concentration of CH_4 compared with the other land-use types. Nevertheless, biogenic sources are mainly responsible for these high concentrations (Fernández-Baca et al. 2021).

Despite the results in the CP were not exactly as expected, fluctuation in concentrations in the CC and the CA recorded high concentrations as hypothesized.

This study didn't also succeed in identifying what is exactly behind these concentration differences. Therefore, further investigation is required for identifying the sources behind these CH_4 in the urban area.

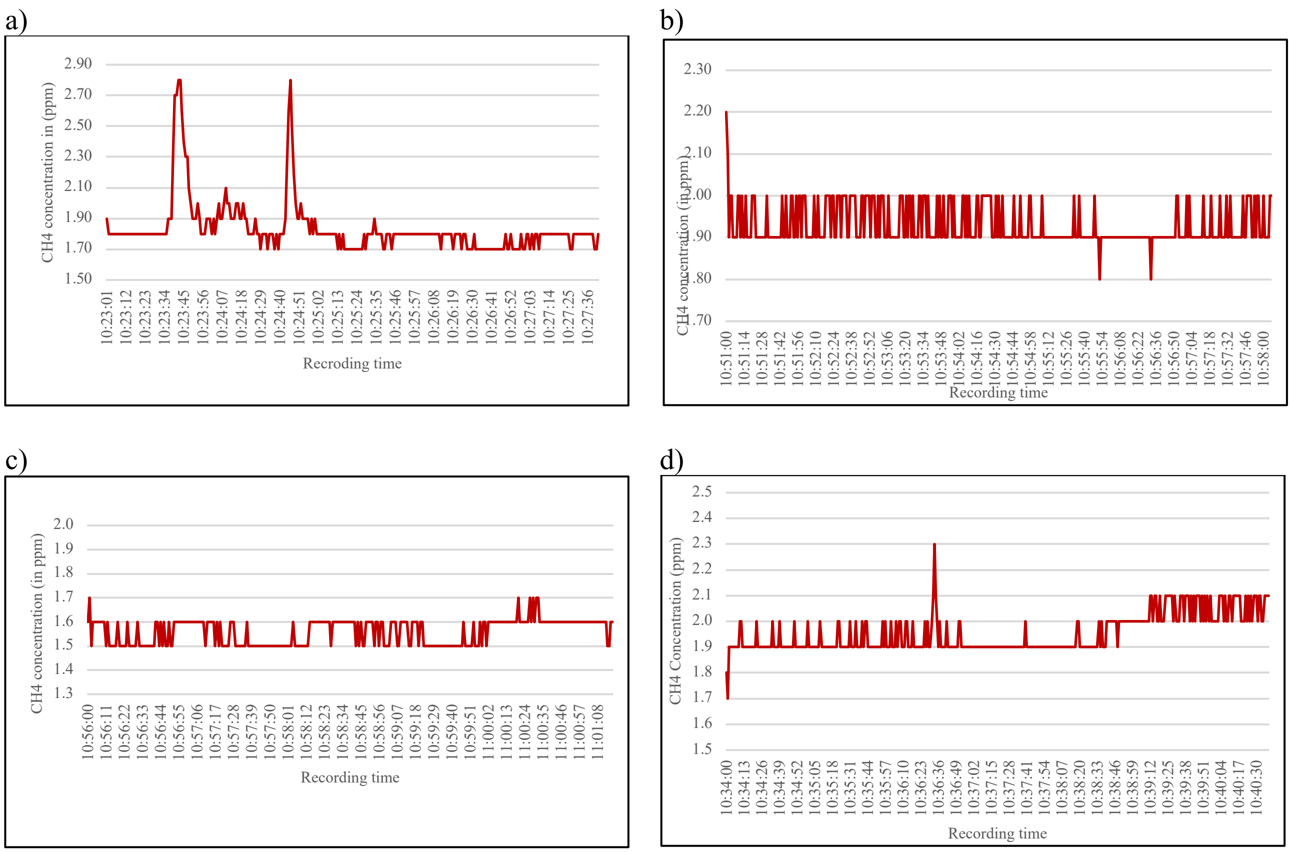

Figure 2. Atmospheric CH_4 concentrations (in ppm) per recording time estimated in the different land-use areas, a) city center CC, b) central park CP, c) residential area RA, and d) commercial area CA.

From anthropogenic perspective, the CP was considered away from human activities of traffic, industry or combustion of fossil fuels. However, from our estimation, as illustrated in Figure 2, average CH_4 concentrations are high in comparison with the commercial and the city center estimates. The average concentration of CH_4 was estimated at 1.9 ppm. In addition, the minimum and the maximum values of these concentrations were 1.8 and 2.2 ppm, respectively.

City center area is considered very busy with commercial activities and high traffic. This is supposed to influence CH_4 emissions and by default the quality of air. The average concentration of CH_4 in the city center is approximately high compared with the residential area average concentration, but still less with 0.1 ppm from the commercial area with high traffic. Nevertheless, this central area had high records of 2.3, 2.6, 2.7 and 2.8ppm.

Table 1. Statistics of CH_4 street-level concentration in (ppm) of the four land-use types including mean, maximum, and minimum values in addition to the standard deviation (SD)

Land-use type	Mean	Max	Min	SD
CC	1.8	2.8	1.7	0.2
CP	1.9	2.2	1.8	0.1
RA	1.6	1.7	1.5	0.1
CA	2.0	2.3	1.7	0.1

Results in our study of the four areas indicated that CH_4 concentrations increase in high traffic and the park area which signifies that CH_4 is emitted from natural and anthropogenic sources. Similarly, Takano & Ueyama (2021) estimated that CH_4 emissions from commercial areas are quite high; due to natural gas combustion and transportation in comparison with emissions from residential areas.

However, wind was also one of the main factors that affected the fluctuation of these emissions as stated by Lowry et al (2020), von Fischer et al (2017) and Weller et al (2019). The time and the used method are definitely important factors in estimating the actual CH_4 concentration and to determine their sources which was also mentioned by Lamb et al (2016).

Also, the application of other methods is much expensive in our case study and due to the lack of resources.

CONCLUSIONS

Atmospheric CH_4 concentration estimation studies are important for indicating sources of CH_4 emissions on a city scale. This study estimated atmospheric CH_4 concentration in four different land-use areas, in order to highlight anthropogenic urban activities that are responsible for high CH_4 emissions. From the selected four types, the commercial area and the city center showed higher contribution in CH_4 emissions with more than 2.3 ppm.

However, the residential area recorded the least contribution in street-level CH_4 as supposed at the beginning of the study with a mean value of 1.6 ppm. Surprisingly, the central park, which was supposed to have the least contribution in CH_4 concentration, from an anthropogenic perspective, was estimated to have high records approximately close to the concentrations in CC and CA.

This study succeeded to indicate that land-use policies may affect CH_4 atmospheric concentration in the urban area and showed high concentrations in areas with increased anthropogenic activities in CC and CA. At the same time, this study couldn't precisely identify the actual sources behind those high concentration values which recommend further investigation in the urban area.

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ISSN 1582-1021
e-ISSN 2668-4764
Edited by "AUREL VLAICU" University
Arad, Romania

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