## Methane Footprint of the Bishkek Municipal Landfill. Satellite data.

**The Bishkek municipal landfill polygon** (henceforth BMLP or 'landfill') was opened in 1978 (but technically worked from 1972 onwards), at this time it was designed to receive the waste of 400,000 people. Currently, according to unofficial statistics around 1.2 million people live in the capital and the landfill site has expanded to cover over 46 hectares[1].

This is the only current place for disposing of waste. It is located 10 from the city and receives waste from the city and new housing developments (figure 1). The actual usage period of the landfill site has surpassed the regulatory usage period by more than 10 years. Today more than 24 million cubic metres of waste are stored on the landfill, even though the site was intended to hold 3.3 million cubic metres of municipal solid waste.


Figure 1. The location of the Bishkek Municipal landfill polygon, data from 2014[2].

The landfill is located in a region that has high levels of groundwater, which leads to filtration of the wastewater from the landfill into aquifers. Wind currents carry waste across the

[1] https://economist.kg/novosti/vlast/2022/11/11/pochemu-musornyj-poligon-v-bishkeke-vse-eshhe-gorit-i-kuda-potratili-dengi-na-ego-likvidaciju/

[2] World's Fifty biggest dumpsites, Waste Atlas 2014, https://d-waste.com/Atlasreport2014/Waste-Atlas-report-2014-webEdition.pdf

surrounding area, thus polluting the soil layers and surface water. The products of burning, eroding, and rotting waste pollute the atmospheric air. [3].

One of the pollutants from the landfill are waste gases, which are primarily composed of methane (50-70%), CO2, and a small quantity of non-methane organic compounds. Landfills are the third largest anthropogenic source of methane on the planet and are responsible for around 11% of global methane emissions[4].

**Methane** is a greenhouse gas and is the second largest contributor to global warming after carbon dioxide. It is 20-25 times more effective at maintaining heat in Earth's atmosphere than CO2. Although it is a relatively short-lived gas, its presence in the atmosphere can last around 10±2 years. Reducing its concentration in the atmosphere would be an effective means of mitigating global warming in the coming years (i.e., within the next 25 years)[5,6].

The concentration of methane in the atmosphere has increased more than twofold over the course of the last two centuries. For a long time, its concentration was around 750 ppb and started to quickly grow after 1700-1750, reaching around 1750 ppb in the year 2000, and 1900 ppb in 2022 according to some estimates (globally averaged)[7]. Global methane emissions by 2020 are estimated at 9,390 million metric tonnes of carbon dioxide equivalent (million tonnes CO2E), of which around 60% of methane emissions came from anthropogenic sources (i.e., resulting from human activity), which includes landfills[8].

Beyond the indirect impact on the climate, methane emissions negatively affect air quality and contribute to smog. Methane reacts with nitrogen oxide to create ozone pollution and correspondingly smog. This pollution seriously worsens people's health: it affects respiratory organs (which exacerbates respiratory illnesses such as asthma and chronic bronchitis), the cardiovascular, reproductive, and nervous systems. If the exposure is prolonged, the risk of early death increases[9].

**Possible methane pollution from the Bishkek municipal landfill polygon**. Unfortunately, there is not any high-level data about methane pollution from the landfill, because quality measurements have not been carried out. This sort of data can be obtained using indirect methods, such as, satellite information.

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[3] Экологический обзор Кыргызской Республики. ГАООСИЛХ КР, 2009. http://aarhus.kg/wp-content/uploads/2017/01/Ecoobzor_2009.pdf

[4] Управление по охране окружающей среды США (U.S.EPA), 2011 г. ПРОЕКТ: Глобальные антропогенные выбросы парниковых газов (кроме CO2 ): 1990–2030 (отчет EPA 430-D-11-003), www.epa.gov/climatechange/economics/international.html.

[5] https://www.iea.org/articles/global-methane-emissions-from-oil-and-gas

[6] https://scied.ucar.edu/learning-zone/how-climate-works/methane

[7] Laboratory, US Department of Commerce, NOAA, Earth System Research (November 7, 2022). "Globally averaged marine surface annual mean data". https://translated.turbopages.org/proxy_u/en-ru.ru.4d0c15fb-64615bb2-6c05db71-74722d776562/https/gml.noaa.gov/webdata/ccgg/trends/ch4/ch4_annmean_gl.txt

[8] Управление по охране окружающей среды США (U.S. EPA), «Глобальные антропогенные выбросы парниковых газов (кроме CO2): отчет за 1990–2030 гг.» www.epa.gov/climatechange/Downloads/EPAactivities/EPA_Global_NonCO2_Projections_Dec2012.pdf.

[9] https://theconversation.com/methane-is-a-potent-pollutant-lets-keep-it-out-of-the-atmosphere-103055

The use of satellites is one of the most recent and promising developments in the understanding of methane pollution levels across the world. Various satellites that are active today can provide evaluations of methane concentrations in the atmosphere in various geographical regions. This is especially pertinent in those regions where observations are not being made or are being made irregularly, as is the case with the BMLP [10].

*Aim of the work – to try to define the quantity of methane that the BMLP using satellite data.*

The data involved are maps for the research of air pollution over the Bishkek landfill taken by the satellite Sentinel-5 Precursor (Sentinel-5P). This is a space satellite, launched in 2017 by the European Space Agency (ESA) with the aim of monitoring the chemical composition of the Earth's atmosphere on a daily basis, as well as its levels of pollutants and greenhouse gases. The primary useful cargo on the satellite is the sensor TROPOMI (Tropospheric Monitoring Instrument), which collects data.

Methane content is usually measured as parts per million or billion (ppm and ppb respectively). The data from Sentinel-5P is given in ppb (or $bn^{-1}$) of dry air. However, cloud levels seriously influence the measurements of concentrations of this gas, therefore measurements are only possible in absolutely cloudless weather. Time resolution of the sensor is 1 day with global coverage. Due to the marked influence of cloud levels on the measurement of methane concentrations, it is advisable to map its concentration by averaging measurements over a long period of time (a month, a season, a year)[11].

We will analyse methane pollution in a radius of 4-5 kilometres from the landfill (in order to account for the effects of atmospheric conditions (i.e., wind) on the diffusion of pollution) and directly above the landfill itself, showing the highest and lowest levels of methane pollution, that have been observed in this area.

Figure 2 is a model of an interactive map with data on the methane concentration in the area surrounding the BMLP. Around the landfill there is an obvious increase in methane concentration.

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[10] https://www.undp.org/sites/g/files/zskgke326/files/2022-10/kachestvo_vozdukha_v_bishkeke_ru_1.pdf - Качество воздуха в Бишкеке: Оценка источников выбросов и дорожная карта для содействия управлению качеством воздуха.

[11] https://innoter.com/articles/issledovanie-zagryazneniya-atmosfery-po-kosmicheskim-snimkam-sentinel-5p/

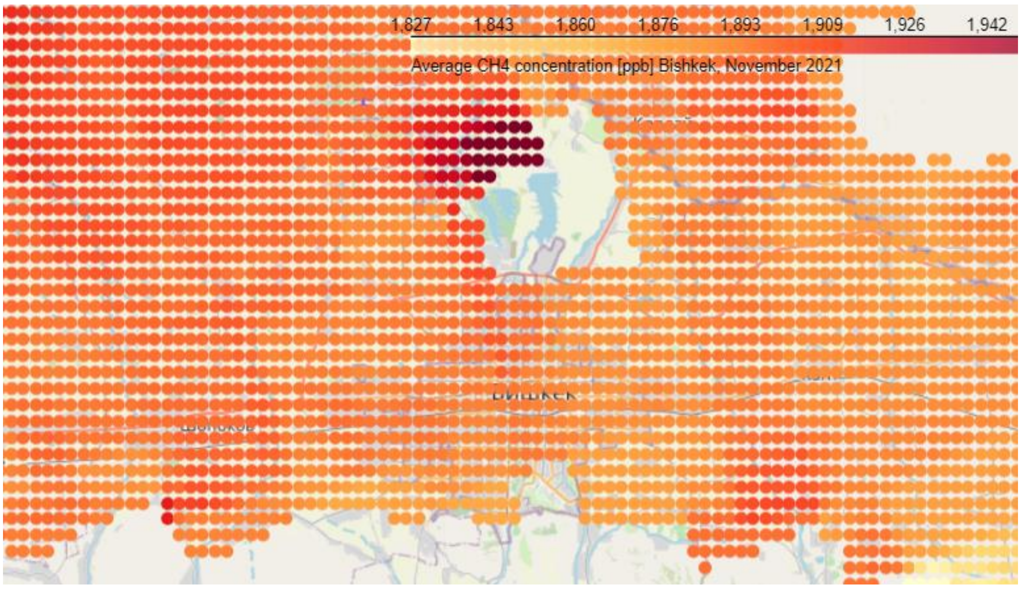


Figure 2. Average methane levels in Bishkek in November 2021, data from satellite Sentinel-5P, sensor TROPOMI, ppb or $bn^{-1}$.

Using these data, a map of average methane pollution per month, covering the four-year period from 2019-2022 was created. Despite some gaps in the data, the first interesting results have been obtained.

Figure 3 shows the annual course of methane concentrations averaged over 4 years (2019 - 2022), both directly in the area of the landfill itself and in a surrounding 4-5 km radius.

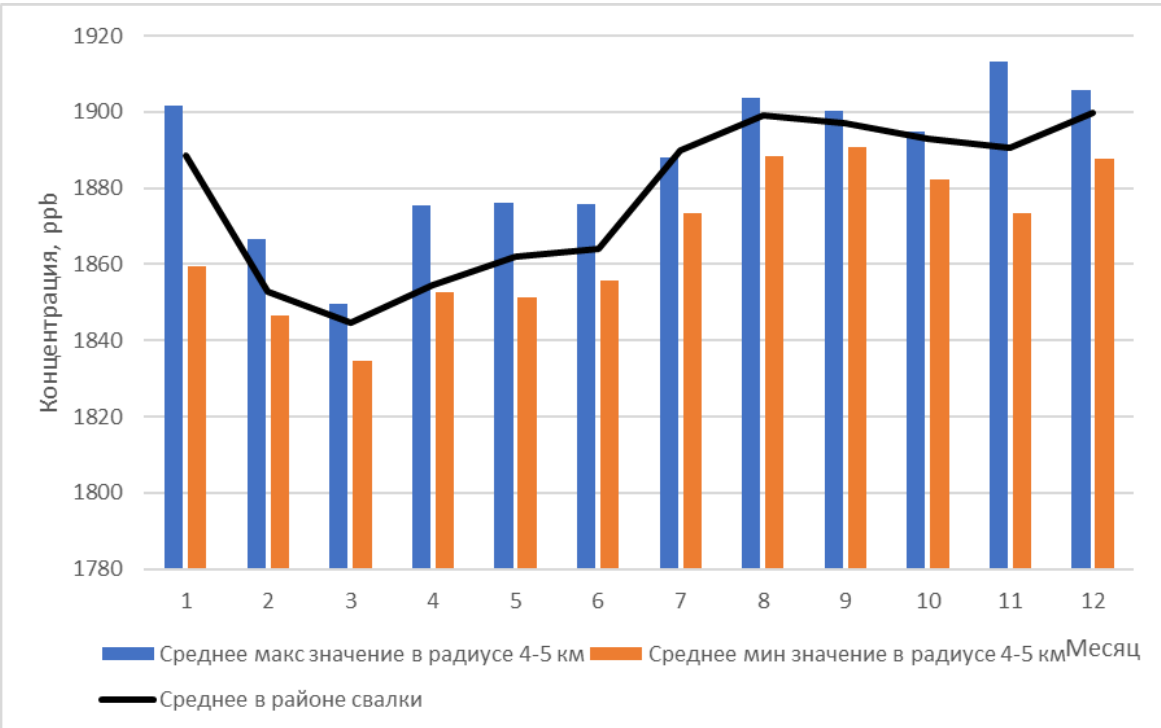


Figure 3. Monthly methane concentration levels averaged over 4 years (2019-2022), in the area of the landfill and in a radius of 4-5km from it, measured in ppb.

In the area *immediately above* the landfill, methane emissions are unevenly distributed throughout the year. The highest average values are observed from July to January, ranging from 1,889 to 1,900 ppb. The highest values are recorded in August and December. The lowest average values are observed from February to June and range from 1845 to 1864 ppb, with the lowest value occurring in March.

*Within a radius of 4-5 km* from the landfill, the trend of methane concentration distribution continues. The highest concentrations out of the maximum average values are observed between August and January and are between 1900 and 1913 ppb, with the maximum in November. The lowest of the maximum average values are the same as in the landfill itself in March with 1850 ppb.

The highest concentrations of methane from the minimum average values occur from August to October and in December, and range from 1882 to 1891 ppb, with a maximum value in September. The lowest of the minimum average values is observed from February to July (1835 to 1853 ppb) with a minimum in March at 1835 ppb.

Methane concentration in the atmosphere over the landfill area can vary from year to year, but generally the annual pattern repeats itself, with maximum values from August to January and the lowest values in March. The distribution of methane concentrations in the atmosphere by year is shown in Figure 4.

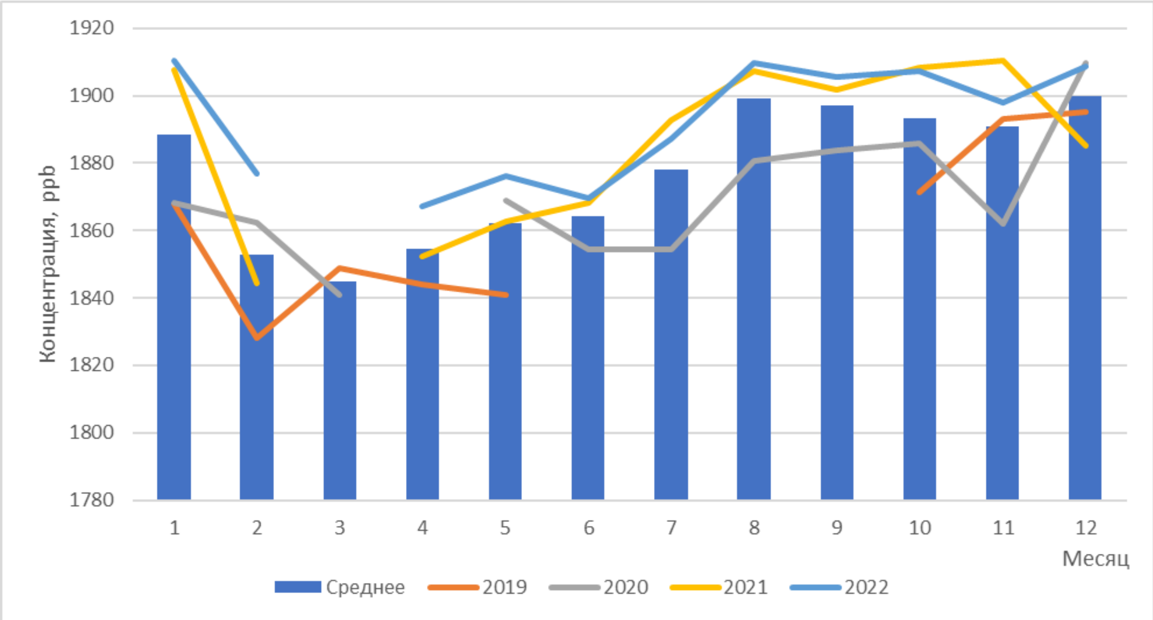


Figure 4. Monthly distribution of methane concentration by individual years over the landfill area, measured in ppb.

It can be seen that the highest methane emissions occurred in 2021 and 2022, with average annual methane concentrations of 1,886 and 1,892 ppb respectively. At that time, the maximum values did not fall below 1900 bbl-1 and the minimum values did not fall below 1845 bbl-1 (unfortunately, data for March are not available). Methane pollution in 2020 was generally lower (a yearly average concentration of 1870 ppb), although maximum values also reached 1900 ppb (December), but minimum values dropped to 1840 ppb (March). Data for 2019 is not available for every month of the year.

Most likely, such an annual distribution of methane emissions over the landfill can be explained by the constant processes taking place in within the landfill. The differences in these values can be explained by factors affecting these processes (landfill volume, air temperature, amount of precipitation, etc.).

Outside the landfill area (at a distance of 15 km from the landfill) and away from areas with methane-emitting activities (e.g., agricultural activities), methane levels in the atmosphere are lower according to satellite data (average for 2019-2022) and are 1826 - 1871 ppb depending on the month of the year. Figure 5 shows the monthly distribution of methane concentration averaged over 4 years over the landfill area and within a radius of 15 km (away from possible sources of methane emissions). It can be assumed that the difference in methane concentration is due to the impact of the landfill.

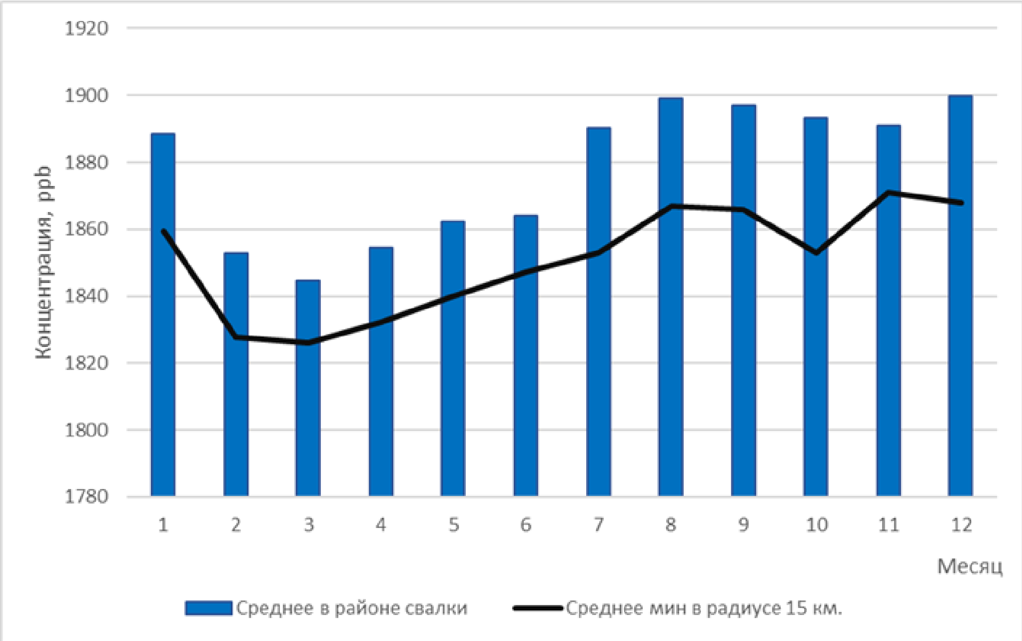


Figure 5. Monthly distribution of methane concentrations averaged over 4 years (2019-2022) in the landfill and within a 15km radius, measured in ppb.

It can be seen (Figure 5) that, in general, the annual course of concentrations is identical on and off the landfill site. The largest difference (methane contribution from the landfill) is observed in the warm period of the year from July to October and in December-January, amounting to 29 - 40 ppb. In the other months, i.e., in November and from February to March (the lowest point), the difference is around 17 - 25 ppb. Cumulatively, the annual contribution of the landfill was 326 ppb averaged over 4 years (2019 - 2022). This is important because the landfill produces methane emissions which are significant enough for the satellite to “notice”.

It can also be assumed that near the Earth's surface methane concentrations are high enough to affect human health (the health effects of methane are discussed above), both those working at the landfill and those living in the residential areas near and around the BMLP.

Thus, for the first time, complete systematic data on methane concentrations over the landfill area and within a radius of 4-5 km from it have been obtained. The available data (for each month of the year from 2019 to 2022) on methane concentrations from the BMLP show:

- *The landfill contributes to atmospheric methane pollution*, the difference in methane above the landfill and outside the landfill area averages between 17 and 40 ppb per month, and for a year it is 326 ppb;

- *Elevated methane concentrations up to 1913 ppb are also observed within a radius of 4-5 km from the landfill*, this is due to the influence of atmospheric conditions (e.g., wind, etc.) on the spread of pollution;
- *Year on year, methane concentration in the atmosphere from the landfill increases*, on average by 10 ppb in the years studied;
- *The distribution of atmospheric methane emissions has a regular annual pattern*, which can be explained by the constancy of processes occurring on the landfill site;
- Some annual variation in methane concentration above the dump and within a radius of 4-5 km can be explained by changing factors affecting it (volume of waste, the air temperature and temperature of the waste itself, precipitation levels, etc.)
- It can be assumed that the methane concentration at ground level is high enough to affect the health of people both working at the landfill and living in the residential areas surrounding the BMLP.