

NITROUS OXIDE EMISSION FROM LANDFILLS: A BIBLIOMETRIC ANALYSIS

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Abstract:

Urban solid wastes need to be properly disposed and one of these means is the landfill, where wastes organic fraction degradation occurs. One of the by-products generated in this environment shows high ammonia nitrogen concentrations in its constitution, which can cause the increase in nitrous oxide (N₂O) production rates. N₂O is one of the main greenhouse gases, with high global warming potential. In view of the scarce information on the N₂O emission into landfills, the objective of this study was to evaluate the research trends on the emissions of this gas, especially in landfills, using bibliometric analysis as a tool. The publications survey was conducted in the Web of Science database from 1991 to 2021. First, papers on N₂O emission sources were researched and, later, the scientific studies that were only related to landfill emissions were verified. The following parameters were evaluated: scientific journals, authors, countries, number of publications over time, research institutions, keywords occurrence, and Web of Science categories. 3,988 papers on N₂O sources in general and 146, on landfill emissions were found. In both analyses, there was a predominance of Chinese publications and very few Brazilian publications, since among the studies on the various emission sources, 125 Brazilian papers and no paper in the case of landfills were found. Regarding the temporal analysis, there was a trend of linear increase in the number of publications for both analyses. With this survey, the need to conduct more research on the N₂O emission in landfills was found, especially in Brazil, to obtain an accurate knowledge on how this source can affect the global balance of this gas with high impact in climate changes.

Keywords: Greenhouse gases, emission sources, solid wastes.

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INTRODUCTION

Urban solid waste (USW) represents a major challenge in the management of environmental public policies. The inadequate final disposal of USW can generate several impacts that are not only limited to environmental problems, such as groundwater and soil contamination, and also comprise public health aspects where the proliferation of disease-causing vectors is evidenced (Klein *et al.*, 2018).

An alternative widely used in several countries for the final disposal of this waste is the landfill (Yang *et al.*, 2014). The use of landfills is an economically and environmentally appropriate option for the disposal of such waste. This method is based on engineering principles for the containment of solid waste to the smallest possible area, covering them with land (ABNT, 1984).

In the landfill, the USW undergo several physical, chemical and biological transformations that result in a liquid by-product, with high concentrations of reactive nitrogen (N) in its constitution, especially ammonia-N. The presence of high levels of reactive N can intensify nitrous oxide (N₂O) emission rates by nitrification and/or denitrification mechanisms, depending on the different control variables such as: dissolved oxygen (DO) availability, redox potential, pH, temperature, among others (Wrage *et al.*, 2001).

N₂O is considered one of the main greenhouse gases (GHGs), with a global warming potential higher than carbon dioxide (CO₂) by 273 times (IPCC, 2021). In addition, unlike other GHGs, N₂O also acts indirectly on the consumption of stratospheric ozone (O₃) (Ravishankara *et al.*, 2009; Müller, 2021).

Currently the average concentration of N₂O in the atmosphere is 333 ppb, representing an increase of 22% when compared to the pre-industrial period (IPCC, 2014; NOAA, 2022). This increase of N₂O in the atmosphere is the result of N₂O emissions intensification in recent years, especially those from anthropic sources, such as agricultural activities. Globally, the average N₂O emission rate was 0.79 ± 0.05 ppb year⁻¹ for the period from 1995 to 2011, while in the period from 2011 to 2019, this amount corresponded to 0.96 ± 0.05 ppb year⁻¹ (IPCC, 2021). However, regarding the N₂O emission by landfills, there is little precise information regarding its contribution, since this

source of emission is not taken into account in the IPCC Guidelines.

In view of the above, conducting a survey on the research trends on the topic is of utmost importance. Bibliometric analysis has been used in several areas of knowledge in order to evaluate scientific production and research trends, allowing the mapping of different variables of interest, such as the number of productions over time, organizations that produced more content, and funding agencies that most contributed to scientific production in the area (Ho, 2014; Tan *et al.*, 2014; Teixeira & Ribeiro, 2014; Santos *et al.*, 2019; Zhang *et al.*, 2019). For this reason, this study aims to analyze research trends on N₂O emissions, especially in landfills.

METHODOLOGY

In order to develop a bibliometric analysis about the various sources of N₂O emission, especially landfills, a search for publications was conducted in the web of science database. Web of science database was selected because it significantly represents global scientific production, with more than 70 million registered papers. For the data processing and the elaboration of maps, electronic spreadsheets and VosViewer software were used.

First, all papers on N₂O emission sources were researched. For that, the following search algorithm were used: $ts = ((\text{"nitrous oxide"})$ and $(\text{"emission source"})$). The acronym 'ts' refers to what web of science classifies as 'topics', which covers the fields: title, abstract and keywords. Therefore, the database will look for scientific papers where the terms nitrous oxide and emission source appear in the title, abstract, or keywords. The research was conducted for the period from 1991 to 2021, considering the papers published until September of this last year.

In this bibliometric analysis, the following parameters were evaluated: scientific journals, authors, countries, number of publications over time, research institutions, keywords occurrence, and web of science categories. Subsequently, a survey was also conducted on scientific studies on nitrous oxide emissions from landfills only. So, the following algorithm was used: $ts = ((\text{"nitrous oxide emission"})$ and ("landfill")). The period considered was the same as the previous analysis and the same parameters were evaluated.

RESULTS

Bibliometric analysis of publications on N₂O emission sources

For the considered period, from 1991 to 2021, the number of publications returned by the search was

3,988 papers. The identification of the scientific journals that most publish papers on a given topic makes the choice by researchers easier regarding the journal that they should submit their papers. **Figure 1** shows the most prominent scientific journals in the publication of scientific papers on the various sources of N₂O emission.

The scientific journal with most publications on the topic studied was the *Science of the Total Environment*, which is in the area of Environmental Sciences and has 167 published papers. To investigate the identification of the authors who appear most in papers on a given topic is extremely important to identify who contributes the most to scientific production. **Figure 2** lists which authors are most prominent, considering the number of publications on the topic of N₂O emissions from different sources.

The generated data showed that the main authors are, respectively, Zhang, J.; Butterbach-Bahl, K. and Li, Y. The author with the greatest number of publications has Chinese nationality.

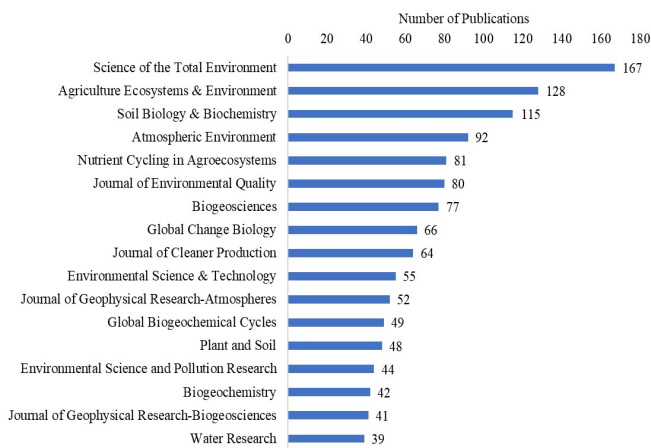


Fig. 1 Scientific journals that have published the most on the various N₂O emission sources.

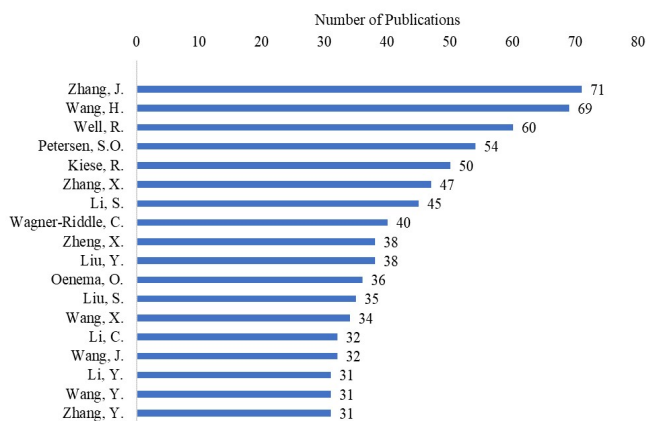


Fig. 2 Researchers and their relevant contributions regarding the various N₂O emission sources.

Assessing the nationality of the authors who publish the most about N₂O emission is a good indication to identify those countries that invest most in research in the area. **Figure 3** shows the distribution of countries with the greatest number of publications on N₂O emission sources.

Among the 3,988 papers found on the topic, most of them are from the USA. China ranks 2nd with 880 publications; Brazil ranks 15th with 125 publications.

Another parameter evaluated was the evolution of the number of publications over time. **Figure 4** shows the number of papers published annually on the topic from 1991 to 2021.

The number of papers published on the topic showed a trend of exponential increase during the analyzed period, and it is noticeable that scientific production was more prominent in the last 10 years. It is important to point out that, to date, the peak of publications occurred in 2020, characterized as a pandemic year. The analysis was performed considering the papers published until September 2021, that is, the number of publications of this last year may still be higher than that hereby shown.

The parameter on research institutions informs which universities or research centers contribute the most to the scientific production of journals. **Figure 5** shows the distribution of research centers with greater emphasis on the number of publications on the topic of different sources of N₂O emission.

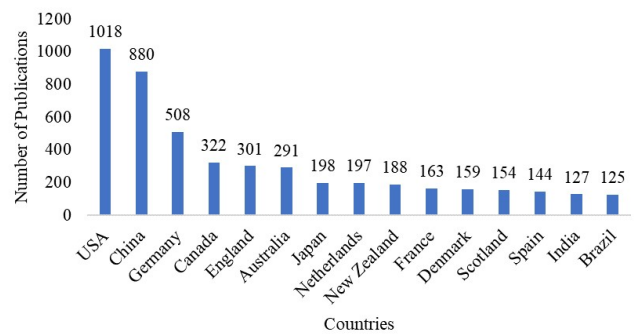


Fig. 3 Countries that have published the most on N₂O emission from various sources.

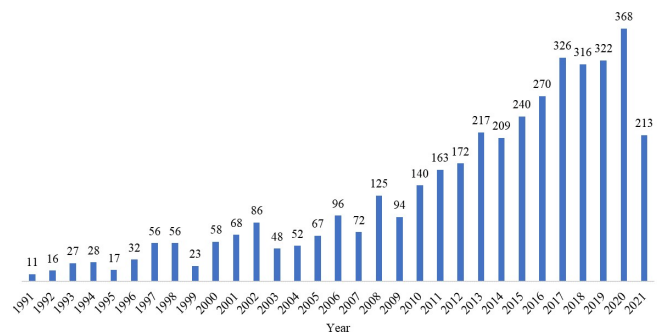


Fig. 4 Evolution of the number of publications on N₂O emission sources over time.

The journals that are most prominent are *Waste Management* and the *Journal of the Air & Waste Management Association*, since together they account for 20% of all publications on N₂O emissions in landfills from 1991 to 2021. The main authors who published N₂O emissions in landfills are shown on Fig. 9. The generated data shows that the main authors are, respectively, Zhang, H.; Wang, X. and Chen, S. The author with the greatest number of publications has Chinese nationality.

Figure 10 shows the distribution of countries with the highest emphasis by the number of publications on N₂O emissions into landfills. From the 146 papers found on N₂O emission, specifically in landfills, most of them are of Chinese origin. The United States ranks 2nd, with less than half of published papers compared to China. Figure 11 shows the number of papers published annually on the topic from 1991 to 2021.

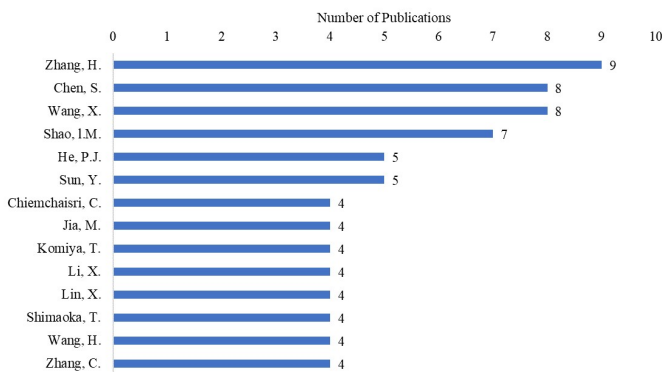


Fig. 9 Authors who published more on N₂O emissions in landfills.

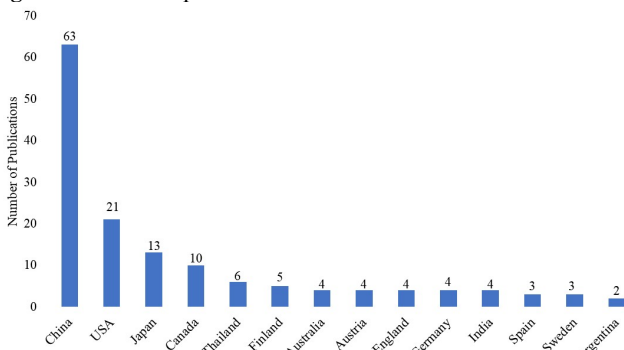


Fig. 10 Countries that have published the most on N₂O emission in landfills.

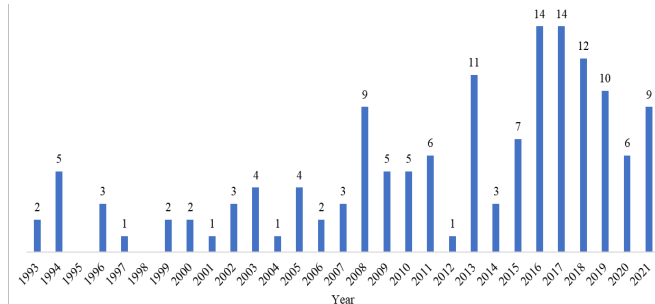


Fig. 11 Growth trend in the number of publications on N₂O emissions in landfills over time.

Analyzing the chart generated, it is noticeable that scientific production shows many variations over time. However, it is observed that there is a trend of linear growth. Figure 12 shows the distribution of research centers with the greatest prominence by the number of publications on N₂O emissions in landfills.

China, in addition to being considered as the country that publishes the most on N₂O emission in landfills, is also where the institution that produces most of the papers on the topic is located: the *Chinese Academy of Science*. It is important to point out that among the 15 research institutions with the greatest prominence in the number of publications on the topic, 7 are Chinese.

Figure 13 shows a map of the main keywords used by the authors and the co-occurrences between them over time. As noted, most of the papers published on the topic occurred in the area of Environmental Sciences. The difference between the number of papers inserted in the two main categories is quite expressive. From the 146 published papers, 74% of them are included in the Environmental Sciences area, while in the second main category, Environmental Engineering, 39% of the papers are inserted.

The words that appeared the most were: *nitrous oxide emissions* (35 occurrences), followed by *methane* (30 occurrences), *denitrification* (28 occurrences) and *nitrous oxide* (23 occurrences). Figure 14 shows the bibliometric map representing the density of publications in the different categories of the Web of Science.

The other most influential areas were: Meteorological Atmospheric Sciences (15%) and Microbiology Applied to Biotechnology (7%). Considering that publications can be inserted in more than one *Web of Science* category, the sum of the percentages assigned to all categories results in a value greater than 100%.

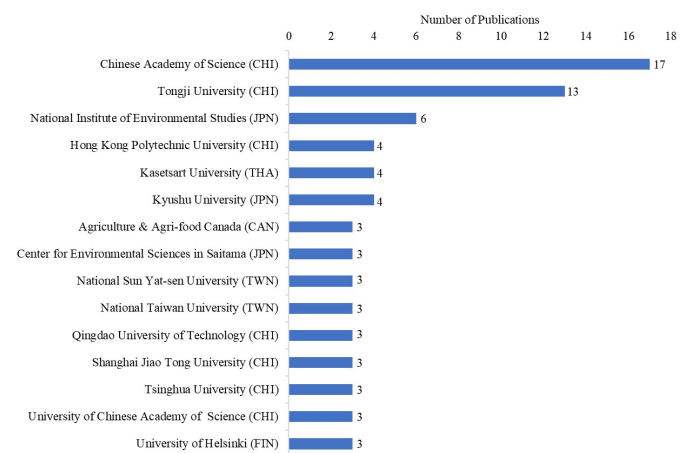


Fig. 12 Publications made in research centers on N₂O emission in landfills.

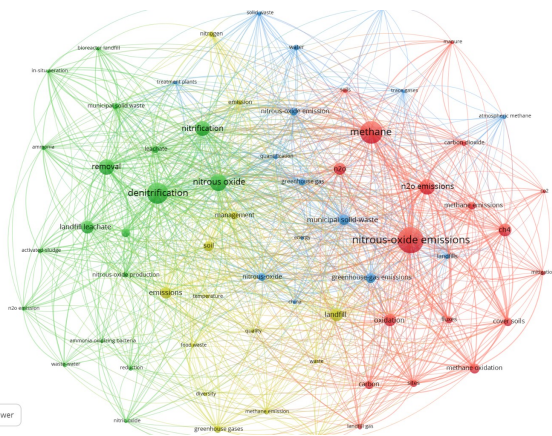


Fig. 13 Keywords in publications on N₂O emission in landfills.

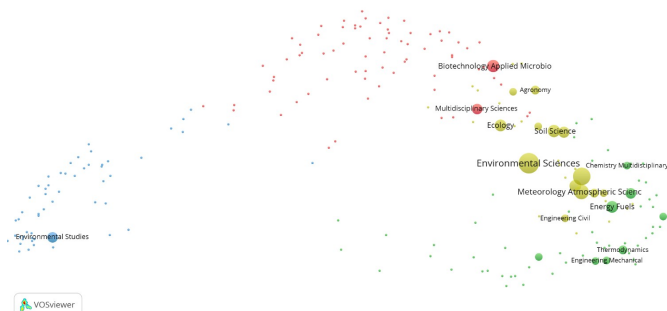


Fig. 14 Main categories of *Web of Science* where papers on N₂O emission in landfills are inserted.

CONCLUSIONS

GHGs emissions have become a major global concern, mainly due to its influence on climate changes. N₂O, although emitted in a lower amount than CO₂, has a high global warming power. In addition, N₂O is currently the main gas emitted by anthropic activities that act indirectly on the consumption of stratospheric O₃. For these reasons, verifying what the research trends on N₂O emission is of paramount importance, mainly by anthropic sources that are not evaluated in the IPCC reports.

Through bibliometric analysis, 3,988 papers on N₂O sources were found in general, considering the period from 1991 to 2021. During this period, we observed that scientific production has been more prominent in the last 10 years, and most studies are conducted by Chinese and North American researchers. The research centers that contribute the most to these studies are also located in these countries. Brazil ranks 15th in the ranking of countries that publish the most on the topic.

Regarding N₂O emission specifically in landfills, only 146 papers were found in the same period. We found that scientific production, in this period, showed many variations, however there is a trend of linear growth in the number of publications. There was also a predominance of papers published by Chinese researchers, besides the number of research centers located in China. No Brazilian papers were found.

Therefore, further research on N₂O emission in landfills needs to be conducted, mainly in Brazil and also in developing countries, in order to obtain an accurate knowledge on how this emission source can influence the global balance of this gas with high impact in climate change compared to other GHGs.

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