Original Article

pISSN 2383-9309 ▌eISSN 2383-9317
J Dent Anesth Pain Med 2024;24(1):67-73 ▌https://doi.org/10.17245/jdapm.2024.24.1.67

Nitrous oxide splurge in a tertiary health care center and its environmental impact: No more laughing stock

Amit Sharma, GD Puri, Rajeev Chauhan, Ankur Luthra, Gauri Khurana, Amarjyoti Hazarika, Shyam Charan Meena

Anaesthesia and Intensive Care, PGIMER, Chandigarh, India

Background: Nitrous oxide has been an integral part of surgical anesthesia for many years in the developed world and is still used in developing countries such as India. The other main concerns in low-resource countries are the lack of an advanced anesthesia gas-scavenging system and modular surgical theatres. As a greenhouse gas that has been present in the atmosphere for more than 100 years and damages the ozone layer, nitrous oxide is three times worse than sevoflurane. Here, we conducted an observational study to quantify the annual nitrous oxide consumption and its environmental impact in terms of carbon dioxide equivalence in one of busiest tertiary health care and research centers in Northern India.
Methods: Data related to nitrous oxide expenditure' from the operation theatre and manifold complex of our tertiary care hospital and research center from 2018 to 2021 were collected monthly and analyzed. The outcomes were extracted from our observational study, which was approved by our institutional ethics board (INT/IEC/2017/1372 Dated 25.11.2017) and registered prospectively under the Central Registry (CTRI/2018/07/014745 Dated 05.07.2018).
Results: The annual nitrous oxide consumption in our tertiary care hospital was 22,081.00, 22,904.00, 17,456.00, and 18,392.00 m^3 (cubic meters) in 2018, 2019, 2020, and 2021, respectively. This indicates that the environmental impact of nitrous oxide (in terms of CO_2 equivalents) from our hospital in 2018, 2019, 2020, and 2021 was 13,016.64, 13,287.82, 10,289.94, and 10,841.24 tons, respectively.
Conclusion: This huge amount of nitrous oxide splurge is no longer a matter of laughter, and serious efforts should be made at every central and peripheral health center level to reduce it.

Keywords: Anesthesia; Air Pollution; Nitrous Oxide; Global Warming; Occupational Safety; Gas Scavenging System; Greenhouse Gases.

INTRODUCTION

When discussing greenhouse gases, we usually talk about carbon dioxide. When discussing ozone layer depletion, we invariably consider the cooling towers of coal power stations. This is reasonable because carbon dioxide is the main contributor to greenhouse gas emissions, most of which originate from the energy sector and the combustion of fossil fuels.

However, the greenhouse issue also involves other gases. Other significant greenhouse gas producers include methane and nitrous oxide (N_2O). In terms of global warming, both gases have a significantly greater impact on climate than carbon dioxide.

One ton of methane released into the atmosphere is comparable to 34 tons of carbon dioxide emissions, whereas one ton of N_2O is equivalent to 298 tons of

Received: November 5, 2023 • **Revised:** January 11, 2024 • **Accepted:** January 16, 2024
Corresponding Author: Shyam Charan Meena, Associate Professor, Department of Anaesthesia and Intensive Care, Postgraduate Institute of Medical Education and Research, Chandigarh, Sector 12, 160012, Chandigarh, India
Tel: +91 7891669817 E-mail: drshyam.pgi@gmail.com

carbon dioxide. Carbon dioxide is the unit of measurement for climate change. N_2O is used as a carrier gas and analgesic-anesthetic agent to provide anesthesia during surgery in India and other developing countries. This reduces the induction time and dosage of inhalational or intravenous agents [1].

Although N_2O gas has many advantages, there are concerns over its safety in the workplace and the environment. Ongoing exposure to high amounts of N_2O has been linked to increased chances of spontaneous abortion, congenital abnormalities, and decreased fertility, according to several observational studies [2,3]. Numerous studies have found that occupational exposure to nitrous gas can alter vitamin B12 status and cause genotoxicity, depression, and decline in cognitive abilities, including attentiveness [2-7].

N_2O is three times worse than sevoflurane as a global warming gas, lasting for more than 100 years in the atmosphere and depleting the ozone layer [8].

In our tertiary health care and research institute, N_2O is used effectively for an average of 9 h in elective procedures and for 20 h in emergency surgical theatres. During the study period, we performed surgery in approximately 50 surgical theatres. Our surgical theatres are still old and lack an anesthetic gas-scavenging system. The existing medical gas pipeline system (MGPS) is more than 50 years old; therefore, there is a fair chance of leakage from older gas pipelines. Currently, N_2O gas is used only in developing countries such as India. N_2O is not used in hospitals in developed nations, owing to environmental concerns. Therefore, we conducted this observational study to quantify the annual N_2O consumption and its environmental impact in terms of carbon dioxide equivalence in our tertiary health care and research center.

METHODS

This health center has provided necessary health services to more than four northern states of India (Chandigarh, Punjab, Himachal Pradesh, and Haryana) for many years. N_2O is only used in surgical theatres and is supplied to patients through central pipelines and small cylinders. We extracted the N_2O consumption data from the manifold department. We studied four years (2018–2021) of data related to N_2O consumption at our health institute. The outcomes were extracted from our observational study, which was approved by our institutional ethics board (INT/IEC/2017/1372 Dated 25.11.2017) and registered prospectively under the Central Registry (CTRI/2018/07/014745 Dated 05.07.2018).

Data related to Nitrous oxide expenditure from the operation theatre and manifold complex of our tertiary care hospital and research center from 2018 to 2021 were collected monthly. After obtaining the data, the environmental impact in terms of carbon dioxide equivalents was calculated monthly and annually as per the standard conversion formula (1 kg N_2O = 298 kg of CO_2 or 1:298).

The average working hours in the operation theatre were noted, and N_2O consumption (at the user end level) was calculated by multiplying the N_2O gas flow with the time. This amount was compared to the monthly consumption, as shown by the manifold team. Subsequently, it was calculated for the entire year. By doing this, we were able to determine the disparity between actual nitrous oxide consumption at the user end (operation theatre areas) and N_2O oxide consumption by manifold. We used N_2O in 42 elective and emergency surgical theatres during the study period. N_2O is used effectively for an average of 9 h in elective surgeries and 20 h in emergency surgical theatres. The average flow of N_2O use in our operation theatres was 1-1.5 liter per minute.

Our primary aim of this observational study was to quantify the annual N_2O consumption at our institute. The secondary objectives of our study were to quantify the annual environmental impact of N_2O in terms of CO_2 equivalence and the disparity between actual consumption at the surgical theatre and at the manifold end. Our intention was to determine the real cause of N_2O splurge in our institute so that we could rectify it accordingly.

Table 1. Annual Nitrous oxide consumption and its environmental impact (in term of carbon dioxide equivalent) between year 2018 – 2021

YEAR	Annual Nitrous oxide consumption (in m^3)	Annual Nitrous oxide consumption (in ton)	Annual Environmental impact of Nitrous oxide {in term of CO_2 equivalent (in ton)}
2018	22081	43.68	13016.64
2019	22904	44.59	13287.82
2020	17456	34.53	10289.94
2021	18392	36.38	10841.24
Average per year	20,208.25	39.97	11911.06

One m^3 = 1000 liter; One ton = 505.517 m^3 nitrous oxide; One ton of nitrous oxide = 298 tons of carbon dioxide; CO_2, carbon dioxide.

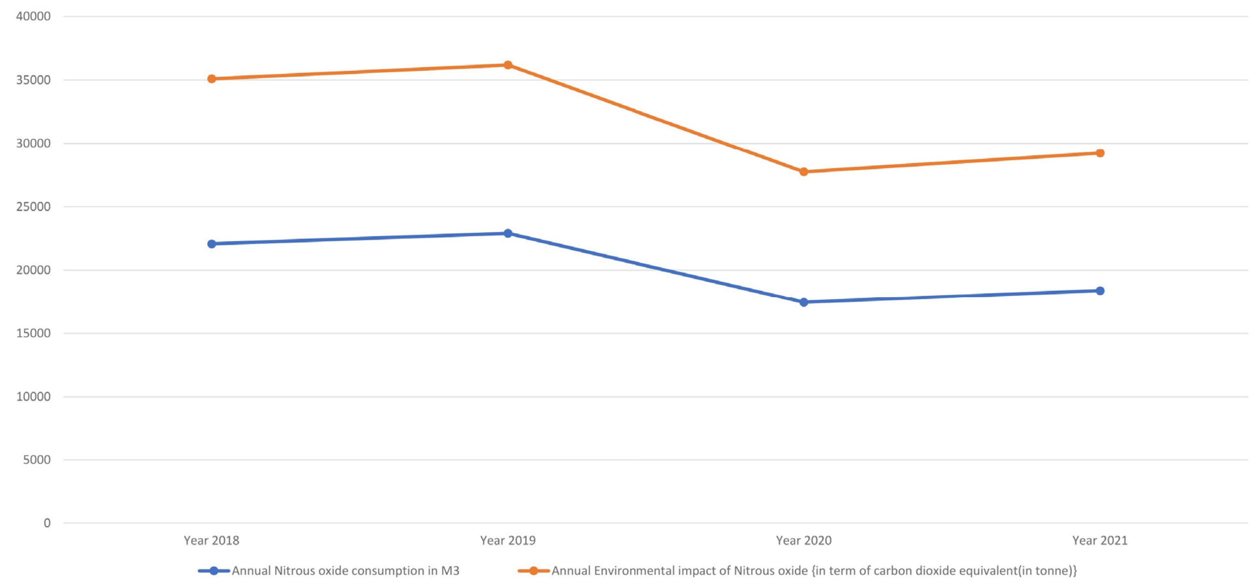

Fig. 1. Annual Nitrous oxide consumption and its environmental impact (in term of carbon dioxide equivalent) between year 2018-2021

RESULTS

This study was conducted in a tertiary care health and research center in India, where more than 60 operation theatres serve the population. As shown in Table 1 and Figure 1, the annual N_2O consumption in our tertiary care hospital was 22,081.00, 22,904.00, 17,456.00, and 18,392.00 m^3 (cubic meters) in 2018, 2019, 2020, and 2021, respectively. Monthly N_2O consumption was also analyzed, as shown in Figure 2. One ton of N_2O is equal to 298 tons of carbon dioxide, which is the unit of measurement for climate change. This means that the environmental impacts of N_2O (in terms of CO_2 equivalent) from our hospital in 2018, 2019, 2020, and 2021 were 13,016.64, 13,287.82, 10,289.94, and 10,841.24 tons, respectively.

The annual N_2O consumption was also quantified, and an attempt was made to identify any disparity between the user and manifold ends. Accurate estimation of N_2O consumption in surgical theatres is difficult. The average working hours in the operation theatre were noted, and N_2O consumption (at the user end level) was calculated by multiplying the N_2O gas flow with the time. This amount was compared to the monthly consumption, as shown by the manifold team. Subsequently, it was calculated for the entire year. By doing this (as shown in Table 2), we were able to find the disparity between the actual N_2O consumption at the user end (operation theatre areas) and the N_2O consumption by manifold. The medical gas pipeline system in our hospital is quite old, and efforts are being made to find leakage sources and

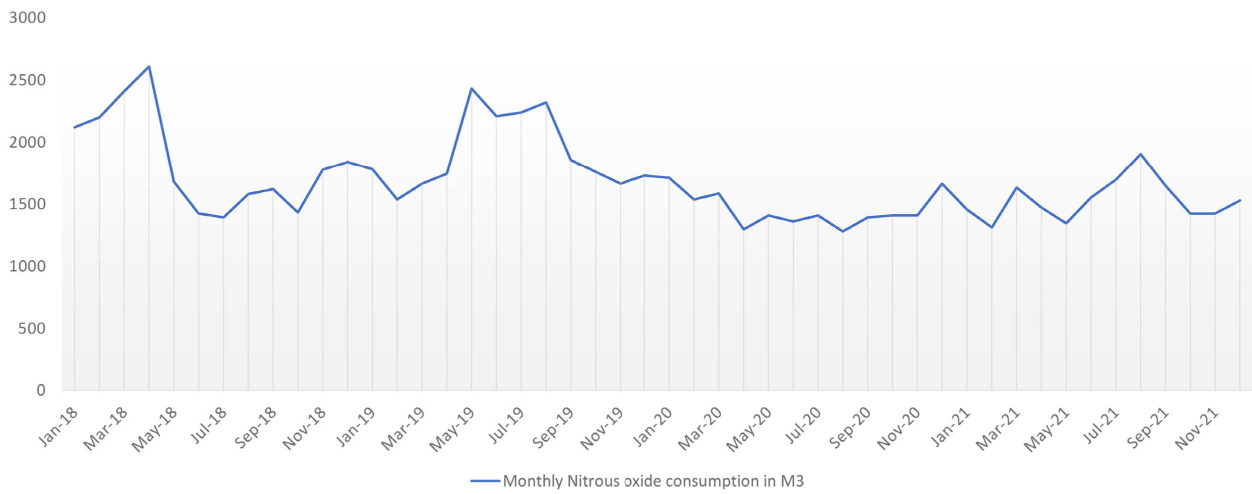

Fig. 2. 2 Monthly Nitrous oxide consumption in m^3

Table 2. Disparity of Yearly Nitrous Oxide Consumption (in m^3)

Year	Consumption as per manifold (in m^3)	Consumption as per OTs working hours calculation	Approximate wastage disparity/leakages at multiple ends
2018	22081	11160	49%
2019	22904	11160	51%
2020*	17456	6696	62%
2021*	18392	6696	63%
Total	80833 m^3	35712 m^3	55%

One m^3 = 1000 liter; One ton = 505.517 m^3 Nitrous oxide; One ton of nitrous oxide = 298 tons of carbon dioxide.

repair them. The most probable explanation for the overconsumption of N_2O is leakage from multiple sources, including at the patient end, anesthesia machine end, and pipeline joint levels, at the time of filling and opening of the cylinder, and other devices.

The study period was also affected by the COVID 19 outbreak. The surgical theatres in 2018 and 2019 were fully functional, while the functional status of OTs in our hospital during COVID 19 was affected, and there was an approximately 60% reduction in the total number of surgical cases. N_2O consumption, as shown by the manifold, decreased by only 25%. The constant splurge of N_2O, even in the less utilization of the surgical theatres due to the COVID 19 outbreak, raised the leakage concerns from the old designed medical gas pipeline system (MGPS). After checking the existing MGPS at our health center, minor leakages were found. Because of these leakages, the gas manifold showed higher consumption than the actual usage during the COVID 19 outbreak. The concerned authority came into action and implemented possible strategies, including strict supervision of the use of these gases to reduce wastage, repairing the MGPS, emphasizing total intravenous anesthesia (TIVA) practices, use of air instead of N_2O, and training health care personnel. After the implementation of these practices, N_2O is being used very cautiously, and its waste has been reduced significantly. We plan to conduct the study to quantify N_2O use before and after the implementation of these practices.

DISCUSSION

Considering the present scenario of anesthesia services in underdeveloped and developing countries, efforts must be made to improve anesthesia practices for both patient safety and environmental sustainability.

N_2O in the atmosphere is mainly derived from nitrogen-based fertilizers. However, the operation theaters of hospitals in developing countries are also an important contributor of N_2O pollution [9].

Historically, the N_2O and oxygen flow rate to provide anesthetic gas was at least 2 L/min in normal general anesthesia cases. However, this is more than twice or thrice what the body requires. Anesthetic gas molecules are removed from the system's surplus flow and released into the environment. N_2O is eliminated from the body almost entirely through the lungs, although a small amount diffuses through the skin [10].

The atmospheric life of N_2O is 110 years. N_2O is removed from the environment through a mechanism that depletes ozone. Therefore, N_2O harms the ozone layer in addition to acting as a greenhouse gas [11].

In this observational study, we quantified the annual N_2O usage in our tertiary healthcare and research center to assess the annual environmental impact in terms of carbon dioxide equivalents.

In our study, we found that the yearly average N_2O consumption in our tertiary care hospital was 20,208.25 m^3 (approximately 40 tons of N_2O). One ton of N_2O is equal to 298 tons of carbon dioxide, which is the unit of measurement for climate change [12].

Thus, every year, the average environmental impact of N_2O (in terms of CO_2 equivalent) in our hospital is 11,911 tons of CO_2. This huge amount of N_2O splurge is grievous and no longer a matter of laughter.

The Indian health infrastructure is still far behind developed countries in terms of advanced modular operation theatres (MOTs) and medical gas pipeline systems (MGPSs). There are old-fashioned surgical theatres and old pipelines in most government hospitals. These old gas pipelines have not been upgraded according to the increased workload and modern standards. In recent times, although efforts have been made to install a newer pattern of MGPS in newly established healthcare institutions along with proper scavenging systems, existing healthcare institutes are still in the hope of upgrading [13].

We also observed a significant disparity between N_2O expenditure shown by the manifold and the data calculated by users (anesthesiologists at the operation theatre level). This N_2O splurge must be due to leakages from multiple sources, including the patient end, anesthesia machine end, pipeline joint levels, timing of filling and opening of the cylinder, and unavailability of a proper anesthesia scavenging system in old-designed operation theatres.

Our tertiary care health institute has well-ventilated surgical theatres, but all lack a proper scavenging system. We have very busy surgical theatres and are quite overcrowded. In this institute, our anesthesia practice in the maintenance phase is fairly variable, but mainly involves the use of N_2O and other inhalational anesthetic agents. We found variable values of N_2O in the surgical theatre environment, the majority of which were at ppm levels that far exceeded the National Institute of Occupational Safety and Health (NIOSH) recommendations in our previous study. We quantified high ambient N_2O in working operation theatres (up to 2443 ppm) and post-surgery recovery environments (up to 50 ppm) in our previous study at the same hospital and research center [14].

This N_2O split at larger hospitals must be considered seriously, as this overexpenditure or pollution of N_2O will create significant concerns in terms of occupational hazards to healthcare personnel, negative environmental impact due to greenhouse effects, global warming impact of N_2O, and economic burden.

Therefore, for hazard awareness, prevention, control of exposure to waste anesthetic gas (WAG), and environmental safety, it is crucial to implement better control measures [15] during anesthesia, total intravenous anesthesia (TIVA) practice, periodic training by effective education curricula, regular monitoring of trace levels of WAG, establishment of a modular OT with a scavenging system, and a newer medical gas pipeline system (MGPS).

Conclusion

In this observational study, we observed that N_2O is used in most surgical theatres via old-designed medical gas pipeline systems. Safety measures still require improvement. The huge splurge of N_2O gas from a single tertiary health center is alarming for the sustainability of the current surgical anesthesia system.

Strength and Limitations

is observational study was a first step towards the N_2O over expenditure and its impact on environmental concerns. One of the limitations is that we should also compare N_2O consumption before and after the implementation of preventive measures; for example, before and after TIVA versus inhalational anesthesia practices.

AUTHOR ORCIDs

Amit Sharma: https://orcid.org/0009-0000-8555-8035
Gauri Khurana: https://orcid.org/0000-0001-7451-3800
Amarjyoti Hazarika: https://orcid.org/0000-0001-6563-1477
Shyam Charan Meena: https://orcid.org/0000-0003-0645-2836

AUTHOR CONTRIBUTIONS

Amit Sharma: Data curation, Writing - review & editing
GD Puri: Conceptualization, Data curation
Rajeev Chauhan: Formal analysis, Writing - review & editing
Ankur Luthra: Formal analysis, Supervision, Writing - review & editing
Gauri Khurana: Data curation, Writing - review & editing
Amarjyoti Hazarika: Data curation, Writing - review & editing
Shyam Charan Meena: Conceptualization, Data curation, Formal analysis, Methodology, Supervision, Writing - original draft, Writing - review & editing

CONFLICT OF INTEREST: There is no conflict of interest.
FUNDING: NIL

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