

## Atmospheric Pollution in Cardiac Operating Rooms

The ecological footprint of healthcare is enormous.<sup>[1]</sup> Almost 10% of the United States' greenhouse gas (GHG) emissions are contributed by healthcare.<sup>[2,3]</sup> More than a third of all hospital waste are generated during the perioperative period and surgical care. Inhaled anesthetics account for 2.5% of the GHG emissions attributed to the National Health Service of the United Kingdom.<sup>[1]</sup> In 2014, the global volatile anesthetic gases release to the atmosphere was estimated to be 3.1 + 0.6 million metric tons carbon dioxide (CO<sub>2</sub>) equivalents.<sup>[4]</sup>

Global warming potential (GWP) is the capacity of a gas to trap heat. The calculation of GWP is based on the atmospheric life of a gas and its infrared absorption capacity.<sup>[1]</sup> The GWP of carbon dioxide (CO<sub>2</sub>) is considered as reference and is assigned a value 1. Volatile anesthetics are stable halogenated molecules which do not disintegrate in the atmosphere. Waste anesthesia gases (WAGs) rise up to the troposphere, remain nondegraded for extended periods (sevoflurane - 1.1 years, isoflurane - 3.2 years, desflurane - 14 years, and nitrous oxide - 114 years),<sup>[1]</sup> and tend to trap the earth's radiant heat. The Infra-red absorption potential of all agents is similar but the estimated 100 year-GWP (GWP100) for different volatiles is: sevoflurane 130, isoflurane 510 and desflurane 2540.<sup>[5]</sup> Desflurane has a high GWP100 because it is likely to remain suspended in the atmosphere for a long period as it's molecule doesn't degrade. Out of the WAGs in clinical use, only isoflurane and nitrous oxide can react with the highly reactive ozone in the stratosphere and damage the earth's protective ozone barrier.<sup>[6]</sup>

Pollution in operating room (OR) has been a cause of concern for long, as WAG pollution can be hazardous to OR personnel. In the open ether era, anecdotes of anesthesia residents falling off to sleep during afternoon classes, were almost folklore. During that era, all OR personnel at work inhaled ether and other inhalational anesthetics as no scavenging systems existed and very high fresh gas flows (FGFs) were used. ORs had high atmospheric content of various agents, and this was linked to spontaneous abortions in women and developmental defects in their offspring.<sup>[7-9]</sup> Animal studies reported teratogenicity and fetal death following exposure, with even fetal death reported after 9 ppm exposure in a case.<sup>[10,11]</sup> Blokker-Veldhuis *et al.* have recently expressed concern about the potential effects of occupational exposure although the data on adverse health responses still remain inconclusive.<sup>[12]</sup>

National Institute for Occupational Safety and Health, USA standards specify a global ceiling exposure limit of 2 ppm for all halogenated anesthetic agents, over a sampling

period not exceeding 1 h.<sup>[13]</sup> In 1989, the American Conference of Governmental Industrial Hygienists assigned a threshold-limit-value time-weighted-average (TLV-TWA) for nitrous oxide of 50 ppm for a normal 8-h workday. In Europe, the TLV-TWA limits for different inhalational agents vary from 20 to 50 ppm. There are however no specific Occupational Safety and Health Administration recommended exposure limits prescribed for inhalational anesthetic agents in use today (isoflurane, sevoflurane, desflurane).<sup>[13]</sup>

Health and safety of OR personnel should be accorded utmost priority in any health system. The long-term effect of WAG on the environment has always been a concern although the pollution inside ORs is not routinely monitored. No facilities to monitor OR atmospheric levels of WAG are available at any center in our country, and possibly, most of the world but regulatory agencies recommend methods to reduce atmospheric pollution (leak tests, training, gas scavenging, usage of low flow anesthesia). Anesthesia gas scavenging systems (AGSS) were introduced to reduce the WAG pollution. The resurgence of low and minimal FGF anesthesia, to reduce consumption of inhalational agents, reduced venting of WAG into the OR environ. However, a large number of ORs in our country do not have AGSS installations nor do they use closed anesthesia circle systems, leave alone low flow anesthesia. FGF flows in most OR vary from 2 to 4 L/min. Most cardiac ORs in our country have modern machines and use closed anesthesia circuits, but the use of low/minimal flow anesthesia still has not caught on in cardiac OR.

Volatile agents use is recommended during cardiopulmonary bypass (CPB) to provide anesthesia, enhance myocardial protection, vasodilation, and to prevent response to noxious stimuli.<sup>[14]</sup> The simple design of the CPB machine oxygenator gas circuit results in venting of WAG into the OR atmosphere. The ill effects of this venting of WAG from oxygenators have not been looked into. CPB machines have oxygen/air blenders, and volatile anesthetics are added by placing a flow-over vaporizer in circuit. FGF in the gas interface is nonphasic, and there is no provision for placing a closed circuit or a rebreathing system for gas exchange. Measuring concentration of volatiles is not feasible with the current design. Perfusionists set FGF based on arterial blood gas levels of oxygen and CO<sub>2</sub>, while volatile vaporizers delivery rates are regulated based on hemodynamics. Gas outlet ports are usually not connected to AGSS even though they vent WAG at flow rates >5 L/min.<sup>[14]</sup> It is recommended that AGSS be adapted to the CPB oxygenator vent ports to limit OR atmosphere pollution although higher number of air exchanges limits the pollution.<sup>[14-16]</sup>

Nigro Neto *et al.* were possibly the first group of investigators to devise a system to safely dispose off WAG from the oxygenators of CPB.<sup>[17]</sup> They designed a filter with activated charcoal to adsorb volatile anesthetic agents vented out from the main outlet port of the CPB oxygenator. The Z79.11 standard of American National Standards Institute restricts negative pressures for scavenging of WAG to 0.5 cm of water (0.37 mmHg).<sup>[17]</sup> They suggested substitution of the AGSS with this filter, as use of this filter avoided transmission of negative pressure and back pressure on the membrane oxygenator.<sup>[17]</sup>

In this issue of the journal, Simone *et al.*, from the same group, present another prototype scavenging device which is interposed between the oxygenator gas exit port and the suction line.<sup>[18]</sup> The secondary port is open to the environment and connects to the oxygenator gas exit port, the WAG disposal line, and a side branch. The side arm is designed as a convergent tube with an aperture opening to the environment, which functions like a venturi system. The flow of air through this aperture allows discharge of any excessive negative pressure generated by the suction. The authors have successfully used this device with no adverse effects, no overpressurization, cracking of oxygenators, or dysfunction/disruption of the CPB circuitry.

Although global climate changes are primarily due to CO<sub>2</sub> emission from industry and vehicles, GHG emissions attributed to healthcare sector cannot be ignored. WAG contributes about 0.25% to the global GHG, and so anesthesiologists have a social obligation to work to protect the environment. Cardiac ORs have an extra load of CPB WAG contributing to OR pollution. There is a need to spread this awareness, to restrict adverse effects to the OR personnel as well as restrict environmental pollution. Industry needs to improve CPB/oxygenator design by incorporating anesthesia gas regulation and WAG disposal systems.

### Mukul Chandra Kapoor

Department of Anaesthesia, Max Smart Super Specialty Hospital,  
New Delhi, India


**Address for correspondence:** Dr. Mukul Chandra Kapoor,  
6, Dayanand Vihar, New Delhi - 110 092, India.  
E-mail: mukulanjali@gmail.com

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<b>Quick Response Code:</b> 	<b>Website:</b> <a href="http://www.annals.in">www.annals.in</a>
	<b>DOI:</b> 10.4103/aca.ACA_126_17

**How to cite this article:** Kapoor MC. Atmospheric pollution in cardiac operating rooms. *Ann Card Anaesth* 2017;20:391-2.