

Advanced Oxidation Plasma Air Purification to Mitigate Hospital and Restroom Odor Issues

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Abstract

Background: The smell in a hospital is an amalgam of smells, emanating from varied sources. But primarily the smell is from the strong cleaning agents used in corridors, including phenyl and bleaching powder, etc. Chemicals that trigger odors may cause health effects. A strong urine odor is also responsible for foul smells in hospitals and other public facilities. Strong odors may cause some people to feel a burning sensation, leading to coughing, wheezing, or other breathing problems.

Methods: In order to investigate the odor elimination efficacy of the Advanced Oxidation Plasma (AOP) air purification system, Virushield or Odoshield AOP devices were installed at the three separate hospitals (Apollo, Manipal & Sri Ayurveda Hospital) and PES University in Bangalore, India. The feedback from the facility manager, staff members, students, as well as patients was noted down daily using the odor sensory method.

Results & Conclusions: It was found that drastic reduction of the strong restroom odor as well as the hospital-associated smell with the Virushield or Odoshield AOP air purification system. A 40-50% reduction of odor was achieved on Day-1 & very less smell was observed on Day-2. After Day-3, there was no foul smell or suffocation issue faced by occupants. Additionally, AOP technology has shown antimicrobial efficacy that helped to reduce cross-contamination in closed spaces. The AOP technology was tested and evaluated for its antimicrobial efficiency by the Indian Council of Medical Research (ICMR, GOI) recommended CSIR institutes.

Keywords: Public health; Hygiene; Foul Odor; Hospital smell; AOP Technology

List of Abbreviations

AOP: Advanced Oxidation Plasma; PES: People's Education Society; VOCs: Volatile Organic Compounds; ICMR: Indian

Council of Medical Research; CSIR: Council of Scientific & Industrial Research; CCMB: Centre for Cellular & Molecular Biology; IIT: Indian Institute of Technology; GOI: Government of India; IGBC: Indian Green Building Council; CII: Confederation of Indian Industry; NABH: National Accreditation Board for Hospitals; VVIP: Very Very Important Person; ISO: International Organization OF Standardization; EPA: Environmental Protection Agency; ICU: Intensive Care Unit; IAQ: Indoor air quality; ASHRAE: American Society Of Heating, Refrigerating and Air-Conditioning Engineers; WHO: World Health Organization; CDC: Centers for Disease Control & Prevention; ACH: Air Changes per Hour.

Introduction

For many people, their time spent in hospitals is limited to the occasional trip to the emergency room or short visits with family or friends. During that time, catching a whiff of a few unique smells is possible here or there. However, for nurses, hospital staff & doctors, the smells of a hospital are a huge part of their day-to-day experience. The distinctive “hospital smell” is caused by a variety of factors, including strong-smelling cleaning chemicals used to disinfect the surfaces, the chemicals & medicines used in medical procedures, and materials used in hospital equipment & furniture. Foul odors in the hospital environment mainly come from patients, specifically their excrement and discharge [1].

Additionally, bodily fluids mainly urine & other organic matter can contribute to the odor. In restrooms, persistent urine odors may emanate from urine that has penetrated porous grout on floors or walls, behind toilets, and underneath urinals. Since restrooms, as well as hospital ICUs, have a lot of moisture sink faucets, the room can quickly become a hotbed for molds, bacteria, and germs [2]. This will lead to a discomforting smell inside the closed spaces. Cleaning chemicals, aerosol sprays, room fresheners, etc. generate odorous gases or VOCs as secondary pollutants in the air.

The chemicals that trigger odors may cause health effects. Strong odors may cause some people to feel a burning sensation that leads to headaches, coughing, wheezing, or other breathing problems, and people feel dizzy and nauseous. One study found that about 30.5% of the general population reported scented products on others irritating, 19% reported adverse health effects from air fresheners, and 10.9% reported irritation by scented laundry products vented outside. 27% of people with asthma say their disease is made worse by such exposures [3].

Studies have indicated that “mood is better when the odor is pleasant,” encourages productivity, reduces anxiety, and produces an overall relaxing effect. A positive ambient odor may support recovery from major illness, which has been associated with depression. The smell may impact the well-being of both patients and healthcare workers, who experience high rates of burnout [4, 5]. Multiple sources have verified that SARS-CoV-2 can be detected within toilets, and people can be infected in restrooms through contaminated air circulation [6, 7]. United States EPA found that the indoor environment is 2–5 times more toxic than the outdoor environment, and in some cases, the air measurements indoors have been found to be 100 times more polluted (EPA 2016). Therefore, maintaining a hygienic and safe environment in closed indoor spaces such as public toilets, restrooms, hospital areas, offices, etc. is a top priority.

The primary role of a hospital or other healthcare facilities is to provide medical treatment and nursing care to patients. Also, keep safe, to hospital staff, visitors & critical patients from hospital-acquired infections by maintaining good indoor air quality. The strategies to maintain hygiene standards and improve IAQ in hospitals or other healthcare facilities are i) the use of less volatile cleaning solutions ii) following ASHRAE/ WHO guidelines for ventilation standards to dilute and remove contamination in the form of odor, airborne microorganisms, and viruses, and hazardous chemical and radioactive substances iii) use air filters and air purifiers for air pollutants and odor mitigation [8, 9, 10]. CDC [11] and ASHRAE [12] recommended air change rates for outdoor air & total air for healthcare facilities in terms of air changes per hour (ACH).

There are basically two methods of measuring the Odors: instrumental or odor sensory or olfactory method. The instrumental

methods measure the chemical components of odors present in the air, whereas the sensory method involves a human panel to assess air quality and/ or odor exposure. Odor sensory methods are often more helpful than instrumental methods in many applications because they do not have a limit of detection issues and reflect the actual human perception of odor [13, 14].

This paper presents the results of experiments carried out at three reputed healthcare facilities & an educational institute for odor control. The Apollo Hospital at Bannerghatta is a 250 bedded hospital. The hospital is equipped with state-of-the-art technology making it a powerhouse of healthcare in Bangalore. The hospital has over a hundred consultants. Therefore, a huge crowd from all over Bangalore visits this hospital for treatment. The hospital engineering team received complaints from working staff members of foul smell issues & suffocation faced in the corridor area, nursing section, waiting area, and VVIP patient rooms present at the platinum wing.

Manipal Hospital Whitefield is a 284-bedded inpatient facility and provides specialized medical and quaternary care services with out-patient Centre of Excellence departments cardiology, nephrology, neurology, obstetrics & gynecology, orthopedics, pediatric & child care, anesthesiology, clinical psychology, dental medicine, nutrition and dietetics, pathology, pharmacy, physiotherapy, plastic and cosmetic surgery, radiology, rehabilitation medicine, reproductive medicine department, etc. who delivers the best care for the patient.

Sri Sri Ayurveda Hospital is a multispecialty Ayurvedic Hospital, which is ISO:9001 certified, ISO:22000 certified, and NABH accredited, located in Bangalore, India. The hospital is truly world-class with modern state-of-the-art diagnostic facilities that offer 268 beds for patients, consulted by highly experienced doctors and attended with the support of our trained and proficient staff. People's Education Society University (PESU), is a state-private university in Bengaluru, India.

More than 250 vehicles have been parked in the parking area in each hospital daily, which emits harmful gases into the hospital environment. Heavy human traffic affects indoor air and increases the risk of cross-contamination in hospitals. Therefore, it is important to eliminate hospital-associated strong odors as well as restroom odors to maintain hygiene and improve the health of healthcare workers, visitors, patients, and students. The aim of this study is to study the effectiveness of odor removal of AOP technology in hospital facilities and university washrooms in Bangalore, India.

Materials and Method

The Virushield / Odoshield AOP air purifier unit has been conceptualized, designed, developed, and manufactured by Ultrapure Envirocare, Mumbai, India. The AOP wall-hung device image is shown in Figure 1. The AOP air purifier is powered by proprietary GreenPro Eco-labelled technologies, named nanoX & plasmOX technology. This study was conducted in three separate hospitals: Apollo Hospital Bannerghatta, Manipal Hospital Whitefield Branch, Sri Ayurveda Hospital Chordahalli, Kanakapura branch, and PES University in Bangalore. In the present study, the odor-sensory method was used to evaluate the performance of the Virushield AOP air purifier. At each location, the odor experienced by the occupants was checked by facility team members on a decided time slot each day & noted down the result on a daily basis. The duration of the studies was decided by each site management.

Six units of each Virushield or Odoshield AOP (plug & play type, wall hung) air purifiers were installed at VVIP patient wards, pantry area, near washroom area, nursing section, hospital corridor & in the sample collection room of the Apollo hospital (Level-3, Tower A, Platinum Wing). A total of 358 cubic meters of area were selected for AOP demo purposes. Figure 2 shows a schematic representation of the installation of AOP devices in Apollo Hospital Bannerghatta.

Two units of the AOP devices were installed in the ground floor men's washroom area, at Manipal Hospital. Approximately 50 cubic meters of room air were treated with AOP technology. To cross-check the odor elimination efficacy of the AOP unit, the same AOP device has shifted to the fourth-floor washroom area, opposite the dialysis room. At PES University, two AOP devices were

installed on the ninth floor to cover 113 cubic meters of the men’s washroom area, and a single AOP unit was applied to treat 68 cubic meters of air space at Sri Sri Ayurveda Hospital.

Figure 3 shows the installation of AOP demo units in the Apollo Hospital corridor area and PES University boys’ washroom area. The number of AOP devices was selected as per the odor issue, type of odor, number of occupants, & coverage area, etc. (Table 1).

Image1: Image of Virusshield / Odoshield AOP - Wall Hung air purifier



Image2: Schematic representation of installation of AOP devices in Apollo hospital

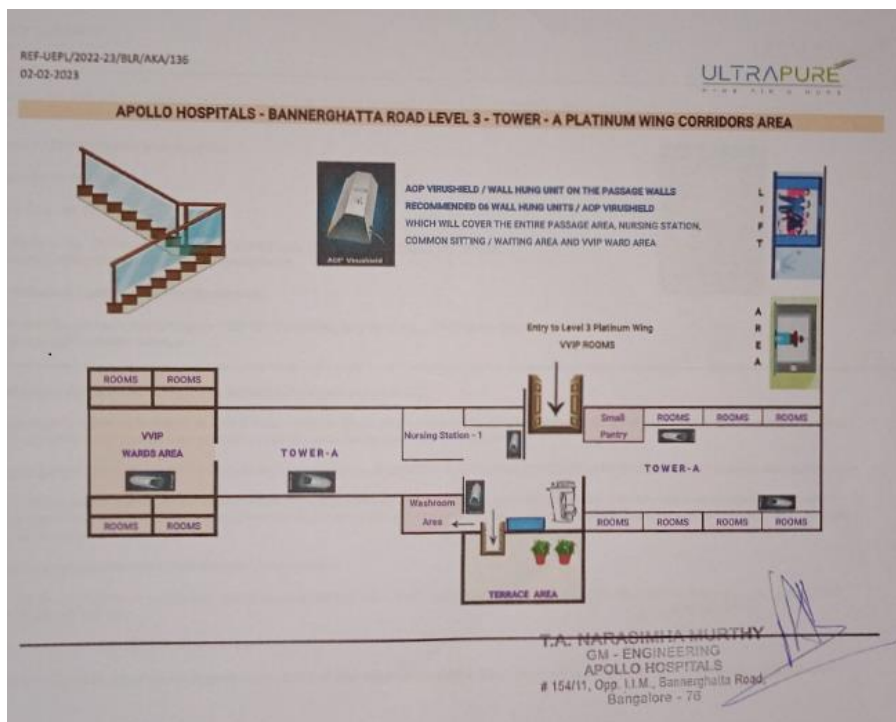


Image3: Installation of Virushield (Odoshield) AOP devices



Table1: Summary of the studies conducted at different sites

Name of the Organization	Sri Sri Ayurveda Hospital	Manipal Hospital	Apollo Hospital	PES University
Issue faced	Foul odor	Foul odor	Foul odor & suffocation	Foul odor
Area selected for study	Men’s common Restroom area (ground floor)	Men’s Common washroom area (ground floor)	Level 3, Platinum wing Hospital corridor area, & sample collection room	Boy’s restroom area (9th floor)
Coverage area (sq. ft.)	300 (68 m3)	220 (50 m3)	1580 (358 m3)	500 (113 m3)
No. of AOP units selected for study	1	2	6	2
Demo conducted	11/1/2022	1/1/2023	2/1/2023	11/1/2022

Results

The results of these case studies to determine the odor removal capability of Virushield or Odoshield AOP are presented in Figure 4. The results were plotted based on a demo report provided by each hospital and university facility team. At the Sri Sri Ayurveda Hospital, the team noticed improvement. The foul smell began to diminish from Day-1 with only one AOP unit hanging from the wall (Figure 4a).

At Manipal Hospital, the first demo was carried out on the ground floor common washroom area, after satisfactory results the hospital team decided to cross-check the device performance by changing the location (Figure 4b). The same AOP devices were moved to the fourth-floor washroom in front of the dialysis room & it was observed that the device successfully eradicated total foul smell from the washroom area too.

At Apollo Hospital, at the Day-3 Hospital staff had begun to feel more comfortable as they themselves were feeling the reduction in the hospital's foul odor (Figure 4c). A report of the AOP demo at a sample collection room (Apollo Hospital) is shown in Figure 5. At PES University, the team found drastic improvement and the restroom smell had reduced completely with the help of the AOP devices (Figure 4d).

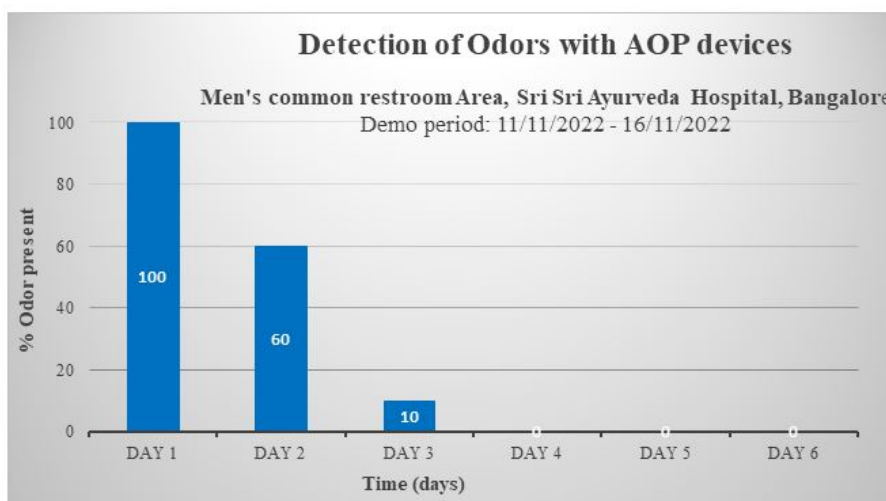


Image4a: Sri Sri Ayurveda Hospital, Chordahalli Kanakpura, Bengaluru.

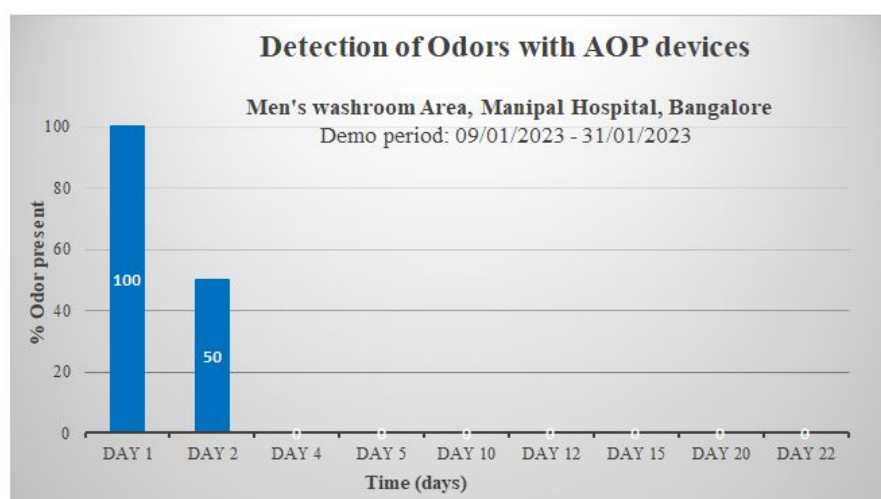


Image4b: Manipal Hospital, Whitefield, Bangalore

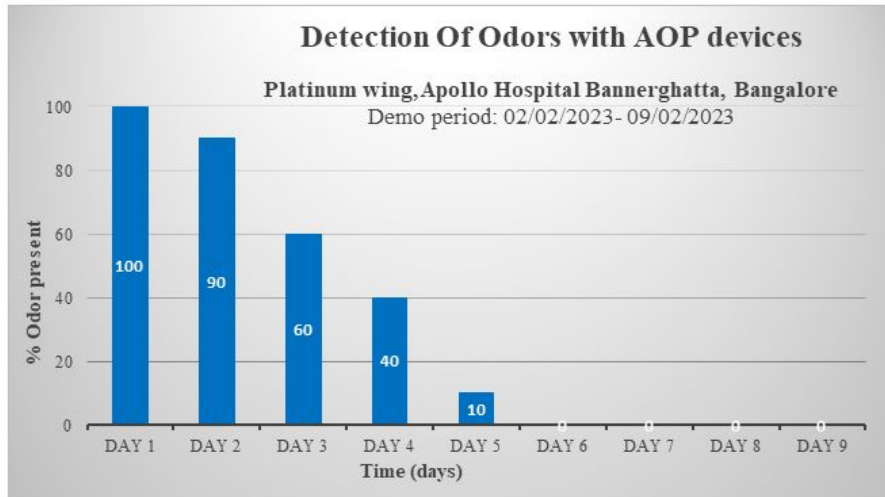


Image4c: Apollo Hospital, Bannerghatta, Bangalore

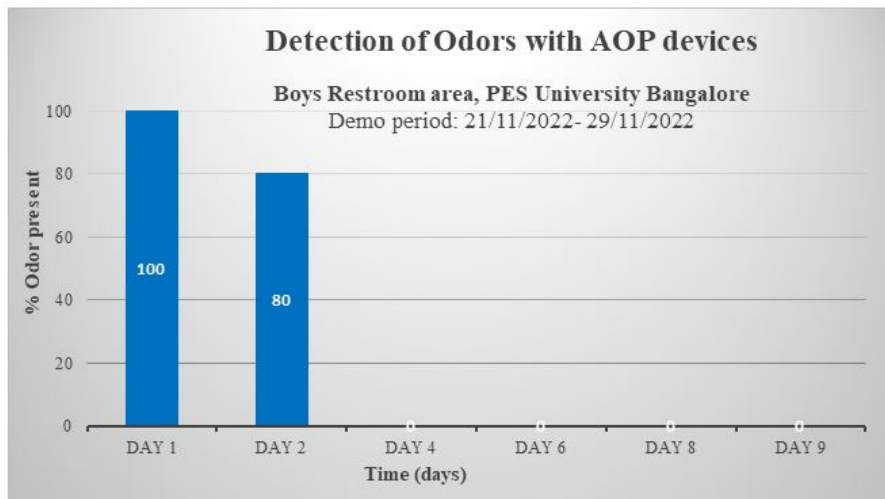
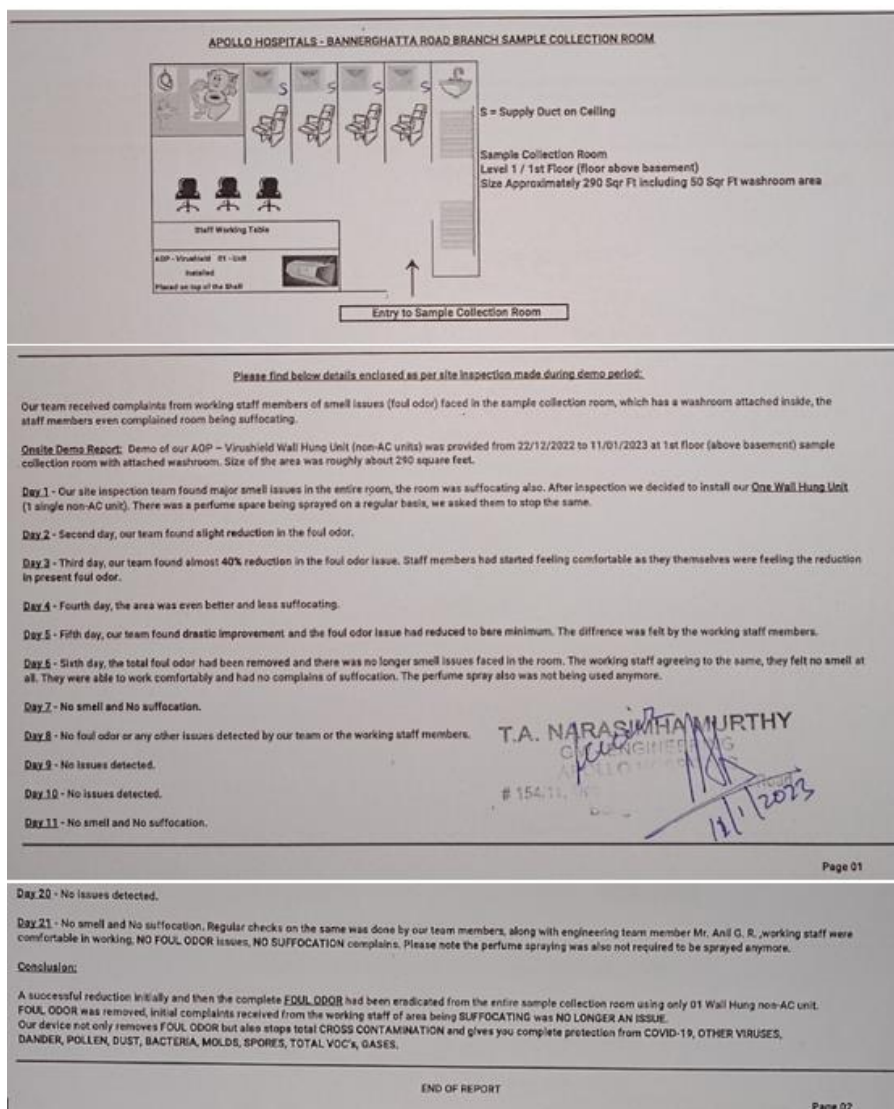


Image4d: PES University Banashankari, Bengaluru

Image4: Odor-eradicating performance of the Virushield AOP air purifier at (a) Sri Sri Ayurveda Hospital, Chordahalli Kanakpura, Bengaluru (b) Manipal Hospital, Whitefield, Bangalore (c) Apollo Hospital, Bannerghatta, Bangalore & (d) PES University Banashankari, Bengaluru

Image8: Demo report (sample collection room) provided by Apollo Hospital



Discussion

In the present study, it was observed that the Virushield / Odoshield AOP units installed at four different locations (Bangalore, India) showed complete elimination of the foul odor and occupants felt fresh air. AOP units showed a 10-50 % reduction of foul odor in a day in the selected premises. The percentage of odor removal capacity differs from location to location with the parameters such as the number of daily visitors, coverage area, number of AOP units placed, types of odor-generating activities, types of cleaning chemicals & room fresheners used, etc. After the fifth day of the demonstration, there were no problems with the smell and suffocation in the hospitals.

Additionally, air purifiers based on AOP technology have been tested and verified for their antimicrobial (against COVID-19 virus & H1N1 influenza virus, etc.) effectiveness through third-party government virology laboratories. The AOP cell toxicity study determined that this air purification system is safe for building occupants. This air purifier has been found to be effective in oxidizing harmful VOCs. It is GreenPro Eco-labelled product, certified by CII- Green Products & Services Council (IGBC).

Therefore, the AOP technology not only eliminated the foul odor but also maintained a healthy environment at Apollo hospitals, Manipal hospitals, Sri Sri Ayurveda hospitals & PES university campus.

Conclusion

It has been concluded that air purifiers based on the Advanced oxidation Plasma (AOP) technology, i.e., Virushield (Odosshield) AOP successfully eradicate the foul smell and suffocation issues. The AOP purifier is a safe and certified green IAQ solution. The technology has been shown antiviral efficacy against novel SARS-CoV-2 and H1N1 Influenza A virus, tested & evaluated by CSIR-CCMB, Hyderabad & IIT Guwahati, Assam, India respectively. It shows antifungal efficacy against black molds, *Aspergillus* & other fungal species. Also, the AOP device helps to reduce particulate matter circulating in indoor spaces.

Therefore, it will be an excellent and promising solution to control foul odors & maintain a healthy environment in various indoor areas including the food processing industry, hospitals, public washrooms, railways washrooms, clinical laboratories, pharma & paints industry, offices, etc.

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