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Indoor air pollution: innovative solution for active purification treatments

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Abstract Indoor air is heavily polluted, much more so than outdoor air, but unfortunately it's indoors that we spend most of our time. This pollution can have a real impact on health, which is why it's necessary to treat it. To do this, various methods exist, including photocatalysis. Technopure is a French company that manufactures air purification equipment using this technology. Its devices were then tested under real-life conditions to prove their effectiveness and non-hazardousness. These two points have been validated by various criteria.

Keywords: air pollution, active purification, photocatalysis

1. Introduction

Quality of life is influenced by the quality of the air we breathe. In many places, whether inside public or private buildings, or in means of transport, the air is much more polluted than we think. But it's indoors that we spend most of our time (80 to 90% of our days). Indoor pollution can come from a variety of sources, including outdoor air, furniture, decoration or human activity. The main categories are chemical pollutants such as Volatile Organic Compounds (VOCs), physical pollutants such as dust and allergens and biological pollutants such as bacteria and viruses.

Poor air quality can be harmful to health, leading to major problems such as allergies or respiratory problems, which are widespread throughout the word. *C.T Jani et al (2025)* studied data collected between 1990 and 2019, in the world's ten most populous countries, on lung cancer deaths. It turns out that the main causes of this type of death has changed. Until now, the leading cause was tobacco and the second was asbestos. The study showed that air pollution, or more specifically VOCs, has taken second place in this ranking. This pollution now accounts for 20% of cancer-related deaths.

To reduce health risks, it is essential to reduce the spread of pollutants in the air. Various treatment techniques are available for this purpose. Some also called passive methods are insufficiently effective or unsuitable, as they retain pollutants rather than removing them. Technopure is a company dedicated to more effective air treatment using active purification techniques. Its techniques tackle chemical pollutants (like VOCs), physical and biological pollutants and odors. Its main technology is photocatalysis.

To generate a photocatalytic reaction, an ultraviolet (UV) lamp and a photocatalyst such as titanium dioxide (TiO_2) are needed. The UV lamp activates the semiconductor, which reduces the dioxygen (O_2) and oxidizes the water (H_2O) in the air to produce superoxide ions and radicals that degrade proximal organic pollutants, as shown in **Figure 1**.

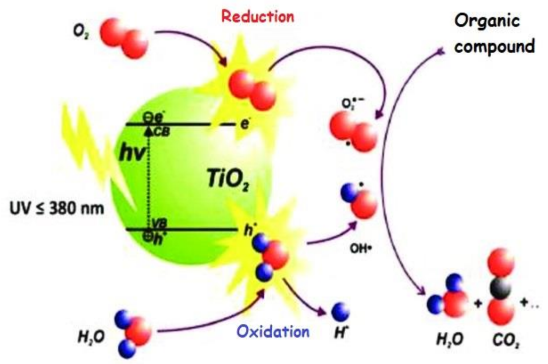

Figure 1. Principle of photocatalysis

To prove that this technology is effective and non-hazardous, independent certified laboratories have carried out tests in situ and in human presence. For example, Bureau Veritas, carried out tests on buses and tramways. For each study, two vehicles were compared in their normal operating mode: one equipped with our purification devices and one without equipment, as a control vehicle. Microbiological contamination and VOCs levels, as well as any release of TiO_2, were monitored on surfaces and in the air

2. Material and methods

All samples were taken at the same locations on both vehicles, both in accessible areas and out of reach of passengers and staff. In the equipped vehicle, the first samples were taken before the equipment was switched on, then the systems were operated continuously. Next samples were therefore taken during operation. In the second vehicle, all samples were taken before any cleaning/disinfection operations.

2.1. Biocontamination

Biocontamination was studied by sampling and counting the microorganisms present. Samples were taken from surfaces and air, the first by swabbing and the second using a biocollector. All samples were then sent to the laboratory for culture and enumeration of total flora on PCA culture media and fungal flora on Sabouraud culture media.

2.2. Volatile Organic Compounds

VOCs in the air were sampled using a Gilair pump. Two analyses were then carried out. The first quantified the acetaldehyde and formaldehyde present, using HPLC/UV to study DNPH cartridges. The second was used to screen VOCs, with Tenax tubes analyzed by ATD/GC/MS/FID to quantify the ten main compounds and the total VOCs content.

2.3. Titanium Dioxide

The possible release of TiO_2 nanoparticles by disinfection systems was verified. Samples were taken using a Particlever impactor, then the aerosol was characterized using XRF and SEM/EDX.

3. Results and discussion

These analyses were used to check the rate of pollutant degradation and the possibility of nanoparticle release from the systems.

3.1. System efficiency

Microbiological contamination levels were measured before the units were switched on, as references points, and during operation, in comparison with the non-equipped vehicle. The **Table 1** summarizes the microbiological degradation rates after 2 and 15 days. It can be seen that in the equipped vehicle, the abatement rate is generally higher than in the control vehicle and frequently exceeds 90% which shows that our devices are effective against microbiological contaminants.

Table 1. Rate of reduction in microbial contamination as a function of sampling points in a control bus and in a bus equipped with a Technopure disinfection system after 2 days and 15 days of operation

Sampling points	Total flora (CFU / 25 cm²) Before cleaning / disinfection	Reduction rate (%)			
		Control bus without treatment	Equipped bus during disinfection	Control bus without treatment	Equipped bus during disinfection
	T0	T1 = T0 + 2 days		T2 = T0 + 15 days	
Door release button at driver's station	1600	92,5	94,38	85	93,75
Steering wheel	600	80	96,33	46,67	93
Horizontal bar on right-hand luggage rack	400	80	96	60	92
Hinge bellows left bar	400	0	98	60	98,5
Plastic cover for "Stop requested" display	400	-300	97,5	0	99
Rear door left vertical bar	1200	66,67	99	80	99,5
Plastic armrest	800	70	98,25	96,88	89,25
Vertical bar on center door, above call button	20000	92,5	98,5	99,4	99,69
Left seat handle	4000	84	98,25	94	98,35
Bottom horizontal bar	400	10	82,5	80	75
Inside bus roof above last row of seats	160	-250	81,25	-7400	80
High horizontal bar at center door	400	90	72,5	93,75	81
Average	**2530**	**10**	**93**	**-550**	**92**

Concentrations of the 10 main VOCs, as well as acetaldehyde and formaldehyde, were measured. The values in both vehicles were below the guideline values for indoor air, but there was a general decrease in the values in the vehicle fitted with our devices, proving their effectiveness against VOCs.

3.2. Compounds released

TiO_2 levels were measured during operation of the devices. The levels observed were below the analytical method's limit of quantification and well below the exposure limit for ultra-fine TiO_2. This shows that there is no release of TiO_2 outside the units, making them non-hazardous.

4. Conclusion

Tests carried out by certified organizations under real-life conditions have proven the effectiveness of our devices and their non-hazardous nature. Our systems reduced microbiological contamination and VOCs levels as predicted, compared with the control vehicle. The absence of TiO_2 release has also been noted. Our equipment are efficient and can be used in human presence.

References

C. T. Jani *et al.*, « Evolving trends in lung cancer risk factors in the ten most populous countries: an analysis of data from the 2019 Global Burden of Disease Study », *eClinicalMedicine*, vol. 79, janv. 2025, doi: 10.1016/j.eclinm.2024.103033