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# Improving Indoor Air Quality in Hospital Environments and Dental Practices with Modular Stand-Alone Air Cleaning Devices

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## ABSTRACT

The goal of this study was to investigate the effectiveness of stand-alone modular air purification systems in improving air quality in dental practices, hospital and laboratory environments. As air pollutant make-up and concentration may vary significantly in different indoor environments, the air cleaning technologies utilised should be optimised for the pollutants targeted in a particular environment. Reduction of mercury vapours and formaldehyde were examined because of their importance for indoor air quality in dental practices. In addition, the reduction of particles and microorganisms was investigated as well as the removal of substances which are noticeable due to their strong odours. The air purifiers used in the study were configured to contain the most suitable air cleaning technology for each of the indoor environments. The systems use high-efficiency particulate air (HEPA/ULPA) filters, activated carbon-based filters with and without impregnation and/or activated alumina-based filters with impregnation. The maximum airflow of the systems ranges between 220 and 500 $m^3$/h, depending on the filter configuration. The units were investigated under laboratory and simulated field conditions to determine removal efficiencies for various substances. High removal efficiencies for mercury vapour, formaldehyde, particles and microorganisms could be observed. The elimination of strong odours (orange oil, cinnamon oil and menthol) is difficult, if the source of the odour is not removed. The unit's effectiveness in dental practices and in hospital treatment rooms will be analysed in follow-up studies including personal bio-monitoring investigations. The data will facilitate the evaluation of the role that optimised air purification systems can play in reducing pollutant exposure of medical personnel and patients.

## INTRODUCTION

This study investigated the efficiency of decentralised modular air purification devices [**IQAir, Switzerland**] with regard to the reduction of mercury vapours, formaldehyde, microorganisms and particulates. Earlier investigations have shown, that this kind of air cleaning technology can successfully be used in residential settings with certain air quality problems [1,2].

The filter combination of the device has been optimised to target a variety of pollutants present in varying medical environments. In dental environments it is the removal efficiency for mercury vapours, disinfectant compounds, and, to a certain degree, the reduction of odours that is of interest. In hospitals the emphasis should be placed on the removal of microorganisms, disinfectant compounds, and in specific cases, the removal of anaesthetic gases.

## METHODS

<u>Air filters</u>
The devices used within the confines of this study [**IQAir**] are of modular design; i.e. they feature several modular, consecutively arranged filter stages. The first filtration stage consists of a coarse and fine dust filter, which is followed by a 5-speed fan motor.

In the devices for the control of gaseous pollutants, the second filtration stage consists of four cylindrical gas filter cartridges [**IQAir GC Series**]. For the control of mercury vapours, the cartridges contain activated carbon impregnated with sulphur to adsorb mercury and convert it into stable mercury sulfide [**IQAir Dental Hg FlexVac & IQAir Dental Pro**]. For the removal of formaldehyde the cartridges contain activated alumina-based potassium permanganate impregnated media causing the oxidation of the aldehyde [**IQAir MultiGas GC & IQAir Chemisorber GC**]. The final filtration stage consist of a particulate post-filter which is designed to remove any dust that may be generated by the gas phase media.

In devices that do not aim to remove gaseous pollutants [**IQAir Cleanroom Series**], the second filtration stage consists of a high-efficiency particulate air (HEPA) filter for the removal of airborne particulates and microorganisms.

The recirculation models of these air cleaning devices draw in air at the base, which is then expelled through slots on all four sides at the top of the units. Specialised models for the extraction of contaminants at their source are equipped with a spot-suction system [**FlexVac & VM FlexVac**] that guides the air to the base of the unit via a flexible suction arm with a diametre of approximately 10 cm . As with the recirculation models, the air is expelled via the openings at the top of the unit.

<u>Experiment Set-up</u>

*Mercury:* A beaker containing about 10 ml of metallic mercury was placed in the test room. Mercury concentrations were measured with a mercury analyser (Hg MAK-Monitor, Dr. R. Seitner Mess- und Regeltechnik, detection limit: 2µm/$m^3$). After one hour the mercury concentrations measured in the test chamber levelled out at between 16 and 26µm/$m^3$. The tests was undertaken in a 34.5$m^3$ room with no windows and no ventilation.

*Formaldehyde:* Formaldehyde was emitted from beakers filled with formalin solution (37%). The formaldehyde concentration in the air was monitored using an electrochemical detector (Interscan Corp. Mod.1166).

*Particulates:* The reduction of particles was examined in real-life conditions. The measurement was undertaken with a particle counter (Met One, Model 3113). The device measures particle concentrations in the air for six different particle sizes (0.3, 0.5, 1.0, 3.0, 5.0, 10.0 µm). The margin of error of the counter is < 5% at 4*105 particles/cubic foot. The air volume of the test room was 43.2 $m^3$.

*Microorganisms:* Samples were taken at the air intake and at the outlet of the unit (Biotest RCS Plus, Biotest GK-A). No further analysis with regard to the type of the germs was undertaken.

*Odours:* The removal efficiency was assessed by two persons for orange and cinnamon oil, as well as menthol.

## RESULTS AND DISCUSSION

*Reduction of Mercury:* In the first experiment the test room was contaminated with mercury vapour. The effectiveness of the air cleaning device [**IQAir Dental Pro**] was measured with the pollution source remaining in the room at all times. Measurements taken directly from the air outlet of the filtration device showed that mercury levels were below the measuring threshold (2 µg/$m^3$). Measuring the air within the test chamber it was found that the original concentration of 16 µg/$m^3$ without filtration device, was reduced to less than 2 µg/$m^3$ within six minutes with the help of a unit with a spot suction arm [**IQAir Dental Hg FlexVac**] placed about two meters away from the mercury source (Fig. 1). The airflow rate of the device was 220 $m^3$/h, which means that the air within the test chamber was filtered

0.7 times. Airflow rates of 150 m³/h and below resulted in diminished removal efficiencies in the room. At airflow rates of 40 m³/h the reduction of mercury vapour concentrations to levels below the detection threshold were reached after three hours (Fig. 2).

In a second experiment the suction arm of the filtration device was positioned 30 cm above the contamination source. No mercury contamination build-up (< 2µg/m³) in the room air was detected even at the lowest airflow rate of 40 m³/h.

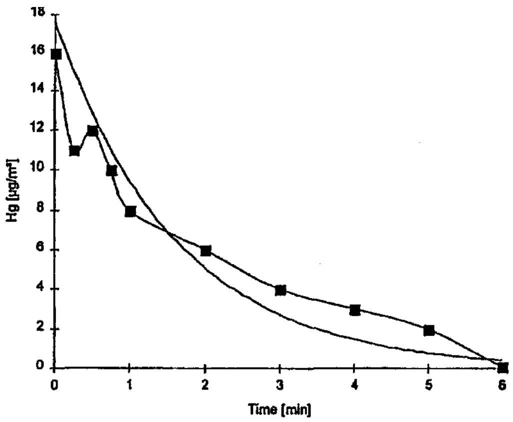


Fig.1: Reduction of mercury vapour
(Airflow rate: 220 m³/h; room size 34.5 m³)

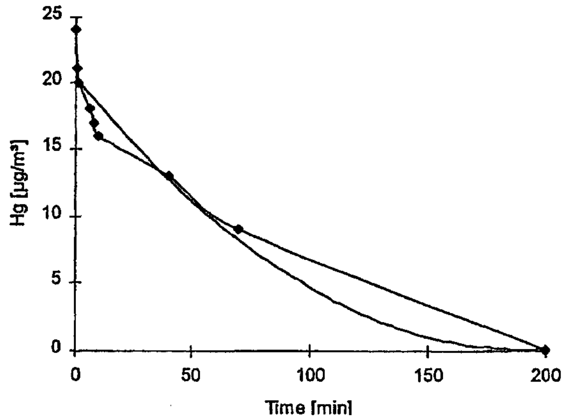


Fig. 2: Reduction of mercury vapour
(Airflow rate: 40 m³/h; room size: 34,5 m³)

Suitable air cleaners can effectively reduce mercury vapours which, for example, may stem from the use of amalgam for fillings in dental practices [3]. In those practices the average levels lay between 1.8 and 2 µg/m³ [4], although peak concentrations of mercury during the handling or the removal of amalgam fillings were significantly higher [5].

*Reduction of Formaldehyde:* For the removal of formaldehyde from the room air, the device was fitted with four cylindrical filter cartridges filled with activated alumina [**IQAir Chemisorber GC**]. Due to the impregnation of the activated alumina with potassium permanganate ($KMnO_4$), the formaldehyde retained in the filter is being destroyed in an oxidisation process. The removal efficiency for formaldehyde was investigated in simulated field conditions, using a device fitted with a suction arm. The maximum concentration in the room was 0.36 ppm. Depending on the air flow rate, this concentration was reduced within 60 minutes down to less than 0.1 ppm (the threshold level for indoor air laid down by the Federal German Environmental Department). No formaldehyde concentration built-up was detectable in the room at an airflow rate of 220 m³/h when the suction arm [**FlexVac**] was positioned above the pollution source. The results of these tests are particularly important in the light of the fact that other research studies have found the efficiency of portable air cleaners to be inadequate for the removal of gaseous pollutants, such as formaldehyde [4].

*Reduction of Particulates:* The reduction of airborne particles may be desirable for a number of reasons. Particles may be chemically active or carry pollutants into the lungs (e.g. tobacco smoke, diesel soot). Since particle bound allergens are responsible for triggering allergic reactions, air cleaners are increasingly used as an additional tool in fighting allergies caused by airborne allergens. Former investigations have shown, that allergens from house dust mites can be retained by air filtration devices [6]. The removal efficiency for airborne particulates was examined under real-life conditions, using devices equipped with a high-efficiency particulate air (HEPA) filter [**IQAir Cleanroom Series**].

A clear drop in the initial particle concentrations of 25*103 particles per litre of air could be observed during the running of the filtration device. A typical reduction cycle for particles of > 0.3 µm over the course of a day is depicted in Fig. 3. The particle reduction in the room air followed an exponential course ($r^2 = 0.67$). Readings that deviate from the curve are due to activity within the room. After a short time the air was free of particles sized between 5 and 10 µm. Particles sized between 3 and 5 µm were only detectable in concentrations of < 10 per litre. During the operation of the filtration device a close correlation was evidenced between the count of particles sized between 0.3 and 1 µm. This measurement showed that the removal of particles from the air was effective. This makes it save to assume that this type of filter could also be used to efficiently remove chemical substances with the low vapour pressure which attach to particles.

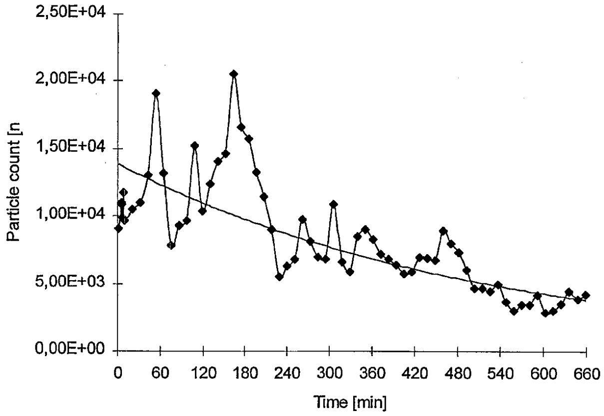


Fig. 3: Reduction of particles

*Reduction of Microorganisms:* Since microorganisms are particles, it can be expected that the removal of microorganisms with the use of a high-efficiency particulate air (HEPA) filter [**IQAir Cleanroom Series**] would be effective. Corresponding examinations were undertaken in a microbiological laboratory. A count at the air intake of the device [**IQAir Cleanroom H13**] revealed a maximum of 30 microorganisms whose identity was not investigated further. The expelled air was free from microorganisms. Hence, the counts relating to the reduction of particles could be confirmed.

*Reduction of Odours:* The device used for the removal of odours was equipped with four filter cartridges containing granular activated carbon [**IQAir VOC GC**]. A clear drop in the odour intensity was evidenced in the immediate vicinity of the device. Without elimination of the odour source, the odour intensity in the room could merely be reduced. However, the intensity of the odour could be reduced to a subjectively imperceptible level after the elimination of the odour source.

It can finally be stated, that a modular room air cleaner configured to reduce special contaminants can significantly improve indoor air quality in an appropriately sized room. The deployment of air cleaners should however take place, where possible, in combination with appropriate measures of source control and ventilation. Specialized air cleaners will be particularly beneficial in certain medical environments where source control measures are either not possible or limited. An appropriately equipped air cleaner could thus make a significant contribution in supporting and optimizing a comprehensive strategy of source control and ventilation for improved indoor air quality in medical environments.

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