# A Review paper on Improving the Indoor Air Quality (IAQ) in green and conventional buildings using sustainable materials.

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***Abstract :*** This paper review the methods of improving the indoor air quality in buildings using a sustainable and effective material. Indoor air quality is the quality of the air inside our buildings and it is one of the important parameters to be adopted for the safe and healthy life of the occupants ,and sustainable materials are those materials which are being produced and used in a required volumes but without depleting the available non renewable resources and without disrupting the established equilibrium state of the environment. Studies found out that people spent 90 percent of their time indoors and because of poor indoor air quality many are having symptoms of sick building syndrome, therefore various researchers are sensing the need and urgency of finding out an effective and economical methods in improving the quality of the indoor air. The methods which have been discussed in this paper are biofiltration technology, a plant based technology which has been adopted for many years in improving the indoor air; photocatalytic paint- an innovative paint material which helps in the degradation of the air pollutants such as; energy recovery ventilators- a system that helps to remove the stale and contaminated air and allowing clean and fresh air to enter our rooms, and; UV technology- a technology which has been adopted in different situations, is found out to be an effective method in deactivating various bacteria and viruses which may enter our buildings. The sample indoor air quality report of a building is included in this study, and is compared with various guidelines from WHO and ASHRAE and was found to be in accordance with it.

***Key words*** **– Indoor Air Quality, Sick Building Syndrome, Biofiltration technology, Photocatalytic paint, Energy Recovery Ventilators.**

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## I. INTRODUCTION

We all know that the life we live now in this century is all at risk which is mainly related to health. But this specific problem we are talking about is mostly happen due to lack of proper clean air in the surrounding whether its indoor or outdoor air. This unclean air we breathe in or in other words we will describe it as air pollution is the condition of polluted air of different kinds of poisonous gas matter which can be $CO_2$, $NO_2$, $SO_2$, radon gas etc that is emitted from different source such as industries, automobiles, combustible materials etc. But for us human being to be able to survive we need a good air quality that helps us to run our body for circulation of blood stream. Therefore, in today's everyday life, it's a problem for us to breathe in fresh air because of the rise in air pollution, especially in urban cities where it runs 24 hours and the condition is so critical to the point that we were not able to notice the quality of air until a certain survey is usually adopted. But for the purpose of the project, we are only going to study about the indoor air quality and the methods of improving it. Even the indoor air contains air pollutants that is generated by our body or by certain electronic devices or particles coming from outside sources. This polluted air will cause health problem such as heart disease, stroke, headache, insomnia, etc which mainly affect elderly and young generations, as their metabolism is weak therefore, they need clean air to maintain air circulation to have a healthy life. A study is being carried out by researchers which shows that the quality of the indoor air is more serious than the outdoor air. Various research indicates that 90 percent of the people spend more time indoors[9]. Inadequate ventilation will contribute to lots of air pollutants level by not able to bring in enough outdoor air to dilute emissions outdoor dust particles, gas vehicles, which is entering through large open space, door cracks or by large members in the building; also, products for electronic machine; central heating and cooling systems and humidification devices; and mainly outdoor sources such as harmful gases from pesticides, dust particles, and radon. Therefore, if the condition of these pollutants reaches the critical value people will suffer many health problems i.e., mental or physical problem and may also lead to critical condition. Usually, lung diseases are the most common injury by air borne pollutants which people were not able to breathe in properly. Especially those who is having asthma which they need filter air to inhale, whether a person reacts to a pollutant depends on individual sensitivity, which varies tremendously from person to person. Some people can become sensitized to biological or chemical pollutants after repeated or high-level exposures. Therefore, a study is needed to help solve the problem for indoor air quality to fight for clean air. The study includes using of vegetative plants which will reduce the indoor air pollutants mainly carbon dioxide, $NO_2$ as plants can also reduce stress, increase work performance, and reduce symptoms of ill health[3], photocatalytic paint, which is an important part in this study, energy recovery ventilators and UV based technology are also included in this study.

Fig.1 Areca palm

Fig.2 Snake plant

## II. Methodology

In this paper, different methods have been gathered from different research papers and are studied thoroughly. Some of themethods which are being studied are

- Biofiltration technology
- Photocatalytic paint
- Energy Recovery Ventilators (ERVs)
- UV based technology

But from the above mentioned methods, Photocatalytic paint is being studied thoroughly and compared with the normal paint. Apart from the above methods, indoor air quality analysis report datas are being collected and compared with the guidelines from the WHO (World Health Organisation) and ASHRAE( American Society of Heating, Refrigerating and Air Conditioning Engineers) as shown below.

**Indoor Air Quality Standards**

| IAQM parameters | WHO guidelines | ASHRAE |
|---|---|---|
| Particulate Matter ($PM_{10}$) | 50 $\mu$g/m3 (24 hr) | 150 $\mu$g/m3 (24 hr) |
| $PM_{2.5}$ | 25 $\mu$g/m3 (24 hr) | 3000 $\mu$g/m3 (8 hr at ceiling height) 65 $\mu$g/m3 (24 hr in breathing zone) |
| Sulphur Dioxide ($SO_2$) | 20 $\mu$g/m3 (24 hr) | - |
| Nitrogen Dioxide ($NO_2$) | 200 $\mu$g/m3 (1 hr) 40 $\mu$g/m3 (Annual) | - |
| Carbon Monoxide (CO) | 10 ppm (8 hr) | 9 ppm (8 hr) |
| Carbon Dioxide($CO_2$) | | 1000 ppm |
| Humidity | | 30% - 65% |
| Temperature | | 68°F - 74.5°F (20 – 23.6℃) (winter) 73°F - 79°F (22.8 – 26.1℃) (summer) - |

(WHO- World Health Organisation
ASHRAE- American Society of Heating, Refrigerating, and Air Conditioning Engineers)
(Apart from the above mentioned pollutants, it is also necessary to monitor the other pollutants such as Volatile organic compounds (VOCs), methane, formaldehyde, ozone ($O_3$), hydrocarbon (HC), asbestos etc.)

The sample indoor air quality report is shown in table below:

| Indoor Air Quality Analysis Report | | | |
|---|---|---|---|
| Sr. No. | Parameter | Result | Units |
| 1. | Temperature | 22.5 | ℃ |
| 2. | Relative Humidity | 45 | % |
| 3. | Particulate Matter ($PM_{10}$) | BDL | $\mu$g/m3 |
| 4. | $CO_2$ | 0.022 | % |
| 5. | $SO_2$ | BDL | Ppm |
| 6. | Air Velocity | BDL | mt/sec |

| | | | |
|---|---|---|---|
| 7. | CO | 0.18 | Ppm |
| 8. | Oxides of Nitrogen (NOx) | BDL | Ppm |
| 9. | $O_2$ | 22.0 | % |
| 10. | Ozone ($O_3$) | BDL | $\mu$g/m3 |
| Remark- BDL- Below Detectable Limit. | | | |

## III. Results

From the indoor air quality report table, we can observed that nearly all the parameters required for a good quality indoor air are found to be within the guidelines limit, and some of the pollutants are even below the detectable limit. Therefore, it is justified that the particular building is having a good indoor air quality.
In another theoretical findings, Photocatalytic paint proves to be more efficient than a normal paint. Paint is a liquid material which is applied to any surfaces for the decorative purposes or to prevent a surface from getting rust, whereas photocatalytic paint not only serve the decorative purpose or prevention from rust but has the ability to self cleaning surfaces and purify the air inside rooms by degrading the air pollutants.

## IV.Discussions

Building is the place where people lived and spent most of their time, and the quality of it is important to be ensured so that the health conditions and life of the occupants is not affected. The quality of the building is comprised of many factors and the most important one which people neglected is the quality of the indoor air. Indoor air quality (IAQ) is one of the factor which if neglected can lead to many health issues of the occupants, such as sick building syndrome, fever, respiratory problems etc. In these COVID-19 times, the quality of the indoor air is a major concern, and various researchers have tried to find solutions of improving the indoor air quality. Some of the methods which have been gathered from different research papers are discussed below:

### A. Biofiltration technology

A plant based technology which can be easily adopted in both rural and urban buildings. This is the most efficient technology because of its aesthetics, economical, social and environmental aspects. The technology mostly adopted in green buildings, using green walls and various microalgae structures[2].
Plants filter the air and convert $CO_2$ into $O_2$ and biomass, and thus help in filtering the air. This system of plant based technology can also use algae but is currently being investigated. This development will help to improve the living conditions in terms of air quality for the occupants. But to adopt this technology in built environment can have some limitations in terms of its restriction in wide range of applications, and it is found that some species produce certain VOC's under particular conditions[1]. Example of some plants which can be used to improve indoor air quality are Areca Palm (fig.1) -one of the best air purifying plants for general air cleanliness. Snake plant (fig.2)- helps to removes nitrogen oxides and absorbs formaldehydes, money plant etc.
In the year 1996, Lohr et al. performed a study in terms of productivity in the working environment and has found that the plants planted in the interior environment may improve the productivity of the workers and also may help to reduce stress when working in a windowless environment. The outcome also suggested that in the presence of plants the reaction time of the workers was 12% faster than in the absence of plants. Lohr et al. also reported that in the presence of foliage plants, the accumulation of particulate matter in the interior space became lower in both rooms than in the absence of plants[3][4].

### B. Photocatalytic paint

Photocatalytic paint is an innovative paint material which exhibits an intense photocatalytic activity under the presence of direct and diffuse visible light for the degradation of the present air pollutants. The photocatalytic paint is being prepared by using a photocatalytic powder and a photo paint. A photo powder is prepared by using chemicals such as Tritanium (IV) oxysulfate hydrate ($TiOSO_4xH_2O$), ammonium hydroxide (25% $NH_4OH$), and manganese (II) acetate tetrahydrate ($Mn(CH_3COO)_2$) . One of the leading applications of this technology is the combination of $TiO_2$ with construction materials which has the ability to self cleaning surfaces along with air purifier ability[5].
A lab test and a real case study test was performed by Maggos et al. using the photo paint in which the former was performed in a specially designed photo reactor while the latter in a military medical building. The main pollutants required for the degradation are Nitrogen Oxide (NO) and Toluene, and the concentrations of these pollutants are being monitored between the room with photo paint and the room without photo paint. The monitoring process was carried out to estimate the efficiency of the photo paint in degrading the above pollutants. The results of this case study was found out in the lab scale test, a reduction of 60% NO and 16% Toluene was achieved while in a real case situation an improvement of the indoor air quality upto 19% and 5% was achieved even though the reduction of pollutants was significantly lower as compared to lab scale test[6].

### C. Energy recovery ventilators (ERVs)

Energy recovery ventilators are the systems which have been designed to be connected to the ducts that are a part of the HVAC systems. The systems are designed by way of two fans, in which the ERVs draw the clean and fresh air into our homes or offices and removes the stale air, and also helps to reduce the energy consumption which is associated with the conditioning of ventilation air[7]. In addition to this transfer of air streams, ERVs systems capture pollutants, contaminants, allergens, pollens etc and thus helping to ensure that the air that enters into our homes is free from any pollutants and is clean and healthy. Some of the

benefits that we can get by adopting this technology are- it helps to improve respiration for asthma sufferers; reducing cooking, bathroom and pet odors; helps to extend the life of HVAC systems.
Other options of improving the indoor air quality which may not be sustainable but may be important to adopt especially during the rising cases of COVID-19, is listed below.

**D. UV based technology**

One of the direct approach technology in deactivating airborne pathogens i.e., viruses and bacteria. Ultraviolet Germicidal irradiation (UVGI) having a UV wavelength of 253.7nm, is one which has been long established and has the ability to deactivate airborne pathogens, but it possess limitations because of its human health hazards relating with eyes and skin. Recently, it has been found that far-UVC light having a wavelength of 207-222nm can efficiently deactivate viruses and bacteria and thus can reduce the concentrations of COVID-19. It is believed that this technology is applicable to large buildings, but its economics and safety have not been thoroughly studied[1].
UV photolysis is one of the UV based technology which relies on the degradation of viruses, bacteria, fungi by ultraviolet radiation, and proves to be an effective method for sterilization at ambient temperature and pressure. But the main drawback of this technology is high energy consumption and high cost of lamp acquisition, and also it is harmful for human health. In addition, as a result of unspecified action of UV radiation, unwanted compounds such as ozone and secondary organic pollutants might be released[8].

## IV. Conclusion

According to the Environmental Protection Agency (EPA), the average person in developed country spends 93% of their life indoors. 87% indoors, and another 6% in automobiles. That's only 7% of our entire life outdoors. That's accounted only one half of one day per week outdoors. Statistics suggest that in developing countries, health impacts of indoor air pollution far outweigh those of outdoor air pollution. Indoor air pollution from solid fuels accounted for 3.5 million deaths and 4.5% global daily-adjusted life year (DALY) in 2010; it also accounted for 16% particulate matter pollution.
This begs the question what are the means to stop or reduce the effects of indoor air pollution and to maintain is sustainable and suitable indoor air quality. These days most people enjoy the benefits of central air system in the homes and offices these systems keeps us warm in winter and cold in summer but what most people don't realise is that these systems can spread airborne contaminants throughout the area. Bacteria, viruses, moulds and even pollens are carried throughout the area via air through these systems. This happens because the system constantly recirculate in the air in our homes out of all of those pathogens some can even make us sick these pathogens can eventually clog the air system filters and turn them into a breeding ground for germs. The environmental health agency considers indoor air quality to be one of the top 5 health hazards of today. On our review on how to improve indoor air quality we have found various methods which can be beneficial and sustainable these methods being biofiltration which is a plant based air purifying system which generally focuses on converting $CO_2$ into $O_2$ and biomass though this process has a lot of limitations, it is one of the most diverse and economically sustainable methods of the list it has a wide variety of uses and as mentioned various plants can be used to achieve various outcomes for example as mentioned earlier plants like palm are one of the best air purifiers in general and also snake plant it can also be used to remove nitrogen gas and absorb formaldehyde and the list goes on this method is as aesthetically pleasing as its uses and effectiveness this can be used in almost every scenario and buildings especially green buildings which mostly focus on environment friendly and sustainable methods. Moving on to the next method we found that paint it can affect the indoor air quality especially for childrens and infants as the pollutants tend to be on the lower half of the room thus this poses a problem especially if there are childrens. On the other hand, large building build up dirt and grime which requires a large maintenance but what if the external surfaces, windows cells can clean on it's own the Photocatalytic paint contains active ingredients like titanium dioxide which reacts with the simplest of things like being exposed to light which then causes chemical reaction to occur at the surface producing active oxygen species continually these species have stronger oxidising power than hydrogen peroxide. This paint have three major effects firstly the active oxygen decomposes dirt soot and organic components through oxidation which turns them into carbon dioxide and water secondly water is highly absorbent for this paint the pressure of absorption doesn't allow to form droplets of water rather these water former sheet which undercuts the dirt while cleaning the surface thirdly the high water attraction neutralizes the surface hence making it antistatic which doesn't let dust particles stick into it. Outdoors, this paint breakdown smog into harmless byproducts while indoors reduced the risk of air pollutants particles off dirt and harmful microbes. Cost effective simple and eco-friendly and this paint can be applied on glass, concrete, metal and marvel hence this innovative paint can bring a revolution to the future.
Now moving on to the next method which focuses on the HVAC systems installed in buildings we came across the energy recovery ventilators which are installed in the air ducts which intake fresh air and has a rotating filter these ventilators also transfers moisture hence keeping the indoor air quality fresh the rotating filter it is usually made of fibre of polymer structure which has a silica paste gel and rotates at a speed of 40 to 90 RPM. Well the air is passed through the rotating filter it gets purified of air particles the air on its way out passes from the other side of the same rotating filter which consists of pressure sensor that allows us to know if the filtration is proper or whether the filter is blocked and needs to be changed, this system also acts as a heat recovery ventilator which can keep us warm in winter and cool in summers. This is the very effective way to keep the indoor air clean but the only issue we have found is the filter needs to be cleaned and maintained which process to on next method which is UV based technologies which can be implemented on air ducts for Air purifying filters. For 100 of years scientists have known the germ killing effects of UV lights and its various applications reducing their applications of dangerous chemicals. The particular UV lights effective for killing germs fall in between the UVC section of the spectrum. For many years UV technologies have been used in hospitals to disinfectant the room and the instruments used similar technologies are also used in food now adays water purifier both large and small contains UVC lights which work by breaking the cell wall and destroying the DNA molecule of germs pathogens and other microbes which prevents them from reproducing. The UV based technology is generally installed in the air handler where the coils of filters off air purifier exist and the effects of the UV light it is limited to that area thus reducing the chances of exposure to UV radiation. The methods mentioned above can provide, is safer and much healthy

indoor air which can reduce the chances of becoming sick from the various airborne diseases or exposure air dust particles. We spend most of our times indoors and hence it is crucial for us to maintain the indoor air quality.

**References**

[1] Naglaa A. Megahed, Ehab M. Ghoneim,2020, Indoor Air Quality: Rethinking rules of building design strategies in post-pandemic architecture.

[2] Kisser, J., Wirth, M., De Gusseme, B., Van Eekert, M., Zeeman, G., Schoenborn, A., et al., 2020. A review of nature-based solutions for resource recovery in cities.

[3] Lohr VI, Pearson-Mims CH and Goodwin GK. Interior plants may improve worker productivity and reduce stress in a windowless environment. J Environ Horticult 1996.

[4] Tatiana Armijos Moya, Andy van den Dobbelsteen, Marc Ottele´ and Philomena M. Bluyssen,2019, A review of green systems within the indoor environment.

[5] Federico Salvadores, Martin Reli, Orlando M. Alfano, Kamila Koci, Maria delos Milagros Ballari, Efficiencies Evaluation of Photocatalytic Paints under Indoor and Outdoor Air Conditions.

[6] Thomas Maggos, Vassilios Binas, Vasileios Siaperas, Antypas Terzopoulos, Panagiotis Panagopoulos and George Kiriakidis, A Promising Technological Approach to Improve Indoor Air Quality,2019

[7] Peng Yang, Li Li, Jianqin Wang , Guilin Huang and Jingli Peng, Testing for Energy Recovery Ventilators and Energy Saving Analysis with Air-Conditioning Systems.

[8] Angela Luengas, Astrid Barona, Cecile Hort, Gorka Gallastegui, Vincent Platel, Ana Elias, A review of indoor air treatment technologies.

[9] Indoor air pollution: An introduction for health professionals surveyed: EPA's report on environment/ the inside story: A guide to indoor quality.

[10]https://www.ppsthane.com/indoor-air-quality-monitoring-testing?gclid=Cj0KCQiApsiBBhCKARIsAN8o_4haLh4sicfNCi5vRVp4tqgVzlA1jc0-nTbzYpcY4ETjnKnUqFQOfWgaAmUfEALw_wcB