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A cutting-edge survey on indoor air contamination and systems for indoor air contamination control

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K E Y W O R D S

Toxin
Particulate matter
Inorganic mixtures
Air quality
Indoor air contamination

A B S T R A C T

Indoor air contamination has generally had less consideration than outside contaminationregardless of insidecontamination levels are ordinarily two times higher, and individuals go through 80-90% of their time on earth in expanding water/air proofstructures. In excess of 5 million individuals die consistently rashly from diseases owing to poorindoor air quality, which additionally makes multi-mogul misfortunes due diminished worker's efficiency,material harms and expanded wellbeing framework costs. Indoor air poisons incorporate particulate matter,natural poisons and north of 400 distinct substance natural and inorganic mixtures, whose fixations are administered by a few outside and indoor elements. Counteraction of toxin isn't consistentlyin fact, attainable, so the execution of practical dynamic decrease units is required. Up todate no single physical-substance innovation is equipped for adapting to all indoor air toxins in a cost-effective way. This issue requires the utilization of successive innovation designs at the costsof predominant capital and working expenses. Also, the presentation of traditional physical substanceinnovations is as yet restricted by the low focuses, the variety, and the inconstancy of poisons inindoor conditions. In this unique circumstance, biotechnologies have arisen as a practical and reasonablestage fit for adapting to these restrictions dependent on the biocatalytic activity of plants, microbes,growths, and microalgae. For sure, organic based cleansing frameworks can further develop the energy productivity ofstructures, while giving extra stylish and mental advantages. This audit basically evaluatedthe best in class of the indoor air contamination issue and avoidance methodologies, alongside the newpropels in physical-substance and natural advances for indoor toxins decrease.

1. Introduction

Nowadays, air pollution and human exposure to low-quality air is the most critical env threat to public environmental health worldwide according to World Health Organization (WHO)[1]. In recent reports, on the global scale, 1 out 10 deaths are taking place due to air pollution. It is alone caused 5.5 million deaths approximately in 2013 in the World (World Bank and Institute for Health Metrics and Evaluation, 2016)[2] (Fig. 1). In the recent update at the European level, the data have ascribed more than the 500,000 premature deaths in 2016 for longer-term exposure to air pollution. The particulate matter (PM) which is from 412,000 corresponded to it, 71,000 to NO_2 and 15,000 to O_3(European Environmental Agency, 2019)[3]. As there is continuous growth which affects even more critically in majority cities. There is about 90% of the population worldwide are survived in an urban area in which they exposed to air quality levels that exceed WHO guidelines which are based on Particulate matter pollution.

In the recent studies, human exposure to indoor pollution stated that the environment indoor would be at least twice as polluted as in outdoor environments. In urban streets, the air in the average traffic is cleaner than in the living room. The indoor air pollution has significantly less than the pollution in outdoor air pollution, especially in dense traffic areas and in the more industrialized areas. Though the threats were posed in long-term exposure to indoor air pollution, it has become more in recent years as they are against the outside environment to obtain cooling and heating energy savings. Most of the buildings depend on mechanical ventilation to circulate indoor air with reduced outdoor air dilution levels which leads to the accumulation of pollutants. There will be health problems such as building-related illness, chemical sensitivity, and building syndrome which are extensively reported [4]. However, the indoor air pollutants levels and the associated symptoms may reduce in renovated or new buildings during the first six months, the poor and its associated symptoms have been reported over years [5].

In this context, the exposure of humans to indoor air such as workplaces, houses, or using transport exceeds 80% in developed countries and 85 to 90% in Europe (Fig. 1). Similarly, the National Human Activity pattern survey in the US revealed that an adult spends 86% of the time is indoors, and the next 6% should be added as time spent inside vehicles or transport [6]. The significance of the global shift in the economy from manufacturing towards the knowledge and service sectors that operate in indoor environments [7]. For poor indoor air quality, they are classified as a problem affecting the health of children while it is considered as one of the largest national environmental threats by the US- EPA [8].

As being responsible for respiratory illnesses, cancerous diseases, and even allergies, poor IAQ has a noteworthy economic impact as it damages valuable objects from archives, museums, libraries and reduces employees' productivity in working places by 10-15% [9] (Fig. 1). The associated cost to air pollution in the WHO European Region includes exposure to both indoor and outdoor air, amounts to 1.431$ trillion in 2010 (Fig. 1), which is from 42.9$ billion corresponded to Spain [10], [11].

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Fig. 1. Key data of the indoor air quality problem.

2. Main pollutants and sources

The important indoor air pollutants were investigated including volatile inorganic compounds, volatile organic compounds, and particulate matter. The particulate matter is classified as a function of its size, the most reported value of particle which corresponds to its concentration with a mean diameter lesser than 2.5mm (PM2.5). Carbon monoxide (CO), Carbon dioxide (CO_2), ozone (O3), and nitrogen oxides (NOx) ranks in most studied inorganic compounds. VOCs includes a group of gas pollutants organic which has low boiling point ranging from 50/100˚C to 240/260˚C and it has low vapor pressure in indoor environments [12].

In recent research projects, the investigating of indoor air pollution where it focused on public and private buildings. In these environments, they are different in terms of pollutants and concentration ranges. The public indoor environments comprise office buildings, shopping centers, schools, libraries, and so on. In private indoor spaces which involve detached dwellings and apartment buildings. Most of the studies stated that the levels of pollutants which are in before and after renovated buildings, refurbishment or remodeling that implements the new energy-saving and hence there is high in airtightness and accumulation of pollutants in indoor. The main sources (Fig. 2), most of the health risks, and the concentrations of indoor pollutants are discussed. PM, VOCs like trichloroethylene, a-pinene, benzene,

Table 1
Physical/chemical properties of the most relevant indoor air pollutants.

Compound	CAS number	Molecular weight (g/mol)	Boiling point (°C at 1 atm)	Vapor pressure (mmHg at 25 °C)	Water solubility (mg/L at 25 °C)	Environmental risks[a]	Henry constant (mol/m^3·Pa)
CO	630-08-0	28.0	−191.7	>35 atm	26.8 at 20 °C		9.64E-06
NO_2	10102-44-0	46.0	21.0	720	Reacts		1.20E-04
O_3	10028-15-6	48.0	−111.7	>1 atm	570 at 20 °C	H400; H410	1.10E-04
Benzene	71-43-2	78.1	78.8	101	940.0	H412; P273	1.70E-03
Toluene	108-88-3	92.1	110.6	27.7	320.0	H412	1.50E-03
Ethylbenzene	100-41-4	106.2	136.2	9.21	110.0	H412	1.30E-03
o-xylene	95-47-6	106.2	145.9	5.99	120.0	H412; P273	2.08E-03
m-xylene	108-38-3	106.2	140.6	7.61	99.0	H412; P273	1.37E-03
p-xylene	106-42-3	106.2	139.6	7.94	100.0	H412	1.48E-03
Naphthalene	91-20-3	128.2	221.5	0.159	140.0	H400; H410	2.20E-02
Formaldehyde	50-00-0	30.0	−19.5	3460	$1.98 \cdot 10^5$		3.20E+01
TCE	79-01-6	131.4	87.2	72.4	390.0	H412; P273	9.50E-04
α-pinene	80-56-8	136.2	157.9	3.5	8.9	H411	2.12E-04
Limonene	138-86-3	136.2	175.4	1.54	3.4	H400; H410; P273	6.27E-04

[a] Code: H400: very toxic to aquatic life; H410: very toxic to aquatic life with long lasting effects; H411: toxic to aquatic life with long lasting effects; H412: harmful to aquatic life with long lasting effects; P273: avoid release to the environment.

toluene, ethylbenzene, xylenes, formaldehyde, naphthalene; and VICs like O_3, NOx, CO_2were selected depending on their occurrence in indoor spaces and concerns in terms of human health (Table. 1)

The solid particles known as particulate matter (PM), were suspended in the air that able to enter into the respiratory tract of humans which has a particle size is less than 2.5 mm. There is one more thing known as fiber in which there is asbestos and fiberglass that can be included in this group [13], [14], [15]. In indoor, there should be proper ventilation as there are combustion-based appliances like heaters or stoves, ovens, and also tobacco smoke and fireplaces. When there is biomass that is used as fuel then the indoor PM levels may exceed in the polluted areas. The exposure of longer-term to the PM, that can provoke critical conditions from cardiovascular and respiratory problems like bronchial irritation, eyes, nose, throat, asthma to fibrosis, anthracosis, and lung cancer [13], [16], [14], [17], [18].

One of the toxic gases that are emitted is Carbon monoxide which results in an incomplete combustion process. Tobacco smoke is the main source of CO and there are also some sources like fireplaces, heating devices, defective cooking, and vehicle gases in garages. It also included that outside air exchangers in heavy traffic areas and highly industrialized areas [13], [19], [14], [15], [20], [18], [1].

3. Prevention of indoor air pollutant emission

There are different approaches among them to control the indoor air quality, emission first rank in terms of cost-effectiveness and prevention of formation of air pollution. To prevent these emissions there are several strategies and to decrease the gas pollutants concentration in indoor environments that have been proposed. The easiest way is ventilation that measures to prevent indoor pollution accumulation. The concentration of indoor pollutants was typically reduced when there is an increase in the outdoor air exchange rate unless the concentration of outdoor pollutants were higher such as the areas with an increase of industrial activities and traffic. Mostly the mechanical ventilation is used to introduce fresh air from the outdoor into the buildings and which dilutes the concentration of air pollutants indoors. Some sources can be sealed and removed by professionals like using other insulation fibers and asbestos [21], [19], [14], [22] An effective measure should be taken to ban smoking since there is

ve chemicals that
nts have resulted
ronment [19].

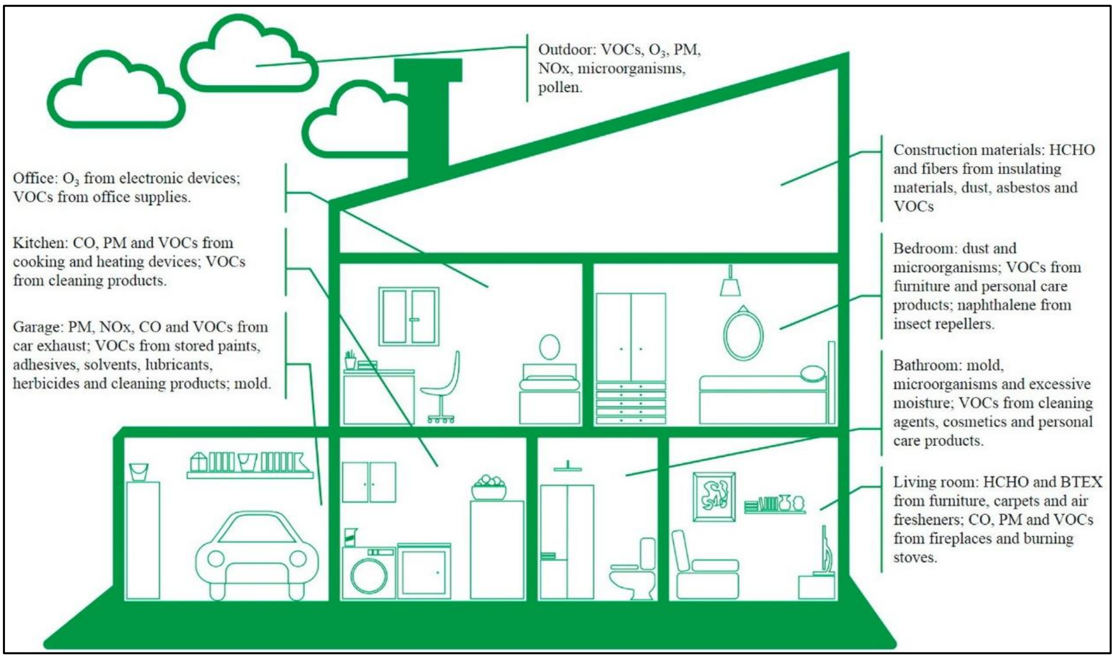

Fig. 2. Main sources of pollutants at homes.

The main indoor air pollutants include BTEX, PM, NOx, or CO which emits during the combustion processes in houses such as heating and cooking. The prevention of indoor pollutant accumulation is done by reducing the combustion gases and increasing the ventilation in the room. The devices which are used for combustion are to be checked and maintained to prevent the malfunctioning and emission of pollutants to the indoor environment [13][14][17][18].

and other VOCs. The construction materials also include plastics, paints, glues, and other materials that emit VOCs usually BTEX as additives or solvents. Some of the pollutants can be prevented by using emitting fewer pollutants materials such as improved paints, plastics, and old furniture or solid wood [13], [18], [19], [23].

Table 2
Performance of physical-chemical technologies for the removal of particulate matter.

Design parameters	Air flow (m^3/h)	Single pass efficiency (%)
Mechanical filtration		
Multilayer (glass + synthetic fibers) non-woven filter (≈MERV 16 filter) filter installed in HVAC system 5.08 cm depth	2.5 m/s	Black Carbon: 88%/Ultrafine PM: 86% PM(0.3–2.5 μm): 91%/PM(>2.5 μm): 88%
MERV16 filter + 12 gas-phase filters + particle postfilter Dimensions: $0.41m^2 \times 1.95$ m (portable)	1362	Black Carbon: 90%/Ultrafine PM: 94% PM(0.3–2.5 μm): 92%/PM(>2.5 μm): 75%
PVC/PU fibers (8 w/w%) on filter paper support Membrane: 100 cm^2, 20.72 g/m^2	1.91/5.01	PM (0.3–0.5 μm): >99.5%
Polyester filter with sericin coating	145	PM(2.5,10 μm): ≈56%
ZIF8-SiO2 nanofiber composite membrane (2 h growing time) Dimensions: Ø30mm disc (7.07 cm^2)	0.05	Soft smoke PM: > 99.95%
Double layer nonwoven filter: PP-g-DMAEMA (Dimethylaminoethylmethacrylate)-rGO (reduced graphene oxide) (6.3%) + PP-g-DMAEMA sheet Filter: 25 g/m^2	19.2	65% (PP-DMAEMA-rGO) 76.4% (PP-DMAEMA) 72.2% (Double Layer)
Electronic filtration		
Ion-spray with carbon fiber electrodes (charger and plates) Charger outside-mounted (emit ions to ambient air) Dimensions: 120 × 185 × 85 mm^3	120	PM (0.3 μm; laboratory): 47.8% PM (0.3 μm; real chamber): 39.8%
Electrostatic precipitator based on corona discharge and parallel plates	120	PM (0.3/0.5/1/3): 67.7/67.7/40.6/14.5%

There is another pollutant which is known as VOCs that is emitted from the construction materials. There is a wooden-based material that is used in construction like fiberboard or plywood, that utilizes the resins and varnishes which contains formaldehyde

Therefore, there should be good ventilation that ensures the indoor to outdoor air exchangers are feasible prevention to solve most problems that related with the air pollutants accumulation. Especially as it is known the source of the pollutant which is not a continuous emission like painting, cooking, refurbishing, and so on. Ventilation is the best option that reduces the cost. It is necessary to define the source of indoor pollution is for prevent them from combustion devices, solvents or construction materials, stored paints, and it should be properly maintained. To avoid undesired

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emissions, the manufacturer'srecommendations should be followed for indoor air pollution.

Table 3
Performance of physical/chemical technologies for the removal of VOCs.

Design parameters	Air flow (m^3/h)	Pollutant Removal Capacity	Single Pass Efficiency (%)
Adsorption			
Indoor passive panels (gypsum based; different treatments) Dimensions: 0.089 m^2	0.2	HCHO: 40–140 $\mu g/m^2 \cdot h$ Toluene: 30–210 $\mu g/m^2 \cdot h$	–
Granular activated carbon Ø46mm, 150 mm tube; 7.0 g of adsorbent Thermal desorption (300 °C)	0.06	–	Benzene: 81.5–91.6 Toluene: 86.6–100 Ethylbenzene: 91.6–99.2 Xylene: 89.9–100
Porous ferrihydrite/SiO_2 composite (different aging times); 0.27 g of adsorbent in Ø140mm petri	–	HCHO: 6.30–8.11 mg/g 6 mg/g after 7 cycles	
Polyester filter with sericin coating	145	–	Benz: 2.96; Tol: 2.96 Et-Benz: 3.71; Xyl: 4.18
Carbon nanotubes (LNCT) and carbon microspheres (LCM) Dimensions: Ø16mm, 90 mm; Adsorbent: 3 g	0.001	Tol/Et-Benz/o-xyl LCNT: 52.2, 78.0, 102 mg/g LCM: 47.1, 64.0, 62.7 mg/g	Tol/Et-Benz/o-xyl LCNT: 57.8, 47.5, 61.8 LCM: 51.7, 53.5, 52.6
Alkaline-treated carbon nanotubes (LNCT) and carbon microspheres (LCM) Dimensions: Ø16mm, 90 mm; Adsorbent: 2 g	0.001	Tol/Et-Benz/o-xyl LCNT: 1821, 964, 1076 mg/g LCM: 1093, 895, 996 mg/g	Tol/Et-Benz/o-xyl LCNT: 84.0, 83.3, 82.6 LCM: 82.5, 83.4, 74.8
High-grade activated carbon filter (portable)	510		HCHO: 0.6; Toluene: 32.0 n-decane: 40.0 Tetrachloroethylene: 31.3
Activated carbon prefilter (portable)	569		HCHO: 0.2; Toluene: 7.8 n-decane: 12.5 Tetrachloroethylene: 6.0
Carbon-zeolite mixture impregnated with potassium iodide (29.5 kg)	272		HCHO: 4.0; Toluene: 19.4 n-decane: 31.3 Tetrachloroethylene: 33.1
Activated charcoal filter (portable)	225		HCHO: 0.4; Toluene: 5.6 n-decane: 6.0 Tetrachloroethylene: 5.2
Non-woven polyester filter (2 layers) impregnated with activated carbon (portable)	340		HCHO: 1.5; Toluene: 26.0 n-decane: 62.0 Tetrachloroethylene: 22.5
Granular activated carbon + $KMnO_4$-impregnated alumina (in-duct)	–		HCHO: 1.4; Toluene: 3.5 n-decane: 3.4 Tetrachloroethylene: 3.3
Photocatalytic oxidation			
Indoor passive panels + UV–Vis light (TiO_2-wood flooring; wallpaper; fabric) Dimensions: 0.089 m^2	0.2	Toluene: 59–120 $\mu g/m^2 \cdot h$; 58–70 $\mu g/m^2 \cdot h$; <15 $\mu g/m^2 \cdot h$	
Roofing tiles (three types) and corrugated sheets containing TiO_2 (143 cm^2; 12.1–46.4 mg/cm^2 and 90 cm^2; 22.2 mg/cm^2, respectively)	–	Toluene (RT/CS): 308–512 $\mu g/m^2 \cdot h$ at RH47% 248 $\mu g/m^2 \cdot h$ at RH47%	Toluene (RT/CS): 28.2–62.9 at RH47%; 78 ± 2% at RH1% 22.7 at RH47%
UV light (253.7 nm) TiO_2 converter (+MERV11 filter) (in-duct)	720		Benz: 0.58; Tol: 0.58; Et-Benz: 0.50; Xyl:0.32; EtOH: 0.19%; n-hex: 0.26; HCHO: 0.08
UV light (253.7 nm) TiO_2 converter (+MERV11 filter) (in duct)	3600		O_3 (UV off): <2 O_3 (UV on): 15
ZnO nanorod-wrapped PTFE nanofiber antibacterial membrane with Ag nanoparticles Ø30mm (7.07 cm^2); 0.1 mm thick	Bacteria: 0.06 HCHO: 0.013	HCHO: 1989 $\mu g/m^2 \cdot h$	Bacteria: >99 HCHO: ≈60
Cellulose/Polyester/Polyamide filter coated with P25 TiO_2/SiO_2 as catalyst (in duct) Filter: 400 cm^2, 250 μm thick, 17 g/m^2 TiO_2	25.8	Toluene: 15687 $\mu g/m^2 \cdot h$ n-decane: 15071 $\mu g/m^2 \cdot h$ TCE: 1646.9 $\mu g/m^2 \cdot h$	Toluene: 8.63 n-decane: 5.76 TCE: 0.17
VUV lights + MnO_x/TiO_2 on Ni foam catalyst Photocatalyst: 834 cm^2, 8 mm thick	120		TVOC (UV off/on): 50.14/74.86
Polyacrylonitrile (PAN)-TiO_2 filter at different designs (simple membrane; monolith; truncated cone; corrugated); Properties (cm^2, g/cm^2): 30, 0.33; 198, 0.48; 136, 0.23; 121, 1.01	9.5	Acetaldehyde Membrane: 2300 $mg/m^2 \cdot h$ Monolith: 2228 $mg/m^2 \cdot h$ Trunc. cone: 2300 $mg/m^2 \cdot h$ Corrugated: 3414 $mg/m^2 \cdot h$	Acetaldehyde Membrane: 5.36% Monolith: 4.43% Truncated cone: 5.36% Corrugated: >4.99%
Two honeycomb monoliths coated with TiO_2 as catalyst + 3 UV lamps (in-duct)	–		HCHO: 1.6; Toluene: 1.8 n-decane: 2.5 Tetrachloroethylene: 0.7
SiO_2/TiO_2-coated glass fiber tissue 6.5 g/m2 SiO_2 + 6.5 g/m2 TiO_2 Ø76mm in-coated tube	2		Benzene: ≈30 Propionic acid: ≈49.8
Non-thermal plasma			
Post-catalytic plasma with different catalysts (Pt/Al2O3, Cu–Mn/TiO_2, Fe_2O_3+MnO_2, CuO + MnO_2) and energy densities (J/L) Ø42mm tube; 15 g of catalyst	0.6		Toluene (all catalyst): >90 at RH0%, 2.5 J/L Toluene (Pt/Al2O3): 39–61 at RH30-72%, 10 J/L O3 (Pt/Al2O3): ≈90 at all RH

4. Physical-chemical technologies for indoor air treatment

The generation or intrusion of indoor air pollutants always cannot be decreased in a technically feasible manner or cost-effectiveness. In these conditions, the active apartment can be initiated to eliminate or lower the levels of air contaminants. Traditionally, these consist of chemical and physical technologies like filters or ozonizes installed of central heating and the

Table 3 *(continued)*

Design parameters	Air flow (m^3/h)	Pollutant Removal Capacity	Single Pass Efficiency (%)
Dielectric barrier discharge NTP Dimensions: Ø12mm, 20 mm tube (exposure time of 0.06/0.12s)	Bacteria: 0.75 Fungi: 1.71		Bacteria: >95 Fungi: 85-98
Dielectric barrier discharge NTP 6.5 g/m^2 SiO2 + 6.5 g/m^2 TiO_2 Ø76mm in-coated tube	2		Benzene: 29–52 Propionic acid: 10.3–34.7
Hybrid methods			
Activated carbon (Jo et al.) + PCO device Inner surface Ø20mm tube, 0.5 mg/cm^2 of TiO_2 Thermal desorption (300 °C)	0.06		Benzene: 95.0–98.7 Toluene: 97.5–100 Ethylbenzene: 98.3–100 Xylene: 96.6–100
Plasma deodorization unit + Activated charcoal filter (portable)	408		HCHO: 1.2; Toluene: 6.7 n-decane: 9.6 Tetrachloroethylene: 5.8
Electronic cell + Activated carbon postfilter (portable)	544		HCHO: 0.3; Toluene: 2.0 n-decane: 8.1 Tetrachloroethylene: 1.5
High intensity UV lamp + Photocatalytic semiconductor + Pleated activated carbon filter (in-duct)	–		HCHO: 3.0; Toluene: 42.1 n-decane: 44.8 Tetrachloroethylene: 46.6
ZIF8-SiO_2 nanofiber composite membrane Dimensions: Ø30mm disc (7.07 cm^2)	0.013	HCHO: 36.04 $\mu g/m^2 \cdot h$; 48.87 mg/g	HCHO: ≈80
Dielectric barrier discharge NTP + UV light + SiO_2/TiO_2-coated glass fiber tissue 6.5 g/m^2 SiO2 + 6.5 g/m^2 TiO2 Ø76mm in-coated tube	2		Benzene: 58–90 Propionic acid: 63.8–94.8
Electrostatic precipitator + Vacuum-UV lights + MnO_x/TiO_2 on Ni foam catalyst + MnO_2 catalyst for O_3 removal MnO_x/TiO_2 catalyst: 834 cm^2, 8 mm thick	120		TVOC: 4.04 No O_3 generation
MOF TiO_2/UiO-66-NH_2 composites + UV light Toluene exp: 100 mg of cat. on 250-mesh screen Acetaldehyde exp: 100 mm, Ø6mm tube	0.06	Toluene (25/75/90%w TiO_2): 106.7/164.4/142.0 mg/g CH_3CHO: (75%w TiO_2): 275.3 mg/g	Toluene (25/75/90%w TiO_2): 47.2/72.7/62.8 CH_3CHO: (75% w TiO_2): 70.74
Double layer nonwoven filter: PP-g-DMAEMA (Dimethylaminoethylmethacrylate)-rGO (reduced graphene oxide) (6.3%) + PP-g-DMAEMA sheet; Filter: 25 g/m^2	0.18	Benzene/Toluene/Xylene PP-DMAEMA-rGO: 51.4/50.6/48.9 mg/g PP-DMAEMA: <5 mg/g each Double layer: 39.1 mg/g overall	

ventilation system or it can be operated as a portable unit [22]. In today's market, the physical/chemical technologies for the air treatment indoor were dominated by mechanical and electrical filtration, ozonation, and absorption (Tables. 2 and 3).

Mechanical filtration is based on the forced circulation of air where the pollutants were captured by passing through a fibrous material and it is the simplest and also popular method for particulate matter removal. The efficiency in removal of PM depends on several factors like the material of filter and type of filter that airflow [24], [22]. They need regular replacements to maintain the capture efficiency that prevents the emission generated again and to avoid the development and growth of microorganisms in the filter material on the organic matter [8].

Based on the electric filtration, there is an attraction of negatively charged particles to an object with opposite polarity, and the particles were retained. There are two commercial devices: the ion generators which are dispersed into the air ions that will be subsequently pollutants are attached to it and another one is electrostatic precipitators ionizing pollutant particles. These technologies have exhibited higher capital and operating cost than mechanical filtration which are partially ion generators and it requires the removal actively of the particles that accumulated on the object. The generation of harmful pollutants by using electrical filtration such as ozone ions or other emissions from VOCs ionization [25], [22]. Electrical filtration has fewer efficiencies compared with mechanical filtrations and it ranges between 14.5% and 67.7% for different PM sizes[26]. (Table 2)

Overall, no single technology that can be capable of indoor air pollutants coping with the manner of cost-effectiveness in which it requires sequential technology usage configurations of maintenance cost and superior capital. To eliminate the particulate matter to the other abatement technology as the mechanical filtration installed [22-46]. (Table 3)

Conclusion

In recent years, there is a prominent problem of exposure to indoor air pollution as humans spent more time indoors more than 70% of which are in buildings and partially sealed against the environment for saving energy from heating or cooling. Some of the recent studies have shown that the poor IAQ contributes majorly to the health problems which causes the multi-millionaire losses. Hereby, there is no one technology that can be physical-chemical with efficiently done all challenges which are related to indoor air purification of pollutants. The only method to prevent this pollution is biological which means growing plants in the indoor environment. This can help humans to balance the air quality in the indoor atmosphere which purifies the air naturally and prevents microorganisms. Other sources that can help to prevent indoor air pollution are that by using a biological-based purification system that uses the solution that can prevent microorganisms. These features can lead to a green energy-efficient system that can able to improve indoor air quality. Some hybrid solutions are integrated with physical/chemical systems that can be proposed to overcome the limitations.

In modern buildings, some regulations are based on promoting saving energy, which entails the air exchange reduction and increases the concentration of the air pollutants. The recommendations and regulations in the modern constructions compromise between the progress in tightness of building and guarantee of good indoor air quality which leads to the decreasing of building requirement energy. As the refurbishment and construction as per the regulations, these technologies here should have more investment for development. However, first to optimize and develop at the laboratory level of these technologies, and then it is to incorporate in the cost-effectiveness which can integrate the indoor space that combines the optimal performance with acceptable aesthetics.

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