A REVIEW ON DEVICES AND TECHNOLOGIES ON FILTRATION OF AIR POLLUTION

Vinay Teotia[1], Ayush Pathak[2], Mohnish Yadav[3], Shivam Sharma[4] & Dharmendra Singh[*]

Students, Department of Mechanical Engineering, ABES Engineering College, Ghaziabad India[1234]
Professor Mechanical Engineering, ABES Engineering College, Ghaziabad, India.[*]

*Email: vinay.16bme2046@abes.ac.in[1],ayush.16bme2004@abes.ac.in[2], shivam.16bme2012@abes.ac.in[3], mohnish.16bm2027@abes.ac.in[4], dharmendra.singh@abes.ac.in**

Abstract: *In today's world it is a dire need for clean air, every year rate of pollution is increasing drastically, in response to that we are designing a machine to cope with the air pollution to some extent. It draws on the natural science and strategy writing to give interdisciplinary into the best air quality arrangement measures. In our design we are using the technique of electrostatic precipitation where dust particles upon entering electric field gets charged and are attracted to opposite charge. at first level large particles are filtered by physical filters and then by ionization process small particles with PM2.5 or less are filtered then again the air is passed through one more set of filters and then it is released in the atmosphere with sufficiently high flow rate, thus making the surrounding air clean.*

Keywords**:** *Pollution, Electrostatic Precipitation, Electric Field, Ionization, PM2.5*

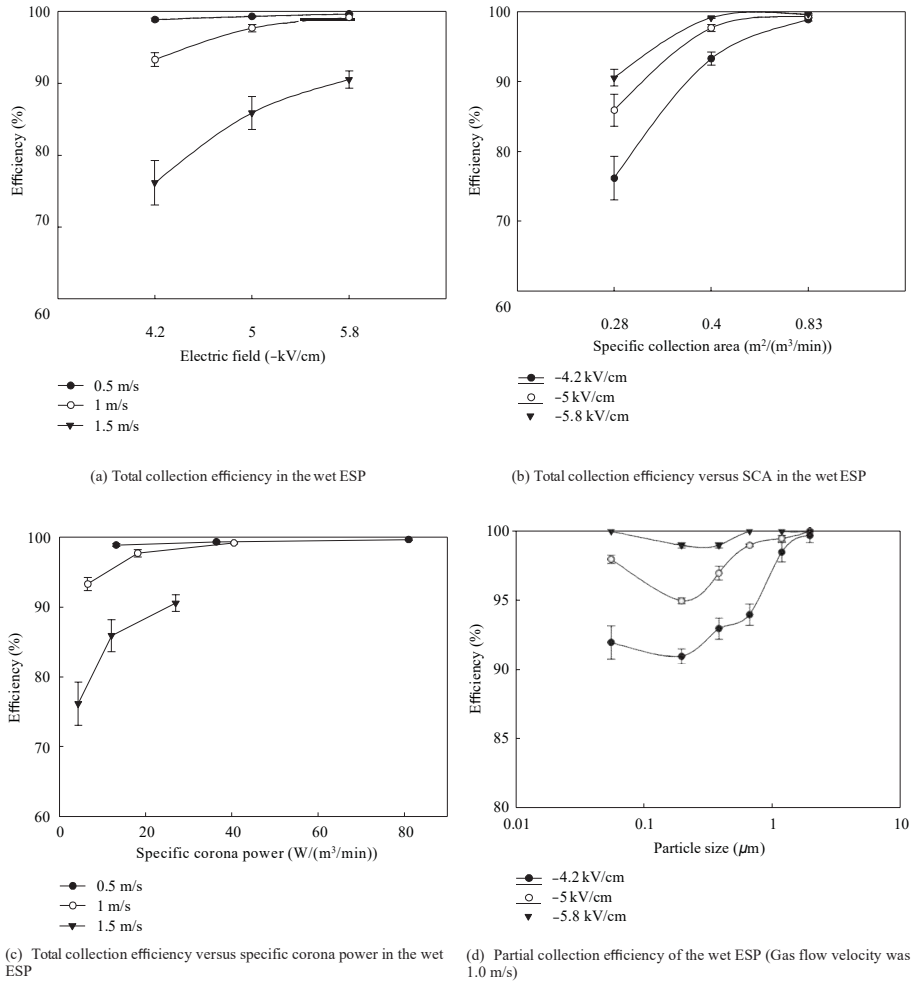
1. INTRODUCTION

One of the most concerned issues in today's world is air pollution which is engulfing the whole world in its clutches so thus in response to that everywhere in world people are coming up with new innovative ideas and techniques to fight with it. Similarly, we are designing an air purifier which can clean air in local areas such as parks and other public places, with the help of Cad designing software's such as solid works and AutoCAD in our project. Our air pollution cleaning machine has a form of vertical tower which filters air in multiple stages air passing through physical filters, electrostatic precipitator and wet scrubber etc. At the top most of tower cleaned air is removed into the atmosphere.

2. Related Work

Jong-Ho Kim et al. [1] used wet electrostatic precipitator procedure to wipe out corrosive fog and fine particles which fundamentally re entrained in the assortment terminal. In any case, because of erosion the assortment proficiency devalues. In this way, they changed the WESP structure with establishment of a PVC dust precipitator where the fluid (mostly water) is provided instead of the assortment anode. Now With such changes they had the option to build a minimal wet ESP with little explicit zone which can get high assortment proficiency. Besides the paper examines a few ends, for example, [1.1] Higher the electric field quality the higher the residue assortment proficiency [1.2] there results likewise shows that greater the particular assortment territory higher the residue assortment productivity, in there analyze the estimation of explicit assortment region and residue assortment effectiveness were seen to be with least explicit assortment region (0.28m2/(m3/min)and comparing dust assortment proficiency ended up being 76.2% most extreme explicit assortment region of (0.83m2/(m3/min)) prompted dust assortment proficiency of 99.7% [1.3] Explicit aureole influence is another deciding reason in power consumption of electrostatic precipitator (P/Q) where P is power in watts and Q is gas

flow rate in m3/min, in there study they discovered explicit aureole influence at lowest dirt gathering competence(76.2%) to be 4.4W/(m3/min)at maximum efficiency(99.7%) to be 81.0W/(m3/min) here interesting fact is that these results specific corona power are similar to that of typical dry electrostatic precipitator. [1.4] it is also observed that collection efficiency of dust particles of each size at an electric field of -4.3, -5.0 and -5.8kv/cm. the minimum value that collection efficiency reaches at particle size of range 0.1 to 0.7 micrometer thus the size range shows an interaction between diffusion of particle and electric field strength.



(a) Total collection efficiency in the wet ESP

(b) Total collection efficiency versus SCA in the wet ESP

(c) Total collection efficiency versus specific corona power in the wet ESP

(d) Partial collection efficiency of the wet ESP (Gas flow velocity was 1.0 m/s)

The above figures show a relationship between particle collection efficiency and other interactive elements (such as electric field, specific collection area, specific corona power and particle size).

Vyas S et al. [2] explored on particulate contamination and its significant ramifications for human wellbeing, as it is an issue of worldwide concern. He examined the quantity of particles somewhere in the range of 0.5 micrometer and 2.5 micrometer inside whereas utilizing reasonable air purifying systems in the severely contaminated metropolitan city Delhi. The examination expresses that in indoor the air quality is improved yet it is lower than whatever other city which has moderate contamination. As in winter the open-air contamination is marginally high so indoor additionally increments. Along these lines, air purifiers are not a substitution for open activity in locales like Delhi. Albeit private arrangements may fill in as a band-aid, reducing surrounding air contamination must be a general

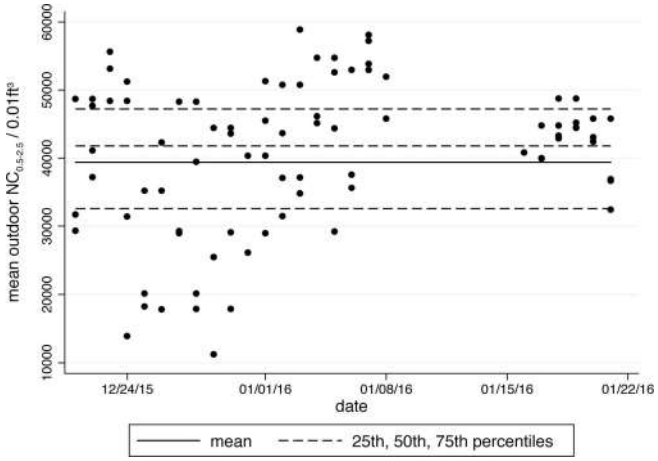
wellbeing and strategy prerequisite in anywhere locality where air contamination is on a par with Delhi's throughout the seasons. So ,from Summary statistics[2.1] , Open air NC0.5±2.5 over 10,000 for all tests. Every point speaks to the mean over the range outside NC0.5±2.5 during a test. Seventy-two outside test implies are made known. The general open-air averages of all moment shrewd estimations are appeared as a strong mark. 25th percentile, 50th percentile and 75th percentile is appeared as run lines. Open air NC0.5±2.5 were collected from a gallery local to a testing room.

All this data collected in [2.1] is gathered from a gallery neighboring the test lab .The Numeral fixations were unswervingly more than 104 particles for every 0.01ft3 throughout the weeks where the investigation was performed. The complete minute-wise mean found out to be 39,378, and the 25th percentile 32,552, 50th percentile 41,787, and 75th percentile 47,219 separately. Mean outside NC0.5±2.5 was remarkably more notable than 5*104 for thirteen out of the 72 tests. As we can see from [2.1] , there was substantial variety in outside NC0.5±2.5 over this timeframe.

In Table, they have demonstrated generally mean outside NC0.5±2.5 by several trial condition. The trial of equivalence points out that the methods are not measurably unique in relation to each other. This outcome is very important end result to remember, since it shows us that the square randomization technique gives us the required result: outdoor air quality is not linked with the test conditions.

Table: 1 Outdoor pollution level in different test conditions.

	Outdoor NC0.5±2.5 per 0.01ft3	Standard Deviation
1 Filter A, Opening and closing of door every 30 min	37,754	12,916
1 Filter A, door kept closed	40,002	14,133
2 Filter As, door opened and closed every 30 mins	38,435	11,459
2 Filter As, door kept closed	38,831	10,106
Filter B, door opened and closed every 30 mins	41,265	9,020
Filter B, door kept closed	39,957	12,157
p-value on F-test (H0: means not statistically different) = 0.97		



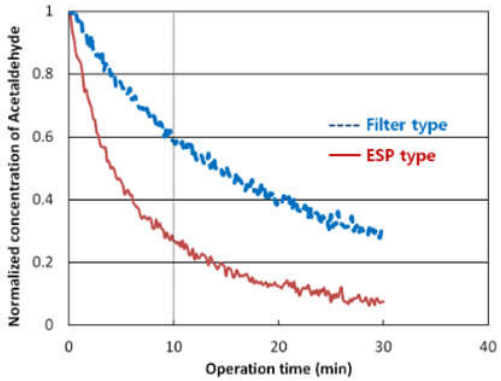
[2.1] Summary statistics: Outdoor NC0.5±2.5 above 10,000 for all tests. Each point represents the mean outdoor NC0.5±2.5 during a test. 72 outdoor test means are displayed. The overall outdoor mean of all minute wise measurements is shown as a solid line. 25th, 50th, and 75th percentiles are shown as dashed lines. Outdoor NC0.5±2.5 were collected from a balcony near to the testing room.

Aditya Roy et al. [3] examined the present situation of the issues of air contamination and featured the brutality of the issues. Creator introduced an aggregation of the most well-known and noteworthy strategies for refining air, for example, those utilizing the utilization of HEPA channels, electrostatic smoke precipitators, enacted carbon and UV light. The absolute most present-day techniques for purging air, for example, those utilizing straightforward PAN channels, photochemical conducting materials, soy (alpha) proteins and silk fibroin Nano fibrils have been envisioned and inspected in their examination in order to achieve better filtration of air particles. Their investigation with straightforward PAN channels shows productivity over 95% for sifting through PM 2.5 which changes as per the surface science of creation of the polymer channel just as the straightforwardness to be accomplished. Heterogeneous photocatalyst helps in expulsion of NOx discharges. Titanium Dioxide (TiO2) is the most widely recognized and used photocatalyst and its cleaning efficiency can be improved by mixing it with building material like cement, concrete and paints. By utilizing SPI (Soy protein segregate) and BC (Bacterial Cellulose) in air channels in proper proportion, efficiencies of 99.4% to 99.95% can be accomplished for Particulate matter 2.5 and Particulate matter 10 separately, in the mean time keeping up a high air entrance pace of 92.629%. It was found that these methods are more economical for PM 2.5 filtration as comparison to HEPA filters. Based on the study the outcomes are Straightforward PAN channels banking up on the way that windows give us a decent measure of surface zones for presenting a level of channels without giving up natural light and air circulation. A Photocatalytic material gives us a novel pathway to check Nitrogen oxides discharges. Soy (alpha) proteins and silk fibroin Nano fibrils provides us with a strategy for using characteristic assets to purge air.

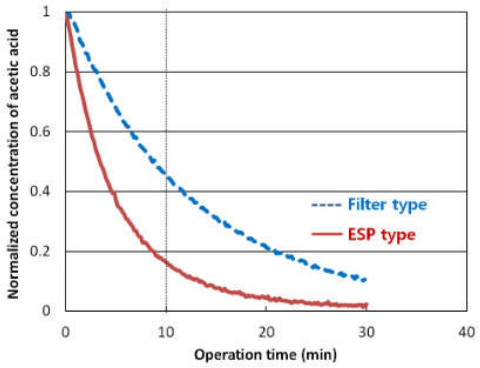
Akshey Bhargava [4] concluded that Wet scrubbers are good and successful air contamination control gadgets which can stops the particulate issues and dirtying gases coming out of modern procedures as air contaminating discharges. There are various types of wet scrubbers but he discussed Spray Towers and its design. He structured a Spray Tower of a 100 Tons per Day concrete plant dependent on Vertical Shaft Technology (VSK) in the wake of observing the air outflows in regard to designed parameters under variable conditions on a time scale. The efficiency of the designed Spray Tower has been to the tune of more than 95 percent.

An effort has been made by the author to design Spray Tower as wet scrubbing device to control particulate matter emitted from a 100 Tons per Day capacity cement plant based on Vertical Shaft Kiln Data (VSK) located in State of Rajasthan. Since the particulate matter from such VSK plants are having moistures, the selection of Spray Tower was considered suitable for the control of particulate matters. Hence, the Spray Tower was designed which gives the efficiency to the tune of 95 percent by reducing the initial concentration of 2000 mg/Nm3 to outlet concentration of 100 mg/Nm3 of particulate matter after the Spray Tower. This has resulted in bringing the pollutants level well below the prescribed limit of 250 mg/Nm3 and hence found safe. Such Spray Towers can be designed and installed in VSK based mini cement plants to control particulate matter with in the permissible norms.

Hak-Joon Kim [5] played out an investigation on evaluating suburbanites' introduction inside open or private transportation vehicles. He fabricated up an innovative electrostatic air purifier with enacted carbon fiber channel for indoor air nature of traveler vehicles. The barrel shaped sort air purifier comprised of electrostatic gadget with brush charger for molecule expulsion and actuated carbon channel for gas evacuation. The stream pace of the gadget was around 300 liter per minute. The purifier was tried in an office of 1 m3 with 0.3 micrometer particles and three gases, for example, smelling salts, acidic corrosive, and ethanal. The gas filtration execution of the air purifier was contrasted with business commercial purifiers with a HEPA channel and enacted carbon pellets. He found that spotless air conveyance pace of the electrostatic air cleaner was 0.219 m3/min, which is 35% higher than that of a HEPA channel type. He did a correlation in [5.1] and [5.2]which show the exhibitions between ESP(Ø 100 ×190 mm) with 7.3 g of an actuated carbon sheet and a channel type air cleaner (180 × 180 × 80 mm) with a HEPA channel and enacted carbon pellets of 49g. The gas debasement proportion by the activity of the electrostatic air cleaner against acidic and acetaldehyde was roughly 80% after 10 min of the persistent activity, while around 45% with the business one after a similar activity time. His outcomes inferred that the air cleaner utilizing ESP with a carbon brush charger and an actuated carbon fiber sheet (7.3g) could accomplish a higher clean air conveyance rate and quicker gas expulsion execution than those of an air cleaner (180 × 180 × 80 mm) with a HEPA channel and enacted carbon pellets (49g).



[5.1] Normalized acetaldehyde gas concentration



[5.2] Normalized acetic acid gas concentration

S. Ketkaew [6] introduced an investigation of structure and development of Air purifier with the help of High Voltage Electrostatic field with 126 m3/hr repeated cycle of air flow limit with respect to a 15 m2 room. Now with the help of the working of exchanging circuit that controls the voltage fluctuation of fly- back transformer code TLF l4649F. It can produce stimulated ionizing field with voltage potential up to 8.0 kV to 4.0 kV for ionization area and dust gathering. The required and intended outcome is to expel residue and small particles with diameter in the range 0.01 micrometer to around 200 micrometers. The simulation movement test result which was performed to draw dust, the joss sticks and tobacco smoke through have demonstrated that air cleaner can trap these residue and smoke. Furthermore, it can reduce risk from current that impact workers. In this way, it is introduced as switch for Discharging Electrostatic. Air cleaner empowers to get the residue in 0.01 micron which 1s the minuscule particle. In part of Switching circuit that controls the voltage of fly back transformer , can utilize the recurrence and obligation cycle for altering the size of the voltage varying. There is a switch for releasing in electrostatic by utilizing magnetic Contactor to keep the risk from electric flow for the client. In parts of ionization and Collector , they can be expelled for washing and set up for utilizing as common after great drying. The result of testing is given in table[6.1]

Table: 2 Test results of mass efficiency in dust collector

Serial Number	Weight Before dust settling in collector(g)	Weight after dust settling in collector(g)	Effectiveness(%)
1	10	9.15	91.5
2	10	9.68	96.8
3	10	9.92	99.2
4	10	9.23	92.3
5	10	9.13	91.3
6	10	9.58	95.8
7	10	9.78	97.8
8	10	9.63	96.3
9	10	9.78	97.8
10	10	9.93	99.3

Table: [6.1]

Thus, with the help of results from above table, thus average mass efficiency of dust collector comes out to be:

(91.5+96.8+99.2+92.3+91.3+95.8+97.8+96.3+97.8+99.3)/10 = 95.92

M.Karunakaran [7] performed a study on electrostatic precipitator using in ash removal system. He focused on the various issues that occur in electrostatic precipitator. He did a detailed study and investigations to increase the collection efficiency of electrostatic precipitator. He addressed a brief theory on methodologies of electrostatic precipitation, usage of two phases ESP, high voltage high force gracefully and thunderous converter. By tackle different categories of high voltage power can boost the interpretation of electrostatic precipitators. The inception of high recurrence high voltage power supplies for the utilization on electrostatic precipitators will have these following outcomes.

- Enhanced assortment execution
- New open door for recognizing and setting up power supplies
- Disparate philosophies to support and help vacillations to control gracefully buying procedures.
- Fluctuations to power supply purchasing

Xingxing Zhang [8] played out an examination of a synergistic impact of various air decontamination innovations, air purifying hypothesis, materials and measures. He checked on various air cleaning advancements by kept various factors, for example, separating execution, air quality, vitality and financial conduct, warm solace and acoustic effect. They did innovative work of air filtration innovation to increase an economical and sound ventilation. In the wake of investigating diverse air filtration advances the summed up as:

Traditional stringy channels have various favorable circumstances and hindrances also. The points of interest are high evacuation proficiency, low beginning expense and straightforward structure and weaknesses are high weight drop, high keep up expenses and channel colonization. So as to expand their proficiency, customary physical channels required a covering of synthetic substances or nanoparticles to show fungicidal or fungistatic properties. The fundamental issue happens when distinctive kind of poisons are available. For this situation, stringy channels become ineffectual.

Electrostatic air channel can accomplish 82% to 94% air filtration effectiveness of the particles. Cooled plasma (or non-warm plasma) air purification is compelling on account of parasitic dormant bacterium and airborne microscopic organisms, moreover it can accomplish 85% to 98% purification even with low presentation contact time (0.06 s). The Trombe divider framework built of breathing divider boards can accomplish high air filtration effectiveness (99.4%) on account of Particulate matter 10 and at amazingly small obstructive rate (with 60 years of administration life), even in dirtied metropolitan situations. Biofiltration strategy is perceived as 'most handily adjusted to precisely ventilated structure or on the pit fanatics of normally ventilated structures'

The filtration productivity of general stringy channels is legitimately corresponding to the pneumatic stress drop. High weight drop suggests extra vitality utilization and expanded working expense. In this sense, nanofiber has a preferred position since it joins extraordinary air filtration proficiency and little weight drop. Nonetheless, here the greatest impediment is its large beginning expense. Contrasted and stringy channels, high weight decline is preventable by electrostatic field air channels and biofiltration frameworks. Dynamic plant air filtration frameworks can diminish 20% of outside air gracefully without antagonistically influencing indoor air quality, which on account of Syracuse atmosphere could spare 10–15% of yearly vitality utilization.

Table:3 shows the efficiencies of different air filtration technologies.

Air filtration technique		Effective Particles(Diameter)	Efficiency
Fibrous Filter	Medium filter	> 0.3 µm	60-90%
	HEPA	> 0.3 µm	>99.99%
	ULPA	0.12-0.17-µm	>99.999%
	Glass fiber	2 µm to 10 µm	99.00%
	Nano Fiber	<0.3µm	>99.99%
Trombe wall		> 10 µm & <0.01 µm	99.4% for PM10
Biofilter	Dynamic botanical air Filtration system	Mixture of VOCs	>33% for toluene & 90% for formaldehyde
	Integrated biofiltration system		99%
Electrostatic Air filter	Electrostatic	<0.1mm	82%-94%
	Air filter Electrostatic Precipitators	>0.1mm	lower than HEPA
Cold Plasma air filter		<0.1 mm also effective at VOC	85%-98%

4. Conclusion

As we have seen above there are many technological advancements which are being used to tackle air pollution either a way to mitigate the pollution at the source level or remove it from the air with filters and other technologies the ultimate goal is to live in a pollution free environment. We have focused on electrostatic precipitator and physical filters combinations which are being used in today's world in this article. Compared wet electrostatic precipitator with dry electrostatic precipitator looked into its efficiency and power consumption physical filters with the help of material science advancements are also improving day by day, we see a future where one day the polluted air will be cleaned efficiently and with minimum power consumption as if it was never been polluted to begin with.

5. Acknowledgement

We thank professor Dr. Dharmendra Singh, Mechanical Engineering Department, and HOD Mechanical Prof. Rajendra Kumar Shukla for assistance in research and guiding us throughout in gathering data and valuable knowledge imparted on us.

6. References

[1] *Jong-Ho Kim, Hee-Jung Yoo, You-SeongHwang ,and Hyeok-Gyu Kim :Removal of Particulate Matter in a Tubular Wet Electrostatic Precipitator Using a Water Collection Electrode. The scientific world journal Volume 2012 |Article ID 532354.*

[2] *Vyas S, Srivastav N, Spears D (2016) An Experiment with Air Purifiers in Delhi during Winter 2015-2016. PLoS ONE 11(12): e0167999.*

[3] *Aditya Roy , Chetan Mishra , Sarthak Jain , Naveen Solank :A REVIEW OF GENERAL AND MODERN METHODS OF AIR PURIFICATION Journal of Thermal Engineering, Vol. 5, No. 2, Special Issue 9, pp. 22-28, February, 2019 Yildiz Technical University Press, Istanbul, Turkey.*

[4] *AksheyBhargava : Wet Scrubbers – Design of Spray Tower to Control Air Pollutants . IJEPD (2016) 68–73 © Journals Pub 2016 International Journal of Environmental Planning and Development.*

[5] *Hak-Joon Kim, Bang woo Han, Chengyu Woo, Yong-Jinn Kim, Gi-TaekLim,andWeonGyu Shin: Air cleaning performance of a novel electrostatic air purifier using activated carbon fiber filter for passenger cars. Proc. 2016 Electrostatics Joint Conference.*

[6] *Ketkaew, S. (n.d.). Air cleaner by using high voltage electrostatic. Proceedings. International Conference on Power System Technology. doi:10.1109/icpst.2002.1067805*

[7] *M.Karunakaran, P.Sivakumar, N. Chira-Electrostatic Precipitator in Ash Removal System: A Comprhensive Review.International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278-3075, Volume-8 Issue-4S, February 2019.*

[8] *GuoliangLiu, ManxuanXia, XingxingZhang, CsillaGal, XiangjieChen, LinLiu, SongPan, JinshunWu, LlewellynTang, DerekClements-Croome: A review of air filtration technologies for sustainable and healthy building ventilation.April 2017 Sustainable Cities and Society 32DOI: 10.1016/j.scs.2017.04.011*

[9] *Hanley, J., Ensor, D., Smith, D., & Sparks, L. (1994). Fractional aerosol filtration efficiency of induct ventilation air cleaners. Indoor Air,4, 169–178*

[10] *Brincat, J. P., Sardella, D., Muscat, A., Decelis, S., Grima, J. N., Valdramidis, V., et al.(2016). A review of the state-of-the-art in airfiltration technologies as may be appliedto cold storage warehouses.Trends in Food Science & Technology,50, 175–185*

[11] *Wang, Z., & Zhang, J. S. (2011). Characterization and performance evaluation of a full-scale activated carbon-based dynamic botanical airfiltration system for improvingindoor air quality.Building and Environment,46, 758–768*

[12] *JEMA (1995). The household air cleaner, Tokyo, Japan, Japan Electrical Manufacturers' Association (JEM 1467).*

[13] *Liang, Y., Wu, Y., Sun, K., Chen, Q., Shen, F., & Zhang, J. (2012). Rapid inactivation ofbiological species in the air using atmospheric pressure nonthermal plasma.Environmental Science & Technology, 46, 3360–3368.*

[14] *Imbabi, M. S., & Peacock, A. D. (2004).Allowing buildings to breathe. USA: SovereignPublications.*

[15] *US Embassy. Ambient Air Quality Data; 2015. Database: New Delhi and Consulates 2015 [Internet].Accessed: https://newdelhi.usembassy.gov/airqualitydataemb/jan-nov2015.csv*

[16] *US Embassy. Ambient Air Quality Data; 2016. Database: New Delhi and Consulates 2016 [Internet].Accessed: http://newdelhi.usembassy.gov/airqualitydataemb/jan-2016.csv*

[17] *Power plant Technology (M.M.EI- WAKIL)*

[18] *Power Plant Familiarization Vol.2 (NPTI)*

[19] *A review of air filtration technologies for sustainable and healthy building ventilation- Publisher: Elsevier*

[20] *Portable air cleaner furnace & HVAC filters- UNITED STATES EPA*

[21] *The Scrubber Manual (Revised). Northbrook, Illinois: The McIlvaine Company; 1995.*

[22] *SrikumLukton. SnoisgWatkok, SiiriyaTliaworn, ClinithatUt-tlnwong. "Waste-Air Treatment Machine by Electrostatic Method" Thesis Department of Power Electrical Engineering, MaJanakornUniversity " Techno1ogy, 2000.*