International Journal of Women in Technical Education and Employment (IJOWITED)
The Federal Polytechnic, Ilaro Chapter
ISSN: 2811-1567. Volume 2 – Issue 2. December 2021
https://fpiwitedjournal.federalpolyilaro.edu.ng

Reducing Air Pollution: A Risk Factor in Covid-19 Infection using Ornamental Plant as Phytoremediation

Oluwaseun Okparavero, Temitope Coker & Olamilekan Akinlade.
Department of Agricultural Technology, The Federal Polytechnic, Ilaro, Ogun State, Nigeria
oluwaseun.okparavero@federalpolyilaro.edu.ng;temitope.coker@federalpolyilaro.edu.ng

ARTICLE HISTORY

Received: April 29, 2021
Revised: May 6, 2021
Accepted: November 2, 2021

Abstract

Coronaviruses are a small-sized group of viruses that have single-strand ribonucleic acid (RNA). They comprise four sub-families: Alphacoronaviruses, Betacoronaviruses, Gammacoronaviruses and Deltacoronaviruses. These viruses are easily transferred from animals to humans and vice versa. In December 2019, it was identified in China, a place called Wuhan and since then it has gone around the world. This pandemic disease has caused numerous deaths and poses a great threat to human health and existence. The virus is responsible for the disease called Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), the disease is known as Coronavirus Disease 2019 (COVID 19). World Health Organization (WHO) Statistics shows that air pollution is responsible for the death of about 7 million people worldwide on yearly basis, there is no doubt that it causes severe health challenges in humans (respiratory disease, cancer, stroke, cardiovascular illness). Air pollution has been adjudged to trigger respiratory complications that weaken the immune system, as a result of this underlining illness, Coronavirus thrives leading to the death of COVID 19 patients. Although eradication of air pollution seems almost impossible, it can be reduced by ornamental plants acting as a natural filter. This review identified some Ornamental plants as bio-decontaminator and air purifier to reduce air pollution which is a risk factor in covid-19 infection as Ornamental plants absorb gases (pollutants) through their stomata, surface area of leaves, intercept particulate matter on their leaves and release oxygen thus serving as both indoor and outdoor air purification.

Keywords: coronavirus, covid 19, ornamental plants, particulate matter

Citation
Okparavero, O., Coker, T. & Akinlade, O. (2021). Reducing Air Pollution: A Risk Factor in Covid-19 Infection through the use of Ornamental Plant as Phytoremediation. International *Journal of Women in Technical Education and Employment (IJOWITED), The Federal Polytechnic, Ilaro Chapter*, 2(2), 110-120.

1. Introduction

A novel virus was identified in Wuhan in December 2019, due to high number of pneumonia cases of unknown source, samples collected from affected patients shows that the Pneumonia symptoms was caused by an infection with a virus. The pathogen was identified and named Severe Acute Respiratory Syndrome Corona Virus 2 (SARS – CoV-2), (Manoj, et. al., 2020; Travaglio et. al., 2020), the disease it caused is called Coronavirus disease 2019 (COVID 19). Coronaviruses are member of the Kingdom Orthornavirae, Class Pisoniviricetes, Order Nidovirales, Family Coronaviridae and Subfamily Coronavinae. (King *et al*., 2012).

These viruses are minute in size, the length of the viral genome is between 26-32 kbs, they are made up of positive, single stranded RNA. (King *et al*., 2012). Coronaviruses families are made up of four sub groups namely, Alphacoronaviruses, Betacoronaviruses, Gammacoronaviruses, Deltacoronviruses. These viruses infect birds and mammals, although Alpha and Betacoronaviruses infect mainly mammals while Gamma and Delta coronaviruses infect birds mainly, but some can infect mammals as well (Cui, *et al*., 2019). Coronaviruses are zoonotic, meaning they can be transmitted from animal to man. Air pollution may be associated with high Covid-19 intensity (Bourdrel *et al*., 2020), to combat infections a strong immune system is required, immune

defences are being weakened as a result of air pollution (Mary Prunicki, 2020), when an individual is infected with this virus and the immune system is weakened it might worsen the condition of the individual.

Air pollution can be defined as existence of harmful substance in the atmosphere that has negative effect on both human and other living organisms. (Jilian Mackenzie, 2016). Air pollutants are everywhere both indoor and outdoor, they are grouped into three, Gases (Ammonia, Carbon monoxide, Sulfur dioxide, etc), Particulates (Particulates matters forms are, PM_{10} and $PM_{2.5}$ metals having harmful effect) and biological molecules. (Khallaf 2011). There is no doubt that air pollutants are detrimental and pose great threat to human health, studies have revealed that the consequence of being exposed to air pollutants have effect on the respiratory, cardiovascular, ophthalmologic, dermatologic, neuropsychiatric, hematologic and reproductive systems. (Ghorani-Azam et. al., 2016), hence, to reduce air pollution there is need for air purification and this can be done using ornamental plant.

Ornamental plants are plants grown mainly for aesthetic purposes, it can be in form of a shrub, broad leaf, evergreen, deciduous, palms and others (Encyclopedia, 1979). Although they are grown majorly for beautification they perform other functions like removal of air pollution, this is done through the stomata, they help in removing carbon from the air and is being captured in plants, function in the production of oxygen, removal of dust and reduction of glare (Bayewu and Olayiwola, 2005; Kapoor, 2017; Grupta and Dube 2018).

This review therefore aims to discuss the use of ornamental plants as bio-decontaminator and air purifier to reduce air pollution which is a risk factor in covid-19 infection.

2. Review

The Covid -19 Pandemic

Viruses are microscopic infections creatures that are classified based on the sort of genetic material they contain (Petrosillo *et al*., 2020; El-Tanbouly *et al*., 2021). A retrovirus is a single stranded positive-sense RNA virus with DNA intermediate that targets a host cell as an obligatory parasite. Once within the cytoplasm of the host cell, this virus produces DNA from RNA genome using its own reverse transcriptase enzyme (Quadri *et al*., 2016). SARS-CoV-2 which causes coronavirus disease-2019, is a member of this family (Covid 19) (El-Tanbouly *et al*., 2021). The retroviruses generally are made up of an enveloped, positive-stranded RNA that encodes the genetic information and also promoters and regulatory regions for viral RNA transcription. (Zhang *et al*., 2015; Dhama, 2020; Kim *et al*., 2020; Lu *et al*., 2020; .El-Tanbouly *et al*., 2021). Historically, a lot of pandemic diseases as affected human beings, SARS (Severe Acute Respiratory Symdrom) was the first pandemic of the 21st century which occurred in Guangdong Province, China in 2002) (Cherry and Krogstad 2004; El-Tanbouly *et al*. 2021). Moreover, in June 2012 another virus was discovered in Saudi Arabia and named Middle East Respiratory Syndrome CoV (MERS-CoV), when a man with serious case of pneumonia was hospitalized. In December 2019, in Wuhan a novel virus was identified as a result of increase in the number of Pneumonia cases, samples collected from the patients shows that an infection with a virus was the cause of the symptoms, the pathogen was identified and named Severe Acute Respiratory Syndrome Corona Virus 2 (SARS-CoV-2) (Manoj, et. al.,2020; Travaglio et. al.,2020). This virus possesses a high infection rate for the fact that it can be transmitted easily when compared to others in the same family. (Billah *et al*., 2020; Liu Y., *et al*., 2020; Read *et al*., 2020; El-Tanbouly *et al*. 2021). Studies have revealed that SARS-CoV-2 can be transmitted through; Horizontal transmission (direct contact, aerosol, droplets) and Vertical transmission (Surgical operations) (Belser, Rota, and Tumpey 2013; Jiang *et al*., 2020; Rahman *et al*., 2020; El-Tanbouly *et al*. 2021). The virus SARS-CoV-2 has posed a lot of threat to the public health as a result of this and to curtail the rate at which the virus spread different measures was enforced by the government for example the use of face mask, social distancing and recently vaccines are being made available.

The SARS-CoV-2 Virus

SARS-CoV-2 belongs to the coronaviridae family are a made up of positive-sense, single stranded RNA (CoV) (Sturman and Holmes 1983; El-Tanbouly *et al*. 2021; Li *et al*., 2019). SARS-CoV and MERS-CoV are two extremely pathogenic virus that can be responsible for respiratory syndrome in humans. (Li *et al*., 2019) and this has affected human for decades. There is similarity between Covid 19 and SARS based on its clinical features although, it has fatality rate of 2.3% lower when compared to that of SARS 9.5 % and far lower when compared to that of MERS (34.4%), due to the fact, virus can exsit in the air for a long period, necessitating the use of air filtration as mitigating strategy. (Petrosillo *et al*., 2020; El-Tanbouly *et al*. 2021). The major symptoms of patient infected with Covid -19 includes dry cough, breathing, headache, fatigue, sore throat, pneumonia, tiredness etc., (El-Tanbouly *et al*. 2021; Hosseini *et al*., 2020), this corroborate to the fact that clean air is vital, hence polluted should be bio-decontaminated/purified.

COVID 19 In Nigeria

Index case was discovered in Nigeria on 24th of February, 2020 (NCDC, 2020) and since then the virus has spread across the country. As of 14th September, 2020 Nigeria has 56,388 confirmed cases with 37 States affected including the Federal Capital Territory, 35,773 male while 20,615 female. Globally 28,918,900 confirmed cases with 922,252 deaths. Although, Nigeria has been grouped as one of the 13 high-risk African countries with weak state of heath care system. (Marbot, 2020; Amzat *et. al*, 2020). To curtail the spread of this virus, different measure was put in place by the Federal government which includes, an initial lockdown of non-essential activities, closure of schools, ban on international flight, ban was placed on large gatherings, people being advised to use face mask etc, although the lockdown is being eased in phases. (NCDC, 2020).

Air Pollution and COVID 19

Studies have revealed that the means by which SARS-CoV-2 spreads is by three source; Aerosol; they are solid particles such as dust, fumes and smokes or liquid droplets such as fogs and midst suspended in the air (Enclopedia of Toxicology 2014), respiratory droplets that are large and contact with surfaces that are infected. (Pagliano and Kafil 2020; El-Tanbouly *et al*. 2021), these are the means by which this viruses spreads, people with underline ailments when infected with this virus may not survive because of the underline ailments they have and one the root cause of this disease is polluted air. Air pollution is the presence of harmful substance in the atmosphere that can bring about or pose threat to human health, have negative effect on living organisms and the environment at large (Admassu, and Wubeshet, 2011). Air pollutants are everywhere, it can be outdoor or indoor. According to WHO, air pollution is the world largest single environmental health risk, if this menace can be combated, millions of lives will be saved. According to WHO to 2012, both indoor and outdoor air pollution can cause cardiovascular diseases (Ischaemic heart disease), cancer, respiratory diseases (Acute Respiratory Infections and Chronic Obstructive Pulmonary Disease).

The Assistant Director-General Family, Women and Children's Health says, to prevent chronic diseases and minimize disease risk, the air we breathe in should be clean. People died as a result of cardiovascular diseases majorly, due to polluted air.

Outdoor air pollution-caused deaths – breakdown by disease;
40% - ischaemic heart disease;
40% - Stroke;
11% - Chronic Obstructive Pulmonary Disease (OCPD)
6 % - lung cancer
3% - acute lower respiratory infections in Children.
Source; (WHO, 2012)

Indoor air pollution – caused deaths – breakdown by disease
34% - Stroke;
26% - ischaemic heart disease
22% - COPD;
6%- lung cancer
Source; (WHO, 2012).

Table 1: Major Outdoor Air Pollutant Sources and Effects in Public Health

Pollutants	Sources	Effects
Ozone (O_3)	Formed when Nitrogen Oxide and Volatile Organic compounds mix in sunlight.	Frequent Asthma, Sour throat, Dyspnea.
Carbon dioxide (CO_2)	Burning oil, coal and natural gases	Vision defects, reduces respiration and brain function.
Carbon Monoxide (CO)	Fossil fuels, furnaces and heaters	Faintness, Headaches.
Nitrogen dioxide (NO_2)		Cough, short breath, respiratory infections, defect in lungs.
Sulphur dioxide (SO_2)	Industrial processes, coal, oil in power plant	Irritation of the eyes and nose, respiratory inflammations.
Toxic Air Pollutants	Chemical plants.	Cancer
Suspended Particulate Matter (PM_{10} $PM_{2.5}$ SPM)	Mixture of solid and liquid organic and inorganic materials.	Respiratory illness, Abnormal lungs gas exchange functions.

Source; (Kapoor, 2017; Jonathan Levy, Harvard School of Public Health. Based on information provided by the Environmental Protection Agency).

A study was conducted at Harvard University (Study awaiting peer review) revealed that an individual exposed to high-particulates pollution has 8% likelihood to die when compared with the individual less exposed (just one small unit less), (Paul Costello, 2020). To corroborate another study was conducted in Italy deduced that air pollution can trigger fatality rate due to Covid 19 infection. (Bon Lau, 2020). Particle pollution are particles that can be inhaled, (PM_{10} inhalable particles and PM $_{2.5}$ fine inhalable particles), Particulate matters with diameter of size 2.5 are fine particles that can be inhaled deeply even to the lungs and can travel all through the body, this can result in chronic disease in human. It is important for us to understand the level of pollutants our body can tolerate; with this we know how vulnerable our body may be to this disease. (United States Environmental Protection Agency, 2018; Paul Costello, 2020).

An individual that has been exposed to pollution, the immune system of that individual is suppressed as a result of the exposure and thereby increasing the risk of death when infected with the disease. (Bon Lau, 2020). A review also identified that people with prior Chronic diseases (Diabetes, Hypertension, Respiratory System Disease) and cardiovascular diseases are more susceptible to Covid 19 by triggering proinflammatory responses that can cause weak immune system. (Bon Lau, 2020). As a result of the negative impact of polluted air, hence, there is need for air purification, although this can be done using different methods (filtration and radiation) however, the method is expensive and impracticable for residual use, a method that can be employed that is environment friendly and cheap is the use of ornamental plants to purify the air.

Death from Respiratory disease and Covid-19

All parts of the respiratory system suffer from COVID-19 virus, the airways and alveoli, the pulmonary components (Shari *et al.*, 2020**)**. United Kingdom recorded 14% deaths of COVID-19 patients who had asthma (Docherty, A. B., Harrison, E. M. and Green, C. A. 2020) and International Severe Acute Respiratory and

Emerging Infection Consortium (ISARIC) had similar report from chronic pulmonary disease and asthma patients (16% and 13% respectively) (ISARIC (2020). United State of America centre for disease control implicated Chronic Respiratory Diseases (CRDs) as one of the prevailing underlying diseases in COVID-19 patients hospitalized (aged 18–29 years) (Garg, S., Kim, L., and Whitaker, M. 2020).

Ornamental Plant as Phytoremediation

The removal of air pollution from the atmosphere is part of the important function that plants performs, they also reduce heat build-up and remove dust from the air (Baiyewu *et al*, 2005; Kapoor, 2017), and beautify the environment. Plants have an important part in human survival by promoting a healthy lifestyle, which results in a stronger immune system capable of battling disease. Asight aesthetic purpose, ornamental plants help in regulation of temperature and humidy of advantage in human mental. (Deng and Deng 2018; (El-Tanbouly *et al*., 2021). Photosynthesis is a well-known mechanism in which plants purify the air by taking in carbon dioxide and producing oxygen, plants absorb oxygen and releases carbon dioxide through the process respiration. Based on these two processes there is inflow and outflow of air through the stomata which is the major components in plants, used for absorption and filtration process. (El-Tanbouly *et al*., 2021). In choosing an ornamental plant, location, purpose, adaptability to soil, weather, all these factors vary widely, and they should be considered, the vulnerability of plant species to air pollutants varies as well.

Features of ornamental plants that can be used to reduce pollution

The important factors to consider in the ornamental plants to be used are evergreen, large leaved, rough bark, native to the environment, ecologically compatible, low water requirement, minimum care, high absorption of pollutants, resistant pollutants, canopy spread, aesthetic features (attractive flower) ability to tolerate pollution and remove dust (Reshma *et al*, 2017; Kumar *et al*., 2013).

Ways in which plants and trees reduce air pollution includes, (Brethour *et al*., 2007; Reshma *et al.*, 2017 McPherson, 2005).

- Absorption of gases through their leaves and stomata
- They intercept Particulate Matter on plant surfaces.
- Oxygen is released through the process of photosynthesis
- Transpiration and shading of building surfaces occur, which lowers local air temperature.
- Lowering of Parking Lot temperatures and Cars been shaded reduces evaporative emissions of hydrocarbon from fuel tanks and hoses. (McPherson, 2005).

Scientific Research on Phytoremediation of Ornamental Plants.

Research have shown that, some ornamental plants can remove some toxic gases (Ammonia, Formaldehyde, Toluene, Volatile Organic Compounds) from the environment (Kapoor, 2017). A study was conducted using commonly used ornamental species 28 in number, for interior plantscapes to examine their ability to remove volatile pollutant, Aromatic hydrocarbon (Benzene and Toluene), alphatic hydrocarbon (octane), halogenated hydrocarbons {(trichloroethylene TCE)}, and terpene (a-pinene). Four ornamental species, *Hemsigrapahis alternata*, *Hendera helix*, *Hoya carnosa*, and *Asparagus densiflorus* exhibited greater removal efficiency for all pollutants, *Tradescantia pallida* displayed higher removal efficiency for four VOCs out of five (i.e benzene, toluene, TCE and a-pinene). Their removal efficiency ranged among the five species from 26.08 to 44.4 g/m3.m2/h of the total VOCs. *Fittonia argyroneura* effectively removed benzene, toleuene and TCE, *Ficus benjamina* effectively removed octane and a-pinene, moreso, *Polyscias fuiticosa* effectively removed octane. Due to variation in removal of efficiency among the species, multiple species are required for optimum improvement of indoor air quality.

Enete and Ogbona worked on five species of outdoor ornamental shrubs (Ixora Red, Yellow Bush, Masquerade Pine, Tuja Pine and Yellow ficus) reported that Ixora Red had the highest Air Pollution Tolerance Index while yellow bush with the lowest, Ixora Red tolerate pollutants more when compared to other ornamental plants. (Enete and Ogbona, 2012; Reshma *et al.* 2017). Gawronska and Bakera, 2014 also conducted a study on removal of Particulate Matter from indoor air using Spider plant, it was revealed that spider plants accumulate Particulate Matter and also contribute to air quality. Moreso, the report of the research conducted by Abass *et al.*,2017 on indoor plant for passive removal of indoor ozone, also reported that indoor plants removed ozone moderately from indoor air. (Abass *et al*,. 2017; Sharma *et al*., 2019).

Table 2: Indoor and Outdoor Ornamental Plants That Can Improve Air Quality

Scientific Name	Common Name	Family	Growth Habit	Type of Plant
Ficus benjamina	Weeping fig	Moraceae	Small plant	Indoor plant
Draceana frangrans	Draceana	Liliaceae	Small plant	Indoor plant
Codiaeum variegatum	Croton	Euphorbiaceae	Medium plant	Outdoor and Indoor plant.
Dieffenbachia seguine	Dumb cane	Arecaceae	Small Plant	Indoor Plant
Sansevieria trifasciata	Mother-in-laws tongue	Asparagaceae	Small plant	Indoor plant
Ficus alii	Alii ficus	Moraeae	Small palnt	Indoor plant
Aloe barbadensis	Aloe vera	Liliaceae	Small plant	Indoor and Outdoor
Psidium guajava	Guava	Myrtaceae	Small tree	Out door plant
Azadirachta indica	Neem	Meliaceae	Large tree	Out door plant
Polyalthia longifolia	Masquerade Tree		Large/Tall Tree	Outdoorplant
Delonix regia	Flame of the forest	Fabaceae	Large tree	Outdoor plant
Eucalyptus camaldulensis	Southern blue gum	Myrtaceae	Large/Tal tree	Outdoor plant

Source: (Beckett *et al*., 2000; Freer-Smith *et al*., 2004; Rzepka *et al*., 2005; Lakshmi *et al*., 2008; Kim *et al*., 2008; Tripathi *et al*., 2009 and Jaya, 2010; Kapoor, 2017; El-Tanbouly *et al*. 2021).

Clean Air Reduces the Risk of Covid 19

Wu *et al.*, (2020) reported that part of the factors that increases death rate of Covid 19 is air quality, underlined health issues (respiratory and cardiovascular) of some people, aggravated the risk of death ratio (Karuppasamy, 2020) when infected with the virus. WHO reported that dirty air leads to the death of 7 million annually, this occurs as a result of people being exposed to polluted air, for example Particulate Matters, when inhaled, causes some health challenges example hypertension, Heart disease, Breathing trouble and diabetes, all this aggravates complications in Coronavirus patients which can lead to death, but an individual that is less exposed to polluted air, without underlined health issues, have more chance of survival when infected with the virus. (Geographic, 2020).

3. Conclusion

To combat the menace of respiratory illness as a result of polluted air, which increases death rate of Coronavirus patients, the availability of ornamental plants both indoor and outdoor is important, helps in cleaning the air (absorbing the pollutants) and making the environment more conducive which reduces mortality rate. This study was able to review and identify some Ornamental plants that can serve as bio-decontaminator and air purifier to reduce air pollution which is a risk factor in covid-19 infection.

References

Abbass, O. A., Sailor, D. J. & Gall, E.T. (2017). Effectiveness of indoor plants for passive removal of indoor ozone. *Building and Environment*, 119, 62-70.

Abd El Aziz, N. G., Mahgoub, M. H., Azza, M. M., Farahat, M. M. & Abouziena, H. F. (2015). Potentiality of ornamental plants and woody trees as phytoremediators of pollutants in the air: a review. *International Journal of Chem Tech Research*, 8 (6), 468-482.

Admassu, M.. & Wubeshet, M. (2011). For Environmental Health Science Students. *E. Miaśkiewicz-Peska and M. Łebkowska,"* Effect of antimicrobial air filter treatment on bacterial survival*," Fibres & Textiles in Eastern Europe*, *19*, 1.

Amzat, J., Aminu, K., Kolo, V. I., Akinyele, A. A., Ogundairo, J. A. & Danjibo, M. C. (2020). Coronavirus outbreak in Nigeria: Burden and socio-medical response during the first 100 days. *International Journal of Infectious Diseases*, *98*, 218-224.

Baiyewu, R. A., Amusa, N. A. & Olayiwola, O. (2005). Survey on the use of ornamental plants for environmental management in Southwestern Nigeria. *Research Journal of Agriculture and Biological Sciences,* 1(3), 237-240.

Beckett, K.P.; Smith, P.F. and Taylor, G. 2000. Effective tree species for local air quality management. Journal of Arboriculture, 26(1): 12-18.

Belser, J. A., Rota, P. A., and Tumpey, T. M. (2013). Ocular Tropism of Respiratory Viruses. *Microbiol. Mol. Biol. Rev.* 77 (1), 144–156. doi:10.1128/mmbr.00058-12.

Billah, M. A., Miah, M. M., and Khan, M. N. (2020). Reproductive Number of Coronavirus: A Systematic Review and Meta-Analysis Based on Global Level Evidence. *PLoS ONE* 15 11, 1–17.

Biotechnology – Prospects for Phytomonitoring and Phytoremediation, Springer, Tokyo, Japan, 221-234.

Bon, L. (2020). How Air Pollution Contributes To the Spread of COVID-19. Retrieved September, 2020 at https: //earth.org/air-pollution-exacerbating-the-spread-of-covid-19/

Bourdrel, T., Annesi-Maesano, I., Alahmad, B., Maesano, C. N., & Bind, M. A. (2021). The impact of outdoor air pollution on COVID-19: a review of evidence from in vitro, animal, and human studies. *European Respiratory Review*, *30*(159).

Brenda, L. & Tesini, M. D., (2020). Unversity of Rochesterr School of Medicine and Dentistry, Coronaviruses and Acute Respiratory Syndromes (Covid-19, MERS and SARS), 2020.

Brethour, C., Watson, G., Sparling, B., Bucknell, D. & Moore, T. (2007). Literature review of documented health and environmental benefits derived from ornamental horticulture products. Final reports. George Morris Centre,

Cherry, J. D., and Krogstad, P. (2004). SARS: The First Pandemic of the 21st Century. *Pediatr. Res.* 56 (1), 1–5.

Chhotu, D. J. and Fulekar, M. H. (2009). Phytoremediation of heavy metals: Recent techniques. *African Journal of Biotechnology*, 8(6):921-928.

Cui, J., Li, F., & Shi, Z. L. (2019). Origin and evolution of pathogenic coronaviruses. *Nature Reviews Microbiology*, 17(3), 181 – 192.

Dhama, K. (2020). Update on COVID-19, 10-2020. *Clin. Microbiol. Rev.* 33 (4), 1–48.

Docherty, A. B., Harrison, E. M. and Green, C. A. (2020). Features of 16,749 hospitalised UK patients with COVID-19 using the ISARIC WHO Clinical Characterisation Protocol. *MedRxiv* 2020; preprint [https://doi.org/10.1101/2020.04.23.20076042

Dubbey, S., Shri, M., Grupta, A., Rani, V. & Chakrabarty, D. (2018). Toxicity and detoxification of heavy metals during plant growth and metabolism, *Enviromental Chemisty Letters*, 16(4), 1169-1192.

El-Tanbouly, R., Hassan, Z., & El-Messeiry, S. (2021). The Role of Indoor Plants in air Purification and Human Health in the Context of COVID-19 Pandemic: A Proposal for a Novel Line of Inquiry. *Frontiers in Molecular Biosciences*, *8*, 624.

Enete, I. C., & Ogbonna, C. E. (2012). Evaluation of Air Pollution Tolerance Index (APTI) of Some Selected Ornamental Shrubs in Enugu City, Nigeria. *IOSR Journal of Environmental Science, Toxicology and Food Technology* (IOSR-JESTFT), 1 (2): 22- 25.

Freer-Smith, P.H.; El-Khatib A.A. and Taylor, G. 2004. Capture of particulate pollution by trees: a comparison of species typical of semi-arid areas (Ficus nitida and Eucalyptus globulus) with European and North American species. Water, Air, and Soil Pollution, 155: 173–187.

Garg, S., Kim, L., and Whitaker, M. (2020). Hospitalization rates and characteristics of patients hospitalized with laboratory-confirmed coronavirus disease 2019 - COVID-NET, 14 States, March 1–30, 2020. *MMWR Morb Mortal Wkly Rep* 2020; 69: 458–464. doi:10.15585/mmwr.mm6915e3

Geographic, N. (2020). Pollution made COVID-19 worse. Now lockdowns are clearing the air. *Sci. Coronavirus Cover*.

Ghorani-Azam, A., Riahi-Zanjani, B., & Balali-Mood, M. (2016). Effects of air pollution on human health and practical measures for prevention in Iran. *Journal of research in medical sciences: the official journal of Isfahan University of Medical Sciences*, 21, 65.

Hosseini, E. S., Kashani, N. R., Nikzad, H., Azadbakht, J., Bafrani, H. H., and Haddad Kashani, H. (2020). The Novel Coronavirus Disease-2019 (COVID-19): Mechanism of Action, Detection and Recent Therapeutic Strategies. *Virology* 551, 1–9.

ISARIC International Severe Acute Respiratory and emerging Infection Consortium 6th May 2020 Report. Oxford, ISARIC, 2020.

Iuliana F. G. and Barbu I. (2011). The Effects of Air Pollutants on Vegetation and the Role of Vegetation in Reducing Atmospheric Pollution, The Impact of Air Pollution on Health, Economy, Environment and Agricultural Sources, Mohamed K. Khallaf, IntechOpen

Jiang, F., Deng, L., Zhang, L., Cai, Y., Cheung, C. W., and Xia, Z. (2020). Review of the Clinical Characteristics of Coronavirus Disease 2019 (COVID-19). *J. Gen. Intern. Med.* 35 (5), 1545–1549.

Jilian Mackenzie, (2016), Natural Defence Council, Air Pollution Everything You Need To Know.

Kapoor, M. (2017). Managing ambient air quality using ornamental plants-an alternative approach. *Universal Journal of Plant Science*, *5*(1), 1-9.

Karuppasamy, M. B., Seshachalam, S., & Natesan, U. (2020). Air pollution improvement and mortality rate during COVID-19 pandemic in India; global intersectional study. *Air Qual Atmos Helath* (2020).

Khallaf, M. (Ed). (2011). The impact of air pollution on health, economy, environment and agricultural sources. BoD- Book on Demand.

Kim, D., Lee, J.-Y., Yang, J.-S., Yang, J. W., Kim, V. N., Chang, V. H., *et al*. (2020). The Architecture of SARS-CoV-2 Transcriptome. *Cell* 181 (4), 914–921.e10.

King, A. M. Q., Adams, M. J., Carstens, E. B., & Lefkowitz, E. J. (2012). Order-tymovirales, virus taxonomy.

Klassen, S. P, McLean, J. E. Grossel, P. R. & Sims, R.C. (2000). Fate and behavior of lead in soils planted with metal resistant species (River birch and small wing sedge). *J. Environ. Qual.*, 29: 1826-1834.

Kurmar, R. S., Arumugam, T., Anandakumar, C. R., Balakrishnan, S. & Rajavel, D. S. (2013). Use of Plant Species in Controlling Enviromental Pollution-A Review. *Bull. Env. Pharmacol. Life Sci.*, 2 (2): 52-63.

Lakshmi, P. S., Sravanti, K.L. and Srinivas N. 2008. Air pollution tolerance index of various plant species growing in industrial areas. The Ecoscan, 2(2): 203-206

Li, X., Luk, H. K. H., Lau, S. K. P., and Woo, P. C. Y. (2019). *Human Coronaviruses: General Features*. Amsterdam, Netherlands: Elsevier. doi:10.1016/b978-0-12-801238-3.95704-0

Lu, R., Zhao, X., Li, J., Niu, P., Yang, B., Wu, H., *et al*. (2020). Genomic Characterisation and Epidemiology of 2019 Novel Coronavirus: Implications for Virus Origins and Receptor Binding. *The Lancet* 395 (10224), 565–574. doi:10.1016/s0140-6736(20)30251-8

Manoj, M. G., Kumar, M. S., Valsaraj, K. T., Sivan, C., & Vijayan, S. K. (2020). Potential link between compromised air quality and transmission of the novel corona virus (SARS-CoV-2) in affected areas. *Environmental Research*, 110001.

Marbot, O. (2020). Coronavirus Africa Map; Which countries are most at risk? retrieved September, 2020 at

Mary Prunick, (2021). Stanford researcher discusses link between air pollution and COVID-19. Retrieved November 24th at https:// news.stanford.edu/202/06/30/links-covid-19-air-pollution.

McPherson, E. G. (2005). Trees with Benefits. *American Nurseryman* April1: 34-40

McPherson, E. G. 2005. Trees with Benefits. American Nurseryman April 1: 34-40

Myint, S. H. (1994). Human coronaviruses: a brief review. *Reviews in Medical Virology*, *4*(1), 35.

Pagliano, P., and Kafil, H. S. (2020). Protection and Disinfection Policies. *Le Inferziono in Medicina* 2 (April), 185–191.

Pan American Health Organization (PAHO), 2021.

Petrosillo, N., Viceconte, G., Ergonul, O., Ippolito, G., and Petersen, E. (2020). COVID-19, SARS and MERS: Are They Closely Related? in Clinical Microbiology and Infection (January).

Rahman, H. S., Aziz, M. S., Hussein, R. H., Omer, S. H. S., Khalid, E. S., Abdulrahman, N. A. (2020). The Transmission Modes and Sources of COVID-19: A Systematic Review. *Int. J. Surg. Open* 26, 125–136. doi:10.1016/j.ijso.2020.08.017

Read, J. M., Bridgen, J. R. E., Cummings, D. A. T., Antonia, H., and Jewell, C. P. (2020). Novel Coronavirus 2019-NCoV: Early Estimation of Epidemiological Parameters and Epidemic Predictions. *MedRxiv* 2020 (January). doi:10.1098/rstb.2020.0265

Reshma, V. S., Prashant, K. and Chaitra, G. S. (2017). Significant Role of Ornamental Plants as Air Purifiers – A Review. *Int.J.Curr.Microbiol.App.Sci*. 6(8): 2591-2606.

Rzepka, M.A., Cuny1, D., Davranche, L., Cazier, F., Denayer, F.O. and Haluwyn, C.V., 2005. Air quality assessment in an industrial area in France using monitoring plants. In Books of Abstracts, Third International Conference on Plant and Environmental Pollution, 29th Nov.-2, Dec., NBRI, Lucknow, India. p. 9 SI/O- 17

Sawidis, T., Marnasidis, A., Zachariadis, G., & Stratis, (1995). A Study of air pollution with heavy metals in Thessalanoniki city (Greece) using trees as biological indicator. Archives *of Environmental Contamination and Toxicology*, 28 (1), 118-124.

Shari B. Brosnahan, Annemijn H. Jonkman, Matthias C. Kugler, John S. Munger, David A. Kaufman (2020). COVID-19 and Respiratory System Disorders: Current Knowledge, Future Clinical, and Translational Research Questions. Article in Arteriosclerosis Thrombosis and Vascular Biology. DOI: 10.1161/ATVBAHA.120.314515 Downloaded from http://ahajournals.org by on February 22, 2021

Sharma, P., Toma, P. C., & Chapadgaonkar, S. S. (2019). Phytoremediation of indoor pollution-a mini review. *World J. Pharma Res*, 8, 2136-2143

Sturman, L. S., and Holmes, K. V. (1983). The Molecular Biology of Coronaviruses. *Adv. Virus. Res.* 28 (C), 35–112. doi:10.1016/s0065-3527(08)60721-6

Travaglio, M., Yizhou, Yu., Popovic, R., Liza, Selley., Nuno Santos Leal, & Luis Miguel Martins. (2020). Between air pollution and COVID-19 in England. MRC Toxicology Unit, University of Cambridge.

World Health Organization, (2020). Coronavirus disease: What you need to know. Retrieved September, 2020 (https://www.afro.who.int/news/coronavirus-disease-what-you-need-know).

Yoneyama, T., Kim, H. Y., Morikawa, H. & Srivastava, H. S., (2002). Metabolism and detoxification of nitrogen dioxide and ammonia in plants, In, K. Omasa *et al*., (eds) Air Pollution and Plant.

Zhang, W., Cao, S., Cao, S., Martin, J. L., Mueller, J. D., and Mansky L, M. (2015). Morphology and Ultrastructure of Retrovirus Particles. *AIMS Biophys.* 2 (3), 343–369. doi:10.3934/biophy.2015.3.343