***TECHNOVAIR*: ARDUINO-BASED AUTOMATED AIR FILTRATION, INDOOR AIR QUALITY MONITORING, AND NOTIFICATION SYSTEM**



**A Capstone Research Project Presented to**

**The Senior High School Department**

**Malayan Colleges Mindanao**

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**May 2022**

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In Partial Fulfillment

Of the Requirements for the

STEM 9 Capstone Research Course

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**CHAPTER 1**

**INTRODUCTION**

**Background of the Study**

Smart-Air, an IoT-based indoor air quality monitoring platform, was developed to counter the growing concern of consuming air pollutants indoors (Jo et al., 2019). Since an infectious disease, COVID-19, has forced everyone to stay within their homes, ensuring the cleanliness of the indoor air quality (IAQ) is now imperative (Agarwal et al., 2021). With that, proper ventilation and filtration can decrease harmful air particles. This device, developed in 2020, incorporates multiple sensing devices, such as a laser dust sensor, Volatile Organic Compounds (VOCs) sensor, carbon monoxide sensor, carbon dioxide sensor, and a temperature and humidity sensor, which are programmed to forward the collected data to the server used, the Amazon Web Services (AWS).

However, air purifiers and air filtration systems, in general, that run for 24 hours a day can consume up to 450 kilowatts a year and thus are extensive in using electricity (Energy Star, 2018). Another problem with some air filtering systems, known as ionizers, is that they generate ozone, which can aid in particle removal, but the ozone is actively harmful to the user’s health (Yoda et al., 2020). Furthermore, although the operating costs of the air purifiers today are low, the initial purchase of the system is high-priced, and the usual system available on the market is not a portable device, resulting in the lack of indoor air quality monitoring systems in households (Liu et al., 2021).

In the global context, a study presented by the Maharashtra Institute of Technology from India introduced an air purification system intended to improve indoor air quality within small public spaces and apartments. To lessen the dangers brought by air pollutants, the invention is equipped with basic sensors, filters (dust filter, pre-filter, and fine filter), and an air monitoring system, all controlled by a microcontroller of the Arduino Uno Series (Panicker et al., 2020). However, the system’s main limitation is its incapability to have a decent notification system as the system is only equipped with a Liquid Crystal Display (LCD) informing the user about the air parameters and the quality of air being purified.

In addition, in the national setting, a device invented by Polytechnic University of the Philippines students used the microcontroller Arduino Mega 2560 with its specialized gas and dust sensor systems. As one of the most prevalent concerns of the Philippines, air pollution was chosen as the subject of study by the researchers. They utilized low-cost sensors to develop a portable Air Quality Monitoring System to identify various air pollutants. This prototype was then tested in Tagaytay City because of the Taal Volcano’s recent eruption (Balatbat et al., n.d.). Regardless of how advanced the system is, it could still be incorporated with a filtering system through different filters available in the market and an enhanced notification system aside from using LCD to allow real-time monitoring to the users. Also, the device should be tested indoors and not just the Air Quality Index (AQI) outdoors for everyone’s air quality and environment safeguard and health protection.

In the local setting, a study conducted by the Mindanao State University – Iligan Institute of Technology introduced and tested an Arduino-based air quality testing, air filtering, and disinfecting device, initially aimed at addressing the air pollutants within hospital rooms that are necessary to filter and disinfect regularly. The invention comprises an Arduino Uno Board, multiple filters, sensors, and a UV lamp, which are tested to be of ideal use in these spaces (Positos et al., 2017). However, this project can still be improved, built with low-cost materials to meet market demand, and can be used by everyone, especially those living in densely populated areas where constant monitoring will provide them with knowledge about environmental changes and an understanding of the proper management control of particulate pollution in the environment.

Looking at these contexts in different settings, it is evident how current research in this field of study needs to be further explored. Hence, this project is designed to develop a portable automated air filtration and monitoring system, which calibrates the IAQ, filters out the pollutants, and maintains a healthy air quality level to avoid the intake of contaminated air. TECHNOVAIR will feature multiple sensors, such as the PMS5003 fine particulate matter (PM) Air Quality Sensor that detects PM1, PM2.5, and PM10 dust concentrations, MQ131 Gas Ozone Detection Sensor for ozone (O3) concentration identification, and SGP30 Multi-Pixel Gas Sensor for VOCs and equivalent carbon dioxide reading that will be utilizing Arduino Mega to reduce the amount of energy required through mechanization.

As for the filtration of criteria pollutants, the device will be integrating a High-Efficiency Particulate Air (HEPA) filter, Activated Carbon Filter, and Pre-filter. Lastly, the device will include a notification system that sends updates to the user through a phone and personal computer application. Through this device, not only can the users avoid any airborne disease, but they can also improve their indoor living by guaranteeing the cleanliness of the air they breathe.

**Project Objectives**

This research project study aims to achieve the following objectives at the end of the course:

1. To design an automated air filtration and monitoring system that notifies its user about the particulate matter level, ozone gas concentration, VOCs, and equivalent carbon dioxide utilizing Arduino software.
2. To test the automated air filtration and monitoring system unit in terms of its:
   1. Functionality
   2. Usability
   3. Reliability
   4. Performance
   5. Supportability
3. To decrease pollutants in the air using a project with less required energy consumption through automation and inform individuals regarding the households’ IAQ condition.

**Significance of the Study**

The project will provide an understanding of Indoor Air Quality (IAQ) monitoring while highlighting significant knowledge gaps for future studies. In particular, the study holds its importance as a benefit for the following:

*Household Members.* This project will be able to help household members by giving them the option to spend less or even none on buying cleaning agents and other manufactured purifiers. This way, they will also be exerting less physical effort in maintaining the cleanliness of their establishments and homes.

*Workers* *in Enclosed Spaces.* Rooms with no ventilation would be one of the areas that could extensively use the help of this project. Ventilation is always important as it keeps the air clean and circulated, optimal for serene breathing and increased productivity. It would help workers within enclosed spaces have better respiration and ease breathing, especially those working at offices, Business Process Outsourcing (BPO) Companies, and Hospitals.

*Individuals with Respiratory Ailment.* This project will help prevent breathing problems from triggering or worsening their illness. Air particles could easily be mixed with dust and can be directly inhaled by a person, and so it would be rather challenging if a person with respiratory ailment were exposed to such. Providing them with clean and purified air is necessary to breathe correctly and move without complications.

*Government Sector - Department of Environment and Natural Resources (DENR).* This study aims to protect, conserve, and manage the environment and the citizens of this country, given the current situation (COVID-19). Considering the Department of Environment and Natural Resources (DENR) mission and vision, this study ensures environmental quality that will surely benefit and promote human well-being.

*Government Sector – Department of Science and Technology (DOST).* This study seeks to preserve and nurture the mandate, mission, and vision of the Department of Science and Technology (DOST). It also grants innovative solutions that will lead to a better quality of life.

*Future Researchers.* The study will serve as a reference for future studies discussing related topics. The study may also serve as a cross-reference that will help give future researchers an overview of discussed topics.

**Scope and Delimitation of the Study**

To address the growing concern of indoor air pollution, this project will be conducted to produce a portable automated air filtration and IAQ monitoring system that will be useful to household owners, workers within enclosed areas, people with respiratory ailments, and the government sectors, specifically the DENR and DOST. However, considering the COVID-19 pandemic, which has prohibited the developers from gathering simultaneously, they will be pursuing an alternative setup in conducting the project, which is online. Furthermore, the project will be applying a qualitative research design, wherein the developers will utilize nonnumerical data to define the device’s performance and determine its functionality. As qualitative research design is known for its subjectivity, it allows the developers to gather unique opinions and experiences from the respondents regarding their device (MacKellar, 2022). This approach will allow them to gain different perceptions since the respondents can provide varying answers to open-ended questions. By that, the researchers will analyze the gathered data and take necessary measures to ensure that the device runs smoothly.

The study also delimits the abilities of the device as it will be utilizing sensors with certain technical specifications. The PMS5003 sensor can distinguish particles as small as 0.3 micrometers, and its effective range in PM2.5 standard is about 0~500 μ g/m³, with a maximum range of ≥1000. To power this sensor, a minimum of 4.5 Volts (V) and a maximum of 5.5V DC power supply is needed (Yong, 2016). In addition, the MQ131 Gas Ozone Detection Sensor can only sense a 10-1000ppm Ozone concentration. Its sensitivity can be negatively affected when in contact with water, frozen, or when used with a higher voltage. Furthermore, its heating voltage is 5.0V±0.2V AC or DC, while the loop voltage is ≤24V DC (“MQ131 Semiconductor,” n.d.). Lastly, the SGP30 Multi-Pixel Gas Sensor’s specified measurement range for Ethanol signal is 0.3 ppm to 30 ppm and 0.5 ppm to 10 ppm for H2 signal. Its minimum supply voltage is 1.62V, and its maximum is 1.98V (“Datasheet SGP30,” 2017).

With the help of the selected sensors, the device will cover the filtration of the following criteria pollutants: dust concentrations, ozone concentration, VOCs, and equivalent carbon dioxide. Dust particles in the air determine the particulate matter. The dust density in the air is measured in micrograms per cubic meter (µg/m3), VOCs and ozone concentration in parts per billion (ppb), and carbon dioxide in parts per million (ppm). However, the specific room coverage of the sensors is yet to be determined as it is not stated in the manual. Also, the phone and PC notification system will only be functional within a certain distance from the room outwards, limiting its ability to send notifications within a \_\_ radius. The project will be conducted during the academic year 2021-2022 and is presumed to develop its concept design from January to May of 2022. No final product will be presented as the project only aims to design the said device.

**CHAPTER 2**

**REVIEW OF RELATED LITERATURE AND SYSTEM**

This section will mainly cover the related literature regarding indoor air filters and air purifiers. Moreover, to help elucidate the project’s intentions, five (5) related systems that are highly associated with the project will be tackled, together with the theoretical and conceptual frameworks that will be the study‘s foundation. To ensure the clarity of the content, multiple terms will also be provided alongside their operational definitions. The developers have gathered several studies, articles, and other data to aid in understanding the project’s concept and visualize the desired product’s features and application.

**Related Literature**

While there are a wide variety of air filters and air purifiers, common indoor prototypes will specifically be focused on in this study. The developers conducted extensive readings concerning its different key aspects, and after careful consideration, this segment has been divided into six themes. To have a better idea as to what indoor air filters and purifiers are, the anatomy, systems, and how they function should be well understood. Thus, the developers will expound on the features of various projects, their applications in different settings, and the multiple concerns that arose while using these systems. In addition, the system development tools and different sequential modeling techniques will be discussed and how they can improve the existing indoor air filtration systems.

*Common Indoor Air Filters and Air Purifiers*

A typical air filter comprises a cardboard frame that encloses a bunch of spun fiberglass material, pleated material, or cloth. There are two methods by which they work, based on the material used in the process of filtration. The first method is mechanical filtration. It filters air pollutants by letting it usually run through a microfine fiberglass media, which is stabilized and folded many times over for higher effectivity. Conversely, its second purpose is to trap and paralyze charged particles on flat plates or surfaces. (Liu et al., 2017)

In addition, further studies showed that an overlooked component of the Heating, Ventilation, and Air Conditioning (HVAC) System is the air filter used within a home’s furnace, air conditioner, or heat pump. It is necessary to consider several aspects that fall under the user’s intention before buying something too costly or cheap. As stated by Kabrein et al. (2017), there is a hierarchy in filter efficiency, and one of those that needs to be considered is the varying sizes of the proximity where the filter will be used. Once a factor is overlooked, the user may not experience the machine’s full potential they purchased.

For that reason, some purchasers ask experts advice about the Minimum Efficiency Reporting Value (MERV) rating, which is crucial as it determines the filter’s efficiency and performance. The standard MERV values range from 1 to 16, indicating how well the air filter can purify the air. Ordinary standard filters of 1 to 4 offer basic filtration levels, 5 to 8 are often used for residential areas, and 9 to 12 are mid-range filters of high quality. Lastly, 13 to 16 are the best versions that filter particles as small as 0.3 particulates (Stephens et al., 2016).

However, regardless of how compatible the air filter is with the designated area, its efficiency may decrease once left dirty. After continuous usage, it is most likely to get clogged, leading to HVAC system malfunctions and more cost and energy used to fix it. It can also amplify the air impurities circulated in the household (Davis Air Conditioning & Heating, 2015). Additionally, other purifiers, such as a negative ion emitting air purifier, may sound very proficient, but the possibility of creating ozone emissions is the downside to this resort.

Despite the multiple disadvantages of air filters or air purifiers, users could still benefit from their abilities. They help maintain pure air and are commonly good for personal use as they ensure ventilation for users’ private space, especially in this time when viruses are everywhere (Park et al., 2016). The benefits of using air purifiers lie in how it helps in alleviating symptoms and preventing reactions. These include sickness triggers for people with low immunity and or high sensitivity. After continued use, there is an increasing possibility of experiencing fewer allergic reactions, asthma symptoms, and the like (van Boven et al., 2020).

To maximize their efficiency, the air filters should be built with a fibrous filter, which is the best material. Room air filters should also be designed to maximize the Clean Air Delivery Rate (CADR). The optimization of such relies not only on the subjective aspects but also on how the users will be using them. Users should always have them turned on, around the clock, and placed in a single room. Keeping the windows and doors closed would also be a huge factor in helping these machines function better and less costly (Vijayan et al., 2015).

*Usage of Indoor Air Filters and Air Purifiers*

A study was conducted within three European cities to determine the significance of air purifiers within households. It observed air purifiers in bedrooms with indoor PM2.5 concentration and perceived indoor air quality, resulting in the reduction of PM concentrations by 45% to 69%. It also presumes that the common reason for using air purifiers was that it provide a cooling effect in the rooms. In addition, another motivation to use air purifiers may be the users’ health condition, for multiple participants were experiencing respiratory issues (Cooper et al., 2022).

Similarly, during winter, a case study was set in an apartment in Delhi, India, with considerably high air pollution levels. The test rooms represent the upper-class residences, and the results indicate that outdoor air particle count varied during the observation. It is also stated that when outdoor air pollutions are high, air purifiers and air filters can worsen the levels indoors, depending on the leakages and rate of filtration. Even though air purifiers and filters can reduce particulate matter, the number of particles left remains concerning to users (Vyas et al., 2016).

Meanwhile, a study set in a hospital within Melbourne, Australia, studied the airflow and efficacy of air purifiers in a ward used by COVID-19 patients. Glycerine-based aerosol was deployed to replicate the SARS-CoV-2, and results show that the sole use of HVAC systems is not enough to clear aerosols. With that, air cleaners can protect the staff from airborne diseases. Two air cleaners in a patient room can take up to 5.5 minutes to clear 99 percent of aerosols, and it is quite cheap for medical facilities (Buising et al., 2021).

Another study took place in a kindergarten in Gliwice, Poland. It was done to address the increased susceptibility of children to air pollution, and at the end of the study, it was deduced that humans are the main source of most bioaerosols within the building. A figured ratio of indoor/outdoor bacteria ranged from 1.72-4.12, which means air pollution is higher indoors than outdoors. Air purifiers can reduce these by 18 percent, with a maximum efficiency value of 26 percent (Brągoszewska & Biedroń, 2021).

In addition, another observation was done in high school classrooms in a school in Germany during the Coronavirus (COVID-19) pandemic. Air purifiers with HEPA filters were utilized, resulting in its confirmed ability to reduce the virus-containing particles that infected persons may respire. In just two hours of being with an infected person within a closed room, the estimated inhaled dose can decrease by a factor of six if the air purifier’s air exchange rate is 5.7 h−1. However, it is also noted that its noise levels must be low to avoid class disruptions (Curtius et al., 2021).

Lastly, a study set in a workplace was conducted in four countries: China, India, the United Kingdom, and the United States of America. Specifically, PM2.5 concentrations inside the buildings were recorded, and findings indicate that indoor concentrations are generally lower in facilities that utilize mechanical ventilation and filtration. The filters are highly effective during operating hours. Those with the highest MERV ratings can provide the safest space for employees to occupy. They also reduce the mortality ratio due to related diseases (Jones et al., 2021).

*Problems Encountered in Present Indoor Air Filters and Air Purifiers*

*Efficiency.* Indoor air quality (IAQ) refers to the quality of air inside buildings, with a focus on the health and comfort of those who live there (Heitzmann, 2015). Air cleaners are highly effective at removing particles, while others are not as reliable. A cleaner with a high air-circulation rate but a less efficient collector will not be effective, nor will one with a low air-circulation rate but a more efficient collector. Most air cleaners are not built to remove a variety of gaseous air pollutants.

*Health concerns.* Zeng et al. (2021) conducted a series of studies to evaluate the effectiveness of a commercially available induct bipolar ionization device in eliminating gas and particles, and the likelihood of byproduct formation. While the ionizing device reduced some VOCs, it raised others, most notably oxygenated VOCs, which are commonly found in paints and aerosol sprays. As a result, VOC exposure has been linked to a variety of health issues, including nausea and liver, kidney, and central nervous system damage (Study Finds Safety Concerns With Air Purifiers, 2021).

*Contradictions.* Outside of Japan, air filtration has been shown to reduce indoor concentrations of PM2.5 and allergens, hence relieving asthma symptoms (Yoda et al., 2020). Furthermore, air purification has improved cardiovascular and pulmonary functioning in the elderly. However, numerous contradicting data demonstrate no discernible alterations in cardiovascular and pulmonary functions in the elderly. These studies show that the effects of air purification have been tested in older people or patients with respiratory illnesses such as asthma.

*System Development Tools Used in the Study*

Microcontroller gas-sensing devices are well-suited for air quality sensing because it is accessible to both non-experts and professionals in programming languages (Heyasa & Galarpe, 2017). With that, the designed air quality monitoring system will be primarily made up of PMS5003 fine Particulate Matter (PM) Air Quality Sensor, MQ131 Gas Ozone Detection Sensor, and SGP30 Multi-Pixel Gas Sensor. These sensors will help detect criteria pollutants that harm human health and the environment and cause property damage.

In addition, this study will present the utilization of a set of filters for improving air quality in indoor areas. The developers will use a Pre-filter, High-Efficiency Particulate Air (HEPA) filter, and an Activated Carbon filter to trap the air pollutants in the filtration system (Chan et al., 2016). Also, the application of a text-based information system using the Global System of Mobile Communications (GSM) module and Liquid Crystal Display (LCD) will be incorporated in the design for data dissemination. In this way, users will know the meaning of each air quality index reading.

*Arduino Mega 2560 Microcontroller.* To address indoor air pollution issues, a study conducted by Panicker et al. (2020) showed that a functional air filtration system should be used in enclosed spaces. With that, instead of the conventional way of turning on the filtration system all day, using an Arduino Mega 2560 Microcontroller and low-cost gas sensors through Arduino Software Integrated Development Environment (IDE) could save a significant amount of energy (Louis, 2016).

*PMS5003 sensor*. PMS5003 sensor is a digital and universal particle concentration sensor that will specify the amount of particle matter (PM) concentration (PM1, PM2.5, and PM10) and output the data digitally. The laser scattering principle is used for such a sensor, which produces scattering by radiating suspended particles in the air with a laser, then collecting scattering light to a certain degree, and obtaining the curve of scattering light change over time (Bulot et al., 2019).

Incorporating this sensor in the design is essential since clinical studies have found that PM air pollution significantly influences health more than gaseous components. It has numerous adverse effects on human health, notably the cardiovascular system. Exposure to PM air pollution, both acute and chronic, is associated with a higher risk of fatal injury from cardiovascular diseases such as ischemic heart disease, cardiac arrest, and ischemic/thrombotic stroke (Hamanaka & Mutlu, 2018). Thus, it is essential to know this specific pollutant before reaching a critical threshold in our households.

*MQ131 Gas Ozone Detection Sensor*. MQ-131, a low concentration ozone gas sensor, contains the detection compound known as Tungsten trioxide (WO₃). This sensor can measure concentrations in the range of 10–1000 ppb. It has lower conductivity in pure air and higher conductivity when there is a high ozone concentration (Carrillo-Amado et al., 2020). If the gas and air in the sensor exchange well, the sensor is more sensitive and quicker response and recovery time.

Although the focus on air quality has been on particulate matter, particularly PM2.5, in fast-expanding nations such as China and India in past years, “invisible” ozone pollution is progressively recognized as a significant health threat (Ma et al., 2016). Ground-level ozone concentrations are usually most significant on hot days with low humidity and stagnating wind. Thus, having this sensor would benefit everyone, especially those staying indoors with lesser air ventilation, especially those living in the Philippines, a tropical country.

*SGP30 Multi-Pixel Gas Sensor*. According to Al-Okby et al. (2022), the Sensirion Gas Platform (SGP) multi-pixel gas sensor is based on a heated film of metal-oxide (MOx) nanoparticles used in the SGP30. The oxygen on the metal-oxide particles absorbs oxygen, adapts with the target gas, and emits electrons. The sensor measures the electrical resistivity of the metal-oxide layer, allowing quantification of Total Volatile Organic Compounds (TVOC) levels and the equivalent Carbon Dioxide (eCO2). This sensor provides long-term stability that traditional metal-oxide gas sensors do not.

This sensor will be essential in providing users with the number of pollutants and harmful gases in the indoor air in specific areas. This notion is supported by Shuai et. al. (2018) where their study showed that VOCs emission by an industrial company in Korea could have negative cancer and non-cancer health effects and that risk management is required. Thus, many studies have cited these findings suggesting that VOCs should be monitored for better regional air quality due to their apparent effects on the environment and human health.

*Pre-filter*. Filter systems should guarantee mechanical separation and be capable of capturing or neutralizing undesirable chemical compounds (Smith et al., 2019). For filtration, pre-filters are the first phase in the air filtering process of an air purifier. A pre-filter prevents the central air filters from becoming clogged with debris, allowing them to trap microscopic pollutants. This pre-filter is typically the least expensive of the filters in the device, and it is used to extend the life of the main filters.

*High-Efficiency Particulate Air (HEPA) filter*. The HEPA air filter will be used to thoroughly purify the air, composed of many fine fibers arranged into a matt to trap both microscopic and larger particles. HEPA filters, by definition, can capture nearly 100% of particulates in the atmosphere that are 0.3 microns or smaller (Basińska et al., 2021). Thus, HEPA filters have at least almost 100% effectiveness for stripping away all particles, with even higher efficiencies for particles larger and smaller than 0.3 microns. This filter has become an essential component in the preservation of biological safety.

*Activated Carbon filter*. On the other hand, activated carbon filters have unique properties that enable them to clear away volatile organic compounds (VOCs), odors, and other gaseous pollutants from the air (Madiraju et al., 2020). It does so differently from other air purifiers, such as HEPA, which only filter particulate pollution from the air. Activated carbon filters can particularly benefit people who suffer allergies or aggravation from impure air, including secondhand smoke.

Since urban and rural localities have grown as a result of urbanization, inevitably, this causes terrible air pollution and poses a danger to public health and the environment. With that, a study by Rajapandian et al. (2019) showed that air filtration is one of the essential factors in cleaning indoor air. It improves human health by combating allergies, offensive odors, and snoring. His findings showed that fiber air filtration is the most widely used and developed among the various air-cleaning techniques.

*Processing Integrated Development Environment (IDE).* Processing open source application allows users to create interactive applications in a variety of programming languages that includes Java, Android, Python, and Javascript. The main goal of this program is to visually teach non-programmers the fundamental concepts of computer programming. In terms of structure, the Processing IDE is comparable to Arduino and they can communicate via serial communication which aids in sending data from the Arduino to the Processing IDE and from the Processing IDE to the Arduino (Miller, 2021).

*MIT App Inventor.* MIT App Inventor is a web-based development platform that users can use to solve problems in the real world. It offers a web-based "What you see is what you get" (WYSIWYG) editor for creating Android and iOS mobile phone apps. It makes use of Google Blockly, a block-based programming language (Fraser, 2013). The user does not need to write instructions because all they have to do is choose and organize the options available on the website so that they can quickly build an application by finding the appropriate blocks.

*Implications of the System Development Tools Used in the Study*

Most widely used room ventilation systems lack an adequate mechanism for monitoring and cleaning households’ air (Smith et al., 2019). The motivation for tackling this issue stems from the desire to provide the beneficiaries with access to air free of mechanical and chemical pollution, which harms human health. As a result, this whole design collaborates with the air quality monitoring system and filter consisting of many layers, which will operate so that each function is highly connected and operates concurrently.

People have recently preferred appliances that feature innovative air purification technologies while highlighting reliable performance and high energy efficiency (Alavy & Siegel, 2019). Thus, the process of improving indoor air quality will be based on reactionary air purification by the device if an anomalous concentration of one of the detected contaminants is identified. With that, an Arduino Mega development board will be used to strike a precarious balance between energy consumption and the system’s processing speed (Tuyen & Hieu, 2019).

Overall, air filters and purifiers impact a home’s interior air quality. However, relying solely on HVAC systems to remove certain toxins is ineffective (Buising et al., 2021). There have been reports of health issues and concerns despite reducing PM2.5 levels indoors. As a result, the Arduino Software IDE will be used to control the gas sensors whenever the presence of criteria pollutants reaches a specified threshold. It should also perform mechanical separation and neutralization of undesired chemical components.

**Related System**

This section evaluates existing related systems that will have to be explored,serving as a benchmark in this study. These related systems are the following: Household Gas and Air Quality Safety Monitoring Device by Xue and Xue (2017), Contaminant Monitoring and Air Filtration System by Pliskin (2019), AIR-MO-FY: An Air Quality Index Monitoring and Purifying Device by Maminta (2019), Selective Gas Detection and Measurement System by Clifford (1985), and Air Treatment System by Pippel et. al. (2012). These related systems provide explanations and logical connections between previous research and the present work.

**Xue and Xue (2017), Household Gas and Air Quality Safety Monitoring Device, CN108317546**

This system, originated from China by Xue Zhenggen and Xue Dahai in 2017, mainly focuses on the innovation of monitoring device for household gases. The monitoring system can detect the household’s air quality, and then the device can optimize the air quality. The gadget may immediately alert and stop the gas solenoid valve when the gas leakage amount surpasses. The benefit of this system is to help the people in the household optimize their household’s air quality, especially when cooking. When cooking, many gases are found in the kitchen, such as carbon monoxide, carbon dioxide, nitrogen dioxide, and water vapor. Thus, this helps remove those gases found in the kitchen as it can detect the gas and automatically optimize the kitchen’s air quality.

The device includes a PM2.5 sensor, camera, wireless signal receiving device, wireless signal transmitting device includes a control module, a power supply module, a temperature monitoring module, an exhaust module, a gas alarm, and an electromagnetic gas valve, where the power supply module is connected to the control module. The temperature monitoring module is connected to the control module’s input end, the gas alarm is connected to the control module’s input end, and the control module’s output end is connected to the electromagnetic gas valve.

This device comprises indoor formaldehyde, VOC, carbon dioxide, carbon monoxide, and PM2.5 detection sensor. Also, its fresh air system control device and air purifier control device are both parts of the air optimization system control device, which are transmitted wirelessly to the system host. The system host transmits signals when the gas sensors send the detected values. Following the comparison of the gas level of the kitchen to the setpoint, the processing is carried out. When the detected value exceeds the setpoint, the system host instructs the fresh air system control device and the air purifier control device to turn on.

Despite what preceded, the system is not portable, and its materials are quite expensive. In addition, although there are several sensors included in the study, its maximum reach is not widespread, causing the scope of the research to be only in the kitchen. With that, the device can be improved by adding sensors that will not be limited to being a kitchen gas monitoring device and instead can be used in the overall scope of a household. Also, to become energy-efficient, an enhanced microcontroller can be used to save electricity as the research setting is inside the households. These observations will be utilized to make a household-friendly indoor air quality monitoring device currently proposed. In the design’s coding, the researchers will use a logical technique in which the device will foresee that the IAQ level detected is close to the critical threshold, thereby mitigating the impact of criteria pollutants before they reach the dangerous threshold. Also, for the monitoring and notification system of the device, it will incorporate a phone and personal computer applications, which is a convenient and cost-effective method to keep track of the sensor’s data.

Diagram, engineering drawing

Description automatically generated

*Figure 1. Xue and Xue (2017), Household gas and air quality safety monitoring device, CN108317546*

**Pliskin (2019), Contaminant Monitoring and Air Filtration System, US10422727B2**

Invented by Harry Leon Pliskin in 2019, this device is a contaminant monitoring and air filtration system from the United States of America. Implementations of the current disclosure specifically cover equipment for air intake, monitoring, sampling, analysis, and filtering. Since every year, he stated that around 99,000 individuals die because of healthcare-associated infections, also known as HAIs, an innovation needs to be made to prevent this. His invention is especially for those who live in communities in hospitals and other healthcare settings. The system determines and monitors the particulate concentration levels in the room; depending on the level of particulate concentration, the system will enhance the filtration based on the increased needs. The air filtration system can be converted to portable, wall-mounted, ceiling-mounted, and corner mounted.

Furthermore, the materials used in the device are the following: cabinet, power cord, speed control device, inlet arrows, exhaust vent, outlet arrows, blower, inlet filter, pre-filter, final filter, air sampling device, microprocessor, sound absorption material, indicator lights, hosted server, communication network, communication channel, and wheels and handles for the portable air filtration system. Devices and methods for communicating with a system, including air filtering units with advanced features such as connectivity and reporting, are provided. The device and its strategies can perform various operations, including reporting and remediation, based on identified values associated with the air contamination and particulate matter formed in the air.

However, this system can be improved by adding microcontroller gas-sensing sensors and more efficient air purifiers through filters that are powerful enough to clean the air in enclosed spaces and inexpensive enough that it is reasonable to have a wider spread throughout the area. With that, this will be incorporated into the current research proposed. The researchers will also use a logical technique in the design’s coding. As a result, the device will indicate that the detected IAQ level is nearly equal to the critical threshold, consequently offsetting the influence of criteria pollutants before they attain the dangerous level. In addition, a phone and personal computer application will be included in the device's monitoring and notification system, making it a suitable and cost-effective way to take control of the sensor's data.

Diagram

Description automatically generated

*Figure 2. Pliskin (2019), Contaminant Monitoring and Air Filtration System, US10422727B2*

**Maminta (2019), AIR-MO-FY: An Air Quality Index Monitoring and Purifying Device, PH12019050128A1**

Karize Ann Maminta’s (2019) device, which originated in the Philippines and was invented in 2019, is an air quality monitoring device allowing everyone to take precautionary measures to adjust to their environment. Growth and concentration of population in cities and how people consume energy in urban areas through transportation or heating and air conditioning systems, among other things, result in the emission of massive amounts of harmful gases. With that, the researcher invented a device that used an Arduino Uno microcontroller, six led bulbs, six resistors, 16 x 2 I2C LCD, MQ135 gas sensor module, single 5V relay, air revitalizer, and plastic casing, and adopted a schematic diagram that will serve as the project’s framework with an expert in the field of electronics. The wiring of the device was completed following the schematic diagram. An expert technician was in charge of overseeing all wiring jobs and used the Arduino program to create lines of code that were later uploaded to the Arduino Uno in order for the system to function. The device was tested to oversee and document various air quality readings in various locations.

Data collected at various locations were tabulated for comparison to take the necessary actions. After collecting air quality indexes for each area, the air quality can be classified as good, moderate, unsafe, very unsafe, or hazardous for human settlement. The location tested can be classified as either air polluted or safe for human habitation using this information. It asserted that the Air Quality Monitoring Device interprets the same air quality of a particular location and that AQI is higher in urban areas than in rural areas. It also led to the realization that workplaces such as rice mills, power stations, and construction sites have a greater capacity to contribute to air pollution.

Thus, the device can be improved by adding more sensors that specify which gas is prominent in the area and strengthening the information dissemination system. The current proposed study will implement these observations. Similar to the preceding related systems, the logical technique, which is not applied in this device, will be used in the design’s coding by the researchers. As a result, the device will predict that the detected IAQ level is close to the critical threshold, thus offsetting the impact of criteria pollutants before they reach the dangerous level.

Graphical user interface

Description automatically generated

*Figure 3. Maminta (2019), AIR-MO-FY: An Air Quality Index Monitoring and Purifying Device, PH12019050128A1*

**Clifford (1985), Selective Gas Detection and Measurement System, EP0161266A1**

With a country of origin from the United States of America, this system made by Paul Clifford in the year 1985 can selectively detect, measure, and identify a certain amount of carbon monoxide, hydrocarbons, hydrogen, acetone, ammonia, hydrogen sulfide, alcohol vapors, solvent vapors, and several more gases in the environment. Once the gas is determined, the processor will signal if a particular gas concentration reaches a predetermined value or when gas concentrations or combinations of gas concentrations surpass predetermined threshold values displayed on the system’s interface.

This system only has one sensor, the Taguchi Semiconductor Gas Sensor. While responsive to combustible or lessening gases at the parts per million level, this homogeneous semiconductor sensor is restricted by its response nonlinearity and absence of selectivity. In practice, a gas sensor is only helpful if it can identify the intended gas in the existence of background constituents. As a result, their main applications have been confined to smoke detection rather than gas identification or low-concentration gas detecting. The main restriction of this device is that it reacts to many reducing gases to varying degrees, so current measuring systems equipped with these sensors can only be used to determine the cumulative impact of the combustible gas components of the mixture of gases and cannot be used to differentiate one gas from another.

Regardless of its limitation, this innovation employs a homogeneous semiconductor gas sensors model that explains the causative factors of their poor selectivity, attempts to measure their response to gas combinations, and presents a comprehensive understanding of gas interactions. With that, it can still benefit the users as it can alarm a signal through the use of the gas detection system composed of the array, an approach to measuring the resistances of the array’s sensors, an electronic processing unit, and a signal interface if an identified gas is harmful to humans for them to be alert to their environment. Because this system has an alarm signal that alarms if the gas is dangerous or not, this would be useful if people wanted to know if their environment is safe.

Many leading-up sensors can be used in this invention, significantly increasing its utility. If a study’s system has multiple sensors, the gas detection will be more precise and detect a broader range of gases. The device can also be added with different filters or semipermeable membranes, incorporating its monitoring device. These observations will be assimilated to enhance further the system proposed in this study.

Diagram, engineering drawing

Description automatically generated

*Figure 4. Clifford (1985), Selective gas detection and measurement system, EP0161266A1*

**Pippel et. al. (2012), Air Treatment System, KR101209974B1**

This device by Bradley Pippel, Gregory Evans, Michael Miles, and James Dodds is an air treatment system that originated from Korea and was invented in the year 2012; where the key drivers of this innovation are improved health awareness and increased understanding of the problems connected with polluted air. Airborne pollutants, for example, can cause or contribute to a variety of respiratory issues, such as respiratory infections, asthma, and allergies. Furthermore, some pollutants transported by air might emit an unpleasant odor. Thus, consumers who want better air quality will significantly benefit from this system.

The system uses various filters and sensors to have better quality air; it filters and purifies the air supplied to human living or working spaces. The system also has a gas separation or purification device that is adapted for specific applications for cleaning the air in buildings. This device’s traditional air treatment systems are incorporated with blowers that allow air to travel through the filter elements and are available in various configurations. The blower and filter element are usually housed together, with the blower set to suction or exhaust air via the filter element. With that, the materials used in the system are the following: filter housing, front portion, a rear portion, pre-filter, particulate filter, antimicrobial filter, outlet duct, blower, electronic control system, finger guard, motor gasket, sensor airflow passage, particulate sensor, sensor plug, remote-control, remote-control holder, particulate filter frame, and filter frame.

To expand the process, when the blower is turned on, it introduces ambient air into the system via the front shield, pre-filter, particulate filter, and malodor filter. Each filter operates to eliminate particulate matter and bad smells from the air as it goes through it. Following that, air reaches the impeller’s front through the finger guard and is compressed radially outward through the impeller’s side to be pushed into the compartment of the outlet duct. At high speeds, the filtered air is pushed outward and upward through the second cutout of the outlet duct and exits the mechanism through the rear shell grille. Air flows forward of the device and then upwards apart from the system’s rear, flowing freely around the room in which it is used.

Although the device can be deemed beneficial, changes can still be made for maximum usability. This system will be improved by adding a monitoring system that helps check and maintain the criteria pollutants in enclosed spaces. Also, the system is innovated by automation using Arduino products that guarantee low-cost materials and improved energy-saving features. Lastly, since household appliances need portability to move quickly, the device will be made portable in the proposed project design.

Diagram, engineering drawing

Description automatically generated

*Figure 5. Pippel, Evans, Miles and Dodds (2012), Air Treatment System, KR101209974B1*

**Theoretical Framework**

This section discusses relevant theories for the advancement of this research. Task-Technology Fit Model by Goodhue and Thompson (1995) and Theoretical Perspectives on Adaptive Automation by Scerbo (1996) are the two conjectures selected as they are particularly relevant to the study. These fields, terminologies, and models lay the groundwork for subsequent discussions while also strengthening the logic and veracity of the claims and analysis presented in subsequent sections.

Task-Technology Fit Model by Goodhue and Thompson (1995). The Task-Technology Fit Model written by Goodhue and Thompson (1995) offers a lens to view technology adoption and its significance to the users. The model assumes that the valuation of technology is produced by the conformity, or fit, of the task requirements and its technical characteristics that enable the user to carry out the tasks in an environment where individuals use technology to perform these tasks. The analysis by Goodhue and Thompson sought to demonstrate that a beneficial impact of technology necessitates a good. As a result, when technology is tailored to the task characteristics it is intended to facilitate, it should lead to improved outcomes. Improved performance is generally the result of a smooth implementation of the project, a reduction in the cost of performing the task, or working to make the task easier to complete.

The theory contributes to the current study by presenting a behavioral model for predicting technology adoption through the proposed Indoor Air Quality filtration and monitoring system for users’ healthy lifestyles. Understanding the present air quality level in enclosed spaces can warn people to wear appropriate protective defenses and raise environmental consciousness, allowing them to take the initiative to regulate air pollution. With that, in order to ensure a positive impact on individuals’ health performance, researchers must posit that the innovation concocted must be a good fit with the task (or have a correspondence between its functionality and the task requirements). Keeping in mind the methodology formed by the researchers and their proper knowledge in programming, their innovation will benefit their target beneficiaries.

Theoretical Perspectives on Adaptive Automation by Scerbo (1996). The Theoretical Perspectives on Adaptive Automation authored by Scerbo (1996) states that human-computer systems wherein the “division of labor” or the interface among both human and machine intermediaries is not fixed but rather dynamic. In this theory, function allocation serves as a design decision that determines which processes are to be executed by humans and by machinery to obtain the necessary system goals, and it is tightly linked to the issue of automation. Based on the theory, it is not advisable to automate as many tasks as possible to develop an efficient and adaptable human-machine system. Although machine performance in some areas is exceptional, hardware and software are not always reliable. As a result, the human is frequently assigned the supervisor’s role, with the power to influence when automation fails. Humans are thought to learn faster and outperform machines when performing tasks in a novel or unexpected situations, such as intervening when machines fail to function as intended. The anticipated benefit of adaptive automation is that humans and machines can work together, when necessary, taken in and out of the loop. The effectiveness of the human-machine system is assured by dynamically allocating work to humans or machines, regardless of disturbances in the capabilities of its components or change of environment demands.

This theory, in turn, has important implications in the development of the study. Indoor Air Quality filtering and monitoring involves cleaning particulate matter and other criteria pollutants in the atmosphere, which will run the whole day. With that, machines alone cannot work correctly if left uncalibrated or unchecked. All mechanical components and sensors will show signs of wear over time. Thus, calibration is essential to ensure that the sensor performs as well as it did on day one. Aiming to improve human health, the users and the machine have the same purpose of ensuring the quality of life for people living in the household. Overall, the theory supports the idea that choices about the onset, interruption, and type of mechanization in adaptive systems are shared by the human operator and machine intelligence for a common intention.

These theories claims that for innovation to succeed, it must be well-suited to the job at hand. Researchers suggest an Indoor Air Quality filtering device for consumers’ healthy lifestyles in this instance. Filtering and monitoring indoor air quality include removing particles and other criteria pollutants from the environment throughout the day. Over time, all mechanical components and sensors will exhibit indications of wear. If machines are left uncalibrated or uncontrolled, they will not function properly. With that, coordination of the users and the device is needed in order to achieve the objectives needed to obtain.

**Conceptual Framework**

This project follows the flow of the Input-Process-Output (IPO) model as its conceptual framework. In general, three requirements need to be met in the input: knowledge, software, and hardware requirements. Upon meeting these prerequisites, the developers will then conduct the study. In the process, a series of tasks are designated for the project to flow seamlessly and for the timeline to remain organized. After accomplishing the procedure, a successfully tested model of TECHNOVAIR is presumed to exist by the end of the study.

**INPUT**

**Knowledge Requirement**

1. Analysis on existing air filtration systems
2. Target users and their expectations
3. Crash course on Basic Programming/Robotics

**Software Requirement**

1. Arduino Integrated Development Environment (IDE)
2. Processing Software Integrated Development Environment (IDE)
3. MIT App Inventor
4. Office Word
5. Office Excel

**Hardware Requirement**

1. Laptop

Minimum requirements:

* CPU: 9th Gen Intel Core i5
* Display: 13.3-inch FHD
* RAM: 8GB
* Storage: 256GB SSD
* GPU: Integrated Intel UHD 620
* Battery: Up to 5 hours

1. Sensors

* PMS5003 fine particulate matter (PM) Air Quality Sensor
* MQ131 Gas Ozone Detection Sensor
* SGP30 Multi-Pixel Gas Sensor

1. Air Filters

* Pre-filter
* High-Efficiency Particulate Air (HEPA) Filter
* Activated Carbon Filter

**PROCESS**

1. Initial Planning

* Brainstorming
* Initial Investigation of the study

1. Planning

* Going through existing projects and determining their gaps
* Developing feasible solutions to the existing projects

1. Requirements

* Finalization of the project’s objectives
* Noting the hardware and software requirements

1. Analysis & Design

* Testing sketches
* Designing the prototype
* Other documentations

1. Implementation
2. Testing
3. Evaluation

* Observation of the device
* Correction of errors

1. Deployment

**OUTPUT**

*TECHNOVAIR:* Arduino-based Automated Air Filtration, Indoor Air Quality Monitoring, and Notification System

*Figure 6. Input-Process-Output (IPO) Conceptual Framework for TECHNOVAIR: Arduino-based Automated Air Filtration, Indoor Air Quality Monitoring, and Notification System*

Before the developers commit to the project, they must consider the following requirements under input. They should gather initial data about the topic of interest to develop an overview of the project. Hence, it is necessary to have knowledge of the indoor air filtration systems, the product’s target users, and their expectations. In addition, a crash course in basic programming is crucial in creating the desired device as it involves formulating codes that will allow it to effectively perform its functions. Apart from this, three software must be installed in the developers’ laptops, including the Arduino Integrated Development Environment (IDE), Office Word, and Office Excel. Lastly, the hardware requirements will contain the minimum laptop specifications so that the developers may experience little to no inconvenience while constructing the system. Sensors and filters that will be incorporated into the system are also included. When these requirements are met, the developers will advance to the process of designing TECHNOVAIR.

The procedure will begin by investigating the selected system and collating ideas within the group. The developers will also explore existing projects, determine their gaps, and identify solutions for their innovation. This will be followed by developing the project’s objectives and specifying requirements. Running multiple codes, designing the device’s blueprint, and documenting the entire process will fall under the next task. Afterward, the device will be constructed and then undergo trials to be evaluated. The developers will rectify its errors and take more run-throughs before deployment. Once found to be as close to the envisioned project, the product will then be the developers’ output, the official prototype of TECHNOVAIR.

**Operational Definition of Terms**

This section contains definitions of unfamiliar terms that appear and are mentioned in the research paper relevant to the study.

Air Quality Monitor – a device that measures and monitors the level of common air contaminants of indoor air and is used to oppose its serious concern on the research locale of the study

Criteria Pollutants – air pollutants for which tolerable exposure limits can be calculated, and an ambient air quality standard has been established. These include particulate matter, ozone concentration, VOCs, and their equivalent carbon dioxide

Equivalent Carbon Dioxide (eCO2) – a method of comparing greenhouse emissions based on their global warming potential (GWP) by converting amounts of other gases to comparable concentrations of carbon dioxide with the same GWP.

Indoor Air Quality (IAQ) - air quality found within the household.

Micrograms per Cubic Meter (μg/m3) – is the unit used to measure the air's particulate matter or dust density.

Ozone (O3) – a colorless hazardous, poisonous gas that is one of the criteria pollutants that the air quality monitoring device will detect.

Particulate Matter (PM) - refers to the tiny particles found in the air that is one of the criteria pollutants that the air quality monitoring device will detect.

Parts per million (ppm) - a unit of measurement used to measure volatile organic compounds (VOCs) and ozone concentration.

Sensor - a device that detects the amount of air pollutants indoors and records, indicates or responds through cellular phone and computer applications.

Volatile Organic Compounds (VOCs) - are any carbon compounds that participate in atmospheric photochemical reactions that will be totaled by the sensor and are one of the criteria pollutants that the air quality monitoring device will detect.

**CHAPTER 3**

**METHODOLOGY**

This chapter will primarily discuss the project’s methodology. It will comprise the research design and process model implemented in the study and the chosen setting for the research locale. The respondents will also be specified, along with their selection criteria and the sampling method that will be utilized in the selection process. In addition, the developers will also expound on the research assessment tool, system development tools, and the data collection procedure. Finally, the developers take the study’s trustworthiness and the ethical considerations into account in determining the project’s outcome.

**Research Design and Process Model**

As the study aims to design a device that will be implemented in live environments, it will be best performed by applying qualitative research design. It is a subjective approach, focusing on producing an in-depth understanding of events and looking for unique insights rather than numerical evidence, hence using words as data (“Qualitative Study Design,” 2013). Moreover, as it is interpretive and naturalistic, the developers do not have to alter the environment because they may study their product in its natural setting (“Qualitative Research,” 2019). They can perform direct observations of the product during trials and conduct focus group discussions with industry experts to inquire about their own observations and feelings toward the device (Busetto et al., 2020). This can further improve the product because the respondents may provide meaningful ideas and solutions to troubleshoot the device’s errors. Therefore, this approach is highly suited to the study as it can prevent costly project errors in the future (“What is Qualitative Design?,” 2012).

In addition, the developers will be implementing the Iterative Process model as its Software Development Life Cycle (SDLC) Process model. This approach provides the developers an opportunity to test the device and gain feedback from their respondents to improve its function by repeating the process. As stated by Martins (2021), it is a trial-and-error methodology as it allows the developers to refine their product until it has met all the project’s objectives. Hence, the product may initially be constructed with flaws until it is gradually shaped into the developers’ intended prototype (Eby, 2019). The process will mainly involve eight (8) phases: Initial Planning, Planning, Requirements, Analysis and Design, Implementation, Testing, Evaluation, and Deployment.

*Initial Planning.* The process begins with the brainstorming of the developers and the selection of a topic of interest. Once they have chosen a topic, they will be performing initial investigations regarding its background.

*Planning.* During this phase, the developers will be diving deeper into the topic, exploring various existing projects, determining their gaps, and considering this for their prototype.

*Requirements.* The developers will construct the project’s objectives and identify the hardware and software requirements necessary to build the product.

*Analysis & Design.* Once the objectives have been finalized, the developers will proceed to create a plan for the prototype. Here, they will incorporate necessary codes and design its software and hardware. In addition, they will be consulting industry experts to ensure that the design can effectively pursue the device’s intended functions.

*Implementation.* After creating a blueprint, the developers will begin to construct the said prototype. The individual requirements will be combined to generate the idealized concept design.

*Testing.* The product will undergo testing to ensure that the system is running as planned. The developers will do this with the industry experts to help them identify the bugs and errors of the prototype.

*Evaluation.* In this phase, the developers will be having a Focus Group Discussion (FGD) with the industry experts to point out the malfunctions they have assessed during the testing phase. Once they conclude that there is a need for improvement, the process will return to the first phase to tweak the device or troubleshoot the errors.

*Deployment.* Once all trials are done and both the developers and industry experts are satisfied with the results, the device will be endorsed as TECHNOVAIR in a live environment.

Diagram

Description automatically generated*Figure 7. The Iterative Process Model*

**Research Locale**

The developers will conduct this study in a house located in Astana Subdivision in Matina Pangi, Davao City, Davao Region. Davao City is the administrative capital of the Davao Region and is Mindanao’s most populated city and the Philippines’ third largest. It is known for its dynamic economic growth, urban development, and modern facilities and is one of the island’s most important economies and the Philippines’ third most crucial metropolitan hub (Infrastructure Modernization for Davao City 2045, n.d.)*.* Because the researchers and the targeted respondents are currently situated in this city, the developers have purposefully selected this location for its efficiency and advantages in obtaining the data. It is also evident that the citizens who stay mainly at home would greatly benefit from this project because of the new setup society has today in both work and education. Thus, the researchers decided to choose the subdivision indicated above, and the device will be tested inside the bedroom of the house. With this, it creates awareness regarding the Indoor Air Quality (IAQ) pollution that directly affects people, especially the household members, allowing everyone to intervene in the environmental phenomena. Due to the circumstances that the pandemic has pushed everyone into, the study will be conducted online.

**Research Respondents**

The respondents of this project are the different industry experts who are skilled and knowledgeable regarding the research design development and the device in general. Mainly, the sample size would be a total of four respondents who will answer the open-ended questionnaire provided by the developers to guide them in troubleshooting the device. The researchers will make use of the purposive sampling method as this involves finding and choosing individuals or groups of persons who are particularly educated or experienced about a topic of interest (Cresswell & Clark, 2017). The purposive sampling method may prove to be effective when only limited numbers of people can serve as primary data sources. It is one of the most cost-effective and time-effective sampling methods available.

The research capstone respondents are selected through the following   
 criteria:

1. Air Quality Control Specialist: Must be a resident of Davao City who is a professional that is trained to conduct research, inspections, and investigations on levels of air pollution, as well as to take the required procedures to ensure adequate air quality to address public health problems. Also, he or she should voluntarily participate in the research capstone project.
2. Software Developer: Must be a resident of Davao City who is a professional with the technical ability to construct programs or supervise the researchers’ device. Through testing and maintenance, they can keep track of the quality and performance of the invention. Also, he or she should voluntarily participate in the research capstone project.
3. Mechanical Engineer: Must be a resident of Davao City who is a professional trained to guarantee that all mechanical systems of the device operate safely and effectively to meet users’ needs. Also, he or she should voluntarily participate in the research capstone project.
4. Electrical Engineer: Must be a resident of Davao City who is a professional responsible for carrying out risk evaluations and ensuring adherence to safety standards and electrical engineering codes. Also, he or she should voluntarily participate in the research capstone project.

**Research Assessment Tool**

This study will utilize a self-made research questionnaire based on the FURPS software product quality model. FURPS, a Hewlett-Packard quality model, was released in 1995. It is also referred to as a quality characteristics table (Vern & Dubey, 2013). The FURPS model used in this study will be developed based on its Flexibility, Usability, Reliability, Performance, Scalability, or Supporting capabilities. The overall items for each component will be converted into a 22-item, open-ended questionnaire (attached as Appendix A). The respondents in this study will be asked to answer the questions through FGD to ensure that the device is ready for deployment to the end-users. To guarantee that the researchers are posing questions that assess the non-functional and functional requirements of the product, the questionnaire will be validated.

**System Development Tools**

In this research, the Arduino Mega 2560 microcontroller board will serve as the central data processing element for all sensors and displays in the device. The sensors that continuously monitor the air environment will provide the input and transmit electronic signals to the Arduino Mega 2560 Microcontroller through data-transmitting electronic cables. The microcontroller will subsequently process the data collected by the sensors. The result will then be shown on the LCD, phone, and computer applications. If the device detects the air quality near the critical threshold based on the logical technique applied in the design’s coding, the device will notify the owner through the applications to start the filtration process.

|  |  |  |
| --- | --- | --- |
| Development Tool | Description | Function |
| Arduino Integrated Development Environment (IDE) | Arduino IDE is the software for the Arduino microcontroller. It’s used to write code, compile it to see if there are any issues, then upload the code to the Arduino. It is compatible with the C/C++ programming languages. | The main text editing program used for the device programming which connects to the Arduino hardware to upload programs and communicate with them. |
| Processing Integrated Development Environment (IDE) | An open-source programming language for making images, animations, and interactive experiences. It is based on Java, and all of the code is precompiled and converted straight into Java code. | It is used mainly for building proof-of-concepts for visualisations of the system. It enables the users to have a monitoring and notification system through a personal computer application. |
| MIT App Inventor | Using a web browser and either a connected phone or an emulator, App Inventor allows users to create Android/IOS apps. The App Inventor servers keep a record of users’ projects and store their work. | A starter program used for phone application building in order to keep track of sensor data and used for notification in case the indoor air quality reaches near the critical threshold. |
| Arduino Mega 2560 Microcontroller | This is a microcontroller based on the ATmega2560 capable of computing and programming through languages such as C/C++. It comes with everything the researchers need to start the design by plugging it into a computer with a USB cable or powering it with an AC-to-DC adapter or battery. | It will perform general functions serving as the device’s brain that performs the code, engaging with modules such as the sensors, relay, and other inputs and outputs. |
| Relay Module | A relay module is a programmed electrical switch that Arduino can control. It is used to programmatically regulate the on/off of high voltage and high current devices. | It will be used to turn on/off the filtration system of the device before reaching the critical threshold. |
| PMS5003 sensor | The PMS5003 is a laser dust sensor that measures the value of dust particles suspended in the air using the laser light scattering technique. | It will be utilized as the particulate matter concentration sensor to determine the quality and quantity of dispersed particulate matter in the air in terms of unit volume and a digital interface in the form of output. |
| MQ131 Gas Ozone Detection Sensor | This sensor, which has high sensitivity and a very fast response time, can determine the ozone concentration (10～1000ppb) in ambient air. Tin dioxide (SnO2) is the sensor’s sensitive material, and it has a low conductivity when the air is clean, but it increases in the presence of ozone. | It will be used as the ozone detection sensor to determine the quality and quantity of dispersed ozone in the air in terms of unit volume and a digital interface in the form of output. |
| SGP30 Multi-Pixel Gas Sensor | This is a gas sensor designed for indoor air quality monitoring that can detect a wide variety of Volatile Organic Compounds (VOCs) and H2. When connected to the microcontroller, it will provide a Total Volatile Organic Compound (TVOC) reading as well as an equivalent carbon dioxide reading (eCO2) over I2C. | It will be used as the VOCs detection sensor to determine the quality and quantity of dispersed VOCs in the air in terms of unit volume and a digital interface in the form of output. |
| Pre-filter | A pre-filter is a type of air filter that eliminates big particles from the air, such as dust, dirt, and hair. Pre-filters are the initial step in an air purifier’s air filtration process. | A pre-filter will keep the primary air filters from becoming clogged with debris, allowing them to collect microscopic contaminants. Because HEPA filters have no trouble absorbing these massive particles, the pre-filter will not affect the purifier’s performance. Instead, the notion is that it will lengthen one’s life. The advantage of pre-filters over HEPA filters is that they may be washed and cleaned regularly. |
| High-Efficiency Particulate Air (HEPA) filter | HEPA filter is a kind of air filter that can theoretically remove 99.97% of dust, pollen, mold, germs, and any other particles larger than 0.3 microns (m). | HEPA filters will be designed to trap microscopic particles successfully, but they do not filter out gasses or odor molecules. This will be used in conjunction with the pre-filter to extend its lifespan. |
| Activated Carbon filter | Activated carbon filters are used in air purifiers to collect volatile organic compounds, which are the chemicals that cause odors and are also known to be critical indoor air pollutants. On the other hand, activated carbons aren’t employed to filter particulates. | The Activated Carbon filter will work in tandem with the HEPA filter to collect other microscopic particles such as dust, lint, mold spores, pet dander, and pollen. Beyond the particulate filtration given by HEPA filters, an activated carbon filter adds an additional layer of filtration. |
| 16x2 Liquid Crystal Display (LCD) | LCDs are widely used in many electronic applications because they are ideal for presenting simple information, such as sensor data, while inexpensive. | This will be used to project real-time pollutant levels to inform the users of indoor air quality in their households. |

*Table 1. System Development Tools*

The entire system is powered by a combination of codes for each sensor and the LCD. It combines the fundamental Arduino, Javascript and C++ Programming methods with additional sensor-specific functionalities. The code begins with sensor and display initialization and then runs continuously throughout the test, projecting data from the sensors to the LCD, phone, and personal computer application, which is refreshed every two (2) seconds and loops throughout the test duration.

**Data Collection Procedure**

The developers will use a self-made research questionnaire using the FURPS software product quality model to help gather information for convenience, not only for the researchers but also for the respondents. The air filtration system will be used in various rooms with different levels of particulate matter, ozone gas concentrations, VOCs, and equivalent carbon dioxide, and it should be able to notify the user of the about it. The developers will gather data using an online assessment tool following the alpha testing. Because the respondents of the beta testing have a degree and are of consenting age, the developers will obtain informed consent from them, indicating that they are a part of the analysis and are able to understand the purpose of their participation. The developers will then send links for the beta testing questionnaire. In addition, the developers will submit a letter of approval and permission to the principal and the school's guidance counselor to obtain authority to continue the report and assessment. Furthermore, the data gathered during the beta testing by the industry experts will be discussed with the researchers, and the data will be handled securely and confidentially.

*Phase 1: Development Stage*

Once the assessment tool has been finalized, the alpha and beta testing will start. The developers will gather the initial data as well as issues and bugs during the alpha testing process. Afterwards, the device will be tested by the industry experts to gather data and issues to be fixed during the beta testing stage. Additionally, all the data gathered during both testing processes will remain confidential, and the industry experts will be informed regarding their involvement in the project and the testing process. To make sure that the device is ready for the second phase, the focus group discussion will be initialized for the deliberation of the problems identified during the first testing.

*Phase 2: Re-development Stage*

After the first beta testing process, the developers will fix the issues, bugs, and concerns discussed by the industry experts. The discussion during the previous stage will be helpful and will be used to improve the device’s quality and functionality once it is ready for the market. Once the device is redeveloped, it will be tested once again by the respondents and another discussion will follow. Moreover, this process will be repeated as needed until the respondents are satisfied with the device.

**Trustworthiness of the Study**

*Credibility.* To enhance the credibility of this research, researchers ensured that rigor was maintained throughout the data collection process, particularly during the surveys, where researchers avoided making conclusions from the surveys and instead relied solely on factual data obtained directly from the respondents. This is supported by Suter (2012), who states that credibility refers to the confidence in the believability of the findings, which is enhanced by evidence such as confirming evaluation of conclusions by research respondents.

*Transferability.* Researchers detailed the research context and essential assumptions to address transferability and displayed all data transparently as feasible. Readers can make judgments about transferability based on the rich and detailed descriptions. The reader may transfer information from this article to different situations and assess whether the findings can be transmitted.

*Confirmability.* To avoid data distortion, researchers left aside personal beliefs, assumptions, and judgments to address the confirmability of the study. To verify all of the given data, the researchers will present it to the respondents to evaluate and verify all of the statements they have made to support the research. Respondents will also scrutinize it before confirming that it is fit for publication. If participants wish to exclude, redact, or alter their statements, their requests will be considered, and researchers must conform.

*Dependability.* A third-party evaluator will be brought in to evaluate the research assessment tool developed to guarantee the data’s dependability. The evaluator will scrutinize the questions and ensure that they will produce results that are consistent and unvarying, as well as results that will be beneficial in the research study. They will evaluate the questions and suggest adjustments to enhance the questions that will be used and any required proofreading.

**Ethical Consideration**

As addressed in the consent form, the developers will always secure the individual’s right to privacy and guarantee their safety. While maintaining identity and confidentiality, it will be thoroughly vetted. The data collected from the questionnaire will not be disclosed to others, and nothing will be intrinsically linked with the tester’s name. They have the right to alter their minds and withdraw from the study if they do not want to be a part of it. This ensures that the researchers and respondents avoid accidents and unnecessary delays to the research. The researchers will manage the respondents honestly and fairly and stick and follow their principles as a researcher. When addressing people at the societal level, the developers will consider all data ethics, specifically transparency, justice, privacy, confidentiality, and safety.

*Transparency*. The researchers will not withhold any information related to the research and will relay it to the respondents and update the respondents regarding the progress of the research and its usability. Transparency embodies truthfulness and open communication. The researchers will not force their respondents to participate in the research if they are unwilling and will respect the respondents’ decision and will not use force, blackmail, or any underhanded methods to achieve the desired results. When aggravating, developers should be ready or inclined to withhold information. Furthermore, transparency also pertains to the developers being objective and trustworthy about their behavior, including consistent with their principles.

*Justice*. The researchers will comply with the benefits and terms that have been agreed upon between the researchers and the respondents. The concept of justice refers to the ethical imperative to fairly distribute the benefits and drawbacks of research. Developers must not exploit the weak and vulnerable or exclude some who stand to benefit from project testers for humanitarian purposes.

*Informed Consent*. Implied consent is one of the ethical principles’ core concepts. According to the developers, respondents should join the study willingly (voluntarily) after getting complete instructions about what it entails and giving their approval before doing so. As a result, people are given the freedom to choose and answer questions at their leisure and supply information via Google forms.

*Social Value.* This capstone project takes extensive precautions to ensure that the testers’ experiences are entirely safe. Because no direct benefits are expected from the respondents, the benefit aspect of the risk analysis is presented.

*Privacy and Confidentiality*. Research respondents’ privacy and confidentiality state that an individual participating in human subject research has privacy rights. Many survey participants are upset because their privacy was violated due to their participation in research. It results in a situation in which a researcher is aware of the identity of a research tester but takes action to prevent the identity from being revealed to others. Topic confidentiality is not as standard in human subject research as in other fields because most human research requires signed documentation of consent. The researchers will not use any information acquired regarding its respondents without their approval, as it is part of their principles as a researcher.

*Risk, Benefits, and Safety*. The safety of testers is fully considered during project design and ethical review. The researchers oversee assessing potential risks and estimating the likelihood of the risk occurring. As a result, they will ensure the safety and benefits of the testers as the project is improved.

*Qualification of the Developers.* The developers will ensure that the capstone project will be subjected to consideration, suggestions, consultations, and a thorough justification of the content by capstone research examiners. As a result, the developers will provide the required approval sheets and documents as proof that the capstone project is being carried out at Malayan Colleges Mindanao.

*Adequacy of Facilities.* Data collection will begin once the researcher obtains a document from the Department of Education and obtains permission from the testers’ parents to collect information using Google Forms. Because the data will be collected online, the developers will keep the information between the testers and the developers to a minimum.

*Community Involvement*. This capstone project ensures that no indigenous customs, history, or people are disrespected or jeopardized. The report, on the other hand, will be made available for academic purposes as well as for the benefit of society. This research will be presented at conferences on education and migrant workers, with a focus on Science and Technology.

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**APPENDICES**

**APPENDIX A**

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| ***TECHNOVAIR*: ARDUINO-BASED AUTOMATED AIR FILTRATION, INDOOR AIR QUALITY MONITORING, AND NOTIFICATION SYSTEM** |
| **Questionnaire**    Name of the Respondent: **­­­­­­­­­­­­­­­­­**\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ |
| **Functionality** |
| Does the device can monitor the criteria pollutant’s level? |
| Does the device can start the filtration process before reaching the critical threshold? |
| Does the device can project criteria pollutant’s data on the LCD screen? |
| Does the device can send SMS to notify the start of the filtration process? |
| **Usability** |
| Is the device easy to operate, control and appropriate to use? |
| Is there consistent responsiveness of the device? |
| Is the device beneficial to ordinary people? |
| Is the device’s user interface pleasing appealing to the market? |
| **Reliability** |
| Does the device meet the needs for reliability under normal operation? |
| Is the device operational and accessible when required for use? |
| Does the device operate as intended despite hardware or software faults? |
| Can the device recover data directly affected and re-establish the system's desired state? |
| Does the device have the ability to recover wholly from failure? |
| **Performance** |
| Is there a fast response of the GSM to notify the filtration process? |
| Is there a fast-processing time of the device during the monitoring? |
| Does the device have the ability to start the filtration system before reaching the critical threshold quickly? |
| Can the device stop the filtration system immediately after detecting the criteria pollutant’s normal level? |
| **Supportability** |
| Can the device effectively and efficiently be adapted for different or evolving hardware, software, or other operation or usage environments? |
| Can the device be successfully installed and uninstalled in a specified environment? |
| Can the device replace a specified software product for the same purpose in the same environment? |
| Can the device be effective and efficiently modified without introducing defects or degrading existing product quality? |
| Can the device perform required functions efficiently while sharing a typical environment and resources with other products? |