Health Informatics Solution to Indoor Air Pollution: An Opportunity for Epidemiological Research

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Health Informatics Solution to Indoor Air Pollution: An Opportunity for Epidemiological Research

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HEALTH INFORMATICS SOLUTION TO INDOOR AIR POLLUTION

Abstract

Indoor air pollution accounts for the particulate matters and chemical compounds from outdoor sources that penetrate into the home environment. It also contains chemical particles from cleaning products, wall paints, personal care products, indoor combustion, and microbial agents. Mounting evidence links sources from indoor air pollution to sick building syndrome (SBS). SBS decreases human productivity, impacts learning abilities, and has the potential to trigger existing asthmatic symptoms, cause dizziness, nausea, fatigue, irritation to the lungs, etc. To improve the management of IAQ among population health and for environmental health to keep up with its technological counterpart, it is crucial to increase awareness around this subject and to provide innovative means of collecting IAQ data. Therefore, this Capstone paper encapsulates a project spearheaded by the American Lung Association in Washington which is composed of an IAQ mobile gaming application with two components paramount to its functionality: a real-time air sensing device to collect data, and a health mobile application that enables data visualization. To explore the future of IAQ monitoring system, this paper focuses more heavily on the health informatics perspective of the sensing (or monitoring) device and its health mobile application. It also aims to examine potential research opportunities that would facilitate IAQ improvements and policy regulation around air pollution.

Keywords: Indoor air pollution, indoor air quality, home monitoring device, American Lung Association, asthma, health informatics, mobile health, geographic information system, patient portal
Health Informatics Solution to Indoor Air Pollution: An Opportunity for Epidemiological Research

**Introduction**

Indoor air quality (IAQ) is a growing concern in both developed and developing countries. While there is an extensive set of literature linking the adverse effects of outdoor ambient pollution and cardiopulmonary diseases, less is known about the impact of indoor air pollution (IAP) on morbidity and mortality (Breysse et al., 2010). IAQ depends on the quality of the atmospheric air that penetrates from the outdoors and on the presence of IAP sources; hence, the indoor environment consists of a complex mixture of agents which varies in intensity and potential health effects (Breysse et al., 2010). IAQ also differs across geographic area, seasonal change, cultural backgrounds, and socioeconomic status (Breysse et al., 2010).

In developing nations, poor IAQ is widely attributed to solid fuel combustion for household cooking, heating, and lighting where proper cooking stoves and ventilations are lacking. However, in the modern metropolises of developed nations, IAQ is significantly affected by outdoor environments (such as particulate matter from nearby construction sites, industrial plants, and roads), anthropogenic sources (such as wooden construction materials, oil based paints, fragrant decorations, and indoor plants), consumer products, and radioactive byproducts (such as radon) (Leung, 2016). In 2016, The World Health Organization (WHO) linked over four million premature deaths attributable to exposure to IAP. Nearly 90% of these premature deaths from exposure to IAP are from noncommunicable diseases including stroke, ischemic heart disease, chronic obstructive pulmonary disease (COPD), and lung cancer (WHO, 2016). In the most recent Global Burden of Disease study, household air pollution is the eighth risk factor for the global disability-adjusted life year (DALY) (GBD Compare, 2016).
Maintaining good IAQ is important for overall well-being and productivity of home occupants. The American Lung Association in Washington has a rich history of improving the air we breathe and is dedicated to providing continuous services to protect lung health for its fellow Americans. As elusive as it remains, it is a public health issue that needs to be addressed and remediated. Thus, it is crucial to shed some light into the ambiguity of IAQ by diving into innovative solutions to combat this issue.

This paper aims to explore the future outlook of The American Lung Association in Washington’s project in IAQ mitigation with the integration of:

- Smart home air quality monitoring devices for real-time IAQ assessment that utilizes cloud-based applications to collect data for meaningful use.
- Mobile health (mHealth) to raise awareness, guide, and inform users about IAQ to allow them to make better decisions in their daily lives.
- Mobile game (gamification) to enrich user’s knowledge on IAQ and to motivate positive behavioral change.

Secondly, this paper aims to explore future epidemiological research opportunities derived from this innovative project. Possibilities include:

- The addition of IAQ indicators to patient portal systems in healthcare facilities to enable clinicians to track patients progress in disease management; and to provide epidemiologists with a wider recruitment base to study IAP determinants to health.
- The utilization of indoor air monitoring devices and mobile applications improve IAQ data collection for geospatial analysis at a granular level.
Background

HomeAir Matters is an IAQ project at its primary stages by the American Lung Association in Washington. The goals of this project are to increase awareness of the importance of healthy indoor air quality, to facilitate behavioral change by educating people about IAQ, and to decrease environmental exposure/triggers for people with asthma or other related allergic reactions. Ultimately, these would lead to the enhanced usage of telemedicine to treat pulmonary exacerbations and other adverse health outcomes associated with poor IAQ and to increase data collection and spatial analysis around indoor air quality to aid health interventions and policy-making decisions.

Indoor air pollutants consist of volatile organic compounds (VOCs) such as nitrogen oxides (NO\textsubscript{x}), sulfur dioxide (SO\textsubscript{2}), ozone (O\textsubscript{3}), carbon monoxide (CO), particulate matter (PM) of different size range, radon, and microorganisms (Leung, 2015). Effects of these pollutants on humans are dependent on their toxicity, concentration, exposure time, and may vary from person to person. The most common effect is called sick building syndrome (SBS), in which people experience uncomfortable or acute health effects such as irritation of nose, throat, eyes, skin diseases, allergies, and so on (Leung, 2015). Strong epidemiological and molecular evidence suggests that exposure to toxic and carcinogenic indoor pollutants may lead to acute and chronic cardiopulmonary conditions, adverse pregnancy outcomes, cancers, etc. Maladies due to poor IAQ can be easily circumnavigated by awareness of the risks, proper ventilation, and risk mediation efforts.

Although conventional monitoring devices used to collect data for outdoor pollution can be used to measure VOCs and PM accurately, they are not practical for indoor use because they are generally incapable of addressing temporal and spatial heterogeneity of indoor air pollution,
and are bulky, noisy, expensive to install, and collect excessive data (Kumar et al., 2016). Unlike outdoor air pollution, there is a massive data gap for IAP. This lack of data availability prevents researchers to fully assess the impact of indoor air to health which in turn hinders public health professionals to provide evidence-based intervention.

Recent advances in air sensor technologies have led to the emergence of a number of hi-tech air sensing devices (Kumar et al., 2015; Snyder et al., 2013), capable of measuring a range of common indoor air pollutants and would provide a more robust data on IAQ. These devices are becoming compact, light-weight and inexpensive (up to US$500) (Holstius et al., 2014). A lot of these devices also have the capability to send real time IAQ updates to its accompanying smart phone application.

mHealth is an emerging area that has the potential to change the delivery of health care. Smartphones have the ability to provide unobtrusive continuous monitoring (Lo Re et al. 2013). Smartphone applications enable users to make instant adjustments and changes to maintain healthy IAQ. This feature is also beneficial for people who often experience respiratory problems such as asthma, COPD, and severe allergic reaction to synthetic chemicals. The real-time tracking system coupled with the mobile application provides users with an interface to observe and ascertain pollutants that trigger their physiological response. Hospitals utilizing patient portals would be able to link these personal health records (PHRs) to electronic health records (EHRs) providing another paradigm in the meaning use (MU) model in health informatics. Patient portals, for example, would allow researchers to study asthma rates attributable to social determinants of health.
The use of indoor air monitoring devices and patient portals would provide improvements in the IAQ data gathering for epidemiological research. For example, PM found indoors includes particles that originate from indoor sources such as the burning of candles, use of the fireplace, etc. However, indoor PM will also contain particles of outdoor origin that migrate indoors and in homes without smoking or other strong particle sources; indoor PM would be expected to be the same as, or lower than, outdoor levels. Researchers could compare indoor PM versus outdoor PM using GIS such as kriging methods since quantifying a variety of IAQ on a county level can be tricky, and no household air quality is similar.

**System Design Characteristics and Population Health Management**

The first system design layer of this plan involves a smart home air quality monitoring device (Figure a) that utilizes cloud-based applications to collect real-time data for meaningful use. This device measures indoor chemical compounds such as PM$_{2.5}$, VOCs, carbon dioxide (CO$_2$), and the overall home condition which includes temperature and humidity (Figures b, c, d, and e). It is portable, operates on battery, low-cost, takes accurate measurements, uses GPS tracking, utilizes electrochemical sensors, and is linked to smartphones. For easy indication on IAQ status, the device uses blue to signal good air quality and orange for bad air quality (Figures f and g). The color indication based on the quality of air will allow users to be more aware of their environment, trigger behavioral change, and pinpoint allergic triggers.

The monitoring device collects data to be uploaded into a cloud-based application every five seconds to allow real-time tracking of IAQ. Data collected in cloud storage uploads to an application programming interface (API) that sends out IAQ trends to a mobile application that provides detailed information regarding IAQ (Figures h, k, and l) and educates users about the
detected pollutants (Figures i and j). Another way of retrieving data for meaningful use is through a wireless sensor network (WSN). It has been proven that WSNs improve user accessibility by increasing compatibility between the system and other equipment, collecting real-time data to assess the need for an increase or a decrease in monitoring, and heightening data accuracy and reliability (Yu et al., 2013).

Standards on pollutant detection on both monitoring device and the mobile application such as the Air Quality Index (AQI), PM$_{2.5}$, and VOCs adhere to recommendations made by WHO and the Environmental Protection Agency (EPA).

The introduction of mHealth is the second and crucial layer to this design. This project enables the capability of linking monitoring devices to its corresponding mobile application. Upon setting up the mobile application, questions will be asked regarding the house’s indoor environment to build users’ home profile (Figure m). For instance, users check “yes” or “no” to questions such as “Do you have a stove fan?”, “Do you suspect mold in your home,” and “Do you have an air purifier?” (Figure n). Based on the first assessment, the mobile application will then craft a list of tasks for the users such as installing ventilation systems, removing dust and dust mites, sealing any wall openings (Figure o).

Once it is ready to be used simultaneously with the monitoring device, either the API or the WSN can be used to retrieve data from cloud services. This mobile application serves as a virtual IAQ assessment where recommendations are tailored to meet specific air standards based on IAQ trends and alert users about potential risks. Users are encouraged to check-off completed recommended actions. Therefore, notification service is an integral part of this application, it will inform users about the change in IAQ level and recommends users enter activities associated with it (Figure p). Users are also able to craft their pollution prevention routine (Figure q). The
routine ranges from using products that are highly rated by the Environmental Working Group (EWG) to lessen the exposure to products that contain harmful chemicals to washing couch covers every month to prevent the accumulation of dust mites and dust. The app also educates users about the need for recommended activities such as the importance of ventilating the kitchen and bathroom space (Figure r). This consumer health informatics feature gives users helpful feedback, encourages healthy behavioral change, raises awareness, and supports users’ involvement with healthcare.

In a clinical setting, a desktop version of the mobile application is designed specifically for clinicians to monitor and evaluate IAQ trends of their patients. This would aid clinicians to associate any allergic reactions, asthma attack, and other pulmonary exacerbation to IAQ. This feature could increase treatment efficacy by helping patients receive advice and feedback from their doctors through phone calls immediately after exposure has occurred.

The third layer of this project involves creating a gaming application as a method to motivate positive behavioral change in users. Research has shown that well-designed games are not only enjoyable but engaging and provides users basic need satisfaction (Johnson et al., 2016; Mekler et al., 2014; Przybylski et al., 2010; Tamborini et al., 2011). Thus, turning health education and behavioral change programs into games might be an excellent way to motivate users to expose themselves to engaging in positive IAQ management (Johnson et al., 2016; Wouters et al., 2013). The gaming application will be in the form of augmented reality where users are required to do recommended tasks to improve their IAQ to get incentives or proceed to the next level.

The technological variation of this project would open a myriad of opportunities for research. The indicators and data collected by the monitoring device and the mobile application
can be assimilated into patient portal systems which consist of PHRs and EHRs. This would be an effective method for disease management and for recruiting patients for studies. This would further encourage quality improvement of health care services and to aid epidemiological research, health facilities that utilize patient portals could merge information gathered by the monitoring device and mobile application into the system. Furthermore, patient portals can be used to collect demographic, behavioral, and clinical data to allow clinicians and epidemiologists to target risk factors attributable to poor IAQ accurately.

Besides datasets obtained through the air monitoring device, users will be asked to enter home characteristics (e.g. the number of rooms, the number of stories, and the presence of basement) before using the mobile application. To gather a more robust dataset, public records will be used to assess the property area and geographic data (e.g. zip code, location and number of outdoor air pollution site monitor). These data characteristics will aid researchers in modeling predictions and in conducting regression analyses about indoor and outdoor air pollution at a county level via the use of Geographic Information System (GIS). For example, GIS technology will query IAQ data from the monitoring device via cloud services and data from site monitors to obtain outdoor PM levels for regression analysis on the effect of outdoor air pollution on IAQ. Traffic pollution data can be queried from another database, and a geographic heat map can be used to assess the impact of IAQ in urban areas due to high traffic volume.

Lastly, all devices used to collect data and healthcare providers who will be using the device must be compliant with the Health Insurance Portability and Accountability Act (HIPAA) (HIPAA Journal, 2015). All entities must safeguard the electronic Personal Health Information (ePHI) stored in the system by providing regular risk assessments, maintenance, and improving security defenses (HIPAA Journal, 2015). Furthermore, the involved parties must consider the
use of encryption for transmitting ePHI, particularly over the Internet. HIPAA also requires covered entities to implement technical policies and procedures that allow only authorized persons to access Protected Health Information (HIPAA Journal, 2015).

**Implementation Strategy**

Partnerships with existing air monitoring device companies such as Foobot is a critical first step to creating a pilot launch to provide feedback on the project and to hand out devices at a heavily discounted rate for any pilot studies. Furthermore, Foobot partners with HomeLab, an established IAQ assessment mobile application company. Both companies have an existing user base in the United States, making recruitment for a data pilot easy. Incentives such as a free or heavily discounted monitoring device, free subscription to the mobile application, and recognition can be given out to volunteer participants when the project launches.

The American Lung Association in Washington has an IAQ program, Master Home Environmentalist (MHE), leveraged because this program consists of a pool of clients from different demographic backgrounds in the Seattle area. Furthermore, the American Lung Association will create a website for recruiting purposes.

The MHE program acquires referrals from Seattle Children’s Hospital, thus partnering with hospitals, clinics, or physicians is another strategic way to recruit participants with asthma, allergies, or chronic respiratory problems and to publicize the intervention plan.

After getting evaluation results and feedback about the product from the data pilot, responsible parties will work on improving the system. Information gathered through data analysis will be shared with potential sponsors such as non-profit organizations and software/technology companies. Sponsors could include companies such as Amazon or
Microsoft which can provide benefits regarding cloud computing and the selling of monitoring devices and mobile applications. After a sizable volume of data has been collected by the monitoring device and through the mobile application, it can be licensed to academic institutions or private research companies for data analysis.

**Plan for Sustainability**

Innovative features such as If This Then That (IFTTT) web service can be integrated into the intervention plan. IFTTT allows people to create conditional statements which is an ideal service to be coupled with monitoring devices. This service could be integrated into the monitoring device or to air ventilation system, dehumidifiers, and filter systems to turn systems on or off depending on the level of indoor pollutants via Wi-Fi plugs.

User subscription fees for accessing more features of the mobile application could be another source to provide sustainable income. Data licensing fees from government agencies, academic institution, and private research centers could be another stream of revenue. Institutionalizing the project to nonprofits or for-profits could be another way to ensure that the project remains viable, that innovative ideas are routinely contributed, and to allow for new leadership teams to provide management skills for the project.

Lastly, MHE’s program is funded by King County’s Health Department; additional funds may be requested to support this health informatics program. This would also be an opportunity for the American Lung Association to purchase monitoring devices and HomeLab subscription for MHE clients. Simultaneously, this allows to King County to acquire new and more accurate IAQ data sets for analysis to improve home environment for residents and to craft behavioral intervention plans.
System evaluation

The first evaluation study will be conducted during the data pilot, to test for behavioral change, numbers of tasks that have been done per recommendation will be pooled to see user response rate. Surveys will also be prompted in the mobile application to provide feedback on the application itself to assess if users find the recommendations helpful. Clinicians using the desktop software to monitor their patients’ condition will be asked if it has helped with identifying allergic triggers and if it has helped with providing consultations promptly to their patients with asthma.

Researchers using the data to perform analysis via GIS would report back the accuracy of predictions and regressions. Health facilities utilizing patient portals that have integrated the data collected by the monitoring device and mobile application will provide regular system reports. Researchers will conduct pilot studies to test the efficacy of using patient portals as an alternative method to recruit desired participants for studies and to investigate the effectiveness of determining social determinants of IAQ. Regular evaluation will be done after the full launch of the intervention plan to maintain system accuracy and to improve the system. Evaluation of electrochemical sensors will allow the monitoring device company to assess the precision of sensors, to allow for improvements, and to introduce new sensors into the device.

Population Health Impact

Indoor air pollution is associated with a myriad of cardiopulmonary diseases. To illustrate the burden of attributable diseases, the first part of this section explores one of the most common respiratory problem affecting the U.S. population - asthma. The Center for Disease Control and Prevention (CDC) estimated that 24 million people (approximately 8.4% prevalence), including
more than 6 million children have asthma (CDC, 2015; EPA, 2016). In 2015, nearly half (46.9%) of the children and adults among the U.S. population with current asthma reported having one or more asthma attacks (CDC, 2015). Asthma accounts for 14.2 million physician office visits, 439,000 discharges from hospitals, and 1.8 million emergency department visit each year (EPA, 2016). In 2013, the U.S. personal health care expenditure on asthma cost $32 billion, 1.55% of the total expenditure ($2.10 trillion) with an annual change of 5.33% since 1996 (IHME, 2016). Most of this spending went into prescribed pharmaceutical, $19 billion; ambulatory services, which were mostly utilized by individuals aged 20 and below, $7.0 billion; in-patient care, $4.5 billion; emergency department visit, $1.9 billion; and nursing facility care, $353 million (IHME, 2016). Asthma bears a significant health and economic burden to the affected individual, their family, and society.

Studies have also shown that low-income, racial/ethnic minority neighborhoods carry a disproportionate burden of substandard and poor-quality housing, especially in urban areas (Pacheco, et al., 2014). Literature suggests a correlation between poor quality housing and indoor allergen exposure and sensitization, which increases morbidity and mortality among individuals in these groups. Poor IAQ in houses that do not meet the standard for optimal ventilation can result in a high concentration of environmental tobacco smoke, CO₂, VOCs, and radon. Excess moisture allows for the breeding of mites, mold, and cockroaches. Additionally, low-income neighborhoods tend to be situated near highways and in proximity to areas of large vehicle traffic that would result in ambient PM invading their homes. Households below the federal poverty line tend to have higher asthma rate (11.1%) compared to households in 250% to less than 450% of the federal poverty level (6.3%) (CDC, 2015). Regarding race and ethnicity, non-Hispanic African Americans and Puerto Ricans are more likely to be affected by asthma (CDC, 2015;
EPA, 2016). For instance, non-Hispanic African Americans are three times more likely to visit the emergency department and are twice as likely to be hospitalized when compared to non-Hispanic whites (EPA, 2016). Similarly, asthma in Puerto Ricans is two times greater than non-Hispanic whites and 1.5 times higher than non-Hispanic African Americans (EPA, 2016).

Washington State has been identified by the CDC as having one of the nation’s highest rates of asthma (8.7% prevalence) in both adults and children (American Lung Association, 2016). Currently, 524,562 (7.3%) of adults and 105,281 (1.5%) of children have asthma (American Lung Association, 2016). About 75 people per year die from asthma, more than 100 people every week are hospitalized as a direct result of asthma, and about 53,000 adults with asthma make at least one emergency department visit per year (Washington DOH, 2014). Hospitalization rates are highest for children under 5, but deaths rates are highest for people older than 65 (Washington DOH, 2014). Similar to the national asthma trends, social inequities especially annual incomes are significantly associated with asthma prevalence in Washington. However, unlike the national data, American Indian/Alaska Natives have a higher prevalence of asthma than non-Hispanic whites, and African Americans have significantly higher rates of death due to asthma than non-Hispanic whites (Washington DOH, 2014). Asthma hospitalization rates are higher in urban areas than in rural areas 65 (Washington DOH, 2014).

A real-time IAQ monitoring device that allows users to track different air pollutants and make informed behavioral decisions to reduce their risk of being exposed to harmful chemicals is an innovative method to lower the burden of asthma and other respiratory diseases. It has the potential to decrease unplanned doctor visits and expensive hospitalizations. Coupling the device with a smartphone application allows users to see IAQ trends over time, positive impacts associated with behavioral change, to pinpoint allergic triggers, and to make better decisions.
Gamification provides users with incentives and acts as a tool to motivate users to perform tasks and to serve as an educational tool. Recommendations and reminders for IAQ improvement included in the mobile and gaming application will mitigate any cumulative effects of potentially harmful activities. For example, the application will send out reminders that ask users to remove dust or dust mites on a regular basis and to ventilate their home if a high level of PM or VOC is detected. The application also provides explanations and steps to guide users through the process of creating a healthy home environment. In addition, this program acts as a conduit for IAQ advocacy, as IAQ awareness increases, tenants will urge landlords to improve housing condition and to take necessary steps to ensure healthy IAQ for their occupants.

Healthy People 2020 environmental health’s objectives include “increasing the proportion of the Nation’s elementary, middle, and high schools that have official school policies and engage in practices that promote a healthy and safe physical school environment” (Department of HHS, 2017). To expand beyond the scope of residential home health, this system could also be used in schools to ensure students are breathing in non-toxic air. Similarly, this system can be integrated into the work place to safeguard workers from the loss of labor productivity to SBS. Aging adults are more susceptible to health complications because of their weakened immune systems; therefore, nursing homes and assisted living houses could benefit from monitoring devices which can provide unlimited aid to controlling and monitoring environmental-linked health triggers. Although adoption of this technology might be a drawback among the older population.

The desktop application for health care providers would aid clinicians to have better environmental health related diseases management protocols with their patients. Real-time data collection and interpretation of IAQ allows patients and doctors to assess environmental risks at
the peak of its concentration. It also heightens the importance of environmental health among health care providers. Initial risk assessment and disease identification lowers the health and economic burden patients.

Patient portals would be an opportunity for epidemiologists to gather data and to recruit participants for future IAQ studies. Simultaneously, this enhances interoperability between technology and health care facilities in the exchange of health data. This would aid in population health management and make targeted interventions based on information gathered.

Every feature in this system promotes interoperability from the users to data collection, tracking, and analyses. Compared to the conventional method of collecting air quality data, home sensing devices increases spatial resolution, data coverage, reduces uncertainty, and ultimately improves the robustness of risk assessments (Kumar et al., 2016). As a result of the increased spatial resolution, it will be possible to target specific sources by monitoring associated pollutant emission processes (Kumar et al., 2016). This will be particularly useful in developing countries from cooking stove emissions but also in developed countries where residential heating via kerosene heaters, biomass boiler, or open gas is prevalent (Hanoune and Carteret, 2015). Similarly, this would aid in the simultaneously monitoring of indoor VOCs and PMs monitoring. It also saves users from purchasing an expensive device that only detects one chemical component. For example, a VOC monitor cost ranges from $300 to $4,000.

IAQ datasets allow researchers and environmental health departments to identify indoor environmental data gaps in public health data systems to increase environmental public health capacity at state and local levels (Esri, 2011). To this date, data retrieved for air pollution studies have been gathered via outdoor air monitoring stations. Predictions on indoor air pollution such as indoor PM levels have been made based on outdoor air monitoring stations. Home air
monitoring devices provide a secure, reliable, and expandable means to link environmental and health data (Esri, 2011). With this data, researchers can also perform geospatial analysis at a more granular level to control and to prevent environmentally related health problems in populations (Esri, 2011), thus allowing policy makers to quickly visualize problems (Esri, 2011) about existing environmental health concerns to effectively target concerning risks by enforcing IAQ and landlord tenant laws. For instance, Washington State usually has high humidity levels throughout the year, and this leads to moisture problems which eventually promotes mold growth. Under Section 302.2.1 of Washington State Building Code, ventilation is required for kitchen and other areas of the room (Washington State Building Code Council, 2006), but there are not any requirements for it to be vented outside and on the type of stove vents that should be installed to avoid excess moisture and smoke to be trapped in homes. Furthermore, it is not a code violation for building units to have vent-less stoves. Monitoring devices can sense humidity levels in real-time which would be helpful in documenting the effects of improper kitchen ventilation system on mold growth and its impact on health.

**Conclusion**

The American Lung Association in Washington and its future partners in the HomeAir Matters project is dedicated to improving the quality of lives of individuals with lung diseases in its state and eventually nationwide. The association has been committed to offering IAQ education, raising IAQ awareness, and providing free home assessments to residents in Seattle since the start of its MHE program in 1992. It is the time that the organization embraces technological advances to provide innovative solutions to IAP with HomeAir Matters.
Real-time sensors gather different data, predict trends, alert users, and make recommendations to take action that maintains good air quality. Conventional methods for monitoring IAQ often take a longer trending period, and useful information is usually only available long after the exposure has already occurred (Kumar et al., 2016). Thus, it is important to revolutionize IAQ monitoring methods to aid various interventions at individual, clinical, and the policy level.

To this end, such tools can play a significant role in improving IAQ and associated health outcomes. It holds a promising opportunity for researchers and clinicians to better understand the interaction between IAP and the physiological functioning of our body. Real-time tracking of rich novel datasets is able to create a strong structural foundation to IAP epidemiological research. This will not only allow researchers to better understand the burden of poor IAQ but to further investigate associated social disparities. Lastly, the public health field must keep up with its technological counterpart to promote innovative health solutions.
disease/estimated-prevalence-and-incidence-of-lung-disease/


https://www.cdc.gov/asthma/most_recent_data.htm#modalIdString_CDCTable_3


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http://dx.doi.org/10.1016/j.scitotenv.2016.04.032


Figures

Figure a. Foobot home IAQ monitoring device
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Figure f. Foobot device air quality indicator

Figure g. Fluctuation of IAQ detected by Foobot is reflected by colors in the mobile application and device
Figure h. HomeLab’s main application page that provides users with an overview of their IAQ.
Figure i. HomeLab’s information about associated colors

Stoplights

- **Red**: Your exposure level has exceeded the healthy limit set by the World Health Organization, EPA, or Building Performance Institute.

- **Yellow**: Your exposure level is close to the healthy limit set by one of the above organizations.

- **Green**: Your exposure level is considered acceptable by one of the above organizations.

Pollutant Categories

**Particulates (PM 2.5):**
measured in microns (µm3)

Particulates come from dust, mold, bacteria, viruses, vehicle emissions, cooking, pet dander, and other sources.
Pollutant Categories

Particulates (PM 2.5): measured in microns (μm3)

Particulates come from dust, mold, bacteria, viruses, vehicle emissions, cooking, pet dander, and other sources. Fine particulates, also called PM2.5, have been shown to increase risk of heart and lung disease and are linked with asthma triggers.

- Red: Above 25 μm3
- Yellow: Between 15 and 25 μm3
- Green: Below 15 μm3

Volatile Organic Compounds (VOCs): measured in parts per billion (ppb)

Volatile Organic Compounds come from a variety of everyday products. Pressed wood, plastics, pesticides, cleaners, paints, furniture and more. They include chemical gases such as formaldehyde and benzene which are classified as probable or known carcinogens.

- Red: Above 350 ppb

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Figure q. Pollution prevention routine list
Install and vent a bathroom fan

Over 90% of moisture in a home is carried through the air, and the bathroom is a key source of it. Bathroom fans are a great way to remove pollution – whether it’s humidity, VOCs or particulates. Use them at least 20 min after a shower and regularly throughout the day to clear your air. Open your windows and use exhaust fans to draw air in and ventilate the home.

Figure r. IAQ education provided by HomeLab to raise awareness