INVESTIGATING HOW TO INFORM THE PUBLIC ABOUT AIR QUALITY IN ZÜRICH, SWITZERLAND

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Investigating How to Inform the Public about Air Quality in Zürich, Switzerland

An Interactive Qualifying Project Submitted to the Faculty of WORCESTER POLYTECHNIC INSTITUTE in partial fulfilment of the requirements for the Degree of Bachelor of Science

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Submitted on: 10 October 2019

Abstract

Our project goal was to recommend ways to satisfy public interest and reduce knowledge gaps about air quality in Zürich, Switzerland. To accomplish this, we measured air quality and surveyed the general public. We determined average present air quality in Zürich to be below Swiss federal limits and residents to be concerned but not well informed about actual air quality. To address this, we recommend that smartphone weather applications be expanded to include user-friendly ways to access air quality data.

Acknowledgements

We would like to thank the members of the Institute for Environmental Engineering at the Swiss Federal Institute of Technology Zürich (Eidgenössische Technische Hochschule Zürich Institut für Umweltingenieurwissenschaften) for all of their support during our project, including Dr. Professor. Jing Wang, Dr. Xiaole Zhang, Dr. Yang Yue, Alix Grünhagen, and Jean Schmitt. We would also like to thank Professor R. Creighton Peet and Professor Blake Currier for their helpful guidance and feedback throughout this research. We are extremely grateful to the Interdisciplinary and Global Studies Division (IGSD) at WPI and Professor Nancy Burnham for their oversight and coordination of this project. Finally, we would like to extend a thank you to Dr. Professor Ulrik Brandes for his assistance in improving our public opinion survey.

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Executive Summary

Air pollutants, such as bioaerosols and particulate matter (PM), end up suspended in the air due to natural and human processes. Air pollution can have harmful effects on the human body such as respiratory decline, allergies, infectious diseases, cancer, and death. It has been a growing problem since the industrial revolution, but policies have been enacted to reduce pollutants. Despite improvements to air quality in the past few decades and having relatively better air quality than other countries, Switzerland's annual air pollution levels exceed recommended limits.

Since air pollutants are harmful to both human health and the environment, they are a problem that may garner public concern, but the level of public concern in Zürich was previously unknown. We utilized actual air quality measurements to add context to the current level of public concern and education about air quality. We compared air quality data that we measured, and data collected by the Swiss Federal Office for the Environment with public opinion data collected through a survey to determine the relationship between the two sets of data. The purpose was to determine how well-informed the public was about the air quality where they live and on which topics the public could be better informed. This information allowed us to make appropriate recommendations for informing residents of Zürich about local air quality.

In order to reach our goal we achieved four objectives: to determine public opinion about air quality in 3 different regions of the greater Zürich area, to determine actual air quality in these different regions in Zürich, to determine the relationship between public concern and measured air quality, and to determine how to best inform the public about the quality of air in the places where they live and work.

We conducted a survey in three locations in Zürich to determine public opinion of air quality. We used quota sampling, with a quota of twenty-five respondents at each location, and

used a closed questionnaire administered to eighty willing participants. Based upon the survey we determined that respondents were concerned but did not feel informed about air quality. Air quality data were collected during our public survey visits using three different sensors; the senseBox, the dBluetech High BioTrap, and the Temtop LKC-1000S Indoor Air Quality Monitor. We then compared these data to measurements obtained by the Swiss Federal Office for the Environment. After doing so, we determined that while the air quality we measured did not on average exceed federal limits for particulate matter, the average air quality in the past twelve months did exceeded federal limits. Then we compared survey results with air quality data. When given the choices of poor, acceptable, good, or excellent; 85% of respondents surveyed thought that the air quality in Switzerland was good or excellent. Also, 55.1% recognized that the federal limits were being exceeded but only 10% felt very informed. Based on this, we identified a need for further education about air quality in Switzerland. Using responses from our survey, we determined that a majority of Swiss residents wanted to be informed about air quality via a smartphone application using a color rating scale once a week. Despite air quality data already being publicly available, only 17.9% of those surveyed have looked at it. Based upon this, we recommended several improvements to preexisting Swiss weather applications that provide air quality information.

Overall, we learned from this research that Swiss residents are concerned about their air quality, indicating a potential interest in becoming further educated. Therefore, there could be a widespread benefit to improving air quality information provided in Swiss weather applications that makes information more visible and accessible to residents. Once this is developed, Swiss residents can become more informed about their air quality, which will allow for social and political action that could improve long-term air quality.

Chapter 1: Introduction

Air pollution can affect or damage the human respiratory system, cardiovascular system, immune system, and even cause cancer (Brunekreef & Holgate, 2002). Deaths due to acute respiratory infections in children resulting from air pollution exposures are estimated to be over 2 million per year worldwide. Particulate matter (PM) emissions, which are the result of industrialization and urbanization, have increased significantly and are causing public health problems that need to be addressed urgently (World Health Organization, 2019). From 1960 to 2009, global concentrations of $PM_{2.5}$ (particulate matter 2.5 micrometers or less in diameter) have increased by 38% (Butt et al., 2017). Particulate matter emissions, along with other air pollutants, are a cause for concern for everyone because the small particles can be inhaled and cause health problems (Brunekreef & Holgate, 2002).

Public concern is a large motivator for policy change and governmental action (Dons et al., 2018). Europe has been home to innovative air quality improvement policies, motivated by public concerns over air quality impacting public health (Murch, 1971). However, air quality is something that is hard for the average person to quantify without the appropriate measurement tools. Many organizations exist that have the appropriate equipment to monitor air quality and make air quality data publicly available. Europe, for example, has the highest number of organizations reporting air quality data according to the World Health Organization (2018). Despite a large amount of air quality data being available to those living in Europe, there is a disconnect between how most of the public perceive air quality and how it is reported by scientists (Bickerstaff, 2004). This disconnect makes it hard for the public to effectively enact policy change.

Since the industrial revolution during the twentieth century, Europe has made significant policy efforts to reduce air pollutant levels, but many countries still exceed their limits for $PM_{2.5}$

and PM_{10} (Brimblecombe, 2006). Switzerland is among the European countries that are exceeding regulatory limits for pollutants, and levels of multiple types of particulate matter exceeded the regulatory limits of air pollutants in Switzerland in 2016 (Federal Office for the Environment, 2016). Europe has also been home to several public opinion studies that explore the relationship between measured air quality and public opinion (Williams & Bird, 2003; Jacquemin et al., 2007; Dons et al., 2018). These studies, however, have lacked information about how participants would like to be informed about air quality and focus on Europe as a whole.

Research on air quality in Switzerland has been previously conducted and monitored (Federal Office for the Environment, 2016; Yue et al., 2018). However, no information has been collected that directly explores the relationship between the public's opinion and measured air quality and no information has been collected that examines how the public would like to be better informed about air quality. Researchers at ETH Zürich are interested in investigating the general public's understanding of air quality and improving the accessibility of available data in a user-friendly format. These data could, in turn, help improve air quality in Switzerland through actions taken by a better-informed public.

In this project we worked with ETH Zürich's Institute of Environmental Engineering to measure air quality in Zürich and determine the public's opinion of air quality to determine how accurate people's perceptions of air quality were in comparison to actual air quality. In order to fulfill this goal, we measured and analyzed air quality using several particulate matter sensors and laboratory techniques, including microorganism culturing. Public awareness data were gathered through a survey of residents in areas where air quality was measured. We analyzed our data to determine the relationship between measured air quality and public opinion, which allowed us to determine the validity of any public concerns. We determined that while air quality in Zürich was generally good, it still sometimes exceeded federal limits for PM and that most respondents we surveyed were not informed about air quality and wanted easy to understand information. We provided ETH's Institute of Environmental Engineering with recommendations on the ways in which residents of Zürich would most like to get information on air quality, and what information they should receive. Residents more informed about air quality in Zürich would be able to find ways to reduce their contributions to pollution through acts such as reducing transportation use and proper waste management. In addition to this they would be able to make informed voting decisions when electing government officials that support air quality improvements. This will open opportunities for more informed, citizen-led action that can have effects on improving air quality in Switzerland.

Chapter 2: Background

In this chapter we will discuss air pollution, where it comes from, its history, its impact, policies created to combat it, and what the public thinks about it. This information will then be explained in the context of Swiss air quality, Swiss policies to improve air quality, and Swiss public opinion about air quality.

2.1 Introduction to Air Pollution

Air pollution is the existence of pollutants such as bioaerosols, particulate matter, ozone, carbon monoxide, and sulfur dioxide within the air (NSW Government, 2013b). These pollutants come from a variety of natural and human-made sources and can be harmful to human health (NSW Government, 2013a). Concentrations of these pollutants also vary depending on the location of sources (Qui et al., 2019).

2.1.1 Particulate Matter

Particulate matter (PM) is a combination of solid and liquid particles found in the air (U.S. Environmental Protection Agency, 2018). It is often classified by its size, specifically particle diameter (U.S. Environmental Protection Agency, 2012). Two common size classifications are $PM_{2.5}$, referring to fine particles equal to or smaller than 2.5 micrometers in diameter; and PM_{10} referring to coarse particles equal to or smaller than 10 micrometers in diameter. Finer particles of size $PM_{2.5}$ tend to be more hazardous to human health as they can spread further and penetrate deeper into the lungs due to their smaller size (Rathnayake et al., 2017). To put these PM measurements into perspective, they may be compared to a human hair with a diameter of about 100 micrometers (National Pollutant Inventory, 2018).

2.1.2 Bioaerosols

Bioaerosols are particulate matter that either come from or contain living organisms, such as virus particles, bacteria, fungal spores, and plant pollen (Max-Air Systems, 2009). They are affected by environmental conditions such as air currents, temperature, humidity, and gravity. Bacterial cells that compose bioaerosols can thrive under high humidity conditions while fungal cells thrive at low humidity, which demonstrates the variance of composition of bioaerosols under differing conditions. Bioaerosols can be divided into 4 broad categories: virus, bacteria, fungi, and pollen (Wang-Li, Simmons, & Wheeler, 2012). Viruses tend to be the smallest in size, followed by bacteria, fungi, and pollen as the largest. These bioaerosols account for around 30% of particulate matter greater than 2 micrometers in diameter in outdoor air.

Viruses, bacteria, and fungi in the air can all cause infectious diseases, and certain cancers can be caused by viruses (Douwes, Thorne, Pearce, & Heederik, 2003). The workplace is a common route for increased exposure to these bioaerosols. For example, bacteria are commonly spread via the air in hospitals, spas, and meat packing facilities. Fungi are naturally existing and common around mold, rust, yeast, and mildew (Löndahl, 2014). They can also be inhaled from exposure to soils, feces, or decaying matter (Douwes et al., 2003). While certain fungi can be used to create medicines, they can also cause diseases, allergies, and crop diseases (Löndahl, 2014). Many people have allergies to pollen, which can affect their day-to-day life (Zuberbier, 2016). It is important to understand these bioaerosols in terms of the effects that they have on human health, as the implications of poor air quality can motivate more investigations.

Fungi in particular are becoming a major concern due to the emerging worldwide outbreak of *Candida auris* (Schelenz et al., 2016). *Candida auris* is a multidrug resistant fungal pathogen, commonly found in yeasts, that is originating in hospitals where patients already have weakened immune systems. In the study conducted by Schelenz et al. in a London hospital, 50 patients were found to have *Candida auris* infections over a 16-month observation period. This fungus can cause infections in the bloodstream resulting in the deaths of more than 1 out of 3 patients (Centers for Disease Control and Prevention, 2018). Since its discovery 10 years ago, *Candida auris* has spread to over a dozen countries and is still hard to identify as well as very hard to treat.

Pollen is naturally created by plants and humans can have a negative reaction to it (Rathnayake et al., 2017). Concentrations of pollen in the air vary strongly from day to day, but they thrive in the warmer temperatures of spring and summer. Rain acts as a trigger that releases trapped pollen into the air. Also, pollen size can range greatly, typically falling around PM_{10}, but can be larger or smaller. Particle sizes may get even smaller, around $PM_{2.5}$ and thus more dangerous to those inhaling them, following rain. In some cases, rain can actually be beneficial to public health by transporting the pollen to the ground (Zuberbier, 2016). Pollen types vary and originate from trees, weeds, and grasses.

Agriculture, particularly animal raising, is a large contributor to bioaerosols (Wang-Li, Li, & Byfield, 2013). Components such as animal skin, feed, bedding materials, and fecal materials are the main sources. These substances can be home to many fungi and bacteria. They may affect the air directly or spread to other regions when disposed of improperly. To support the higher demand for agriculture as a result of increasing population, more and more agricultural products are being generated, which is further increasing bioaerosol concentrations (Douglas, Robertson, Gay, Hansell, & Gant, 2018).

Similar to the livestock industry, sawmills are a strong source of bioaerosols (Rusca, Charrière, Droz, & Oppliger, 2008). Airborne wood dust, fungi, and bacteria can affect workers and those living in areas close to sawmills. When twelve sawmills in Switzerland were investigated by Rusca et al., each of the sawmills was found to have exceeded the recommended limit of fungi set forth by the Swiss National Insurance company. Although there was no confirmation that the wood dust has an effect on health, the fungi were found to cause respiratory symptoms such as increased coughing.

Smoke from cigarettes is considered a bioaerosol since cigarettes are created from the leaves of tobacco plants (Larsson, Pehrson, Dechen, & Crane-Godreau, 2012). Along with that, the tobacco contains different microorganisms, bacteria, and fungi. The smoke then generated from the tobacco plants has been found to contain the same microorganism that originates from the leaves, including the pesticides (Larsson et al., 2008). It was also found that the fungi and bacteria in the cigarettes could grow if left in ideal growing conditions.

2.1.3 Carbon Pollutants

Carbon pollution is increasingly common and damaging to both the environment and humans (Majewski, 2016). Specific examples of these carbon pollutants include carbon monoxide (CO) and carbon dioxide (CO_2). The concentration of carbon-based pollutants in the atmosphere is constantly increasing since they are a key element of fuels being used for energy generation.

The transportation industry is heavily reliant on the use of carbon-based fuels (U.S. Environmental Protection Agency, 2019a). For example, the US Energy Information Administration (2019) reported that petroleum products in 2018 accounted for 92% of total U.S. transportation. This reliance, in turn, can increase the concentrations of carbon pollutants through the burning of these fuels.

The second biggest source of carbon-based pollutants is electricity production, which mainly comes from burning fossil fuels to generate electricity (U.S Energy Information Administration, 2018). Another major generator of carbon-based pollutants is agriculture; particularly animal agriculture (U.S. Environmental Protection Agency, 2019b).

2.1.4 Concentrations of Air Pollutants

Air pollutant concentration varies depending on emission sources (Qui et al., 2019). Specifically, the location of pollutant sources has a large impact on concentration of air pollutants. Air quality will differ between areas with many emissions and areas with few emissions. In section 2.1.3 we discussed vehicular emissions in the form of carbon-based products; these emissions would be greater in an area where there is heavy traffic as compared to an area that has limited traffic (Zheng et al., 2014). Air quality would also differ in areas that have many plants versus areas that have few plants, as plants convert carbon dioxide to oxygen, and absorb other particulates through this process (Qui et al., 2019). For example, Qui et al. determined that concentrations of $PM_{2.5}$ and PM_{10} varied depending on the amount of plant coverage in an area. This study examined the influence of plants in impacting air quality because the plants were able to purify the air of particulates. Figure 2.1 examines the phenomenon of air quality being location dependent by visually demonstrating that air pollutant concentrations are greater along major roads, areas with high concentrations of people, and areas with high concentrations of industry in Los Angeles (Mcdonald et al., 2014).

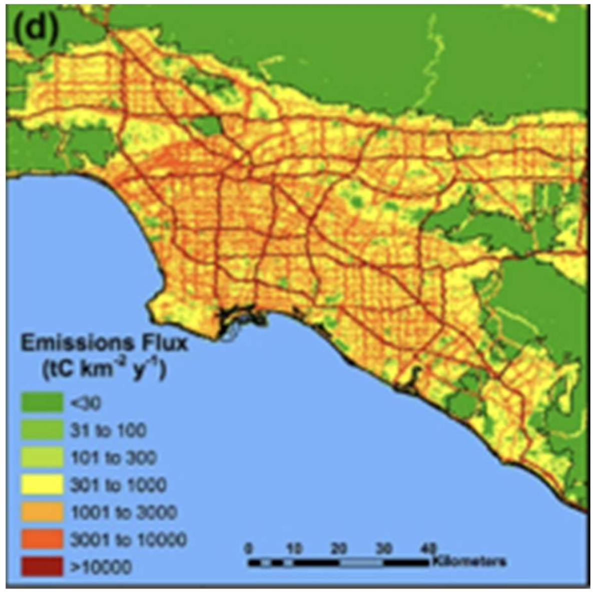

Figure 2.1: On-road emission fluxes of CO_2 in Los Angeles. (Adapted from McDonald et al., 2014).

2.2 History of Air Pollution

Air pollution has been a problem and a reality since the days of ancient Rome (Stromberg, 2013). However, modern air quality is much more prevalent and dangerous for human beings than it was during the time of ancient Rome. In this section we will discuss the history of air pollution in Europe and examine historical public opinion data on air pollution.

During the late eighteenth century, the Industrial Revolution introduced a major set of technological advances, and these technological advances introduced new sources of air and water pollution (History.com Editors, 2009). During the industrial revolution, towns and cities were dependent mostly on coal to create energy for industrial and residential consumption. This newfound dependency on coal created smoke, fog, and pollution, which caused major health problems (Brimblecombe, 2006). The creation of the Royal Society in the United Kingdom allowed for the development of significant research efforts to reduce air pollution. This research demonstrated the visible effects of air pollution and the damage it caused to health, allowing effective policy to be made (Brimblecombe, 1978). Once countries started to recognize the negative effects created by the high levels of air pollution, many industrialized nations introduced policies (mostly in the last half of the twentieth century) to address the growing problem of air pollution. Two examples of the most robust set of policies to tackle this environmental problem was the Clean Air Act passed by the United States of America in the 1970's (U.S. Environmental Protection Agency, 2019c), and the first Clean Air Act passed by the United Kingdom in 1956 (Brimblecombe, 2006).

2.2.1 History of European Air Quality

The industrial revolution originated in Europe, and since then air pollution has increased in Europe and eventually in other parts of the world (Brimblecombe, 1978). Europe was one of the first places affected by modern air and water pollution. Currently, Europe is a pioneer in terms of renewable energy and technologies that improve the environment through air and water treatment (European Commission, 2015). Due to Europe's long history of air pollution, during most of the nineteenth and twentieth centuries, a wide range of health and environmental problems developed that, to this day, are noticeable and harmful.

England is one of the countries with the most documentation on air pollution and was a large consumer of coal during the nineteenth and twentieth centuries (Brimblecombe, 1978). In London alone "the coal imports rose above a million tonnes per annum in the 1780's, which represents an increase by a factor of 2.5 in a century" (p. 116). According to Brimblecombe, London was importing an unsustainable quantity of coal, which made it evident that the consequences of utilizing pollution-causing substances in such quantities would have negative implications for air quality. Despite concerns regarding air pollution, no policy action was taken to address the issue until nearly a century later.

2.2.2 Implementation of Air Policy in Europe

European air quality legislation has reduced emissions of air pollutants across Europe since the 1970's (Brimblecombe, 2006). Most of these policies started in the 20th century, some before the 1970's. Britain had one of the most remarkable and successful policies on air pollution, created during the 1950's. London experienced the greatest air quality effects from the industrial revolution, and in the 1950's London's sky was ravaged by coal smoke. During that time, the government enacted the Clean Air Act (in 1956), which had impacts farther reaching than those intended at the time (Brimblecombe, 2006).

Switzerland is another European country that has had success with policies to improve air quality. During the 1980's Switzerland enacted a set of policies to tackle air pollution and has since seen positive results, by dramatically improving air quality (Organisation for Economic Co-operation and Development, 1998). "These results are largely attributable to a consistent and ambitious federal strategy for air pollution abatement and efficient implementation of regulatory measures by the cantons" (para. 5). Due to Swiss renewable energy generation, many goals set by their Energy 2000 program have been attained, which has further reduced the use of fossil fuels such as coal that were contributing to Swiss air pollution. In fact, "Switzerland's emissions per unit of GDP are the lowest or among the lowest in the OECD area" (para. 8). Nonetheless, Switzerland has not been able to meet its targets for nitrous oxides (NO_x), volatile organic compounds (VOC) emissions, and ozone. Moving forward, Switzerland is expected to meet its target for the regulations of these air pollutants with the help of new, greener technologies.

2.2.3 Public Awareness and Concern of Air Quality

Air pollution and environmental pollution have been generally recognized by the public as a serious issue that needs to be addressed (Murch, 1971). However, despite the fact that in a survey conducted by Murch (1971), 74% of respondents believed that air pollution was a serious issue, only 13% of them acknowledged that pollution was a serious threat in their communities. It is difficult for people to understand how pollution affects them, even though they do understand that it is an existing problem. This was observed to be part of a bigger trend, in which most people may agree that a problem exists, but fewer people think that the problem directly affects them. Despite this study being outdated, a study conducted in London much more recently has had similar results, indicating that public perception is not a good indicator of local air quality (Williams & Bird, 2003). The survey administered by Williams and Bird (2003) even attributed the public dislike of cars causing air pollution to a dislike of road traffic and not to the potential health impact on the residents. These surveys help us to better understand public opinion of air quality across different decades.

The study conducted by Williams and Bird (2003) in which participants were asked to assess the perceived air quality in the location in which they were being surveyed found that "overall, 44% of the total respondents perceived the air quality as 'moderate', 28% as 'high', 17.5% as 'very high' and only 10.5% as 'low'" (p. 255). Surprisingly, the air quality was low 97% of the days in these locations when the interviews were taking place. The terms "low", "moderate", "high", and "very high", which denoted air quality, were quantified by the Automatic Monitoring Network for Greater London, as people's opinions of how they felt the air quality was during that day were arbitrary. The results of this research demonstrate that people do not have a solid understanding of air pollution, and that they are not informed about the air quality in their respective places of residence.

A third study examined the annoyance due to air pollution in different areas of Europe and found that "14% of the Europeans are highly annoyed by air pollution and more than half reported some degree of annoyance" (Jacquemin et al., 2007, p. 810). As clearly observed by the several studies discussed, people generally are not very informed on the subject of air pollution and environmental pollution. And even though most people acknowledge the problem, they are unable to elaborate on how the problem affects them or what the current status of air quality is.

2.3 Public Health Implications

The following section reviews the health impacts of poor air quality, the global effects of these health impacts, and strategies that reduce the risk of some air quality associated health problems.

2.3.1 Health Impacts of Poor Air Quality

People need to breathe to sustain life. An adult breathes about 20,000 times a day, breathing fifteen to twenty cubic meters of air (Brown, 2014). Therefore, polluted air has a direct impact on human health. Air pollutants are harmful to the human body in many respects. PM can damage the human respiratory system, cardiovascular system, immune system, and even cause cancer (Kampa & Castanas, 2008).

Deaths due to acute respiratory infections in children resulting from air pollution exposure are estimated to be over 2 million per year (Brunekreef & Holgate, 2002). $PM_{2.5}$ can go directly into the alveoli in the lungs, be engulfed by macrophages, and remain in the alveoli forever. Short-term acute symptoms mainly include eye and nose irritation, cough, and fever. Long-term exposure can lead to the aggravation of the conditions within patients with chronic respiratory diseases, increased mortality and increased incidence of malignant tumors. Bioaerosols created by farming can also lead to respiratory problems (Douglas et al., 2018). Studies have shown that children living in proximity to farmhouses may have an increased chance of asthma, and workers living at farmhouses showed inflamed biomarkers indicative of respiratory problems caused by poor air quality. Poor air quality can affect the quality of lives of residents and make the medical burden heavier on the country in which these residents reside.

Air pollution also has a serious impact on the human cardiovascular system (Brunekreef & Holgate, 2002). Brunekreef and Holgate found that hospital admissions for asthma and chronic obstructive pulmonary disease (COPD) among people older than 65 years increased by 1% (0.4–1.5) per 10 $\mu g/m^3$ of PM_{10} inhaled, and admissions for cardiovascular disease (CVD) increased by about 0.5% (0.2–0.8) per 10 $\mu g/m^3$ of PM_{10} inhaled, and by about 1.1% (0.4–1.8) per 10 $\mu g/m^3$ of black smoke inhaled, suggesting an important contributor was diesel exhaust which is a source of these particles. $PM_{2.5}$ pollution is closely related to the mortality rate among people with cardiovascular diseases, an increased rate of hospitalization and emergency room visits, and the deterioration of people with related diseases. Long-term exposure to atmospheric $PM_{2.5}$ is also associated with an increased risk of arrhythmia, heart failure, and cardiac arrest. $PM_{2.5}$ can also promote the development of atherosclerosis.

Air pollution can also reduce immune function, increase susceptibility to bacteria, viruses, and infections, and reduce the body's resistance to infectious diseases (Koenig, 1999). When pathogenic microorganisms enter the body with particulate matter, the body's resistance can be reduced, and infectious diseases can occur. Long-term exposure to combustion-related fine particulates is an important environmental risk factor for lung cancer mortality, as $PM_{2.5}$ particles are very small and deposit deep in the lungs when inhaled (Pope et al., 2002). These carcinogenic substances can travel through the blood, infecting other organs.

Brunekreef and Holgate (2002) had also found that the general health impact of air pollutants was associated with life shortening. They mentioned two US cohort studies that observed that life expectancy tended to be longer during the 1970s to 1980s, when the air pollution concentration was much lower at that time.

2.3.2 Global health impacts

Air pollution is considered a serious environmental problem globally and may impact the climate on a global scale (Kan, Chen, & Tong, 2012). Gases that cause air pollution should be considered not only in industrial areas, but also in the world as a whole. Due to long-term changes to the composition of the atmosphere from air pollution, there are consequent effects to climate change. China is a classic example of the air pollution problem.

In China, air pollution causes serious problems for public health (Chen, Wang, Ma, & Zhang, 2013). The Global Burden of Disease Study 2010 found that particulate matter with an aerodynamic diameter of less than 2.5 μm ($PM_{2.5}$) has become the fourth biggest threat to the health of the Chinese people. It is difficult to prevent and control air pollution in China, not only because of the existing pollution, but also because there are a large number of pollutant sources. China faces a challenging task in tackling air pollution (Chen et al, 2013). In order to improve air quality and reduce the health impacts of air pollution, the Chinese government has taken strict measures to prevent and control air pollution. However, the public still expressed concern about the air pollution. Yan (2016) surveyed people and found that 44% of Chinese people feel air quality is worse now than a year before, and 72% of the people felt air pollution has affected their health. The main finding of this study was that 52% of people did not know that air pollution and prevention laws exist in China.

2.3.3 Strategies to Reduce the Risk of Health Problems

In terms of personal habits, we can generally divide pollution into outdoor air pollution and indoor air pollution; there is no direct correlation between the two (Andersen, 1972). Indoor air pollution occurs when harmful chemical, physical and/or biological particulate matter enters the indoor air and has a direct or indirect, short-term or long-term, and potentially harmful effect on human health (Lu, Deng, Li, Sundell, & Norbäck, 2016). Sick building syndrome (SBS) was defined as certain medical symptoms experienced by occupants in specific indoor environments, which includes symptoms such as headaches, fatigue, and irritation in the upper respiratory tract, nose throat, eyes, hands, and facial skin. Laumbach, Meng, and Kipen (2015) found that closed windows, usually associated with the use of air conditioning in the developed world, can reduce air exchange rates by about 50%, leading to reduced infiltration of ambient air pollutants to the indoor environment.

Outdoor air pollution is a mixture of multiple pollutants originating from a myriad of natural and anthropogenic sources (Loomis et al., 2013). People who enjoy outdoor activities might encounter high concentrations of particulate matter. People can reduce possible health risks by wearing filtering-facepiece respirators outside (Laumbach, Meng, & Kipen, 2015). Personal exposure to ambient air pollution can be reduced on high air pollution days by staying indoors, reducing outdoor air infiltration to indoors, and limiting physical exertion, especially outdoors and near air pollution sources.

2.4 Strategies for Reducing Air Pollutants

Factors impacting pollutant emissions ranging from fossil fuel use, agriculture, waste treatment, and industry contribute to ambient particulate matter levels (Aneja, Schlesinger, & Erisman, 2009). Global efforts to study and reduce air pollutant concentrations have been undertaken by many nations in recent years. A study by the National Renewable Energy Laboratory in the United States found that compliance with state renewable portfolio standards reduced national emissions by tens of thousands of metric tons of sulfur dioxide, nitrogen oxides, and $PM_{2.5}$ (Wiser et al., 2016). These renewable portfolio standards encouraged the implementation of renewable energy and greater energy efficiency instead of the burning of fossil fuels, indicating that a successful method for reducing air pollution levels is the implementation of policies that encourage renewable energy use and reduction. Similarly, Chinese efforts to improve air quality through aggressive policies have yielded a 30% decrease in $PM_{2.5}$ in the past five years (Yu, 2018). These efforts included China's Academy for Environmental Planning allocating over two hundred billion USD to combat urban air pollution in urban areas. This funding went towards stricter enforcement of preexisting policies and measurement of air quality in urban areas with the poorest air quality. Chinese policies also required residences to switch from using coal to natural gas for heating. These Chinese policies have had significant positive effects on the air quality in China in the past ten years. The United States and China are both examples of the policy efforts of developed countries that have yielded measurable improvements to air quality.

2.4.1 Swiss Air Quality Improvement Efforts

Many successful global efforts to reduce air pollution levels have also been applied by the Swiss government in the form of policy. The following section explores Switzerland’s efforts thus far to improve air quality and how public opinion may have influenced these policy decisions, and how it may influence future policy decisions.

The Swiss government has taken air quality seriously since the 1980’s (Kutlar, Eeftens, Gintowt, Kappeler, & Künzli, 2017). Air quality in Switzerland is regulated by the Federal Environmental Protection Act and the Ordinance on Air Pollution control of 1985 (OAPC). While these regulations have significantly improved Swiss air quality in the last forty years, ambient particulate matter concentrations still exceed regulatory limits.

There are several government organizations dedicated to monitoring air quality in Switzerland (Federal Office for the Environment, 2016). The National Air Pollution Monitoring Network (NABEL) measures air pollution at a variety of locations throughout the country, including both urban and rural areas. The Swiss Tropical and Public Health Institute (TPH) is also a government-sponsored organization that monitors air quality. Additionally, there are private organizations that are dedicated to monitoring air quality (SenseBox, 2019). One example of these organizations is senseBox, which is a German company that sells various air quality sensors for academic research. This organization makes information collected using their product available for public reference on their openSenseMap. While SenseBox does not monitor air quality themselves, they provide customers of their product a database to exchange data.

Switzerland is involved in several international organizations that focus on a multilateral approach for reducing air pollution levels in Europe (Federal Office for the Environment, 2016). These organizations include the UNECE Convention on Long-range Transboundary Air Pollution and the UNECE World Forum for Harmonization of Vehicle Regulations: Working Party on Pollution and Energy. Both organizations have been ratified by many European nations and are enacting various protocols for air pollution reduction.

One policy effort that the Swiss government has employed to reduce emissions from transportation that can contribute to air pollution is through the OAPC (Ehsani & Mwaniki, 2015). The United Nations Environment Programme estimates particulate matter from transportation to be the greatest source of air pollution in Switzerland. This ordinance has an amendment that acts as a blanket statement for vehicle emissions. The amendment states that emissions that have no specified limit in the ordinance can be regulated by authorities as far as "technically and operationally feasible and economically acceptable" (Der Schweizerische Bundesrat [The Swiss

Federal Council], 2018, article 4, section 1). These vehicular emission regulations, in concert with emission regulations that require particulate filters on diesel engines, have been applied to reduce vehicular emissions that contribute to particulate matter concentrations in Switzerland. Some success has been seen from such policy, between 2008-2015 domestic carbon emissions went down by 5% (SWI, 2018).

Exposure limits have been mandated by the Swiss government for several types of PM by the regulatory agencies and policies mentioned above (Der Schweizerische Bundesrat, 2018). The Ordinance on Air Pollution Control has a particulate matter emission limit for engines fueled by diesel of 50 mg/Nm^3. The Swiss government has also established safe occupational exposure limits for multiple types of PM. These limits include 30 ppm of carbon monoxide, 5000 ppm of carbon dioxide, 30 μg/m^3 of nitrogen dioxide, 1.3 mg/m^3 of sulfur dioxide, 20 μg/m^3 of PM_{10}, 10 μg/m^3 of $PM_{2.5}$, 100 μg/m3 of ozone, and 0.1 mg/m^3 of diesel particulates.

Looking at 2016 NABEL data on nationwide PM levels measured at each of the sixteen NABEL monitoring stations, levels of multiple types of particulate matter exceed the regulatory limits (Federal Office for the Environment, 2016). Ozone levels far exceeded the regulatory limit of 100 μg/m^3, reaching values that exceeded 150 μg/m^3 in multiple regions in Switzerland. Nitrogen dioxide levels also exceed the regulatory limit of 30 μg/m^3 by minimal amounts, reaching up to 35 μg/m^3 in some areas. While measured PM_{10}, carbon dioxide, and sulfur dioxide concentrations did not exceed annual regulatory limits on average, they did exceed daily regulatory limits during June and July of 2016. Based upon the most recently available air quality data it is clear that while Swiss air quality often meets annual average concentration regulatory limits, there is still a great number of pollutants whose outputs could be reduced to meet mandated limits.

The European Environmental Agency (EEA) (2015) has estimated that over 5000 premature deaths occurred due to Swiss air quality during 2012. This indicates that the threat of air quality to public health is a legitimate concern, despite improvements made through legislation by the Swiss government within the last forty years. Additional legislation supported by public concern could be a possible route for further improvements to air quality.

2.4.2 Public Perception of Air Quality

Social action often motivates political action, and therefore data pertaining to public awareness and concern surrounding air quality has been of interest both in Europe and specifically in Switzerland (Dons et al., 2018). One method of quantitatively examining subjective public perception and concerns about air quality is through annoyance scores, which are ratings on a scale of one to ten where a subject denotes annoyance or sensitivity to air quality (Jacquemin et al., 2007). Jacquemin et al. discussed annoyance scores associated with air quality and demographics of European citizens. These annoyance scores were compared to different demographic data about each subject. Researchers observed a correlation across many categories; for example, smokers generally were less likely to report high levels of annoyance, while those exposed to environmental tobacco smoke were more likely to report high levels of annoyance. Not only did this study examine the correlation between demographics and air quality concerns, but researchers also made the general conclusion that "forty-three per cent of participants reported moderate annoyance" (p. 818), which led Jacquemin et al. to the conclusion that Europeans are moderately concerned about their air quality. Dons et al. (2018) found that 33% of surveyed residents of Zürich were concerned about the health effects of air pollution, echoing the concerns identified by Jacquemin et al. among Europeans.

Another study conducted by Oglesby et al. (2000) specifically studied the annoyance scores of Swiss residents in alpine, rural, and urban areas. This study developed a model that determined correlation, if any, between annoyance scores of Swiss residents, health problems, and measured PM levels. Oglesby et al. specifically examined levels of PM_{10} and nitrogen dioxide, Jacquemin et al. (2007) compared annoyance scores with levels of $PM_{2.5}$ and sulfur content, and Dons et al. (2018) gathered data based on levels of $PM_{2.5}$ and nitrogen dioxide concentrations.

Along with the study of different types and sizes of PM, these three public opinion studies also quantified "annoyance" of air quality in different terms. Jacquemin et al. (2007) quantified the public opinion of participants in terms of low, moderate, and high annoyance. Dons et al. (2018) asked participants if they were worried or not worried about air quality, which gave fewer options than the Jacquemin study. They surveyed 7622 people across Europe and found that 58% were concerned about air quality. In Zürich specifically, 33% of the 1007 respondents said they were concerned. Alternatively, the study conducted by Oglesby et al. (2000) quantified annoyance caused by air pollution by having participants rank their annoyance on an eleven-point scale. Each of these methods quantified annoyance in different ways, and each has its own merits because annoyance and public opinion is subjective. However, this makes it difficult to compare any of the public opinion studies in terms of public opinion alone.

Each study, rather than just determining arbitrary rankings of annoyance and worry towards air quality, sought to correlate public opinion with actual air quality measurements to assign validity to public opinion. Oglesby et al. (2000) validated public opinion by generating a regression of average annoyance scores against average PM concentrations and found a strong linear relationship and a high statistical correlation ($r > 0.85$). Jacquemin et al. (2007) conducted a similar statistical analysis of annoyance score data by comparing demographic data to public opinion data and air quality data to evaluate the validity of annoyance. This study found that 14% of the Europeans are highly annoyed by the air pollution among 7867 people, and more than half reported annoyance at some degree. These analyses allowed researchers to adequately quantify public opinion in terms of air quality and, in doing so, were able to reduce the subjective qualities attributed to public opinion data.

2.4.3 Knowledge Gaps

Swiss air quality has been improving since the implementation of regulations and standards, but more action needs to be taken to further reduce particulate concentrations that exceed regulatory limits (Federal Office for the Environment, 2016). As Swiss citizens elect their parliamentary representatives, they have a say in what their government does. It is clear that public opinion can influence policy decisions, and thus scientists have been motivated to gather data regarding public concern and the correlation between those concerns and air quality. However, information about public concern is limited. None of the annoyance score studies mentioned in section 2.4.2 compared annoyance scores to both $PM_{2.5}$ and PM_{10}, while it is known that both sizes of PM exist in Swiss air (Yue et al., 2018). Additionally, none of the public opinion studies examined whether respondents would like to learn more, and if so, how they would like to be further informed. Greenpeace International (2019), an environmental lobbyist group, mentioned in a report that “while the global health impacts of air pollution are dominated by $PM_{2.5}$, there are other air pollutants like ultrafine particles, nitrogen dioxide and ozone that pose severe health risks. Looking at $PM_{2.5}$ only does not give a complete picture of air quality and health risks in some regions with relatively low $PM_{2.5}$ levels” (para. 4). This assertion that the full extent of air quality cannot be determined by only looking at one type or size of particulate matter indicates that all types of particulate matter need to be considered when determining air quality.

Dons et al. (2018) asserted that data on subjective public perceptions of air quality "can be leveraged to engage citizens and stakeholders in support of cleaner air policies" (p. 591), and therefore they suggested it is valuable to gather public perception data for use by the Swiss government in making policy decisions. Knowledge of the level of public concern regarding air quality could grant insight into the perceived successes of existing Swiss policies mentioned in 2.4.1 and allow for a comparison between perception of policy successes and air quality improvements due to policy. The juxtaposition of public concern data, ambient particulate matter data, and data about how residents would like to be informed would allow for a broader picture of the relationship between Swiss air quality and public opinions about air quality.

2.5 Summary

Air pollutants exist all around us and can spread anywhere through the air. They come from many sources and can cause numerous health impacts, even death. Policies have been put in place to limit their impact, but standards are not being met. Research shows that residents are being affected by these air pollutants but are not necessarily knowledgeable about where the pollution is coming from or how they are being affected. In the following chapter we will explain the methods that we utilized to carry out research to determine how informed and concerned Swiss residents are about air quality in their country and what can be done to further inform them.

Chapter 3: Methodology

The goal of this project was to measure air quality in a number of locations in the greater Zürich area of Switzerland to determine the relationship between actual air quality and the public's opinion of air quality in those areas in order to recommend ways to improve public awareness of air quality issues. The objectives we identified to reach our goal were:

1. Determine air quality in different regions of the greater Zürich area;
2. Determine public opinion about air quality in different regions of Zürich;
3. Determine the relationship between measured air quality and public opinion;
4. Determine how to best inform the public about Swiss air quality.

In this chapter we describe the methods we used to achieve the above objectives and thus our goal.

3.1 Determining Air Quality

Air quality was evaluated in three locations in Zürich: ETH Hönggerberg, ETH Zentrum, and the Arboretum Zürich. The ETH Zentrum campus and Arboretum Zürich were chosen as urban sampling areas, and the ETH Hönggerberg campus was chosen as a suburban sampling location. Figures 3.1, 3.2, and 3.3 show the sites within each sampling location that were chosen for data collection.

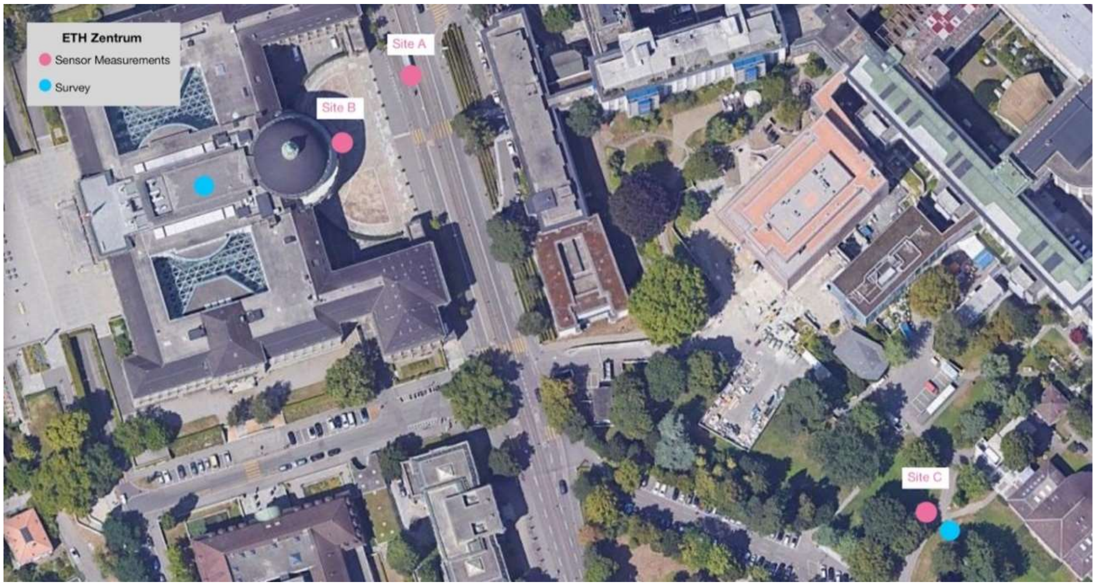

Figure 3.1: Satellite map of the ETH Zentrum campus with data collection sites labeled (Google Maps, 2019b). Site A shows measurements taken at a bus stop, Site B shows measurements taken next to a building, and Site C shows measurements taken in a greenspace.

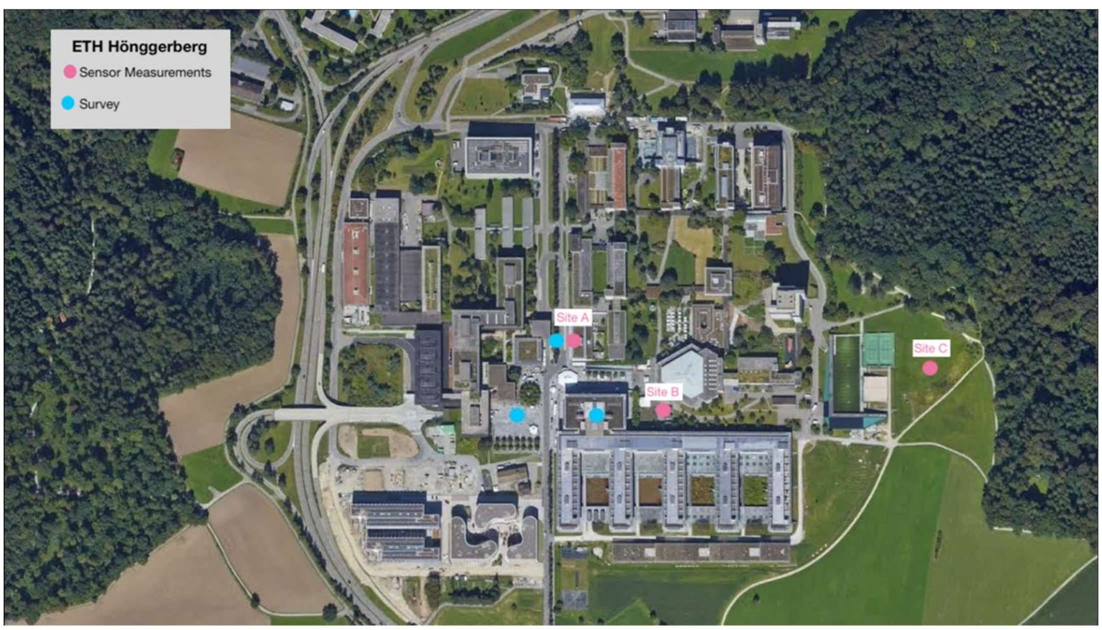

Figure 3.2: Satellite map of the ETH Hönggerberg campus with data collection sites labeled (Google Maps, 2019a). Site A shows measurements taken at a bus stop, Site B shows measurements taken in between buildings, and Site C shows measurements taken in a greenspace.

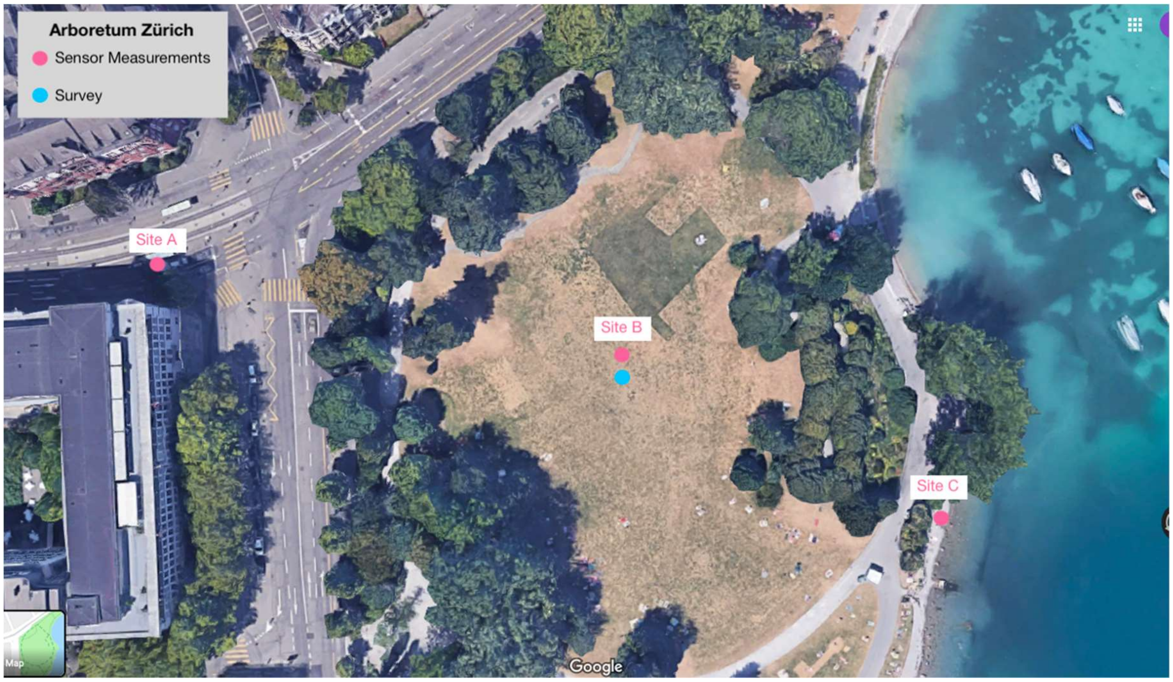

Figure 3.3: Satellite map of Arboretum Zürich location with data collection sites labeled (Google Maps, 2019c). Site A shows measurements taken at a bus stop, Site B shows measurements taken in a greenspace, and Site C shows measurements taken next to water.

Three different sensors were used to gather air quality data at these locations. The first sensor used to determine air quality was the senseBox (2019). Additional information about this sensor can be found in Appendix E. This sensor was programmed using Arduino IDE software and was programmed with a protocol to collect and store data in advance of data collection. The senseBox was equipped with a carbon dioxide (CO_2) sensor and two PM sensors. One PM sensor was more accurate than the other when compared to literature values and data collected by the Swiss government, but both were used so that there was a range of data for later comparison. Additionally, the device had a GPS sensor, that recorded coordinates at each site within each location, along with temperature and humidity sensors. The senseBox contained a micro SIM card allowing for data to be stored and uploaded to a computer. Measurements with the senseBox were obtained at three distinct sites within each of the three locations. The three sites within each location were chosen for their differences. One of the three sites was close to a road or bus stop, the second site was close to a residence or building, and the third site was close to a green space such as a park. This provided a range of data across all three locations. These measurements were taken for one hour at each of the three sites and were initiated by plugging the sensor into an external power source. One hour was the chosen duration due to fluctuations in measurements over time. Measurements using the senseBox were taken twice at each of the three sites.

The second sensor, the Temtop LKC-1000S Indoor Air Quality Monitor, measures PM_{10} and $PM_{2.5}$ concentrations in ambient air (Instrukart, 2019). Additional information about this sensor can be found in Appendix E. The Temtop is a handheld sensor that holds a charge and can be used for up to one full day, providing portability. This sensor was used at each of the three sites within each of the three locations. Scanning with this sensor occurred for three sets of two-minute durations at the same time as measurements with the senseBox. Measurements taken with the Temtop were conducted at the beginning of the hour-long senseBox measurements, at the thirty-minute mark, and at the end. The short duration of Temtop measurement was chosen due to the instrument's ability to quickly calibrate, as well as for practicality, as data on the instrument was not capable of being stored. These measurements were taken during the senseBox measurements to limit variance of data due to weather and time dependent changes in air quality. As the data from this sensor was not capable of being stored by the detector, one group member recorded readings, and the data were entered into a spreadsheet at a later time.

The dBluetech High BioTrap was the final air quality sensor used in this project (Beijing Dingblue Technology, 2017). Additional information about this sensor can be found in Appendix E. The sensor is a large flow bioaerosol sampler that passes ambient air through its sensor onto an agar plate. The agar plates were prepared in advance in an ETH Environmental Engineering laboratory space. One agar solution, Lucia Bertani Broth (LB), was chosen to gather bacteria; the other agar solution, PDA, was chosen to gather fungi. The LB solution was prepared by adding 5 g tryptone, 2.5 g yeast, 2.5 g sodium chloride, 7.5 g agar, a stirbar, and 500 mL of water to an Erlenmeyer flask. The PDA solution was prepared by adding 2 g potato extract, 10 g dextrose, 7.5 g agar, a stirbar, and 500 mL of water to an Erlenmeyer flask. Both solutions were then stirred and heated at 100 °C for ten minutes. After stirring the solutions at temperature, they were separated into four Erlenmeyer flasks and moved into a pressure oven. The oven was at 100 °C and ran for 90 minutes. Once the solutions were done in the pressure oven, they were moved to a sterile fume hood and poured into plastic petri dishes just enough to fill the bottom. Once filled, the petri dishes were covered and sealed with parafilm. After being sealed, the petri dishes were stored in a refrigerator until the day of use. To use the sensor, a petri dish with agar on it was placed into the BioTrap, and a scan was taken for one minute. Once scanning was complete, the agar plate was rewrapped in parafilm and returned to the lab. There, the plates were unwrapped and cultured. Finally, the presence of organisms on the plate was quantified. This method using the BioTrap sensor was conducted three times at each of the three sites of the three locations.

Before taking air quality measurements at each site, time and weather conditions were recorded. The senseBox recorded the temperature and the exact coordinates where measurements were taken using its thermometer and GPS sensors. Air quality measurements were taken twice at each site with the senseBox and Temtop, following the same methodology, to improve statistical significance of data.

3.2 Determining Public Opinion

In order to gather and determine public opinion of air quality, we conducted a survey, which used a questionnaire containing a series of closed questions seen in Appendix B. As part of the questionnaire, we gathered demographic data, including age and residency, in order to statistically group respondents based on demographic characteristics for the analysis described in section 3.3. We conducted our survey at the same three locations as air quality measurements. All surveys were conducted on weekdays from 10AM to 2PM. The raw data can be found in the Appendix N.

We administered the survey using quota sampling in every location. Our quota was at least twenty-five respondents at each location. The survey was administered in public spaces and ETH campuses to willing participants. We asked participants if they would rather take the questionnaire by scanning a QR code to a Google Form containing the questionnaire or by pen and paper. The questionnaire was offered in English and German, so participants chose the language they were most comfortable reading.

To administer the questionnaire, we broke into groups of two and stood in areas with many people, asking people walking by to participate. Before beginning the survey, we introduced ourselves and the goals of our project, using the scripted description at the top of the questionnaire (Appendix B). As all of the questions were closed the responses could be easily quantified. Our Google Form did not ask for a name, allowing all responses to remain anonymous.

We conducted interviews with three members of Dr. Prof. Wang's research team at the Institute of Environmental Engineering at ETH (Appendix C). Interviews with Dr. Prof. Wang's team allowed us to gather detailed information from experts about air quality. Additionally, we interviewed Dr. Prof. Ulrik Brandes at the ETH Social Science Department (Appendix D). This allowed us to obtain guidance about survey methods that reduce bias and produce data that was more statistically significant.

3.3 Determining the Relationship Between Air Quality and Public Opinion

In order to make accurate recommendations for how to best inform the Swiss public about their air quality, we first analyzed air quality data collected by the methods described in section 3.1. In this report, MATLAB R2018b was used for all air quality data analysis of data collected using the Temtop and senseBox air quality sensors (MathWorks Inc., 2019). We used line and bar graphs to visualize the concentration change of $PM_{2.5}$, PM_{10}, and CO_2 within an hour at each different location. We created comparative graphs to see the difference among sites within a location, and the differences among locations. We also utilized microorganism culturing, which allowed us to determine the composition of air samples collected using the BioTrap through laboratory analysis, including quantity of bacteria and fungi in the air.

We also compared our collected data with existing particulate matter data collected by NABEL, a part of the Swiss Federal Office for the Environment (2019c). NABEL uploads data in real time and the data are made publicly available via their website. By using data from this reliable source, we were able to better understand how representative our data truly were of air quality at the times when we collected data. We utilized NABEL data collected at two of their sixteen meteorological stations, the Dübendorf-Empa and Zürich-Kaserne monitoring stations, as they were the closest to the locations where we collected data.

Figure 3.4: The three red dots are the three different locations where we measured air quality, and the two blue dots are the two NABEL meteorological stations from which we accessed air quality data (Google Maps, 2019d).

The senseBox was calibrated at the Dübendorf-Empa air quality monitoring station. It was calibrated by taking a three-hour long measurement ten meters from the station. At the end of the three hours, the average PM concentrations collected by the senseBox were compared to the average PM concentrations collected by NABEL. By comparing our air quality data to data collected by NABEL, and using a calibration, we determined how accurate our sensor was at representing air quality at each of our three locations. This was particularly important because our data collection was only conducted with three portable sensors, each with varying accuracies.

We analyzed the results of the survey using statistical analysis, to find trends in our data. We separated nonresident responses to questions that focused specifically on Switzerland, so that our data would represent public opinion of Swiss residents. To represent our survey data, we created pie charts. Additionally, we examined the statistical significance of our findings in terms of the margin of error associated with our sample size given our population size. These graphical representations of our data, along with the statistical analysis of the significance of our survey results, allowed us to determine an approximation of the public opinion towards air quality. It also allowed for an understanding of topics on which the public was misinformed or uninformed, and how the public would like to receive air quality information in the future.

These two different types of data analysis, air quality and public opinion, were compared. This allowed us to determine if there were any correlations between public concerns and measured air quality, and how informed, or misinformed, Swiss residents were about their air quality. For example, our survey asked respondents if they believed federal limits on air quality were being exceeded. Additionally, we used data collected during the interviews with air quality researchers to examine assumptions and knowledge about public perception of air quality and compared this to our findings.

3.4 Determining How to Inform the Public about Swiss Air Quality

The relationships determined using the methods described in section 3.3 were used to draw conclusions and make recommendations for the best way to inform Swiss residents about their air quality. These recommendations were formulated based off of questions included in the survey which asked what media, format, and frequency residents would like to receive air quality information.

3.5 Summary

The main purpose of this project was to gain an understanding of air quality and public opinion about air quality in Zurich, Switzerland. This was achieved by gathering air quality and public opinion data. In the next chapter we will discuss the results of our research and analyze those results in order to arrive at recommendations for the best way to inform the Swiss public.

Chapter 4: Results and Analysis

The goal of this project was to measure air quality in a number of locations in the greater Zürich area of Switzerland to determine the best way to further educate Swiss residents about air quality. The objectives we identified to reach our goal were:

1. Determine air quality in different regions of the greater Zürich area;
2. Determine public opinion about air quality in different regions of Zürich;
3. Determine the relationship between measured air quality and public opinion;
4. Determine how to best inform the public about Swiss air quality.

In this chapter we describe the resulting data that we collected to achieve these objectives and our goal.

4.1 Determine Air Quality

Following the methodology, air quality was measured at three sites within three locations throughout the greater Zürich area. Three sensors were used to measure air quality across these locations and sites and measured for three types of pollutants: particulate matter, carbon dioxide, and microorganisms. These measurements and their meanings are examined in the following sections.

4.1.1 Particulate Matter Concentrations

We measured concentrations of $PM_{2.5}$ and PM_{10} in $\mu g/m^3$ at each site using both the senseBox and Temtop sensors. Concentrations of $PM_{2.5}$ were consistently lower than concentrations of PM_{10} with both sensors, due to the fact that PM_{10} also includes particles that are 2.5 micrometers or less. On average, the senseBox measurements were about 10-20 $\mu g/m^3$ lower than those recorded with the Temtop. Table 4.1 demonstrates the disparities between average senseBox measurements and average Temtop measurements. This table also demonstrates the disparity between measurements taken with either sensor (Appendices H and J). While the senseBox was a less expensive sensor, its technology was newer, which could explain why it had better accuracy than the Temtop. Additionally, particulates stuck in the Temtop, or human error caused by breathing too close to the sensor could have been behind less accurate readings. When comparing senseBox and Temtop data to data collected by NABEL, the senseBox data more closely matched the data collected by NABEL. This indicates that the senseBox was a more accurate tool for measuring air quality.

Table 4.1: Average concentrations of PM at ETH Hönggerberg Site A measured with both the Temtop and senseBox sensors.

	Temtop (μg/m^3)	senseBox (μg/m^3)
$PM_{2.5}$	22.5	7.3
PM_{10}	31.4	14.3

Measured $PM_{2.5}$ and PM_{10} concentrations were at or below Swiss federal pollutant limits for most locations and sites, 10 μg/m^3 for $PM_{2.5}$, and 20 μg/m^3 for PM_{10} (Der Schweizerische Bundesrat, 2018). The average PM_{10} concentrations collected with the senseBox at each site ranged from 7.8-14.3 μg/m^3, and the average $PM_{2.5}$ concentration ranged from 2.3-7.3 μg/m^3. On the other hand, average PM_{10} concentrations collected with the Temtop at each site ranged from 10.4-45.2 μg/m^3, and the average $PM_{2.5}$ concentration ranged from 7.4-32.2 μg/m^3 (see Appendices I and K for the full dataset). Figure 4.1 demonstrates data collected at ETH Zentrum Site C using the senseBox (see Appendix H). The line going through the data points in Figure 4.1 is an average of all of the data points collected in that data set. This average represents what the average ambient air quality was over the duration of one hour, which was then used for comparison with NABEL data.

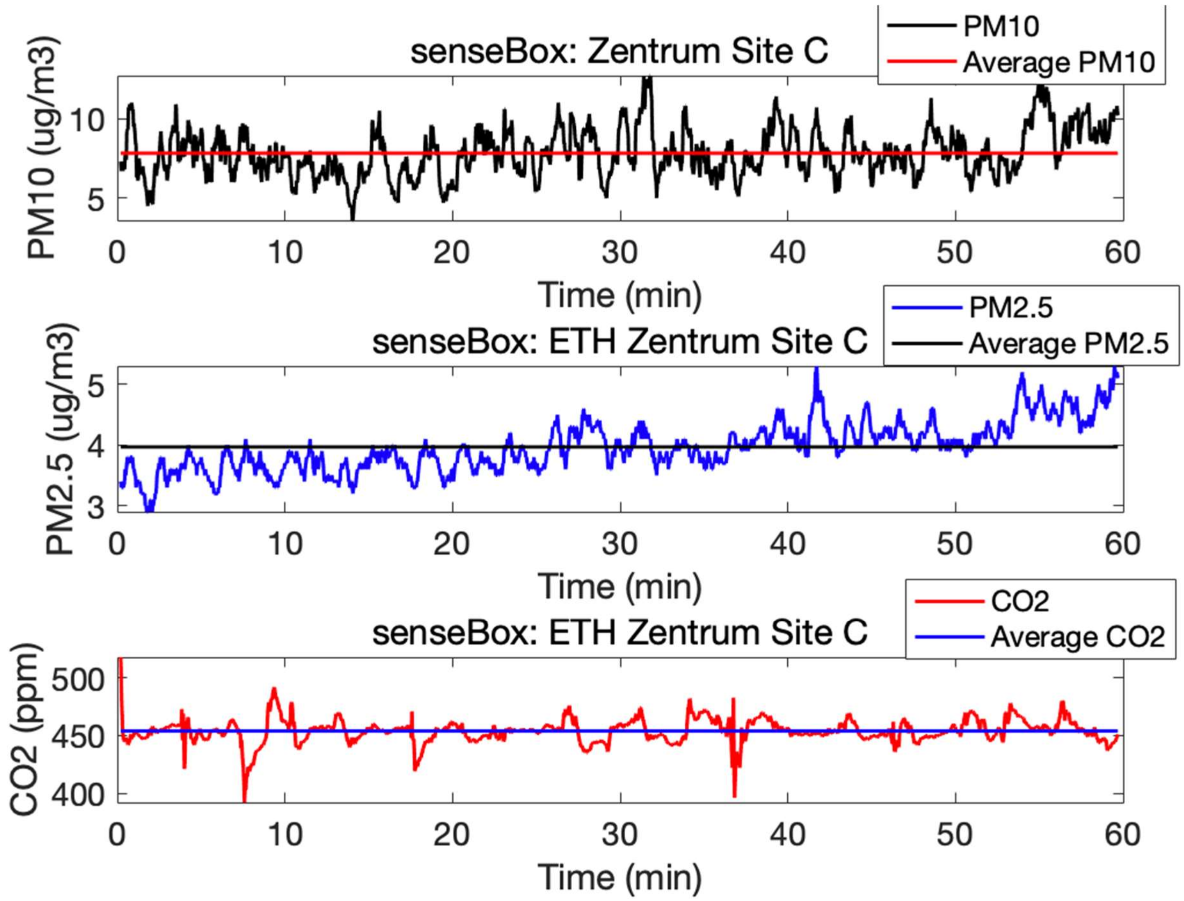

Figure 4.1: ETH Zentrum Site C $PM_{2.5}$, PM_{10}, and CO_2 concentrations as a measurement of time.

Figure 4.2 below shows that PM concentration is the highest at the ETH Hönggerberg campus. These data contradicted our expectations that the ETH Zentrum campus would be the most polluted area among the three locations. We observed that only buses, which are operated using gasoline, stop at the ETH Hönggerberg campus, while mostly trams, which are operated by electricity, stop at ETH Zentrum campus. The fact that electrically operated vehicles contribute less to particulate matter concentrations in the air could be the cause for the unexpectedly high PM concentration at the ETH Hönggerberg campus, despite it being in a less urban area. In addition to this, there were several construction projects taking place at Hönggerberg campus as the time of measurements. Foot traffic is also a factor that may influence PM concentration, as people may kick up dust and other particles as they walk by. However, at site A of all three locations foot traffic was about equal as people came and went to take the tram or bus, so this likely was not a factor in the unexpectedly high measurements of PM at the ETH Hönggerberg Site A.

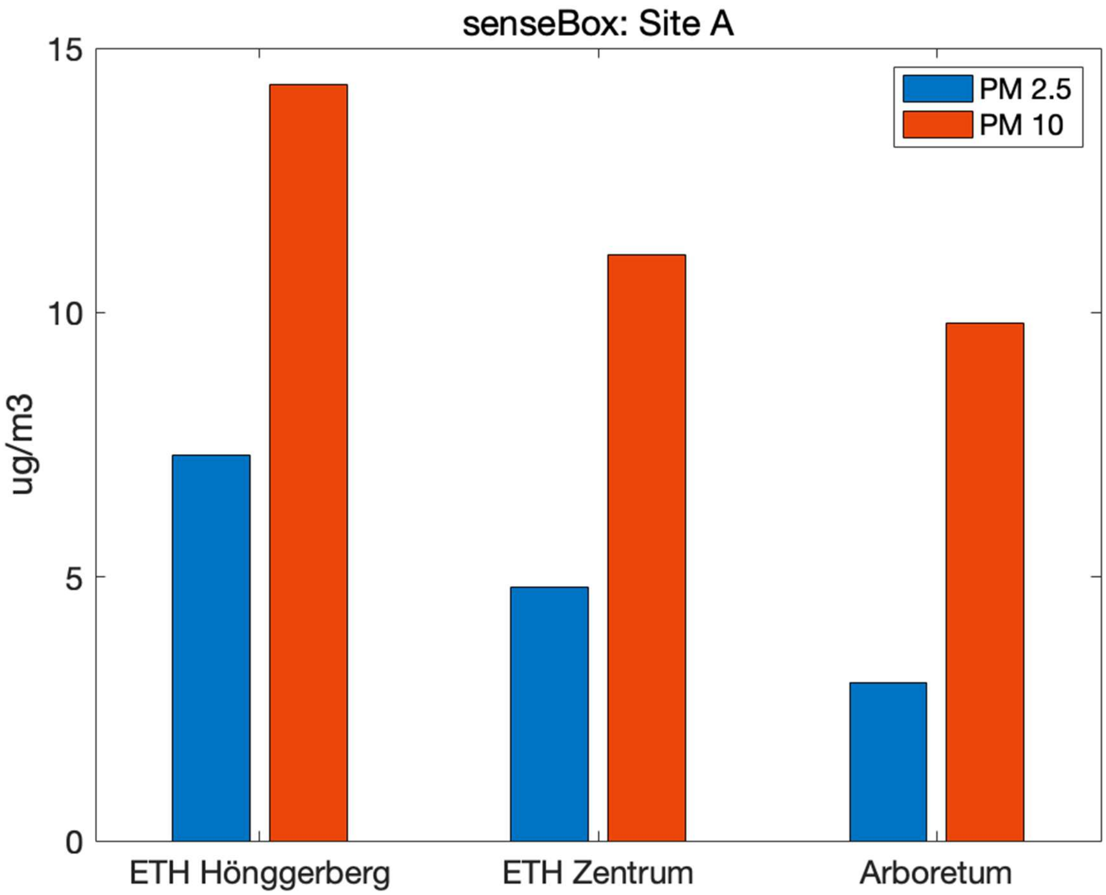

Figure 4.2: Average $PM_{2.5}$ and PM_{10} found using the senseBox at the ETH Hönggerberg, the ETH Zentrum and Arboretum Zürich locations. Each measurement was taken at a bus or tram stop.

The Dübendorf-Empa and Zürich-Kaserne NABEL meteorological stations were the two air quality testing stations run by NABEL that were closest to our data collection locations, as discussed in section 3.1. The Dübendorf-Empa station was closest to the ETH Hönggerberg location and the Zürich-Kaserne station was closest to the ETH Zentrum and Arboretum Zürich locations.

Table 4.2: A comparison of average air quality data for $PM_{2.5}$ that was collected by the senseBox and NABEL (Federal Office for the Environment, 2019c).

Air Quality Data Average Comparison $PM_{2.5}$

NABEL (μg/m^3)	Location and Site	senseBox (μg/m^3)
10.7	ETH Hönggerberg Site A	7.3
9.2	ETH Hönggerberg Site B	5.2
10.0	ETH Hönggerberg Site C	3.3
9.1	ETH Zentrum Site A	4.7
7.7	ETH Zentrum Site B	4.2
6.6	ETH Zentrum Site C	3.3
6.8	Arboretum Zürich Site A	3.0
6.1	Arboretum Zürich Site B	2.3
5.8	Arboretum Zürich Site C	2.2

Table 4.3: A comparison average of air quality data for PM_{10} that was collected by us and NABEL (Federal Office for the Environment, 2019c).

Air Quality Data Average Comparison PM_{10}

NABEL (µg/m^3)	Location and Site	senseBox (µg/m^3)
18.2	ETH Hönggerberg Site A	14.3
15.3	ETH Hönggerberg Site B	10.0
15.3	ETH Hönggerberg Site C	7.8
12.3	ETH Zentrum Site A	11.1
11.7	ETH Zentrum Site B	9.9
11.5	ETH Zentrum Site C	8.5
17.1	Arboretum Zürich Site A	9.8
15.1	Arboretum Zürich Site B	8.0
14.6	Arboretum Zürich Site C	8.5

Based upon the data found in tables 4.2 and 4.3, as well as Appendix I, the NABEL data were consistently higher than the data collected by the senseBox at both of the ETH locations. To investigate this difference, we conducted a calibration of the senseBox. Table 4.4 demonstrates the average concentrations of $PM_{2.5}$ and PM_{10} taken at the Dübendorf-Empa station by both NABEL and the senseBox during a calibration of the senseBox. The senseBox took measurements ten meters away from the NABEL meteorological station for three hours. This calibration allowed us to calculate a ratio to amend inaccuracies of our data. The senseBox consistently measured PM concentrations that were lower than the NABEL Dübendorf-Empa station, and as NABEL has much more expensive and sophisticated technology, the data that it collects is likely more representative of air quality. The senseBox data could then be divided by the calculated calibration ratio to adjust our data to more accurately reflect air quality.

Table 4.4: A comparison of averages of $PM_{2.5}$ and PM_{10} concentrations measured by NABEL and the senseBox (Federal Office for the Environment, 2019c) including the ratio of the senseBox data to the NABEL data.

PM Type	senseBox (μg/m^3)	NABEL (μg/m^3)	senseBox:NABEL
$PM_{2.5}$	3.59	6.35	0.57
PM_{10}	8.41	12.65	0.66

If corrected using these calibration ratios, the senseBox data is much closer to the data collected by NABEL at the same times, as can be seen in Table 4.5. Despite this calibration, however, the senseBox values were still slightly lower than the NABEL values as can be seen below. This comes as no surprise as our measurements were not taken at the NABEL meteorological stations, and air quality can differ greatly in even small distances due to factors such as human activity, construction, and traffic. This is supported by the differences in our measurements across sites within a location, as no site was more than two hundred meters from another. On the other hand, the NABEL stations were much farther than two hundred meters from where we collected our data.

Table 4.5: A comparison of average air quality data for PM_{10} that was collected by us and NABEL, and the calibrated senseBox values (Federal Office for the Environment, 2019c).

Air Quality Calibration Comparison for PM_{10} at the Arboretum Zürich

Site	NABEL (μg/m^3)	senseBox (μg/m^3)	Calibrated senseBox (μg/m^3)
A	17.1	9.8	14.74
B	15.1	8.0	12.03
C	14.6	8.5	12.78

Of the areas in which we measured air quality, we determined the ETH Hönggerberg Site A to have the highest concentration of $PM_{2.5}$ and PM_{10}. The Arboretum Site C had the lowest concentration of $PM_{2.5}$ and the ETH Hönggerberg Site C had the lowest concentration of PM_{10}. This made the Arboretum the location with the best air quality, and the ETH Hönggerberg campus the location with the worst air quality. We found that most of the air quality data that were collected did not exceed Swiss federal pollutant limits for PM, meaning that generally, air quality at all of the measuring locations and sites was good.

4.1.2 Microorganism Concentrations

The number of bacterial and fungal concentrations in the petri dishes we cultured showed varying levels of bioaerosols within the air at the three locations. The highest quantity of bacteria in a petri dish was over 100 bacterial colonies and was collected at the Arboretum Zürich Site B and can be seen in Figure 4.3. The Arboretum being the area with the highest concentration of bacteria is logical due to it being near a zoo, many people and trees, and being right near the water. The lowest quantity of bacteria in a petri dish was collected at Site B on the ETH Hönggerberg campus. This dish had only 1 bacterial colony. Images of the cultured petri dishes can be found in Appendix L, and tabulated counts of bacterial and fungal colonies can be found in Appendix M.

Figure 4.3: Cultured petri dish that was collected using the BioTrap at the Arboretum Zürich Site B with each circle representing a bacterial colony.

In respect to fungi, the petri dish with the most fungi had 8 fungal colonies and was from the ETH Zentrum Site C, which was a green space within a city. On the other hand, the petri dish with the fewest fungal colonies was collected at Site B building on the ETH Hönggerberg campus.

The two different solutions made in the laboratory for each petri dish allowed either bacteria or fungi to grow more successfully. The LB solution allowed bacteria to grow, while PDA allowed fungi to grow better. According to Dr. Yue Yang (personal communication, 2019, 13 September), bacteria or fungi could potentially grow on either dish, but with a very low success rate, only about 5% of bacteria or fungi found in the air are capable of being cultured in the dish, so these data were a small sample size of the greater number of bacteria and fungi found within the air at each location.

These quantities of bacterial and fungal colonies, while useful data for generally determining the air quality in an area, were only taken three times at each site. Additionally, each of the three trials were taken minutes apart. This means that these data are not necessarily representative of the air in these locations as a whole over longer durations. Some petri dishes also experienced overgrowth of spores, which reduced the accuracy of counting the colonies.

4.2 Determine Public Opinion

The survey conducted at each of the three locations to determine public opinion of air quality and how informed respondents were about air quality received a total of 80 responses. The following sections discuss the findings of this survey and interviews with air quality experts.

4.2.1 Survey Biases

A total of 80 people were surveyed: 30 from ETH Hönggerberg, 25 from ETH Zentrum, and 25 from Arboretum Zürich. Of these, 71 identified that they were or had been residents of Switzerland at the time of the survey. As can be seen in Appendix O, the demographic data collected in the survey was skewed towards residents of ages 15-25 due to the survey being conducted largely on university campuses. These data are not very representative of the Swiss public as a whole, as Switzerland has an aging population, and is therefore composed of a higher percentage of people over the age of forty than people below that age (Federal Department of Home Affairs, 2018). Our data had 47.5% female respondents and 52.5% male respondents, and was representative of Switzerland as a whole, as 50.5% of Swiss residents are women and 49.5% are men. Also, 49.4% of respondents were from an urban region, while 20.3% were from a rural region and 30.4% were from a suburban region. This allowed for a split of the regions of Switzerland and represented the locations we surveyed: two urban and one suburban. As 84.6% of Swiss residents lived in an urban area as of 2016, having a greater number of respondents from urban areas made our data more representative of the whole population that we were trying to represent through our sample.

4.2.2 Public Opinion on Air Quality

The public mostly felt that air quality in Switzerland was good, with 85% perceiving it as good or excellent. However, according to Dr. Xiaole Zhang (personal communication, 2019, September 17), this is not necessarily a reflection of the actual knowledge of the Swiss public, but rather could be a stereotype or assumption since Switzerland has a reputation for having good air quality. Despite the public's belief in there being good air quality, Figure 4.4 below demonstrates that 91.5% of Swiss residents surveyed were concerned about air quality. Additionally, the level of concern among respondents mainly fell within a moderate range, rather than high or low levels of concern. What the public was primarily concerned about was split between health and environmental concerns. Additionally, Figure 4.5 shows that 90% of respondents were not confident in their knowledge about Swiss air quality, as they felt they were only somewhat informed or not informed.

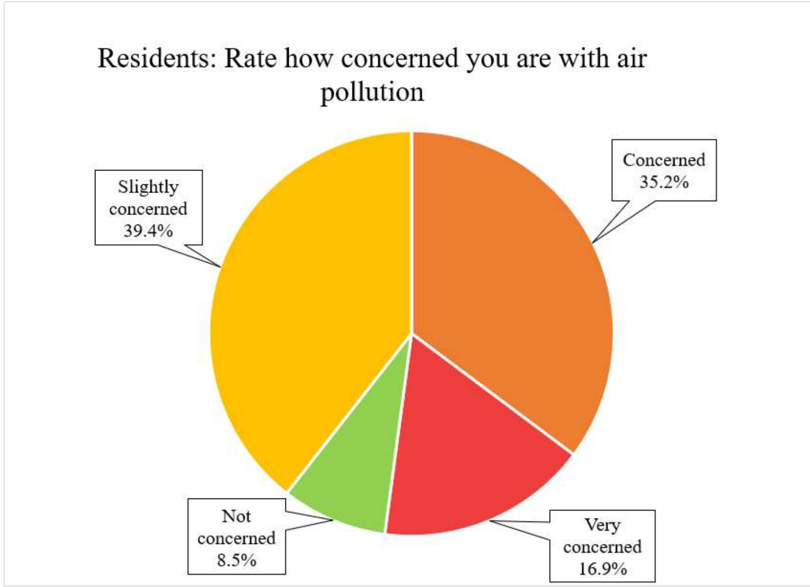

Figure 4.4: Percentage of responses to the survey question "Rate how concerned you are with air pollution." This chart only includes the 71 responses from current or past Swiss residents.

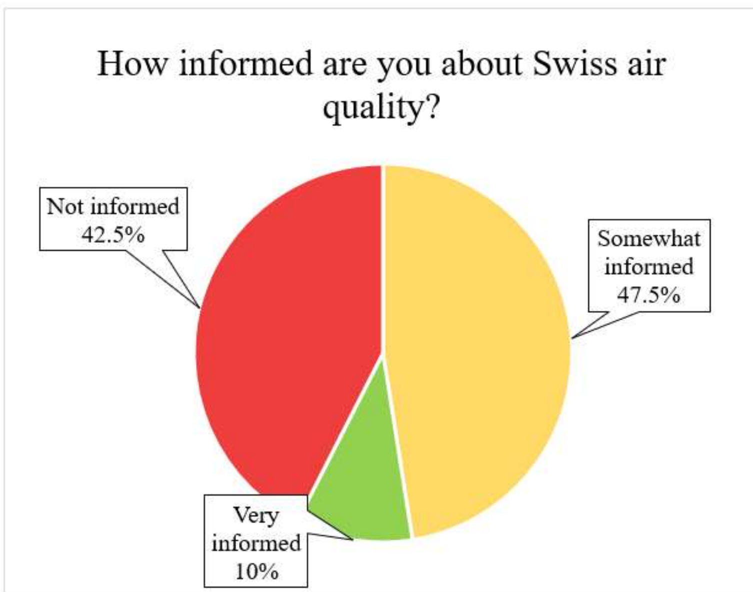

Figure 4.5: Percentage of responses (80) to the question "How informed are you about Swiss air quality?"

Through the survey, it became clear that the respondents were not familiar with publicly available air quality data. As can be seen in Figure 4.6, only 17.9% of respondents had ever looked at publicly available air quality data. This was likely due to a combination of respondents not knowing that the data was available and respondents simply not looking the data up.

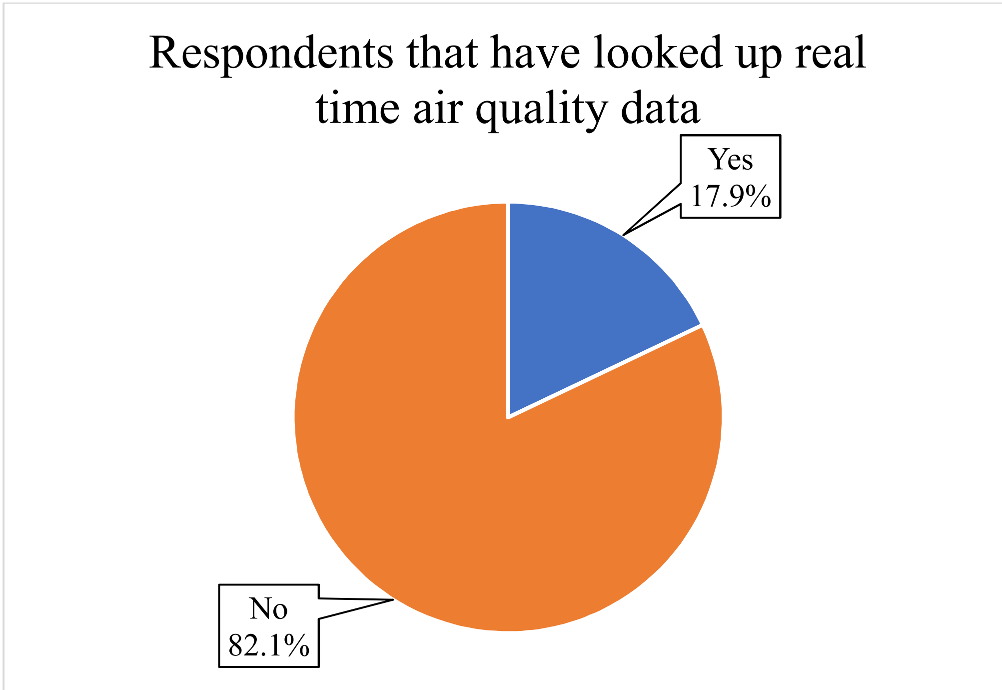

Figure 4.6: Percentage of respondents (out of 80) that have looked up real time air quality data. (This figure was created by merging the survey responses to "Is there somewhere you can look at real time data of local air quality data?" and "Have you ever looked up this data?")

Additionally, we interviewed three air quality experts, all of them part of Dr. Prof. Wang's team. Their responses can be seen in Appendix C. They generally believed the public would perceive their air quality as good, which was supported by the survey. All of them also thought that the perceptions about air quality would be better in Switzerland than in other places. Looking at the non-residents surveyed, only 66.7% thought their local air quality was good or excellent; however, all of them believed Swiss air to be good or excellent. Xiaoxiao Feng thought that people may be concerned about bioaerosols due to pollen, but that their knowledge of air quality may not encompass bioaerosols specifically. The survey showed that 51.3% of respondents did not know what a bioaerosol was at all, despite its effect on everyday life for many. This shows one aspect of air quality that the public could certainly be more informed about. When asked about what questions in our survey they considered to be the most significant, those interviewed believed information about how people want to be informed about air quality and how often was the most useful. This was due to the fact that being able to get information out there, to the general public, is ultimately the end goal of research and data collection. Additionally, the two interviewees that were asked accurately predicted that people would like to be informed through a smartphone application, since it is the most user-friendly option. One of them said she used the MeteoSwiss App for pollen forecasts.

4.2.3 Correlation Between Air Quality and Public Opinion

The data we collected demonstrates that Switzerland on average was below federal limits for concentrations of PM_{10} and $PM_{2.5}$. We were only able to collect data for two days at each location; however, there were general similarities between the data we collected in Zürich and the data reported by NABEL. To further understand trends in air quality, we would need to look at data from a longer time span to fully understand air quality in Zürich and its relationship to public opinion. Figure 4.7 shows average PM concentrations measured by the Dübendorf-Empa NABEL meteorological station from September 2018 through August 2019. The dashed line shows Swiss federal limits on the annual mean concentration of PM_{10}. As can be seen in the graph, only two months in the past year have exceeded this value. Additionally, the average concentration of PM_{10} over the past year was 14.94 $\mu g/m^3$, which is below federal limits. However, when the concentration of $PM_{2.5}$ over that twelve-month span was averaged, the value was 10.48 $\mu g/m^3$, which is slightly over the limit. It is also important to note that air quality during the time in which we gathered data was better than at the beginning of the year, and while in terms of PM_{10} this has no impact on the data exceeding the federal limits, it does have an impact on $PM_{2.5}$, which is exceeding the limits.

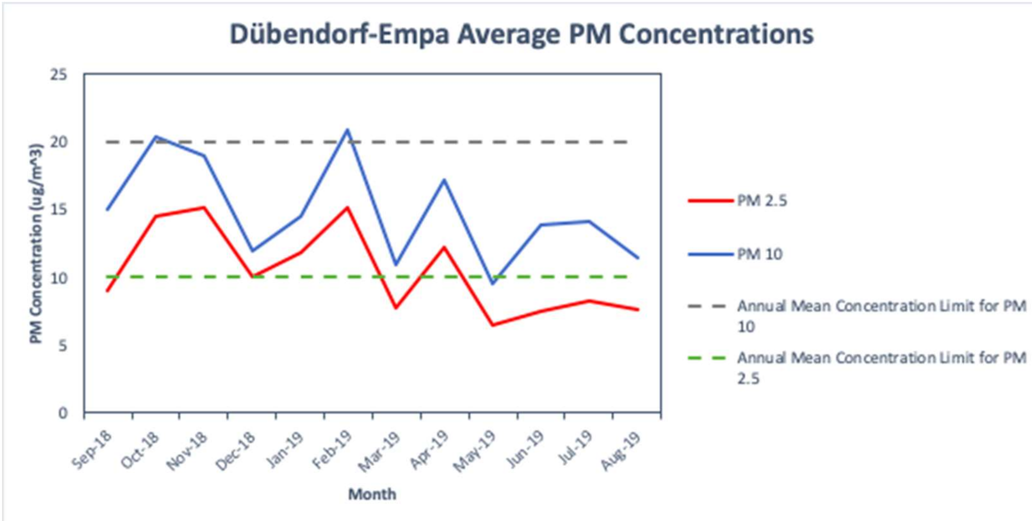

Figure 4.7: PM concentrations measured by the Dübendorf-Empa NABEL station from September 2018 through August 2019 (Federal Office for the Environment, 2019c).

Based upon this information, to conclude that air quality in Zürich is good year-round by only looking at the data that we collected over the course of several weeks would be incorrect. The NABEL data from a longer time period indicates that Swiss air quality still does exceed federal limits for PM during some months of the year, the problem being more prevalent for $PM_{2.5}$. Therefore, the fact that most respondents thought that Swiss air quality was good, despite the fact that over the past year, the federal limit for $PM_{2.5}$ has been exceeded, indicates that there is a gap between what respondents think about air quality and what that air quality truly is. This can be demonstrated when we examine what people answered when respondents were asked if they thought Swiss air quality exceeded federal limits; 55.1% said they thought it did. Moreover, 57.5% of respondents responded that they were either somewhat informed or very informed. However, 37.5% of respondents that said they were very informed and 31.6% of respondents that said they were somewhat informed responded that federal limits were not being exceeded. This divided opinion suggests there may have been people who believed they were informed, but that had inaccurate or incomplete information. However, more research through further surveys and air quality measurements would be required to fully understand why respondents answered the survey questions the way they did.

4.3 How to Best Inform the Public

According to the responses gathered through our survey, most respondents would like to receive information about air quality in a color rating scale or a numerical rating scale. Graphical organizations of these responses can be found in Appendix O and a tabulated version can be found in Appendix N. This means that they do not want a large amount of information about air quality, but rather a short indicator of the overall quality of the air at any given time. Many also said they would want it accessible as a smartphone application. Most of this information is already available on the MeteoSwiss smartphone application. The application contains a health tab, which has pollen, PM_{10}, NO_2, and ozone information. It uses data collected by the sixteen NABEL meteorological stations throughout Switzerland. Even though this application exists and is widely used by Swiss residents, many of our survey respondents either did not know that air quality information was available in the application already or had not looked at it. This indicates that improvements could be made to this already existing source of air quality information. For example, Figure 4.8 below shows a recommendation that would make air quality information more visible on the homepage of the application. In Figure 4.8, the left image is the original homepage and the image on the right is a recommendation for how the homepage could look to make air quality information more visible to the public. In the original version, only those concerned about their health will select the health tab and be able to see that the application contains air quality information. This would reduce the number of Swiss residents who would know that they have access to air quality information because it is likely that only those with preexisting health conditions, such as seasonal pollen allergies, would have an interest in looking at their air quality.

In order to increase the number of Swiss people who are viewing available air quality information the recommended homepage has a tab that goes directly to air quality, making it visible as soon as the application is launched.

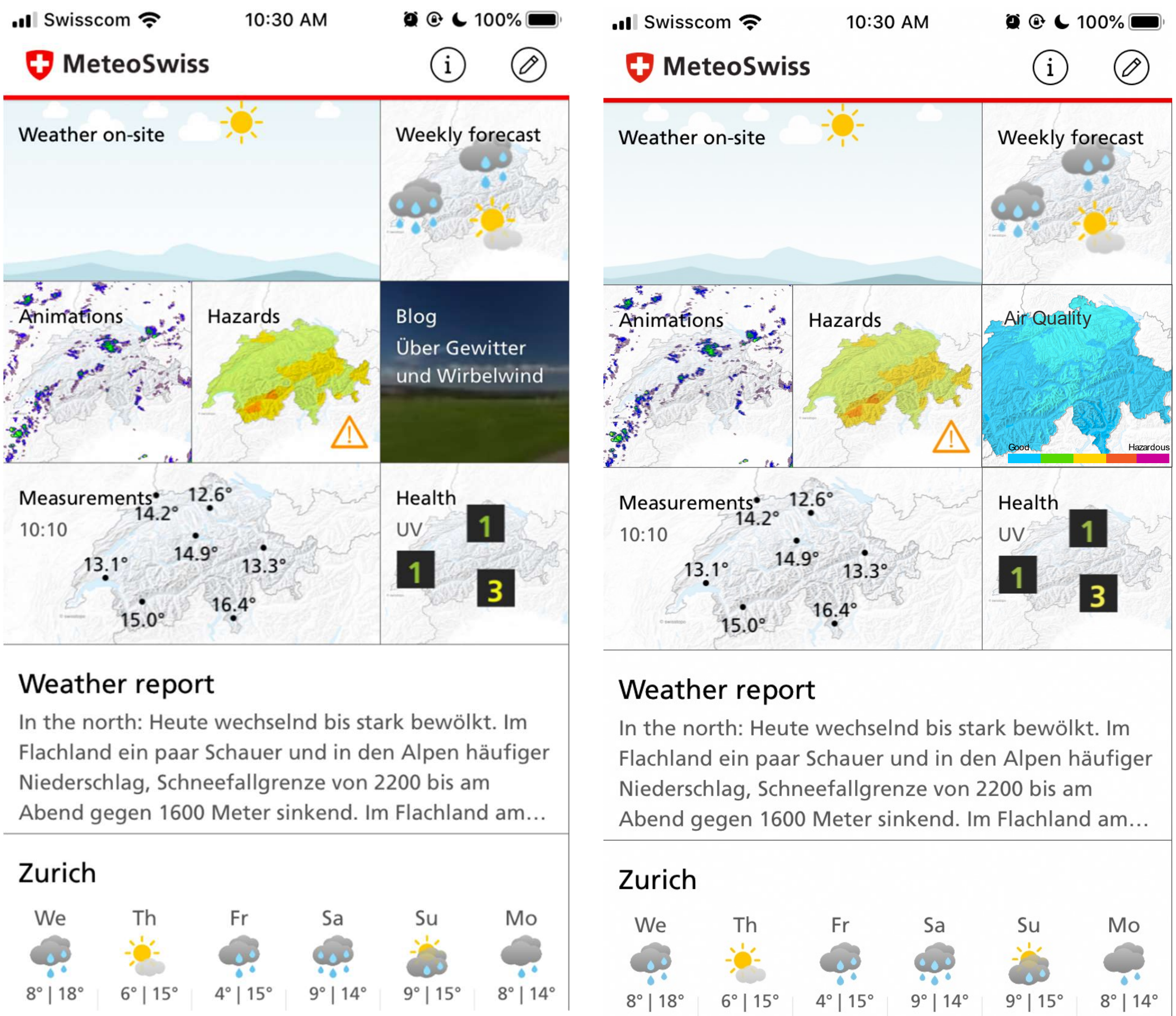

Figure 4.8: MeteoSwiss homepage with a more visible tab for air quality (Federal Office for Meteorology and Climatology MeteoSwiss, 2019). The original homepage is on the left and the recommended homepage is on the right.

In addition to making air quality information more visible on the MeteoSwiss smartphone application, we recommend that the air quality page have a more simplified rating scale and contain more air quality information. Figure 4.9 demonstrates the additions of $PM_{2.5}$ and SO_2 to the application, as this is data that NABEL already collects, making it more accessible in the application would be easy and help to further inform residents. Not only would the addition of this information help to further inform residents but, $PM_{2.5}$ concentrations denote finer particles than PM_{10} concentrations. Finer particles can penetrate more deeply into the lungs and pose greater health risks, which would also make this information useful to the Swiss public. Figure 4.9 also demonstrates improvements to the preexisting color rating scale that can be found in the air quality tab of the application. The current color rating scale contains sixteen different colors and six words to denote air quality, however these denominations of air quality are vague, and it is unclear which word belongs to which colors. To make it clearer, our recommendation contains a five-color rating scale with one word for each color.

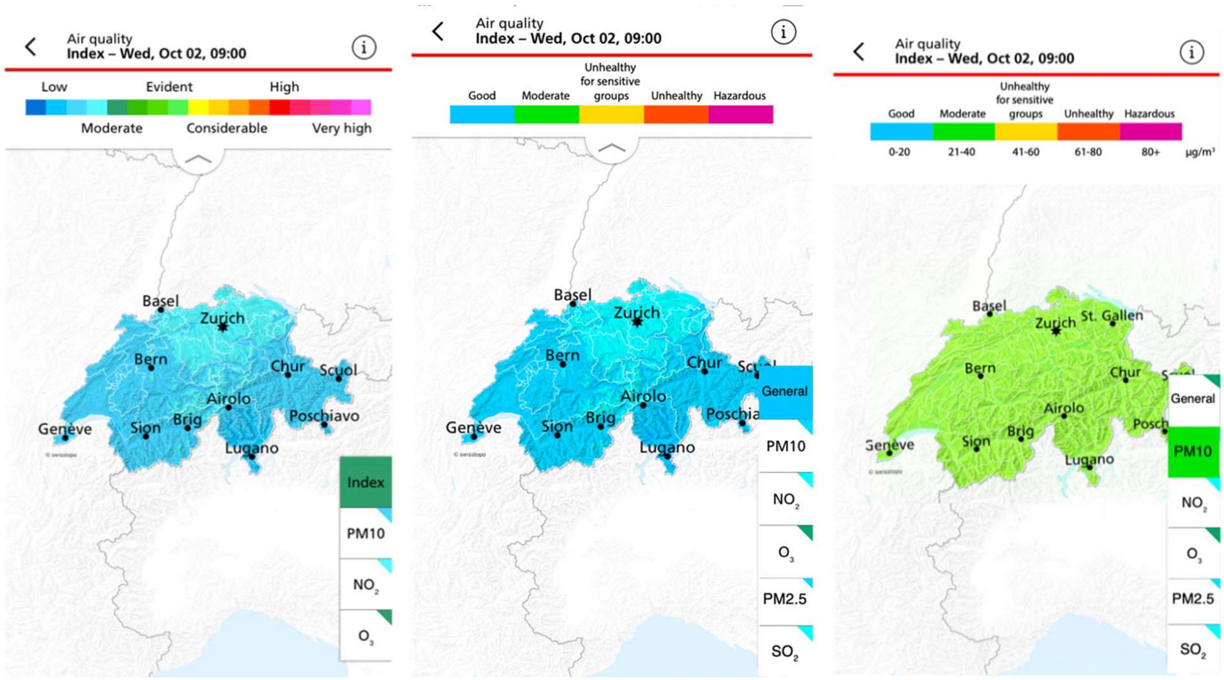

Figure 4.9: A recommended change to the air quality tab on the MeteoSwiss application (Federal Office of Meteorology and Climatology MeteoSwiss, 2019). The image on the left shows the original page, while the images in the middle and on the right show the recommended changes.

In addition to these changes made to the application to make air quality information more visible, we would recommend that in the information tab in the top right of the air quality section of the MeteoSwiss application includes basic information about what each type of pollutant means. The information could include facts that denote health hazards of each pollutant and give the federal limits for each pollutant. This tab could also include information about bioaerosols and what they are, as most survey respondents were either unfamiliar with the term altogether or not clear on what the term meant. This would make information accessible to those interested in learning more about air quality.

4.4 Summary

The goal of this project was to determine if there is a relationship between actual air quality and public opinions about air quality in Switzerland. Through an examination and analysis of both air quality and public opinion data, we were able to determine what the Swiss public knows and does not know about their air quality. In the following chapter we will discuss the implications of the findings of this research, the best way to inform the Swiss public about air quality, and how this research could be continued.

Chapter 5: Conclusions and Recommendations

Based upon the findings of our research, the Swiss people correctly believe that Swiss air quality is good; however, they do not feel well informed about actual detailed Swiss air quality indicators. This chapter will discuss the findings of our research.

5.1 Air Quality

Air quality data were collected in three different locations within the greater Zurich area. Generally, air quality at the three sites was good, falling below federal PM limits. NABEL data also fell below federal PM limits at the time of our data collection. Looking at data collected over a longer term than was conducted through our research showed that over the past twelve months there have been several instances in which Swiss air exceeded federal limits for both $PM_{2.5}$ and PM_{10}. In addition, data collected by NABEL over the past year for $PM_{2.5}$ slightly exceeded the mean federal limit of 10 $\mu g/m^3$. This indicated that while the air quality we measured was good, Swiss air quality over a longer time period was not perfect and could be improved.

5.2 Public Opinion

Our survey of public opinion was conducted in the same three locations as the air quality data we collected. When we asked respondents what the air quality was like in Switzerland, the most common answer was that the air quality was good. As a majority of respondents felt only somewhat informed or not informed at all about actual air quality indicators, it seems that while respondents thought Swiss air quality was good, they did not have this idea based on knowledge about Swiss air quality data. This shows a lack of knowledge among the Swiss public, indicating that the public needs to be more educated about air quality in general. This way they can better understand the consequences of air quality such as the environmental impact and personal health impact. Being more educated about air quality would allow Swiss residents make more informed decisions in terms of their health and safety. For example, given that agriculture can have an impact on children with asthma, an informed citizen could move to somewhere where they would be less exposed, or take measures against exposure. In addition to being able to make more informed decisions about personal health, Swiss residents educated about air quality could actively participate in the policy change necessary to further improve Swiss air quality. Finally, since the majority of respondents were concerned, this suggests they may be interested and open to learning more.

5.3 Correlation Between Air Quality and Public Opinion

People's general perceptions about air quality do, for the most part, match the actual air quality data. While information about air quality is plentiful and widely accessible on the NABEL website and some information is available in the MeteoSwiss application, it seems that a large percentage of Swiss residents may not know this, and even more may not look at this information. The information on both the NABEL website and MeteoSwiss application requires clicking through several pages, requires knowledge of particulate types, and thus is not the easiest way to quickly find out about at local air quality. If the Swiss government were to aim to reach a larger audience, rather than those highly interested and knowledgeable about air quality or already informed on the matter, they could provide data in a more quick, accessible, and digestible format for the average Swiss resident.

5.4 Recommendations for How to Inform the Public

Based on the ways in which our survey respondents wanted to be informed we recommend that additions be made to the existing MeteoSwiss smartphone application. This application, while already containing some air quality information, does not make air quality information immediately visible and only displays certain types of pollutants. We recommend that the air quality information be moved to the homepage, so it is immediately visible, and that the color rating scale currently provided have a reduced number of colors in order to be clearer. Additionally, the application can have further information available about air quality to anyone interested in being more informed. These changes will not only advertise air quality information in the application in a better way but will also encourage Swiss residents to take an active role in becoming informed about their air quality.

We also recommend that the survey be administered again under a different protocol for a more accurate representation of Swiss public opinion. Given the small sample size of 80 respondents for the survey in this research, the data we collected had a high margin of error. Switzerland has approximately 8.5 million residents (United Nations, 2019). Using all residents of Switzerland as the population size in this survey means that with 80 respondents at a 95% confidence level, there was an 11% margin of error (SurveyMonkey, 2019). The margin of error indicates what the percentage range for a certain answer to a survey question would have been if the entire population had been surveyed. This means at an 11% margin of error, there would be a 22-percentage point range for the responses to each question. This is quite a large number and gives a large amount of uncertainty to our findings. In addition to this error, this survey was not randomized and therefore had many biases associated with it (Appendix D). Only willing participants responded, which means those uninterested in the topic were much less likely to participate. If this research were to be continued, a sample size of 390 respondents for the survey would reduce the margin of error of the survey to 5%, and a completely randomized admin listration of the survey would ensure results that more accurately reflect Swiss public opinion of air quality. The recommended distribution of information about air quality would then update to reflect the findings of this survey.

5.5 Summary

In this research we found that while generally good, Swiss air quality does sometimes exceed federal limits. We also determined that the respondents of our survey wanted to be informed about air quality in an accessible and straightforward way. In conclusion, while our findings allow a glimpse into what the Swiss public wants, and needs, to know about air quality in Switzerland, this study would need to be done on a larger scale to conclusively determine how best to inform residents about air quality. A continuation would be beneficial to this research as an informed public can make informed decisions about their air quality and influence change to further improve their air quality.

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Appendix A: Sponsoring Agency

The sponsor of this project is the Swiss Federal Institute of Technology in Zürich (ETH Zürich), specifically the Institute of Environmental Engineering (IfU). The IfU teaches students in disciplines of environmental engineering while also conducting scientific research in the fields of hydrology, water resources, hydromechanics, earth observation, remote sensing, industrial ecology, environmental fluid mechanics and urban water management (ETH Zürich, 2019). ETH Zürich is one of two federal institutes of technology in Switzerland. The Institute is a public university and is one of the world's leading institutions in science and technology (QS Top Universities, 2019). Being a public university means that it is a non-profit organization. We will be working directly with Prof. Dr. Jing Wang who is the Chair of Industrial Ecology at the university. His group's research mission is to "contribute to understanding of environmental, health and safety (EHS) impact of nanomaterials" through studies of airborne particulate matter (ETH Zürich, 2019, para. 1). Prof. Dr. Wang's research interests have previously been funded by the Swiss National Science Fund for Distinguished Young Scholars, the National Natural Science Foundation of China, the Ministry of Science and Technology, the European Community's Seventh Framework Programme, and the National Science Foundation (Yue et al., 2018).

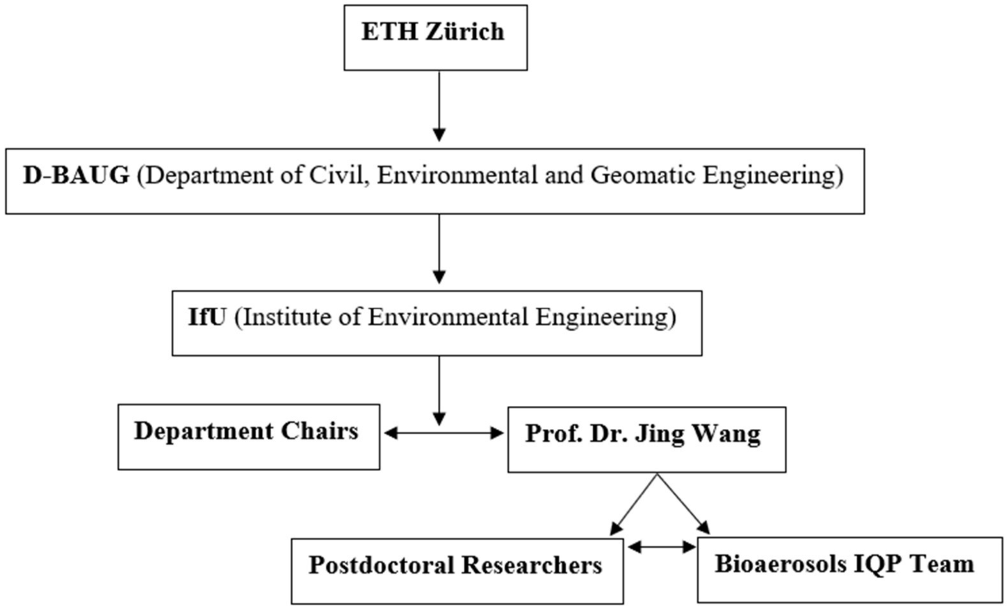


Figure A.1: Administrative structure of ETH Zürich (ETH Zürich, 2019).

The above figure outlines the structure of our sponsor's organization. We will be working at ETH Zürich, specifically under Prof. Dr. Jing Wang. He is one of the chairs in the IfU and we will be collaborating with his postdoctoral researchers. ETH Zürich (2019) is a university for science and technology with around 11,000 total personnel, over 500 of whom are professors.

Most of the resources used for conducting our IQP will be provided by ETH Zurich, including laboratory spaces on campus, handheld particulate matter sensors, electron microscopes, and modeling software. All of these resources are currently used in the data collection protocols enacted by Prof. Dr. Jing Wang's research group.

In Switzerland, air pollution is considered as a serious problem (Swiss TPH, 2019). There are several non-profit organizations committed to improving air quality, including the Swiss TPH, the Swiss School of Public Health, and Geneva University. These organizations collaborate with our sponsor, ETH Zürich, in a joint effort to contribute to improving teaching and training in the fields of air pollution exposure, epidemiology, risk assessment and policy making.

Appendix B: Public Opinion Questionnaire

Project description: We are a group of students from Worcester Polytechnic Institute in the United States. We are working in collaboration with ETH on a two-month research project to determine what the public opinion of air quality is in several locations in Switzerland and to take air quality measurements. The findings of this research will be published by our university.

This five-minute survey is about your opinions of air quality in Switzerland. All responses will be kept anonymous and will only be used for statistical analysis to help us complete our project and to help ETH to identify air quality problems in Switzerland. This survey is completely voluntary; you may terminate participation at any time and skip any question(s) which you do not feel comfortable answering. If you have any questions at any time, please feel free to ask us, we can also be reached at gr-Bioaerosols-IQP@wpi.edu. Thank you!

1. What is your age?
    - 15-25
    - 26-35
    - 36-45
    - 46-55
    - 56-65
    - 66 +
    - Prefer not to answer
2. What gender do you identify with?
    - Female
    - Male
    - Other (ex. Gender non-binary): ___________
    - Prefer not to answer
3. Are you a resident or have you ever been a resident of Switzerland?
    - Yes
    - No

a. What country are you a resident of?
    - Country name: ________________________

4. What type of region are you from?
    - Urban
    - Suburban
    - Rural
5. Rate how concerned you are about air pollution?
    - Not Concerned
    - Slightly Concerned
    - Concerned
    - Very Concerned

a. Please check the primary reason why you are concerned.
    - Health
    - Environmental concerns
    - Quality of life
    - Other:_______________

6. How often do you think about the air quality in Switzerland?
    - Daily

- Weekly
- Monthly
- Yearly
- Never

7. What is the air quality like in the town/city where you are living?
    - Excellent
    - Good
    - Acceptable
    - Poor
8. What is the air quality like in Switzerland in general?
    - Excellent
    - Good
    - Acceptable
    - Poor
9. How informed are you about Swiss air quality?
    - Very informed
    - Somewhat informed
    - Not informed at all
10. Switzerland has federal limits on air pollution. Do you think these limits are being exceeded?
    - Yes
    - No
11. Is there somewhere that you can look at real time data of local air quality?
    - Yes
    - No

a. Have you ever looked up this data?
    - Yes
    - No

12. Do you know what a bioaerosol is?
    - Yes
    - I have heard the term, but I am not familiar with it
    - No
13. If you were to receive information on local air quality, how would you like to receive it?
    - Newspaper
    - Smartphone app
    - Website
    - Text alerts
    - Other _______________
14. If you were to receive information on local air quality, how detailed would you like it to be?
    - Color rating scale of air quality (Ex. green is good, red is bad)
    - Numeric rating scale of air quality (Ex. 1 is good, 5 is bad)
    - One word indicating air quality (Ex. good, moderate, bad)
    - No more than a sentence
    - A few sentences

15. If you were to receive information on local air quality, how often would you like to receive it?

- Daily
- Weekly
- Monthly
- Yearly
- Other ____________

German Version

Projektbeschreibung: Wir sind eine Gruppe von Studenten des Worcester Polytechnik Instituts in den USA. Wir führen ein Wissenschaftsprojekt in Zusammenarbeit mit der ETH durch, in dem wir bestimmen wollen, wie die öffentliche Meinung der Luftqualität in einigen Orten der Schweiz ist und um die Luftqualität zu messen. Die Ergebnisse unserer Arbeit werden von unserer Universität veröffentlicht.

Diese 5-minütige Umfrage zielt darauf ab, Ihre Meinung der schweizer Luftqualität zu ermitteln. Alle Antworten werden anonym behandelt und werden ausschliesslich für statistische Analysen unseres Projektes verwendet, sowie für die ETH, um die Probleme der Luftqualität in der Schweiz zu untersuchen. Diese Umfrage ist vollkommen freiwillig; Sie können jederzeit die Teilnahme abbrechen und Fragen überspringen, die Sie nicht beantworten möchten. Bei Fragen können Sie sich jederzeit an uns wneden, auch unter der E-Mail-Adresse: gr-Bioaerosols-IQP@wpi.edu. Vielen Dank!

1. Wie alt sind Sie?
   - 15-25
   - 26-35
   - 36-45
   - 46-55
   - 56-65
   - 66 +
   - Keine Angabe

2. Mit welchem Geschlecht identifizieren Sie sich?
   - Weiblich
   - Männlich
   - Andere: ___________
   - Keine Angabe

3. Leben Sie oder haben Sie jemals in der Schweiz gelebt?
   - Ja
   - Nein

a. In welchem Land leben Sie?
   Land: ________________________

4. Aus welcher Region stammen Sie?
   - Städtisch
   - Vorstädtisch
   - Ländlich

5. Bewerten Sie, wie besorgt Sie über die Luftverschmutzung sind.

- Nicht besorgt
- Etwas besorgt
- Besorgt
- Sehr besorgt

a. Bitte kreuzen Sie den hauptsächlichen Grund für die Besorgnis ein?

- Gesundheit
- Umwelt
- Lebensqualität
- Andere:_______________

6. Wie oft denken Sie an die Luftqualität in der Schweiz?
   - Täglich
   - Wöchentlich
   - Monatlich
   - Jährlich
   - Nie
7. Wie ist Ihre Auffassung der Luftqualität in der Stadt/Gegend, in der Sie leben?
   - Ausgezeichnet
   - Gut
   - Akzeptabel
   - Gering
8. Wie ist Ihre Auffassung der allgemeinen Luftqualität in der Schweiz?
   - Ausgezeichnet
   - Gut
   - Akzeptabel
   - Gering
9. Wie gut informiert sind Sie, Ihrer Meinung nach, über die Luftqualität in der Schweiz?
   - Sehr gut informiert
   - Etwas informiert
   - Nicht informiert
10. Die Schweiz hat bundesweite Grenzen für den Grad der Luftverschmutzung. Denken Sie, dass diese Grenzen überschritten werden?
    - Ja
    - Nein
11. Gibt es eine Möglichkeit, sich Echtzeit-Daten über die lokale Luftqualität anzuschauen?
    - Ja
    - Nein
      1. Haben Sie sich diese Daten jemals angeschaut?
    - Ja
    - Nein
12. Wissen Sie was ein Bioaerosol ist?
    - Ja
    - Ich habe davon gehört, bin aber nicht vertraut damit
    - Nein

13. Wenn Sie Informationen über die lokale Luftqualität erhalten möchten, wie würden Sie diese gerne bekommen?

- Zeitungen
- Smartphone App
- Internetseiten
- Textbenachrichtigungen
- Andere ______________

14. Wenn Sie Informationen über die lokale Luftqualität erhalten, wie detailliert sollten diese sein?

- Farbencode für die Luftqualität (z.B. „grün" bedeutet gut, „rot" bedeutet schlecht)
- Numerische Bewertungsskala der Luftqualität (z.B. „1" bedeutet gut, „5" bedeutet schlecht)
- Ein Wort für die Luftqualität (z.B. „gut", „mässig", „schlecht")
- Nicht mehr als ein Satz
- Ein paar Sätze

15. Wenn Sie Informationen über die lokale Luftqualität erhalten, wie oft möchten Sie diese bekommen?

- Täglich
- Wöchentlich
- Monatlich
- Jährlich
- Andere ____________

Appendix C: Interviews with Air Quality Experts

Project description: We are a group of students from Worcester Polytechnic Institute in the United States. We are working in collaboration with ETH on a two-month research project to determine what the public opinion of air quality is in several locations in Switzerland and to take air quality measurements. The findings of this research will be published by our university.

This interview is about your opinions on the perception of air quality in Switzerland, and it is for us to further understand the potential results of our survey. This interview is completely voluntary; you may terminate participation at any time and skip any question(s) which you do not feel comfortable answering. If you have any questions at any time, please feel free to ask us, we can also be reached at gr-Bioaerosols-IQP@wpi.edu. Thank you!

Location of Interview: ETH Hönggerberg IfU

Interviewer: Luis D Sanchez

Interviewee: Alix Grünhagen

1. Where do you currently live?

Zurich, Switzerland

2. What do you think the perception of air quality is in Switzerland? Do you think this perception differs across certain demographic groups (i.e. people of different ages)?

Alix thinks it depends on age, people over 80 for example are not informed much about air quality and may think that the air quality is worse than it actually is, younger people may think it is bad as well. The media and newspapers may give people this idea.

3. Based on our questionnaire, what do you think the potential results and main takeaways of our study will be?

She said that the results will serve us to evaluate where people are coming from would allow for a better way to analyze public opinion. In addition, studying how people want to be informed would allow us create an outlook for the future and know what to do going forward in terms of informing the public.

4. Do you think that there are misconceptions among Swiss residents about the air quality in Switzerland?

Alix believed that Switzerland has good air quality compared to China and in general Switzerland is working on improving air quality.

Question 5 had not been added as a question at the time of this interview.

Location of Interview: ETH Hönggerberg IfU

Interviewer: Luis D Sanchez

Interviewee: Xiaoxiao Feng

1. Where do you currently live?

Zurich, Switzerland

2. What do you think the perception of air quality is in Switzerland? Do you think this perception differs across certain demographic groups (i.e. people of different ages)?

Xiaoxiao said people think air in Switzerland and in Zurich is good. Demographics matter, like where you come from. For her, growing up in China, a polluted area, sees the air quality in China was very bad and in Zurich it is very good in contrast.

3. Based on our questionnaire, what do you think the potential results and main takeaways of our study will be?

She said the most important question we have is how people want to be informed because it is very important to know how to get the information out there. And what she thinks is that most people would answer that they want a smartphone app. Also, the end goal of data collection is to get the information to the public.

4. Do you think that there are misconceptions among Swiss residents about the air quality in Switzerland?

She believes that most people are concerned about specifically the pollen component of bioaerosols because of how many common allergies there are. Something important is for people to broaden the idea of what air quality encompasses.

5. Are there any weather or air quality apps you use and / or recommend? What do you like and dislike about them?

She uses MeteoSwiss and thought it is more accurate than the iPhone's weather app and it's user friendly. She uses it for the pollen forecast.

Location of Interview: ETH Hönggerberg IfU

Interviewer: Luis D Sanchez

Interviewee: Huan Liu

1. Where do you currently live?

Zurich, Switzerland

2. What do you think the perception of air quality is in Switzerland? Do you think this perception differs across certain demographic groups (i.e. people of different ages)?

She thought that the perception of the air quality in Zurich and Switzerland would be good and better than many places. Children may be more sensitive to air quality.

3. Based on our questionnaire, what do you think the potential results and main takeaways of our study will be?

She thought the questions about how people want to get air quality information would be useful. Most would probably like an app for looking at data.

4. Do you think that there are misconceptions among Swiss residents about the air quality in Switzerland?

She thought they would be well informed

5. Are there any weather or air quality apps you use and / or recommend? What do you like and dislike about them?

She has used weather apps but doesn't currently. She thought it would be good to see air quality data about $PM_{2.5}$ and PM_{10}.

Appendix D: Interview of a Social Science Professor

Project description: We are a group of students from Worcester Polytechnic Institute in the United States. We are working in collaboration with ETH on a two-month research project to determine what the public opinion of air quality is in several locations in Switzerland and to take air quality measurements. The findings of this research will be published by our university.

This interview is about your opinions on the perception of air quality in Switzerland, and it is for us to further understand the potential results of our survey. This interview is completely voluntary; you may terminate participation at any time and skip any question(s) which you do not feel comfortable answering. If you have any questions at any time, please feel free to ask us, we can also be reached at gr-Bioaerosols-IQP@wpi.edu. Thank you!

Location of Interview: ETH Zentrum

Interviewer(s): Jocelyn Mendes and Luis D Sanchez

Interviewee: Dr. Prof. Ulrik Brandes

1. **Could you tell us a little about your social science work?**

Professor Brandes has a background in computer science but now studies social networks, including the best ways to administer surveys.

2. **Discuss and go over survey with the professor.**

Professor Brandes discussed the biases associated with our questionnaire. Some of the wordings can introduce systematic biases because respondents will try to answer with what they believe we want to hear. For example, rather than asking about what people's perception of air quality is, we can ask them what it is. Either way we are getting information on how they perceive it, but this way we are not leading them. We got rid of a question about transportation, that does not have major relevance to the information we are seeking. Additional wording changes were made to reduce bias. Professor Brandes also suggested when testing the survey on people to include two questions that are asking the same thing but are worded differently, this will ensure that we choose one of the two questions that makes most sense to respondents and will further reduce biases.

3. **Have you administered surveys in your research? If so, do you have any tips that may be useful to administering our survey?**

No survey is perfect and given the limited time and resources that we have to conduct this survey, reducing biases as much as possible is the best we can do, as well as acknowledging that there will be biases in our data. In terms of administration, we should try to approach people by trying to appeal to the social contract to the environment. We need to assure them that we are not selling them anything and are just trying to collect information about air quality.

Appendix E: Measurement Tool Specifications

E.1 senseBox

The senseBox was composed of a microcontroller unit (MCU) and several detachable sensors (SenseBox, 2019). The MCU was mounted on a plexiglass disk and could be programmed to carry out projects using the Arduino IDE. The MCU processor was based on the ARM Cortex-M0 and the SAM D21 processor microchip. The dimensions of the MCU was 132 mm x 93 mm x 16 mm and weighs 104.8 g, making it small and portable. An SD-Bee was attached to the senseBox MCU to allow collected data to be stored on a micro SD card. Its dimensions were 24 mm x 21 mm x 9 mm and it weighed 2.4 g.

The senseBox MCU had several attached sensors, including the HDC1080, the CAM M8Q, and the SDS011 (SenseBox, 2019). The HDC1080 sensor measured temperature and relative humidity. Its dimensions were 25 mm x 25 mm x 9 mm and its mass was 2.3 g. The HDC1080 measured relative humidity in a range from 0% - 100% and had an accuracy of ± 4%, while it measured temperature in degrees Celsius to an accuracy of ± 0.2 °C. The CAM M8Q was a GPS that received longitude, latitude, and altitude data. It had a sensitivity of -167 dBm (dBm is an abbreviation for the power ratio in decibels (dB) of the measured power referenced to one milliwatt) and had an immunity to interfering signals. The SDS011 was a fine dust ($PM_{2.5}$ and PM_{10}) sensor. Its dimensions were 70 mm x 70 mm x 21 mm and its mass was 51.5 g. This sensor took measurements in $\mu g/m^3$ and had a resolution of 0.3 $\mu g/m^3$. All senseBox products were manufactured by Reedu GmhH & Co. KG. Time measurements taken by the senseBox were taken in milliseconds (ms). Figure F.1 demonstrates the set-up that we used for our senseBox measurements.

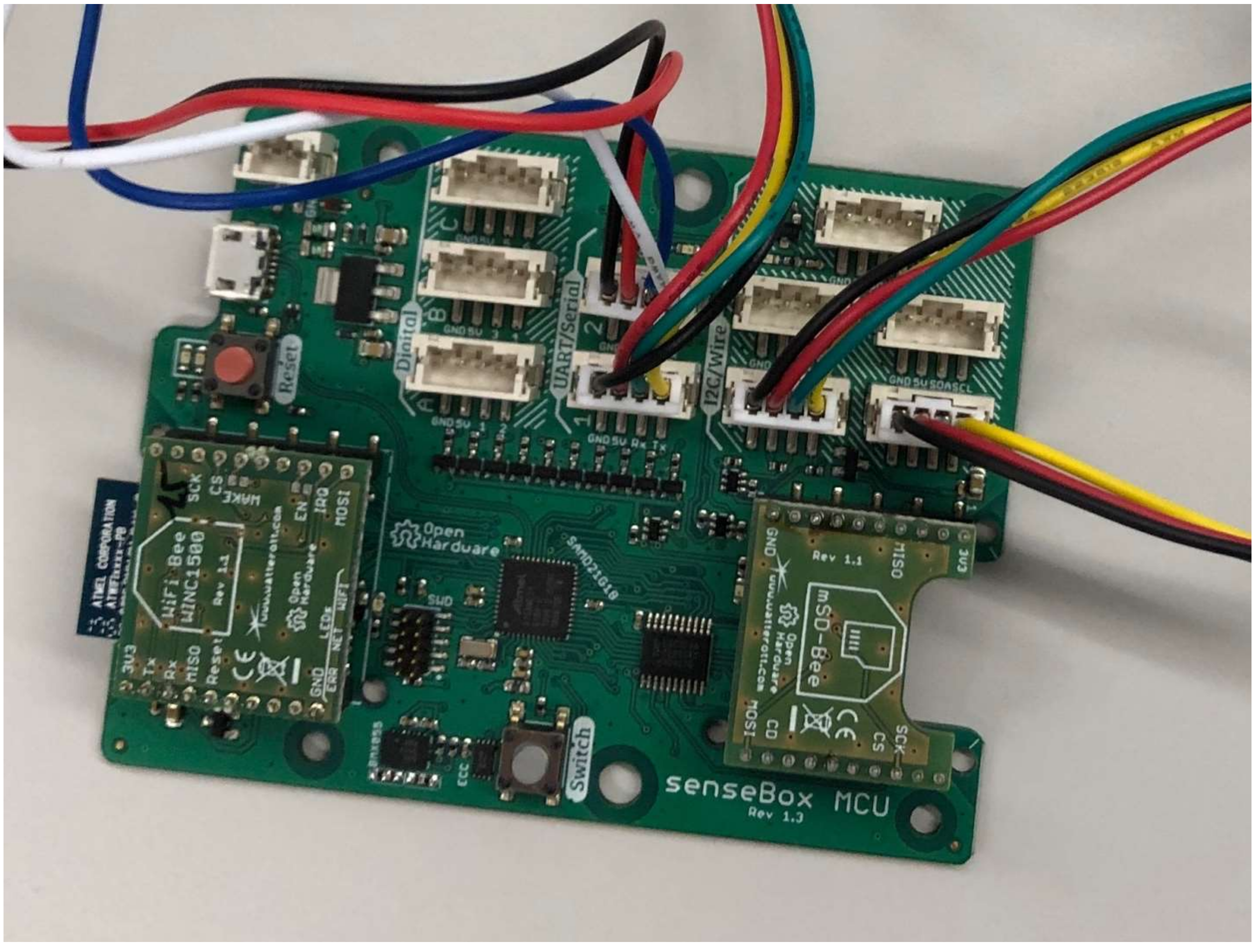


Figure E.1: The senseBox MCU pictured above has sensors connected in the upper portion. The SDS011 is connected to the upper row, and in the lower row (left to right) the White PM, CO_2, and CAM M8Q sensors connected. The SD-Bee can be seen below the CAM M8Q sensor in the lower right corner of the MCU.

The senseBox openSenseMap is a platform run by senseBox which is for publishing of senseBox and other sensor data (SenseBox, 2019). Each senseBox transmits measurements directly to the online map, where anyone can observe, analyze and download the data, because all data published on openSenseMap is available as open data under the Public Domain Dedication and License 1.0.

E.2 Temtop LKC-1000S Indoor Air Quality Monitor

The Temtop is a handheld sensor that records time (seconds), $PM_{2.5}$ ($\mu g/m^3$), PM_{10} ($\mu g/m^3$), and the number of particles in the air (per Liter) (Amazon, 2019). It operates with a measuring range of 0-999 $\mu g/m^3$ for $PM_{2.5}$ and PM_{10}. It operates in a temperature range of 0-50 °C and a humidity range of 0-90 %. Based on the recorded air quality data, it displays a relative condition outlined in Figure E.2 below.

Health Parameter Guide							
PM2.5	PM10	AQI	CO2(ppm)	Status	HCHO(mg/m³)	TVOC (mg/m³)	Displayed Contents
0.0-12.0	0-54	0-50	0-700	Good	0-0.1	0-0.5	Safe
12.1-35.4	55-154	51-100	701-1000	Moderate	> 0.1	> 0.5	Unsafe
35.5-55.4	155-254	101-150	1001-1500	Unhealthy for Sensitive Groups			
55.5-150.4	255-354	151-200	1501-2500	Unhealthy			
150.5-250.4	355-424	201-300	2501-5000	Very Unhealthy			
≥250.5	≥425	≥301	≥5001	Hazardous			

Figure E.2: Temptop classification of air quality (Amazon, 2019). Only classification parameters found in the first two columns were used for the purpose of this research.

E.3 dBluetech High BioTrap

The BioTrap (High Flow Sampler for Assay of Airborne Microorganisms, dBlueTech® HighBioTrap) is a sampler that has a high flow of air but does low damage to samples being collected (Beijing Dingblue Technology, 2017). It has a flow rate of 1000 L/min. The sampler can either use agar medium or oil film to sample and collect air particles and bio-aerosols in particular.

It has a large variety of applications, ranging from collecting suspected biological toxins in the battlefield for military purposes to environmental protection and pharmaceuticals, as well as scientific research.

The capture rate of the BioTrap is of over 90% (including bacteria, fungi) and the Cut-off size is 2 μm. The Temperature range is from -20 °C to 40 °C. It has two Sampling processes, one of 30 seconds and one of 60 seconds.

Figure E.3: The BioTrap pictured above (Beijing Dingblue Technology, 2017). The nozzle on the top left can be removed and beneath is it the sample stage on which the agar is placed. On the right is the touch screen which is where the on/off buttons and start buttons are.

Appendix F: Arduino IDE Code

Primary Test Code

```
#include "SenseBoxMCU.h"
#include "SparkFun_SCD30_Arduino_Library.h"
#include "SD.h"
#include "GPSReader.h"
SCD30 scd30 ;
GPSReader gps;
void setup ( )  {
  Serial. begin ( 9600 ) ;
  delay ( 100 ) ; // the delay is necessary for the serial port to start
  SD.begin(28);
  File dataFile = SD.open("Daten.txt", FILE_WRITE);
  dataFile.println("GPSTime;Longitude;Latitude;Time;Co2;humSCD;tempSCD");
  dataFile.close();
  scd30. begin ( ) ;
  delay ( 10000 ) ;
  gps.begin();
  delay ( 100);
}
void loop ( )  {
    while  ( ! scd30. dataAvailable ( ) )  ;
    float temperatureSCD = scd30. getTemperature ( ) ;
    uint16_t co2 = scd30. getCO2 ( ) ;
    float humiditySCD = scd30. getHumidity ( ) ;
    Serial. print ( "CO2:" ) ;
    Serial. println ( co2 ) ;
    Serial. print ( "Temperature:" ) ;
    Serial. println ( temperatureSCD ) ;
    Serial. print ( "Humidity:" ) ;
    Serial. println ( humiditySCD ) ;

    double latitude;
    double longitude;
    const char* gpsTime;
    if ( gps.hasValidValues() ) {
      gpsTime = gps.getFormatedGPSTime();
      latitude = gps.getLatitude();
      longitude = gps.getLongitude();
    } else {
      gpsTime = "NA";
      latitude = 0.0;
      longitude = 0.0;
    }
    Serial. print ( "latitude:" ) ;
```

```
   Serial. println ( latitude ) ;
   Serial. print ( "longitude:" ) ;
   Serial. println ( longitude ) ;
   Serial. print ( "gpsTime:" ) ;
   Serial. println ( gpsTime ) ;
   unsigned long timeSinceStart = millis();
   File dataFile = SD.open("Daten.txt", FILE_WRITE);
   dataFile.print(gpsTime);
   dataFile.print(";");
   dataFile.print(longitude);
   dataFile.print(";");
   dataFile.print(latitude);
   dataFile.print(";");
   dataFile.print(timeSinceStart);
   dataFile.print(";");
   dataFile.print(co2);
   dataFile.print(";");
   dataFile.print(temperatureSCD);
   dataFile.print(";");
   dataFile.print(humiditySCD);
   dataFile.print(";");
   dataFile.println();
   dataFile.close();
}
```

Particulate Matter and CO_2 Test Code

```
#include "SenseBoxMCU.h"
#include "sensirion_uart.h"
#include "sps30.h"
#include "SparkFun_SCD30_Arduino_Library.h"
#include "SD.h"
#include "GPSReader.h"
SDS011 my_sds(Serial2);
SCD30 scd30 ;
GPSReader gps;
void setup ( )  {
  Serial. begin ( 9600 ) ;
  sensirion_uart_open ( 1 );
  delay ( 100 ) ; // the delay is nessary for the serial port to start
  if( sps30_start_measurement ( )  !=  0 )  {
     Serial. write ( "error starting measurement \ n " ) ;
  }
  Serial2.begin(9600);
  SD.begin(28);
  File dataFile = SD.open("Daten.txt", FILE_WRITE);
```

```
dataFile.println("GPSTime;Longitude;Latitude;Time;Co2;tempSCD;humSCD;GreenPM2.5;GreenPM10;WhitePM2.5;WhitePM10");
  dataFile.close();
  scd30. begin ( ) ;
  delay ( 10000 ) ;
  gps.begin();
  delay ( 100);
}
void loop ( )  {
        struct sps30_measurement measurement;
    s16 ret;
    delay (1000);
    ret = sps30_read_measurement (& measurement);
    if (ret <0) {
      Serial.write ("read measurement failed \ n");
    } else if (SPS_IS_ERR_STATE (ret)) {
      Serial.write ("Measurements may not be accurate \ n");
    }
    Serial. print ( "nc_0p5 a=" ) ;
    Serial. println ( measurement. nc_0p5 ) ;
    Serial. print ( "nc_2p5 b=" ) ;
    Serial. println ( measurement. nc_2p5 ) ;
    Serial. print ( "nc_10p0 c=" ) ;
    Serial. println ( measurement. nc_10p0 ) ;
    while  ( ! scd30. dataAvailable ( ) )  ;
    float temperatureSCD = scd30. getTemperature ( ) ;
    uint16_t co2 = scd30. getCO2 ( ) ;
    float humiditySCD = scd30. getHumidity ( ) ;
    Serial. print ( "CO2:" ) ;
    Serial. println ( co2 ) ;
    Serial. print ( "Temperature:" ) ;
    Serial. println ( temperatureSCD ) ;
    Serial. print ( "Humidity:" ) ;
    Serial. println ( humiditySCD ) ;
    double latitude;
    double longitude;
    const char* gpsTime;
    if ( gps.hasValidValues() ) {
      gpsTime = gps.getFormatedGPSTime();
      latitude = gps.getLatitude();
      longitude = gps.getLongitude();
    } else {
      gpsTime = "NA";
      latitude = 0.0;
      longitude = 0.0;
    }
```

```
    Serial. print ( "latitude:" ) ;
    Serial. println ( latitude ) ;
    Serial. print ( "longitude:" ) ;
    Serial. println ( longitude ) ;
    Serial. print ( "gpsTime:" ) ;
    Serial. println ( gpsTime ) ;
    float pm10 = my_sds.getPm10();
    float pm25 = my_sds.getPm25();


    Serial. print ( "pm25:" ) ;
    Serial. println ( pm25 ) ;
    Serial. print ( "pm10:" ) ;
    Serial. println ( pm10 ) ;
    unsigned long timeSinceStart = millis();
    File dataFile = SD.open("Daten.txt", FILE_WRITE);
    dataFile.print(gpsTime);
    dataFile.print(";");
    dataFile.print(longitude);
    dataFile.print(";");
    dataFile.print(latitude);
    dataFile.print(";");
    dataFile.print(timeSinceStart);
    dataFile.print(";");
    dataFile.print(co2);
    dataFile.print(";");
    dataFile.print(temperatureSCD);
    dataFile.print(";");
    dataFile.print(humiditySCD);
    dataFile.print(";");
       dataFile.print(measurement. nc_2p5);
    dataFile.print(";");
       dataFile.print(measurement. nc_10p0);
    dataFile.print(";");
       dataFile.print(pm25);
    dataFile.print(";");
       dataFile.print( pm10);
    dataFile.print(";");
    dataFile.println();
    dataFile.close();
}
```

Setup and Libraries:
https://sensebox.github.io/books-v2/edu/de/erste-schritte/software-installation.html

Appendix G: MATLAB Code

senseBox Line Graph

```
t = senseBoxData1S5.Timeinmin;
pm10 = senseBoxData1S5.WhitePM10;
pm25 = senseBoxData1S5.WhitePM25;
CO2 = senseBoxData1S5.Co2;

%PM10
ax1=subplot(3,1,1);
plot(ax1,t, pm10,'k','LineWidth',1.5);
hold(ax1,'on');
y=mean(senseBoxData1S5.WhitePM10,'all');
y1=0*t+y;
plot(ax1,t,y1,'r','LineWidth',1.5);
hold(ax1,'off');

ax=gca;
ax.FontSize = 14;
xlabel('Time (min)');
ylabel('PM10 (ug/m3)');
title('senseBox: Zentrum Site C');

%PM25
ax2=subplot(3,1,2);
plot(ax2,t, pm25,'b','LineWidth',1.5);
hold(ax2,'on');
y3=mean(senseBoxData1S5.WhitePM25,'all');
y2=0*t+y3;
plot(ax2,t,y2,'k','LineWidth',1.5);
hold(ax2,'off');
ax=gca;
ax.FontSize = 14;
xlabel('Time (min)');
ylabel('PM2.5 (ug/m3)');
title('senseBox: ETH Zentrum Site C');

%CO2
ax3=subplot(3,1,3);
plot(ax3,t, CO2,'r','LineWidth',1.5);
```

```
hold(ax3,'on');
y4=mean(senseBoxData1S5.Co2,'all');
y5=0*t+y4;
plot(ax3,t,y5,'b','LineWidth',1.5);
hold(ax3,'off');
ax=gca;
ax.FontSize = 14;
xlabel('Time (min)');
ylabel('CO2 (ppm)');
title('senseBox: ETH Zentrum Site C');
```

Temptop Line Graph

```
t = TemptopDataS6.Timesfromstart;
pm10 = TemptopDataS6.PM10;
pm25 = TemptopDataS6.PM25;

% pm10
ax1=subplot(2,1,1);
plot(ax1,t,pm10,'k','LineWidth',1.5);
hold(ax1,'on');
y=mean(TemptopDataS6.PM10,'all');
y1=0*t+y;
plot(ax1,t,y1,'r','LineWidth',1.5);
hold(ax1,'off');
ax=gca;
ax.FontSize = 14;
xlabel('Time (s)');
ylabel('PM10 (ug/m3)');
title('Temptop: Arboretum Site C ( Try 3)')

% pm2.5
ax2=subplot(2,1,2);
plot(ax2,t, pm25,'b','LineWidth',1.5);
hold(ax2,'on');
y2=mean(TemptopDataS6.PM25,'all');
y3=0*t+y2;
plot(ax2,t,y3,'k','LineWidth',1.5);
hold(ax2,'off')
ax=gca;
ax.FontSize = 14;
```

```
xlabel('Time (s)');
ylabel('PM2.5 (ug/m3)');
title('Temptop: Arboretum Site C ( Try 3)')
```

Appendix H: senseBox Graphs

ETH Hönggerberg

Site A

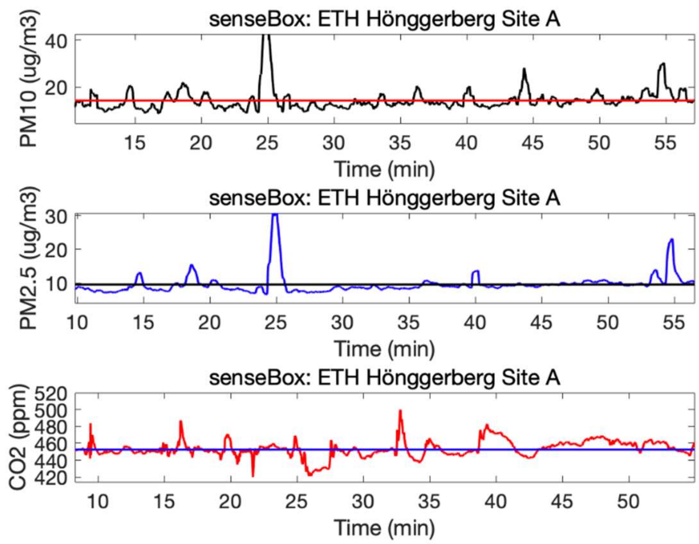


Figure H.1: ETH Hönggerberg Site A $PM_{2.5}$, PM_{10}, and CO_2 concentrations Trial 1.

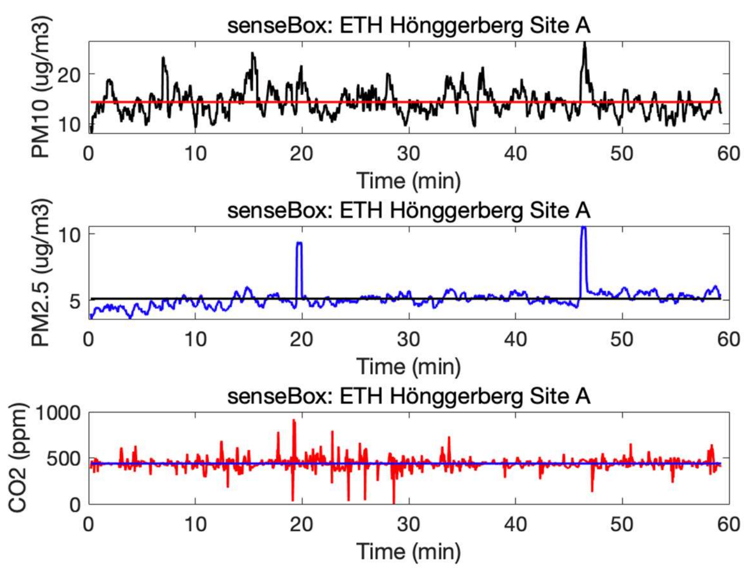


Figure H.2: ETH Hönggerberg Site A $PM_{2.5}$, PM_{10}, and CO_2 concentrations Trial 2.

Site B

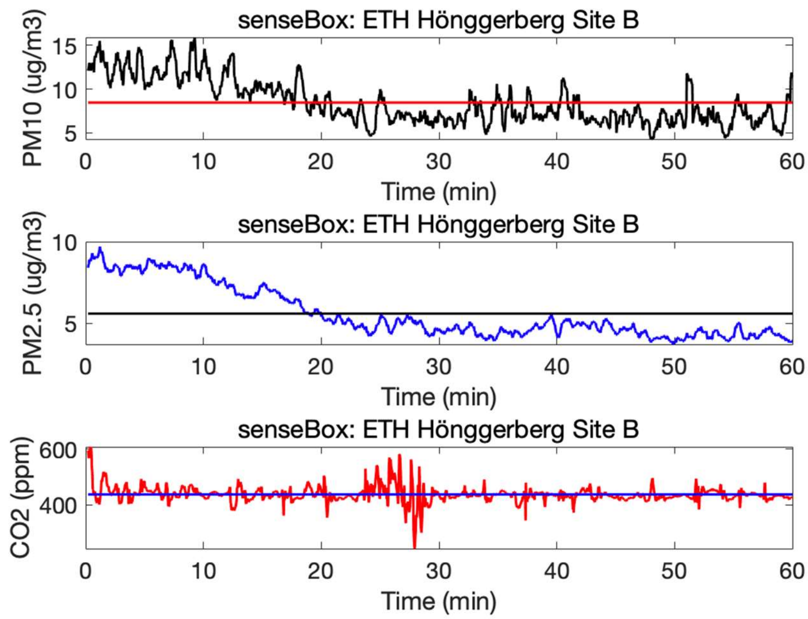


Figure H.3: ETH Hönggerberg Site B $PM_{2.5}$, PM_{10}, and CO_2 concentrations Trial 1.

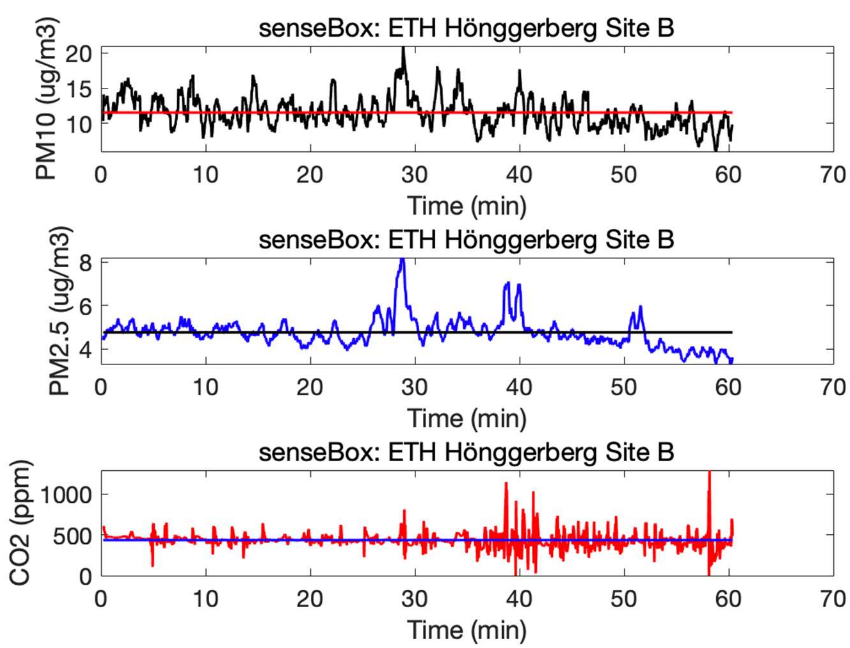


Figure H.4: ETH Hönggerberg Site B $PM_{2.5}$, PM_{10}, and CO_2 concentrations Trial 2.

Site C

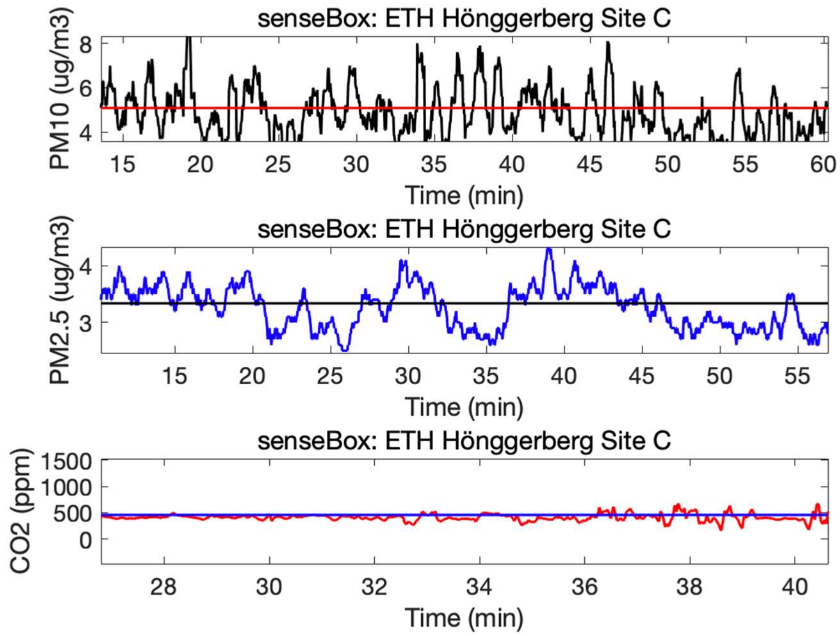


Figure H.5: ETH Hönggerberg Site C $PM_{2.5}$, PM_{10}, and CO_2 concentrations Trial 1.

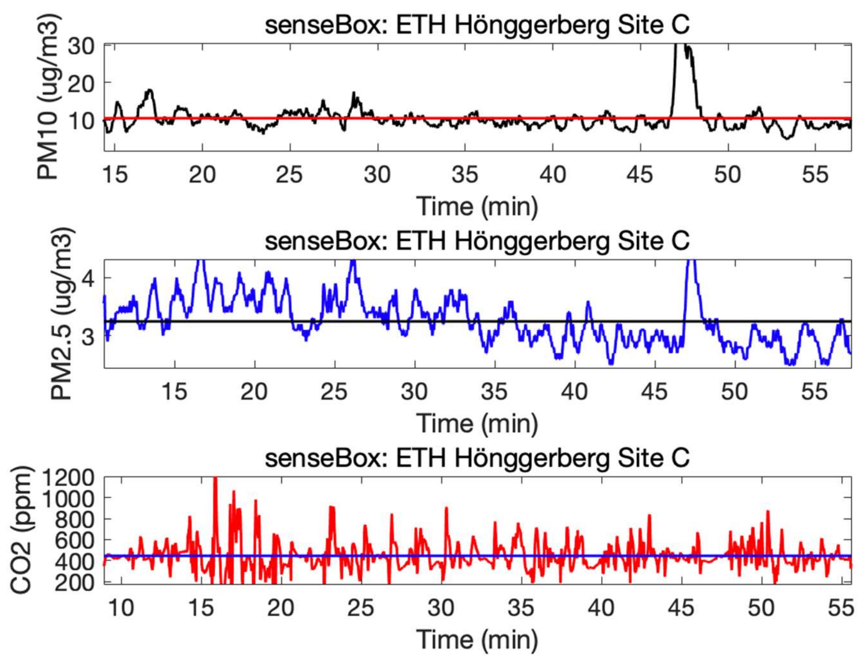


Figure H.6: ETH Hönggerberg Site C $PM_{2.5}$, PM_{10}, and CO_2 concentrations Trial 2.

ETH Zentrum

Site A

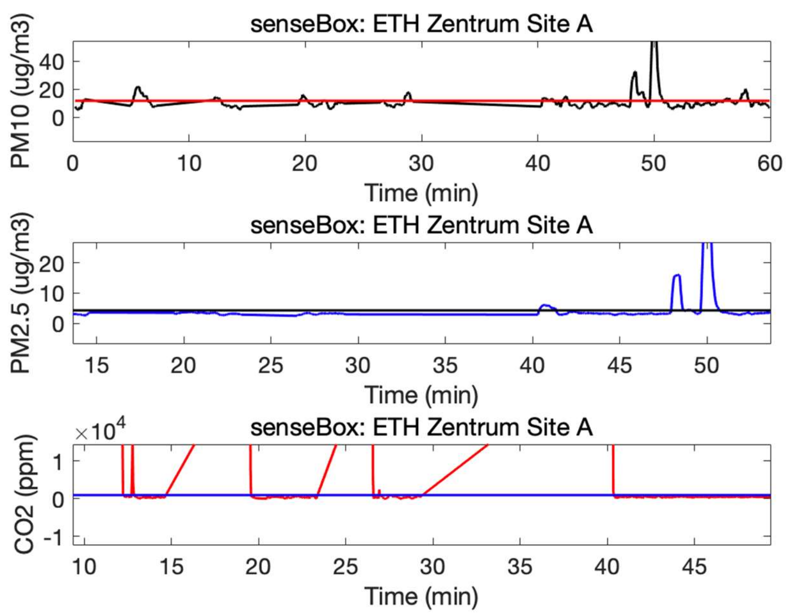


Figure H.7: ETH Zentrum Site A $PM_{2.5}$, PM_{10}, and CO_2 concentrations Trial 1.

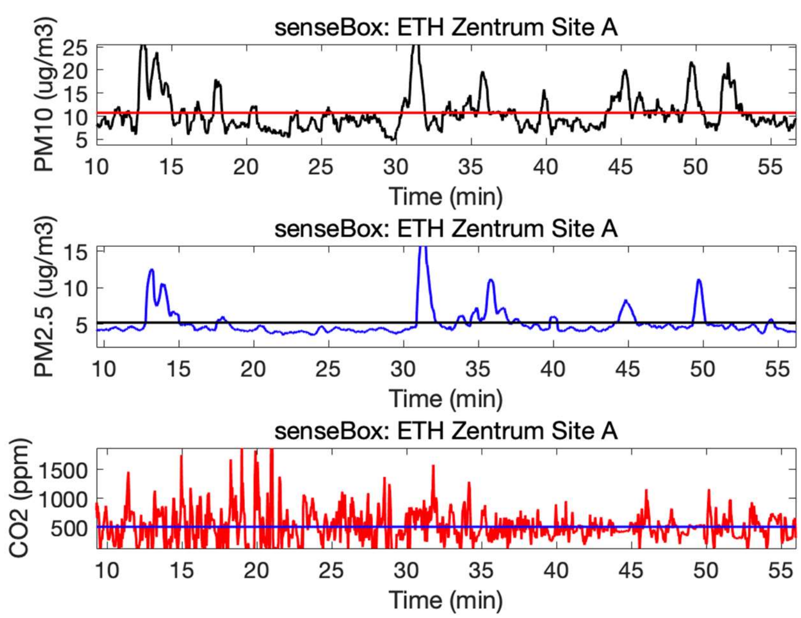


Figure H.8: ETH Zentrum Site A $PM_{2.5}$, PM_{10}, and CO_2 concentrations Trial 2.

Site B

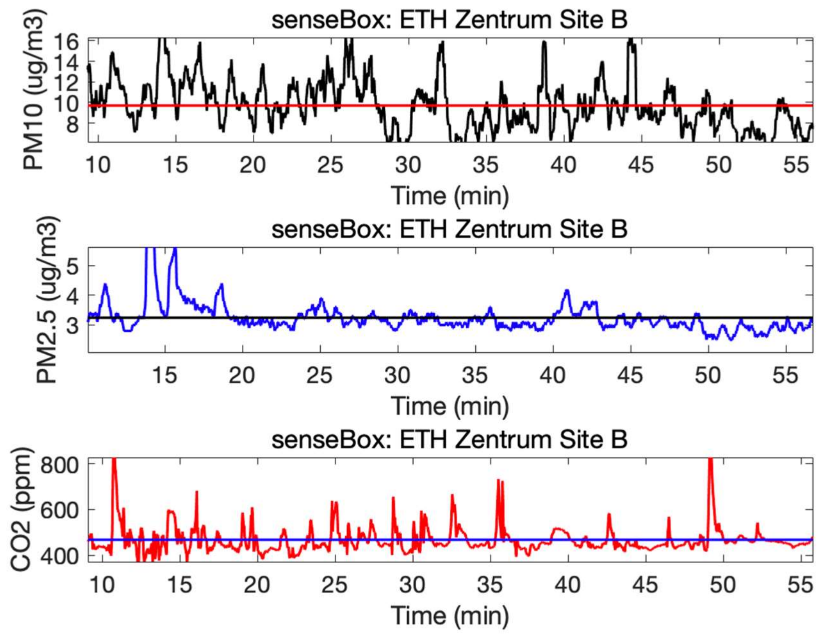


Figure H.9: ETH Zentrum Site B $PM_{2.5}$, PM_{10}, and CO_2 concentrations Trial 1.

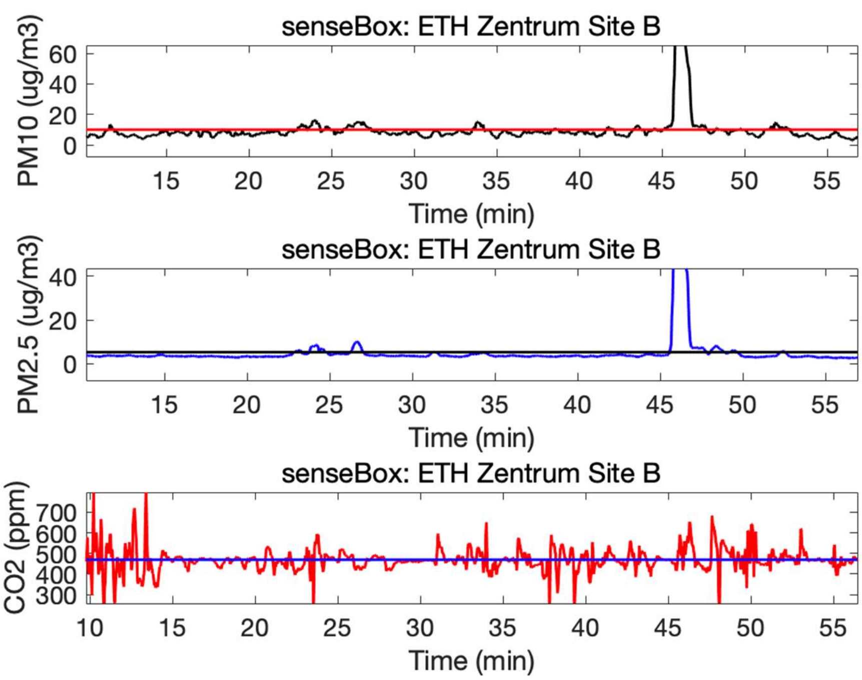


Figure H.10: ETH Zentrum Site B $PM_{2.5}$, PM_{10}, and CO_2 concentrations Trial 2.

Site C

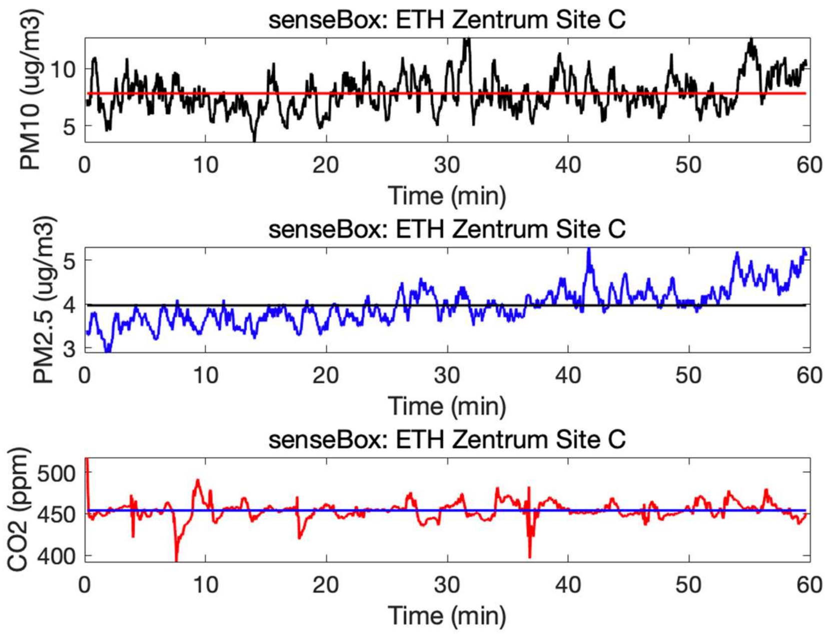


Figure H.11: ETH Zentrum Site C $PM_{2.5}$, PM_{10}, and CO_2 concentrations Trial 1.

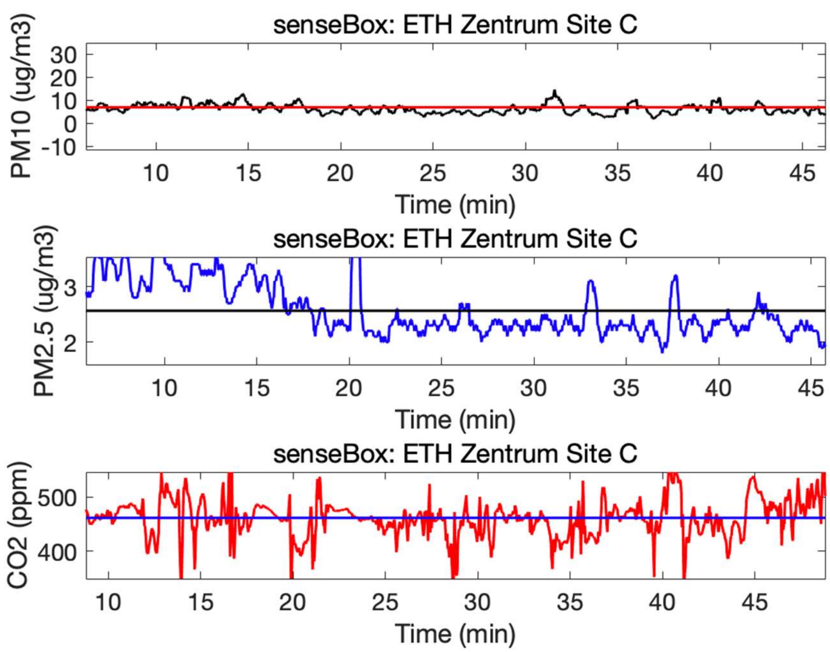


Figure H.12: ETH Zentrum Site C $PM_{2.5}$, PM_{10}, and CO_2 concentrations Trial 2.

Arboretum Zürich

Site A

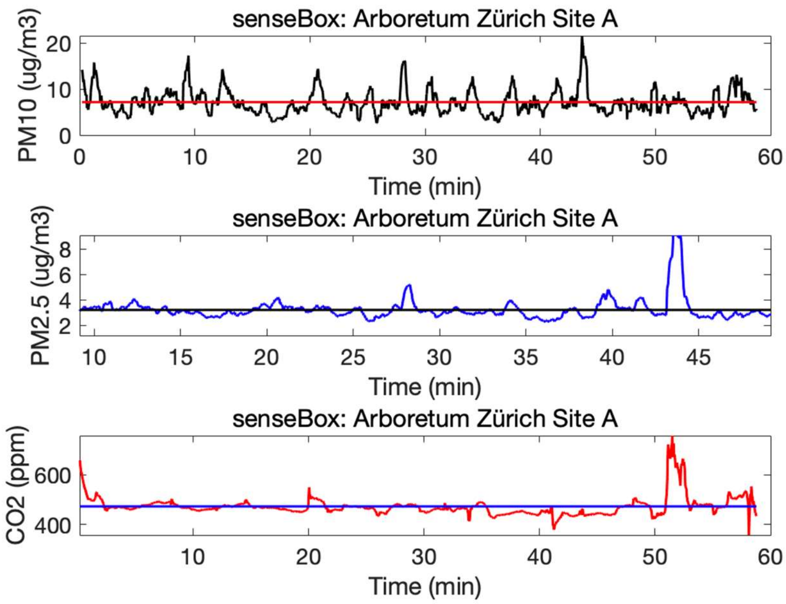


Figure H.13: Arboretum Zürich Site A $PM_{2.5}$, PM_{10}, and CO_2 concentrations Trial 1.

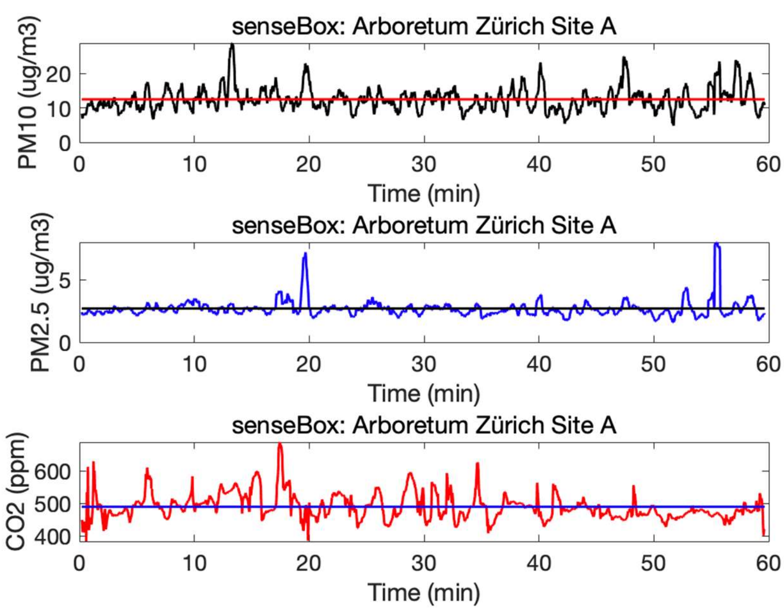


Figure H.14: Arboretum Zürich Site A $PM_{2.5}$, PM_{10}, and CO_2 concentrations Trial 2.

Site B

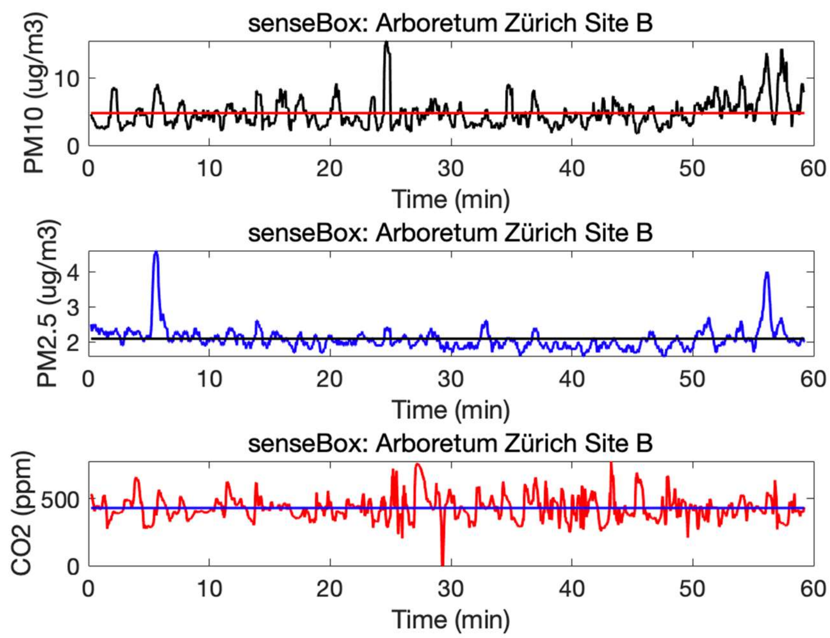


Figure H.15: Arboretum Zürich Site B $PM_{2.5}$, PM_{10}, and CO_2 concentrations Trial 1.

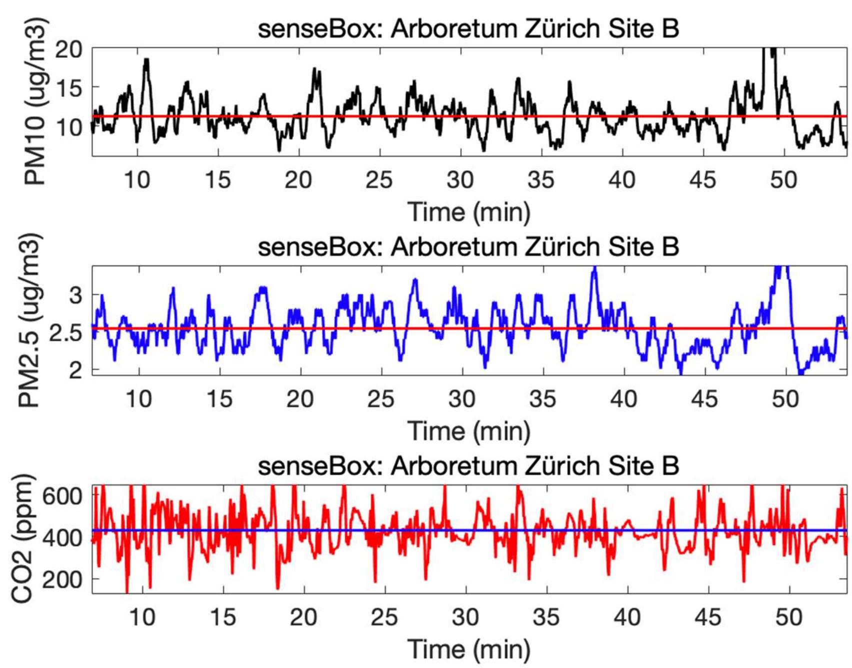


Figure H.16: Arboretum Zürich Site B $PM_{2.5}$, PM_{10}, and CO_2 concentrations Trial 2.

Site C

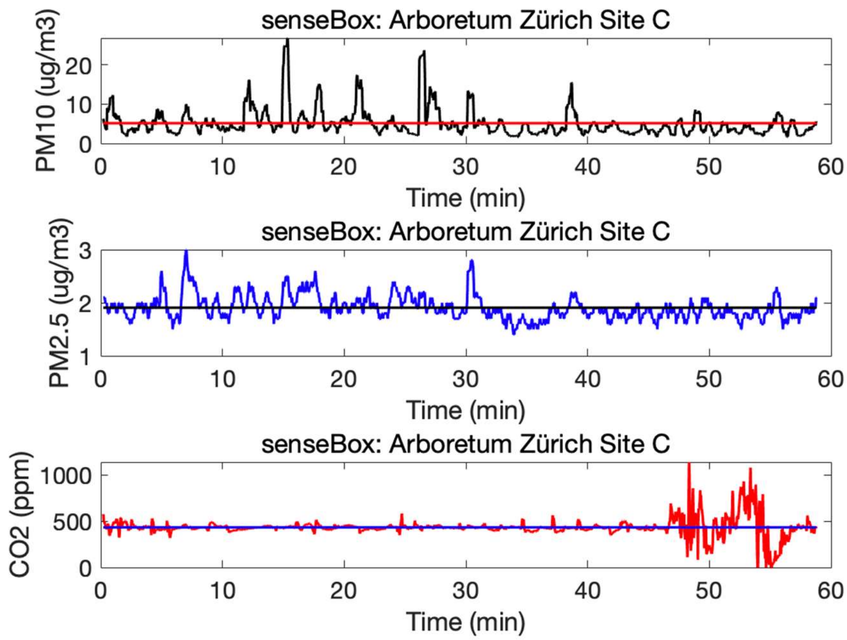


Figure H.17: Arboretum Zürich Site B $PM_{2.5}$, PM_{10}, and CO_2 concentrations Trial 1.

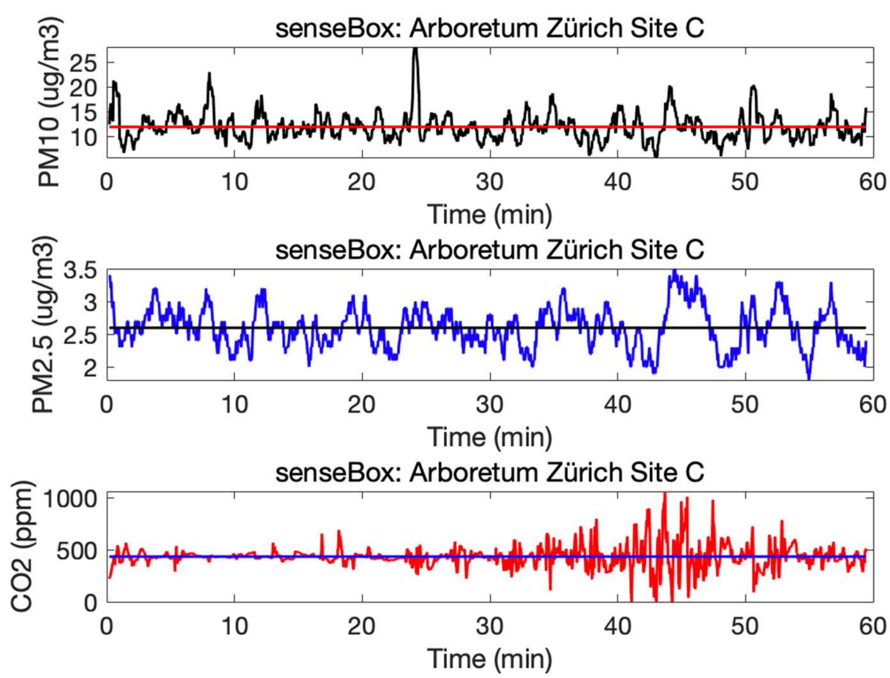


Figure H.18: Arboretum Zürich Site B $PM_{2.5}$, PM_{10}, and CO_2 concentrations Trial 2.

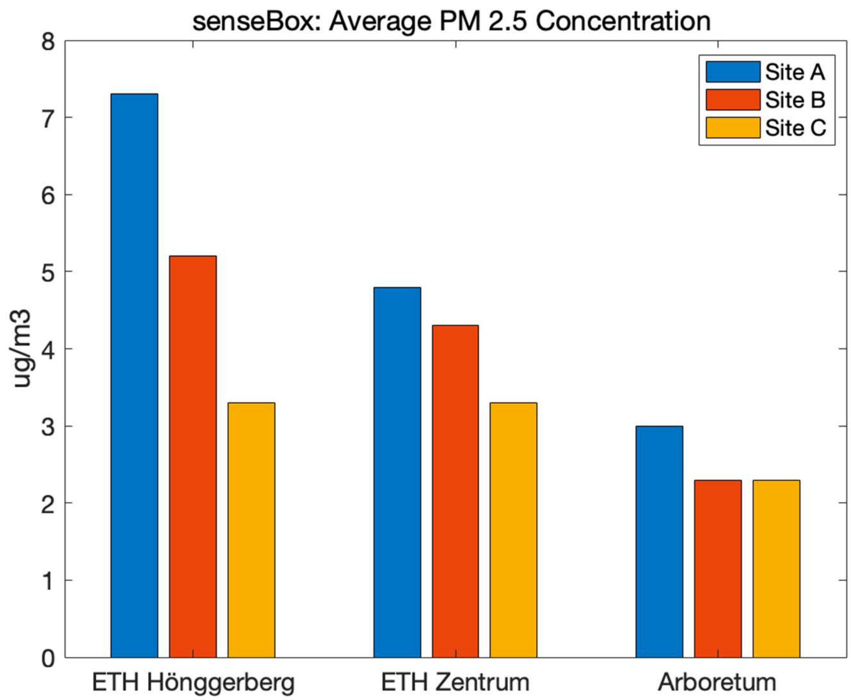


Figure H.19: Average $PM_{2.5}$ for all locations

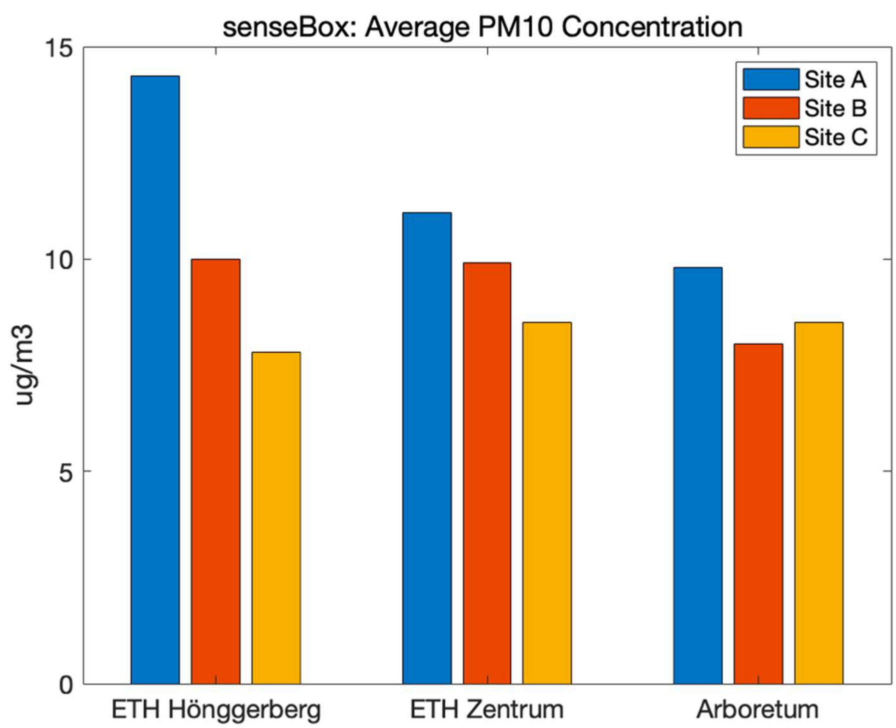


Figure H.20: Average PM_{10} for all locations

Appendix I: senseBox Average Particulate Matter and Carbon Dioxide Concentrations

Table I.1: Average particulate matter and carbon dioxide concentrations from both trials, recorded by the senseBox

Average of both trials			
Location and Site	Average concentration of $PM_{2.5}$ (μg/m^3)	Average concentration of PM_{10} (μg/m^3)	Average concentration of CO_2 (ppm)
ETH Hönggerberg A	7.3	14.3	445.8
ETH Hönggerberg B	5.2	10.0	437.1
ETH Hönggerberg C	3.3	7.8	452.5
ETH Zentrum A	4.8	11.1	728.8
ETH Zentrum B	4.3	9.9	468.1
ETH Zentrum C	3.3	8.5	457.6
Arboretum Zürich A	3.0	9.8	481.6
Arboretum Zürich B	2.3	8.0	430.3
Arboretum Zürich C	2.3	8.5	434.2

Table I.2: Average particulate matter and carbon dioxide concentrations from trial 1, recorded by the senseBox

Trial 1			
Location and Site	Average concentration of $PM_{2.5}$ (μg/m^3)	Average concentration of PM_{10} (μg/m^3)	Average concentration of CO_2 (ppm)
ETH Hönggerberg A	9.5	14.3	452.6
ETH Hönggerberg B	5.6	8.5	438.1
ETH Hönggerberg C	3.3	5.1	458.9
ETH Zentrum A	4.3	11.6	949.1
ETH Zentrum B	3.2	9.7	466.8
ETH Zentrum C	4.0	7.8	454.0
Arboretum Zürich A	3.2	7.2	472.7
Arboretum Zürich B	2.1	4.8	430.7
Arboretum Zürich C	1.9	5.2	433.7

Table I.3: Average particulate matter and carbon dioxide concentrations from trial 2, recorded by the senseBox

Trial 2			
Location and Site	Average concentration of $PM_{2.5}$ (µg/m^3)	Average concentration of PM_{10} (µg/m^3)	Average concentration of CO_2 (ppm)
ETH Hönggerberg A	5.1	14.3	438.9
ETH Hönggerberg B	4.8	11.5	436.0
ETH Hönggerberg C	3.2	10.5	446.1
ETH Zentrum A	5.2	10.7	508.4
ETH Zentrum B	5.3	10.1	469.3
ETH Zentrum C	2.6	9.2	461.2
Arboretum Zürich A	2.7	12.5	490.5
Arboretum Zürich B	2.5	11.2	429.8
Arboretum Zürich C	2.6	11.9	434.6

Appendix J: Temptop Graphs

ETH Hönggerberg

Site A

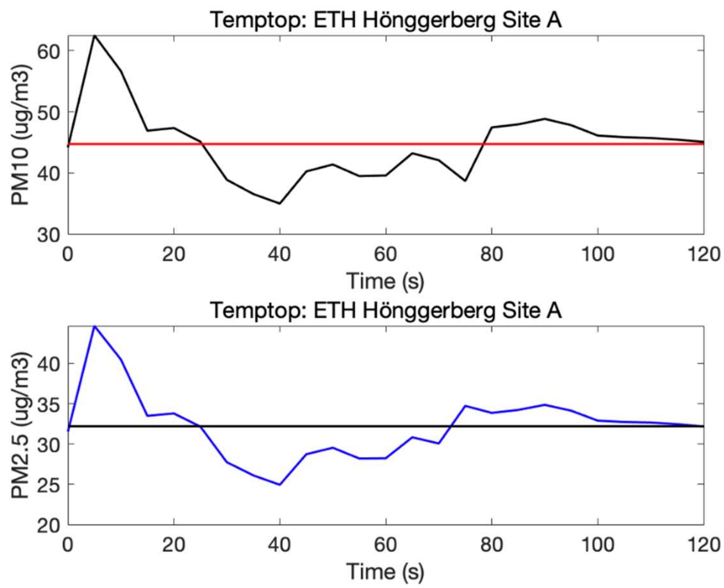


Figure J.1: ETH Hönggerberg Site A $PM_{2.5}$ and PM_{10} concentrations Trial 1.

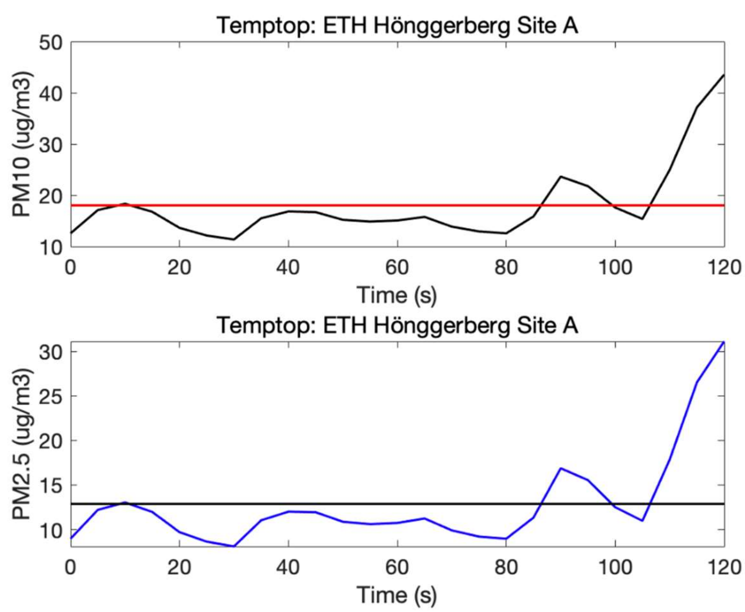


Figure J.2: ETH Hönggerberg Site A $PM_{2.5}$ and PM_{10} concentrations Trial 2.

Site B

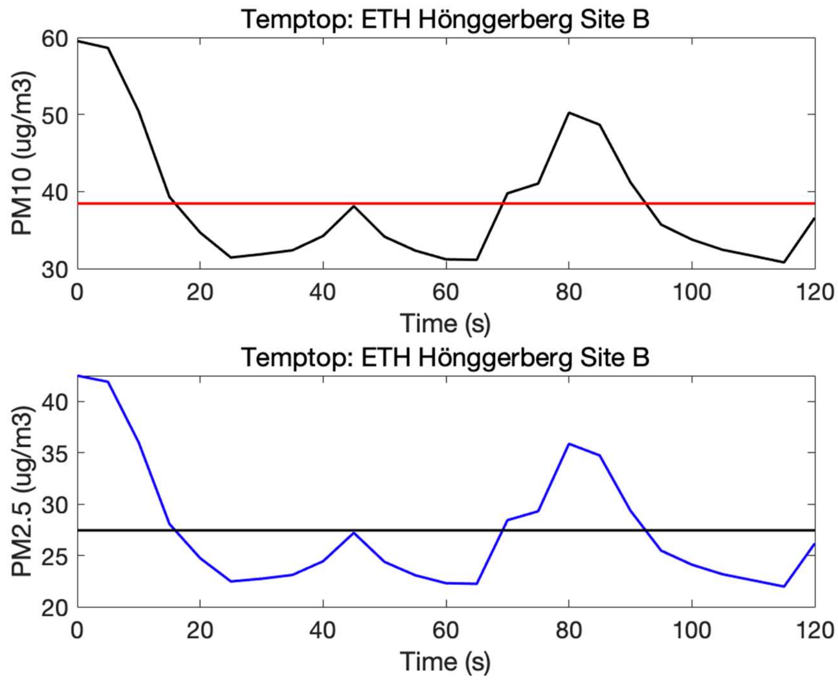


Figure J.3: ETH Hönggerberg Site B $PM_{2.5}$ and PM_{10} concentrations Trial 1.

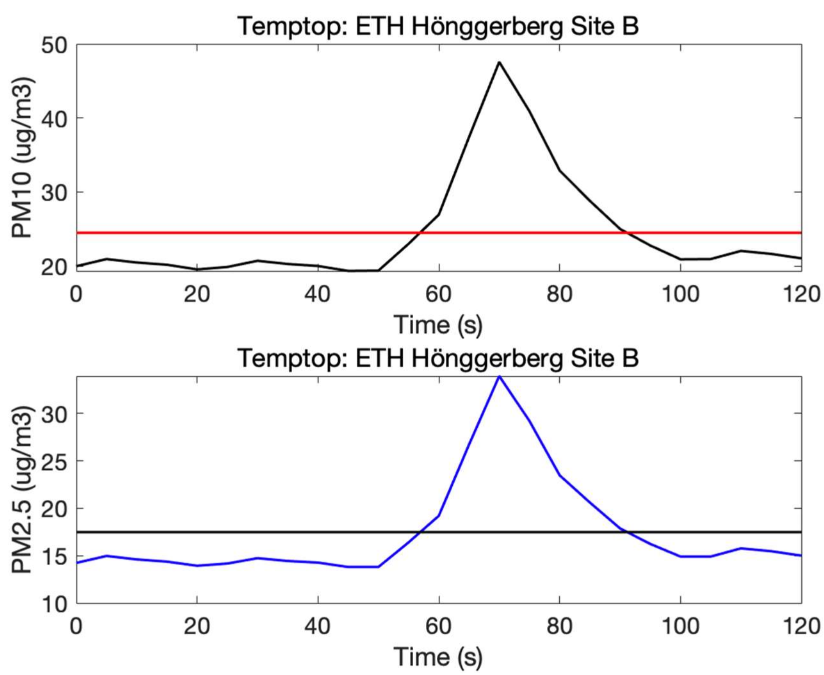


Figure J.4: ETH Hönggerberg Site B $PM_{2.5}$ and PM_{10} concentrations Trial 2.

<u>Site C</u>

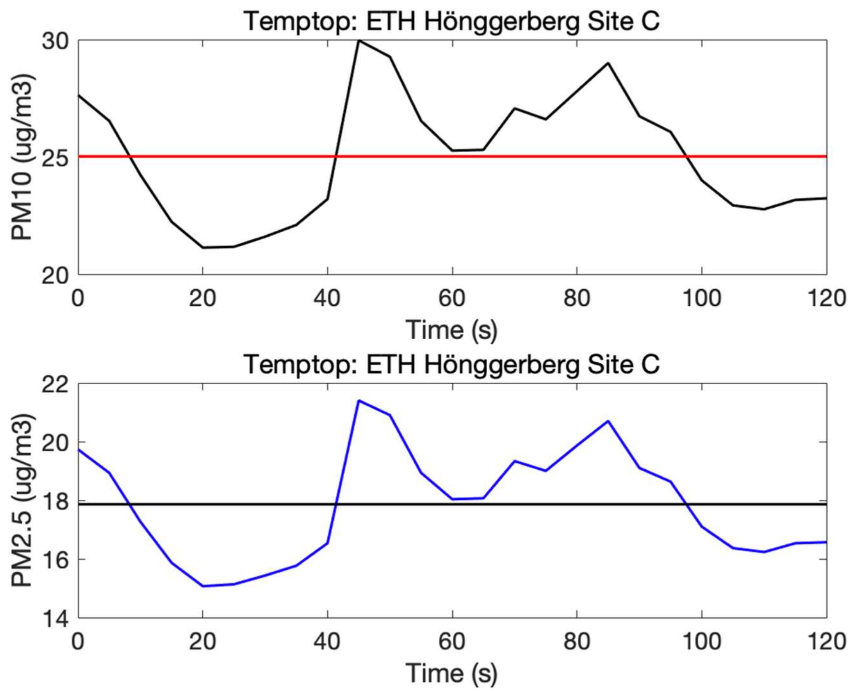


Figure J.5: ETH Hönggerberg Site C $PM_{2.5}$ and PM_{10} concentrations Trial 1.

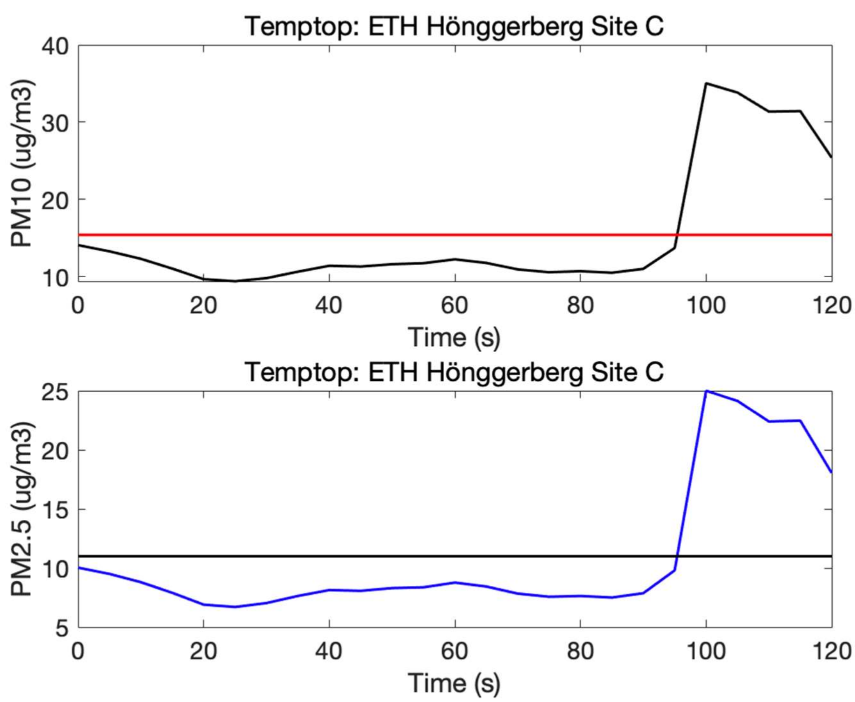


Figure J.6: ETH Hönggerberg Site C $PM_{2.5}$ and PM_{10} concentrations Trial 2.

ETH Zentrum

Site A

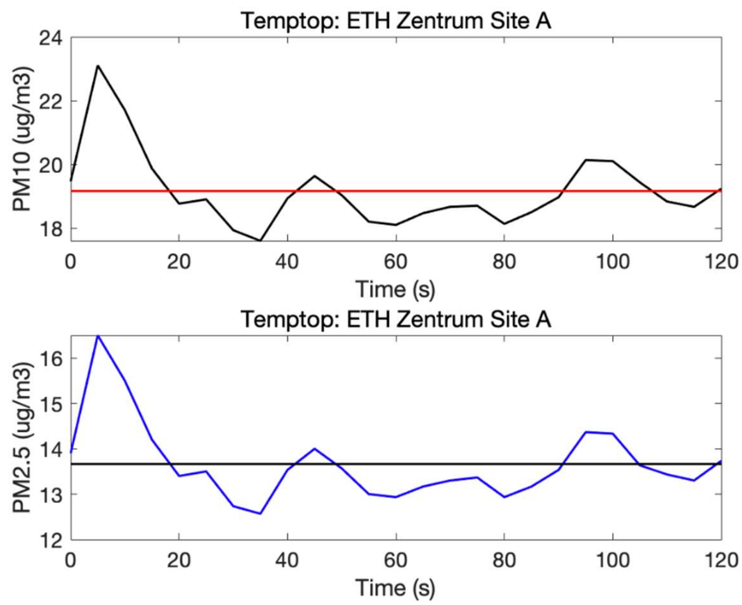


Figure J.7: ETH Zentrum Site A $PM_{2.5}$ and PM_{10} concentrations Trial 1.

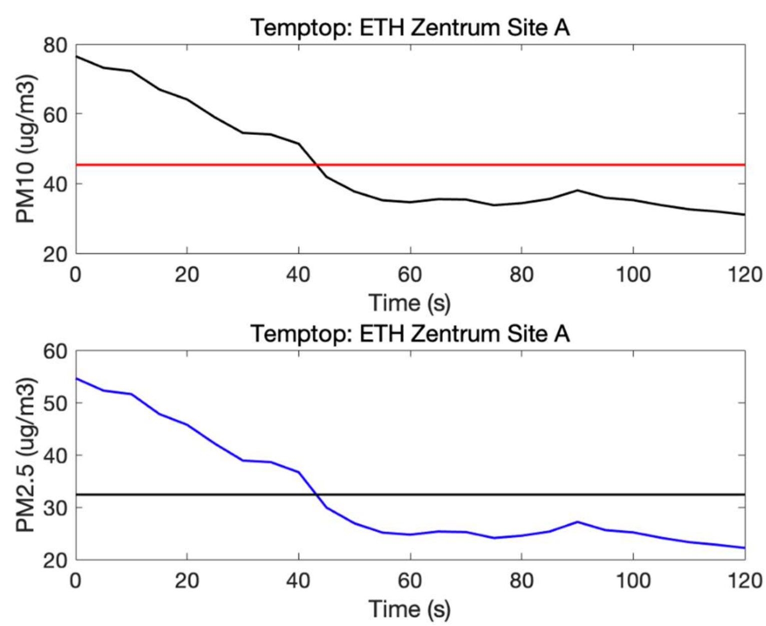


Figure J.8: ETH Zentrum Site A $PM_{2.5}$ and PM_{10} concentrations Trial 2.

Site B

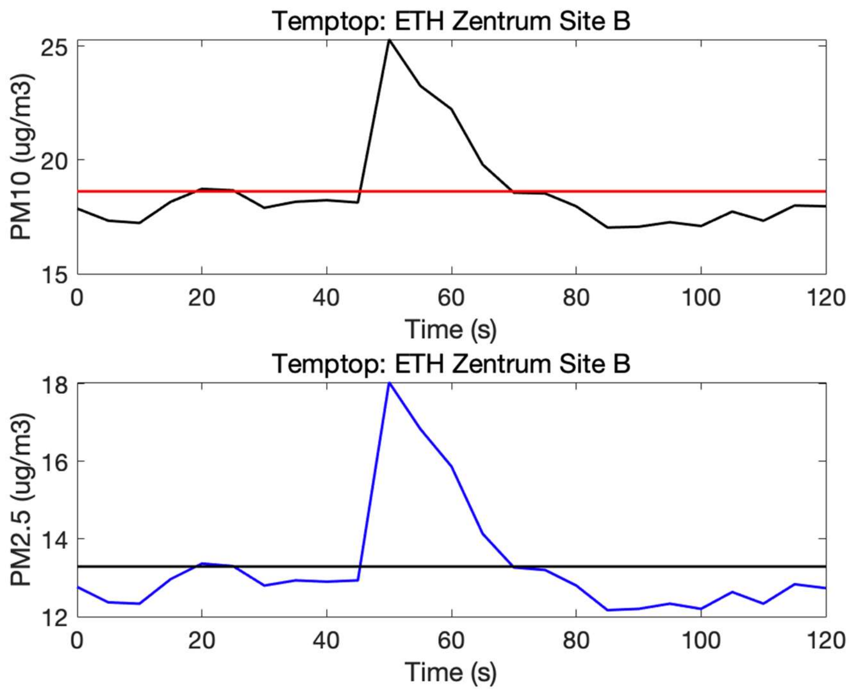


Figure J.9: ETH Zentrum Site B $PM_{2.5}$ and PM_{10} concentrations Trial 1.

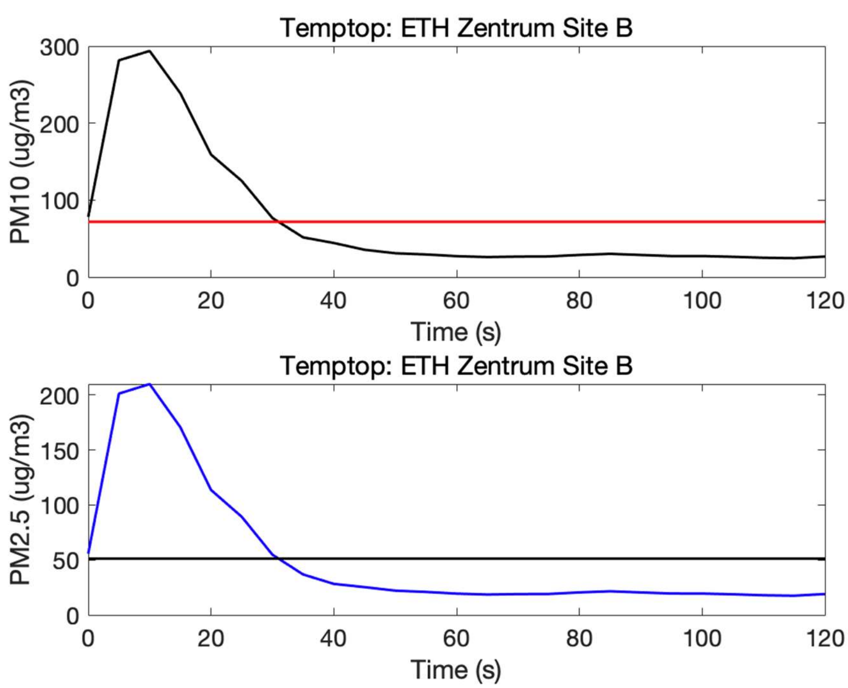


Figure J.10: ETH Zentrum Site B $PM_{2.5}$ and PM_{10} concentrations Trial 2.

Site C

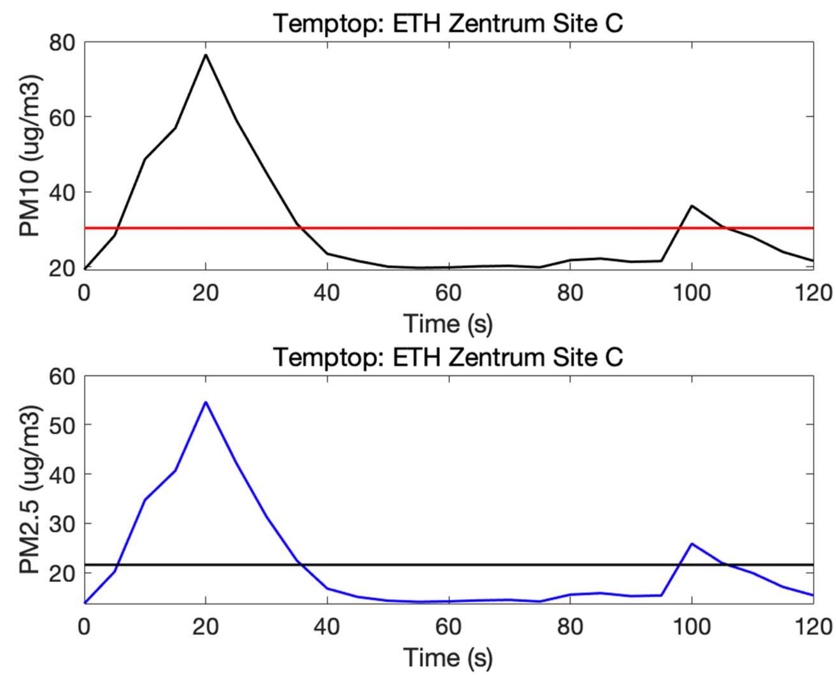


Figure J.11: ETH Zentrum Site C $PM_{2.5}$ and PM_{10} concentrations Trial 1.

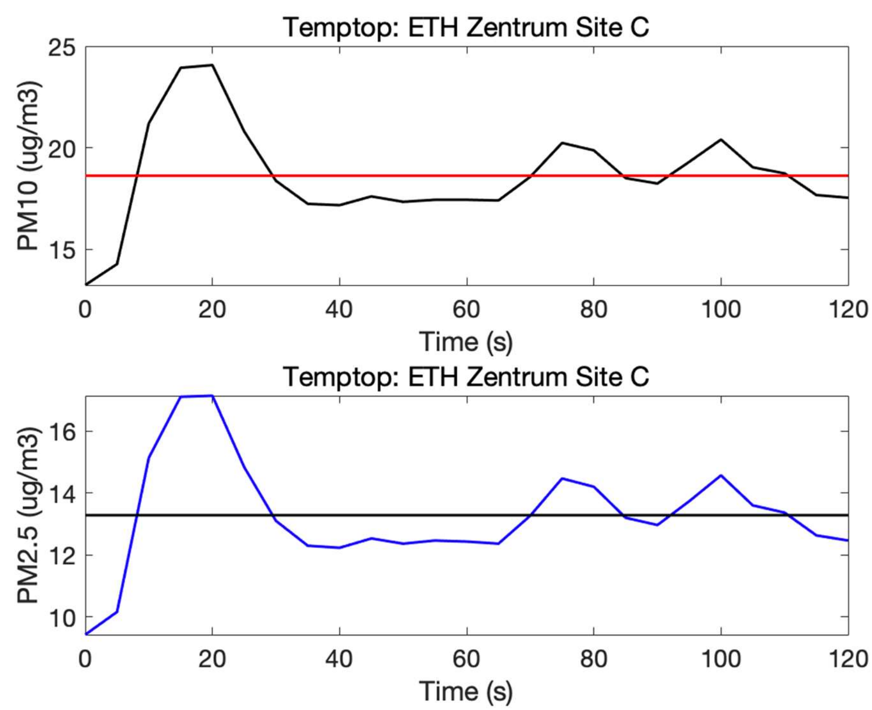


Figure J.12: ETH Zentrum Site C $PM_{2.5}$ and PM_{10} concentrations Trial 2.

Arboretum Zürich

Site A

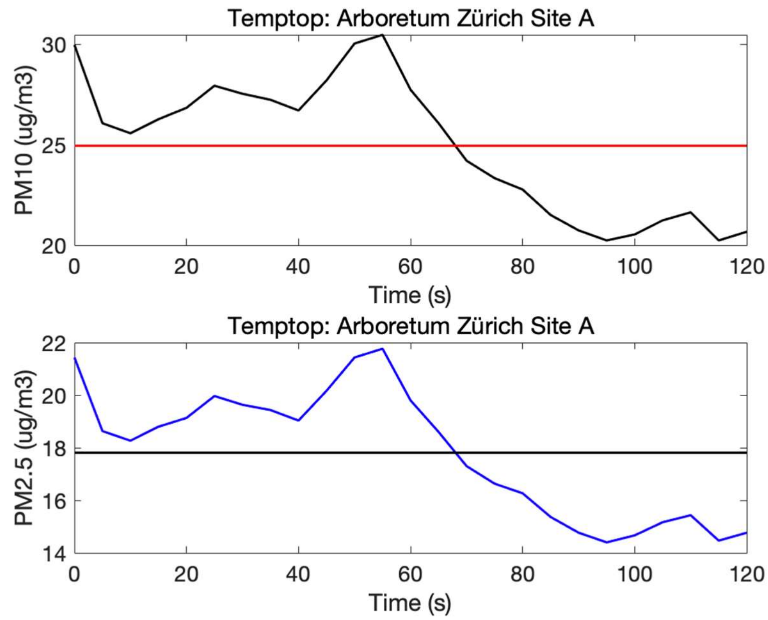


Figure J.13: Arboretum Zürich Site A $PM_{2.5}$ and PM_{10} concentrations Trial 1.

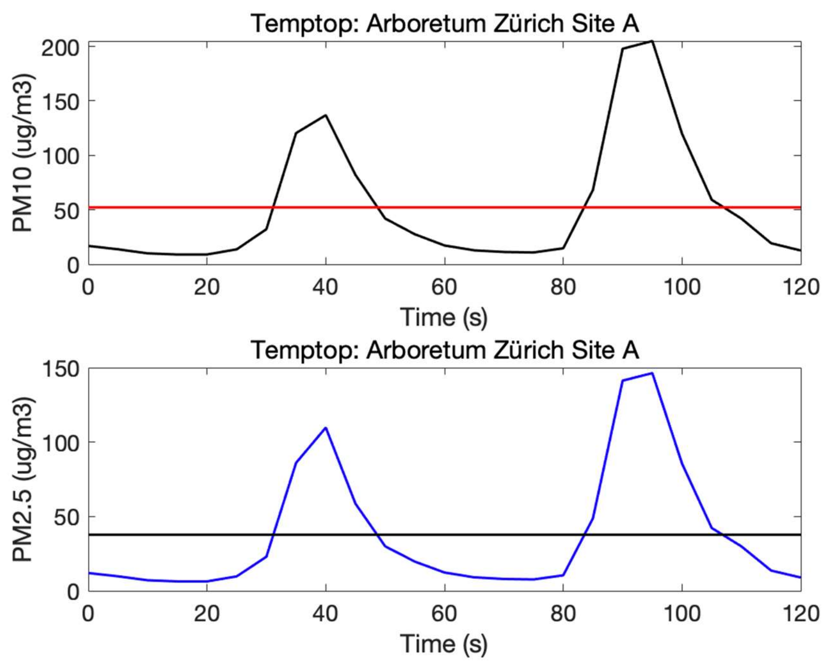


Figure J.14: Arboretum Zürich Site A $PM_{2.5}$ and PM_{10} concentrations Trial 2.

<u>Site B</u>

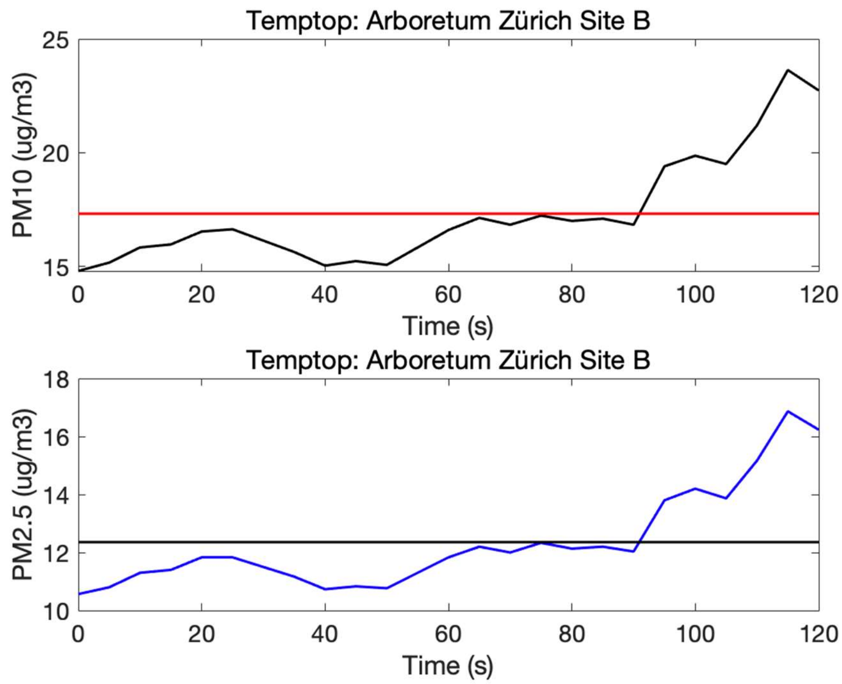


Figure J.15: Arboretum Zürich Site B $PM_{2.5}$ and PM_{10} concentrations Trial 1.

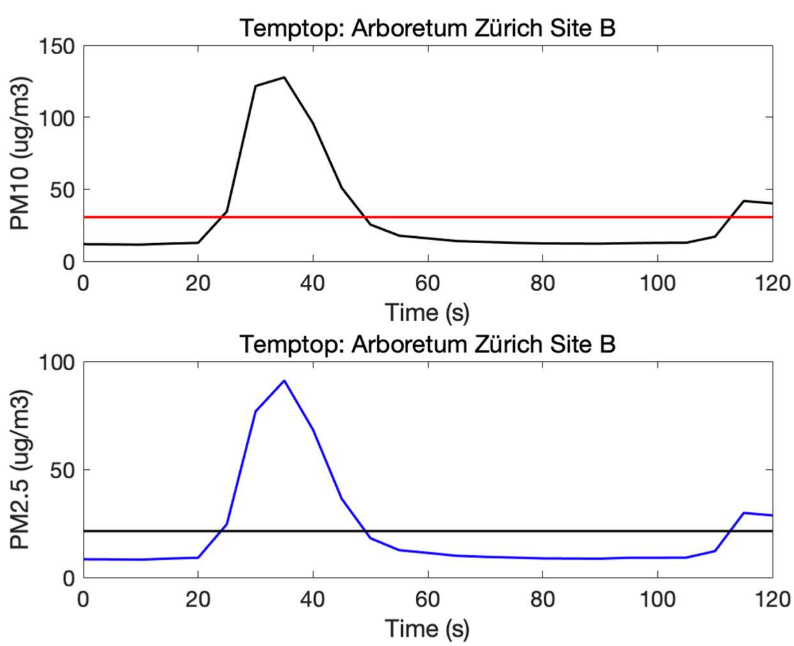


Figure J.16: Arboretum Zürich Site B $PM_{2.5}$ and PM_{10} concentrations Trial 2.

Site C

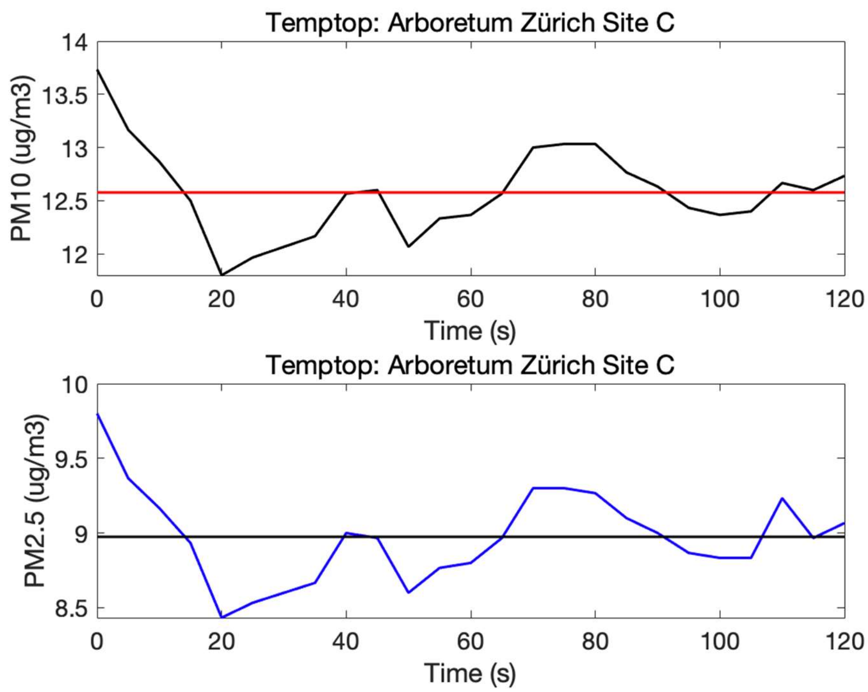


Figure J.17: Arboretum Zürich Site C $PM_{2.5}$ and PM_{10} concentrations Trial 1.

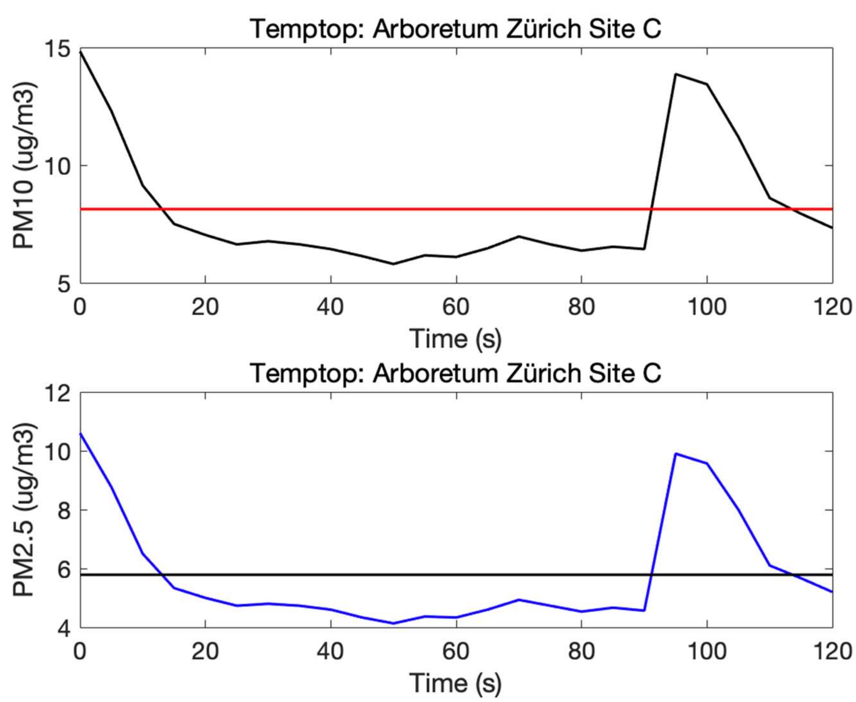


Figure J.18: Arboretum Zürich Site C $PM_{2.5}$ and PM_{10} concentrations Trial 2.

Appendix K: Temtop Average Particulate Matter Concentrations

Table K.1: Average particulate matter concentrations from both trials, recorded by the Temtop

Average of Both Trials		
Location and Site	Average concentration of $PM_{2.5}$ (µg/m^3)	Average concentration of PM_{10} (µg/m^3)
ETH Hönggerberg A	22.5	31.4
ETH Hönggerberg B	22.5	31.5
ETH Hönggerberg C	14.4	20.2
ETH Zentrum A	23.0	32.3
ETH Zentrum B	32.2	45.2
ETH Zentrum C	17.4	24.5
Arboretum Zürich A	27.8	38.5
Arboretum Zürich B	16.9	23.9
Arboretum Zürich C	7.4	10.4

Table K.2: Average particulate matter concentrations from trial 1, recorded by the Temtop

Trial 1		
Location and Site	Average concentration of $PM_{2.5}$ (µg/m^3)	Average concentration of PM_{10} (µg/m^3)
ETH Hönggerberg A	32.2	44.7
ETH Hönggerberg B	27.4	38.4
ETH Hönggerberg C	17.9	25.0
ETH Zentrum A	13.7	19.2
ETH Zentrum B	13.3	18.6
ETH Zentrum C	21.6	30.3
Arboretum Zürich A	17.8	24.9
Arboretum Zürich B	12.4	17.3
Arboretum Zürich C	9.0	12.6

Table K.3: Average particulate matter concentrations from trial 2, recorded by the Temtop

Trial 2		
Location and Site	Average concentration of $PM_{2.5}$ (μg/m^3)	Average concentration of PM_{10} (μg/m^3)
ETH Hönggerberg A	12.9	18.0
ETH Hönggerberg B	17.5	24.5
ETH Hönggerberg C	11.0	15.4
ETH Zentrum A	32.4	45.4
ETH Zentrum B	51.2	71.9
ETH Zentrum C	13.3	18.6
Arboretum Zürich A	37.7	52.2
Arboretum Zürich B	21.4	30.5
Arboretum Zürich C	5.8	8.1

Appendix L: BioTrap Petri Dish Images

ETH Hönggerberg

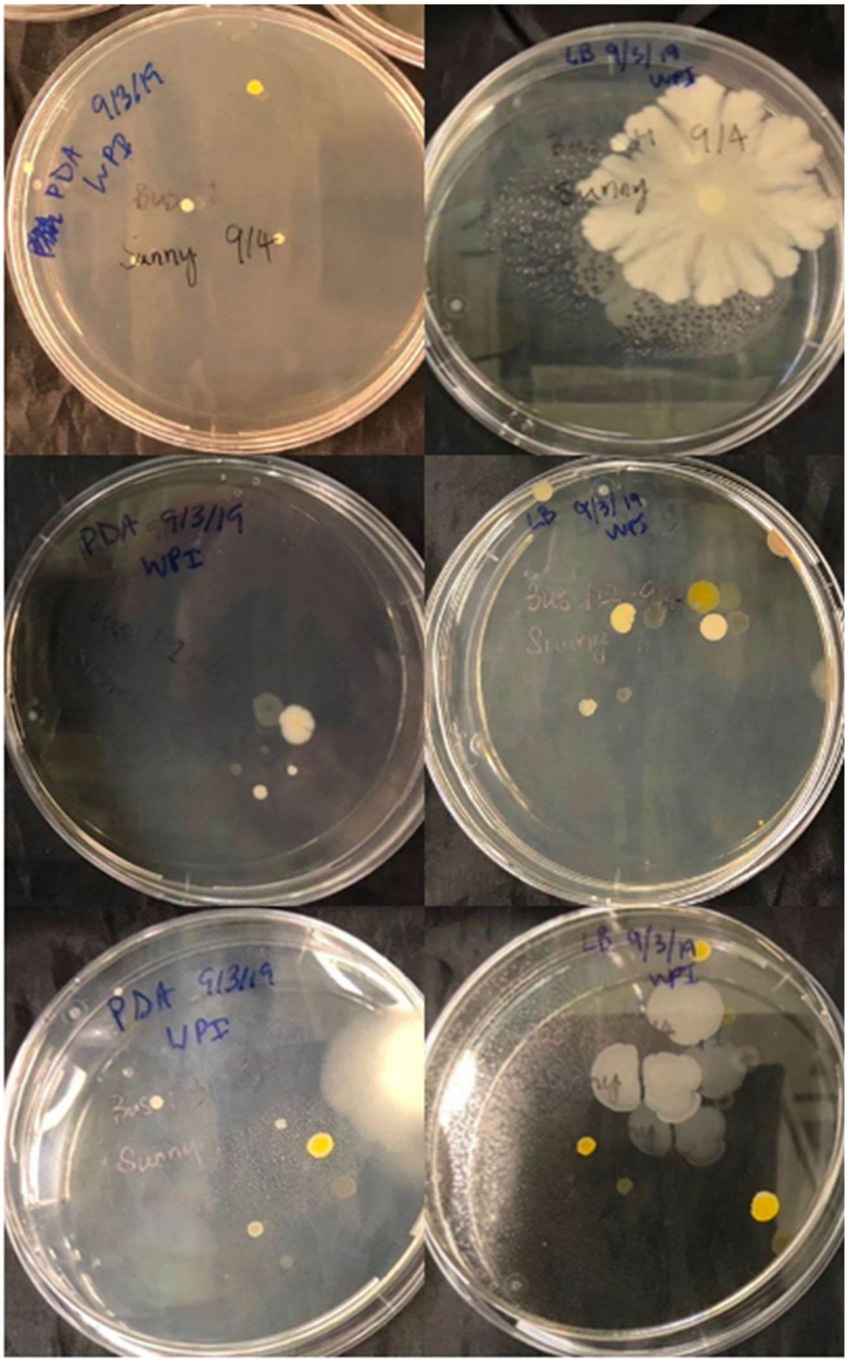


Figure L.1: Images of cultured petri dishes, collected using the BioTrap sensor, from ETH Hönggerberg Site A. PDA dishes are on the left and LB dishes are on the right, in the order in which they were recorded.

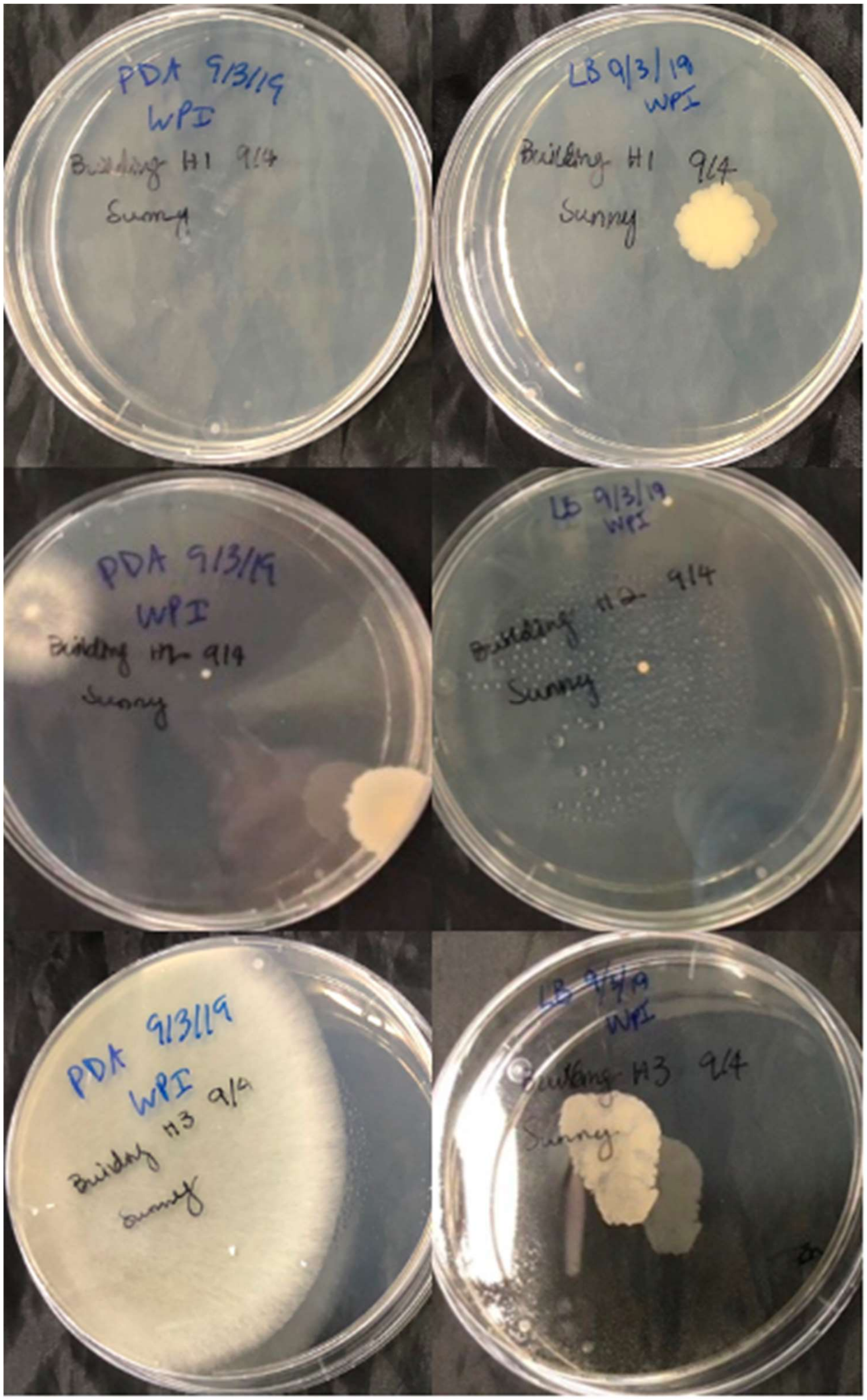


Figure L.2: Images of cultured petri dishes, collected using the BioTrap sensor, from ETH Hönggerberg Site B. PDA dishes are on the left and LB dishes are on the right, in the order in which they were recorded.

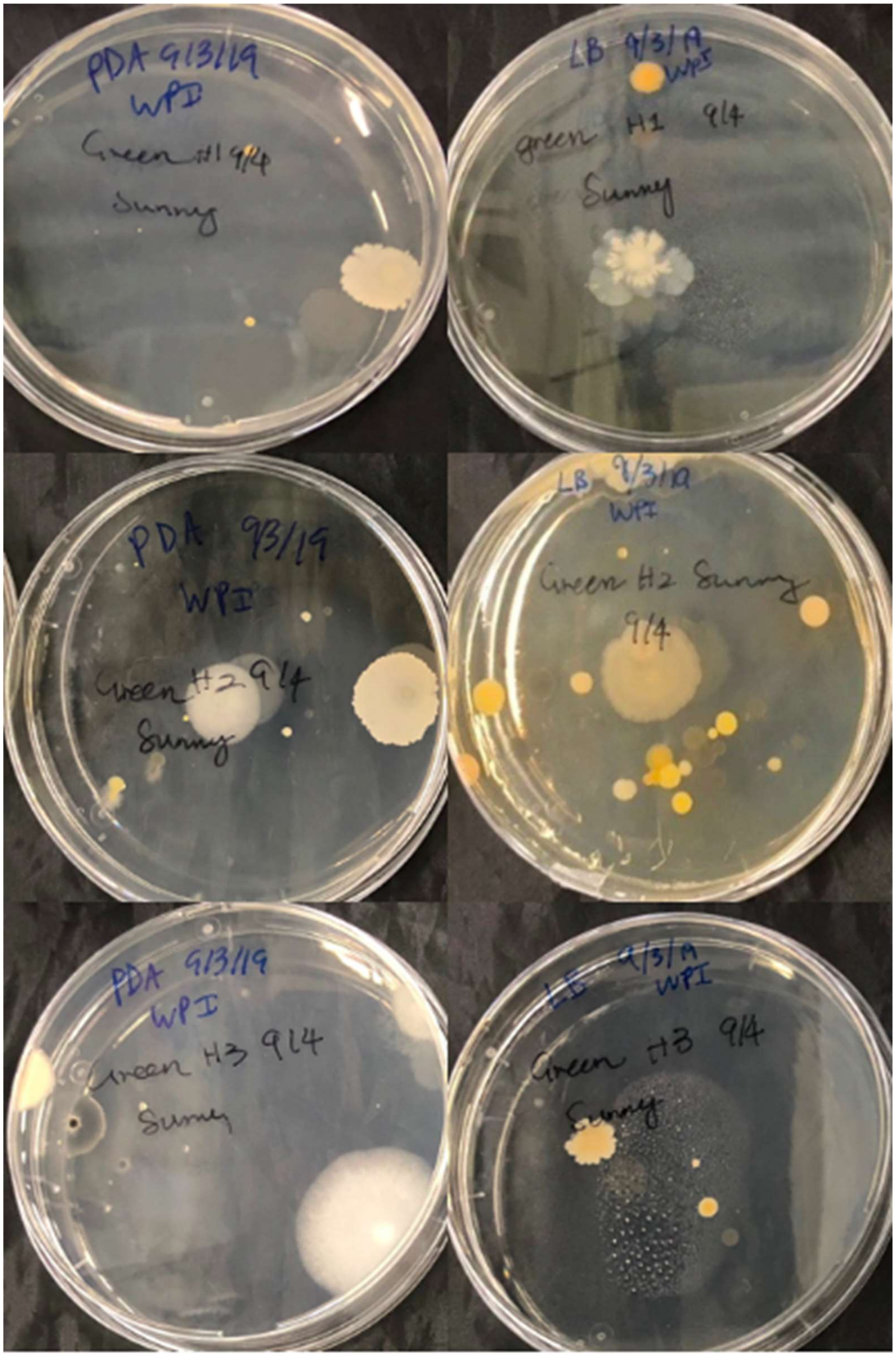


Figure L.3: Images of cultured petri dishes, collected using the BioTrap sensor, from ETH Hönggerberg Site C. PDA dishes are on the left and LB dishes are on the right, in the order in which they were recorded.

ETH Zentrum

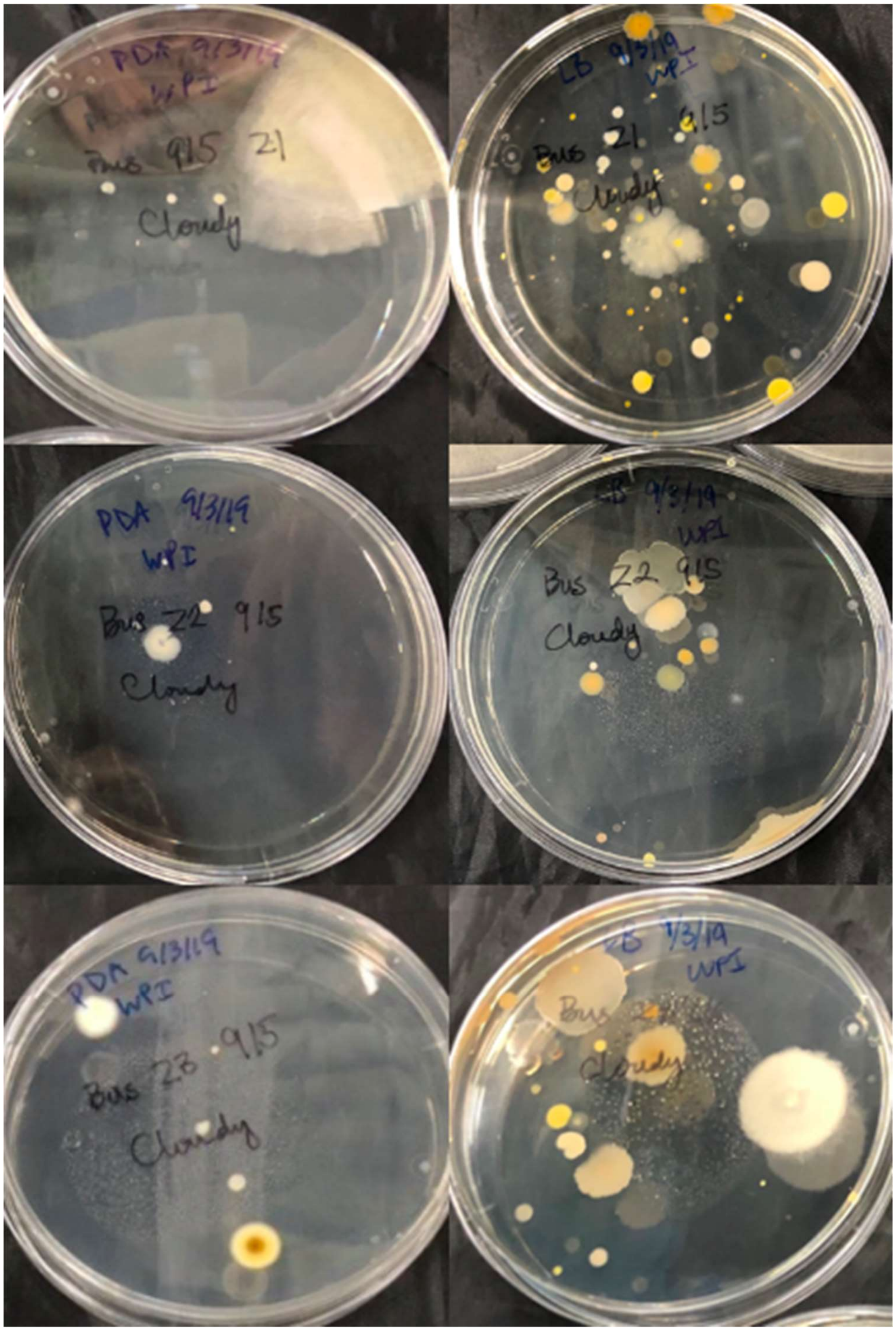


Figure L.4: Images of cultured petri dishes, collected using the BioTrap sensor, from ETH Zentrum Site A. PDA dishes are on the left and LB dishes are on the right, in the order in which they were recorded.

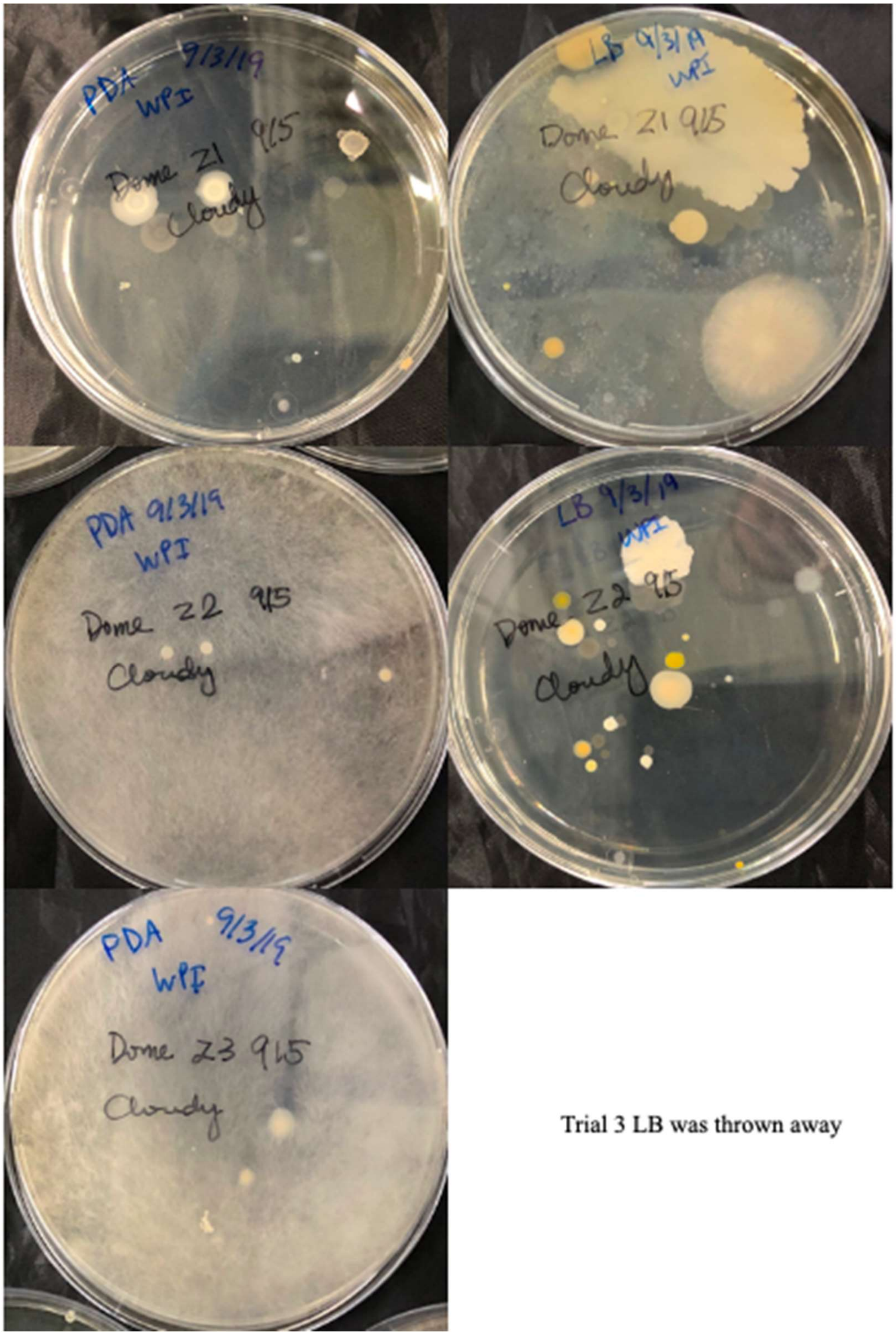
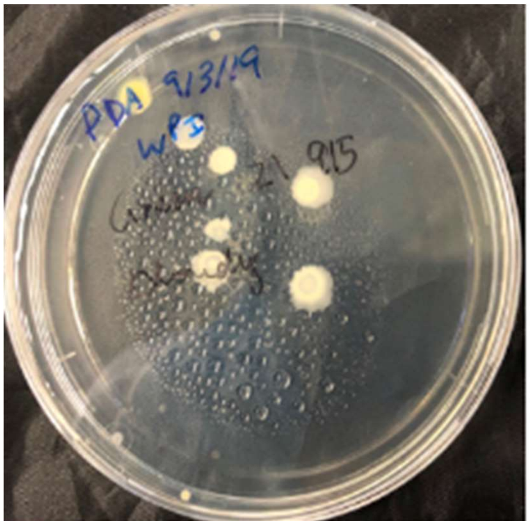
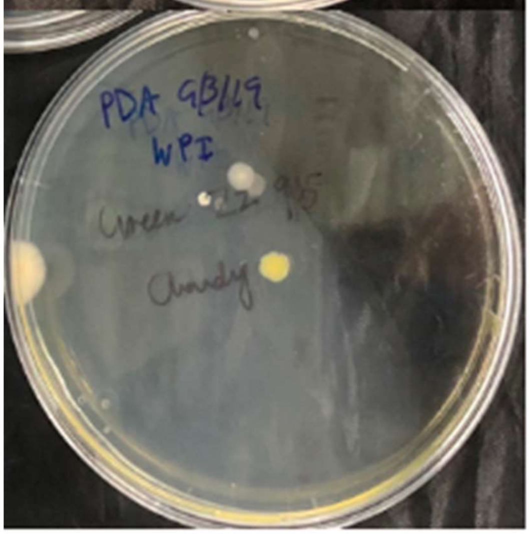
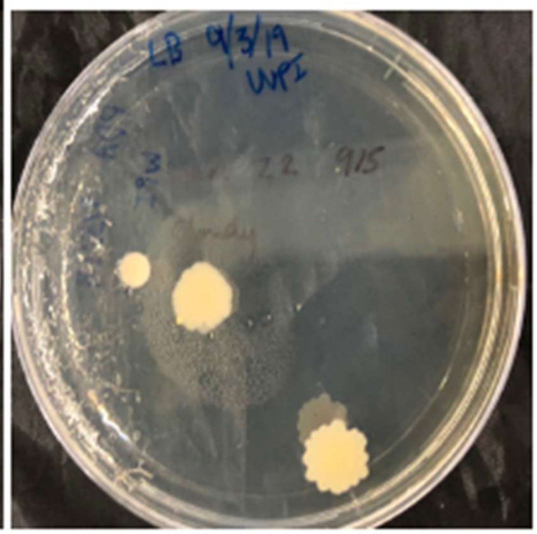


Figure L.5: Images of cultured petri dishes, collected using the BioTrap sensor, from ETH Zentrum Site B. PDA dishes are on the left and LB dishes are on the right, in the order in which they were recorded.



Trial 1 LB was thrown away





Trial 3 PDA was thrown away

Trial 3 LB was thrown away

Figure L.6: Images of cultured petri dishes, collected using the BioTrap sensor, from ETH Zentrum Site C. PDA dishes are on the left and LB dishes are on the right, in the order in which they were recorded.

Arboretum Zürich

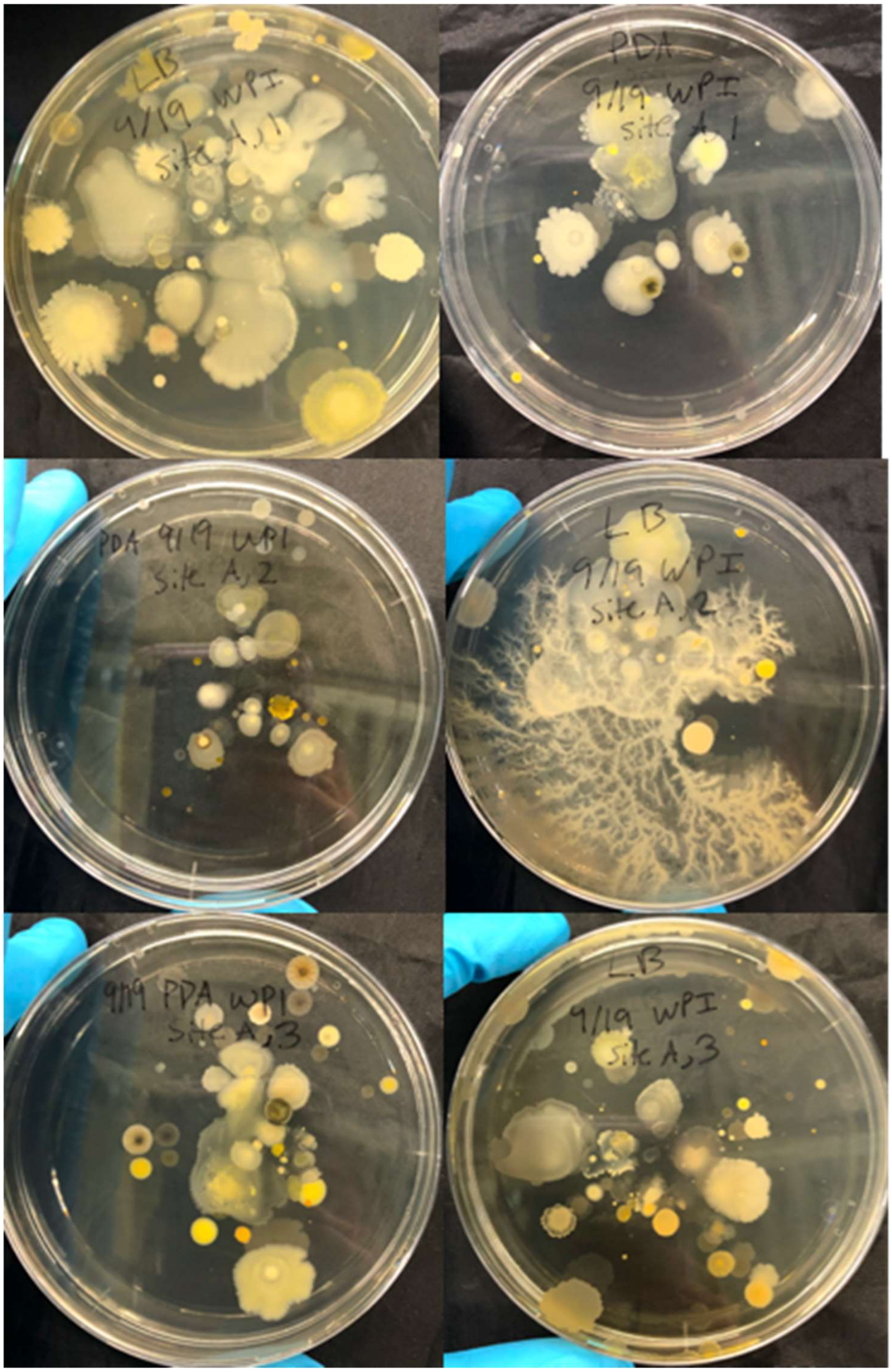


Figure L.7: Images of cultured petri dishes, collected using the BioTrap sensor, from the Arboretum Zürich Site A. PDA dishes are on the left and LB dishes are on the right, in the order in which they were recorded.

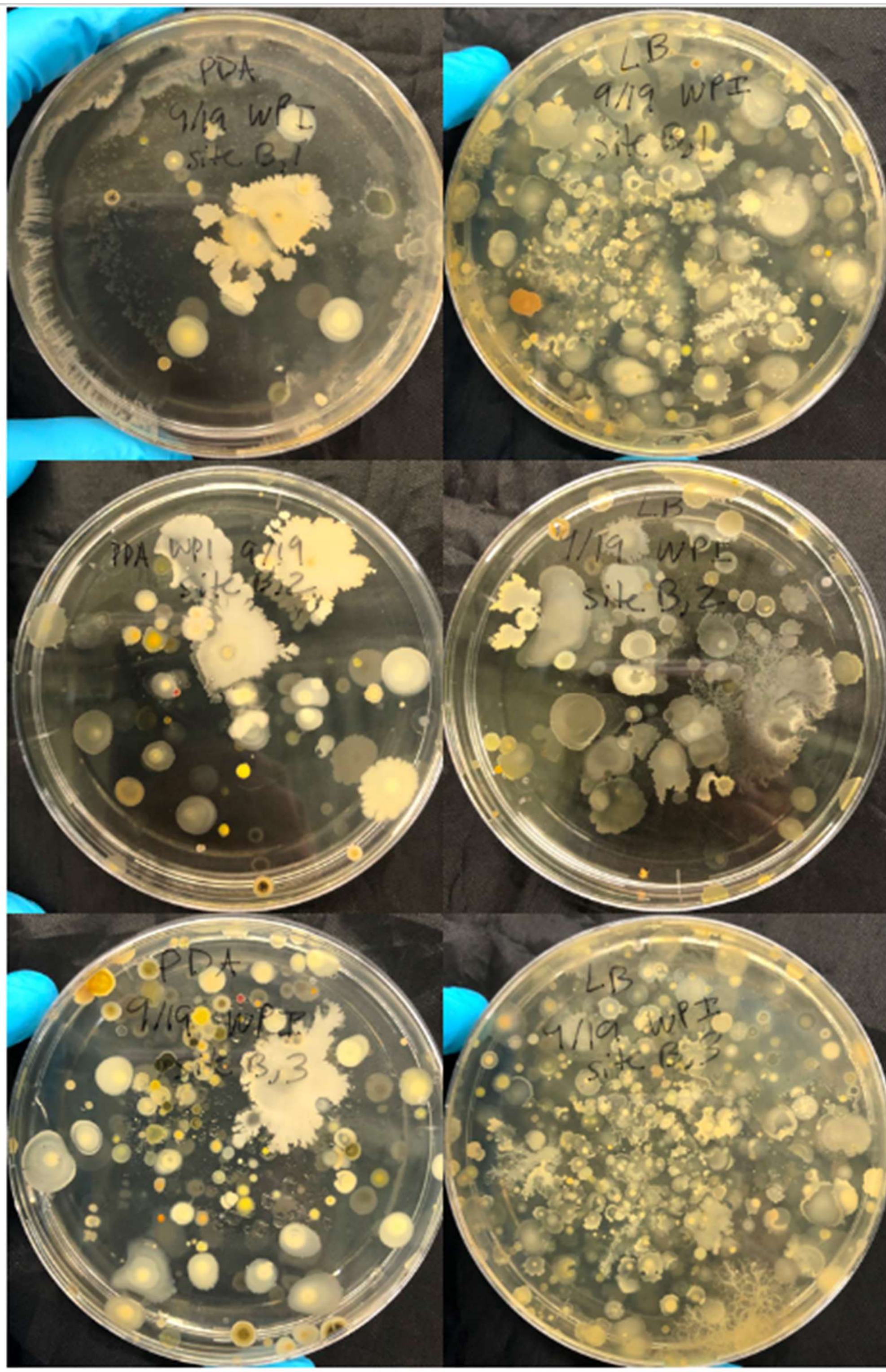


Figure L.8: Images of cultured petri dishes, collected using the BioTrap sensor, from the Arboretum Zürich Site B. PDA dishes are on the left and LB dishes are on the right, in the order in which they were recorded.

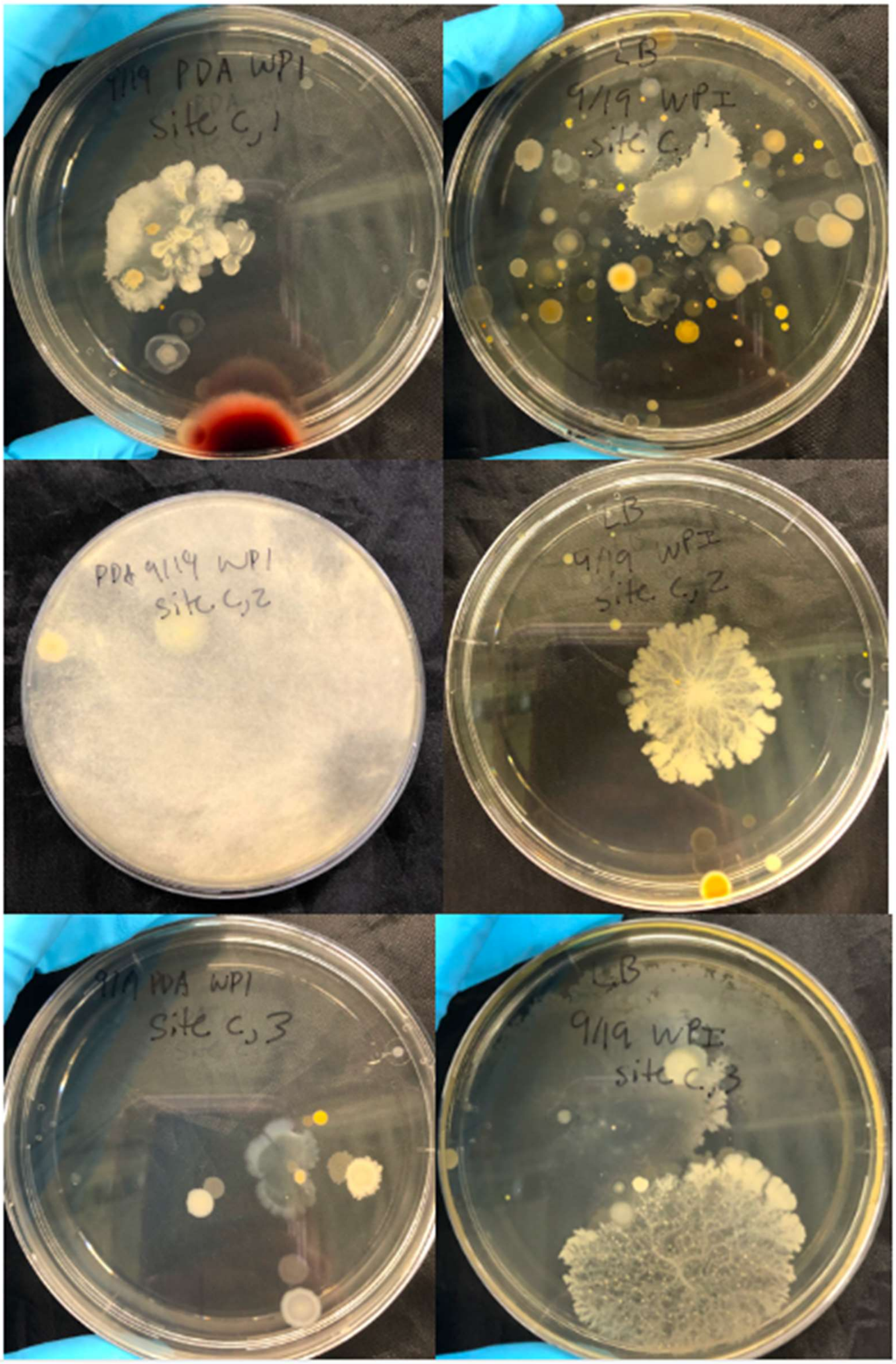


Figure L.9: Images of cultured petri dishes, collected using the BioTrap sensor, from the Arboretum Zürich Site C. PDA dishes are on the left and LB dishes are on the right, in the order in which they were recorded.

Appendix M: BioTrap Bacterial and Fungal Colony Counts

Table M.1: Counts of bacterial and fungal colonies in cultured petri dishes from the ETH Hönggerberg Campus

Date	Weather	Site	Trial	Type	Result	Count
9/4	Sunny	A	1	Fungi/PDA	Success	4
9/4	Sunny	A	2	Fungi/PDA	Success	3
9/4	Sunny	A	3	Fungi/PDA	Success	6
9/4	Sunny	A	1	Bacteria/LB	Fail	-
9/4	Sunny	A	2	Bacteria/LB	Success	8
9/4	Sunny	A	3	Bacteria/LB	Success	6
9/4	Sunny	B	1	Fungi/PDA	Fail	-
9/4	Sunny	B	2	Fungi/PDA	Success	3
9/4	Sunny	B	3	Fungi/PDA	Fail	-
9/4	Sunny	B	1	Bacteria/LB	Success	1
9/4	Sunny	B	2	Bacteria/LB	Success	2
9/4	Sunny	B	3	Bacteria/LB	Success	1
9/4	Sunny	C	1	Fungi/PDA	Success	3
9/4	Sunny	C	2	Fungi/PDA	Success	6
9/4	Sunny	C	3	Fungi/PDA	Fail	-
9/4	Sunny	C	1	Bacteria/LB	Success	2
9/4	Sunny	C	2	Bacteria/LB	Success	17
9/4	Sunny	C	3	Bacteria/LB	Success	3

Table M.2: Counts of bacterial and fungal colonies in cultured petri dishes from the Arboretum Zürich

Date	Weather	Site	Trial	Type	Result	Count
9/20	Sunny	A	1	Fungi/PDA	Success	17
9/20	Sunny	A	2	Fungi/PDA	Success	23
9/20	Sunny	A	3	Fungi/PDA	Success	29
9/20	Sunny	A	1	Bacteria/LB	Success	27
9/20	Sunny	A	2	Bacteria/LB	Success	17
9/20	Sunny	A	3	Bacteria/LB	Success	28
9/20	Sunny	B	1	Fungi/PDA	Success	20
9/20	Sunny	B	2	Fungi/PDA	Success	26
9/20	Sunny	B	3	Fungi/PDA	Success	68
9/20	Sunny	B	1	Bacteria/LB	Success	100+
9/20	Sunny	B	2	Bacteria/LB	Success	46
9/20	Sunny	B	3	Bacteria/LB	Success	100+
9/20	Sunny	C	1	Fungi/PDA	Success	14
9/20	Sunny	C	2	Fungi/PDA	Success	2
9/20	Sunny	C	3	Fungi/PDA	Success	6
9/20	Sunny	C	1	Bacteria/LB	Success	37
9/20	Sunny	C	2	Bacteria/LB	Success	6
9/20	Sunny	C	3	Bacteria/LB	Success	8

Table M.3: Counts of bacterial and fungal colonies in cultured petri dishes from the ETH Zentrum Campus

Date	Weather	Site	Trial	Type	Result	Count
9/5	Cloudy	A	1	Fungi/PDA	Fail	-
9/5	Cloudy	A	2	Fungi/PDA	Fail	-
9/5	Cloudy	A	3	Fungi/PDA	Fail	-
9/5	Cloudy	A	1	Bacteria/LB	Success	52
9/5	Cloudy	A	2	Bacteria/LB	Success	14
9/5	Cloudy	A	3	Bacteria/LB	Fail	-
9/5	Cloudy	B	1	Fungi/PDA	Success	4
9/5	Cloudy	B	2	Fungi/PDA	Fail	-
9/5	Cloudy	B	3	Fungi/PDA	Fail	-
9/5	Cloudy	B	1	Bacteria/LB	Fail	7
9/5	Cloudy	B	2	Bacteria/LB	Success	12
9/5	Cloudy	B	3	Bacteria/LB	Fail	-
9/5	Cloudy	C	1	Fungi/PDA	Success	8
9/5	Cloudy	C	2	Fungi/PDA	Fail	-
9/5	Cloudy	C	3	Fungi/PDA	Fail	-
9/5	Cloudy	C	1	Bacteria/LB	Fail	-
9/5	Cloudy	C	2	Bacteria/LB	Success	3
9/5	Cloudy	C	3	Bacteria/LB	Fail	-

Appendix N: Survey Responses Raw

Table N.1: Survey data from Zürich Arboretum

What is your age?	What gender do you identify with?	Are you a resident or have you ever been a resident of Switzerland?	What country are you a resident of?	What type of region are you from?	Rate how concerned you are with air pollution?	Please check the primary reason why you are concerned	How often do you think about the air quality in Switzerland?	What is the air quality like in the town/city where you are living?	What is the air quality like in Switzerland in general?	How informed are you about Swiss air quality?	Switzerland has federal limits on air pollution. Do you think these limits are being exceeded?	Is there somewhere that you can look at real time data of local air quality?	Have you ever looked up this data?	Do you know what a bioaerosol is?	If you were to receive information on local air quality, how would you like to receive it?	If you were to receive information on local air quality, how detailed would you like it to be?	If you were to receive information on local air quality, how often would you like to receive it?
15-25	Female	No	UK	Urban	Slightly Concerned	Quality of life	Never	Acceptable	Excellent	Very informed	Yes	No		Yes	Text alerts	Number scale rating	Daily
65+	Male	Yes		Urban	Very Concerned	Quality of life	Daily	Good	Acceptable	Somewhat informed	Yes	No		No	Email	Color scale rating	Monthly
26-35	Female	No	Japan	Rural	Slightly Concerned	Health	Daily	Excellent	Good	Very informed	No	No		No	Smartphone app	Number scale rating	Daily
15-25	Male	No	Spain	Urban	Concerned	Health	Never	Poor	Good	Not informed at all	No	Yes	Yes	Yes	Smartphone app	No more than a sentence	Weekly
26-35	Male	Yes		Urban	Very Concerned	Quality of life	Never	Excellent	Excellent	Somewhat informed	Yes	Yes	No	Heard of term	Website	One word indicating	Daily
15-25	Female	Yes		Suburban	Very Concerned	Health	Weekly	Good	Good	Not informed at all	Yes	No		No	Newspaper	A few sentences	Yearly
15-25	Female	No	Ireland	Suburban	Very Concerned	Health	Yearly	Good	Good	Not informed at all	No	Yes	No	Heard of term	Smartphone app	Color scale rating	Weekly
36-45	Female	Yes		Rural	Slightly Concerned	Quality of life	Never	Excellent	Excellent	Not informed at all	No	No		No	Website	Number scale rating	Monthly
56-65	Male	Yes		Urban	Concerned	Health	Daily	Good	Good	Very informed	Yes	Yes	No	No	Website	One word indicating	Weekly
26-35	Male	Yes		Urban	Concerned	Environmental concerns	Yearly	Excellent	Excellent	Somewhat informed	Yes	Yes	No	No	Smartphone app	Number scale rating	Daily
65+	Female	Yes		Urban	Concerned	Quality of life	Weekly	Good	Good	Very informed	Yes	Yes	Yes	No			
26-35	Male	Yes		Rural	Slightly Concerned	Quality of life	Never	Good	Excellent	Very informed	No	No		No	Website	Color scale rating	Weekly
26-35	Male	Yes		Urban	Concerned	Environmental concerns	Daily	Acceptable	Good	Somewhat informed	No	No		Yes	Smartphone app	One word indicating	Weekly
15-25	Female	Yes		Suburban	Slightly Concerned	Health	Weekly	Acceptable	Good	Not informed at all	Yes	Yes	No	No	Smartphone app	One word indicating	Monthly
26-35	Female	Yes			Very Concerned	Health	Never	Excellent	Excellent	Very informed	Yes	Yes	Yes	No	Newspaper	Color scale rating	Daily
15-25	Male	Yes		Suburban	Not Concerned		Weekly	Excellent	Poor	Not informed at all	Yes	Yes	No	Heard of term	Smartphone app	Color scale rating	Monthly
15-25	Male	Yes		Suburban	Slightly Concerned	Environmental concerns	Weekly	Good	Good	Not informed at all	No	No		No	Smartphone app	Color scale rating	Monthly
15-25	Female	Yes		Rural	Slightly Concerned	Quality of life	Monthly	Good	Good	Somewhat informed	Yes	Yes	No	Heard of term	Website	Color scale rating	Weekly
15-25	Male	Yes		Rural	Slightly Concerned	Quality of life	Yearly	Excellent	Excellent	Somewhat informed	No	Yes	Yes	No	Smartphone app	Color scale rating	Weekly
15-25	Female	No	Germany	Suburban	Not Concerned		Never	Good	Excellent	Not informed at all	No	Yes	No	Yes	Website	Color scale rating	Weekly
15-25	Female	Yes		Rural	Concerned	Environmental concerns	Weekly	Acceptable	Good	Not informed at all	Yes	No		No	Smartphone app	Color scale rating	Weekly
26-35	Male	Yes		Suburban	Slightly Concerned	Environmental concerns	Never	Acceptable	Excellent	Not informed at all	No	Yes	No	No	Smartphone app	Number scale rating	Monthly
15-25	Female	Yes		Suburban	Concerned	Quality of life	Weekly	Acceptable	Good	Somewhat informed	Yes	No		No	Smartphone app	Color scale rating	Weekly
15-25	Female	Yes		Suburban	Concerned	Quality of life	Weekly	Good	Good	Somewhat informed	Yes	Yes	No	No	Smartphone app	Number scale rating	Daily
65+	Female	Yes		Urban	Very Concerned	Environmental concerns	Weekly	Good	Acceptable	Somewhat informed	Yes	Yes	Yes	Yes	Website	One word indicating	Weekly

Table N.2: Survey data from ETH Hönggerberg

What is your age?	What gender do you identify with?	Are you a resident or have you ever been a resident of Switzerland?	What country are you a resident of?	What type of region are you from?	Rate how concerned you are with air pollution?	Please check the primary reason why you are concerned	How often do you think about the air quality in Switzerland?	What is the air quality like in the town/city where you are living?	What is the air quality like in Switzerland in general?	How informed are you about Swiss air quality?	Switzerland has federal limits on air pollution. Do you think these limits are being exceeded?	Is there somewhere that you can look at real time data of local air quality?	Have you ever looked up this data?	Do you know what a bioaerosol is?	If you were to receive information on local air quality, how would you like to receive it?	If you were to receive information on local air quality, how detailed would you like it to be?	If you were to receive information on local air quality, how often would you like to receive it?
36-45	Female	Yes		Suburban	Very Concerned	Health and environmental	Monthly	Excellent	Excellent	Not informed at all	Yes	Yes	No	No	Website	Color scale rating	Monthly
15-25	Male	Yes		Urban	Very Concerned	All of these	Monthly	Good	Good	Somewhat informed	No	Yes	Yes	No	My own measurement device	Number scale rating	Daily
26-35	Female	Yes		Urban	Very Concerned	Environmental concerns	Monthly	Good	Good	Somewhat informed	Yes	Yes	Yes	Yes	Smartphone app	Color scale rating	Daily
15-25	Male	Yes		Urban	Not Concerned		Monthly	Good	Good	Somewhat informed	Yes	No		Heard of term	Smartphone app	One word indicating	Weekly
26-35	Male	Yes		Urban	Slightly Concerned	Environmental concerns	Yearly	Good	Good	Not informed at all	Yes	Yes	No	Yes	Text alerts	Color scale rating	Weekly
26-35	Male	Yes		Urban	Concerned	Health	Monthly	Good	Excellent	Somewhat informed	No	No		Yes	Smartphone app	Number scale rating	Weekly
26-35	Female	Yes		Urban	Slightly Concerned	Health	Weekly	Excellent	Excellent	Somewhat informed	Yes	Yes	No	Yes	Smartphone app	Color scale rating	Daily
26-35	Male	Yes		Urban	Slightly Concerned	Health	Monthly	Good	Good	Somewhat informed	Yes	No		Yes	Website	Color scale rating	Monthly
26-35	Male	Yes		Urban	Concerned	Environmental concerns	Monthly	Good	Good	Somewhat informed	Yes	Yes	Yes	Yes	Website	Color scale rating	Monthly
36-45	Female	Yes		Urban	Very Concerned	Health	Monthly	Good	Excellent	Very informed	Yes	Yes	No	No	Smartphone app	No more than a sentence	Daily
36-45	Female	Yes		Urban	Very Concerned	All of these	Daily	Good	Excellent	Somewhat informed	No	Yes	Yes	Yes		Color scale rating	Daily
26-35	Male	Yes		Urban	Slightly Concerned	Environmental concerns	Never	Excellent	Excellent	Not informed at all	No	Yes	Yes	Heard of term	Smartphone app	Color scale rating	Weekly
15-25	Male	No	Israel	Urban	Very Concerned	Environmental concerns	Never	Acceptable	Excellent	Not informed at all				Heard of term	Website	Color scale rating	Weekly
26-35	Male	No	Hungary	Urban	Slightly Concerned	Health	Yearly	Good	Excellent	Not informed at all	Yes	Yes	No	Heard of term	Smartphone app	Color scale rating	Daily
26-35	Female	Yes		Suburban	Concerned	Environmental concerns	Weekly	Excellent	Excellent	Somewhat informed	No	No		No	Smartphone app	One word indicating	Weekly
36-45	Female	Yes		Suburban	Very Concerned	Environmental concerns	Monthly	Good	Good	Somewhat informed	Yes	Yes	No	Heard of term	Smartphone app	Number scale rating	Monthly
36-45	Male	Yes		Suburban	Concerned	Health	Monthly	Good	Good	Somewhat informed	No	Yes	No	Heard of term	Text alerts	Number scale rating	Weekly
15-25	Female	Yes		Rural	Concerned	Health	Monthly	Poor	Acceptable	Somewhat informed	Yes	Yes	No	Heard of term	Website	Number scale rating	Monthly
15-25	Male	Yes		Urban	Slightly Concerned		Monthly	Good	Good	Somewhat informed		Yes	No	No	Website	A few sentences	Weekly
15-25	Female	Yes		Urban	Slightly Concerned	Quality of life	Yearly	Good	Excellent	Not informed at all	No	Yes	No	No	Website	Number scale rating	Yearly
15-25	Male	Yes		Urban	Not Concerned		Never	Good	Excellent	Somewhat informed	No	Yes	No	Heard of term	Smartphone app	Number scale rating	Monthly
15-25	Female	Yes		Rural	Concerned	Environmental concerns	Monthly	Good	Acceptable	Not informed at all	Yes		No	Heard of term	Website	Number scale rating	Monthly
15-25	Male	Yes		Rural	Slightly Concerned	Environmental concerns	Monthly	Good	Good	Not informed at all	No	Yes	Yes	No	Website	Color scale rating	Weekly
15-25	Male	Yes		Rural	Slightly Concerned	Environmental concerns	Monthly	Good	Good	Not informed at all	No	Yes	Yes	No	Website	Color scale rating	Weekly
26-35	Male	Yes		Urban	Slightly Concerned	Quality of life	Monthly	Excellent	Excellent	Not informed at all	Yes	No		Yes	Website	Number scale rating	Daily
65+	Male	Yes		Urban	Concerned	Health and Environmental	Weekly	Good	Good	Very informed	No	No		Yes	Newspaper	One word indicating	Daily
26-35	Female	Yes		Urban	Slightly Concerned	Health	Monthly	Good	Excellent	Not informed at all	No	No		Yes	Newspaper	Color scale rating	Yearly
15-25	Male	Yes		Urban	Concerned	Quality of life	Weekly	Acceptable	Poor	Somewhat informed	Yes	No		No	Smartphone app	Color scale rating	Weekly
26-35	Male	Yes		Urban	Not Concerned		Yearly	Excellent	Excellent	Somewhat informed	No	Yes	Yes	No	Smartphone app	Number scale rating	Weekly
15-25	Female	Yes		Rural	Concerned	Health	Weekly	Excellent	Good	Somewhat informed	No	No		No	Website	Color scale rating	Weekly

Table N.3: Survey data from ETH Zentrum

What is your age?	What gender do you identify with?	Are you a resident or have you ever been a resident of Switzerland?	What country are you a resident of?	What type of region are you from?	Rate how concerned you are with air pollution?	Please check the primary reason why you are concerned	How often do you think about the air quality in Switzerland?	What is the air quality like in the town/city where you are living?	What is the air quality like in Switzerland in general?	How informed are you about Swiss air quality?	Switzerland has federal limits on air pollution. Do you think these limits are being exceeded?	Is there somewhere that you can look at real time data of local air quality?	Have you ever looked up this data?	Do you know what a bioaerosol is?	If you were to receive information on local air quality, how would you like to receive it?	If you were to receive information on local air quality, how detailed would you like it to be?	If you were to receive information on local air quality, how often would you like to receive it?
15-25	Male	Yes		Suburban	Concerned	Quality of life	Monthly	Good	Acceptable	Somewhat informed	Yes	Yes	No	No	Website	Color scale rating	Weekly
15-25	Male	Yes		Urban	Slightly Concerned	Health	Monthly	Good	Acceptable	Somewhat informed	Yes	No		No	Smartphone app	A few sentences	Monthly
15-25	Female	Yes		Suburban	Slightly Concerned	Environmental concerns	Yearly	Good	Good	Not informed at all	No	Yes	No	No	Website	Number scale rating	Monthly
15-25	Female	Yes		Suburban	Concerned	Environmental concerns	Monthly	Good	Good	Somewhat informed	Yes	No		Heard of term	Smartphone app	Color scale rating	Weekly
15-25	Female	Yes		Urban	Slightly Concerned	Health	Monthly	Acceptable	Acceptable	Somewhat informed	Yes	No		Heard of term	Website	Color scale rating	Weekly
15-25	Male	Yes		Urban	Slightly Concerned	Environmental concerns	Monthly	Excellent	Excellent	Somewhat informed	Yes	Yes	No	Heard of term	Smartphone app	Color scale rating	Weekly
15-25	Female	Yes		Urban	Slightly Concerned	Environmental concerns	Monthly	Good	Good	Somewhat informed	Yes	No		Heard of term	Newspaper	Color scale rating	Monthly
15-25	Female	Yes		Suburban	Slightly Concerned	Environmental concerns	Weekly	Acceptable	Good	Somewhat informed	Yes	No		Heard of term	Newspaper	Number scale rating	Monthly
15-25	Female	Yes		Urban	Very Concerned	Health	Monthly	Acceptable	Excellent	Not informed at all	No	No		No	Newspaper	Color scale rating	Monthly
15-25	Male	Yes		Suburban	Concerned	Environmental concerns	Yearly	Excellent	Excellent	Not informed at all	No	No		No	Website	Color scale rating	Weekly
26-35	Male	Yes		Suburban	Concerned	Environmental concerns	Yearly	Acceptable	Acceptable	Somewhat informed	Yes	Yes	No	No	Smartphone app	One word indicating	Daily
15-25	Male	No	Italy	Rural	Slightly Concerned	Environmental concerns	Never	Good	Excellent	Not informed at all	No	No		Heard of term	Smartphone app	Color scale rating	Weekly
15-25	Male	Yes		Rural	Concerned	Health	Monthly	Excellent	Excellent	Not informed at all	No	No		No	Smartphone app	Number scale rating	Daily
15-25	Male	No	Germany	Suburban	Slightly Concerned	Health	Never	Excellent	Excellent	Not informed at all	No	No		Heard of term	Text alerts	Number scale rating	Weekly
15-25	Male	Yes		Urban	Concerned	Environmental concerns	Weekly	Excellent	Excellent	Somewhat informed	No	No		Heard of term	Smartphone app	Color scale rating	Daily
26-35	Female	Yes		Urban	Concerned	Environmental concerns	Weekly	Acceptable	Good	Not informed at all	No	No		No	Website	Number scale rating	Monthly
36-45	Female	Yes		Urban	Slightly Concerned	Health	Yearly	Acceptable	Acceptable	Somewhat informed	Yes	Yes	Yes	Heard of term	Smartphone app	Color scale rating	Weekly
15-25	Male	Yes		Rural	Slightly Concerned	Health	Yearly	Good	Acceptable	Not informed at all	No	Yes	No	No	Website	Number scale rating	Yearly
15-25	Male	Yes		Suburban	Slightly Concerned	Quality of life	Monthly	Good	Good	Not informed at all	Yes	Yes	No	No	Smartphone app	Number scale rating	Daily
15-25	Male	Yes		Suburban	Slightly Concerned	Health	Monthly	Good	Good	Somewhat informed	No	Yes	No	No	Smartphone app	Number scale rating	Daily
15-25	Female	Yes		Urban	Concerned	Environmental concerns	Never	Good	Good	Not informed at all	Yes	No		No	Newspaper	Color scale rating	Weekly
15-25	Female	Yes		Suburban	Concerned	Environmental concerns	Yearly	Good	Good	Not informed at all	Yes	Yes	No	Heard of term	Smartphone app	Color scale rating	Weekly
15-25	Female	Yes		Rural	Slightly Concerned	Environmental concerns	Yearly	Good	Good	Not informed at all	No	No		Heard of term	Smartphone app	Color scale rating	Weekly
15-25	Female	Yes		Rural	Not Concerned		Never	Good	Good	Not informed at all	Yes	No		No	Website	A few sentences	Weekly
15-25	Male	Yes		Suburban	Not Concerned		Yearly	Good	Excellent	Somewhat informed	Yes	No		No	Website	Number scale rating	Weekly

Appendix O: Survey Graphs

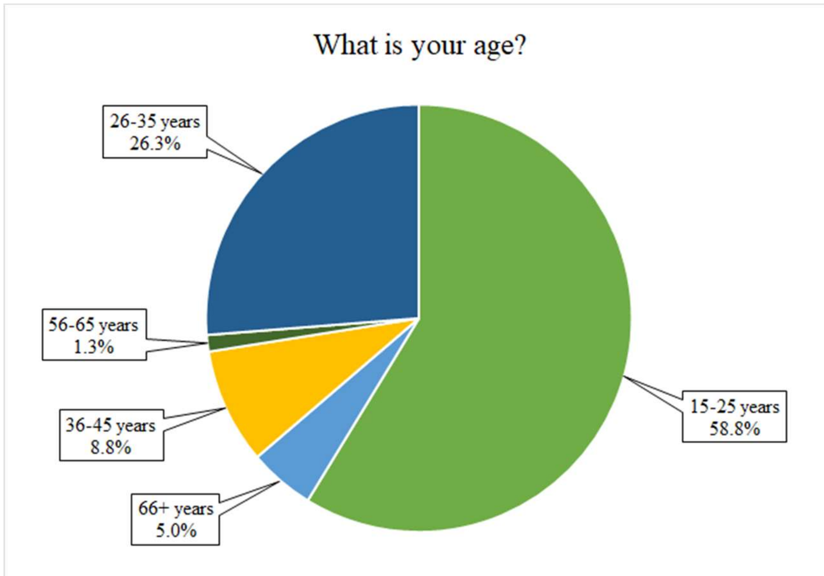


Figure O.1: Survey responses to "what is your age?"

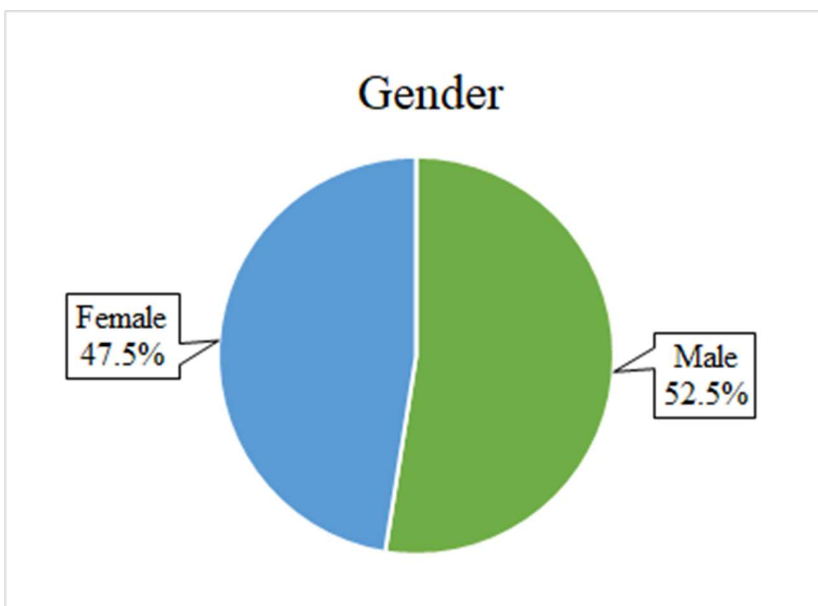


Figure O.2: Survey responses to "what gender do you identify with?"

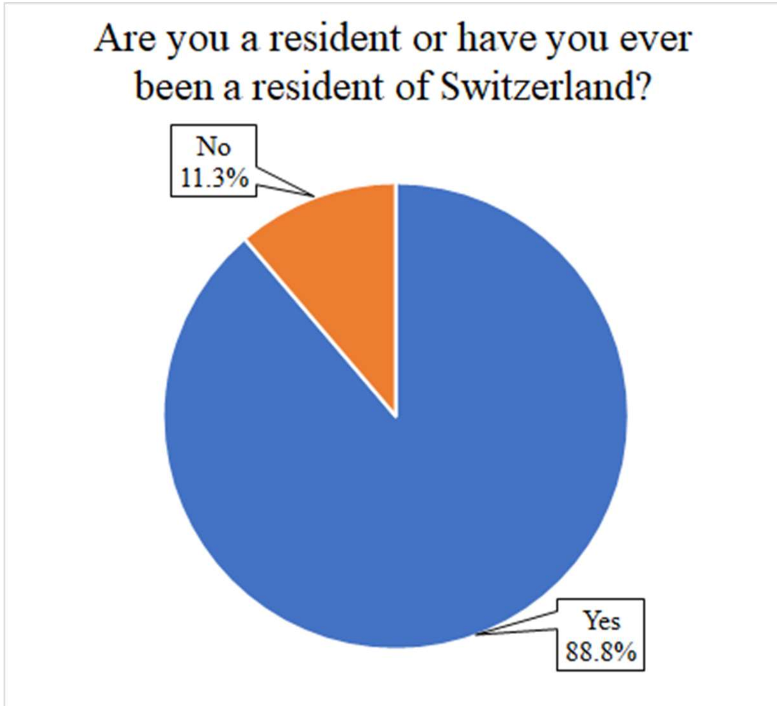


Figure O.3: Survey responses to "are you a resident or have you ever been a resident of Switzerland?"

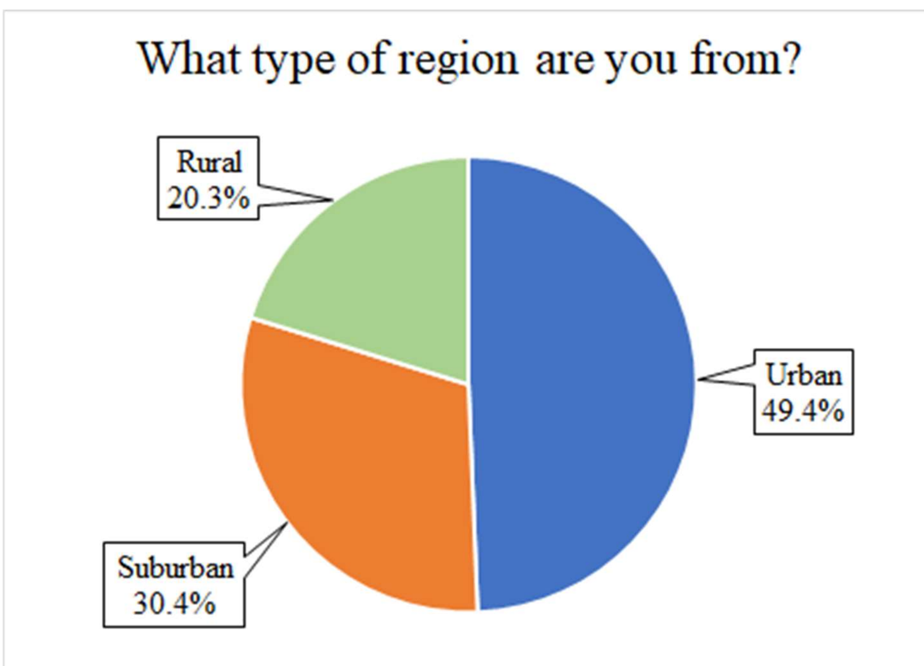


Figure O.4: Survey responses to "what type of region are you from?"

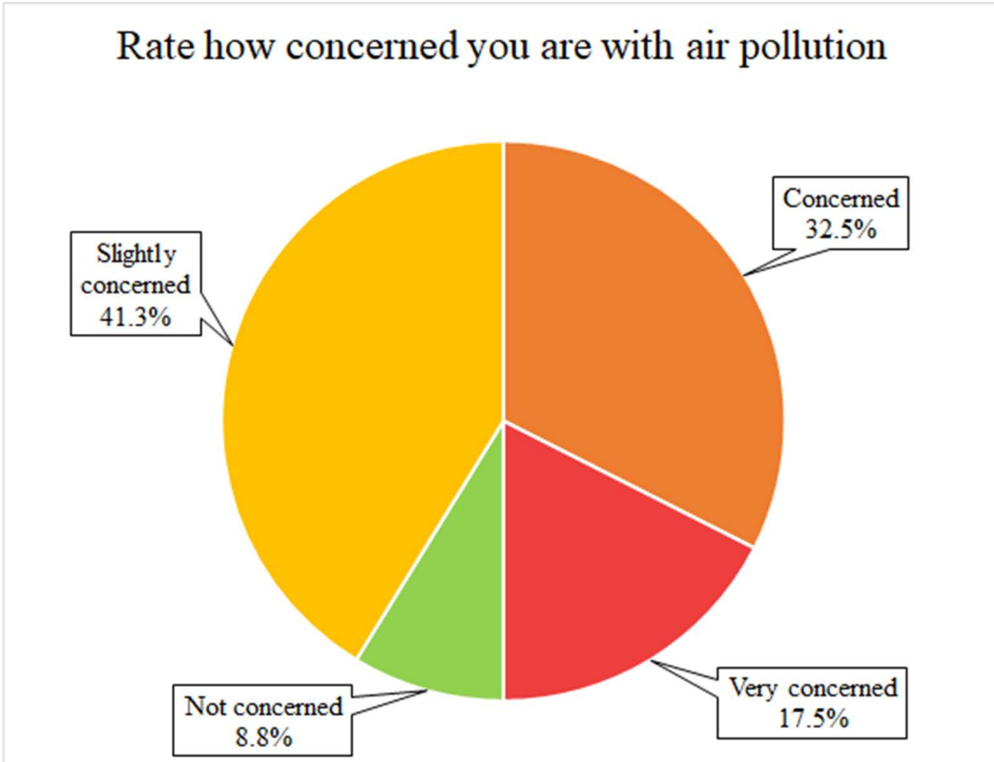


Figure O.5: Survey responses to "rate how concerned you are with air pollution"

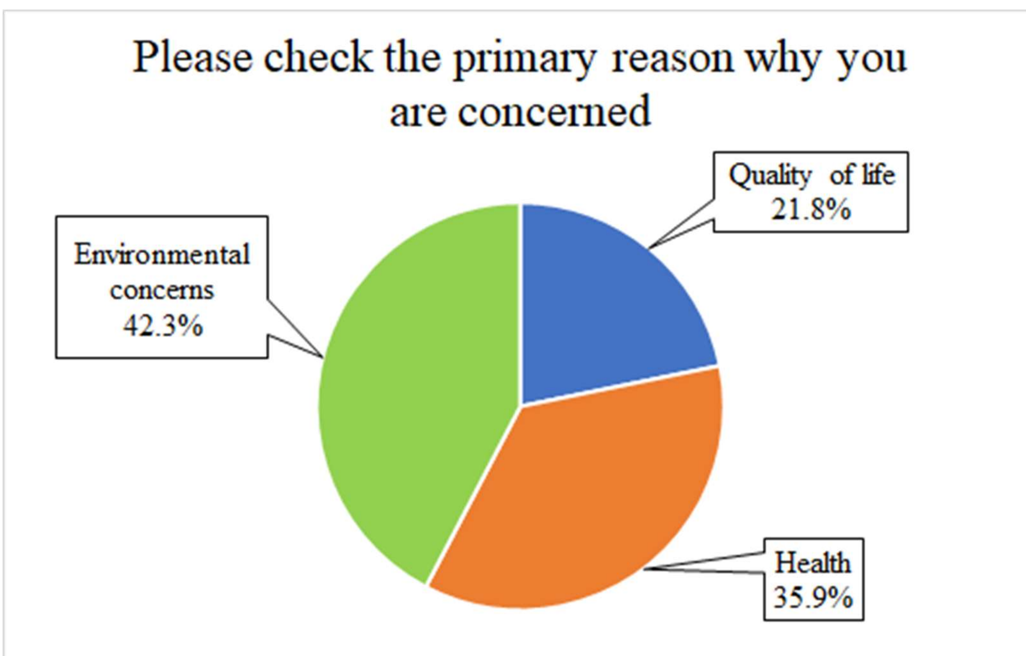


Figure O.6: Survey responses to "please check the primary reason why you are concerned"

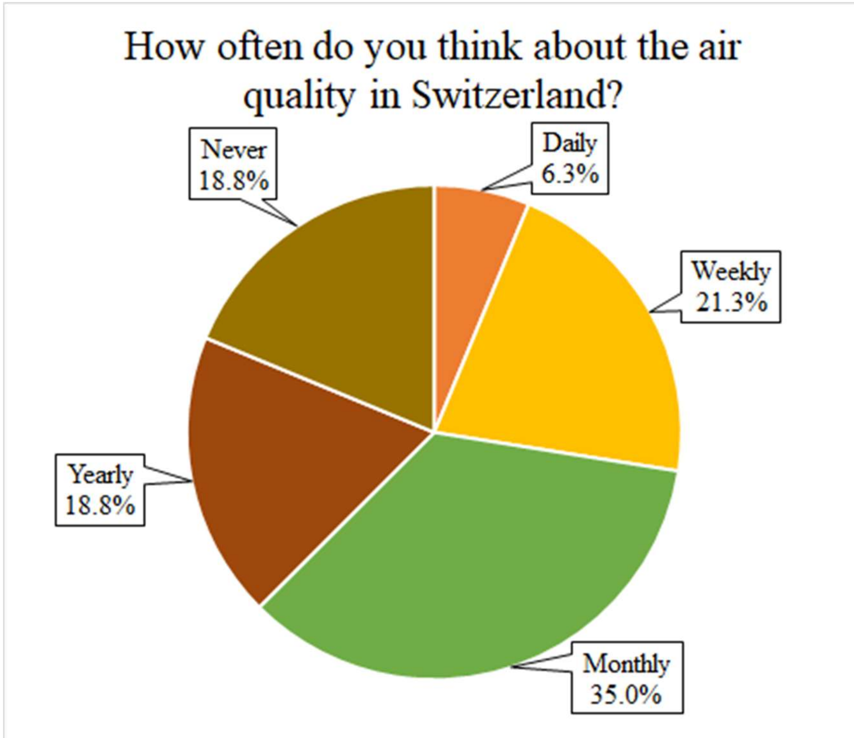


Figure O.7: Survey responses to "how often do you think about the air quality in Switzerland?"

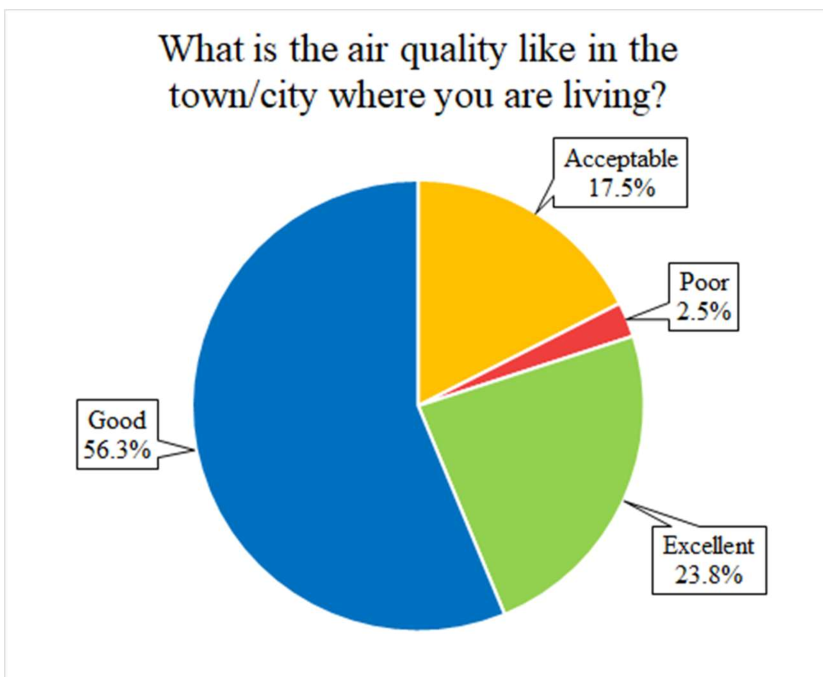


Figure O.8: Survey responses to "what is the air quality like in the town/city where you are living"

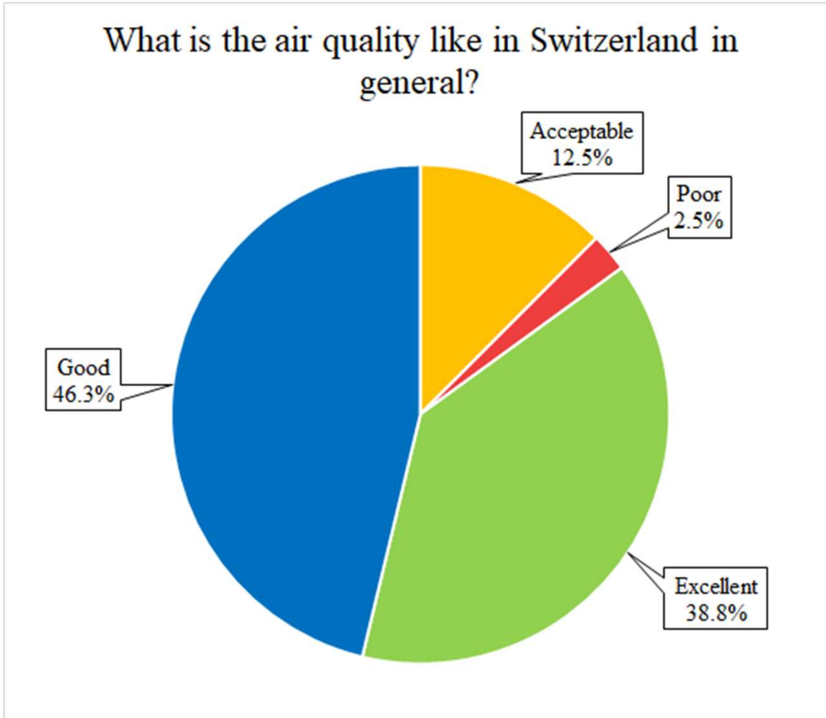


Figure O.9: Survey responses to "what is the air quality like in Switzerland in general?"

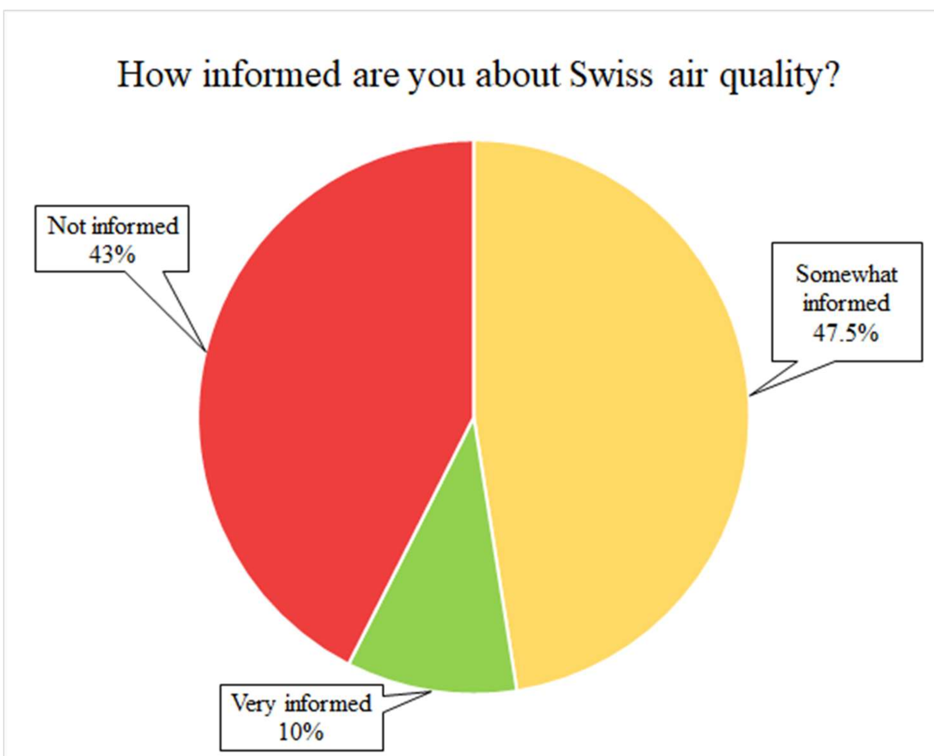


Figure O.10: Survey responses to "how informed are you about Swiss air quality?"

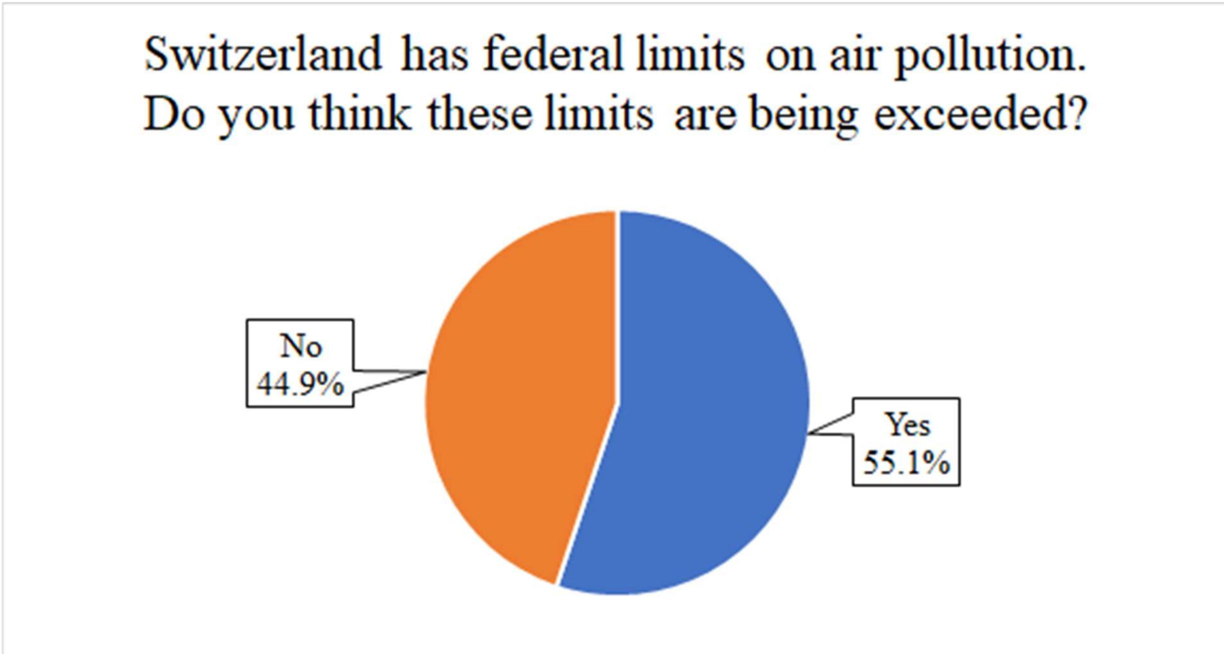


Figure O.11: Survey responses to “Switzerland has federal limits on air pollution. Do you think these limits are being exceeded?

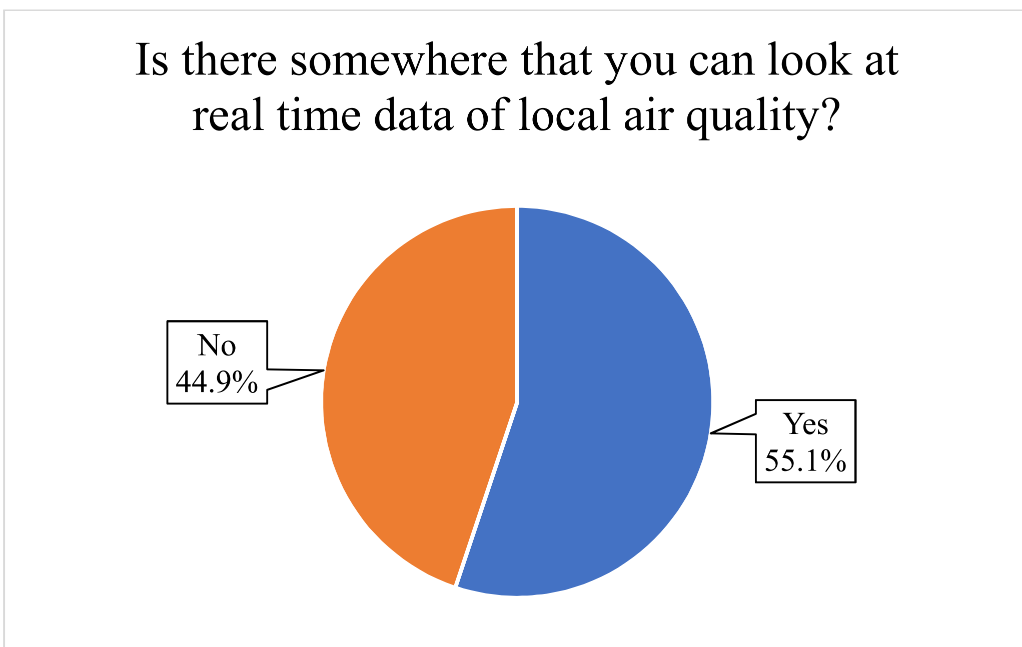


Figure O.12: Survey responses to “is there somewhere that you can look at real time data of local air quality?”

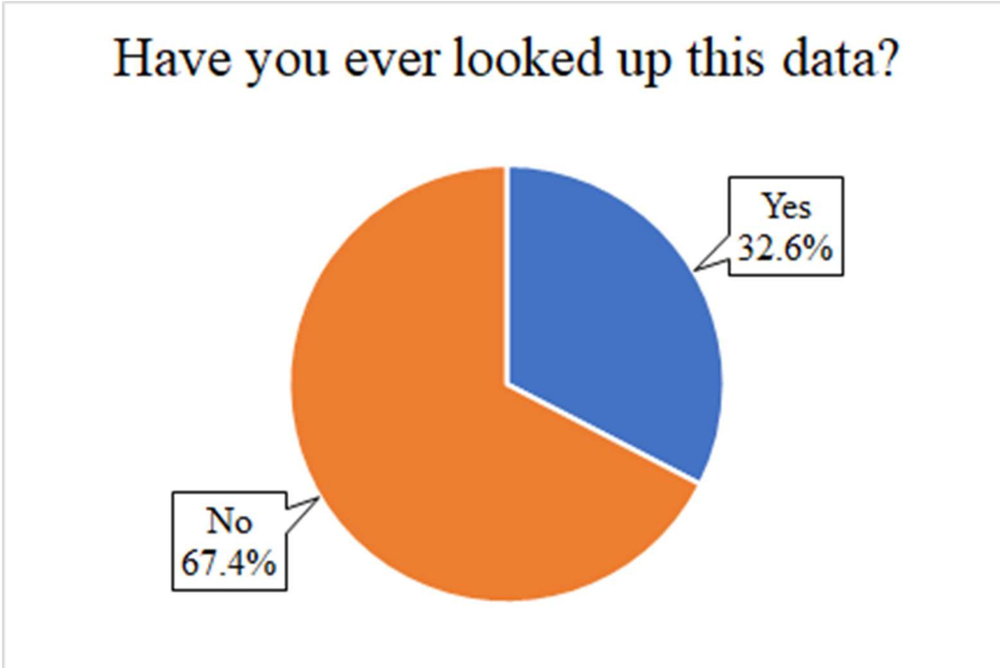


Figure O.13: Survey responses to "have you ever looked up this data?"

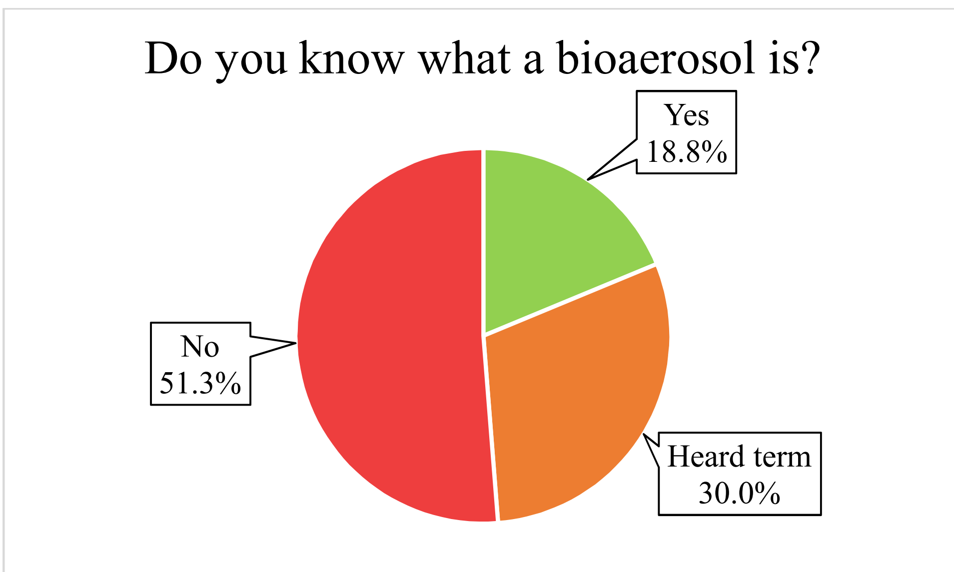


Figure O.14: Survey responses to "do you know what a bioaerosol is?"

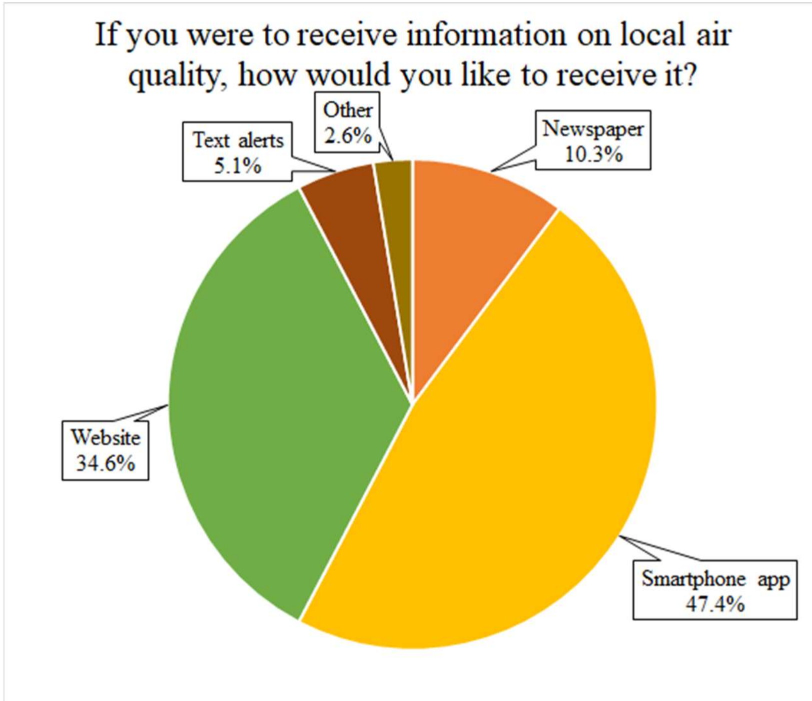


Figure O.15: Survey responses to “if you were to receive information on local air quality, how would you like to receive it?”

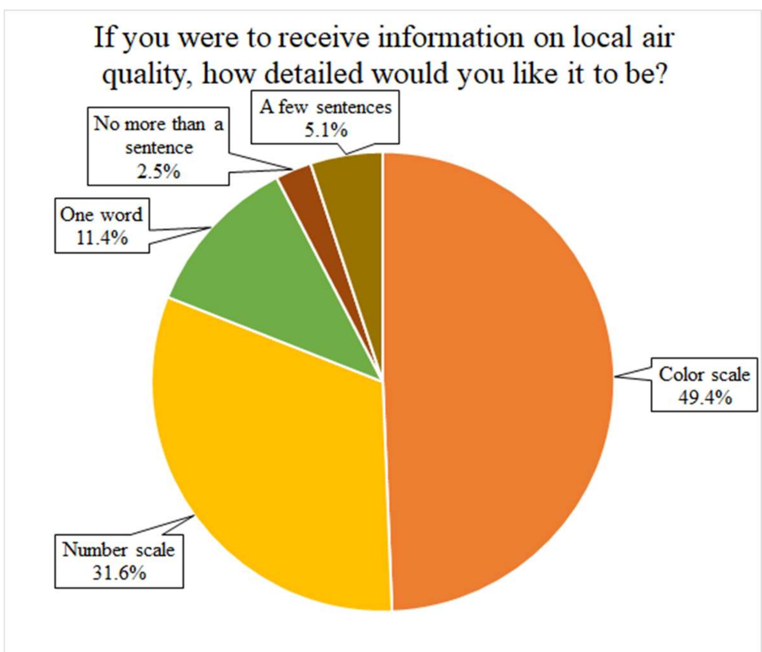


Figure O.16: Survey responses to “if you were to receive information on local air quality, how detailed would you like it to be?”

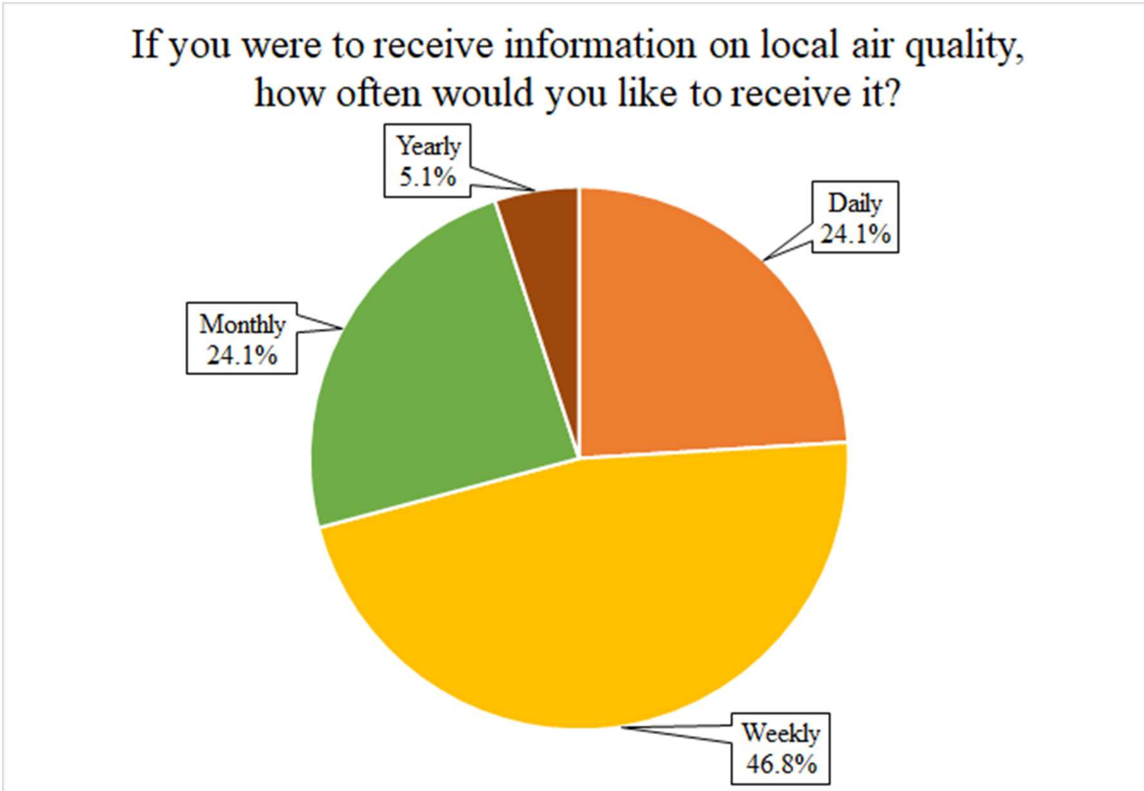


Figure O.17: Survey responses to “if you were to receive information on local air quality, how often would you like to receive it?”