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MicroMitigation: Open Panel Adsorption of Volatile Organic Compounds in Ambient Air using Granular Activated Carbon

Open Protocol, Preliminary Draft; January 2023

Table of Contents

a. list of figures and photos; illustration of an adsorption panel ; AC itself; in situ photos; TD Dynatherm; low-cost air flow measurement device; materials for jar test;

1. Brief Summary and Recent Developments; The Centrality of Open Source; Recent Developments as of May 2022;

2. Introduction Public Health Concerns of Air Pollutants; Toxic Air Contaminants and Criteria Pollutants; Regulation of VOCs in the USA, EU, International Regulation;

3. Overview of Method

4. Proof of Concept Preliminary adsorption panel testing; Timed jar testing to establish adsorption and basic method

5. Inputs: Safety Caveats and Safety Data Sheets; Basic Material Inputs; AC various types; Basic Labor Inputs; Sourcing; International Suppliers; transportation and storage of materials; panel construction;

6. Panel Location and Placement: Location Desiderata; Suggested Locations; Duration of deployment; Relative Humidity and Temperature considerations; panel removal; exigent circumstances and temporary removal;

7. Testing Prior to and during Deployment Preliminary monitoring of ambient air; Adsorption Testing in Situ; MOx v. PID instrumentation

8. Panel Adsorption Improvement

9. Desorption, Decomposition, and Reactivation: International industry practice and applicable standards; kiln types; reactivation; Spent Carbon Profile Forms; Approaches under development- Microwave, catalytic oxidation, electro-chemical decomposition, Fenton process;

10. Processes for Implementation, and for Improvement of the Open Protocol
Ongoing Implementation of Experiments and Adsorption Projects; Formal process for protocol iterations; meetings, alternating times; working groups; remote meeting practices; calls; storage of results on server;

11. The MMWG: Participants, contacts. Micromitigation Working Group Background;

12. Terms and Definitions: Acronyms and Vocabulary

13. References; General works and textbooks on adsorption and air quality;

14. Appendices. List of GAC attributes; world list of AC suppliers; world list of kiln suppliers; world list of carbon regeneration providers; Sieve Size charts and guide; VOC Health effects diagram from the US EPA; WHO EU New Guidance; EPA 325B; EPA 8260B ; EPA TOC-17; CCR 22; CFR re hazardous waste; ATSDR documents; OEHHA documents; California Air Resources Board re TACs and NAAQS; ISO; American Society for Testing and Materials standards; datasheets and refs for instrumentation; Two-page Description of Micromitigation; Safety Data Sheets for Activated Carbon- Coconut Coir; Concise Timed Jar Test Protocol for MOx Devices with IoT components

15. Endnotes

Protocol

1. Brief Summary: The MMWG Protocol for Adsorption of VOC Gas Phase Air Pollutants

MicroMitigation, or Open Panel Adsorption, is a method by which to deploy existing adsorption technology for the mitigation of air pollution using commodity granulated activated carbon, at 'micro-hotspots' in numerous locations in the built environment. The process uses AC, deployed in shallow open screened adsorption panels. Following adsorption and breakthrough, these are desorbed and decomposed through pyrolysis or other means. This Protocol is the first version of a step by step presentation of methods by which to ameliorate air pollution by carrying out OPA.

Why an Open Standard for AQ Mitigation is Needed

A standard is a reproducible recipe which “defines all the processes required for developing and maintaining software systems.” (ISO/IEC/IEEE 12207). The MMWG seeks to transfer open source development of standards, which has worked brilliantly for Linux and Wikipedia, to the context of physical product specifications. There is no GitHub for the design of physical products and methods, but there is nothing to prevent its inception. This project is intended to transpose the software definition to a materials process, in this case an open standard, or protocol for GAC for adsorption of gas phase pollutants. This protocol will involve rudimentary materials and steps, a process accessible to anyone with an undergraduate knowledge of environmental science.

Recent Developments as of December 2022

The goal of the MMWG is to develop clear open protocols, in order that this process can be sourced and carried out successfully anywhere. Clarity is necessary but so is economy, as we have discovered. The MMWG is acutely cognizant of the impediment of funding, as the group itself encountered delays in crucial experiments when trying to use instrumentation in the early Oakland trials.

We are well aware of the need for modest price in instrumentation. The group has been working on altering the instrumentation to make the process more widely feasible. At present, we are using a handheld Ion Sciences Cub Photo Ionization Detector, which can be used in timed jar tests as described in Section 4. To determine how rapidly breakthrough occurs, we are carrying out timed tests of AC sorbent material in a glass flask, with VOC-saturated air, with a Photo-Ionization Detector. We use the PID TVOC detector with an airtight food storage box, specifically the Rubbermaid Brilliance or OXO brand. The compact PID unit is placed into the box, with 50 grams of activated carbon. In this version, activated carbon is added to the open box. We add one eighth of a teaspoon, or 0.616115 mL, of nail polish remover, the listed ingredients of which are acetone, benzophenone, propylene carbonate, and dimethyl glutarate, on a piece of paper towel. This sets the PID's alarm buzzing for the next several hours. During this time the levels dropped rapidly in the sealed box.

For in situ tests, we will start with PID for characterization of TVOCs in an ambient location, followed by deployment of adsorbent panels. We are trying to find a more economical laboratory for TD-GC/MS test to indicate VOC species desorbed (using EPA TO-17 protocol).

It is anticipated that the same impediments, will present themselves when we get to desorption in actual usage rather than testing. But comparable solutions will be engendered as well. These earnest searches for alternative forms of instrumentation in the light of limitations, both institutional and economic, are instructive rather than detrimental to our efforts.

2. Introduction: Air Pollution as World Public Health Challenge

Air Quality and Public Health

"In 2019, air pollution was the leading level 2 risk factor for death and lost years among all environmental and occupational risks. It contributed to 213 million... DALYs and 6.67 million (5.70 7.49) deaths in 2019".

Global Health Metrics: Air Pollution- Level 2 Risk. The Lancet, Vol 396 Oct 17 2020.

"Air pollution- comprising ambient PM_{2.5}, ozone, and household air pollution- is an increasingly important risk factor contributing to death and disability worldwide. In 2019, air pollution ranked 4th among major mortality risk factors globally, accounting for nearly 6.75 early deaths and 213 million years of healthy life lost... these forms of air pollution accounted for more than 1 in 9 deaths worldwide in 2019".¹

Any number of clear-headed but alarming reports concur: air pollution is responsible for a staggering number of deaths worldwide. This loss of life and health is most pronounced in Sub-Saharan and east Africa, South Asia, and parts of China. (The Health Effects Institute report addresses O₃, PM 2.5, and household pollutants including VOCs specifically). The severity of public health concerns brought about by climate change is not in question. It is beyond all doubt, yet only partially overlapping with the ill effects of climate change, another calamity which is not in question². Most dramatic measures are taken to reduce GHG emissions. However, these measures do not obviate the need to ameliorate local NAAQS and VOC emissions.

The dangers of volatile organic compounds (VOCs), a number of which are designated Toxic Air Contaminants (TACs) for which the Environmental Protection Agency has set no safe threshold level of exposure, are not unknown³. These are not innocuous bad odors, but serious carcinogens with no minimum determination of safety⁴.

VOCs cause any number of severe health problems, as well as sub-clinical conditions which commonly result in interruptions to work, sleep, or leisure rather than a visit to the physician. These include neurological effects (toluene, in nail polish products); irregular heartbeat and myeloid leukemia (benzene); CNS disorders (styrene), irritation of respiratory tract and eyes (undecane and nonane), and peripheral neuropathy (hexane). TVOCs, such as the cocktail of contaminants in 'sick buildings', contribute to sensory irritation, headache and fatigue (Godish p412). The U.S. National Air Toxics Assessment recognizes formaldehyde, 1,3- butadiene, and benzene as national cancer risk drivers and contributors (www.epa.gov/nata).

VOCs are an increasing threat in a world with secular trend of higher temperatures, and as Ozone precursors contribute to its production as a secondary aerosol. The Agency for Toxic Substances and Disease Registry at the Centers for Disease Control has specific designations for each TAC, with epidemiological data for each. TACs are tracked by the California EPA's Office of Environmental Health Hazards Assessment (OEHHA), as well as by the EU and the WHO. They are well-understood in environmental health, and yet much of their regulation is overseen at the state and local level. Yet for the purposes of enforcement rather than public health study VOCs are, generally, not taken as seriously as they should be.

Regulatory Efforts in the United States

The ongoing regulatory response over nearly four decades has been multifaceted and effective in improving public health broadly speaking. Developments are consequential although slow- US regulatory agencies are a behemoth, but a lumbering behemoth.

The 1970 Federal Clean Air Act (CAA), which established the EPA, set National Emissions Standards for Hazardous Air Pollutants (NESHAPs), but only seven toxic compounds were added to the list in the first twenty years:

"The U.S. EPA develops regulations for federally defined major stationary sources and area sources. Major sources are sources that emit over 10 tons per year of any one HAP or 25 tons

per year of any combination of HAPs. Area sources are sources that emit lesser amounts of HAPs, like gas stations. The U.S. EPA has issued MACT standards for over 100 source categories since 1990." ⁵

In 1990, major amendments to the CAA, led to the addition of 189 chemical species to the NESHAP inventory. Moreover, the Amendments introduced Maximum Achievable Control Technology (MACTs), specifying best industrial practices and technologies. New Source Permitting Review (NSPR) for a plethora of different stationary facilities has been in practice during this duration as well (Godish, p303).

The USA National Air Toxics Assessment

The EPA Office of AQ planning and standards (OAQPS) is responsible for establishing and reviewing national emissions standards from stationary sources. The sixth NATA National Air Toxics Assessment, in 2014, provides a search tool and epidemiological statistics:

"The 2014 NATA estimates that the nationwide average cancer risk from breathing air toxics is 30 in one million. This is a national average... about half of that nationwide average risk comes from formaldehyde...from other pollutants that chemically react in the air this is [a] secondary formation... the rest of the nationwide cancer risk comes mostly from pollution that is directly emitted to the air." (p1).

National Longitudinal Epidemiological Studies

The EPA launched additional longitudinal national studies during the 1980s. These included NATTS and PAMS: the National Air Toxics Trends air toxics study and the PAM monitoring efforts began, measuring metallic and gaseous toxic air pollutants at over 200 locations. This led to systematization as a surfeit of data was gathered:

" Broad access to and use of these data was hampered by a lack of centralized databases and multiple sampling and laboratory protocols, creating data quality and consistency concerns. To address these inconsistencies, the NATTS network was conceived in 2001, consisting of 27 sites. The sampling protocol typically has been every sixth day for 24 hours.

Among the priority ranked 33 air toxics of U.S. concern, observations of benzene and other common aromatics are generally widespread and relatively reliable. However, other potentially important air toxics are less well represented in air monitoring. During the initial start-up of the NATTS, six priority pollutants (formaldehyde, benzene, 1,3- butadiene, hexavalent chromium, acrolein, and arsenic) were targeted for inclusion, based on results of the 1996 National Air Toxics Assessment" (NATA; <http://www.epa.gov/ttn/atw/natamain/index.html>).

Another major study was PAMS, the Photochemical Assessment Monitoring Station sites [EPA]⁶. Approximately 75 sites in 22 cities were deployed by state and local agencies in the early 1990s to measure ozone precursors. PAMS and the air toxics network (see below) provide the majority of routinely available non-methane organic carbon (NMOC) measurements. A number of ozone precursor C2-C10 alkanes and alkenes, aromatics, formaldehyde, and acetaldehyde are measured using a combination of continuous methods and sampling techniques over 3- and 24-hour collection periods, often limited to the ozone season (April – October). The 1990 CAA Amendments required areas classified as serious and above with respect to the contemporary (1990-1992) ozone NAAQS to implement PAMS, which has undergone minor modifications since then.

TAC and NESHAP designation in California

The administration of NESHAPs emission reductions is delegated to the states. Local agencies may be more stringent if they so decide. This is a mixed blessing: beneficial to the residents of California and New Jersey, yet disappointing for residents of states with environmental policy heavily influenced by the regulated community. The early start of CA in air monitoring and

regulation is far from unknown, as the first regional air district was established in 1947. The California Air Resources Board was established in 1967, by an act signed into law by Governor Ronald Reagan (Carle, Air in California).

In 1983, the California Toxic Air Contaminant ID and Control Act [Tanner AB1807] was passed, and OEHHA developed inhalation cancer potency factors for twenty-one TACs. Cal ARB subsequently implemented airborne toxic control measures (ATCMs). The following year, CalARB also implemented TAC study sites in locations statewide. This was followed in 1987 by the Air Toxics "hot spots" Information and Assessment Act (AB2588), which requires operators of significant-risk facilities to reduce risks from exposure to emitted TACs. These measures generally apply at industrial sites rather than regular ambient air. Subsequent to the enhanced NESHAPs listing, California's TAC list was amended in 1993 to include all Federal HAPs as well.

VOC Pollution Regulation and State and Local Outcomes

Most volatile organic compound (VOC) sampling sites include instrumentation for O₃ and NO_x. Such measures have been consequential. California's 1996 reformulation of gasoline composition led to decline in benzene emissions; and ambient concentrations, in consequence of which there have been major reductions in cancer from TACs⁷.

" Statewide cancer risks were determined using the calculated cancer risk factors and ambient statewide levels for each TAC, 1990-2012...[showing] a 76% decline in cumulative increased cancer risk per million people, from 1990 to 2012, due to inhalation of ambient air."⁸

However, geographically focused studies, such as the South Coast AQMD's MATES, or Multiple air toxics exposure studies, over a number of years, indicated that despite reduced cancer on the basis of gross population, there are still local health illness clusters. Severe intrastate discrepancies remain when considered in a more nuanced fashion by proximity to emissions rather than over the entirety of the state. A staggering amount of study has taken place, but far less action is in evidence. Certainly there are continued higher cumulative health effects in certain populations and localities.

In summation, the United States' response has been uneven in the formation of rules, and weaker in their implementation. As so often in the USA, policy and enforcement in states vary between each other as much as some nations on other continents vary.

Regulatory Efforts in the European Union

However, volatile organic compounds are taken seriously in Europe, where BTEX is monitored indoors and other steps are taken⁹:

"The World Health Organization (WHO) Air Quality Guideline for Europe [in 2000] establishes guideline values for toluene, 260 ug/m³ over 1 week, for formaldehyde, 100ug/m³ over 30 min and for tetrachloroethylene, 250 ug/m³ over 1 year. Additionally, it sets the guideline values for benzene corresponding to the concentration levels associated with an excess lifetime risk of 1/10,000, 1/100,000 and 1/1,000,000 equal to 17, 1.7, and 0.17 ug/m³, respectively. In 2010, the WHO Guidelines for Air Quality in Indoor Air confirmed the guideline values given in 2000 for benzene... the European Air Quality Directive AQD defines as mandatory the monitoring of benzene in ambient air. The AQD states that the reference method for the measurement of BTEX consists of active or online sampling followed by desorption and gas chromatography."¹⁰

International Regulatory Efforts

In the case of the USA and the world- if not the European Union- there is much more study than there is regulation. The Long Range Transboundary Air Pollution (LTRAP) negotiations commenced in 1974 under the auspices of the United Nations, and resulted in the 1979 Convention on Long-Range Transboundary Air Pollution. The VOC Protocol, opened to signatories

in 1991, and was entered into force 1997. Further negotiations resulted in the 1999 Gothenberg Protocol, which was entered into force in 2005 and amended in 2012. The LRTAP has eight sections: we specifically refer to the one regarding control of transboundary fluxes of VOC emissions (Annex 6 of the Gothenberg Protocol). Intended to reduce airborne pollutants through voluntary emissions restrictions and emissions inventories, it is implemented through the national emission ceilings directive (NEC), for Sulphur, NO_x, VOC, and NH₃. As Europe has started to rely less on coal and more on natural gas, the Gothenberg targets have been achieved.

For the rest of the world, this protocol has resulted in databases as much as it has engendered actual changes to practice. Such databases offer preliminary consideration of a nation's emissions, and just requiring this of signatories is a huge advance for larger areas of the world. Requiring emissions inventories, as part of the ongoing LTRAP treaties intended to reduce pollution caused by international air transport, is a benefit for those worldwide. Other emissions inventories are databases, from the IPCC, the UNFCCC, Argonne National Lab, and other parties, which combine top down estimates from industry and stationary facilities, with monitoring for a variety of NAAQS, GHG, and VOCs¹¹.

In a sobering note, there are only 26 signatories to the Gothenberg Protocol. The VOC protocol's endorsements are even more anemic. Signatories number twenty-four, most of them in the EU. It has been signed but not ratified by Canada, Greece, Portugal, the Ukraine, and the USA. Like the other treaties, this one has membership entirely in the Northern Hemisphere, with two North American countries and Armenia among its ranks. There are only fifty or so signatories to the LTRAP itself.

Reducing the NAAQS pollutants, and VOCs, will continue to be extremely difficult. The after-market for vehicles often overwhelms the primary market of vehicles that are in keeping with current emissions standards. (California actively tries to purchase back older vehicles when the owner can be located, but this is probably the exception rather than the rule). Practices such as burning garbage and agricultural by-products, driving antiquated cars and trucks, and cooking with wood or coal- all of which create both NAAQS and VOC pollutants- are a matter of necessity and sustenance. These are likely to persist hand in hand with dire poverty. For most people- even, apparently, many in the AQ community- VOC emissions, let alone mitigation, is far out of the picture.

Recent Illustrations of the Quotidian Severity of Climate Change

In the United States and in the rest of the world, dramatic climate-change related events underline the need for modification of the built environment to push back against pollution (and other hazards) insofar as humanity can do so.

While the regulations have illustrated the problem with scientific facts and data, ongoing toxic emissions have continued to take place. To lend emphasis- by way of excess- concerning circumstances much more dramatically harmful to human health than those encountered by the MMWG's originators in SF and Oakland, one need only read the newspapers. During the last week of April 2022, a fire in Delhi's Ghazipur landfill, as large as forty soccer fields, lasted three days. Other wildfires broke out as a result of the South Asian heat wave. Nigeria's illegal oil refineries, using the quickest and dirtiest methods, continue unchecked. At the University of Manila, a wildfire broke out on informal housing on campus. Brazil's forests continue to burn. The IPCC's sixth report was issued in May 2022, and was not un-noticed but certainly its recommendations were not adhered to. Wildfires forced evacuations in New Mexico, Arizona, and Texas in the western USA. Finally, a new study found the air in Kampala to grossly exceed limits set by the WHO.

Local ambient air quality is an intractable problem and will continue to be so in the foreseeable future. Enforcement- in dozens of countries and hundreds of cities- is almost always carried out locally, and subject to local indifference and corruption. Thus, we turn to mitigation rather than fight the same, often losing, battle hundreds of times.

Inadequacy of the Status Quo

As the human cost is increasingly taken seriously, the cost of VOC emissions mitigation may increasingly seem less and less expensive. Notwithstanding this suggestion, it has not happened yet, and those most harmed by air pollutants are on their own. In the USA and in many other places, a method that is as cheap as coal or nut shells is immensely advisable.

3. Overview of Method

Micromitigation, or open panel adsorption, uses adsorption technology for the mitigation of air pollution, by placing screened adsorption panels of commodity granulated activated carbon in polluted locations. After saturation, the panels are desorbed, the contaminants incinerated or otherwise decomposed, and the AC material is reactivated. The MMWG anticipates that it will work most effectively in the most polluted locations, and at scale, for instance, when adsorption panels cover large impermeable walls. This is crucial, as those who need it most certainly can afford it the least.

4. Proof of Concept Preliminary adsorption panel testing; Timed jar testing to establish adsorption breakthrough

4.1. Proof of Concept

We need proof of concept, defined as the "... realization of a certain method or idea in order to demonstrate its feasibility, or a demonstration in principle with the aim of verifying that some concept or theory has practical potential."

4.2. Initial Open Panel Adsorption Design Test in Situ

If the timed jar tests discussed in the next section are proof of concept, the ambient test in situ is the roughest of prototypes¹².

The design follows in the simplest possible way. The MMWG's first efforts commence with the desiderata of: a) repeated exposure, typically at low ambient air pressure, subject to intermittent acute exposure to pollutants from urban and vehicle emissions; b) extremely selective location, as discussed regarding Meteorological and Topography and regarding Emissions concerning specific urban conditions, and c) high surface area.

The initial experiment demonstrated that passive adsorption using panels of GAC over a period of several weeks (the time has not been determined), is an effective adsorbent method. The group made use of passive modular, movable adsorption panels with high surface exposure, with desorption elsewhere at EPA-approved facilities. These initially took the form of screened open pouches of window screening material, of inert non-oxidizing mesh. The materials were readily purchased from hardware stores. The first sample of the adsorbed AC was deployed at a six-lane arterial street- more accurately, an intra-urban freeway- near the intersection of Alemany Boulevard and Habitat Terrace in San Francisco.

The sample was tested at an analytical laboratory by GC-MS analysis through thermal desorption (TD GC-MS), using a modified EPA Method TO-17 protocol. The results indicated significant hydrocarbons, mostly long-chain alkanes such as pentane, butane, isohexane, and octadecane, and methylbutane, used in car repair. Also included were aromatic BTEX species and ethanol, a central nervous system depressant.

Chlorinated species, specifically chloroform and methylene chloride, a solvent, were present. This is cause for concern because the pyrolysis of such substances can lead to undesired substances in the intermediate steps of pyrolysis. This is admittedly more of a problem with wastewater treatment, in which dissolved pharmaceuticals and PFOAs is observed. The design of MM is such that panels will be placed adjacent to traffic corridors in proximity to human residence and street life. Yet it will have to be addressed, and in fact we have considered this in discussion of alternative desorption and decomposition methods.

The group realized, after the fact that we did not specify desorption at a sufficiently high temperature to desorb the VOCs at a higher Celsius. Our results probably should have evidenced even more species. Yet even these preliminary desorption reports indicate that passive ambient adsorption over a period of time does work. The GAC was not blinded by PM 2.5, nor did competition from adsorbed H2O preclude adsorption of VOCs, in an often foggy location.

4.3. Timed Jar Testing

Jar Testing

For philosophical reasons and logistical necessity, the group needed to begin with the most minimally demanding tests. We have developed several versions, progressively more demanding in terms of continuous connectivity and expense of components. There are various versions of this, depending on availability of components and instrumentation. All will yield evidence that GAC adsorbs ambient VOC species.

A) Timed Jar Test: Minimal- Resource Version with Home Laboratory PID Detector

In the first test, the air is characterized by Photo-Ionization-Detector. Engineer Ken McGary used an Ion Science MiniPID2-HS (>3 ppm range, 0.5 ppb MDL, 10.6 eV), with a .79" diameter. The sensor requires 3.3 v at 100 mA. The PID bulb was connected to a breakout board, then to a breadboard with a SparkFun I2C hub, and a 16-bit analog to digital converter to watch the output of the PID, and finally to an ESP32 Microcontroller unit, and a LiPo battery, USB to power source, and data output at twenty-second intervals by WiFi to the Thingspeak IoT platform.

The air is characterized first. KM used ambient air in a fairly unpolluted backyard location away from vehicular fumes or other VOC sources. [[Insert photograph; credit: Ken McGary, April, 2022]]. The baseline, read by PID and exported to ThingSpeak IoT platform, resolved at approximately .4 ppb ****NOT SURE****.

The measured unused AC is then deposited in the 500 ml glass flask, and Isobutylene calibration gas was added¹³. Isobutylene is the calibration standard for PIDs, so no correction factor would need to be applied to infer the identity of gas species. In our test, we used 100 ppm gas with a fixed flow calibration gas regulator. KM used a small constant flow fixed air pump (K1 brand) with a pipette connection to the isobutylene tank to add .5 liters of the gas per minute, for a duration of 30 seconds, for a total of 1/4 liter added. We then put PID in the flask's aperture (slightly more than 1"), and took a reading. Approximately thirty seconds later, we ascertained on Thingspeak that the readings had jumped up rapidly. We removed the PID without delay, and sealed the flask with its glass stopper. The PID returned to original reading, by the next reading twenty seconds later.

In order to ascertain breakthrough, the sealed air will be tested after a week. We used a laboratory blank with GAC as well, to see if the background baseline levels drop due to the GAC presence. We are aware of the shortcomings of this testing method. It suffers from leakage of air as the PID is removed, albeit swiftly, from the aperture of the flask.

B) Timed Jar Test: Minimal- Resource Version with Commercial Handheld PID Detector

A more perspicacious test requires more extensive resources. A second version of the proof of concept combines a handheld commercial PID TVOC detector with an airtight food storage box. To determine how rapidly breakthrough occurs, we carried out a timed test of AC sorbent material VOC-saturated air, with a Photo-Ionization Detector. We use a handheld commercial PID TVOC unit, with an airtight 2.3 L Rubbermaid Brilliance food storage box. The PID unit is placed into the box, along with 50 grams of activated carbon. One eighth of a teaspoon, or 0.616115 mL, of nail polish remover- listed ingredients acetone, benzophenone, propylene carbonate, and dimethyl glutarate- on a piece of paper towel, is added. This set the PID buzzing its alarm, for the next several hours. During this time the levels dropped rapidly in the sealed box.

C) Timed Jar Test: Continuous-Power Version

The above tests are minimal because they do not require continuous power to the PID. The simplest test is thus likely to yield a correct, but not very precise, answer. However, we want a study that is both correct and precise. This would be a modification of another version of Version A above. We would like to alter it by placing the PID unit with GAC in the food storage container, with apertures for the USB and the Tygon tube. This could offer the advantage of continuous monitoring over a longer period of time. However, we would need an alternate version of the testing chamber.

D) Timed Jar Test: Wind Tunnel

A further and more elaborate design has been discussed. See figure (A) INSERT DRAWING. This would require two PID devices, but would provide insights on the kinetics in an even finer temporal resolution. We are considering constructing such a tunnel from a two-foot length of PVC pipe, perhaps 6" or 8" in diameter; an air flow meter for releasing Isobutylene gas, then ambient air; PID1 (hand-configured as discussed above); an activated carbon adsorption panel, then another PID2 and a controlled egress to prevent backflow. We would test the ambient air, establish a low ambient PID level, set the air flow extremely low, using a fixed flow regulator with an isobutylene tank, and then release the testing gas. The PIDs would test the air both before and after air has traveled through the adsorption panel.

Such a design generally replicates a wind tunnel in its basic shape and enclosure. It differs in that the latter usually tests performance of artifacts in high-wind conditions. We want a "breeze tunnel", so to speak, instead. We are concerned with more typical circumstances, in which air transport takes place in response to surface roughness and diurnal movement of vehicles. In our wind tunnel, ambient air is characterized by steady air flow from one direction only. This is solely for modeling purposes. We also do not know at this point how to simulate laminar versus turbulent flow, especially because the small constant flow fixed air pump controls and minimizes air flow, by its very operation.

The test to ascertain adsorption might be:

PID 1 > PID2 prior to commencement of air flow
PID 1 < PID2 after commencement of air flow

We do not know how much time should elapse- the speed of the kinetics are perhaps as crucial as the material balance of adsorption at which breakthrough is reached.

PID 1 = PID2 should be after a period of time as yet undetermined;

This is a work in progress. We do not know at all what this duration should be and whether and how it should be influenced by the setting of the air flow meter, which can be set at various settings to facilitate transfer from PID1, through the adsorption panel, to PID2. Moreover, we do not know how to facilitate air transport and diffusion in an environmental chamber, which is by definition isolated from the ambient conditions that the MMWG is concerned with. This would be

VOC-laden air in stagnant street canyons with very shallow or no setbacks from traffic, inversion areas at low altitude, etc. Synthetic air flow will have to be thought through.

Jar Testing with MOx Instrumentation

Inescapably, a PID is a costly piece of equipment. This is largely because of the expense of the ionizing bulb apparatus, which is coupled with an electrode that translates the ions to an amplifier, which then translates the measurement to an analog signal. Even a bare bulb PID lamp costs hundreds of dollars. Because of the challenges entailed in obtaining a PID, the group is starting by using MOx for TVOC capture. The group is thus considering using metal oxide (MOx) sensors to begin with. MOx sensors consist of a doped metal oxide membrane comprised of variable resistors which emit different resistances according to the chemical species to which it is exposed¹⁴. These devices include the AdaFruit SGP 30, the Figaro TGS 813 and 822, among others. For TVOC detection they are less precise than a PID¹⁵. However, the group in Oakland has limited access to this expensive instrumentation, and some participants in other locations may find it impossible to acquire a PID. IoT instrumentation with a microcontroller and a MOx sensor is the next best choice. We plan to put together single-board computing modules (RasPi, SparkFun, Particle or a similar microcontroller) with RH and T and PM 2.5 components, all of which we already have on hand. This result inevitably begs for further development and articulation, using ambient air rather than the still air of a sealed airtight chamber with GAC.

5. Inputs to Micromitigation

Material Inputs

Activated Carbon is a highly processed and regulated commodity material, with two major substratum. The two essential ones are biologically based such as nut shells (olive pits), peat, bamboo, coconut shells; and coal (lignite and anthracite). Tests in 2021 used 4x8 mesh coconut shell GAC, the substrate most easily sourced in the United States.

Standards for Activated Carbon and Reactivation

The existence of dozens of incumbent standards will immensely facilitate this process. Technical specifications exist for every aspect of the process from choosing a particular sort, manufacturing, sourcing, testing, through final desorption. In the United States, these include ASTM (American Society for Testing and Materials) and AWWA (for GAC for water treatment) standards. In the EU, there are CEFIC and DIN, the latter being for AC for water treatment. NSF ANSI (American National Standards Institute) standards 42, 53 are for AC in water. NSF is an independent certification body in the USA, and occasionally GAC for gas phase treatment includes its certifications.

A plethora of ASTM standards exists, addressing every aspect of AC usage. To start with, ASTM D2652 defines standard terminology relating to AC. The typical half-dozen features used to describe a product include: ASTM standards for-iodine number; molasses number; ASTM D2866 (2018) for test for total ash content. The abrasion number (AN, or AWWA B604; or ASTM D 3802 89) for Hardness or abrasion number; ball-pan hardness, measures structural strength, or the media's ability to withstand abrasion or size reduction when tumbled. The CTC, or carbon tetrachloride number (CCl₄ number ASTM D 3467 04), relates to the degree of activation and the adsorption potential of a given GAC product.

Other measures include apparent density (ASTM D 2854 09) and moisture as packed (ASTM D 2867 99); ASTM D3466 (2018) to test the ignition temperature of GAC; ASTM D5158 (2019) to test for the particle size of a given sample of powdered AC. There are also technical specifications for N₂ BET total surface; sieve size; in international micron units; particle size distribution; and tests for adsorptive capacity; guide for carbon reactivation. In addition, the significant

distinctions and advantages of coconut shell GAC versus coal based GAC mean that most usages will include both, because of their different strengths.

International Suppliers

Activated carbon is one of humanity's most widely produced commodity products. The USA, United Kingdom, Germany, Denmark, China, South Africa; Sri Lanka, Mexico, Thailand, Bulgaria, and India, as well as other countries, all produce activated carbon and kilns for regeneration and reactivation. AC is much cheaper at volume and thus will need local organization to implement purchase of the larger quantities at which it is economical. We hope self-organization could work as a means to carry out micromitigation, and that this could become an exercise in community organization.

Basic Labor Inputs

Some aspects of the Protocol will specify skill level, such as roles specific to civil engineers versus those with limited technical proficiency. Other questions as to who can carry out this process, are open. Can projects be led by high school chemistry teachers, college teachers, or graduate students? At the moment, we believe that many prospective participants will be mostly chemistry teachers, environmental science teachers, and members of community environmental groups. This wide inventory of prospective project participants, in many countries, is encouraging.

Safety Caveats

The Protocol will include references to Safety data sheets relating to handling the material. The U.S. medical information safety system HMIS indicates that GAC is safe to work with, provided Protective Gear such as closed-toe shoes, safety goggles, and gloves are used as recommended.

Panel Construction

Adsorption panels may be assembled using fungible commodity products, to minimize the actual amount of construction required. In the earliest, we started with cloth bags, or panels made up of window screening material. At present, we favor window screening with duct tape. This will admittedly produce some siloxanes. However, the results are a known quantity and this is the simplest way to produce panels. These materials may be purchased at hardware or household products stores. The measurements we would like would be one foot by four inches by two inches, since these dimensions will be easy to work with and the containers of GAC will be relatively lightweight.

6. Panels Location and Placement

Overview of Micromitigation method; Location Desiderata in Brief; List of suggested locations; Duration of deployment; Relative Humidity and Temperature considerations; panel removal; exigent circumstances and temporary removal;

Location Desiderata in Brief

Opportunity made our original choice for us. The first location was in downtown Oakland, a few hundred feet east of the confluence of several freeways.

Suggested Locations

A. Chosen by emissions:

Should we try to pick location by air quality monitoring data, we would be hard-pressed to find adequately precise data, even by NAAQS. Detailed hyperlocal AQ data is the exception rather than the rule, even in the United States and the EU. It is however, easy to determine where to carry out micromitigation if one chooses by emissions rather than the nearest EPA Federal Reference Method station, which may be several miles, or dozens of miles away. Thus, choose by emissions sources, which are usually painfully self-evident;

Some of the choice could be based on formal search of existing regulatory agency databases. California bill AB2588 established the Toxic Air hotspot emissions database, which is accessed with a simple interface and a zip code. Based on the latter, further exploration could be done. We are concerned with the ill effects of microscale air motion in proximity to local vehicular traffic or TAC hotspots. A preliminary means by which to pick this would be from a foot to a meter above the ground, near vehicle emissions: at roadside medians; on the traffic-facing side of parklets; school bus stops; bus stops; affixed to grillwork on metal gates at entrance to residential buildings.

B. Chosen by built environment topography

The urban canyon phenomenon, in which buildings are impermeable and relatively tall, is generally conducive to buoyancy, turbulence, and transport. But this is the design norm in cities in the developed world. Street canyons are generally good at allowing transport (CITE). We are also concerned with urban topographies in which the opposite is the situation- where turbulence and buoyancy are not working well. Gases move within the troposphere due to transport and to chemical reactions. Small molecules such as NAAQS pollutants characteristically do not persist because of photolysis. However, we seek to place micromitigation adsorptive GAC in proximity to human exposure, as the latter pollutants, as well as others such as VOCs and heavier-molecule HCs may be in relatively high concentration near their source, and may not dissipate so readily. These other sorts of urban topographies, are common worldwide although quite rare in the USA: alleyways, narrow streets; alleyways near the entrance to restaurants or food stalls. These locations may have poor transport, and considerable inhibition of both turbulence and buoyancy. San Francisco's Chinatown, the most densely populated place in North America after Manhattan, would be an excellent site for this. These are the very underbelly of urban spaces: the ongoing and tiny acute AQ incidents in such locations are environmental micro-aggressions in themselves.

Desiderata regarding urban topography for mitigation would include topography that encourages stationary pollutants, such as cul de sacs hemmed in by impermeable walls; areas marked by extreme density in streetside human activity; street markets with cooking or fuel-burning; enclosed alleys. It would also be interesting to try GAC placement in the eaves of buildings, on the first or second story, would allow some benefit from adiabatic lapse in air temperature as air rises. This would suggest that adsorption for micromitigation could be applied in hilly and dense urban environments, rather than only flat areas with a great deal of vehicle traffic.

C. Emissions- Stationary Sources

Watched over with various levels of zeal and enforcement, by the BAAQMD and the DTSC, some emissions sources are obvious. Regulated stationary sources include permitted facilities such as near cement plants, rendering plants, and sewage treatment plants. Emissions plumes create pollution dispersion from point sources¹⁶. These regulated locations are persistent. Other point sources are intermittent but still can be lengthy in duration, and non-compliant with emissions standards. These would include long-term construction sites, construction dust, street work, portable generators, short-duration roofing, and proximity to fugitive emissions.

D. Emissions Type Desiderata- Mobile Sources

There are also copious examples involving mobile sources. Source characterization would be anywhere near an internal combustion engine, adjacent to tailpipes. This includes inner city freeway off ramps, near roadway areas, and habitual locations of traffic jams on arterial roads. Other pertinent circumstances include locations in which traffic jams occur, turning streets into de facto parking garages. Entrances to parking garages, often backed up onto the adjacent street, and parking lots as well, are often episodic and on a predictable schedule. The same is true of school bus stops and school drop-off locations. Others are less predictable, and are best spoken of as opportunistic, but occur before they can be permitted or shut down. Acute episodic

conditions include motorcycle or car rallies or sideshows, as spontaneous and difficult to manage as a flash mob. Much of this will not be evident in case of a place with favorable overall AQI, as per the FRM station, but will result in poor AQI with regard to hyperlocal conditions.

Duration of Placement

Transportation and storage of material

Contingencies and Panel removal

Relative Humidity and Temperature Conditions

This project's first experiments started in June, 2021 in fortunate conditions: under a narrow range of relative humidity and temperature, in a temperate climate; with no freezing temperatures, and very few higher readings as well. The moderate weather in Oakland, California, where temperature rarely exceeds 75F, or is less than 40F, is felicitous.

Yet this is anomalous on a world scale. Such even-tempered weather is even anomalous for the United States, most of which swelters under dangerous heat waves and associated fires, and intense storms and clusters of tornadoes. It is imperative that we widen the conditions prescribed, with collaboration from colleagues in locations with worse weather than Oakland, California, which list is unfortunately most colleagues in most locations.

7. Testing Prior to and during Deployment

Preliminary choice of adsorption locations, monitoring of ambient air; Adsorption Panel Testing in Situ;

Air quality monitoring and testing are integral to Micromitigation at every stage. These steps include finding the best locations at which to place panels; testing prospective locations once located; Jar Testing and Breakthrough in the lab, using air from the sites once determined; and finally testing the adsorption panels after a field deployment.

A. Preliminary Choice of Adsorption Locations

The Protocol calls for testing the ambient air quality in immediate proximity to adsorption sites. An initial search of national, state or local FRM sites will yield reference instrumentation levels for VOCs, although even in CA, coverage varies tremendously¹⁷. Air Toxic Hot spots can be located through CalARB online tools such as CEIDARs. Internationally, the Gothenberg Protocol and related UN efforts are improving the quality of national emissions inventories worldwide. Such databases offer preliminary consideration of an appropriate location. Weather research and forecasting (WRF) models generally are mesoscale, and even when they are microscale are usually insufficiently granular to address the sort of local conditions that we believe our likely constituency will find of concern. Alternatively, one may not need to test to start with at all. More likely is that anyone undertaking micromitigation will be acutely cognizant of need for remediation in a neighborhood location. One can do this from the height of an airplane, or from ground-level and empirical experience of VOCs.

B. Air Quality Monitoring for Preliminary Monitoring of ambient air

Trust but verify, as the proverb goes. Once located through extant data sources, specific locations may be tested using a handheld Photo Ionization Detector. These are manufactured by a number of industrial safety and environmental services companies, and cost from two to five thousand dollars for purchase, or one hundred and fifty dollars per day to rent. In addition, we are currently considering the use of SST (solid sorbent tubes)- essentially sealed laboratory blanks- in addition to adsorption panels. Method 325B, the EPA's 2012 method for fenceline monitoring for BTEX, uses such tubes. Eurofins, the environmental testing laboratory company, offers a service to facilitate such testing with SST delivered and deployed in the field for two weeks, then returned in preaddressed envelopes.

C. Preliminary Adsorption Testing in Situ

We intend to proceed with implementation of an initial ambient test with an adsorption panel placed in ambient air in proximity to vehicle emissions and other VOC sources. Such a test will start with a location where PID testing has verified high levels of TVOCs. We could then remove the adsorption panel, and test what has been desorbed into the panels, by analytical laboratory using TD GC MS.

Dr. Deep Sengupta, PostDoc in Atmospheric Chemistry at U.C. Berkeley (subsequently at Picarro), has suggested that this in Situ testing be carried out in at least two locations, one relatively VOC-laden, the other a control location with very low ambient VOCs. The first location, in our prototype experiments, would be a central Oakland neighborhood, or West Oakland. The second control location would be in the Berkeley or Oakland Hills.

The same protocol could be carried out with more than one sensor configuration. The first approach would require simply a handheld PID to start the selection of a location, then recording of TVOC levels at the beginning and end of the adsorption panel deployment in situ. Then, the adsorbed quantity could be tested by TD GC/MS.

A second continuous monitoring approach could be implemented using metal oxide sensor or MOx instrumentation, with both data logging and augmented sensors. A MOx sensor could be used, and would be more accurate if the continuous power duty cycle is implemented. The IoT mechanism, specifically, would be comprised of a single board computer (SBC), such as a RasPi, Arduino, or Beagleboard unit, with battery power, with RH and T (BME 680), with PM 2.5 (the ubiquitous Plantower unit). Power could be supplied either by battery or by small solar panel. The duration to breakthrough in EPA 325B and Eurofins testing is two weeks at most, and we will use this as well.

E. EPA Protocol Tests of Saturated AC, and Possible Alternatives

The test that has been advised by chemists and laboratory technicians is EPA TOC-17 (ISO 16006-1), which vets the entire Technical Bulletin 530 (Rev 17) Quantitative and Semi-Quantitative list. Although TO 17 is an EPA approved and respected method, Thermal Desorption with Gas Chromatography and Mass Spectrometry is indeed costly. The cost of lab services and implementation is the most problematic aspect of MM so far.

The MMWG is also considering the potential of a less costly test, also based on ionization energy levels. Using a Thermal Desorber, coupled with a Photo-Ionization Detector would be more economical. Perhaps even a heating block, at perhaps a quarter of the cost of a thermal desorber, might work in its place. Since specific VOC species have a signature volatilization point, they should progressively manifest during heating and thermal desorption. This may mean several VOCs appearing at once, but would give a general idea of the makeup of adsorbed chemicals in AC. In rough form, this idea seems straightforward, but actually implementing it is not so^{18,19}, and at present it is not developed as a commercial possibility. The inputs to create the DIY versions are considerable. There are a number of miniaturized devices available commercially, but even used the Infico AG portable GC/MS system costs five thousand dollars. Another change that could make this process far more feasible would be in the price of PID bulbs, but these cost hundreds of dollars at best with no sign of change.

8. Panel Adsorption Improvement

Metrics for Air Intake combined with an Activated Carbon Adsorption Panel

The rudimentary prototype and the timed jar tests discussed in Section 4 offer a way to determine breakthrough by duration. The test indicates that the method works, but this is necessary but insufficient, akin to "first do no harm". The test must instead be effective rather than minimal.

The MMWG started to test in the real world rather than the simulation offered by the jar test. While the jar test elides air flow, in real life this is crucial.

The initial challenge appears to be to deploy panels for the right time duration, rather than gratuitously later than breakthrough. Given the dramatic gradient witnessed in the first timed jar test, we have reason to suspect that breakthrough is faster than we had first thought. The Cub PID device only gave us sixteen hours to work with, far less than our original six-week test. However, dramatic adsorbance was observed during the far shorter time period with the Cub.

We will control for the time duration, and then, using the same quantity of GAC, systematically alter different values of concerning deployment location variables. These attributes are: height of adsorption panel; ambient humidity; light exposure (using lumens, probably from a smartphone app); the panel's proximity to emissions; stronger or weaker air flow (measured with an anemometer); size of adsorption panel (1x and 2x); and ambient temperature. Of these factors, ambient temperature and humidity are given rather than controlled. At present, simply testing these attributes as binary rather than ordinal variables is the most economical option. Much of the instrumentation needed is quite simple: an anemometer, RH, temperature, and mobile handheld PID.

The MMWG will leave adsorption panels in wire mesh protective screened cages (cost about eighty dollars, available from Zoro or Grainger). We plan two tests, with different canonical weather patterns. The first will be in damp, cool weather in the San Francisco Bay area's mild winter, probably February. The second will take place in warm sultry weather, probably in June. Given the same temperature and humidity, we will alter proximity to the emissions source, with one panel approximately 18 inches (45cm) away and the other one meter away, while trying to keep air flow similar between the three panels. Vehicle tailpipes are usually about one foot (30.48 cm) above the ground; varies 8 to 18 inches (20 to 45cm). Exothermic reactions (cite the U Nantes research) take place at far higher temperatures, but we are trying to see if sunlight, at far lower ambient temperatures, will affect adsorption.

Locations for the close-proximity panels will be utility poles or guardrails immediately next to parking lanes. Locations for the further proximity panels will be not much further away- probably simply higher on the utility pole or across the sidewalk. We will use two small panels, one very near the emissions source and one a meter or so away. A third larger panel will also be deployed near the emissions source. The smaller panel will be approximately 8x6", or about 20x15 cm, and the larger panel will be 12x8" (30x20 cm). Please see Figure A- PHOTOGRAPH OF UTLITY POLE STREETSIDE. In a second test, we will alter light exposure while trying to hold proximity to emissions steady.

Because we need to see re quantity and composition of adsorbed chemical species, we simply see no other way to testing the results other than with thermal desorption and gas chromatography / mass spectrometry (EPA Method TO-17, TD GC/MS analysis). We are contacting local analytical laboratories regarding this service.

Such empirical results can be reached without material balances using the tests discussed above. However, these results do not characterize material balances even in an imprecise sense. We need a more precise metric for figuring out the volume of air adsorbed, and total adsorption of VOCs over period of time, so that we can start to generally characterize a few profiles for different AC and breakthrough timing circumstances.

9. Desorption, Decomposition, and Reactivation:

international industry practice and applicable standards; kiln types; reactivation; Spent Carbon Profile Forms; alternative desorption and decomposition methods;

The central fact of physical adsorption is that it is reversible. Reverse logistics are integral to the protocol, and the desorbed contaminants can sometimes be recaptured as well. Micromitigation is not greenwashing. Desorption requires essential elements of heat, leading to pyrolysis and volatilization, carried out in either a rotary kiln or a multi hearth kiln. References in industry and technical sources vary as to the temperature and timing of the regeneration and reactivation processes²⁰. Regeneration uses kilns or the multi hearth ovens, present in every country. Foo and Hameed (2009) indicate problems relating to regeneration and reactivation, most notably the tendency of hearth kilns to work slowly and taking hours to heat. A slow process is not as much a problem for MM since by choice it will invariably trade more time expended in order to obtain for a cheaper process. Foo and Hameed present the usage of microwave energy for both desorption and reactivation as a prospective improvement. This field would appear to be ripe for process innovation, none of which would demand high capital costs or fundamental scientific breakthroughs.

Precision in technical specifics and assurance of environmental safety throughout the entirety of the life cycle is necessary. The 1976 Resource Conservation and Recovery Act provides authority for the EPA, and state agencies, to regulate carbon disposal and to regulate the regeneration of such carbon materials. Both EPA and California entities require certification that the spent carbon is not hazardous waste. EPA standards and CA Department of Toxic Substances Control procedures define this term according to 40 CFR Part 261.3 and Title 22 of the California Code of Regulations, respectively. Characteristics of hazardous waste according to the EPA's Hazard Codes are: ignitable (with flash point less than 140 degrees Fahrenheit); corrosive (acidic or basic); reactive (unstable under normal conditions), toxic (containing mercury, lead, DDT, PCBs), and acute hazardous waste or toxic waste. In addition to following the EPA standards, the DTSC requires the specification of the non-hazardous- or hazardous nature of such wastes. This includes a number of specified wastes: F list (various manufacturing and industrial processes); K list (specific industries, petroleum and pesticides); P list (industrial chemicals), U list (discarded commercial chemical products), and M-list (mercury); (DTSC "defining Hazardous wastes).

The EPA's 8260B requirements for testing adsorbed carbon, specifies gas chromatography and Mass spectrometry processes which test for quantities of air pollutants VOCs in spent carbon. 8260B uses but does not strictly require purge and trap method 624.

Spent Carbon Profile Forms and Requisite Laboratory Testing prior to Regeneration

In the United States, saturated activated carbon must be submitted to regeneration facilities accompanied by a Spent Carbon Profile form and test results indicating that the materials are not hazardous waste as described immediately above. EPA standard 8260b GC-MS is required for spent carbon profile for prospective hazardous waste. This method suggests but does not strictly require purge and trap, and does allow for other methods (see Section 1.2). The MMWG has found this test to cost at least five hundred dollars, or more. Like the relatively expensive GC-MS by desorption test to ascertain the presence of Toxic Air Contaminants, this expense cannot be avoided. That means that in the United States, the sample collection could be about \$500 to submit to regeneration plants.

While our work is deliberately designed to make use of cheap commodity materials, some lab tests simply are costly. On the other hand, figuring out how to get lab results could be a way to do civic engagement, coordination between universities or local Environmental agencies and community organizations. This is an open question and will be even as we start.

10. Processes for Implementation and Improvement of the Open Standard

meetings; inclusion in meetings; working groups; remote meeting practices; calls; storage of results on server;

Our first instinct is one of open dissemination of this work. The second response is one of self-preservation. The Protocol is open, but we have a self-evident imperative to avoid being, retroactively, subject to patent infringement claims. Thus the MMWG placed initial but detailed proposal in a GitHub repository, with clear indication as to its protection by CERN Open Hardware License- Permissive (2.0, 2020). This initial placement will be supplemented on a regular basis.

That being said, the Group continues to self-consciously undertake ongoing research with only a very limited number of in-person meetings, and a majority of meetings by Zoom.

Formal process for protocol iterations

The preliminary open protocol is intended to be rigorous and yet amenable to ongoing modification. We started the working group with the express intention of establishing a working model, and then bringing in new colleagues as quickly as we could, then adopting guidelines for different environments and closer specifications for the process itself.

Rules setting body, meeting specifications

The working group has met at first for the discussion of the most general process; to discuss how to use and improve MM. At least four further demarcations for sub-groups come to mind.

1. A subgroup centered on the adsorption panels and process: testing under difference circumstances; testing for temperature and relative humidity, and in different urban topographies; issues such as different environments; vertical height, duration of implementation;
2. Study of desorption, decomposition, regeneration, and reactivation; We expect this aspect to be the most problematic sticky wicket in micromitigation.
3. Implementation working group; idiosyncratic aspects of the MM process that end up being consequential; how to organize the implementation processes; cost, what sort of cohorts wish to participate in implementation;

Our first practitioners were by necessity a diverse cohort of scientists in different specialties. As of mid-2022 the group was considering our next outreach to environmental justice groups in Oakland, educational non-profits, and others. We intend to systematically take note of the characteristic institutional auspices in which micromitigation develops. Based on the experience of the Open Insulin Project, we are also considering how to engage high school chemistry students and professors, and possibly retired chemists and AQ scientists.

4. Literature review subgroup; implementing such a group is one approach.

Alternatively, review of pertinent literature could be implemented in each of the above groups;

We hope that micromitigation will evolve in efficacy of usage, technical precision and specifications for different world climates and urban settings. Emergent functionalities, such as air pollution mitigation co-benefits in public health and community-building, would be fascinating- although they are by definition unforeseen in our early design. Micromitigation will require standardization and rationalization of extant processes in order to make them more effective. We will attempt process innovation in the design and testing of panels, and look forward to seeing what else emerges. We very much hope to innovate in the institutional organizational format itself. Our success will rely heavily on the development of many small and low-budget experiments.

There are other matters which we have not yet reviewed: requirements for participation other than willingness to agree to open science. This will be stated at the very beginning of every

meeting. Meetings will be recorded and notes taken; who will take minutes; how will the reading materials be available; folder for written materials (preferably both A or Letter formatted paper as well as A4); We will get to the issue of storage of results on server, and any security issues therein, as well at some point. Perhaps additions to MMWG digital materials can be allowed by any group member, but removal of any material should be voted on or otherwise restricted.

Effective organization will be achieved by adherence to scheduled meetings. Since micromitigation is intended to alleviate air pollution in environmental justice neighborhoods, economy and frugality are necessary. Fortunately, the requirements of Zoom calls are quite minimal, requiring Internet connectivity rather than physical presence. The group started with a call at 7:00 pm PST (-8:00 UTC) alternating Thursdays, and later added a 7:00 am Thursday WhatsApp call.

Micromitigation will be a great and fulfilling challenge intellectually, logistically, and in terms of local community dynamics in every place it is carried out. We look forward to the broad participation that will be necessary.

11. The MMWG

Participants, contacts. Background of the Micromitigation Working Group;

Origins of the Group

The Micromitigation Working Group originated in March, 2021 at the Counter Culture Laboratories, an open science community lab and 501 (c)(3) organization in Oakland, California. Micromitigation could not have been developed without the unique environment of the Counter Culture Labs. The CCL is the first home of the Open Insulin Project, as well as ongoing work on Mycology, Vegan Cheese, Kombucha genomics; and Open Bioprinter, among other projects. The idea was previously published under the title "Mitigate Yourself", on LinkedIn in 2017. CCL adopted MMWG as a bi-monthly working group on March 10. Open meetings were posted on CCL's YouTube (on April 15, 2021, and some subsequent meetings), with Twitter posts and open email invitations to CCL's three thousand members. The group will place the protocol in Github or another repository, and disseminate it by CERN Open Hardware License (Weakly Reciprocal, 2020 v2).

The group meets two Thursdays per month, once at 0700 Pacific Time and once at 1900, for participants in different time zones.

This document has also benefitted from extensive discussions and material contributions from the esteemed colleagues who collectively comprise the MMWG: Drs. Bill Horn (UC Davis), Pete Palmer (SFSU), Patrik D'Haseleer (CCL and Lawrence Livermore National Laboratory), Deep Sengupta (UC Berkeley), Emmanuel Chiedu (Federal Institute of Industrial Research, Nigeria); and Roshni Sirvani (CitiesFeedCities non-profit), Peter Fitchen (Google), and Ken McGary (Clarity.io).

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¹¹ SOx NOx NMVOC CH4 NH3 and CO (EMEP CORINAIR guidebook)
IPCC guideline pollutants are CO2 CH4 N2O HFC PFC SF6 as well as precursors NOx CO NMVOC and SO2;
Other inventories include EDGAR for air pollutants and GHG (not to be confused with US legal filing system of the same name);
Emissions inventories in East Asia LTP; EA Grid- Japan;
ACCESS is a top down database developed by Argonne Natl Lab;
GEIA- the international geosphere programme; global gas and aerosol emissions inventory;
The UNFCCC is a global, annual inventory concerning anthropogenic sources;
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¹² Prototype: a working model with limited functionalities.

¹³ Also called 2-methylpropene, isobutylene has a chemical formula of (CH3)2C=CH2. It is a four-carbon branched alkene (olefin) and is one of the four isomers of butylene. Boiling point 19.58f, -6.90 C.

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