



Air Quality InQuiry (AQIQ):

Adapting air quality sensors for use in high school settings
in the United States and Mongolia

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Up on a Rooftop..

- Low-cost air quality monitoring
 - Pre-oil and gas development in North Fork Valley 2012
- Western Slope Conservation Center non-profit set up locations
 - Paonia High was one of them!



Y Pods!

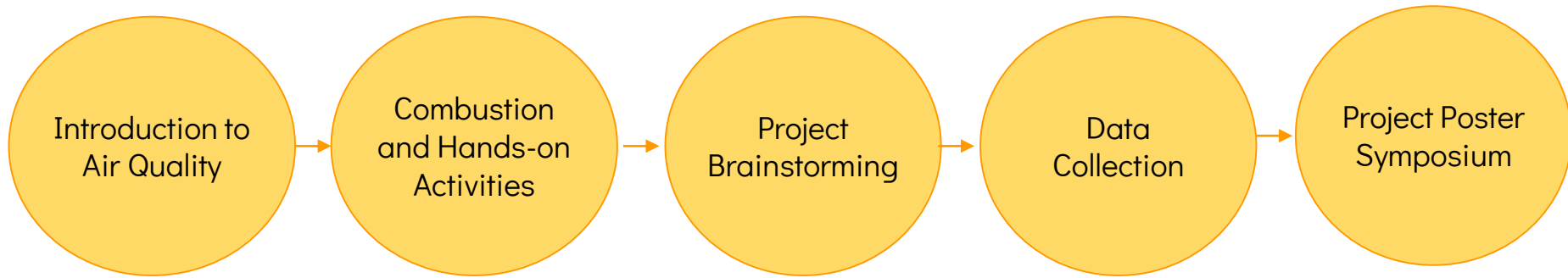


Paonia letter jacket!

...these pods should be *inside* the school

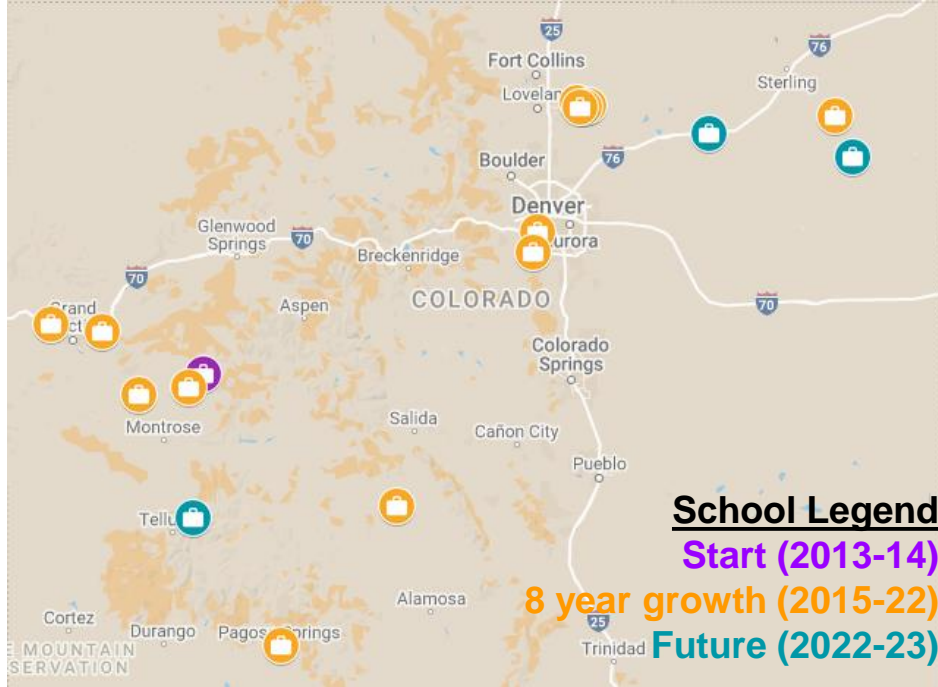
Air Quality InQuiry (AQIQ)

5 Teach Engineering Modules



Guided by CU Boulder mentors
throughout the entire process

AQIQ in Colorado

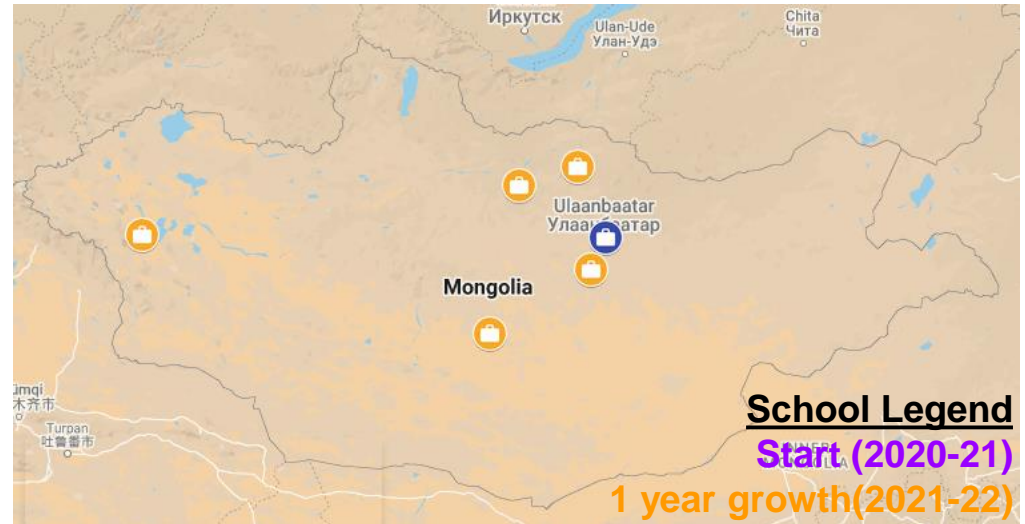


- 8 years later..
 - 15 total schools reached
 - Over 3,000 students
 - 8 school districts
 - Spanning the western slope to front range
- And growing !
 - 3 schools joining in 2022-23 academic year (Ouray, Yuma, Fort Morgan)

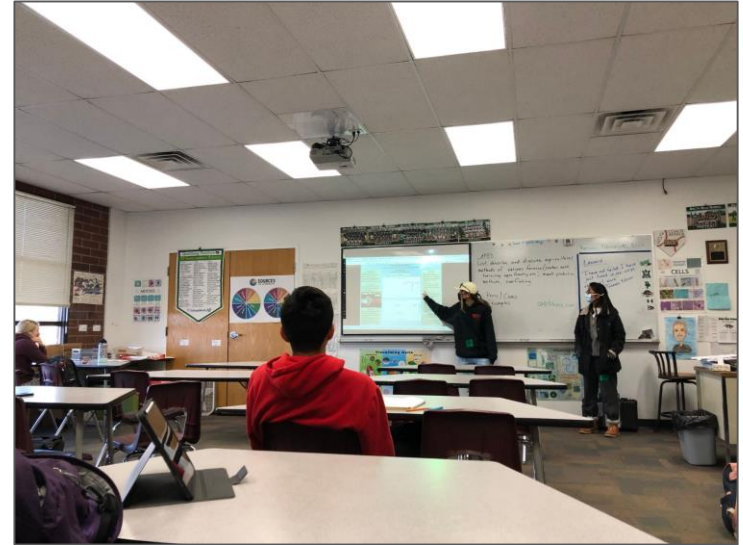
AQIQ in Mongolia



- Student contact with Public Lab Mongolia NGO and National University of Mongolia
- Severe air pollution
- Start : 3 high schools in capital, Ulaanbaatar
- Current : 5 high schools across various provinces
- Doubled # of involved students



From research to a K-12 environment



AQIQ Class, Delta High School 2022



Important Constants

- **YPods at center of curriculum**
 - Project-based → learning by doing rather than telling¹
 - Demystifies science and engineering tools
 - Active engagement - no separation between knowing and doing²
- **Low-cost sensors**
 - Increases accessibility
 - Expands on ideas of citizen science³
- **Same pods used in research**
 - Authentic tools of the profession (students can adopt role)²
 - Used by Hannigan Lab in research settings
 - Allows students to draw ties with higher education/careers

Important Changes

YPod Iterations - 2013



Can measure :

- CO₂
- VOCs (light and heavy)
- NO, NO₂
- Temperature
- Humidity
- Pressure
- Ozone

Other features:

- Janky (disorganized)

Important Changes

YPod Iterations - 2016



Can measure :

- CO₂
- VOCs (light and heavy)
- ~~NO, NO₂~~
- Temperature
- Humidity
- ~~Pressure (discontinued)~~
- Ozone

Other features:

- ~~Janky (disorganized)~~
- Power cable
- Battery power
- Instructions
- Updated circuit design

Important Changes

YPod Iterations - 2020



Can measure :

- CO₂
- VOCs (light and heavy)
- ~~NO, NO₂~~
- Temperature
- Humidity
- ~~Pressure~~
- ~~Ozone~~
- CO
- PM (1, 2.5, 10)

Other features:

- ~~Janky (disorganized)~~
- Power cable
- Battery power
- Instructions
- Updated circuit design
- Choice of gas-only / gas+ particulate


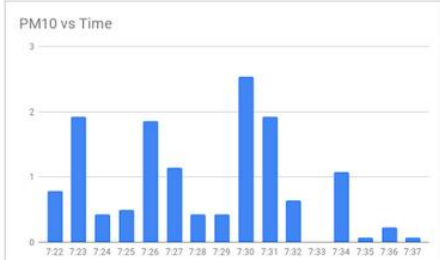
Important Changes

Incorporating PM

- Enhances understanding of air quality
 - AQI and NAAQS (rooted in regulation)
 - Easier for students to visualize
 - Allows to students to measure “Visibility”
 - Expands sources students can study (aerosols, dust, mechanical generation etc.)
- Connects to COVID-19
 - Mask experiment - importance of particle filtration
- Connects to wildfires
 - Place-based, students’ experiences of hazy days
- Over 20% of student projects involved PM in first year!

Particles Against Protection

Palisade High School

Background	Procedure	Analysis																																		
<ul style="list-style-type: none">• Certain masks block more particles than others• Talking produces a lot of particles• Covid-19 is spread through particles	<ul style="list-style-type: none">• Turn the pod and let it warm up for 30 minutes• With no mask, say the ABCs with your mouth 8 in. away from the pod’s vents• record start and stop times with the timer on the paper• Wait 5 minutes for pod to reset to ambient air• Repeat second step with surgical mask• Wait 5 minutes for pod to reset to ambient air• Repeat second step with cloth mask• Wait 5 minutes for pod to reset to ambient air• Repeat second step with n95 mask• Collect all data information and plot it to graph• Determine the difference each mask made to air quality, specifically the difference in average value of particulates	<ul style="list-style-type: none">• Analysis: The highest level of particulate matter was measured while wearing the cloth mask, the lowest was with the N95. So part of our hypothesis was correct. This does not prove that cloth or disposable masks no not work, but only that there was more particulate matter measured.• Sources of error: The masks may have had particles on them, unrelated to the hazardous particulate matter that carries covid, that was expelled from the masks while speaking. We also stayed in the room while the pod was reacclimating to the ambient air, which might have affected the data.																																		
Hypothesis																																				
<ul style="list-style-type: none">• Most particles will be detected when wearing no mask, the least will be with the N95, but there will be less when using the cloth or surgical when compared to no mask																																				
Materials																																				
<ul style="list-style-type: none">• Cloth mask• Surgical mask• N95 mask• YPod with pm sensor• pencil and paper• ruler• timer	 <p>Data</p>  <table border="1"><caption>PM10 vs Time</caption><thead><tr><th>Time</th><th>PM10</th></tr></thead><tbody><tr><td>7:22</td><td>0.8</td></tr><tr><td>7:23</td><td>2.0</td></tr><tr><td>7:24</td><td>0.5</td></tr><tr><td>7:25</td><td>0.6</td></tr><tr><td>7:26</td><td>1.9</td></tr><tr><td>7:27</td><td>1.2</td></tr><tr><td>7:28</td><td>0.5</td></tr><tr><td>7:29</td><td>0.6</td></tr><tr><td>7:30</td><td>2.5</td></tr><tr><td>7:31</td><td>2.0</td></tr><tr><td>7:32</td><td>0.8</td></tr><tr><td>7:33</td><td>0.1</td></tr><tr><td>7:34</td><td>1.1</td></tr><tr><td>7:35</td><td>0.1</td></tr><tr><td>7:36</td><td>0.4</td></tr><tr><td>7:37</td><td>0.1</td></tr></tbody></table>	Time	PM10	7:22	0.8	7:23	2.0	7:24	0.5	7:25	0.6	7:26	1.9	7:27	1.2	7:28	0.5	7:29	0.6	7:30	2.5	7:31	2.0	7:32	0.8	7:33	0.1	7:34	1.1	7:35	0.1	7:36	0.4	7:37	0.1	<ul style="list-style-type: none">• Conclusion• We were half right. The disposable mask had the most collected particles in the end, not the no mask. The N95 mask had the lowest amount of particles collected.
Time	PM10																																			
7:22	0.8																																			
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		<p>Acknowledgements</p> <ul style="list-style-type: none">• Thank you Mr. Klaiber. Thank you Nick and Elsa																																		

With these changes, students are able to explore

- Multiple pollutants
- Environmental factors (T, Rh)
- Place-based AQ questions



Tailpipe emissions activity, Ulaanbaatar



HS student exploring agricultural emissions



Tailpipe emissions activity in Lone Star, 2022

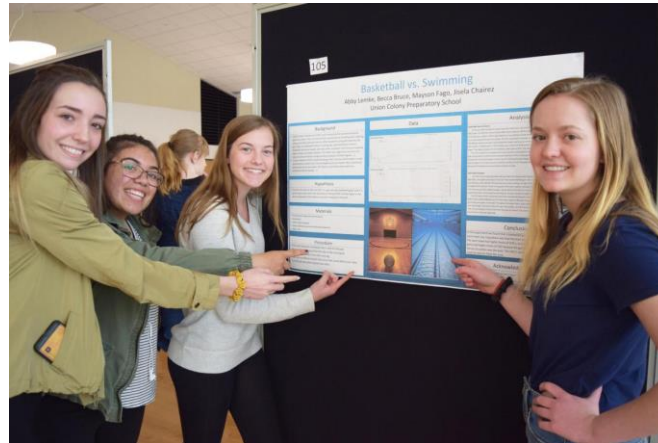


HS student exploring combustion

Past AQIQ Projects



Student AQ Symposium
in Mongolia



Student AQ Symposium
in Colorado



CO₂/Humidity Levels In Music Classrooms



Palisade High School

Background

- We tested the air quality of three different classrooms which performed various musical activities (band, choir, and orchestra), all of which have differing numbers of students and levels of exhalation. We were curious as to which music class would have the highest level of CO₂, considering the activity. High levels of CO₂ in a poorly ventilated room can cause lethargy, poor attendance in schools, headaches, and even impaired mental function.

Hypothesis

When musical activity is performed during the class period, then the CO₂ levels will increase because O₂ is needed.

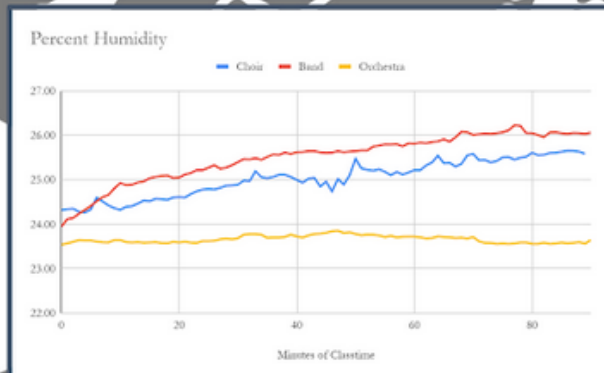
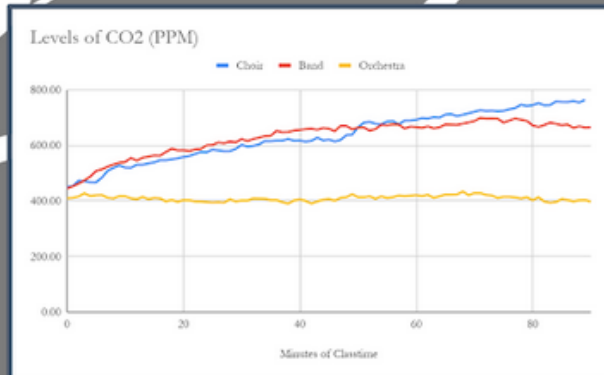
Materials

- Y-Pod to measure air quality
- Computer to record data
- Available rooms to test in
- Students involved during testing

Procedure

- Set Y-pod in each classroom at separate times when the class is active
- Let the Y-pod test for around 1 ½ hours per class
- Collect the Y-pod after the time is done
- Uploaded data to the AQI/Q website, and transferred data to Google Sheets to be graphed
- Make a beautiful poster!

Data



Analysis

- Band had the Highest Humidity increase
- Choir had the highest CO₂ and temperature increase
- Orchestra was the lowest in all categories
- In all classes, air quality levels grew linearly with the exception of the orchestra room
- Sources of error: On the first day of analysis, the choir class was not singing, therefore we could not get an accurate data collection. The sizes of the rooms and the number of students also vary greatly between each class

Conclusion

- Choir had the highest increase in CO₂ and temperature, which was not expected because it has the least amount of people. Band had the highest humidity levels due to the large amount of students participating compared to the other classes. During the class periods, the CO₂ and Humidity levels all increased gradually, and were at their highest at the end of the class period.

Acknowledgements

- Mr/Her to give a big thank you to Mr. Drey, Mr. Mills, and Mr. Kaper for allowing us to collect data during their classes.
- "How Bedroom CO₂ Levels Impact Restful Sleep." *Zolander America*, 15 May 2018. www.zolanderamerica.com/how-bedroom-co2-levels-impact-restful-sleep/

Place-based and multiple pollutants



Dormant Mine



Methane Vent

Coal Mine CO₂ and VOC Emissions in The North Fork Valley

Paonia High School



Reclaimed Mine Land



Active Mine

Background

- The burning of coal releases pollutants into the air: nitrogen oxides, CO₂, and particulate matter, but do the various stages of mining also release pollutants?
- We were curious to find the effects of the coal mining process on the air quality in the North Fork Valley.
- Heavy dense air from the mountains sinks through smaller valleys down into the main valley. Several coal mines are placed in these small valleys and we placed our pod downwind from these sites to measure pollutants.
- Pollutants were measured in an active mine, a dormant mine, reclaimed mine land, and the valley beneath a mine's methane vent.

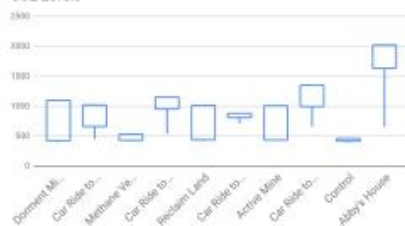
Hypothesis

If the air quality is tested at several mining locations at various stages of life, then the active mine will have the most pollutants, because of the numerous pollutants that are released into the air in this stage.

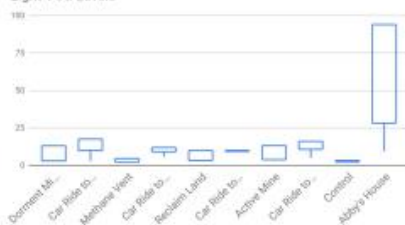
Procedure

- A y-pod from the University of Boulder was placed at several mining locations below the down-valley wind.
- At the first location, the pod was placed at the base of a stream bed on the side of the road for 15 minutes. Cold air blew down this stream bed, and The Bowie Mine was relatively 100 yards above this location.
- At each remaining site the pod was placed at the base of these small valleys beneath an active mine, a methane vent, and reclaimed mine land. Each valley has downward wind and the pod was left at each site for 15 minutes.
- A control was taken at the fork of the Anthracite and Muddy Creeks.
- To examine the data, we used a box and whiskers graphs to compare the various levels of CO₂, light VOCs and heavy VOCs.

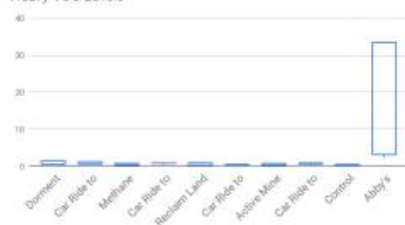
CO₂ Levels



Light VOC Levels



Heavy VOC Levels



Sites where data was sampled:



Analysis

- Pollutants measured in the Coal Mines are not as significant as the pollutants measured in houses or cars.
- **Mines:** the pollutant levels stayed at a low constant rate, with an average of 480 ppm for CO₂, 4.12 ppm for light VOCs, and .4 ppm for heavy VOCs.
- **Transportation in the car:** the pollutant levels spiked, there was an average of 947 ppm for CO₂, 11.4 ppm for light VOCs, and .67 ppm for heavy VOCs.
- **Abby's House:** greatest levels of pollutants were measured while the pod was warming up here, with an average of 1722 ppm for CO₂, 30.5 ppm for light VOCs, and 4.3 ppm for heavy VOCs.

Conclusion

- The hypothesis was rejected by the data: the presence of a coal mine in any stage did not cause a significant change in the levels of pollutants.
- At the mining sites pollutant levels did not spike and had a low overall average of 480 ppm for CO₂.
- In Abby's home the average level of CO₂ was 1722 ppm. Her home is well-insulated keeping these pollutants trapped
- The average CO₂ was 947 ppm while the pod was in the car, because it is a confined space with limited air circulation.
- Conclusion about data: the surrounding air around coal mines has less pollutants than cars and homes.
- A short in the pod's wire caused drops in the data that we had to take into account.

Place-based Mongolia and multiple pollutants

Хураангуй

2021 оны 1 дүгээр сарын 29-ы өдөр Улаанбаатар хотын Хайлааст орчимд 56 м² байшинд туршилтийг хийсэн. Энэхүү судалгаагаар байшинд гал түлэх үед агаар дахь хийн бохирдуулагч хэрхэн өөрчлөгдөж байгааг тодорхойлох зорилготой. Туршилтын үр дүнгээр дотоод орчин дахь нүүрстөрөгчийн дутуу исэл болон дэгдэмхий органик нэгдлүүд нь 15.4%, 2.4%-3.6% тус тус өссөн байна.

Танилцуулга



Агаарын бохирдол гэдэг нь нүүрсний шаталт, үйлдвэрлэл [1] болон тоосжилтоос үүссэн агаар мандалын бүтэц шинж чанарын өөрчлөлт [2] юм.

2019 оны байдлаар Улаанбаатар хотод амьдарч буй иргэд

- 2.0% нь нам даралтын зуухтай
- 0.6% нь цахилгаан халаагууртай



Таамаглал

Сайжруулсан нүүрсийг шатаах үед дотоод орчны агаар дахь хийн бохирдуулагчийн агууламж ихсэх байх гэсэн таамаглал дэвшүүлж байна.

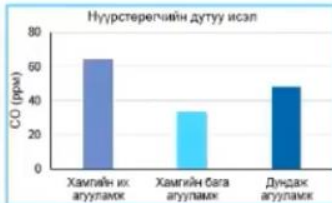
Арга аргачлал

Bekas төслийн зууханд туршилтаа явууллаа. Сайжруулсан нүүрс /8кг/ эд шатаах үед POD төхөөрөмжийг зуухны амсараас 20см зайтай байршуулж хийн хэмжилт явуулсан. Туршилтийг нийт 12 минут явуулсан бөгөөд үр дүнгийн боловсруулалтыг хийхдээ Microsoft excel program ашиглалаа.



Үр дүн

Судалгааны үр дүн дээр агаар дахь хийн бохирдуулагч бодисын агууламжыг үзүүлэв.



Дүгнэлт

Туршилтын үр дүнгээр дотоод орчны нүүрстөрөгчийн дутуу ислийн агууламж галлагааны үеэр 15.4%-иар ихэссэн байна. Нүүрстөрөгчийн дутуу исэл хамгийн ихдээ 64.5, хамгийн багадаа 33.6, дунджаар 47.9 байжээ.

Туршилтын үр дүнгээр дотоод орчны хүнд дэгдэмхий органик нэгдлийн агууламж галлагааны үеэр 2.4%, хөнгөн дэгдэмхий органик нэгдлийн агууламж 3.6%-иар тус тус өссөн үзүүлэлт гарчээ. Галлагааны үеэр дэгдэмхий органик нэгдэл нь 16:01 цагт хамгийн өндөр хэмжээндээ хүрсэн байна.

Үүнээс үзэхэд бидний дэвшүүлсэн таамаглал батлагдаж байна.

Хэлэлцүүлэг

Алдаа гарч болошгүй зүйлс:
Хэмжилтийн цаг нь туршилтын цагтай таараагүйн улмаас хийн бохирдуулагчийн нөлөөллийг бүрэн хэмжигдэхгүй

Ашигласан материал

- [1] Aгаар.mn Агаарын бохирдлын тухай товчхон
- [2] Ikon.mn
- [3] www.1212.mn Статистикийн мэдээлэл

Талархал

Энэхүү судалгааны хөтөлбөрийг зохион байгуулсан биднийг дэмжсэн талархал



how gas pollutants in the indoor air change during using coal burning stoves

Further Plans

Technical -

- Increase data accessibility
 - E.g. Wifi, cellular, Bluetooth
- Expand measuring capability
- Improve sensor calibration

Educational -

- Long-term impact of AQIQ
- Expand curriculum
 - Sensor function
 - Local sources/industry
 - Environmental justice



The screenshot shows the TeachEngineering website interface. At the top, the logo for TeachEngineering is displayed with the tagline 'Ignite STEM learning in K-12'. To the right, it says 'Brought to you by Engineering UNIVERSITY OF COLORADO BOULDER'. A search bar is located in the top right corner. Below the logo, there is a navigation menu with options: 'Browse Curriculum', 'K-12 Engineering', 'Math & Physics', 'NGSS', 'Engineering Design', 'Popular Topics', and 'Prof Dev Workshops'. The main content area features a lesson titled 'An Introduction to Air Quality Research' with a star rating of 0 and a 'Click here to rate' link. Below the title is a photograph of an EPA trailer equipped with air quality monitoring equipment. A 'Quick Look' sidebar on the right provides details: 'Climate Change', 'GRADE LEVEL: 11 (9 - 12)', 'LESSONS IN THIS UNIT: 1', 'TIME REQUIRED: 45 minutes', 'SUBJECT AREAS: Earth and Space Science and Technology', and 'NGSS PERFORMANCE EXPECTATIONS: HS-ESS3-1'.

Teach Engineering website with AQIQ curriculum



More Information

AQIQ Website - <https://www.colorado.edu/aqiq/>

AQIQ Data Analysis Tool - <https://www.colorado.edu/aqiq/resources>

Curriculum - https://www.teachengineering.org/lessons/view/cub_airquality_lesson01

Learning outcomes from previous studies -

A. Collier-Oxandale, et al. "Towards the Development of a Sensor Educational Toolkit to Support Community and Citizen Science." *Sensors* 2022, 22, 2543.

A. Collier, D. Knight, K. Hafich, M. Hannigan, M. Polmear and B. Graves, "On the development and implementation of a project-based learning curriculum for air quality in K-12 schools," *2015 IEEE Frontiers in Education Conference (FIE)*, 2015, pp. 1-7.

D. Knight, A. Collier, M. Hannigan and K. Hafich, "Broadening and sustaining an Air Quality K-12 curriculum through a Digital Library and undergraduate service learning course," *2016 IEEE Frontiers in Education Conference (FIE)*, 2016, pp. 1-5.

K. Okorn, T. Tran, J. Polman, D. Knight and M. Hannigan, "Changing learning opportunities and outcomes with varying levels of remote and in-person engineering education outreach," *2021 IEEE Frontiers in Education Conference (FIE)*, 2021, pp. 1-8.

Polman, J. L., Tran, T. C., & Knight, D. W. Place-based air quality inquiry in U.S. rural contexts. In Miller, K. M.. *Data Literacy in Context: Culturally Oriented and Place-Based Learning Through Data*. Symposium presentation at American Educational Research Association 2022.

Tran, T. C., Polman, J. L., Knight, D. (2022). Organizing outreach for cultural transformation: The design of a STEM education learning pathway. 2022 International Conference of the Learning Sciences. (conference proceedings)

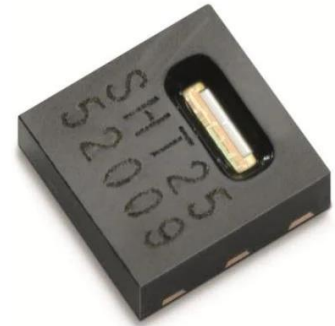
The Sensors



Figaro TGS2600
(sensitive to lighter
VOCs)



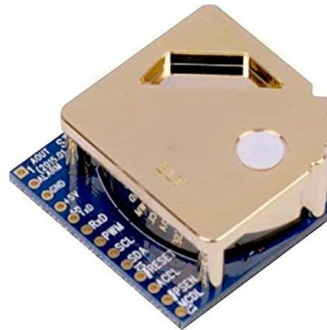
Figaro TGS2602
(sensitive to
heavier VOCs)



Sensirion Surface-
Mount Humidity and
Temperature



Alphasense CO-B4



ELT S-300 CO₂



Plantower PMS5003
Particulate Matter



References

1. Blumenfeld, D. et al. “Motivating Project-Based Learning: Sustaining the Doing, Supporting the Learning”, *Educational Psychologist*, 1991.
1. Christmas, D. “Authentic Pedagogy: Implications for Education” *European Journal of Research and Reflection in Educational Sciences*, 2014, 2(4).
1. Collier-Oxandale A, Papapostolou V, Feenstra B, Der Boghossian B, Polidori A. Towards the Development of a Sensor Educational Toolkit to Support Community and Citizen Science. *Sensors*. 2022; 22(7):2543.