Module 3 – Environmental Measurements

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Station 1
The measurement software

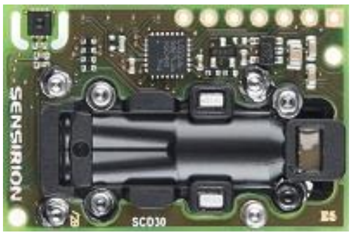
Task 1 – Tutorial

The module enables the measurement of various environmentally relevant variables by means of three sensor modules installed on a circuit board (Fig. 1 left). However, it is only thanks to software, in which the data are displayed graphically, that you can also examine and interpret the measurements (Fig. 1 right).

Fig. 1 Left: Measurement board with three sensor modules. Right: Main menu of the measuring software.

Open the tutorial in the main menu of the software and familiarize yourself with the operating elements. In the tutorial, you can also find out which measured variables are recorded by the three sensor modules. Enter the information below.

SGP30



SCD30

SPS30

Task 2 - Test the sensors

Are the sensors connected correctly and do they work?

Connect the measuring board with the USB cable. Navigate to "Sensors" in the main menu and checks whether the three sensor modules SGP30, SCD30 and SPS30 are connected. If necessary: Change the COM port until it works..

Fig. 2 shows a measurement in which a cellulose handkerchief was first rubbed over the circuit board and then blown or breathed on.

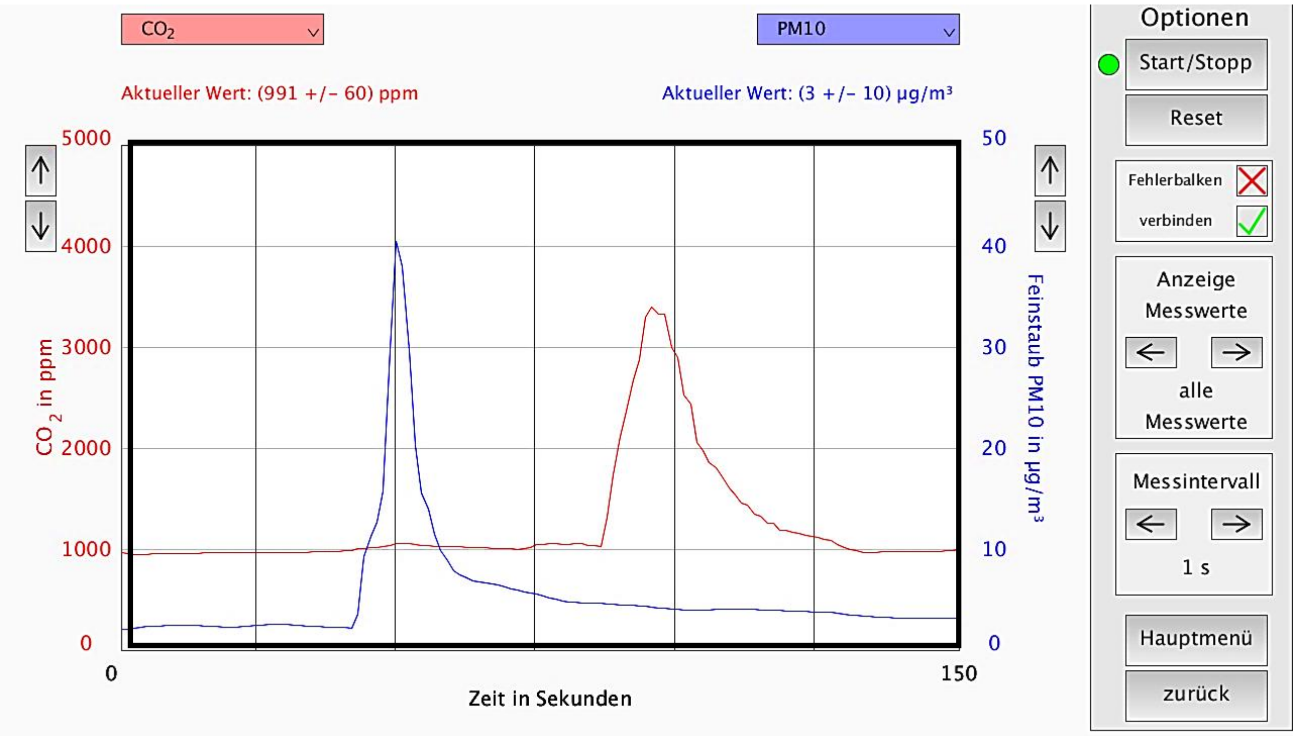


Fig. 2 Testing the sensors for functionality.

Reproduce the measurements shown in Fig. 2. In this way, check the functionality of the particulate matter sensor and the CO_2 sensor.

Finally, check the functionality of the other sensors. Briefly state how you proceeded.

Station 1
The measurement software

	Sensor working	Method of testing
TVOC		
Tempera-ture		
Humidity		
CO_2	✓	Blown at sensor. Increase in CO_2 registered. Afterwards decrease.
Particulate matter	✓	Rubbed on handkerchief. Increase in all PM components registered.

Station 2
Nose vs. Sensor

Task 1 – Nose vs. Sensor

Do you know this? You enter a room in which a class was previously held. Wow, it smells bad ... Open the window!!! The students in the room, on the other hand, didn't think the smell was that bad. Why is that? Well, the nose judges odors relatively: it can smell sudden differences very well. In case of a longer stay in bad air, or in air that slowly gets worse, the nose gets used to the smell and perceives it only weakly. And further: If odors are only slightly different, it is difficult to classify them by smelling alone in the sense of "sample A smells stronger than sample B". Do technical sensors perform better here?

In this experiment, you have to arrange six glasses with different concentrations of ethanol (Fig. 3). Can you win the duel between nose and sensor?

Fig. 3 Experimental setup for measuring the ethanol concentration of 5 solutions.

Smell the samples and arrange the glasses in descending order of ethanol concentration.

Write the letters on the right in the line "Smell Experiment 1".

Put the glasses back in order and repeat the experiment. Write the letters on the left in the line "Smell experiment 2".

Station 2
TVOC

	low concentration				high concentration
Smell expe-riment 1					
Smell expe-riment 2					
correct se-quence					
Sensor experiment 1					

Ask the supervisor for the correct order and also enter it in the boxes on the middle row.

Were you right both times? Congratulations. At least the sensor can still compen-sate. Let's see how it performs.

Navigate in the software Stations → Station 2 - Human vs. Sensor. Place an opened preserving jar in the plexiglas cube for the measurements. Then place the sensor board over it as shown in Figure 3.

Justify why it makes sense to use air quality sensors.

Station 2
TVOC

Task 2 – TVOC-Duels

For many everyday products, in addition to conventional offerings, there are also alternatives that are better in terms of environmental and consumer protection. One example: Conventional paints use toxic solvents that outgas unhealthy volatile organic compounds (VOC'S). With water-based paints, the off-gassing is lower and the VOC's are less hazardous. In this station, we pit four "conventional" products against four "alternative" products in TVOC duels. Do the alternative products deliver what they promise?

First, the olfactory test with the nose...

Navigate in the software to Stations → Station 2 - TVOC Duels. Evaluate the odors of the eight samples with points between **0 (not perceptible)** and **6 (extremely strong).**

Enter the points you assigned in the fields of the table.

	conventional products			vs.	**Low-emission products**		
paints				vs.			
pens				vs.			
adhesives				vs.			
floors				vs.			
		Nose	**Sensor**		**Nose**	**Sensor**	

And now let's see what the sensor "smells"....

Place the eight samples in the plexiglas box one after the other and place the sensor over them. Wait until the sensor signal is approximately constant.

Enter the points assigned by the sensor in the fields of the upper table.

Station 2
TVOC

VOCs include more than 300 different substances. Many of them are considered carcinogenic and have no place in the end product used by the consumer. All eight samples were therefore subjected to an analysis of the ingredients. Navigate in the software to the item "GC-MS Analysis" and look at the results.

Examine the results of the analysis.

- Write down one ingredient and warning for each of the different products. Are the alternative products more favorable?

Station 2
TVOC

Formulate a personal conclusion from the "TVOC duels" experiment.

By the way, better environmental and consumer protection of alternative products compared to conventional products does not only concern outgassing. In principle, it can apply to the entire life cycle:

Raw materials - Production - Distribution - Consumption - Recycling – Disposal

The "Blue Angel" environmental label, for example, identifies a range of alternative products. The consumer magazine "Öko-Test" publishes monthly critical test reports and news about the sustainability of entire product ranges. Take a look on the Internet.

Task 1 – Function principle of the CO_2 sensor.

The measurement of CO_2 is based on the absorption of infrared radiation. The more CO_2 present, the more radiation is absorbed. CO_2 sensors consist of an infrared source, a cuvette filled with the ambient air and a detector. The more radiation is absorbed, the lower the intensity of the light at the detector. Absorption as a function of concentration is described by "Lambert-Beer's law". But why do we actually have to use inf-red radiation? Find out in this simple experiment.

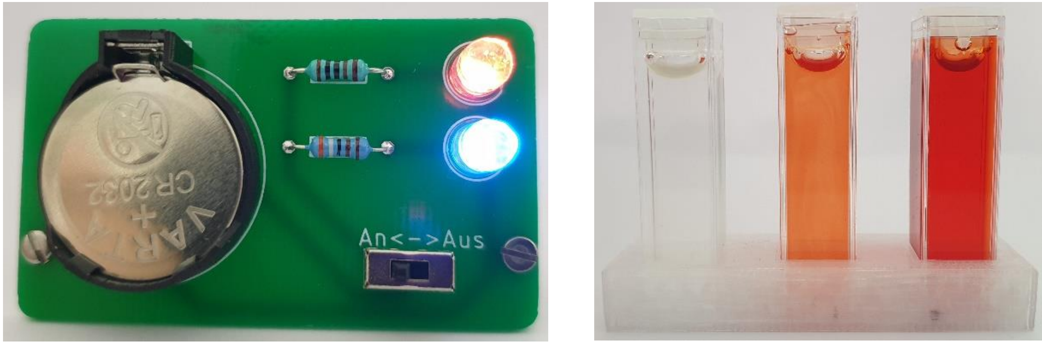


Fig. 4 Experimental setup for the function principle of a CO2 sensor. Left: LEDs of different colors. Right: Cuvettes with differently diluted color.

Shine the two LEDs through the cuvettes with red paint diluted to different degrees. What do you notice? Describe your observations

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Station 3
Thick Air

Make a guess how the observed effect is related to the measurement of CO_2 concentration. Afterwards, report to a supervisor!

Task 2 – Thick Air

If the content of CO2 in the room air exceeds 1,000 ppm (= 1 ‰), it is an indication of "thick air" and ventilation should be provided. The chemist Max von Pettenkofer formulated this recommendation, which is still accepted today, as early as 1858:

„I am most vividly convinced that we would greatly strengthen the health of our y-outh if we would always keep the air in the schoolhouses [...] so good and pure that its carbonic acid content ***could never rise above 1 per mille****."*

But CO_2 is only one "indicator" of bad air: Even Pettenkofer was aware that there are other outgassings of the human body (many VOC's) besides the CO_2 of the exhaled air, which promote fatigue and concentration difficulties. But also temperature and humidity have an influence on the indoor climate. Investigates the influence of humans on indoor air quality (Fig. 5).

In the software navigate to the menu Stations → Station 3 - Thick Air and check your CO_2 and TVOC outgassings as well as the changes in temperature and relative humidity in the walk-in measuring chamber. The exact measurement procedure is explained in the software.

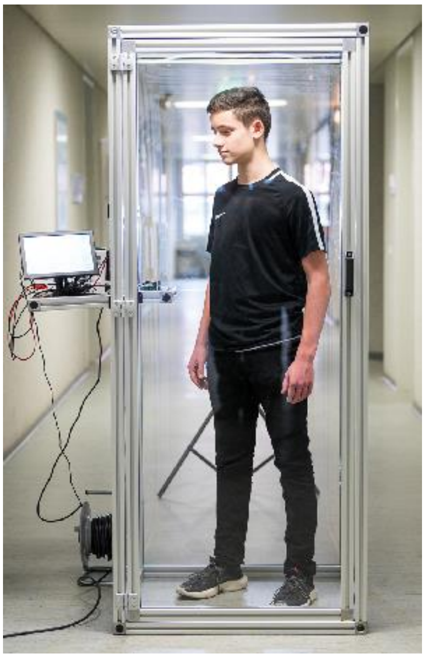
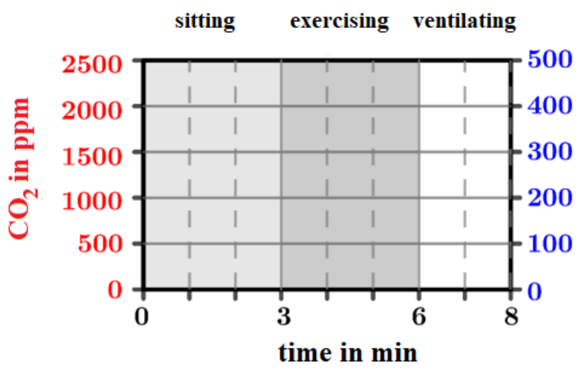


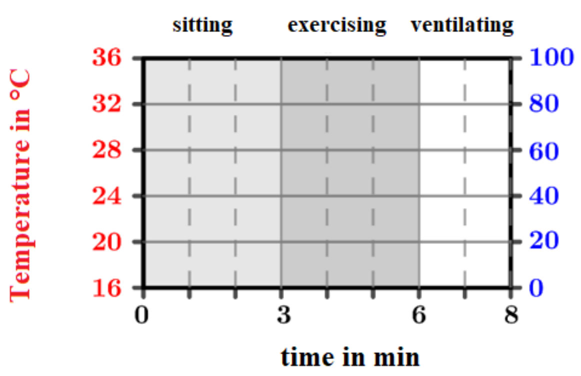
Fig. 5 Walk-in measurement chamber for the investigation of CO2 and TVOC outgassing from humans.

Station 3
Thick Air

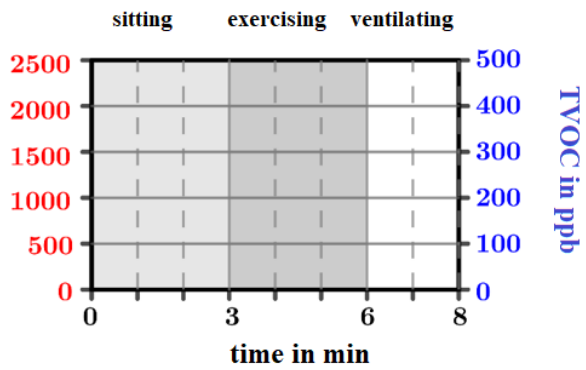
Sketch the measured curves of CO_2, TVOC, temperature and relative humidity with and without ventilation into the diagrams below.

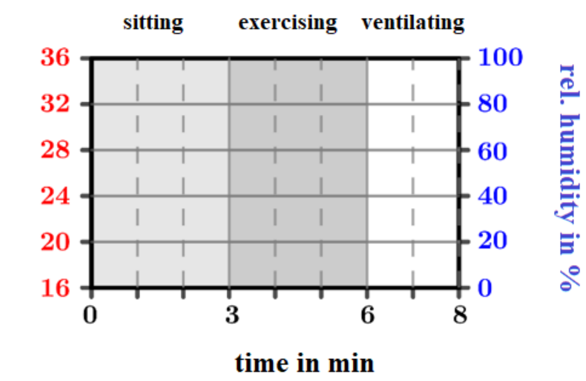
Measurement 1 - without ventilation





Measurement 2 - with ventilation





After the measurement in the walk-in measurement chamber (V = 2 m³) by one person - make a rough calculation: How large are the CO2 and TVOC concentrations in a classroom (V = 200 m³) with initially good room climate after a 90-minute double lesson. Should the room be ventilated?

Station 4
Particulate Matter

Task 1 – Function principle of a particulate matter sensor

For the preliminary experiment we need 3 cuvettes (Fig. 6 left). In addition to water, these contain different concentrations of tiny beads of silicon dioxide (silica for short, Fig. 6 right). In water, the beads form a suspension, i.e. the particles are not dissolved, but the solids "float" in the liquid - similar to fine dust in air. The silica particles thus model particulate matter.

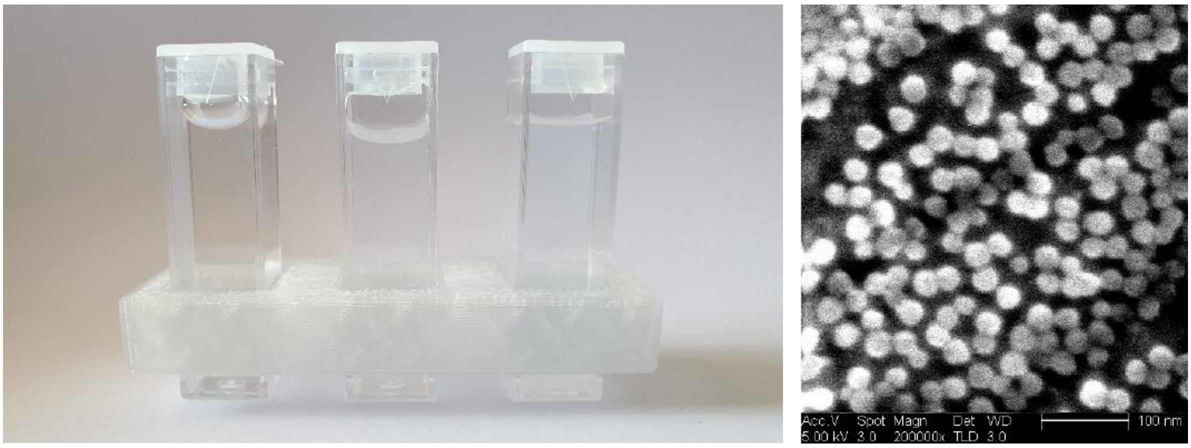


Fig. 6 Left: 3 cuvettes with water and different concentrations of silicate beads. Right: Electron microscope image of silicate beads.

Arrange the liquids in the test tubes according to the descending concentration of silicate beads. A laser pointer is available as an aid.

Enter the letters in the boxes below.

High concentration | | Low concentration

Station 4
Particulate Matter

Justify your decision for the order. In particular, explain how the laser pointer helped you in the experiment.

How could the observed phenomenon related to particle concentration and the effect on the laser light be used to detect particulate matter in air? Explain an idea.

Once you have completed the tasks, please contact your tutor. He will give you a sheet with the solution.

Task 2 – Chalk dust

Although some schools now only use interactive whiteboards or smartboards, writing with chalk on blackboards is still part of everyday teaching in many places. When writing, but especially when wiping dry, particles of particulate matter are swirled, which can be seen with the naked eye as a kind of "cloud". The cloud contains particles of very different sizes. Does it also contain particulate matter? Investigate the emission of particulate matter from different types of chalk during marking and dry and wet wiping with a sponge (Fig. 7).

Fig. 7 Experimental setup for the investigation of particulate matter in chalk. The measuring board is snapped onto the lower edge of the panel.

In the software, open the menu Stations → Station 4 - Chalk dust and check the particulate matter exposure during writing with chalk and subsequent wiping. The exact measurement procedure is explained in the software.

Based on your measurements, record the maximum values of the particulate matter emission for all experimental conditions in the table below.

Station 4
Particulate Matter

	Chalk 1		Chalk 2	
	PM_{10} in µg/m³	$PM_{2.5}$ in µg/m³	PM_{10} in µg/m³	$PM_{2.5}$ In µg/m³
Write on black-board				
Dry wiping				
Write again on blackboard				
Wet wiping				

Assess the measurement results with regard to the annual mean limit value in outdoor air of 40 µg/m³. Go on to address the following in particular:

Differences between writing - dry wiping - wet wiping.
Differences in the types of chalk
Differences in the load of $PM_{2.5}$ and PM_{10}

Station 4
Particulate Matter

Check the following statement:

A piece of chalk crumbles completely into particulate matter in the course of a lesson due to writing and wiping.

To do this, estimate the expected concentration of particulate matter for a uniform distribution of 1 g of chalk as dust in a classroom (V = 200 m3). Compare this value with the measurements directly in front of the black-board.