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UAV-Based Monitoring and AFM Analysis of Airborne Pollutants

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SECTION

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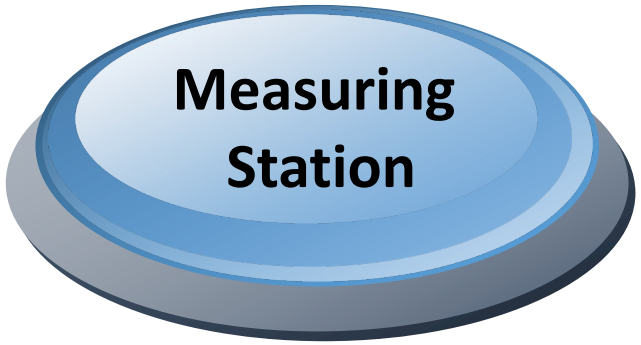
ABSTRACT & KEYWORDS

- A drone-based platform was developed at the Moldova State University (MSU) in the research laboratory Environmental Physics and Modeling Complex Systems (ePhysMCS Lab) for the observation and air analysis for pollution, chemical and radiological contaminations. Software application was used in connection with UAV-based measuring station for computational modeling of environmental factors, which facilitates the analysis and interpretation of the monitoring results. Results on pollutants detection, real-time data recording, and Atomic Force Microscopy (AFM) samples analysis for particulate matter are provided in this article.

- *Keywords* – Environmental monitoring, PM-pollution, Unmanned Aerial Vehicle (UAV), Atomic Force Microscopy (AFM)

AIR CONTENT ANALYSIS SYSTEM SOWA

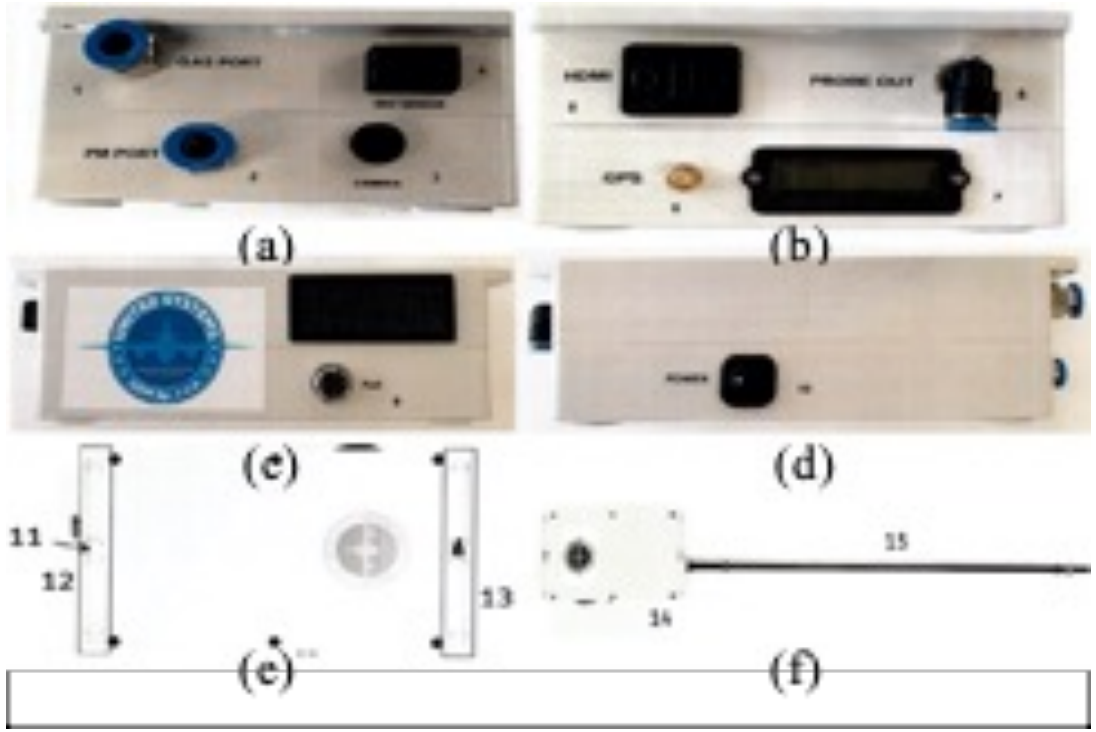


Functionality:
PM, Organic compounds, Formaldehyde, Hydrogen chloride,
Hydrogen cyanide detection;
Humidity range:
from 0 to 100 % RH;
Pressure range: from 300 to 1100 hPa.

Physical characteristics:
Dimensions: 220x150x80 mm;
Weight: 1100 g;
Power supply:
battery Lithium-ion
up to 3 hours;
Power supply charging: 9-29 V, drone supplied, PoE 802.3af; Connectors.

DESCRIPTION OF DEVICE ELEMENTS

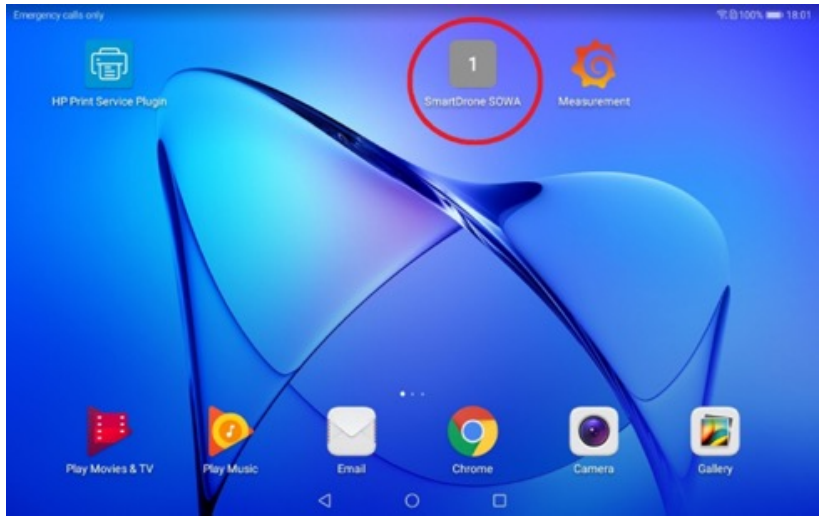
Air content analysis system is a mobile air laboratory, which allows reading air content directly from the source, and it is equipped with a built-in HD camera transmitting the image with the measured parameters to the station operator.



Front (a), rear (b), left side (c),
and right side (d) of the measuring station,
and its components,
(e) and (f).

1. Gas intake;
2. Dust intake;
3. Built-in HD video camera;
4. Temperature, humidity and pressure sensors;
5. HDMI video output;
6. GPS antenna connector;
7. Battery charge indicator;
8. Air outlet from measuring chamber;
9. Power socket/LAN (PoE);
10. Power switch;
11. Place where the screw is attached to the handle;
12. Front grip fixing strip;
13. Rear grip fixing strip;
14. Measuring laboratory;
15. Measuring probes.

PERFORMING MEASUREMENTS

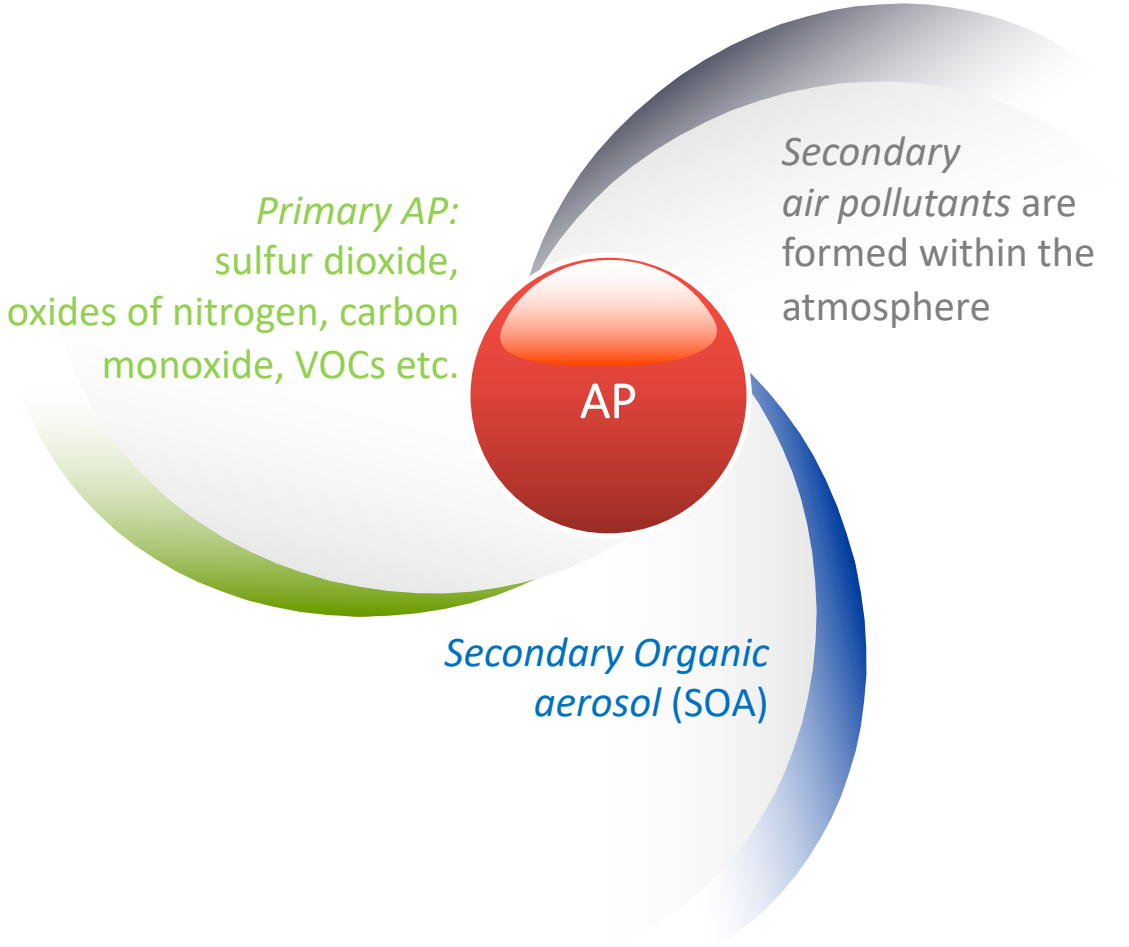


Web browser on the tablet screen.

System login screen view.

Charts with historical data view.

AIR POLLUTANTS (AP): GASEOUS & PARTICULATE

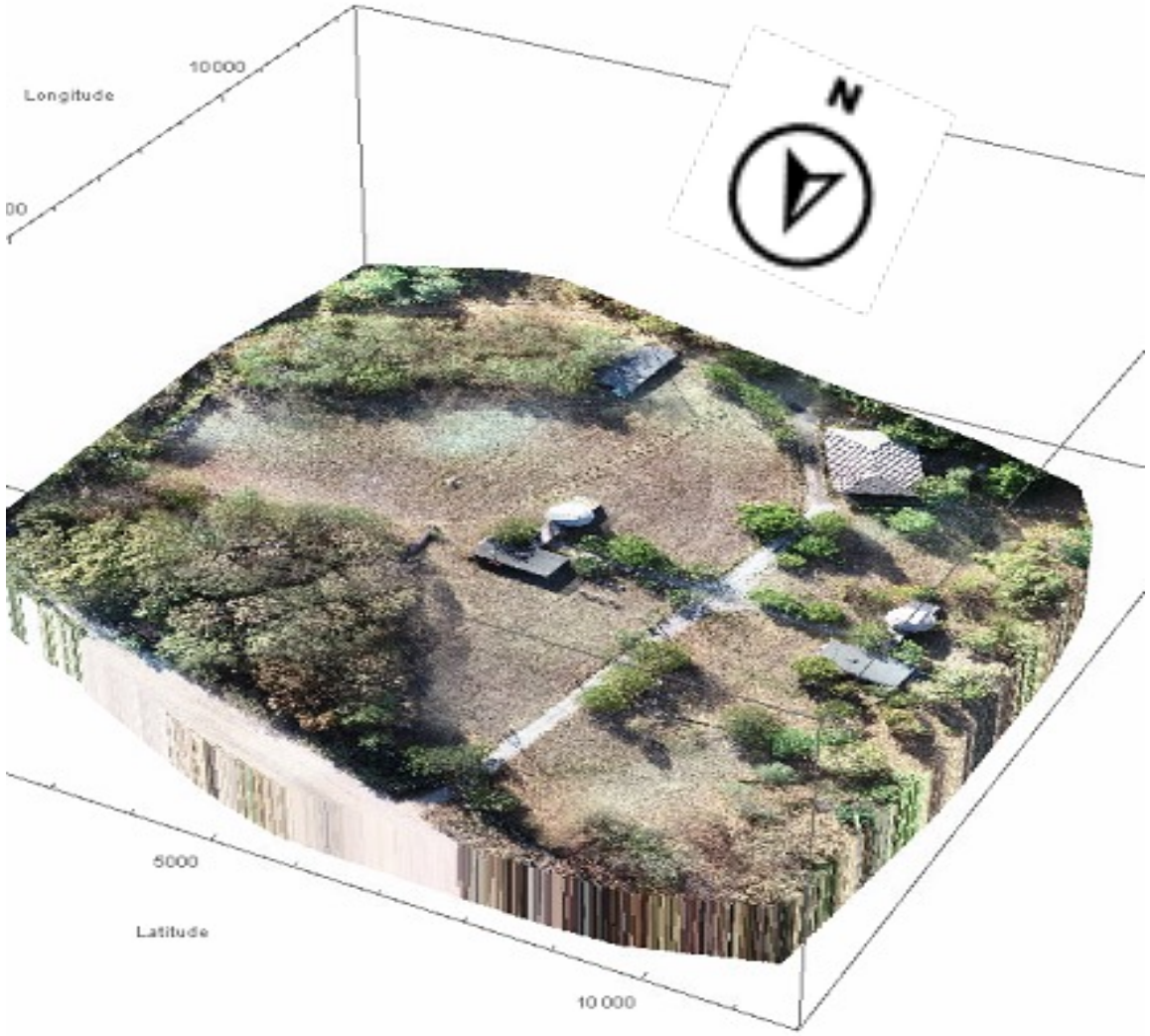


FIELD-MONITORING FLIGHT ON SEPT 17, 2020

DIGITAL 3D MAPPING OF EXPERIMENTAL TERRAIN

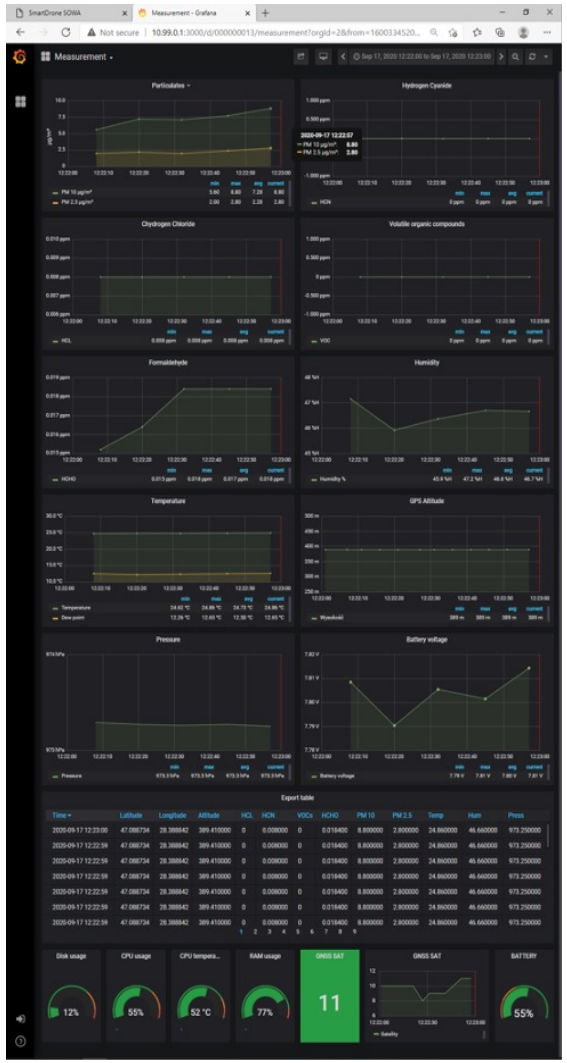
Measurements are performed at the MSU laboratory “Environmental Metrology and Astronomy” near Lozova village in Straseni district with geographical coordinates of (47.09, 28.39).

Figure shows 3D mapping of the corresponding terrain of 3 ha ($3 \cdot 10^4$ m^2) on September 17th, 2020 by Pix4Dmapper's photogrammetry, which algorithms transform ground and aerial drone images in a digital map and 3D model. The site is one of the highest in this region of the forestry in Codru natural reservation.



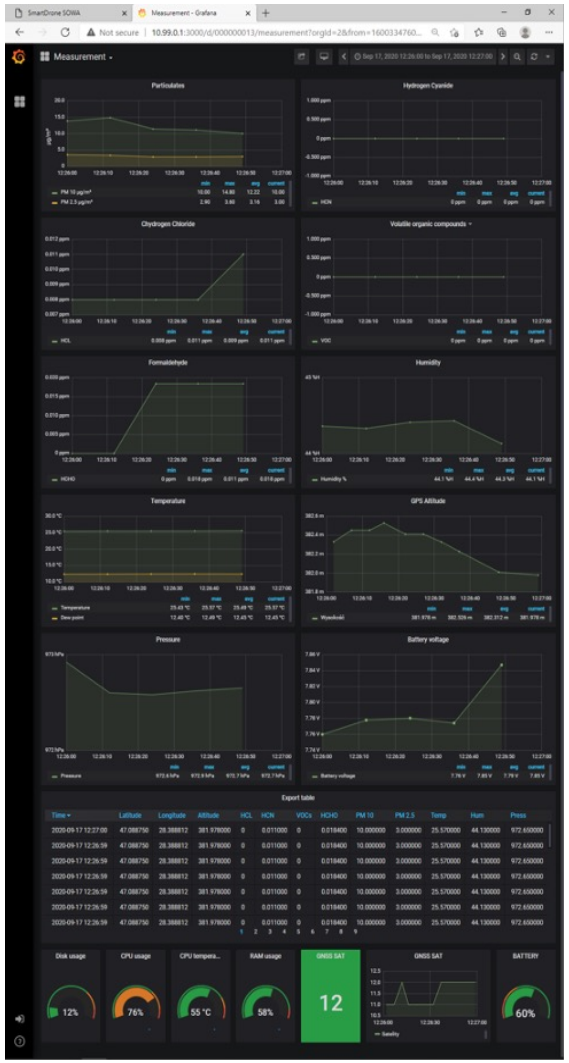
CHARTS WITH RAW DATA, ONE SITE, ALTITUDES 0, 5, 10 M

h=0 m

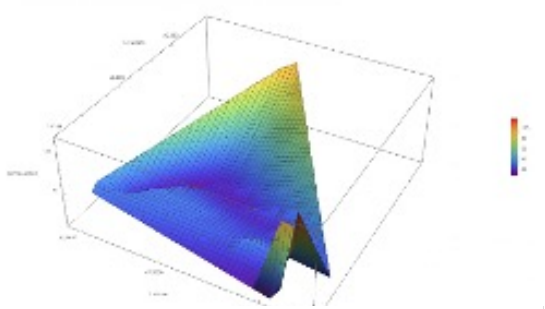


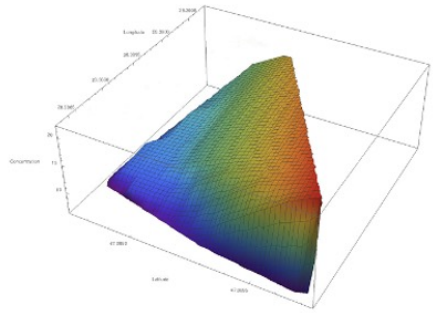
h=5 m

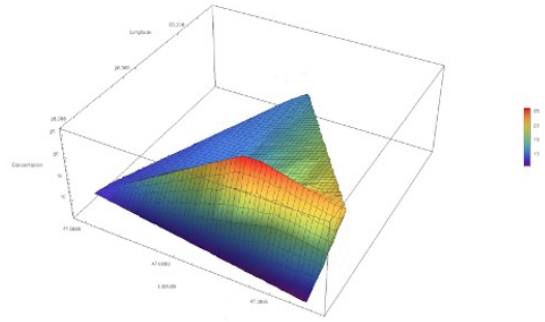
h=10 m



CONCENTRATIONS OF AIR POLLUTION WITH SOLID MICROPARTICLES PM10







- Measurements are carried out at three different altitudes of

  0 m, 5 m, 10 m

  for the given

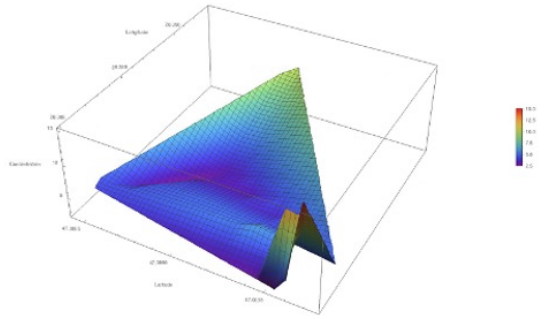
  3 altitudes x 9 sites =

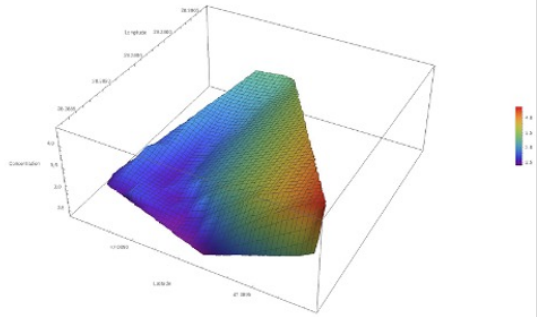
  27 coordinates in space.

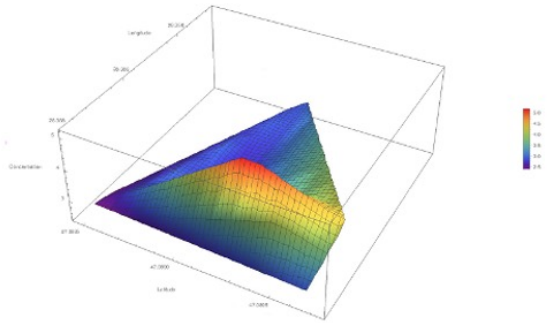
- Concentration:

  0 to 25 µg/m^3 at altitudes of 5 m and 10 m from the ground level, and from 0 to 120 µg/m^3 at ground level.

CONCENTRATIONS OF AIR POLLUTION WITH SOLID MICROPARTICLES PM2.5







- Measurements are carried out at three different altitudes of

  0 m, 5 m, 10 m

  for the given

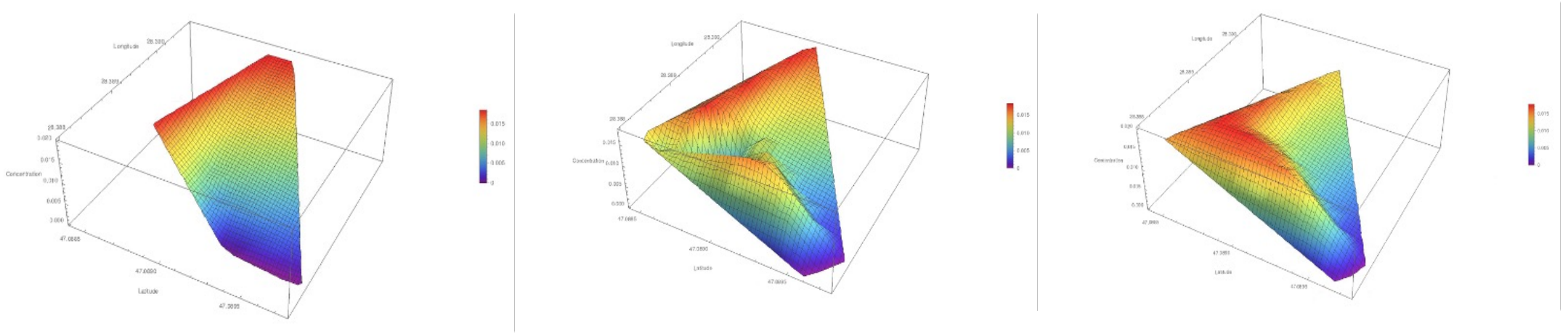
  3 altitudes x 9 sites =

  27 coordinates in space.

- Concentration:

  0 to 5 µg/m^3 at altitudes of 5 m and 10 m from the ground level, and from 0 to 15 µg/m^3 at ground level.

CONCENTRATIONS OF HCHO



- Measurements are carried out at three different altitudes of 0 m, 5 m, 10 m for the given 3 altitudes x 9 sites = 27 coordinates in space.

- Concentration: 0 to 23 µg/m^3.

The presence of air pollution sources, such as adjacent highway and road, as well as dust pollution level of ground surface at the measurement spots and trees at altitudes of over 5 m, is clearly highlighted in all figures.

OTHER EXPERIMENTAL RESULTS AND DISCUSSION

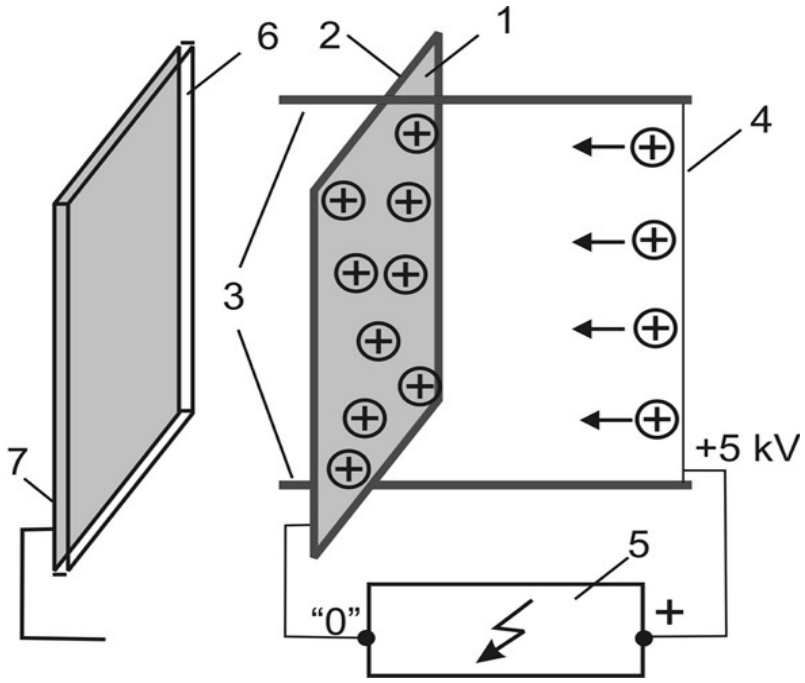
Data view during outdoor measurement & combustion experiment

PM_{10}=36.0 µg/m^3
$PM_{2.5}$=16.6 µg/m^3
Hydrogen Cyanide=0 ppm
Hydrogen Chloride=0 ppm
VOCs=0 ppm
Formaldehyde=0.0236 ppm

PM_{10}=1307.3 µg/m^3
$PM_{2.5}$=582.1 µg/m^3
Hydrogen Cyanide=0.004 ppm
Hydrogen Chloride=0 ppm
VOCs=0 ppm
Formaldehyde=0.2140 ppm

WHO Air Quality Guidelines for 24-hour means of *Particulate Matter* (PM):
PM_{10}=50.0 µg/m^3
$PM_{2.5}$=25.0 µg/m^3

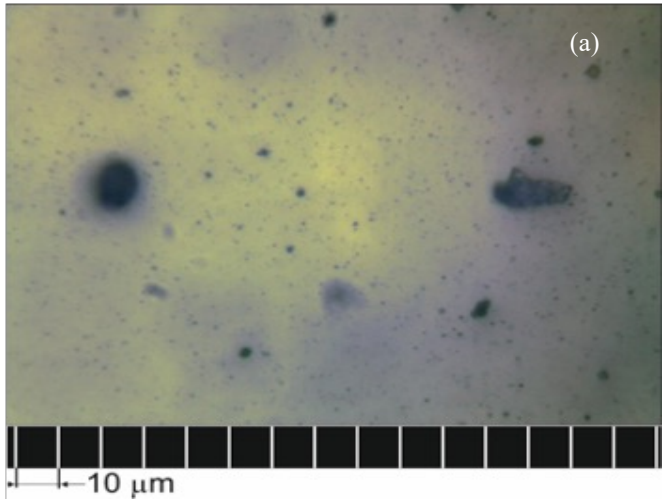
SCHEMATIC REPRESENTATION OF THE AIRBORNE POLLUTANTS COLLECTION DEVICE

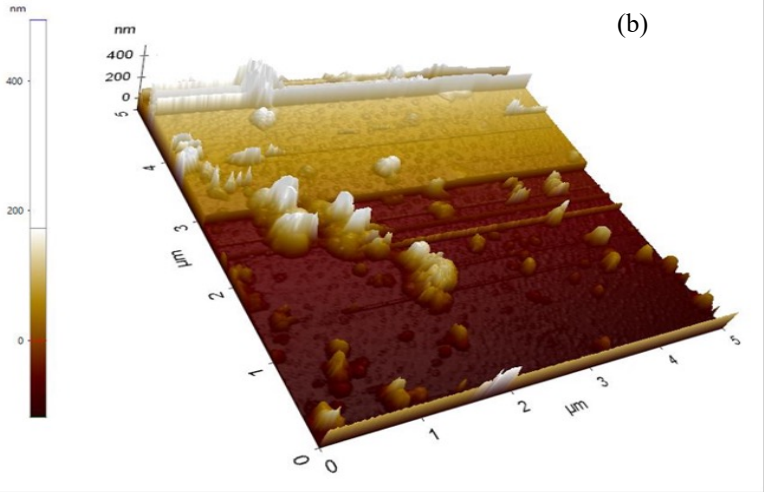


A silicon monocrystalline wafer (1) 20x20 mm in size is installed in a dielectric frame (2). A tungsten filament (4), 30 μm in diameter, is mounted on dielectric holders (3) at a distance of 10 mm from the surface of the silicon wafer (1). When the high voltage source (5) is turned on, a positive potential of +5 kV is applied to the tungsten filament (4). The "0" electrode of the high voltage source (5) is connected to the reverse side of the silicon wafer (1). Solid particles in the air are positively charged and, under the action of an electrostatic field between the tungsten filament (4) and the silicon wafer (1), are collected on the surface of the silicon monocrystalline wafer (1).

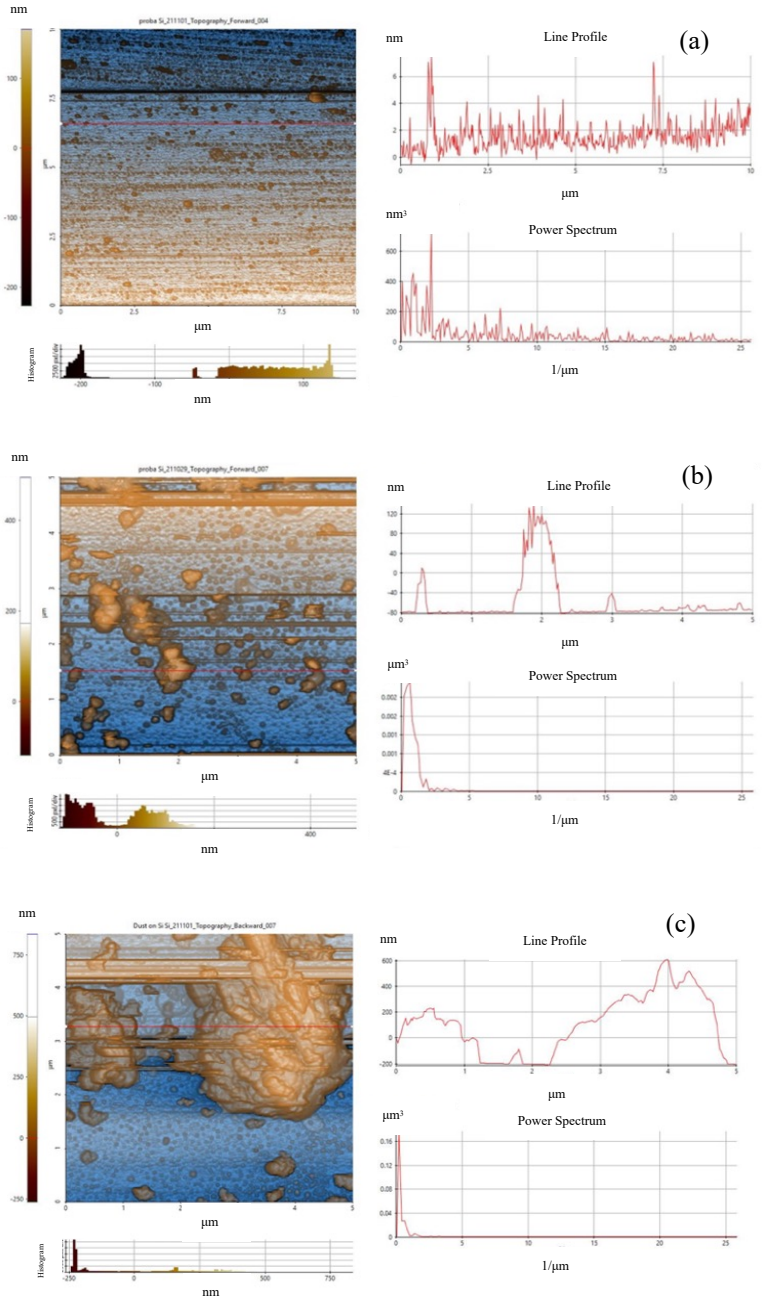
Solid particles collected in such a way on the surface of the silicon monocrystalline wafer (1) can be examined by means of optical microscopy, atomic force microscopy (AFM), and energy dispersive X-ray spectroscopy surveys (EDAX)

IMAGES FROM OPTICAL MICROSCOPE AND AFM



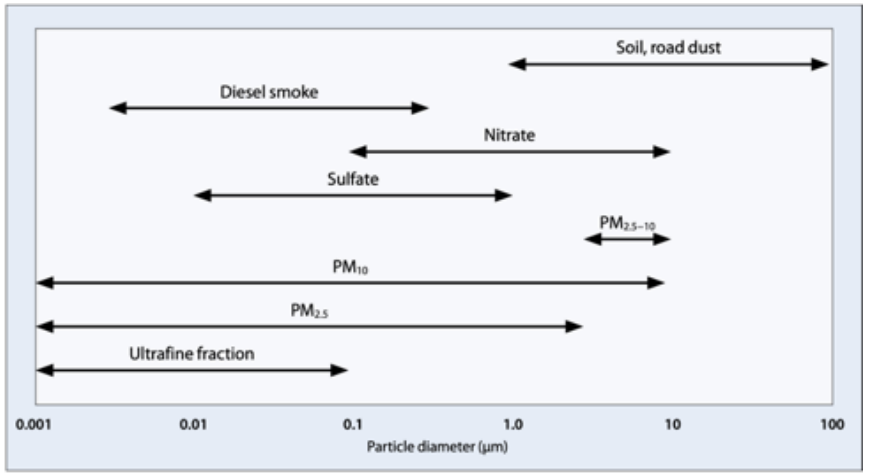


Three-dimensional topographic AFM images for clean flat silicon surface (a), and for two different regions on silicon substrate, (b, c)



PM-POLLUTION

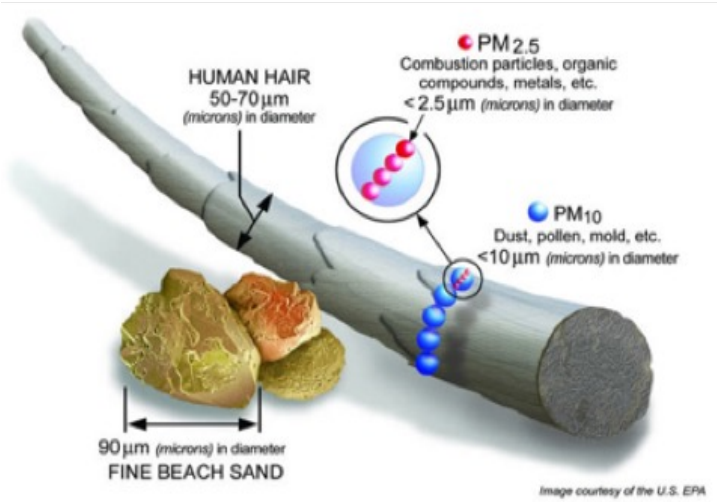
Schematic representation of airborne particles and their size range



Air quality category	PM_{10} μg/m³ averaged over 1 hour
Good	Less than 40
Moderate	40–80
Poor	80–120
Very poor	120–240
Hazardous	More than 240

Secondary air pollutants are formed from chemical reactions of primary pollutants involving the natural atmosphere components:

$NO + O_3 \rightarrow NO_2$ (nitrogen dioxide) + O_2;
$NO_2 + h\upsilon\ (\lambda \leq 430\ nm) \rightarrow NO + O$;
$O + O_2 \rightarrow O_3$;
$NO + RO_2$ (alkyl peroxide) $\rightarrow NO_2 + RO$;
$HNO_3 + NH_3$ (ammonia) $\leftrightarrow NH_4NO_3$



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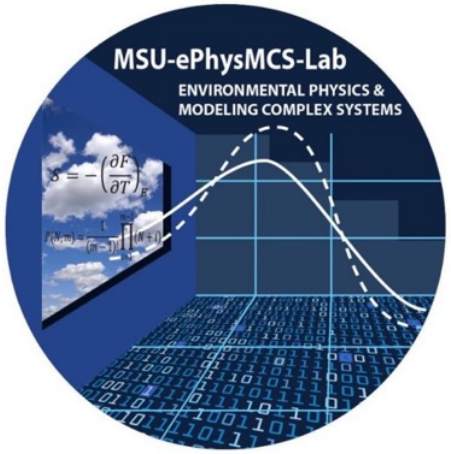

Thank You!

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