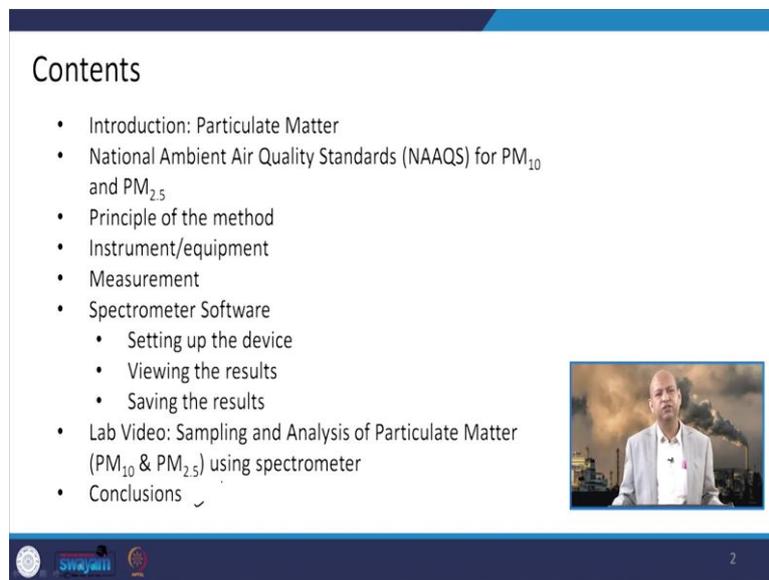


**Air Pollution and Control**  
**Professor Bhola Ram Gurjar**  
**Department of Civil Engineering**  
**Indian Institute of Technology, Roorkee**  
**Lecture 60**

**Sampling and Analysing of Particulate Matter (PM<sub>10</sub> & PM<sub>2.5</sub>) using Spectrometer**

Hello friends, you may recall we discussed about gravimetric methodology to do the sampling or monitoring of like PM<sub>10</sub> and PM<sub>2.5</sub> using the high-volume sampler, we can also do sampling and analysis of particulate matter especially PM<sub>10</sub>, PM<sub>2.5</sub> even less than PM<sub>2.5</sub> like PM<sub>1</sub> using spectrometer-based instruments basically. So, this methodology today we will discuss and this is the last lecture of this particular course.

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**Contents**

- Introduction: Particulate Matter
- National Ambient Air Quality Standards (NAAQS) for PM<sub>10</sub> and PM<sub>2.5</sub>
- Principle of the method
- Instrument/equipment
- Measurement
- Spectrometer Software
  - Setting up the device
  - Viewing the results
  - Saving the results
- Lab Video: Sampling and Analysis of Particulate Matter (PM<sub>10</sub> & PM<sub>2.5</sub>) using spectrometer
- Conclusions ✓



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So, first of all, we will discuss briefly about the introduction, why particulate matter are so important, the National Ambient Air Quality Standards for PM<sub>10</sub> and PM<sub>2.5</sub>, what is the principle of the method of a spectrometer and which kind of equipments are used and how measurements are carried out. Then, the software which is used for this purpose, so how it is used and how does it help in analysis of the data, then the lab-based video we will screen and we will conclude.

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Discussed in Sources and Classification of Air Pollutants

## Primary air pollutant: Particulate Matter

**Particulate Matter (PM)** is a mixture of solid, liquid or both the particles suspended in the air.

Aerodynamic Diameter Scale

Source: (Muhlheid, 2008)



**PARTICULATE MATTER**



So, as this primary air pollutant particulate matter is very important because of its effect on the environment as well as on the health and these fine particles they can go to the respiratory system and they can cause several kinds of health issues basically. So, ultra-fine particles are also very important like  $PM_{10}$  and less and they can also be measured but in this presentation we will discuss about only  $PM_{10}$  and  $PM_{2.5}$ . But using the spectrometer I repeat that even  $PM_1$  and less than  $PM_1$  can be measured basically.

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## National Ambient Air Quality Standards (NAAQS)

Pollutant	Time Weighted Average	Concentration in Ambient Air	
		Industrial, Residential, Rural and other Areas	Ecologically Sensitive Area (Notified by Central Government)
Particulate Matter, $PM_{10}$ , $\mu\text{g}/\text{m}^3$	Annual *	60 ✓	60 ✓
	24 Hours **	100 ✓	100 ✓
Particulate Matter, $PM_{2.5}$ , $\mu\text{g}/\text{m}^3$	Annual *	40 ✓	40 ✓
	24 Hours **	60 ✓	60 ✓

The national ambient air quality standards for Particulate Matter  $PM_{10}$  and  $PM_{2.5}$

Source: Guidelines for measurement of of ambient air pollutants, CPCB, 2013



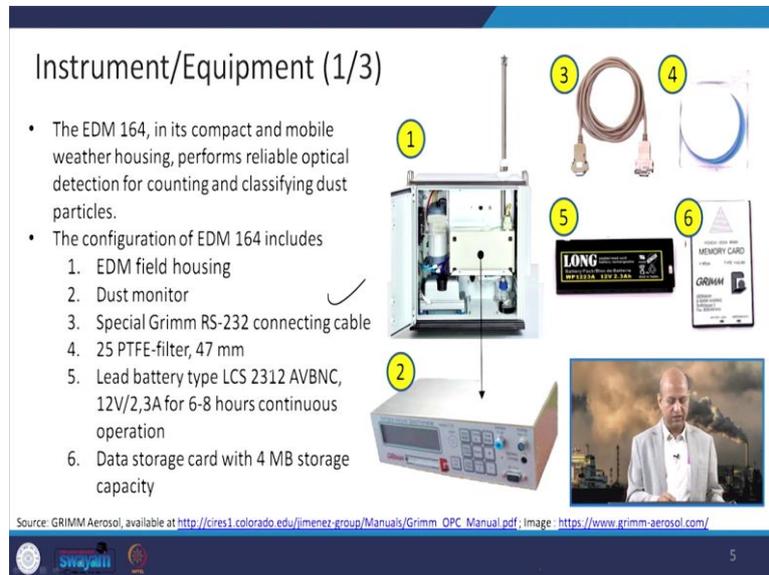
So, this  $PM_{10}$  and  $PM_{2.5}$  air quality standards, National Ambient Air Quality Standards are there like annual 24 hours. So, for those like industrial residential areas or ecologically sensitive areas values are same, like annual concentration of  $PM_{10}$  is 60 in both cases, 24 hours

concentration is 100 in both cases. Similarly, for PM<sub>2.5</sub> annual concentration is 40. So, this should not exceed if we go on getting exposed throughout year and 60 is the 24-hour maximum concentration it should not violate or it should not exceed at a particular location for PM<sub>2.5</sub>.

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### Instrument/Equipment (1/3)

- The EDM 164, in its compact and mobile weather housing, performs reliable optical detection for counting and classifying dust particles.
- The configuration of EDM 164 includes
  1. EDM field housing
  2. Dust monitor
  3. Special Grimm RS-232 connecting cable
  4. 25 PTFE-filter, 47 mm
  5. Lead battery type LCS 2312 AVBNC, 12V/2,3A for 6-8 hours continuous operation
  6. Data storage card with 4 MB storage capacity



Source: GRIMM Aerosol, available at [http://cires1.colorado.edu/jimenez-group/Manuals/Grimm\\_OPC\\_Manual.pdf](http://cires1.colorado.edu/jimenez-group/Manuals/Grimm_OPC_Manual.pdf); Image: <https://www.grimm-aerosol.com/>

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If we talk about the spectrometer based instrument, so basically we have used this GRIMM instrument which houses many these parts or components like EDM, this field housing where the instrument can be put in, then this is the dust monitor, which monitor the particulate matter and you can see like there is a connecting cable and then there is a filter paper with a small size which is put into this instrument and data storage that memory card is there and this is the battery which is used if there is no current available, power available there.

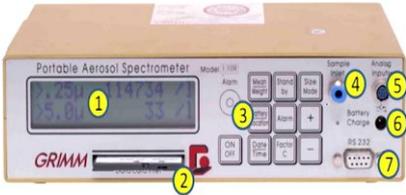
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### Instrument/Equipment (2/3)

➤ Different control elements of the dust monitor

**Front panel**

1. LCD- display
2. Slot for data storage card
3. Keypad
4. Sample inlet
5. Analog input
6. Connection for mains adapter
7. RS-232 interface port



Source: GRIMM Aerosol, available at <http://cires1.colorado.edu/jimenez-group/Manuals/Grimm OPC Manual.pdf>.

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Then if we look into dust monitor, so the front panel houses this LCD panel as well as the keypad here, then this is the slot for data storage that particular card, then sample inlet is there at four number where air inflows and analogue input 5 number, 6 is connecting with the main adapter. And then interface port is the 7 number which can be used for connecting with the like desktop computer.

(Refer Slide Time: 03:55)

### Instrument/Equipment (3/3)

➤ Different control elements of your dust monitor

**Back panel**

8. Filter chamber with bayonet lock
9. Poly Tetra Fluoro Ethylene (PTFE)- filter, 47 mm
10. Warning notice for laser
11. Calibration label
12. Device designation and serial number
13. Sample outlet with end cap
14. Locking feature for battery case (lateral) and lead storage battery



Source: GRIMM Aerosol, available at <http://cires1.colorado.edu/jimenez-group/Manuals/Grimm OPC Manual.pdf>.

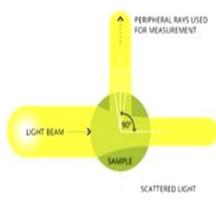
7

Back panel has a space for this putting filter paper and then there are different like for cable and other outlet is also there. So, all these parts are on the backside of the instrument.

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### Principle of the method (1/2)

- The measuring principle of the model is the light scattering of single particles with a semiconductor laser as light source.
- Inside the measuring chamber, the scattering light is being led directly and via mirror with a wide opening angle onto the detector.
- The detector is positioned in the right angle to the incident laser beam.
- This setup of the detector is denominated as 90° scattering light detection.



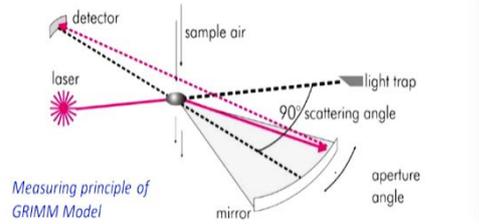
The diagram shows a yellow laser beam entering from the left, hitting a central 'SAMPLE' point. A 90-degree angle is marked between the incident beam and the scattered light. The scattered light is shown as a vertical yellow beam pointing upwards, labeled 'PERIPHERAL RAYS USED FOR MEASUREMENT'. Below the diagram is a small video inset of a man speaking.

Source: GRIMM Aerosol, available at <http://cires1.colorado.edu/jimenez-group/Manuals/Grimm OPC Manual.pdf>; Image: Zakaria et al, 2018

And the basic principle is which is used for this spectrometer they use the light scattering by the single particle. So, each particle that is why this instrument gives not only the mass concentration, but count also, count means number of the particles. So, count is also available in this particular spectrometer. So, this is the way light scattering is there and the light scattering is detected by some method which we can discuss here, detector is there.

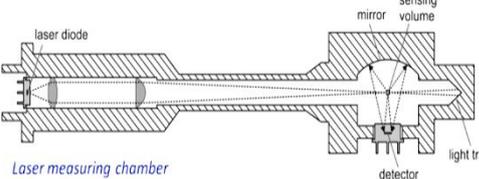
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### Principle of the method (2/2)



The diagram shows a laser beam (red) entering from the left, hitting a 'sample air' region. A 'mirror' is positioned below the sample air, reflecting the light. A 'light trap' is positioned to the right, capturing the light. The scattering angle is marked as 90°. A 'detector' is positioned to the left, receiving the light. The 'aperture angle' is also indicated.

- The scattering light emitted by every particle is being detected by a second optics under a scattering angle of 90° and then directed onto a receiver diode via a wide-angle mirror.



The diagram shows a cross-section of the 'Laser measuring chamber'. It includes a 'laser diode' on the left, a 'sensing volume' in the center, a 'mirror' and 'light trap' on the right, and a 'detector' at the bottom.

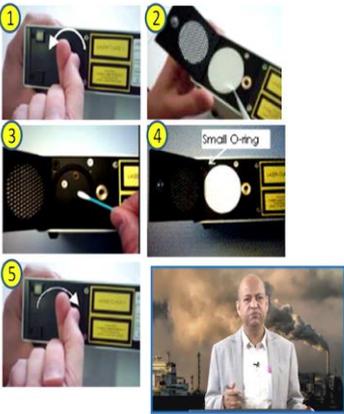
Source: GRIMM Aerosol manual

So, at the 90 degree the laser past so, when it strikes with the particle it scatters the light and then through mirror it is reflected and detector detects it and then that is monitored or that is stored accordingly the number of particles and then the mass concentration can also be monitored.

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### Measurement (1/3): PTFE Filter changing

1. Open the filter chamber door. Remove the old filter with tweezers from the filter holder assembly.
2. Using a cotton swab clean the inner walls of the filter housing.
3. Weigh and record the weight of the new filter, for improved accuracy, weigh the filter three times and take average.
4. Place the new filter into the filter housing ensuring that overlaps the O-ring and four points are visible around the filter.
5. Carefully close the filter door and tighten the screw.



Source: GRIMM Aerosol, available at <http://cires1.colorado.edu/jimenez-group/Manuals/Grimm OPC Manual.pdf>.

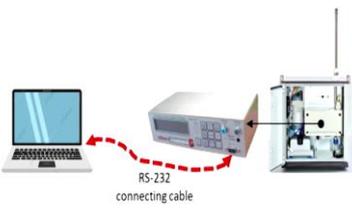
10

When we do the monitoring. So, basically the filter paper we should particularly be careful about how to put it so remove using these tweezers the old one and then clean it very properly and then put a new filter paper and it has to be weighed also 3 times so, that because it is small, so the average weight is taken after weighing it for 3 times and then monitoring is to be done.

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### Measurement (2/3): Connecting spectrometer

- The data can be displayed as particle concentration in the unit **particle/liter (count)** and also as mass concentration in the unit  $\mu\text{g}/\text{m}^3$
- After installing the spectrometer software in system, place the spectrometer in the field housing as shown in figure.
- Connect the spectrometer with the system using the special RS-232 connecting cable.

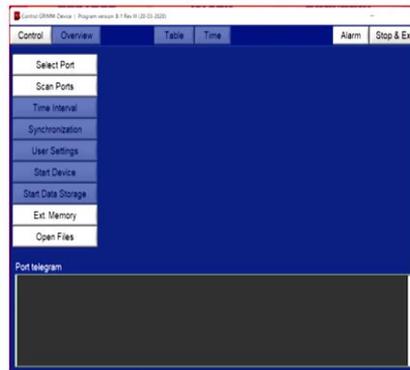


Source: GRIMM Aerosol, available at <http://cires1.colorado.edu/jimenez-group/Manuals/Grimm OPC Manual.pdf>.

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## Measurement (3/3): Monitoring the results in software

- The user interface of the spectrometer software



Source: GRIMM Aerosol, available at <http://cires1.colorado.edu/jimenez-group/Manuals/GRIMM OPC Manual.pdf>.



When data is taken into the desktop and data as I said, it can be like particle per litre count means how many particles are there in per litre, or microgram per cubic metre, the mass concentration can also be there. So, this is the way data is transferred to the laptop or desktop and the software is there its own software is there which gives us different buttons like we can select the port, the time interval, all those things can be set to start the monitoring.

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### Spectrometer Software: Initializing the device

Please press **Scan Ports** to detect the connected devices and to check for valid license files

If not detected you select the ports manually.

Source: GRIMM Aerosol, available at <http://cires1.colorado.edu/jimenez-group/Manuals/GRIMM OPC Manual.pdf>.

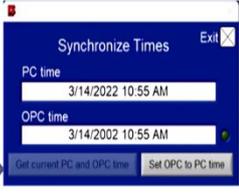


So, you can see here the scan ports are selected, then it can automatically take which particular port it is using otherwise manually we can give the name of this particular port and this is the device which can give the display of this particular port related information.

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### Spectrometer Software: Time interval

- Next step is to **select the time interval**. The minimum time interval is 6 seconds and maximum is 60 minutes (1 hour).
- There is need to **synchronize the device-time** with the PC-time every 3 months or when there is change in the time zone.



Source: GRIMM Aerosol, available at <http://cires1.colorado.edu/imenez-group/Manuals/Grimm OPC Manual.pdf>.

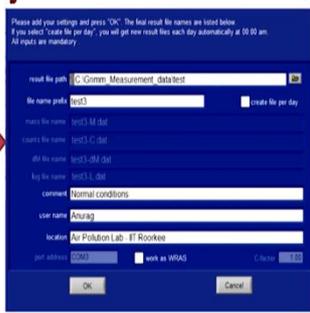
14

Then time interval can be set like from 6 seconds to 1-hour huge range is there. So, depending upon the necessity, we can select how much at the what time interval we need data to be stored like 5 minutes each or each 10 minutes or something like that. So, there is one need of synchronise of the device time with the PC time so that there is no error of the time recording. So, every 3 months they should be basically synchronised otherwise, if a site is changing, time zone is changing particularly in time zone then you can synchronise it more frequently.

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### Spectrometer Software: User setting

- All **user settings** and some additional information about the used device and program version are stored in the header section of each result file.
- These files are ASCII files (spreadsheet format) and can be opened after the measurement with this Spectrometer software, with Excel, or a simple text editor.



Source: GRIMM Aerosol, available at <http://cires1.colorado.edu/imenez-group/Manuals/Grimm OPC Manual.pdf>.

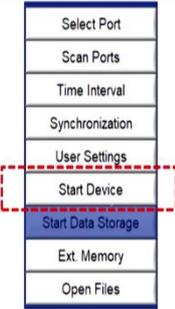
15

Then if we took into this user settings, you can see how this is taken all these parameters and headers are there and spreadsheet files are created basically like Excel etc. So, that data analysis is very easy.

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### Spectrometer Software: Starting measurement

- After completing the settings, all buttons of the control window should be activated.
- Start Data Storage will only be active after **starting the measurement** by clicking on **Start Device**.
- To enable the data logging, please press Start Data Storage



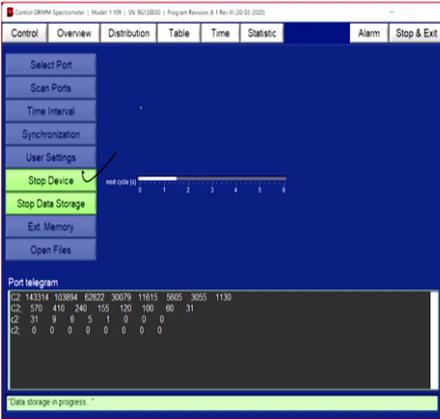
Source: GRIMM Aerosol, available at <http://cires1.colorado.edu/jimenez-group/Manuals/Grimm OPC Manual.pdf>.

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Now, this is the button when we start monitoring. So, the start device button is to be clicked and then this instrument starts functioning and recording the data.

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### Spectrometer Software: Measurements visualization



- The picture shows a measurement in 6 second time interval.



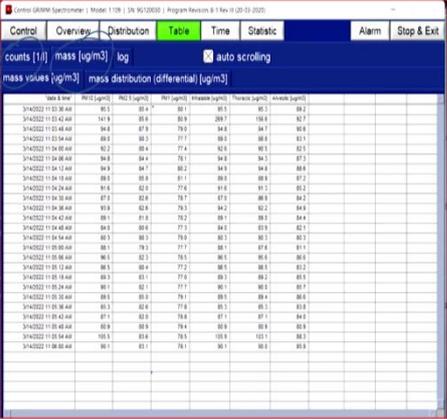
Source: GRIMM Aerosol, available at <http://cires1.colorado.edu/jimenez-group/Manuals/Grimm OPC Manual.pdf>.

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Well after that when monitoring is complete, then a stop device button can be pressed and data is stored and then data can be taken whatever time interval we have selected and it can be transferred to the PC.

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### Spectrometer Software: Viewing the results (tabular form)



- The software displays all measured data according to the set time interval in real-time.
- Unit shown are count per litres or  $\mu\text{g}/\text{m}^3$

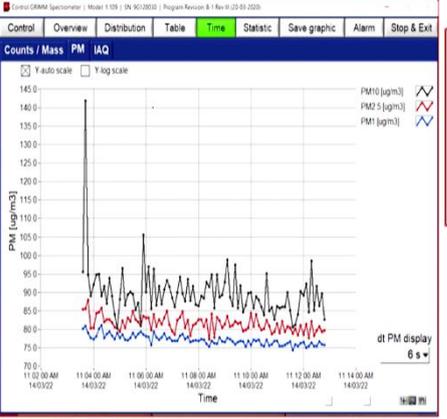
Source: GRIMM Aerosol, available at <http://cires1.colorado.edu/jimenez-group/Manuals/Grimm OPC Manual.pdf>.

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So, this is the way data is collected basically different columns are there and then whether it is count or whether it is mass distribution concentration, we can select according to the requirement.

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### Spectrometer Software: Viewing the results (graphical form)



- The graph can also be obtained in the Time tab for different particle size.
- The graph shows the concentrations of ( $\text{PM}_{10}$ ,  $\text{PM}_{2.5}$ ) vs time.

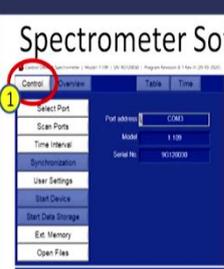
Source: GRIMM Aerosol, available at <http://cires1.colorado.edu/jimenez-group/Manuals/Grimm OPC Manual.pdf>.

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We can analyse the data at per like time interval like particulate matter and mass concentration or count. So, we can analyse and see how data is varying from time to time.

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### Spectrometer Software: Save or open measured data



1. In the main window "Control", you can access the button Memory Card after scanning the ports for a connected spectrometer.
2. Clicking on the button Memory Card opens a dialog where you can read the data.
3. You now have to press "Convert data to spreadsheet format" and choose the path for saving the file.



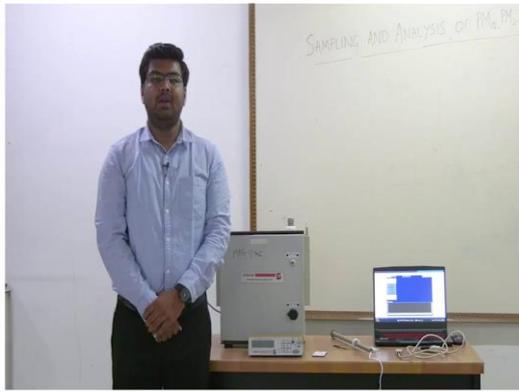
Source: GRIMM Aerosol, available at <http://ccres1.colorado.edu/jimenez-group/Manuals/Grimm OPC Manual.pdf>;

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So, these are the software of the spectrometer, which we are using. So, control software is there which can give different kinds of possibilities and as per the site where we have monitored data is transferred to the particular file and then it is analysed later on.

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### Video: Sampling and Analysis of Particulate Matter (PM<sub>10</sub> & PM<sub>2.5</sub>) using Spectrometer



Here, we present a short video illustrating the Sampling and Analysis of Particulate Matter (PM<sub>10</sub> & PM<sub>2.5</sub>) using Spectrometer

*This video is recorded in Air Pollution Lab at Civil Engineering Department, IIT Roorkee.*



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So, here we present the short video illustrating the sampling and analysis of particulate matter especially PM<sub>10</sub> and PM<sub>2.5</sub> using a spectrometer. So, now you can compare the high-volume sampler and a spectrometer, how do they function, what is their difference in the procedures and whether one is robust or second is robust, and the possibilities the range like it can also give PM<sub>1</sub> etc and this video has been recorded in air pollution laboratory of Civil Engineering

Department in IIT Roorkee. So, enjoy the video and learn about the  $PM_{10}$  and  $PM_{2.5}$  monitoring using spectrometer.

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Narrator: Good afternoon everyone. And I welcome you all in this lab-based series of this lecture for NPTEL. And this is the last lecture in the lab base measurements. And today we will be discussing on the sampling analysis of  $PM_{10}$ ,  $PM_{2.5}$ ,  $PM_1$  using the GRIMM model.

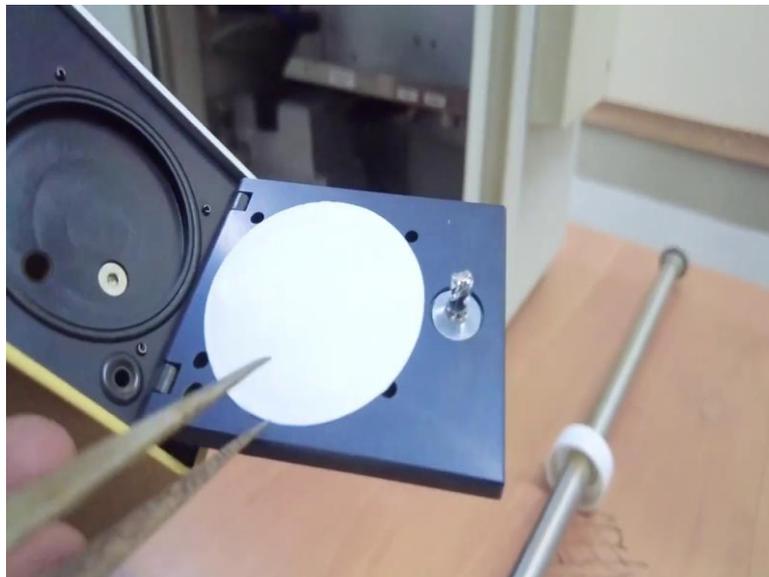
And for that we will be using this apparatus that is the GRIMM EDM, EDM 164 that is Environmental Dust Monitor and in that it is the field housing and this is the spectrometer and this is the memory card which has been inserted in the spectrometer. So, let me just give you a quick intro of this, the parts of this field housing and the spectrometer so as you can see this field housing here we are placing the spectrometer right now.

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So, this is the spectrometer and this is the front panel of the spectrometer, here you can see this LCD screen where we are seeing the readings of all the PM<sub>10</sub> PM<sub>2.5</sub> all the particles and these are the control buttons, where we are using these buttons we are controlling this spectrometer and this is the sample inlet. So, in this sample inlet this sampling pipe is being fitted in this spectrometer and this spectrometer is being placed in this field housing.

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Let me just give you the intro of this back panel, in back panel you can see that lock is there, if you open this lock there is a PTFE filter. So, this PTFE filter this let me tell you this spectrometer or EDM 164 can monitor or sample the  $PM_{10}$ ,  $PM_{2.5}$  using the two modes that is by the optical particle counter and by the gravimetric.

So, optical particle counter can be attained using the spectrometer and also using the gravimetric analysis you can weigh this PTFE filter and you can just analyse or sample the  $PM_{2.5}$  sample. So, after this taking the readings you can weigh this PTFE filter before the sampling and after the sampling then you can analyse the  $PM_{2.5}$  particles.

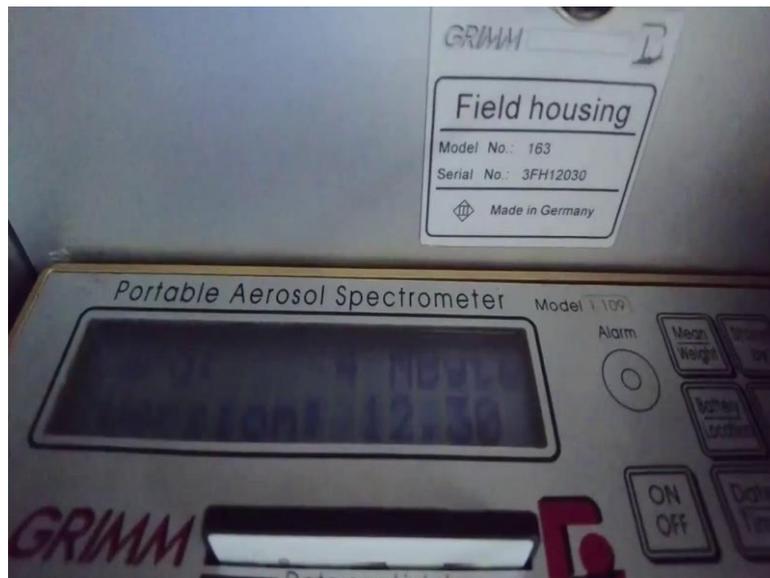
So, you can see we are placing the PTFE filter using these forceps and it is so placed that all the four points I hope you are able to see these four points this 1, 2, 3, 4 actually it is placed

this PTFE filter is placed this side, so it is so placed there like that these four points so that is 1, 2, 3, 4 these four points should be visible. So, after placing this filter we have to play close this panel. So, after this closing the panel and assembling that this PTFE filter your spectrometer is ready to be placed in the field housing.

So, let me just place this spectrophotometer and one more thing that is this spectrophotometer will be attached with the system and software is provided for monitoring the particles and this software is also provided by the GRIMM model and this system and this spectrometer is attached using this RS 232 cable.

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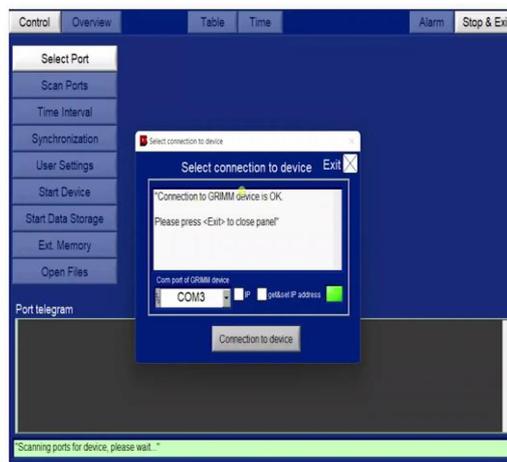
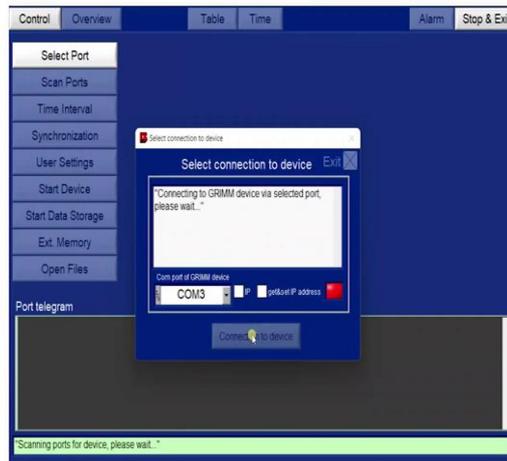
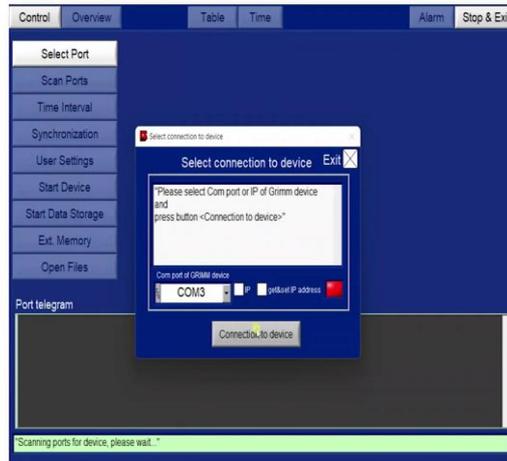
So, let me just attach all the things, so as you can see that the spectrometer is fitted in this field housing and it is connected with this system using this RS 232 cable and the field this sample pipe that is placed in this sample inlet that the port where I have shown earlier, so let me just on the system.

So, as soon as I on the system I hope you are able to see that right now if not I will just let me just tell you as you are on the system you will be seeing the model name first and then the date and time we are displayed in this LCD screen and then thereafter the available memory that how much duration you can go for measurement on analysis that is being displayed and after that it will ask you to this have you change the filter or not.

So, in response you have to just press this plus button in the spectrometer for a few seconds. So, after hearing this beep sound the spectrometer will go for self-test and the self-test is for 30 seconds and after self-test it will start measuring the particles and it will be showing the counts per litre in this spectrometer the units are in it is in counts per meter. I hope you can see right now, it has being starting, I have received a signal like self-test is okay. So, after receiving the signal of self-test is, you can see that a PM<sub>10</sub> and PM<sub>2.5</sub> these two particles are being displayed in this spectrometer.

So, now spectrometer is started now we need to configure the spectrometer according to our requirements and for that we have to go for conferring the spectrometer using the system. So, this is the software which is provided by the GRIMM. So, let me just give you the hands on how to measure or monitor the PM<sub>10</sub>, PM<sub>2.5</sub> and PM<sub>1</sub> samples using this software.

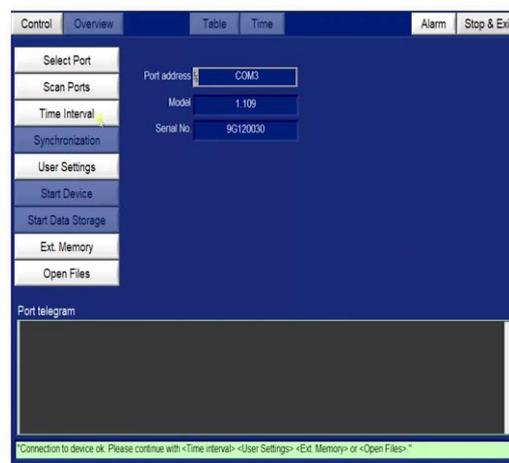
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So, this is the software provided by the GRIMM as you can see this is the UI of the software and here you can see different kinds of options are available this is, first is the control panel next is to overview so, as soon as I connect the software then it will be showing other options as well.

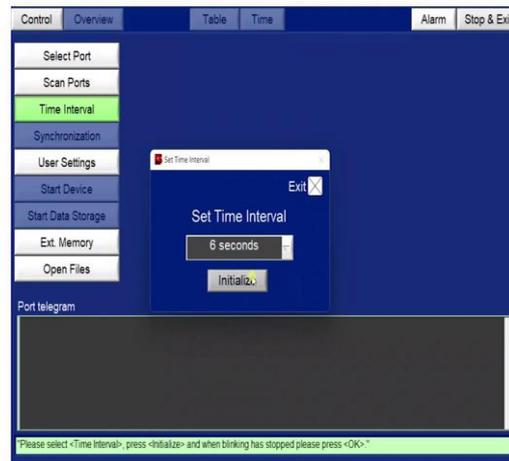
So, here you can see you have to first select the ports or you have to scan the ports, if you know already the port is there, then you can directly or manually select the port right now I am clicking on this scan port, as you can see, it is detected the COM 3 port that is the GRIMM port so the port is already selected. So, now you have to simply click on this connection to device so while connecting with this software and the code you will be hearing some sounds from the spectrometer as well. So, I have got the message that device has connected.

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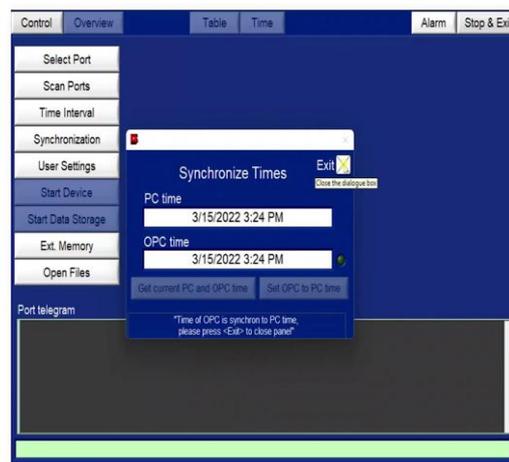
So, simply you have to click on exit now you can see it is searching for some analogue sensors and reading the data it will take a while, so the port is now selected that is COM3 and you can see the model and serial number is all the details are there.

(Refer Slide Time: 16:40)



Next step is to decide the time interval. So, as you can see, the time interval is shown is you have to set the time interval. So, the range varies from 6 seconds to 60 minutes or you can say 1 hour. So right now, I am selecting the 6 seconds and as per the requirements you can select any of the options available right now I am selecting 6 seconds and I am clicking on the initialise, that the time interval has been set, now I simply click on exit.

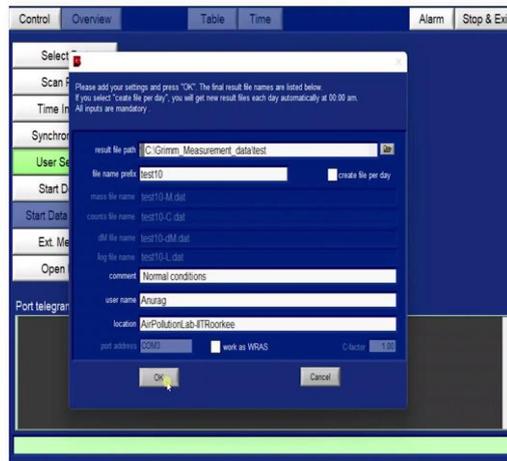
(Refer Slide Time: 17:06)



Now, you have to sync the time of this spectrometer or you can say the optical particle counter, you have to sync the time with your PC time. So, you can see that you can see the option that is to get the current PC time and OPC time is the Optical Particle Count time. So, that will sync the PC time with your Optical Particle Count OPC time. Here I have got the message time on

OPC is synchronised with your PC time. So, the date and time which were we were seeing in the spectrometer that is now synced with your PC time. Now, I am clicking on exit.

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Now, next step is the user setting. So, here we are giving the details of the output file. Right now, this is test 8, for example, I am just giving the name as test 10, so you can see all the relevant files, the mass file, the count files, the dM files and the log files all are being set up accordingly. And also, you can add the details like comments. So meanwhile, I have just set that normal conditions. And I have added the user name, as my name is Anurag and also location. So, right now, we are just taking the readings on air pollution lab at IIT Roorkee. So, I have selected that location, I will click on OK.

(Refer Slide Time: 18:18)

Control Overview Distribution Table Time Statistic Alarm Stop & Exit

Select Port  
Scan Ports  
Time Interval  
Synchronization  
User Settings  
Stop Device  
Stop Data Storage  
Ext. Memory  
Open Files

net cycle(s) 0 1 2 3 4 5 6

Port telegram

Data storage in progress. \*

Control Overview Distribution Table Time Statistic Alarm Stop & Exit

Select Port  
Scan Ports  
Time Interval  
Synchronization  
User Settings  
Stop Device  
Stop Data Storage  
Ext. Memory  
Open Files

net cycle(s) 0 1 2 3 4 5 6

Port telegram

```
P: 22 3 15 15 27 2 0 0 130 5 64 4 0 0 0 6  
K: 1102 1331 1641 10 0 52 95 0 0 0 0
```

Data storage in progress. \*

Control Overview Distribution Table Time Statistic Alarm Stop & Exit

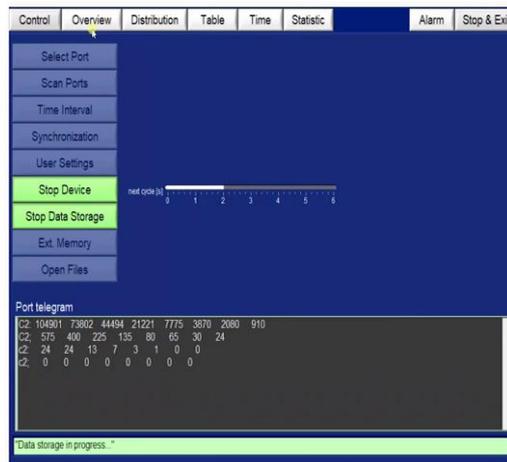
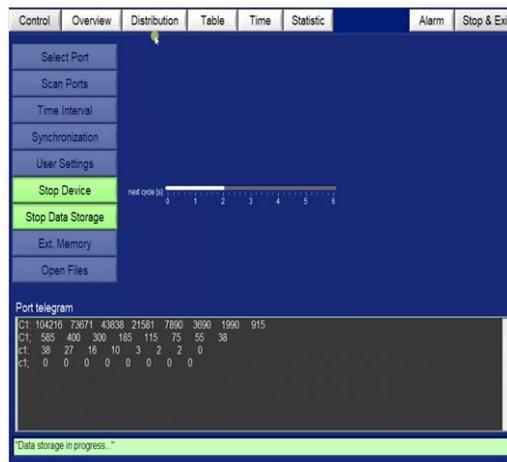
Select Port  
Scan Ports  
Time Interval  
Synchronization  
User Settings  
Stop Device  
Stop Data Storage  
Ext. Memory  
Open Files

net cycle(s) 0 1 2 3 4 5 6

Port telegram

C0:	104400	73242	43633	21281	7745	3675	1935	795
C0:	425	345	235	165	110	95	75	53
C0:	53	15	12	8	2	1	0	0
C0:	0	0	0	0	0	0	0	0

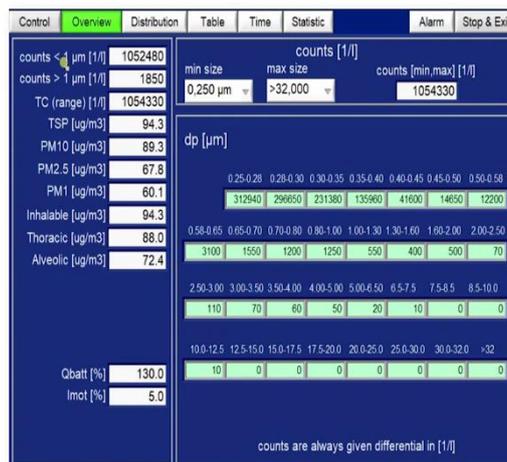
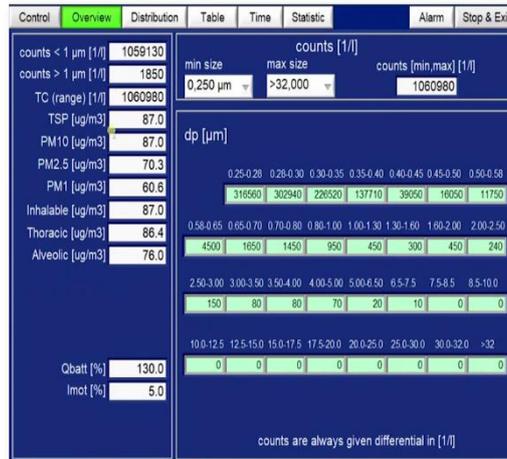
Data storage in progress. \*



Now, by defining the user setting now you can start the device message is being displayed in the bottom you can see measurement is in progress. So, yes you can see the measurement is now being started and in this port telegram, in this window you will be able to see as soon as the reading has been started. So right now it is preparing to start the taking the readings there it will take a while. So, the next message you can see this data storage in progress.

So, as soon as it starts taking the reading, you will be hearing a sound for a spectrometer and all the other options like control, overview, and distribution table. Now, you can see that all the options are now available, you can toggle with all the tabs. So, let me just give you an idea of all the tabs.

(Refer Slide Time: 19:05)







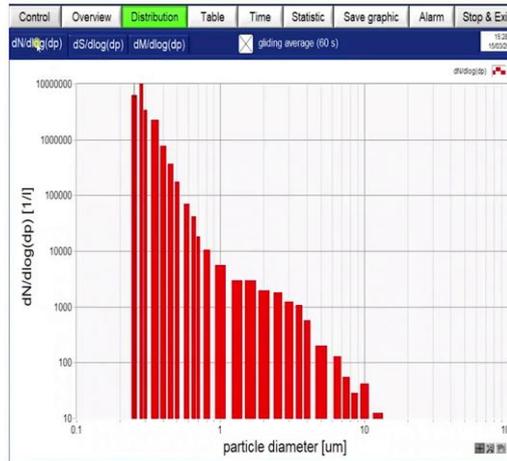
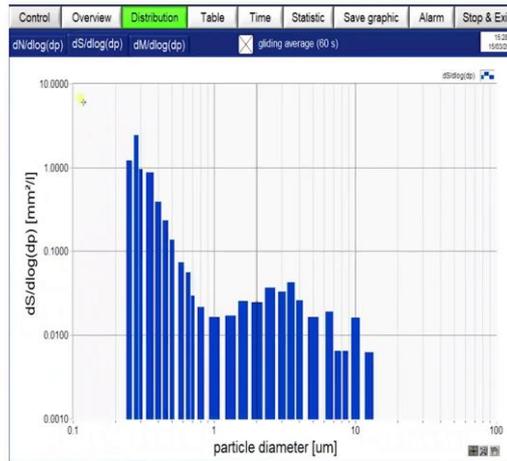
So, control tab we already discussed. The next tab is the overview tab. So, in overview tab, you can see all the details of your readings counts like what are the particles which are less than 1 micrometre what are the particles which are greater than 1 micrometre and total count of the particles total suspended particles PM<sub>10</sub>, PM<sub>2.5</sub>, PM<sub>1</sub> and other particles like it is classified as inhalable, thoracic and Alveolic. So, all the particles like the details of the particle as shown here as an overview, in this particular time.

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So, coming to the next step that is distribution. In distribution tab you can see a log table is being shown. So, in this first table, that is the log table. You can see the X axis you can see the particle diameter or particle sizes and in Y axis, you can see the this microgram (μg/m<sup>3</sup>)(20:04).

(Refer Slide Time: 20:04)



And in this you can see the area divided by this volume of the air being sucked by this sample pipe and in first tab you will be able to see the counts per litre.

(Refer Slide Time: 20:18)

Control	Overview	Distribution	Table	Time	Statistic	Alarm	Stop & Exit
counts [1/l]	mass [ug/m3]	log	<input checked="" type="checkbox"/> auto scrolling				
Time & Date	0.25 um	0.5 um	1.0 um	2.5 um	5.0 um	10.0 um	20.0 um
3/15/2022 3:27:17 PM	31185.0	29650.0	22920.0	15260.0	4570.0	1740.0	370.0
3/15/2022 3:27:23 PM	30445.0	29630.0	22670.0	13890.0	4200.0	1700.0	350.0
3/15/2022 3:27:29 PM	31090.0	29300.0	22370.0	13440.0	3950.0	1700.0	330.0
3/15/2022 3:27:35 PM	31690.0	30240.0	22820.0	13770.0	3960.0	1650.0	310.0
3/15/2022 3:27:41 PM	31294.0	29650.0	22130.0	13090.0	4100.0	1460.0	310.0
3/15/2022 3:27:47 PM	30230.0	29680.0	22720.0	13160.0	3720.0	1700.0	300.0
3/15/2022 3:27:53 PM	31890.0	30540.0	22940.0	13890.0	4200.0	1710.0	290.0
3/15/2022 3:27:59 PM	30210.0	30660.0	22420.0	13490.0	3900.0	1650.0	290.0
3/15/2022 3:28:05 PM	30250.0	29610.0	22470.0	13180.0	3620.0	1710.0	280.0
3/15/2022 3:28:11 PM	30720.0	30550.0	22870.0	13900.0	4050.0	1670.0	270.0
3/15/2022 3:28:17 PM	303440.0	29670.0	22020.0	12400.0	3800.0	1400.0	260.0
3/15/2022 3:28:23 PM	30230.0	29300.0	22870.0	12410.0	4020.0	1640.0	250.0
3/15/2022 3:28:29 PM	31130.0	29260.0	22730.0	13370.0	3620.0	1600.0	240.0
3/15/2022 3:28:35 PM	30870.0	30110.0	22520.0	12910.0	3870.0	1490.0	230.0
3/15/2022 3:28:41 PM	31090.0	30320.0	22470.0	13190.0	3970.0	1590.0	220.0
3/15/2022 3:28:47 PM	30620.0	29960.0	22020.0	13200.0	4240.0	1600.0	210.0
3/15/2022 3:28:53 PM	31080.0	29420.0	22870.0	13200.0	4050.0	1520.0	200.0
3/15/2022 3:28:59 PM	30870.0	30300.0	22810.0	13050.0	3760.0	1440.0	190.0
3/15/2022 3:29:05 PM	30840.0	29570.0	22120.0	12050.0	3800.0	1610.0	180.0

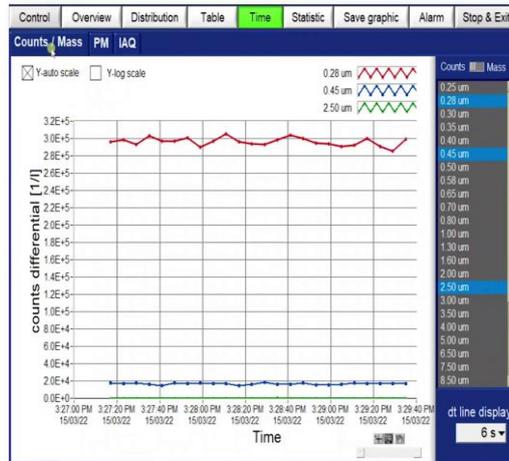
So, this log graph is being shown in distribution tab, in the next tab you can see the live reading you can be able to observe that it every 6 seconds that is the what interval we have decided at every 6 seconds it is showing the readings of all the particles.

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Control	Overview	Distribution	Table	Time	Statistic	Alarm	Stop & Exit
counts [1/l]	mass [ug/m3]	log	<input checked="" type="checkbox"/> auto scrolling				
mass values [ug/m3]	mass distribution (differential) [ug/m3]						
Time & Date	PM10 [ug/m3]	PM2.5 [ug/m3]	PM1 [ug/m3]	PM10e [ug/m3]	Thoracic [ug/m3]	Alveolar [ug/m3]	
3/15/2022 3:27:17 PM	82.8	88.1	83.1	82.8	82.1	73.7	
3/15/2022 3:27:23 PM	87.8	87.9	82.2	87.8	85.9	72.4	
3/15/2022 3:27:29 PM	78.5	82.2	88.8	78.5	78.0	89.4	
3/15/2022 3:27:35 PM	87.5	79.0	80.6	87.5	88.4	76.0	
3/15/2022 3:27:41 PM	89.3	87.8	85.1	89.3	88.0	72.4	
3/15/2022 3:27:47 PM	87.8	88.8	84.4	82.9	88.9	73.7	
3/15/2022 3:27:53 PM	111.8	88.9	81.5	122.2	107.5	74.8	
3/15/2022 3:27:59 PM	78.9	82.8	88.8	78.9	78.2	87.8	
3/15/2022 3:28:05 PM	102.3	87.9	80.0	102.8	98.8	74.8	
3/15/2022 3:28:11 PM	87.8	88.1	88.0	82.9	88.6	72.3	
3/15/2022 3:28:17 PM	78.7	85.7	88.8	78.7	78.2	88.2	
3/15/2022 3:28:23 PM	78.7	82.9	85.1	100.4	84.5	87.8	
3/15/2022 3:28:29 PM	77.8	85.3	88.3	77.8	78.8	89.8	
3/15/2022 3:28:35 PM	86.7	77.8	86.1	86.7	86.5	82.4	
3/15/2022 3:28:41 PM	83.8	86.8	85.3	83.8	82.6	71.3	
3/15/2022 3:28:47 PM	101.0	85.3	88.0	106.3	97.6	72.1	
3/15/2022 3:28:53 PM	100.3	86.8	86.1	341.2	108.2	76.1	
3/15/2022 3:28:59 PM	88.5	86.5	86.2	88.5	87.8	71.8	
3/15/2022 3:29:05 PM	83.3	87.0	85.8	83.3	82.7	72.2	
3/15/2022 3:29:11 PM	83.8	83.8	88.7	121.8	91.1	71.4	
3/15/2022 3:29:17 PM	87.8	85.8	88.3	87.8	88.7	71.7	
3/15/2022 3:29:23 PM	88.2	78.1	88.3	88.2	88.8	78.2	

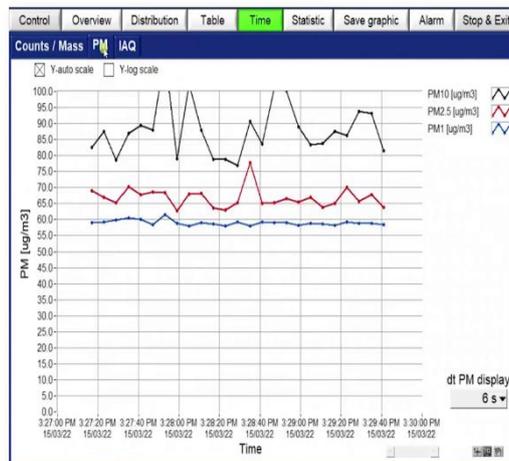
And in the first tab you can see the counts per litre in the next tab you can we will be able to see the PM<sub>10</sub>, PM<sub>2.5</sub>, PM<sub>1</sub> and other particles that is the indoor air quality you can say. So, in this here you will be able to see in microgram per metre cube the unit.

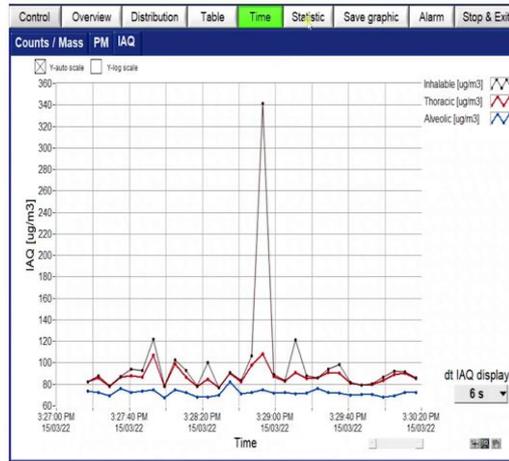
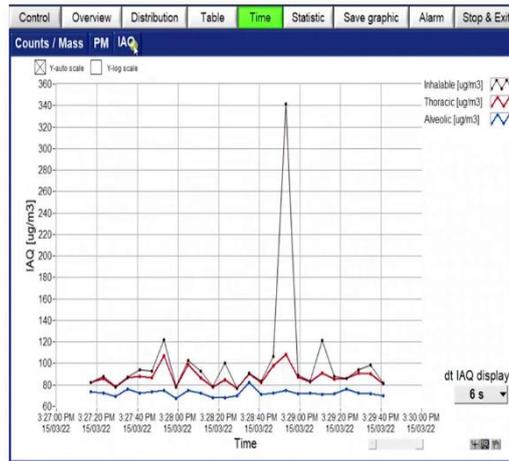
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And coming to the next one now this is the graphical presentation of we were seeing earlier that is in tabular form and this is the graphical form.

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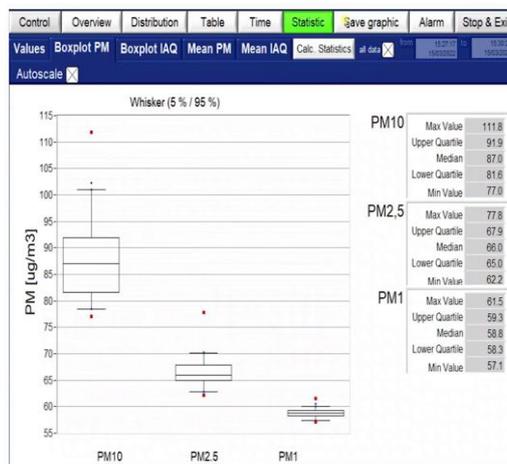
That is count per unit of mass is being seen and this one is particulate matter and next one is IAQ. So, in particulate matter this PM<sub>10</sub>, PM<sub>2.5</sub>, PM<sub>1</sub> are being shown in this indoor air quality this Inhalable, Thoracic, Alveolic, so these are related to this particle is related to the size ranging from according to these organs present in the lungs. So, according to the size of whichever be the sizes like in Alveolic part there is some size ranges and according to that this measurement is being done. So, that particular part is called as Alveolic.

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	Total Counts	Counts <- sum	Counts <- sum	PM10 [µg/m³]	PM2.5 [µg/m³]	PM1 [µg/m³]	Inhalable [µg/m³]	Therosec [µg/m³]	Aesthetic [µg/m³]
Minimum	1014420.0	1012730.0	1200.0	77.0	62.2	57.1	77.0	78.0	87.5
Maximum	1075070.0	1071420.0	2800.0	111.6	77.8	61.5	341.2	109.2	82.4
Stat. Range	58640.0	58890.0	1600.0	34.8	15.6	4.4	264.2	31.4	14.9
Mean	1036873.0	1035172.3	1701.6	87.7	65.5	58.9	88.8	87.1	72.1
Std. Deviation	13124.1	13129.2	310.2	8.0	3.0	0.9	46.4	7.7	3.0
Variation Coef.	0.9	0.9	0.2	0.1	0.0	0.0	0.5	0.1	0.0
Whisker 95%	1055500.0	1054010.0	2000.0	101.0	70.1	60.1	121.6	98.8	78.0
Upper Quartile	1044000.0	1042350.0	1850.0	91.9	67.9	59.3	84.3	80.2	73.7
Median	1035470.0	1033770.0	1650.0	87.0	66.0	58.8	87.8	85.9	72.1
Lower Quartile	1028930.0	1028770.0	1500.0	81.6	65.0	58.3	82.6	80.1	69.8
Whisker 5%	1015200.0	1013850.0	1350.0	78.5	62.8	57.4	78.5	78.0	67.8

In next step, that is the statistics, you can see the values which we are measuring and then all the again the units are there that is counts per litre and microgram per metre cube. So, you can calculate the stats using this particular time.

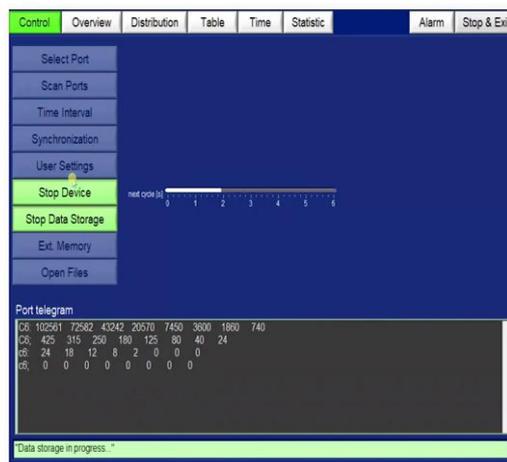
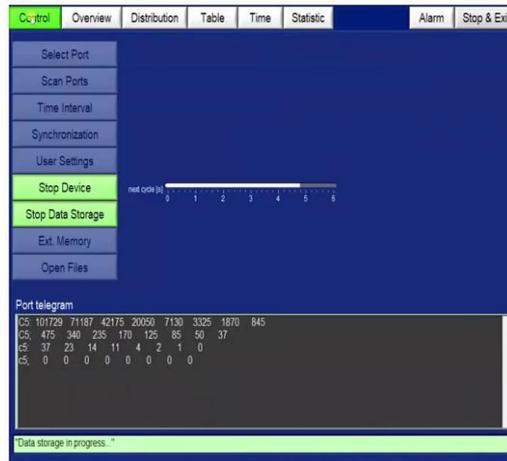
(Refer Slide Time: 21:56)



And also, you can plot the graph now, this showing the stats of this particular measurement. So, boxplot or whisker plot you can say, and at 5 percent confidence interval at 95 percent they are being plotted. So, you can see the PM<sub>10</sub>, PM<sub>2.5</sub>, PM<sub>1</sub> are being plotted. So, in this whisker plot you can see this lower part is the lowest range, the bottom part and this particular line shows the uppermost range and this box, this box shows the interval, confidence interval of 5 percent and 95 percent that is being shown and that this line shows the median, median of the

readings and the values you can observe in this particular window. So, after this what we are going to do, you can also save all the graphics or all the graph right now, it any particular instant.

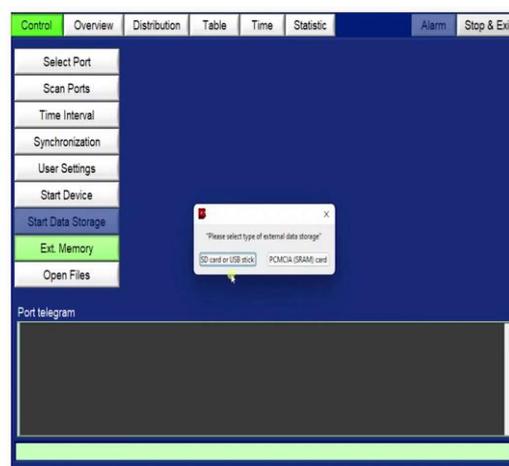
(Refer Slide Time: 22:52)



So, this is all about the, this line monitoring real time monitoring. So, now we have to save the data. So, for saving data you have to first stop the device. So, after stopping the device, what do we have saved that I hope you are remembering that we have saved by using the name test 10 that is being saved. So, the question arises from this like for going for a field condition we cannot take our system and for example, if we want to monitor the particles, for 8 hours or 24 hours or maybe any of the requirements.

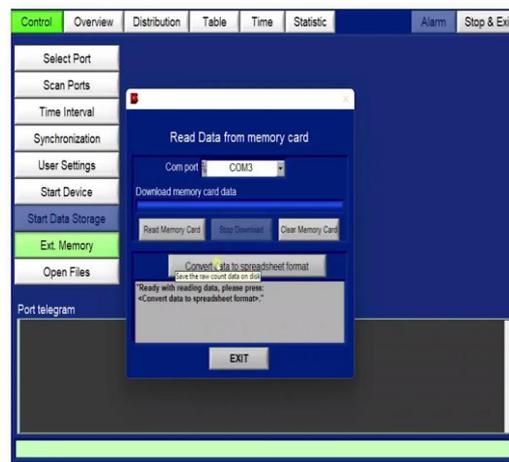
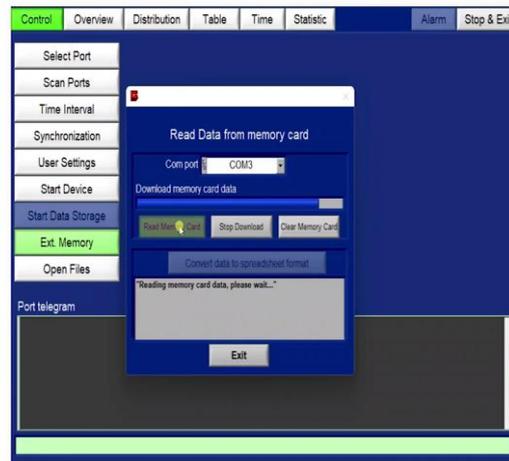
So, in that case, what we are doing, we are simply connecting the device and initialising data using the software. So, after initialising the software starting the device, we can disconnect the cable, this device will still be working and the data will be stored in the memory card. So, sampling time is completed for example, we are taking the reading for 8 hours. So, after starting the device and after completion, you can simply turn off the spectrometer using this on off button that is already in the inner spectrometer. So, using that button you can simply off the device.

(Refer Slide Time: 24:18)



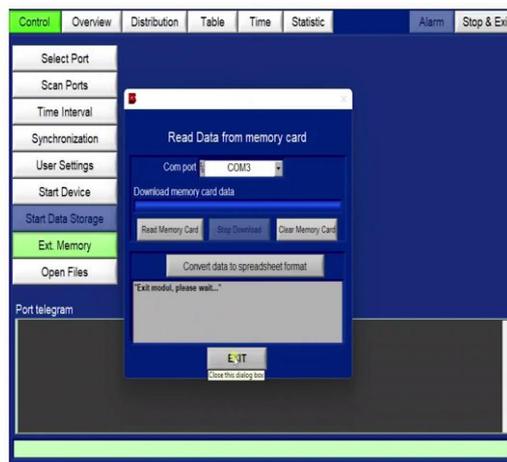
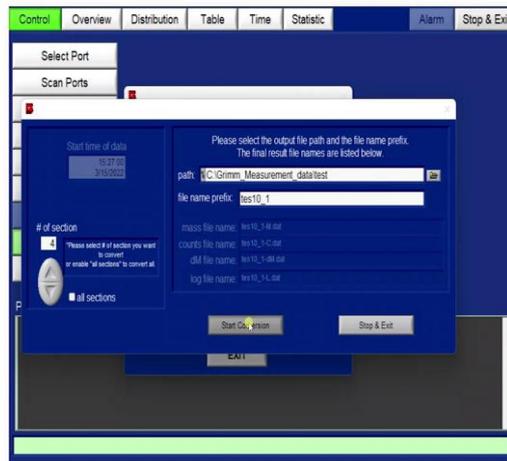
And now to extract what data has been saved you can simply click on the external memory. So, it will ask that whether the data has been saved in SD card or that card that is known as SRAM card or PCMCIA card.

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So, right now, I am clicking on SRAM card. So, again that particular COM port has been selected. Now, you have to go for read memory card after clicking on read memory card it will read the card data it will take a while the data will be downloaded one more information about data if you are going for fresh reading. I would recommend that clear the memory card for going for fresh reading so that the previous reading should not be altered, you can see memory card is being downloaded.

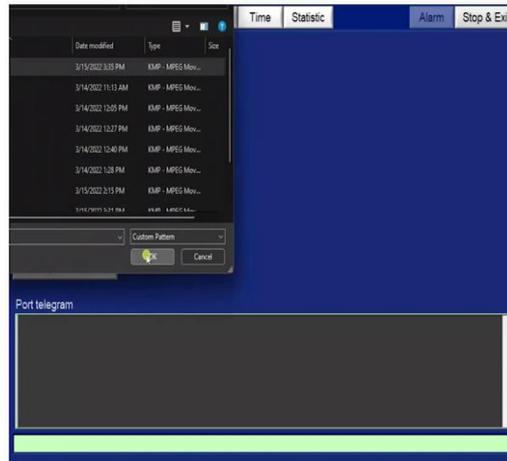
(Refer Slide Time: 25:03)



So, after this data has been downloaded that data can be converted into spreadsheet format using these options, so as soon as I click on data convert to spreadsheet format, this particular window opens and you can see the whichever data we have recorded, right now that you can select the data using this toggle keys that is present here. So right now, I am selecting the fourth one, and you have to just give a name.

So again, I am giving the name as test10\_1. Now, I will click on the start conversion data has been is already been converted. So, let us assume that you have converted the data and we have obtained the 8 hours of reading in particular spreadsheet format. So also, you can import that particular spreadsheet in this software also.

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So, for that we can go for open files, and open files you can see right now it is bar by default, taking the file which I have already saved, okay also you can select or browse at particular locations. So, right now I am again selecting that file just for information.

(Refer Slide Time: 26:21)

Date & Time	PM10 [ug/m3]	PM2.5 [ug/m3]	PM1 [ug/m3]	TSP [ug/m3]	TSP (diff.) [ug/m3]	Alveolar [ug/m3]	log
3/15/2022 3:28:54 PM	83.8	83.8	83.7	121.8	81.1	71.4	
3/15/2022 3:29:05 PM	87.6	85.0	85.3	87.9	85.7	71.7	
3/15/2022 3:29:08 PM	86.2	70.1	58.3	86.2	85.6	76.2	
3/15/2022 3:29:12 PM	87.7	65.8	88.8	84.5	81.0	72.7	
3/15/2022 3:29:16 PM	91.1	67.7	68.8	88.5	82.2	71.7	
3/15/2022 3:29:24 PM	81.6	83.8	58.4	81.6	81.0	69.7	
3/15/2022 3:29:30 PM	79.3	65.2	88.6	79.3	79.1	76.4	
3/15/2022 3:29:36 PM	86.8	86.9	88.4	86.8	86.1	76.4	
3/15/2022 3:29:42 PM	88.4	81.5	83.3	86.7	83.7	69.2	
3/15/2022 3:29:48 PM	82.1	82.2	87.1	82.4	88.4	88.0	
3/15/2022 3:29:54 PM	81.9	66.8	88.6	81.9	86.1	72.7	
3/15/2022 3:30:00 PM	86.1	68.8	87.4	86.3	85.3	72.6	
3/15/2022 3:30:06 PM	88.8	85.7	88.6	87.2	84.2	69.9	
3/15/2022 3:30:12 PM	89.8	81.9	88.5	85.3	86.4	86.2	
3/15/2022 3:30:18 PM	86.8	87.6	88.3	87.1	86.0	72.8	
3/15/2022 3:30:24 PM	77.9	85.9	87.2	77.9	77.7	79.2	
3/15/2022 3:30:30 PM	86.9	69.8	88.8	81.3	86.5	73.1	
3/15/2022 3:30:36 PM	84.7	82.3	87.8	86.1	82.1	66.9	
3/15/2022 3:30:42 PM	72.4	81.5	87.1	72.4	72.3	87.1	
3/15/2022 3:30:48 PM	85.4	85.2	87.9	85.4	88.1	79.2	
3/15/2022 3:30:54 PM	89.3	87.6	87.8	89.3	88.2	79.8	
3/15/2022 3:31:00 PM	89.2	89.9	88.8	89.9	88.2	87.5	
3/15/2022 3:31:06 PM	83.1	87.4	87.6	83.1	82.6	72.7	
3/15/2022 3:31:12 PM	84.9	85.7	88.0	88.9	83.6	89.3	
3/15/2022 3:31:18 PM	87.8	84.8	87.5	88.2	81.1	69.3	
3/15/2022 3:31:24 PM	84.9	88.9	88.5	84.9	84.4	74.4	
3/15/2022 3:31:30 PM	88.6	86.4	87.7	85.0	83.7	79.7	
3/15/2022 3:31:36 PM	78.4	84.8	87.6	78.4	79.2	88.8	

date & time	PM10 (ug/m3)	PM2.5 (ug/m3)	PM1 (ug/m3)	fineaer (ug/m3)	Theroco (ug/m3)	Atheneic (ug/m3)
31/05/2022 1:27:54 PM	80.3	87.8	65.1	96.3	65.3	72.4
31/05/2022 1:27:36 PM	87.8	88.8	58.4	92.9	68.9	73.7
31/05/2022 1:27:36 PM	111.8	68.5	61.6	122.2	107.3	74.8
31/05/2022 1:27:42 PM	78.9	62.8	58.8	78.9	78.2	87.5
31/05/2022 1:27:48 PM	102.3	87.9	58.0	102.8	98.8	74.8
31/05/2022 1:27:54 PM	87.8	68.1	58.0	92.9	68.8	72.3
31/05/2022 1:28:00 PM	78.7	65.7	58.6	78.7	78.2	88.3
31/05/2022 1:28:06 PM	78.7	62.9	68.1	108.4	84.5	87.8
31/05/2022 1:28:12 PM	77.8	65.3	58.3	77.8	76.8	88.8
31/05/2022 1:28:18 PM	88.7	77.8	58.1	98.7	88.8	82.4
31/05/2022 1:28:24 PM	82.8	68.8	58.3	88.8	82.8	77.8
31/05/2022 1:28:30 PM	101.8	68.3	58.9	108.3	97.8	72.1
31/05/2022 1:28:36 PM	108.3	68.6	58.1	141.2	108.2	75.1
31/05/2022 1:28:42 PM	88.8	68.8	58.2	88.8	87.8	71.8
31/05/2022 1:28:48 PM	83.3	67.8	58.8	83.3	82.7	72.2
31/05/2022 1:28:54 PM	83.8	83.8	58.7	121.8	91.1	71.4
31/05/2022 1:29:00 PM	87.8	68.8	58.3	87.8	88.7	71.7
31/05/2022 1:29:06 PM	88.2	78.1	58.3	88.2	88.8	78.2
31/05/2022 1:29:12 PM	83.7	68.8	58.6	84.8	81.8	72.7
31/05/2022 1:29:18 PM	83.1	67.7	58.8	88.5	88.2	71.7
31/05/2022 1:29:24 PM	81.8	68.8	58.4	81.8	81.8	88.7
31/05/2022 1:29:30 PM	79.3	81.2	58.8	79.3	79.1	78.4
31/05/2022 1:29:36 PM	88.8	68.8	58.4	88.8	88.1	79.4
31/05/2022 1:29:42 PM	88.4	63.8	58.3	88.7	83.7	88.2
31/05/2022 1:29:48 PM	82.1	62.2	57.1	82.4	88.4	88.8
31/05/2022 1:29:54 PM	81.8	68.8	58.6	81.8	88.1	72.7
31/05/2022 1:30:00 PM	88.8	68.8	57.4	88.8	88.3	72.1
31/05/2022 1:30:06 PM	88.8	68.7	58.8	87.2	84.2	88.8
31/05/2022 1:30:12 PM	88.8	81.8	58.5	88.3	88.4	88.3
31/05/2022 1:30:18 PM	88.8	67.8	58.3	87.1	88.8	72.8
31/05/2022 1:30:24 PM	77.8	68.8	57.2	77.8	77.7	78.2

And you can click on the open files with the software and you can click on exit. So, you can see now that all the readings which you have taken and that is present here. So, this is the procedure by which you can measure the PM<sub>10</sub>, PM<sub>2.5</sub> and PM<sub>1</sub> using this GRIMM model. So, this is software all about the software, thank you.

Professor Bhola Ram Gurjar: So, you have seen and you know how to use the spectrometer. So, this is a versatile instrument which can give you count as well as mass concentration of particulate matter PM<sub>2.5</sub>, PM<sub>1</sub>, PM<sub>10</sub> huge range is there as I said, and all these data are very important because whenever we want to do so, suppose meant or identification of different sources where they are coming from and if we want to relate different kind of concentrations of PM<sub>1</sub> or PM<sub>2.5</sub> etc, then we need these kinds of data and also to compare whether it is violating the standards or not, so monitoring is very much needed. So, this is all and this is the last lecture of this particular course.

(Refer Slide Time: 27:29)

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These are the references which we have used for this particular lecture. So, I take this opportunity to thank all of you who took so keen interest in this particular course, we enjoyed your interaction through emails etc. And I thank E-Learning centre of IIT Roorkee specially Binoy to schedule lecture recording times as per our convenience and I also thank TAs Anurag and Gaurav and other students like Ria and Apshay and Rahul they have also contributed a lot in this particular course.

So, thanks all and I wish you all the best for your pursuits regarding air pollution control and air pollution studies, whether you are studying as a student or whether you are trying to implement this knowledge in the field. So, all the best for your pursuits. And thanks again.