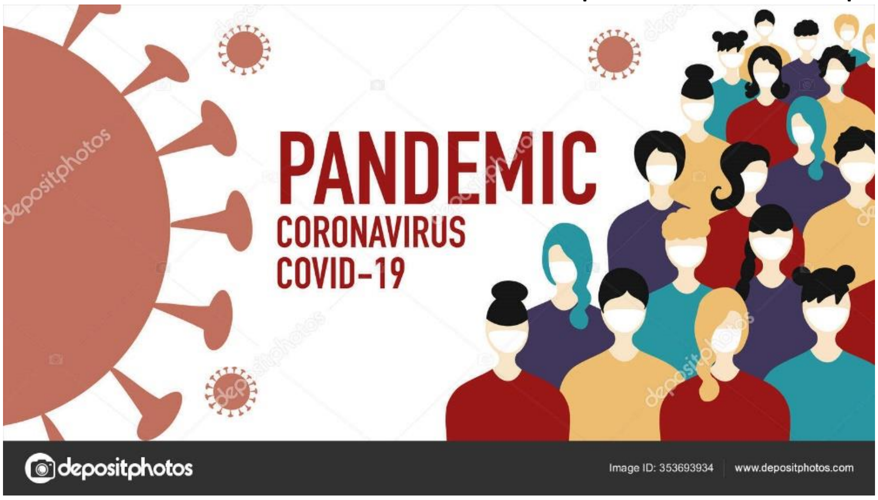
Air Quality

MAKING OUR DIGITAL FUTURE

Introduction

Data science is a powerful tool used by researchers in various fields to test scientific hypothesises. It is a multi-step process which involves pre-processing large data samples, analysing the data samples with various regression tools and then visualizing the results. Here we will go through an example case of using data science to see the effect of COVID-19 pandemic on air quality.

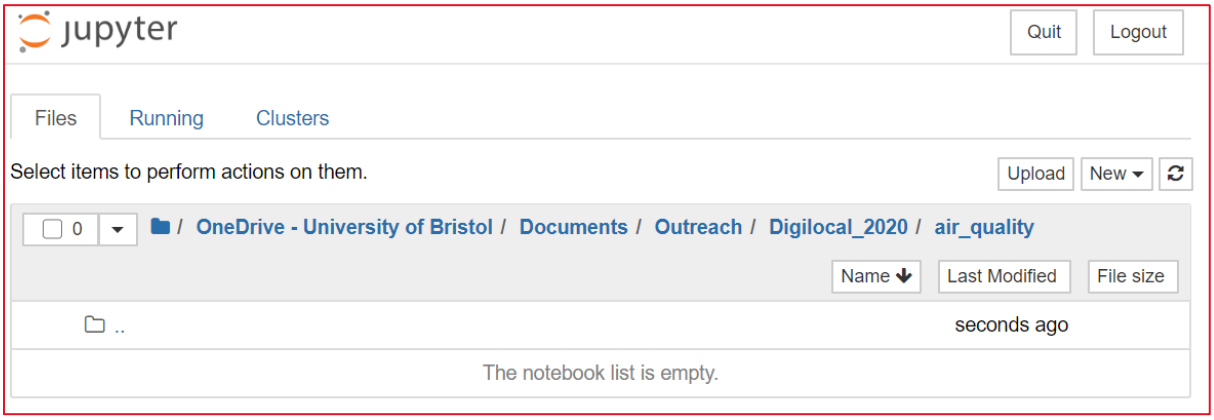


The COVID-19 pandemic started affecting the world starting early 2020. Various countries started implementing lockdown measures to decelerate the spread of this pandemic. The lockdown measures involved restrictions on unessential travels. Travel vehicles emit various pollutant gases such as nitrogen dioxide (NO_2) which directly affect air quality (forming harmful particles) and public health (inflammation of airways). Here we will use data science capability of python to see the effect of the travel restrictions on NO_2 levels in Bristol and London, two largest cities in southern England.

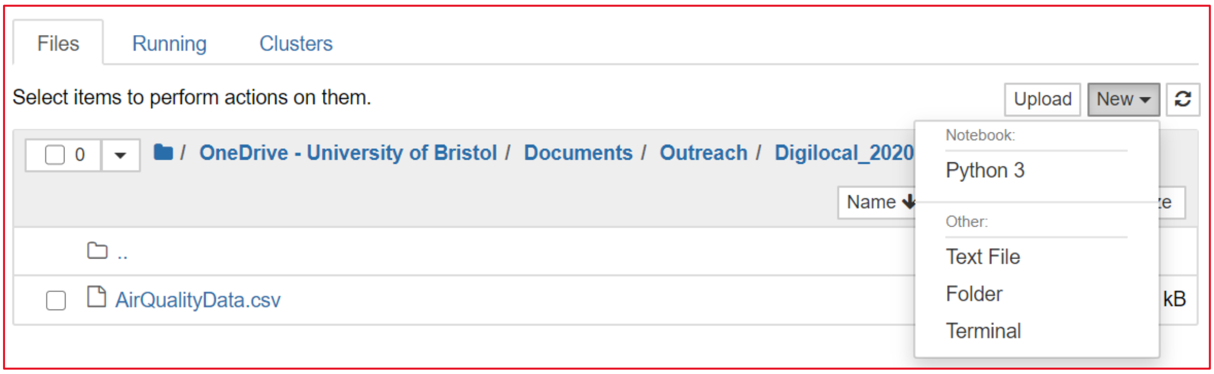
The Department of Environment Food and Rural Affairs (DEFRA) website (https://uk-air.defra.gov.uk/) provides free access to pre-processed measurement data of various pollutants at various sites within the UK. A csv file containing NO_2 measurements from the sites at Bristol Temple Way and London Marylebone Road is provided in the resources folder for this project. Detail instructions on accessing data from the DEFRA website are provided in the Primary Science Teaching Trust website (https://pstt.org.uk/resources/curriculum-materials/post-16-citizen-science-air-pollution).

Step 1: Getting Started with Jupyter

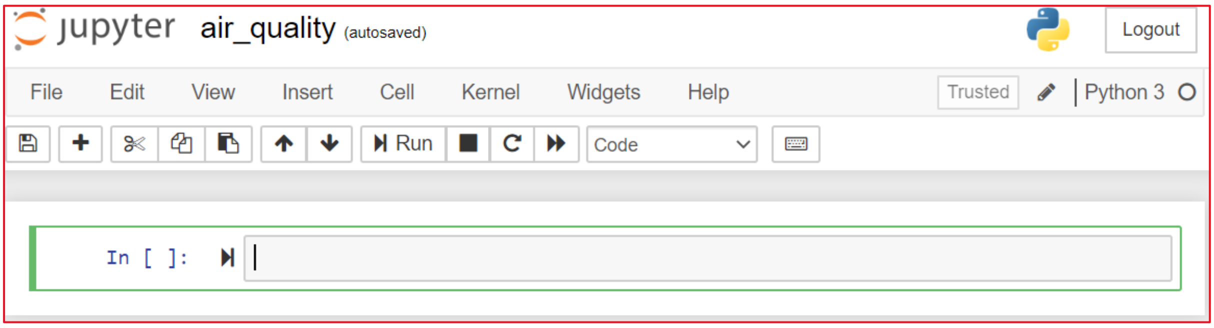
Jupyter is an interactive development environment for python and we will use it to write and execute our python program for data analysis. Before using Jupyter, create a folder named air_qaulity inside your named folder to save all the files for this project. Jupyter will open in an internet browser and you should browse to the air_quality folder we created earlier. After you are inside your air_quality folder which should be empty, upload the AirQualityData.csv file from the python resource folder using the upload button on the right-hand corner as shown below:



After upload you should see the csv file



Create a new Python 3 notebook using the dropdown option under New. This will open a new tab in the browser and a Jupyter notebook titled Untitled will be created. Go back to the Jupyter tab and select the Untitled notebook and rename (button under Files option) it to air_quality.ipynb



Step 2: Importing Modules and Data

Now we will import numpy and pandas modules which are very popular for data analysis in Python. The green box takes the python commands and once you have typed the import command execute it by using shift + return.

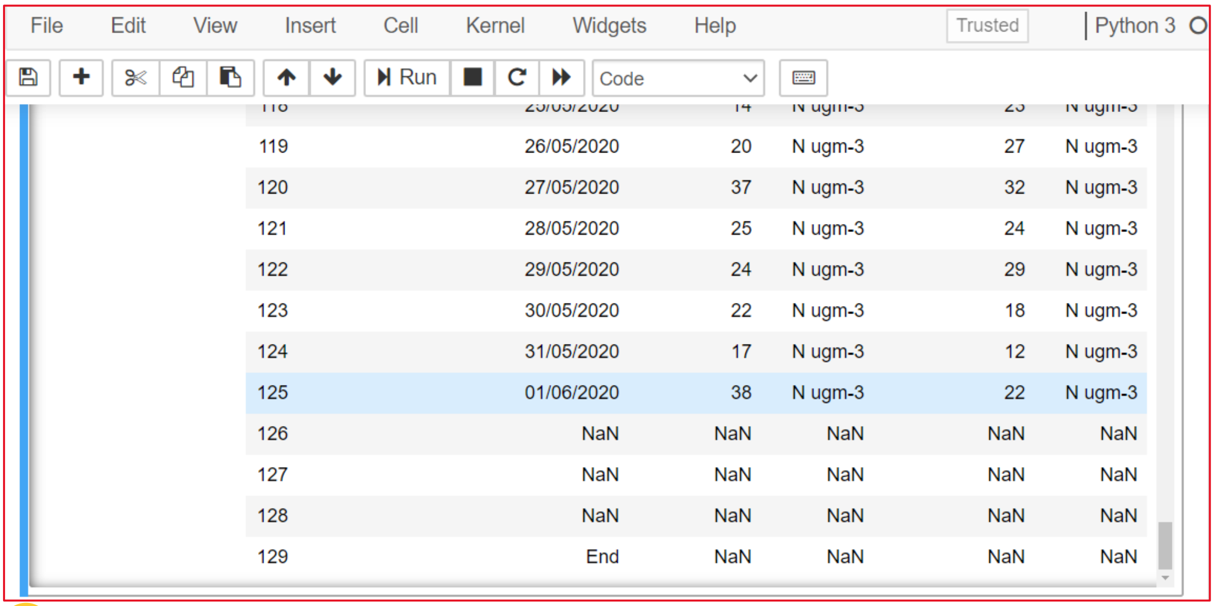
```
In [1]: import numpy as np
        import pandas as pd
```

The pandas module has read_csv class which we will use to import the NO_2 measurement data from the csv files into python as a dataframe, df. We will also display the contents of the measurement file using display command. As the file has quite a lot of rows we need to change the setting of the display command in the second line of code as shown below:

```
In [4]: df = pd.read_csv('AirQualityData.csv')
        pd.set_option('display.max_rows', 1000)
        display(df)
```

	Daily Mean data\t supplied by UK-air on 28/06/2020	Unnamed: 1	Unnamed: 2	Unnamed: 3	Unnamed: 4
0	All Data GMT hour ending	NaN	NaN	NaN	NaN
1	Status: V=Verified P=Provisionaly Verified N=N...	NaN	NaN	NaN	NaN
2	NaN	Bristol Temple Way	NaN	London Marylebone Road	NaN
3	Date	Nitrogen dioxide	Status	Nitrogen dioxide	Status
4	01/02/2020	16	V ugm-3	71	N ugm-3
5	02/02/2020	20	V ugm-3	68	N ugm-3

Now can see the structure of our dataset collected from DEFRA. We can see the first column is index number for the dataset starting from 0. The first four rows only contain description of the data. After that we can see the columns are divided into Date, NO_2 measurement from Bristol Temple Way, Measurement Units, NO_2measurement from London Marylebone Road and Measurement Units. There is also a scroll bar on the right which we can use to explore all the rows of the dataset. Shown below are the last rows of the dataset.



119	26/05/2020	20	N ugm-3	27	N ugm-3
120	27/05/2020	37	N ugm-3	32	N ugm-3
121	28/05/2020	25	N ugm-3	24	N ugm-3
122	29/05/2020	24	N ugm-3	29	N ugm-3
123	30/05/2020	22	N ugm-3	18	N ugm-3
124	31/05/2020	17	N ugm-3	12	N ugm-3
125	01/06/2020	38	N ugm-3	22	N ugm-3
126	NaN	NaN	NaN	NaN	NaN
127	NaN	NaN	NaN	NaN	NaN
128	NaN	NaN	NaN	NaN	NaN
129	End	NaN	NaN	NaN	NaN

We can see that the first four and the last four rows of the file do not actually contain measurement data. As a part of pre-processing of dataset, a new dataframe, sf, is created in the first three lines of code below for this purpose. The i and f values inside the square bracket provide the range of index to be copied into the new dataframe. The fourth line reindexes the dataframe so that it starts from 0 again.

In [7]:

```
i=4 #initial index of the measurement data
f=len(df)-4 #final index of the measurement data
sf=df[i:f]
sf.reset_index(drop=True, inplace=True) #reindexing dataframe
```

.

Challenge Time!

Verify that the dataframe, sf, is indexed properly for analysis using the display command

Step 3: Data Slicing

Now we will slice the imported dataframe into separate arrays for dates and measurements from Bristol and London. Array in Python is a collection of data of the same type which can then be operated on by various functions during data analysis. First the measurement data from London is sliced and saved to an array named ‘London’. The iloc attribute of dataframe is used to select columns with index 1 and 3 for Bristol and London, respectively. The resulting dataframe series is then converted into numpy ‘float type’ array using to_numpy command. This conversion will enable us to use various numpy functions for further analysis of data later. We can see the values stored in the ‘London’ array using the print command

```
In [58]:  London = sf.iloc[:,3].to_numpy('float')
          print(London)

[71. 68. 65. 44. 80. 84. 72. 65. 35. 69. 66. 74. 68. 77. 40. 55. 70. 74.
 76. 64. 74. 57. 40. 70. 86. 59. 54. 74. 61. 64. 61. 87. 90. 37. 62. 77.
 59. 79. 63. 75. 76. 69. 61. 53. 68. 66. 60. 29. 21. 34. 31. 65. 49. 61.
 32. 20.  9.  7. 15. 24. 33. 35. 42. 32. 23. 36. 42. 48. 44. 39. 37. 21.
  4. 24. 46. 44. 21. 17. 11. 14. 15. 18. 30. 27. 21. 25. 31. 19. 27. 27.
 27. 20. 24. 22. 21. 28. 43. 39. 37.  6.  5. 17.  9. 15. 23. 21. 23. 33.
 29. 38. 37. 26. 15. 13. 23. 27. 32. 24. 29. 18. 12. 22.]
```

A similar procedure is applied to extract dates for the measurement. Unlike the measurement values, dates are provided in a different format. We will import the datetime module to format the dates readable in python. The third line in the code below uses list comprehension in which every value stored in the dates series is operated by the datetime commands.

```
In [15]:  dates = sf.iloc[:,0]
          import datetime as dt
          fmt_dates = [dt.datetime.strptime(d,'%d/%m/%Y').date() for d in dates]
          print(fmt_dates)
```

Shown below is the output of the print command

```
[datetime.date(2020, 2, 1), datetime.date(2020, 2, 2), datetime.date(2020,
2, 3), datetime.date(2020, 2, 4), datetime.date(2020, 2, 5), datetime.date
(2020, 2, 6), datetime.date(2020, 2, 7), datetime.date(2020, 2, 8), datetim
e.date(2020, 2, 9), datetime.date(2020, 2, 10), datetime.date(2020, 2, 11),
datetime.date(2020, 2, 12), datetime.date(2020, 2, 13), datetime.date(2020,
```

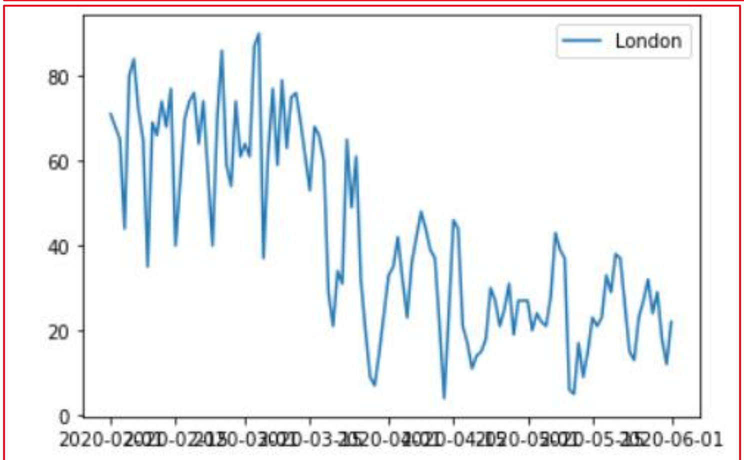
Challenge Time!

Slice the measurements from Bristol and save it to an array named ‘Bristol’

Step 4: Data Visualisation

We will now plot these arrays to visualise the measurements from London. We will import matplotlib module for this as shown in the first line below. A figure object, fig, is created and subplot, ax, is added to it. A plot labelled ‘Bristol’ is created in the ax subplot to visualise the NO_2 measurements in Bristol. The plot and legend are displayed using the legend and show attributes of the matplotlib module

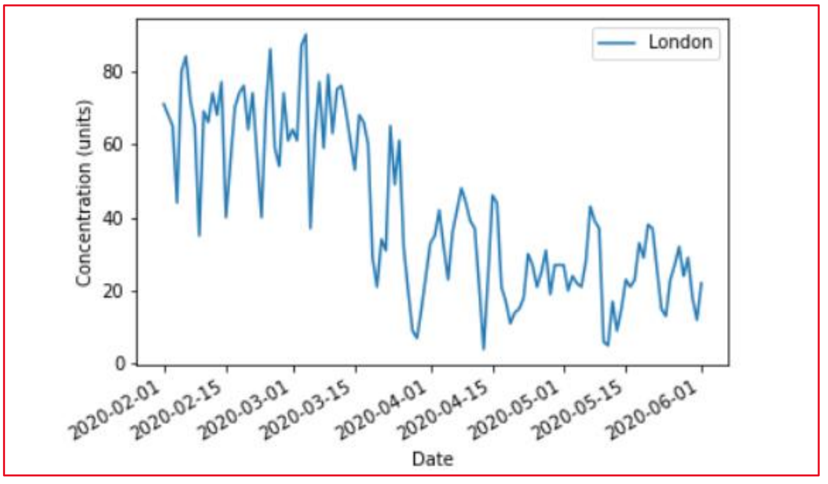
```
In [57]:  import matplotlib.pyplot as plt
          fig = plt.figure()
          ax = fig.add_subplot(111)
          ax.plot(fmt_dates,London, label='London')
          plt.legend()
          plt.show()
```



Further plot commands are added to display labels for the x (horizontal, xlabel) and y (vertical, ylabel) axis. The dates in the x axis is formatted for better visualisation using commands shown in line 7.

```
In [56]:
import matplotlib.pyplot as plt
fig = plt.figure()
ax = fig.add_subplot(111)
ax.plot(fmt_dates,Bristol,label='Bristol')
plt.xlabel('Date')
plt.ylabel('Concentration (units)')
plt.gcf().autofmt_xdate()
plt.legend()
plt.show()
```

The output plot is show below which is much easier to read now!



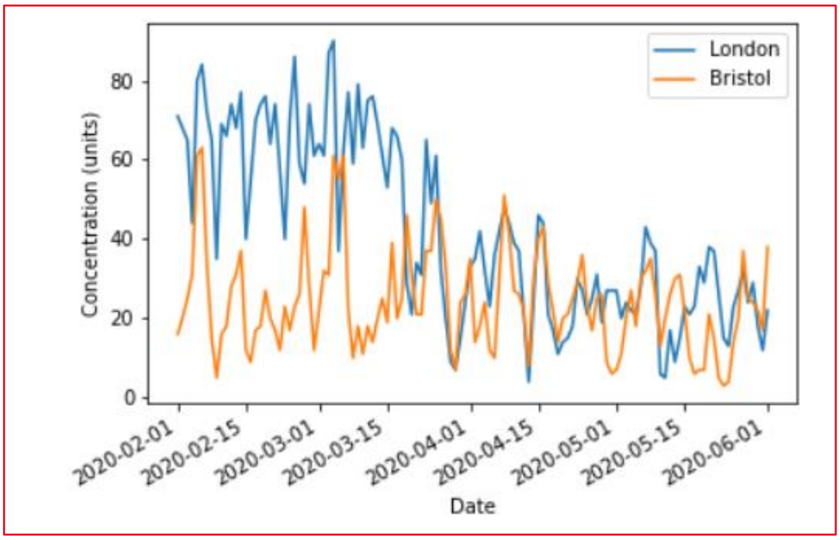
Science Alert!

The concentration units are microgram cubic meter air (µg m^{-3}), 1 µg m^{-3} ~ 1 part per billion air

Challenge Time!

Add a plot in the ax subplot to visualise the measurements from Bristol too.

The final plot should look as shown below:



Step 5: Data Analysis

We can see that the NO_2 concentration has gone down in London starting in April, whereas Bristol measurements have been relatively constant over the four-month time frame. To quantify the change in NO_2 concentration we can average the concentration before and after the lockdown measurements were enforced by the UK government. The lockdown started on the evening of 23rd March and displaying the sf dataframe shows that this date corresponds to index 51.

```
In [32]:  display(sf)
```

49	21/03/2020	21	V ugm-3	34	N ugm-3
50	22/03/2020	21	V ugm-3	31	N ugm-3
51	23/03/2020	37	V ugm-3	65	N ugm-3
52	24/03/2020	37	V ugm-3	49	N ugm-3
53	25/03/2020	50	V ugm-3	61	N ugm-3
54	26/03/2020	45	V ugm-3	32	N ugm-3
55	27/03/2020	33	V ugm-3	20	N ugm-3

The ‘London’ array is split from index 51 into two separate arrays named ‘London_prelock’ and ‘London_postlock’. The print command is then used to confirm the split.

```
In [61]: London_prelock=London[0:51]
         London_postlock=London[51:len(London)]
         print(London_prelock)
         print(London_postlock)

[71. 68. 65. 44. 80. 84. 72. 65. 35. 69. 66. 74. 68. 77. 40. 55. 70. 74.
 76. 64. 74. 57. 40. 70. 86. 59. 54. 74. 61. 64. 61. 87. 90. 37. 62. 77.
 59. 79. 63. 75. 76. 69. 61. 53. 68. 66. 60. 29. 21. 34. 31.]
[65. 49. 61. 32. 20.  9.  7. 15. 24. 33. 35. 42. 32. 23. 36. 42. 48. 44.
 39. 37. 21.  4. 24. 46. 44. 21. 17. 11. 14. 15. 18. 30. 27. 21. 25. 31.
 19. 27. 27. 27. 20. 24. 22. 21. 28. 43. 39. 37.  6.  5. 17.  9. 15. 23.
 21. 23. 33. 29. 38. 37. 26. 15. 13. 23. 27. 32. 24. 29. 18. 12. 22.]
```

We can use mean and std function of the numpy modules to take average and standard deviation values of the measurement values in the two split arrays. The standard deviation represent average fluctuation in the daily measurements.

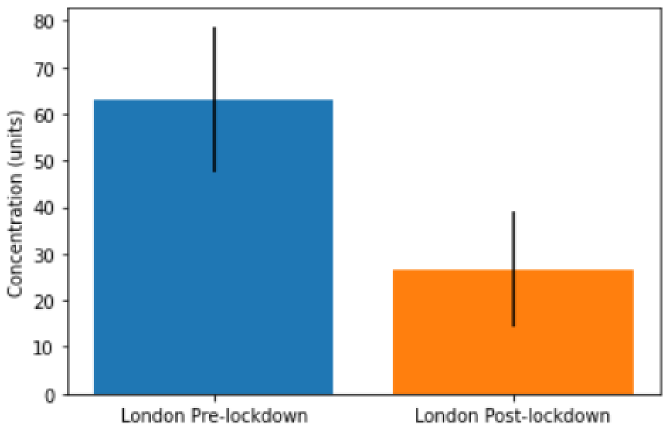
```
In [62]: London_prelock_mean=np.mean(London_prelock)
         London_postlock_mean=np.mean(London_postlock)
         London_prelock_std=np.std(London_prelock)
         London_postlock_std=np.std(London_postlock)
         print('London Prelockdown:', London_prelock_mean,London_prelock_std)
         print('London Postlockdown:', London_postlock_mean,London_postlock_std)

London Prelockdown: 63.01960784313726 15.714973746278199
London Postlockdown: 26.661971830985916 12.43568656477135
```

Finally, we can visualise these results in a bar plot to better summarise the results.

```
In [63]: fig=plt.figure()
         ax = fig.add_subplot(111)
         ax.bar('London Pre-lockdown',London_prelock_mean,yerr=London_prelock_std)
         ax.bar('London Post-lockdown',London_postlock_mean,yerr=London_postlock_std)
         plt.ylabel('Concentration (units)')
         plt.show()
```

Shown below is the bar graph



The black vertical lines in the bar plot represent the standard deviations in NO_2 measurements. The plot clearly shows that the mean NO_2 concentration has decreased after March 23. Moreover, even the upper limit value for the post lockdown measurements, considering fluctuations in daily measurements, never reach the lower limit value for the pre-lockdown measurements [i.e. the two black vertical lines do not overlap vertically]. Thus, we can safely conclude that the NO_2 measurement at the London site has decreased significantly due to the lockdown measures!

Science Alert!

The NO_2 concentration in London has come down to within the recommended upper limit value of 40 µg m^{-3} by the World Health Organisation!

Challenge Time!

Find whether the nitrogen dioxide concentration in Bristol has changed due to the lockdown measures

Fun Challenge!

Find which day of the week had the largest NO_2 concentration on average within the four-month time frame imported for Bristol [i.e. which day was most polluted]