



Air pollution and traffic density

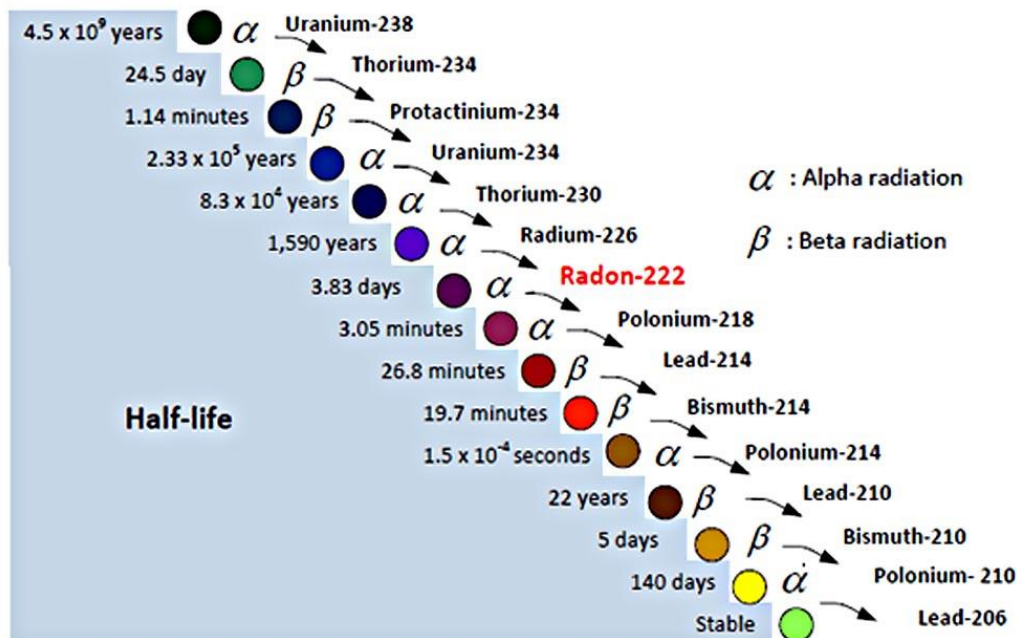
Student workbook

This resource was developed by Scott Chambers and the ANSTO Discovery Centre.

Air pollution and traffic density in Richmond 2016

Background (by Scott Chambers)

Radon-222 is a naturally-occurring, radioactive gas that is part of the Uranium-238 decay chain.



Since Uranium-238 has a half-life of around 4.5 **billion** years it is found in almost all rocks and soils (but not water). Since radon is a gas it can escape from the ground into the atmosphere, but it is a noble gas, so it doesn't chemically react with anything, and it does not dissolve easily in water.

Because radon comes only from land, not water, and does not react with other things in the atmosphere, makes it a very good "tracer" of what air is doing, and where air has been.

Climate scientists like to look at long-term (10s to 100s of years) changes in concentrations of "greenhouse gases" (like carbon dioxide, methane and chloro-fluoro-carbons). But they want to measure these changes in air that is as clean as possible; air that is very well mixed, and has not been near cities or factories for a long time. By measuring very low levels of radon (sometimes down to 5 atoms per litre ... that is about 5 in 10,000,000,000,000,000,000 atoms) we can tell if a certain bit of air has touched a pollution source on land within the last three weeks. ANSTO radon detectors are the best radon detectors in the world!

Some pollution scientists like to know where pollution has come from, and how much that pollution might get mixed or diluted as it moves from one place, over the ocean, to another place. Because no radon comes from the ocean, and we know how much radon is coming from land, if we measure radon at the same time as other pollutants at remote places like Antarctica or Hawaii, we can use radon to help tell us about where the original pollution source was, and how strong it was.

Other pollution scientists like to find out how the atmosphere helps to mix and dilute pollution. On large scales, some clouds (like convective cumulus clouds) act like big vacuum cleaners, and “suck” pollution up from cities and mix it far up into the troposphere (8 to 12 km up!). Other clouds, like blankets of stratus clouds, don’t let the pollution mix very high at all. By using small aeroplanes to measure the change in concentration of radon as you go away from the ground (e.g. from the ground up to 4000 m), we can tell how well different atmospheric processes are diluting pollution.

Another thing that controls pollution in cities is the wind speed. Sometimes on cold autumn or winter nights, when there are no clouds and no wind, when you wake up in the morning and look at the city it might be covered in a layer of brown haze. This is because a lot of pollution from the city – mainly from cars and trucks – is being trapped within a shallow “inversion layer”. This means that the pollution can only mix in a very shallow layer near the ground. By measuring the change in radon concentration near the ground (at about the height of your head as you walk around), we can learn a lot about how mixing in the atmosphere can change the concentrations of pollution that we are exposed to each day. It also helps us to be “atmospheric policemen”, who can tell whether certain areas are producing more pollution than they should.

Methods:

Hourly observations of meteorology, a few trace gas pollutants, Radon-222 concentration and traffic density were collected from the University of Western Sydney (Richmond Campus) in 2016. More detailed information about methods used is available in Chambers *et al.* 2015.

Results

The data collected has been recorded in a large excel sheet. We suggest you take the time to read and understand what each column contains (hover your mouse over the column heading to reveal more information). We've also summarised the different types of data collected in the table below:

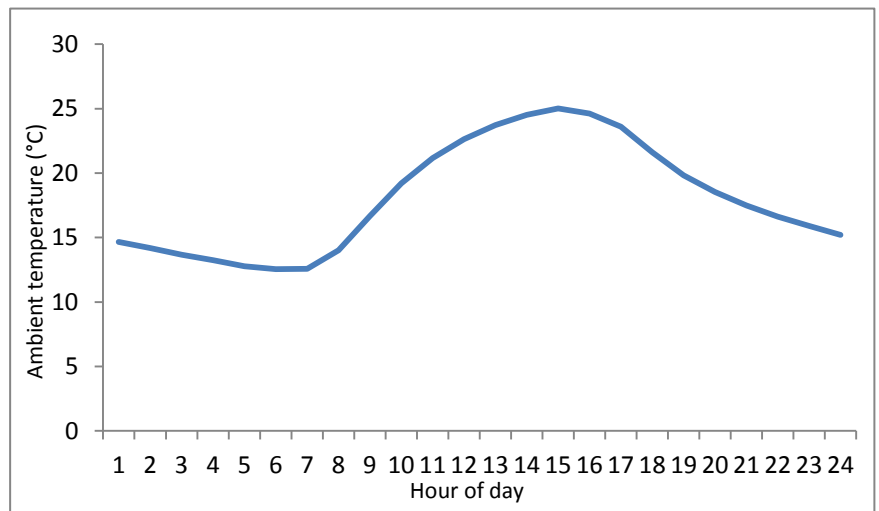
| Air pollution indicators | Meteorological indicators | Traffic density | Atmospheric mixing indicators | Time and date |
|--|--------------------------------------|-----------------|---|-------------------------|
| Nitrous oxide (NO) (pphm) | Ambient temperature (°C) | Total cars | Radon (Bq/m ³) | Day of the year |
| Nitrous dioxide (NO ₂) (pphm) | Relative humidity (%) | Total trucks | Fetch (advected) component of radon observation | Decimal day of the year |
| NO _x (NO + NO ₂) (pphm) | Wind speed (m/s) | | Diurnal (mixing-related) component of radon observation | Month |
| Ozone (O ₃) (pphm) | Wind direction (degrees) | | StabCat (Atmospheric Stability Category) | Day of the month |
| Sulfur dioxide (SO ₂) (pphm) | Standard deviation of wind direction | | | Day of the week |
| Particulate matter (<2.5um) (ug/m ³) | Atmospheric pressure (hPa) | | | Hour of the day |
| Particulate matter (2.5-10um) (ug/m ³) | | | | Public holidays |
| | | | | School holidays |

Task 1:

Pivot tables are a helpful feature in Microsoft Excel that allows you to analyse different variables in a large data set.

1. Highlight the whole data set. Go to **Insert > PivotTable** to insert a PivotTable in a new worksheet.
2. From the PivotTable Field List, drag **Season** to the **Report Filter** box, **Time** to the **Row Labels** box, and **Ta°C** to the **Values** box. This will create a PivotTable in the worksheet with two columns.
3. Click on the drop down arrow on the **Ta°C** in the **Values** box and select **Value Field Settings > Average**.
4. In the PivotTable in the worksheet, select **Autumn** from the **Season** drop down filter. Your PivotTable should now have two columns, the first labelled **Row Labels** with numbers 0 to 23, and the second labelled **Average of Ta°C**. This table represents the average ambient temperature for every hour of the day in Autumn, with "0" representing 12am, "1" representing a 1am, and so on.
5. Make a line graph, like the one below, to illustrate hourly ambient temperature on an average autumn day:

| Row Labels | Average of Ta°C |
|--------------------|--------------------|
| 0 | 14.67608696 |
| 1 | 14.19021739 |
| 2 | 13.67582418 |
| 3 | 13.24945055 |
| 4 | 12.77362637 |
| 5 | 12.55652174 |
| 6 | 12.5673913 |
| 7 | 14.01956522 |
| 8 | 16.68152174 |
| 9 | 19.21086957 |
| 10 | 21.16956522 |
| 11 | 22.63586957 |
| 12 | 23.73478261 |
| 13 | 24.52065217 |
| 14 | 25.01888889 |
| 15 | 24.61318681 |
| 16 | 23.61195652 |
| 17 | 21.62717391 |
| 18 | 19.82391304 |
| 19 | 18.54347826 |
| 20 | 17.48913043 |
| 21 | 16.63804348 |
| 22 | 15.9 |
| 23 | 15.20543478 |
| Grand Total | 18.08623978 |



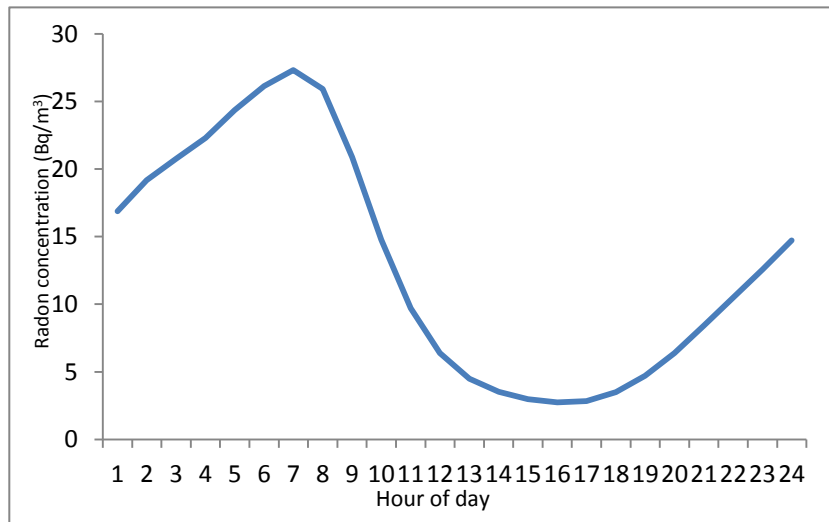
a) Describe how the temperature fluctuates over the course of an average autumn day

Task 2:

Modify the PivotTable in Task 1 to display hourly radon concentrations on an average autumn day. We have selected autumn, because days in autumn tend to be very still and

1. Delete **Average of Ta°C** from the **Values** box in the PivotTable Field List. Drag **Radon** into the **Values** box and use the dropdown arrow to select **Value Field Settings > Average**. You should now have a PivotTable with two columns, the first labelled **Row Labels** with numbers 0 to 23, and the second labelled **Average of Radon**.
2. a) Make a line graph to illustrate hourly radon concentration on an average autumn day

| | A | B |
|----|-------------|------------------|
| 1 | | |
| 2 | Season | Aut |
| 3 | | |
| 4 | Row Labels | Average of Radon |
| 5 | 0 | 16.87161732 |
| 6 | 1 | 19.16960884 |
| 7 | 2 | 20.76808993 |
| 8 | 3 | 22.29674757 |
| 9 | 4 | 24.37279496 |
| 10 | 5 | 26.14509557 |
| 11 | 6 | 27.33844992 |
| 12 | 7 | 25.92569505 |
| 13 | 8 | 20.88726818 |
| 14 | 9 | 14.7620109 |
| 15 | 10 | 9.69749438 |
| 16 | 11 | 6.384494894 |
| 17 | 12 | 4.499433657 |
| 18 | 13 | 3.519494844 |
| 19 | 14 | 2.971400169 |
| 20 | 15 | 2.728731919 |
| 21 | 16 | 2.844747769 |
| 22 | 17 | 3.497918143 |
| 23 | 18 | 4.701327835 |
| 24 | 19 | 6.385549814 |
| 25 | 20 | 8.422795224 |
| 26 | 21 | 10.4969139 |
| 27 | 22 | 12.57204039 |
| 28 | 23 | 14.72861427 |
| 29 | Grand Total | 13.01122427 |
| 30 | | |



b) Describe how radon concentration fluctuates on an average autumn day

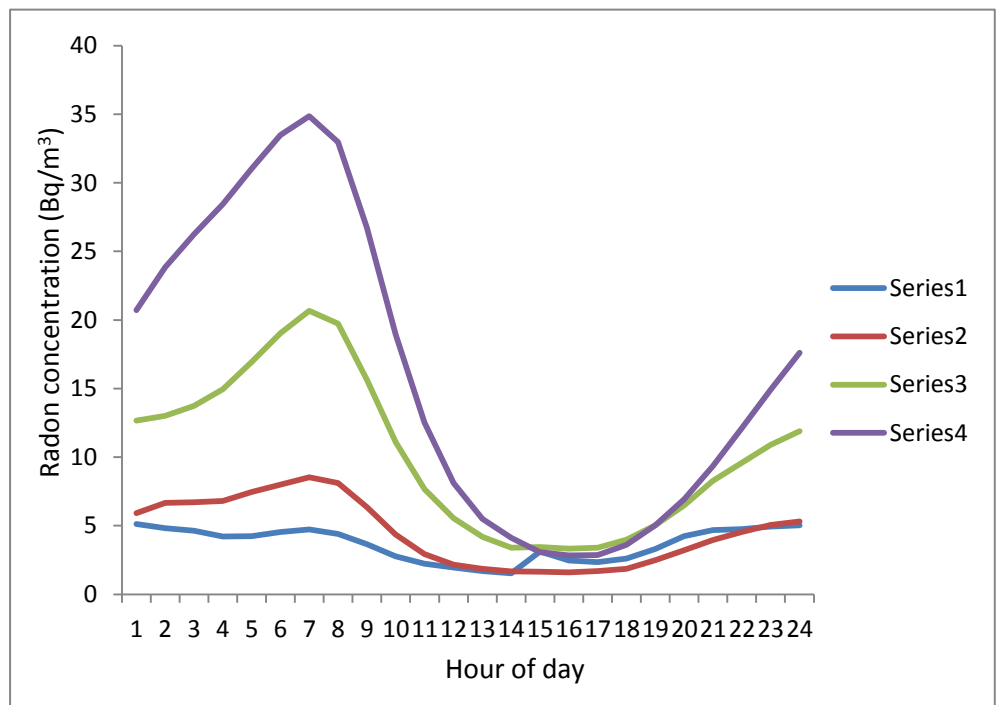
c) The source of radon is from rocks in the ground, and this does not change over the course of the day. After reading the background information, can you propose why radon concentrations show this pattern of change during the day?

Task 3:

Scott has described the atmospheric stability of each day of the year with a “Stability Category” (StabCat). A stability category of 4 are nights with the lowest wind speed and coldest temperatures, and StabCat 4 was allocated to the 25% of days in the year with the most stable atmosphere. A stability category of 1 are nights with the strongest wind speeds and hottest temperatures, and a StabCat of 1 was allocated to the 25% of days in the year with the least stable atmosphere.

1. Modify the PivotTable from Task 2 by adding **StabCat** to the **Report Filter** box. Use the dropdown arrow next to the StabCat field to display hourly average radon concentrations for days with different StabCat values.
2. a) Make a line graph to illustrate the hourly average radon concentration for days with StabCat ratings of 1, 2, 3 and 4.

| | A | B |
|----|-------------|------------------|
| 1 | Season | Aut |
| 2 | Stab Cat | 4 |
| 3 | | |
| 4 | Row Labels | Average of Radon |
| 5 | 0 | 20.70387218 |
| 6 | 1 | 23.84176984 |
| 7 | 2 | 26.23773127 |
| 8 | 3 | 28.42956479 |
| 9 | 4 | 31.0281964 |
| 10 | 5 | 33.48073148 |
| 11 | 6 | 34.84930861 |
| 12 | 7 | 32.97890726 |
| 13 | 8 | 26.72693939 |
| 14 | 9 | 18.94386325 |
| 15 | 10 | 12.52501613 |
| 16 | 11 | 8.110113642 |
| 17 | 12 | 5.502471471 |
| 18 | 13 | 4.124165775 |
| 19 | 14 | 3.06018675 |
| 20 | 15 | 2.825524879 |
| 21 | 16 | 2.850262843 |
| 22 | 17 | 3.598970814 |
| 23 | 18 | 5.038478913 |
| 24 | 19 | 6.926156757 |
| 25 | 20 | 9.352036276 |
| 26 | 21 | 12.09435802 |
| 27 | 22 | 14.90540113 |
| 28 | 23 | 17.61539837 |
| 29 | Grand Total | 15.96748556 |
| 30 | | |

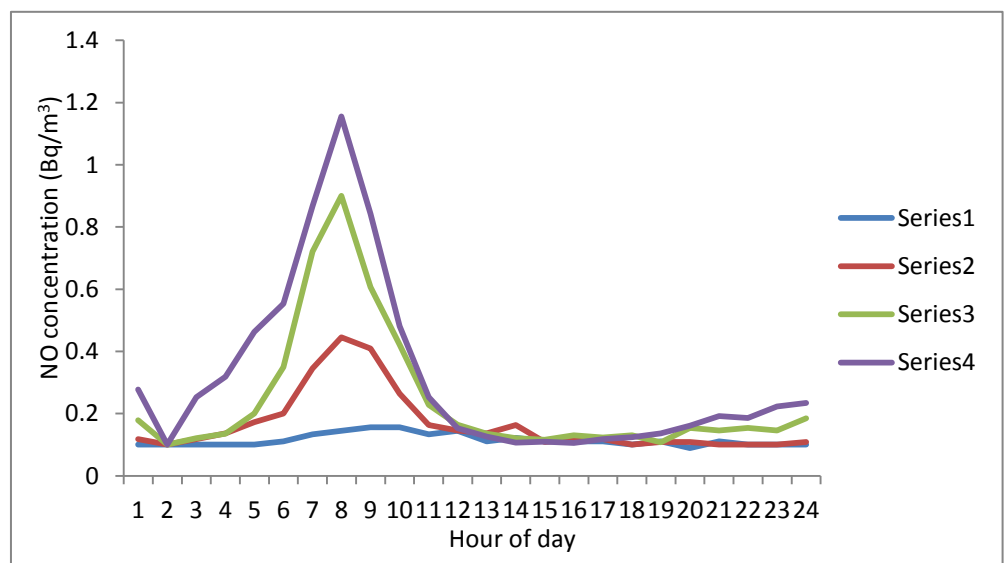


- b) Explain why the daily pattern of radon concentration is different for each StabCat value.

Task 4:

1. Modify the PivotTable from Task 3 by removing **Average of Radon** from the **Value** box in the PivotTable Field List. Drag **NO_pphm** into the **Value** box and use the dropdown arrow to select **Value Field Settings > Average**. You should now have a PivotTable with two columns, the first labelled **Row Labels** with numbers 0 to 23, and the second labelled **Average of NO_pphm**. Use the dropdown arrow next to the **StabCat** field to display hourly average NO concentrations for days with different **StabCat** values.
2. a) Make a line graph to illustrate the hourly average NO concentration for days with **StabCat** ratings of 1, 2, 3 and 4.

| | A | B |
|----|-------------|--------------------|
| 1 | Season | Aut |
| 2 | Stab Cat | 4 |
| 3 | | |
| 4 | Row Labels | Average of NO_pphm |
| 5 | 0 | 0.27755102 |
| 6 | 1 | 0.1 |
| 7 | 2 | 0.253061224 |
| 8 | 3 | 0.318367347 |
| 9 | 4 | 0.463265306 |
| 10 | 5 | 0.553061224 |
| 11 | 6 | 0.867346939 |
| 12 | 7 | 1.155102041 |
| 13 | 8 | 0.842857143 |
| 14 | 9 | 0.481632653 |
| 15 | 10 | 0.253061224 |
| 16 | 11 | 0.153061224 |
| 17 | 12 | 0.126530612 |
| 18 | 13 | 0.106122449 |
| 19 | 14 | 0.109259259 |
| 20 | 15 | 0.105555556 |
| 21 | 16 | 0.118367347 |
| 22 | 17 | 0.124489796 |
| 23 | 18 | 0.136734694 |
| 24 | 19 | 0.16122449 |
| 25 | 20 | 0.191836735 |
| 26 | 21 | 0.185714286 |
| 27 | 22 | 0.22244898 |
| 28 | 23 | 0.234693878 |
| 29 | Grand Total | 0.312478921 |
| 30 | | |



- b) Explain why the daily pattern of NO concentration is different for each **StabCat** value.

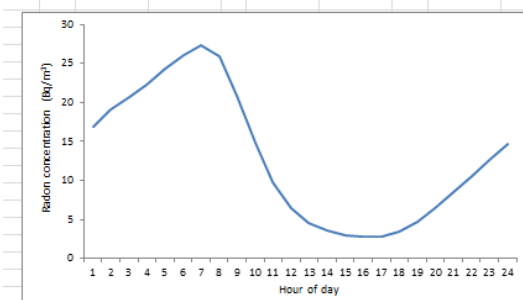
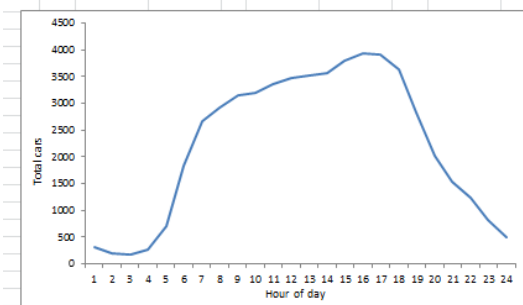
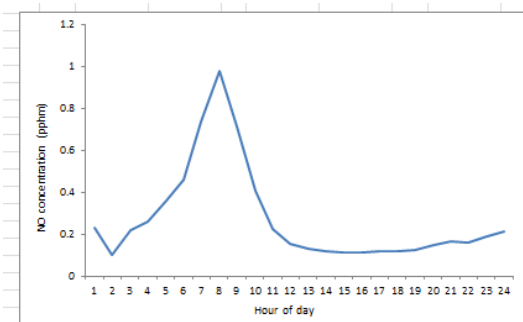
Task 5

Note: This time you will be creating your own appropriate PivotTable without step-by-step instructions.

1. Make the following graphs:
 - a) Number of cars during an average day in autumn
 - b) Concentration of NO during an average day in autumn
 - c) Concentration of radon during an average day in autumn

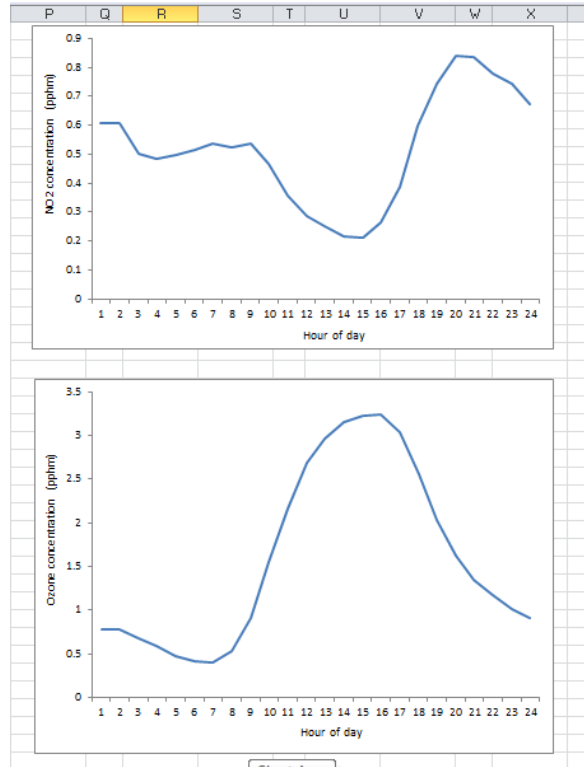
N.B. The air pollution monitoring equipment auto-calibrates itself at 1am every day. We recommend copying and pasting the value you have for 0 hours into the blank space for 1 hours, to ensure your graph is continuous.

| | A | B | C | D | E |
|----|-------------|--------------------|-----------------------|------------------|---|
| 1 | | | | | |
| 2 | Season | Aut | | | |
| 3 | | | | | |
| 4 | Row Labels | Average of NO_pphm | Average of Total_Cars | Average of Radon | |
| 5 | 0 | 0.231521739 | 318.4285714 | 16.87161732 | |
| 6 | 1 | 0.1 | 197.978022 | 19.16960884 | |
| 7 | 2 | 0.218478261 | 172.2222222 | 20.76808993 | |
| 8 | 3 | 0.258695652 | 257.0333333 | 22.29674757 | |
| 9 | 4 | 0.357608696 | 714.7802198 | 24.37279496 | |
| 10 | 5 | 0.458695652 | 1824.472527 | 26.14509557 | |
| 11 | 6 | 0.735869565 | 2675.406593 | 27.33844992 | |
| 12 | 7 | 0.980434783 | 2917.835165 | 25.92569505 | |
| 13 | 8 | 0.714130435 | 3149.604396 | 20.88726818 | |
| 14 | 9 | 0.406521739 | 3197.32967 | 14.7620109 | |
| 15 | 10 | 0.226086957 | 3362.978022 | 9.69749438 | |
| 16 | 11 | 0.154347826 | 3475.472527 | 6.384494894 | |
| 17 | 12 | 0.129347826 | 3512.164835 | 4.499433657 | |
| 18 | 13 | 0.117391304 | 3554.659341 | 3.519494844 | |
| 19 | 14 | 0.111956522 | 3790.197802 | 2.971400169 | |
| 20 | 15 | 0.110869565 | 3931.285714 | 2.728731919 | |
| 21 | 16 | 0.119565217 | 3905.538462 | 2.844747769 | |
| 22 | 17 | 0.120652174 | 3636.967033 | 3.497918143 | |
| 23 | 18 | 0.122826087 | 2824.164835 | 4.701327835 | |
| 24 | 19 | 0.145652174 | 2019.615385 | 6.385549814 | |
| 25 | 20 | 0.166304348 | 1547 | 8.422795224 | |
| 26 | 21 | 0.158695652 | 1227.813187 | 10.4969139 | |
| 27 | 22 | 0.185869565 | 829.2967033 | 12.57204039 | |
| 28 | 23 | 0.210869565 | 508.0549451 | 14.72861427 | |
| 29 | Grand Total | 0.272599638 | 2233.110907 | 13.01122427 | |



2. If NO comes from car exhaust, why doesn't the shape of the NO concentration graph match the shape of the total cars graph?

3. Make the following graphs:
 - a) Concentration of NO_2 during an average autumn day
 - b) Concentration of ozone during an average autumn day



4. Why are the shapes of these graphs different to the NO concentration graph?
