IB internal assessment: Measuring air pollution

Introduction

Air pollution is a serious issue in the environment. Pollution from cars or other vehicles contains toxic chemicals such as oxides of nitrogen and ozone that might affect living organisms. This could include harm to humans, livestock or plants and it is important to try and understand how widespread this harm might be.

The amount of air pollution can be indicated by lichens. Lichens do not grow in polluted areas such as roadsides, power plants and cities. Lichens are plants that grow on exposed surfaces of rocks and tree barks. They have to be good at absorbing water and nutrients to grow there. Rainwater contains just enough nutrients to keep them alive. Air pollutants dissolved in rainwater contain toxic chemicals that can damage lichens and prevent them from growing. This makes them natural indicators of air pollution. Some types of lichen can survive more pollution than others. Foliose are leafy, loosely attached lobed lichens that can tolerate a small amount of air pollution. Crustose lichens are in the form of a crust and can survive in more polluted air. In places where no lichens are growing it is often a sign that the air is heavily polluted.(1) In this experiment, I will measure the abundance of lichen in various areas. The experiment will take place in random locations around Luzern.

Research question

To what extent do distances from roads in different parts of Luzern affect the growth of lichens?

Hypothesis

If the gap away from the road increases, then the abundance of lichens will upsurge because there is a lower amount of pollution where the lichens can absorb enough rich nutrients to keep them alive.

Variable identification

Independent variable: Distance of lichen growth from a road.

Dependent variable: The number of lichens in the area of a grid.

Controlled variable: Height (1 metre) at which measurement is taken.

Apparatus

Measuring tape

Transparent grid sheet (19 x 27 cm^2) total 513 cm^2

Whiteboard pen (non-permanent)

Procedure

1. Choose a site where a road is next to an area where trees grow. Write a description of the site and take a photo.
2. With a measuring tape, measure 5 metres from the road to a tree.
3. Place the transparent 19 x 27 cm^2 grid on the tree, 1 metre above the ground.
4. With a non-permanent pen, dot each 1 x 1cm^2 square where there are lichens.
5. Count the dots on the transparent grid sheet and record the results.
6. Move the transparent grid sheet crosswise and repeat steps 4 and 5 until the whole circumference of the trunk is measured.
7. Add together all of the counted lichen dots and record the results.
8. Make four more trials, moving 5 metres further away from the road while measuring the distance, and repeat steps 3–7 by choosing another tree.
9. Repeat steps 1—8 in a different location.

Trial 1 This road is in a rural area where the number of cars that pass by is quite low.

Trial 2 This location is close to location 1 but has an automobile lot nearby, so there are more cars.

Trial 3 This road is near the centre of Luzern so it is urban, but there is no industry nearby and no trucks or lorries pass by.

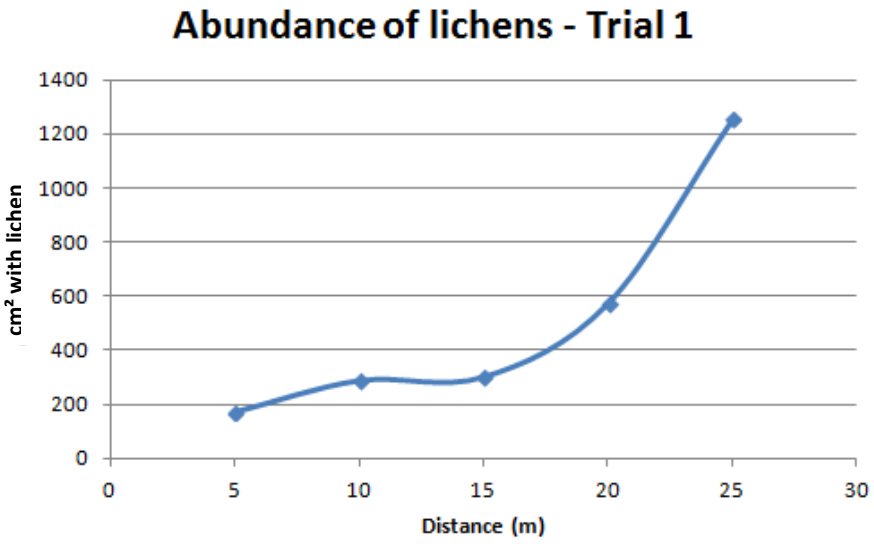
Trial 4 This road is in the city centre where cars pass regularly.

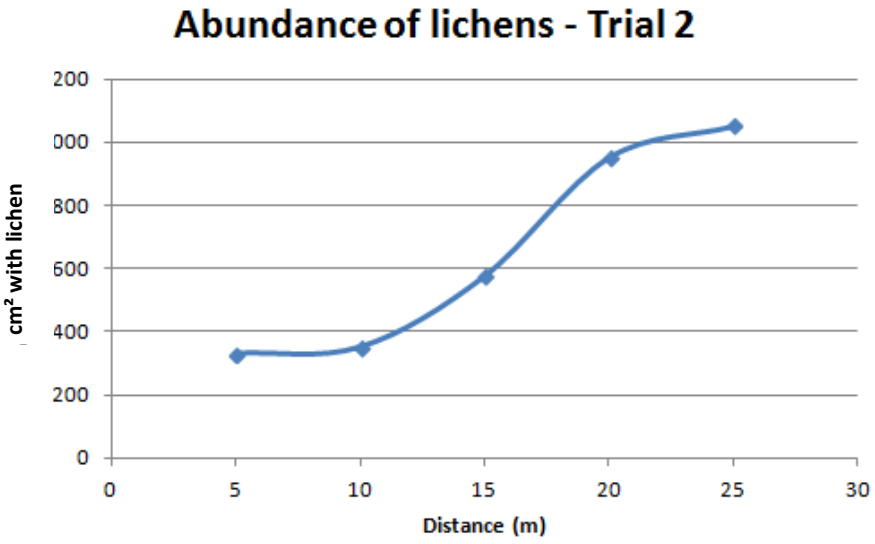
Trial 5 This location is near a freeway. Although the roadside is less built up than in trials 3 and 4, there is a lot of heavy traffic passing by.

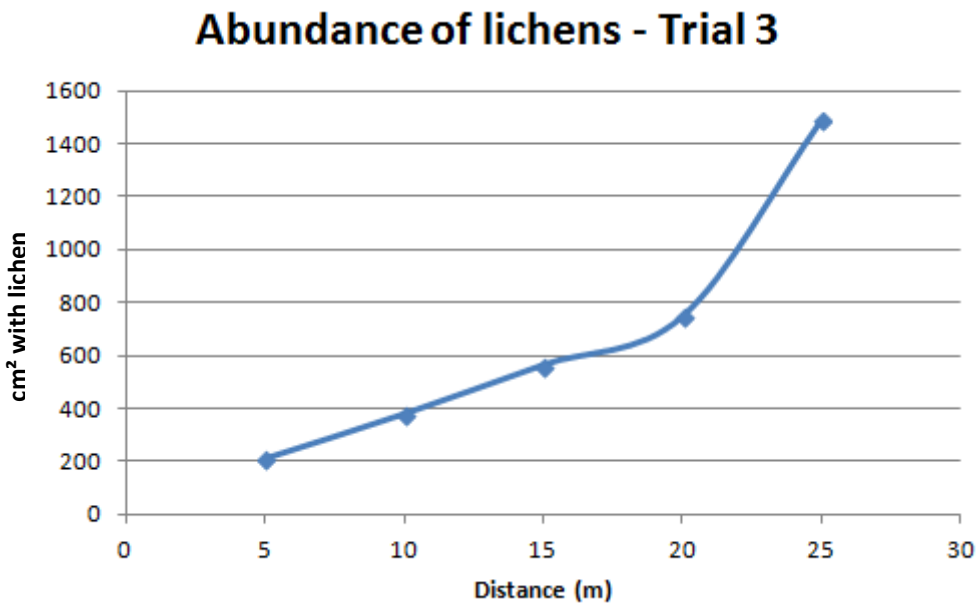
(All images from Google maps)

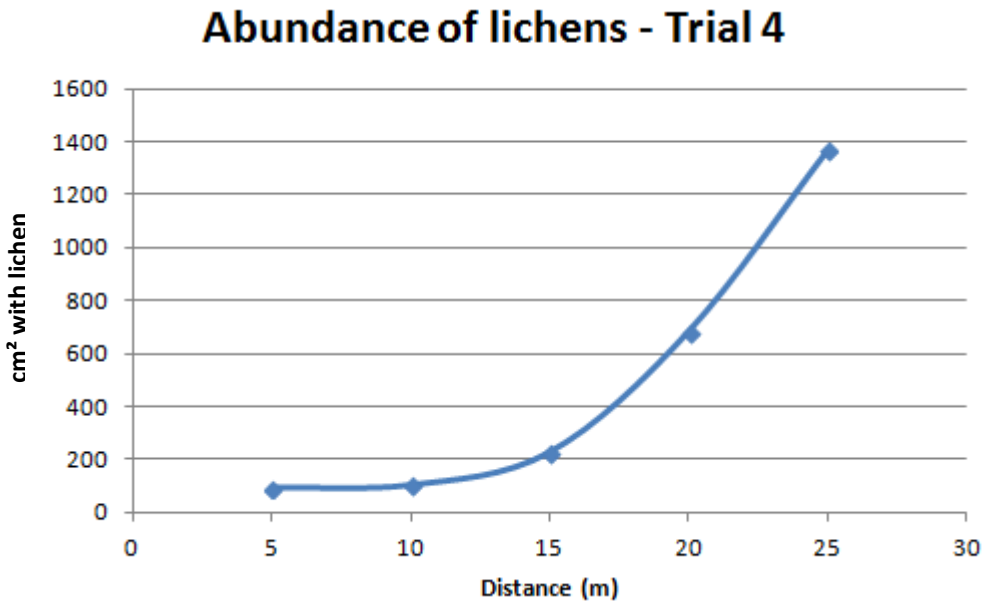
Data table of abundance of lichens vs. distance

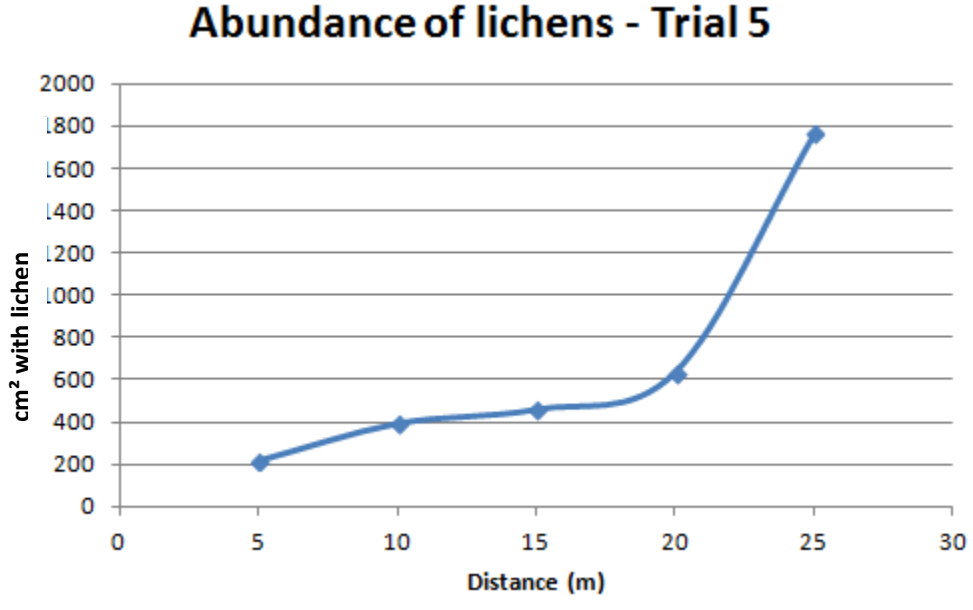
Distance (metres)	Lichen cm^2 trial 1	Lichen cm^2 trial 2	Lichen cm^2 trial 3	Lichen cm^^{2} trial 4	Lichen cm2 trial 5
5	171	330	211	93	212
10	288	350	380	103	389
15	301	575	565	227	456
20	573	952	748	683	632
25	1254	1050	1490	1367	1760






Abundance of lichens - Trial 3
cm² with lichen
1600
1400
1200
1000
800
600
400
200
0
0
5
10
15
20
25
30
Distance (m)


Abundance of lichens - Trial 4
cm² with lichen
1600
1400
1200
1000
800
600
400
200
0
0
5
10
15
20
25
30
Distance (m)

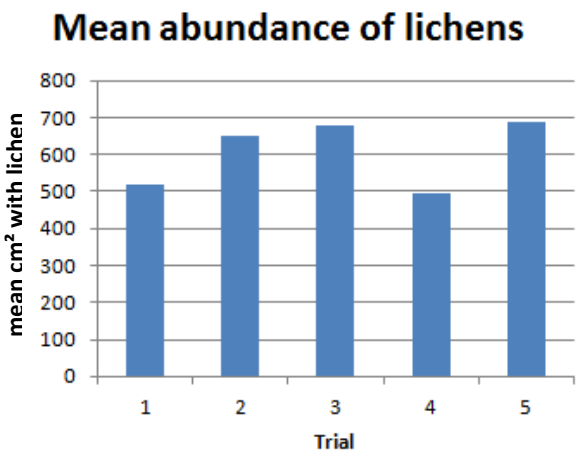

Abundance of lichens - Trial 5
cm² with lichen
2000
800
600
400
200
0
0
5
10
15
20
25
30
Distance (m)

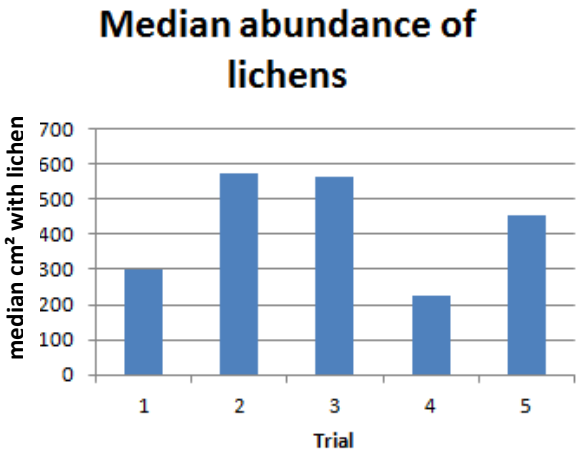
Calculations

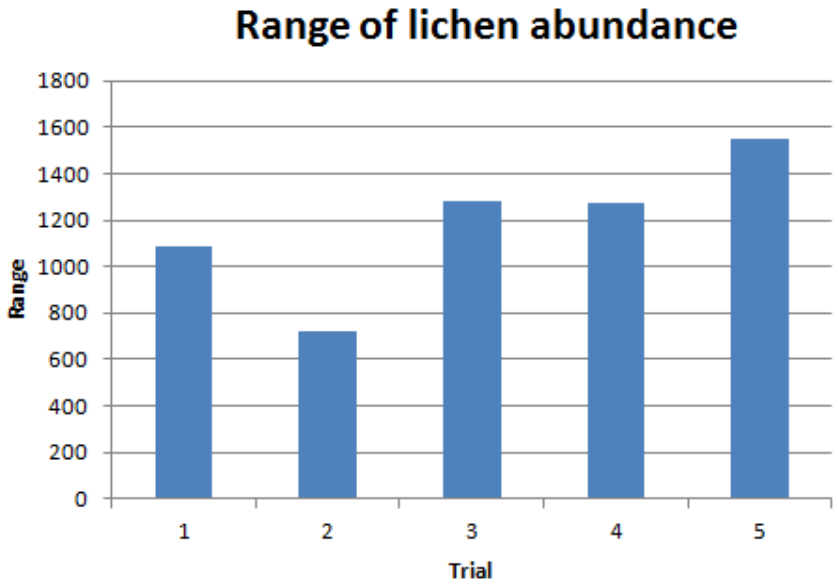
Mean
Trial 1: 171 + 288 + 301 + 573 + 1254 = (2587 ÷ 5) = **517**
Trial 2: 330 + 350 + 575 + 952 + 1050 = (3257 ÷ 5) = **651**
Trial 3: 211 + 380 + 565 + 748 + 1490 = (3394 ÷ 5) = **679**
Trial 4: 93 + 103 + 227 + 683 + 1367 = (2473 ÷ 5) = **495**
Trial 5: 212 + 389 + 456 + 632 + 1760 = (3449 ÷ 5) = **689**

Median
Trial 1: **301**
Trial 2: **575**
Trial 3: **565**
Trial 4: **227**
Trial 5: **456**

Range
Trial 1: 1254 – 171 = **1083**
Trial 2: 1050 – 330 = **720**
Trial 3: 1490 – 211 = **1279**
Trial 4: 1367 – 93 = **1274**
Trial 5: 1760 – 212 = **1548**







$$s = \sqrt{\frac{\sum(x - \bar{x})^2}{n - 1}}$$

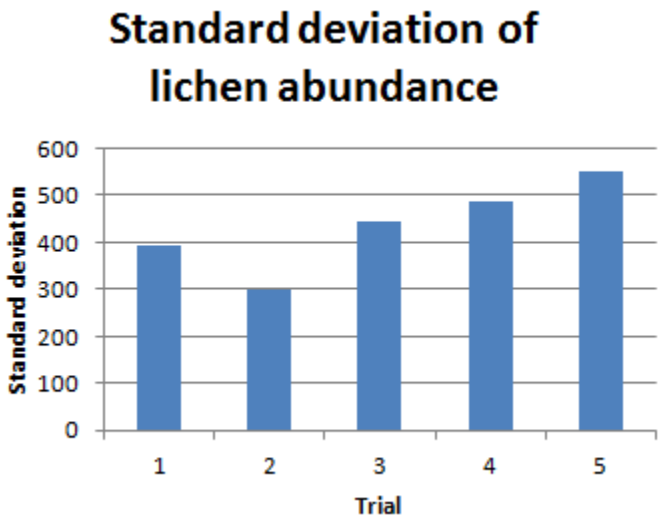
Trial 1
σ = √[∑ (x − 517.4) 2 ÷ 5]
σ = √[((171-517.4) 2 + (288 − 517.4)2 + (301 − 517.4) 2 + (573 − 517.4) 2 + (1254 − 517.4) 2) ÷ 5]
σ = √[((−346.4) 2 + (−229.4) 2 + (−216.4) 2 + (55.6) 2 + (736.6) 2) ÷ 5] =
σ = √[(119993 + 52624.4 + 46829 + 3091.36 + 542580) ÷ 5] = 153023.552
σ = √[(153023.552) ÷ 5] = 153024.552
σ = √[153024.552] = **391**
σ = **391**

Trial 2
σ = √[∑(x−)2 ÷ 5]
σ = √[((330 ÷ 651.4) 2 + (350 − 651.4) 2 + (575 − 651.4) 2 + (952 ÷ 651.4) 2+ (1050−651.4) 2) ÷ 5]
σ = √[((−321.4) 2 + (−301.4) 2 + (−76.4) 2 + (300.6) 2 + (398.6) 2) ÷ 5] =
σ = √[(103298 + 90842 + 5836.96 + 90360.4 + 158882)] = 449219
σ = √[(449219) ÷ 5] = 89843.9
σ = √[89843.9] = **299.74**
σ = **300**

Trial 3
σ = √[∑(x−)2 ÷ 5]
σ = √[((211 − 678.8) 2 + (380 − 678.8) 2 + (565 − 678.8) 2 + (748 − 678.8) 2 + (1490 − 678.8) 2) ÷ 5]
σ = √[((−467.8) 2 + (−298.8) 2 + (113.8) 2 + (69.2) 2 + (811.2) 2)]
σ = √[(218837 + 89281.4 + 12950.4 + 4788.64 + 658045)] = 983902.44
σ = √[(983902.44) ÷ 5] = 196780.488
σ = √[196780.488] = **443.6**
σ = **444**

Trial 4
σ = √[∑ (x−) 2 ÷ 5]
σ = √[((93 − 494.6) 2 + (103 − 494.6) 2 + (227 − 494.6) 2 + (683 − 494.6) 2 + (1367 − 494.6) 2)]
σ = √[((−401.6) 2 + (−391.6) 2 + (−267.6) 2 + (188.4) 2 + (872.4) 2)]
σ = √[(161283 + 153351 + 71609.8 + 35494.6 + 761082)] = 1182820.4
σ = √[(1182820.4) ÷ 5] = 236564
σ = √[236564] = **486.4**
σ = **486**

Trial 5
σ = √[∑ (x−) 2 ÷ 5]
σ = √[((212 − 689.8) 2 + (389 − 689.8) 2 + (456 − 689.8) 2 + (632 − 689.8) 2 + (1760 − 689.8) 2)]
σ = √[((-477.8) 2 + (−300.8) 2 + (−233.8) 2 + (−57.8) 2 + (1070.2) 2)]
σ = √[(228293 + 90480.6 + 54662.4 + 3340.84 + 1145328.04)]
σ = √[(1522104.88) ÷ 5] = 304421
σ = √[304421] = **551.7**
σ = **552**



Discussion

In each trial, I noticed that the abundance of lichens increased when I got further away from the road. Each trial consisted of different levels of pollution within the city and so the pattern of increase was different. By looking at the range of values, as well as mean and median values, I can see how the lichen in each area is changing.

Trial 1
As I did the first trial, the abundance of lichens was escalating as I moved away from the road. The abundance of lichen went from 171 cm^2 to 1254 within 25 metres and with a mean of 517.4 cm^2. This suggests that the amount of pollution nearby the road is extremely high and lichens are having trouble retaining their nutritional needs to grow. The median of the first trial is 301 cm^2, which is in the low range in comparison to the other trials. The range is 1083 cm^2, which is an enormous difference between the richness of lichen within the closest and the furthest distance. The graph of standard deviation demonstrates the spread of data that exists from the mean.

A low standard deviation indicates that the data points tend to be very close to the mean; high standard deviation shows that the data points are spread out over a large range of values. In trial 1 the standard deviation is fairly high because the data is spread widely over a large range of values. (2) The standard deviation of data is 229.7 cm^2, and is 75.6% adjacent to the mean. This suggests that the abundance of lichens is cumulating.

Trial 2
This area has fewer buildings but more automobiles. The abundance of lichens has slowly risen when comparing it to the first trial, but the rise of abundance was less significant. According to the graph, the frequency started out slow and eventually sped then decelerated, this suggests that the quantity of lichen is slowly averaging out. The average abundance of lichen is 651.4 cm^2, which is greater than the previous. The reason is because there is more infrastructure and more automobiles in trial 1 than trial 2. According to my graph, the median of trial 2 is 575 cm^2, which ranks second in contrast with the other trials. This denotes the magnitude of lichens in the area. The range of 720 cm^2 proposes a huge gap between the 5-and 25-metre mark, although my graph of ranges demonstrates a very low alteration in comparison to the other trials. The quantity from 5 metres to 25 metres has increased to 69%. The range of trial 2 is an outlier because it is lower than 1000 cm^2 as when the other trials are over 1000 cm^2. My second trial shows a significant constricted distribution because the standard deviation is very low and further than the mean. The standard deviation is 299.7 cm^2 and 54% away from the mean. According to my statistical graph of abundance of lichen vs. distance, I noticed that the alteration of data is very slow. Not many lichens were abundant from 5 to 25 metres in comparison to trials 4 and 5. The range also shows the narrow difference between the highest and

Trial 3
The abundance of lichens was increasing at a steady rate and increased up to 50% on the last 25-metre mark. This means that the nearby road is extremely polluted because of cars but not because of acid raid, otherwise there would not be any lichens in the area. The smoke from the automobiles creates a big impact on the 50% increase of the abundance of lichens. According to my data, the mean is 768.8 cm^2, which is fairly high in comparison with the other trials. The median of trial 3 is 565, which is also amongst the uppermost range. This indicates the cleanliness of the air quality because a large number of lichens are able to grow there. The range is almost same as trial 4, with a range of 1279 cm^2. The range is substantial because the magnitude of lichens has increased to 86% just within 25 metres. The standard deviation of trial 3 is spread out over huge values just like the first, fourth and fifth trials. The standard deviation of trial 3 is 443.6 cm^2, which is a decent variation from the mean of 678.8 cm^2.

Trial 4
My graph of abundance of lichen vs. distance demonstrates a stable geometric growth. After the first 10 metres, the abundance remained flat from 93 to103, then the number doubled, then tripled, after when it reached the 15-metre mark. The mean of the data is 494.6 cm^2, which is the lowest mean of all the trials. This suggests that there is a heavy volume of air pollution in the area. The cause of this is automobiles parking and the large infrastructures, plus it is located in the middle of a town. The range of values is 1274 cm^2. The significant of the values are huge because abundance of lichen increased from 93 cm^2 to 1367 cm^2 within 25 metres. This signifies the greatness of the lichens' sensitivity to pollution. The quantity of lichen has increased 13 times from the 5-metre line to the 25th. The medium of trial 4 is 227 cm^2, which is the lowest medium in comparison to the other trials. The lessons of the median lichen abundance indicate the greatness of pollution. Trial 4 has an extremely spread-out set of data; its standard deviation is 486, which is 98% away from the mean. This indicates the range will also have a high value where there is a huge difference between the maximum and the minimum. The curve on the graph of abundance of lichen vs. distance demonstrates a sudden increase from 93 cm^2 to 1367 cm^2 of lichens, therefore making the data much distributed from the mean.

Trial 5
My lichen vs. distance graph demonstrates a steady state arithmetic growth until 20 metres, then it escalates up to 1760 on the 25-metre mark. The abundance has raised 278% within 20–25 metres. The mean is 689.8 cm^2 and is the highest mean so far when in contrast with the previous trials. The median of 456 cm^2 is not as high as the previous results, but is worth considering the acceleration stated before the 20-metre mark. The range is 1548 cm^2, which is by far the highest range of all the trials. The high range shows the great cleanliness of the area. From 212 cm^2, it has raised up to 1760 cm^2 just within 25 metres. The values within that distance rose up to 89%. Trial 5 has a similar standard deviation of 551.7 cm^2, which is almost similar to the standard deviation of trial 4. The data is distributed 80% away from the mean, which means that the values are spread over a large range of data.

Conclusion

Lichens can detect air pollution because they are sensitive. My results show that lichens are more abundant in cultivated areas than urban areas. As the distance away from the polluted zones increases, there is bigger chance of lichen growth. All the data I found lies within a certain pattern. There are numerous similarities and differences among all of the trials I have done. Overall, my data showed very similar results. The further I went back from the roadside, the abundance of lichens increased. For example, in trial 1, the result increased from 171 cm^2 to 1254 cm^2 within 25 metres. I discovered that there are similar patterns in all of my trials. The mean and range shows a steady increase as the abundance of lichens upsurges. I have also discovered that when the abundance of lichens increased steadily the standard deviation remains low. As the range of 5–25 metres becomes far apart, the standard deviation will increase and therefore make room for more errors. The closer together the data are, the easier to determine the overall measurement of lichens and chance of error.

Evaluation

As I did the experiment, I was facing numerous problems when counting the lichens. When I first did the experiment, I placed the transparent plastic sheet over one part of each tree and I found out that all my data was the same. I changed the method by measuring the lichens all around the tree at 1 metre in height, rather than measuring only one spot of the tree. Another weakness I faced was finding perfect spots to perform my experiments. Sometimes the trees were too close together or too far apart. Fortunately, I found spots that were abundant with trees; therefore it was easier to work out the measurements that way. I did not take into account whether other factors, such as light intensity, could have been affecting the lichens, because some trees were shaded and others not.

My strengths were collecting the results, which was straightforward to do. There was little room for error in my experiment even though the most of the values did not support my hypothesis.

To improve the investigation I could try to count the number of cars and trucks that were going past the spots where I was testing. Even though I chose the spots carefully by using my knowledge of the area, I did not get information to confirm that there were more cars and trucks in the urban areas compared to the cultivated areas. It would have been hard for me to count cars at the same time as measuring lichens, but if I had got help from a partner, I could have done it.

Solution

Looking at the abundance of lichens can tell us about levels of pollution in rainwater and the air that might be difficult to measure using expensive apparatus. This can give us important information about pollution that may be harmful to the people who are living or working close to the trees. It might also be useful to use these studies to see if a particular site would be suitable for projects such as building schools or raising livestock.

From my studies, I would recommend that new buildings in urban areas would be safer for people if they were placed more than 20 metres away from the road.

Word count: 2207

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