Teachers manual Teatime4science

Instructions & background material

Universiteit Utrecht

Vetenskapsrådet

TEABAG EXPERIMENT

Great that you and your class are going to help us and participate in Teatime4science, the Teabag experiment!

Judith Sarneel, researcher at the Department of Ecology and Environmental Science at Umeå University

Iris van Hamersveld, Project assistant at the Department of Ecology and Biodiversity at Utrecht University

This teacher's guide provides background information to the experiment, detailed instructions and suggestions on integration it with other subjects.

This tea bag experiment is designed by Judith Sarneel, researcher at Umeå University, in collaboration with researchers from the Netherlands and Austria and Vetenskap & Allmänhet from Sweden. Last year 250 Swedish schools participated, and this year we hope to get the help of students in the UK, the Netherlands and Belgium. This project is funded by The Swedish research council Vetenskapsrådet.

The experiment will be conducted in 2016, and in March 2017 you will receive a summary of the results.

ENJOY!

Instructions for the experiment can be found on page 9.
Please join the Facebook group: https://www.facebook.com/groups/teatime4science/
Here you can ask questions about the experiment and see questions and answers from the other participants.

Judith Sarneel, researcher, Umeå University, Sweden
Fredrik Brounéus, project leader of The Teabag Experiment 2015, Vetenskap & Allmänhet, Sweden
Iris van Hamersveld, project assistant, Utrecht University, The Netherlands
Elisabet Carlborg, Project assistant, Umeå University, Sweden

Thanks to: Emilie Fredriksson, Eva Domingo Gómez, Bettina Kaphingst, Anders Sahlman

CONTENT


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Green Tea
Lipton
Rooibos
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Thé Vert
Green Tea

SUMMARY

Decomposition, that is the decay of plant parts (organic material), is a vital process for life on earth. Decomposition occurs when tiny soil organisms such as insects, fungi and bacteria eat the organic material and convert it into nutrients, soil and gas.

One of the gases that is generated is carbon dioxide. In the atmosphere, carbon dioxide contributes to warming our planet through the greenhouse effect. During the past century, human activities have increased levels of carbon dioxide in the atmosphere dramatically, with the ongoing global warming as a result. As the increased temperature in turn affects the decomposition, it is important to study this interaction in detail.

In the Tea bag experiment students will use a simple method to examine how much of the various types of plant parts are decomposed and thus converted into gas, nutrients and soil. The method is to bury tea bags and then dig them up again after about three months.

In the experiment, half of the tea bags will get a special treatment. A plastic cylinder will be placed over the location where the tea bag is buried. The plastic cylinder will function as a small "mini-greenhouse" and will increase the temperature of the soil with a few degrees. In this way, the effect of global warming on decomposition can be simulated and measured.

The difference in tea bag weight before and after it has been buried can be used to calculate how much was decomposed at your location. With the help of the weight losses, Judith Sarneel and Iris Hamersveld will calculate the so-called **Tea Bag Index**, which will be incorporated into the global soil map of decomposition. This map can be used as input to improve climate modeling. Thereby the students contribute to a real global research project.

In the Tea bag project, the students will participate in real research and at the same time learn:

- That there is a biological activity in the soil which converts dead (plant) material into for example carbon dioxide, nutrients and soil.
- That decomposition depends on environmental factors such as moisture and temperature.
- That decomposition is an important process that has a direct impact on the global climate.
- That science can be fun.

BACKGROUND

What is decomposition?

A leaf falls from a tree, lands on the ground and turns into soil. The soil provides nutrients to the tree, which can thereby form new leaves. Decomposition occurs in between, when the "decomposers" - tiny organisms, fungi and bacteria in the soil - eat up the organic matter and turn it into nutrients (a process called mineralization) and soil. Soils are really crowded with such organisms. Under one foot print, ca 50 000 nematodes, 9500 mites and 750 springtails can be found *(Ottosson and Widlund, 2004).* Through decomposition, plants and small soil organisms are provided with food to grow and thrive. When plants remains decompose, their weight reduces, while the gas carbon dioxide (CO2) is released into the atmosphere. Decomposition of plant remains, or "organic matter" is therefore a crucial process for life on our planet.

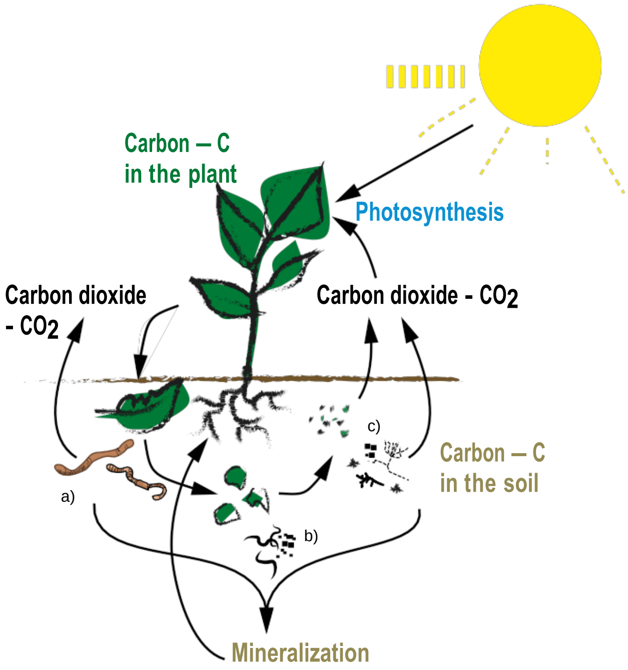


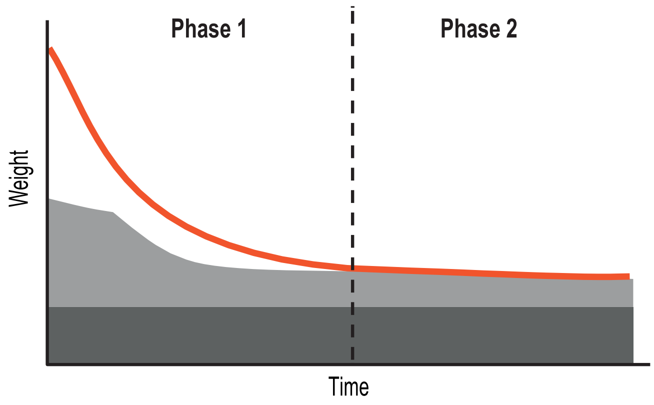
Figure 1: The carbon cycle. The arrows show the way carbon is converted. During photosynthesis, plants will take up carbon dioxide from the atmosphere and convert it into organic material (e.g. carbohydrates, wood or fats). When plants and other organic materials decompose, carbon dioxide is released back into the atmosphere. Organic materials that are not decomposed will be stored in the soil. Mineralization means that decomposition makes minerals available for plants.

Examples of decomposers:
a) Land living animals such as beetles and earthworms
b) Nematodes and unicellular animals
c) Bacteria's and fungi

The tiny decomposers in the soil depend on different factors in their environment as they do not have a thick skin or cloths to help them, for instance, to have a constant body temperature. Therefore, decomposition is slower in cold climates and faster in warmer climates. This also means that in colder climates, less carbon dioxide will be released into the air and more is stored in the soil.

The decomposition rate depends on:
1. Environmental conditions (humidity, acidity, the amount of nutrients in the soil, temperature). These factors affect the activity of the microorganisms; how fit they are and how much food they need.
2. The chemical properties of the material that is going to be decomposed (e.g. a branch compared to a flower or plastic compared to paper). This is because microorganisms prefer some materials over other. Just like us the microorganisms love to eat sugar, but are not so fond of harder materials like wood.
3. Which decomposers are present. Mites, worms, fungi and bacteria all break down the different parts at different speeds.

All organic materials consist of a mixture of materials that are easy to decompose (for example sugars) and materials that are difficult to decompose (e.g. wood/lignin). As different materials will decay with different rates, the whole decomposition process can be separated into two phases (*see figure 2*).



• Red line shows the decomposition.
• The colours below the line show what happens with different leaf components. White indicates easy decomposable materials, such as sugars.
• The grey area shows the parts that are harder to decompose, of which leftovers are barely decomposed.
• The dark grey area shows leaf parts that are really hard to decompose, such as lignin.

Figure 2: Weight loss for organic material during the two phases of decomposition.

In **phase 1** all labile, easy to degrade material is decomposed, and the decomposition rate is fast. During the process a certain amount of the material is converted into material which is harder to decompose, which can be considered as left overs (for instance, you chew on chewing gum, but at one point the taste is gone and it looks different than before). This material is *stabilized*.

In **phase 2** only recalcitrant materials remain, and the decomposition rate is therefore very low. This recalcitrant material will become part of the soil.
The decomposition rates in both phases depend on the three factors mentioned above (environmental conditions, chemical properties of the plant materials and the composition of the decomposer community).

When researchers study the decomposition of plant material they usually calculate the decomposition rate called *k*. The value of *k* usually varies between 0.01 and 0.04, with the lowest value in the cold climate and the highest in the warm. Another constant is called *S* which stands for stabilization factor. The stabilization factor indicates how much of the plant parts will stabilize. Stabilization usually ranges from 0.05 to 0.6 with lower values for warmer or moist locations.

Decomposition and climate change

About a hundred years ago, the atmosphere contained ca. 0.03 per cent of carbon dioxide (CO_2). Today, the level of carbon dioxide has increased to approximately 0.04 percent, which is a very large increase.

Carbon dioxide is a so-called greenhouse gas, which means that it contributes to warming of the earth. Solar radiation warms the earth. Part of the earth's thermal radiation bounces back into the atmosphere and returns to the earth's surface instead of radiating out into space (see Figure 3). The amount of greenhouse gasses in the atmosphere determines how much of the earth's warmth is retained in the atmosphere. This warming effect is called the "greenhouse effect". In this way more energy remains in the atmosphere, allowing the temperature to increase. One could say that greenhouse gasses determine how dense and thus warm the blanket around the earth is. During the past century, human use of fossil fuels (such as oil and coal) has contributed to increased carbon dioxide levels far above normal levels, leading to further warming. Global warming is now one of the biggest challenges for humanity.

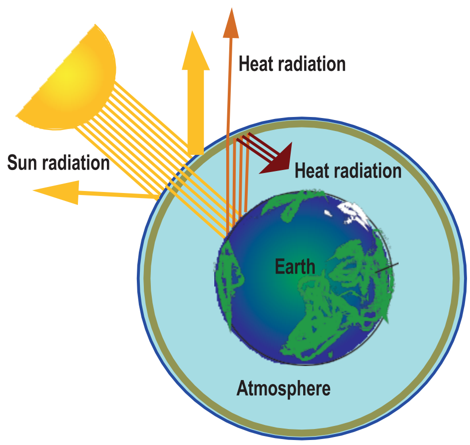


Figure 3: A schematic picture of the greenhouse effect.

The amount of carbon dioxide in the air we breathe is a balance between how much carbon dioxide plants *take up* during photosynthesis[1] and how much carbon dioxide *is released* – e.g. during decomposition. Changes in decomposition can therefore affect climate (i.e. faster decomposition leads to *more carbon dioxide* in the atmosphere and *warmer climate*, while slower decomposition results in *less carbon dioxide* and *colder climate*). However, as we also saw that climate affects decomposition, and knowledge on this feedback is therefore very important. Given the large amount of carbon stored in the soil (2700 billion tons, gig tons, Gt) compared to in the living plants (575 Gt) and in the air (780 Gt), changes in decomposition can have very big effects.

Decomposition research

In order to understand and predict the emissions of carbon dioxide from soils around the world, it is important to know decomposition rates in different types of soils and to test how it is affected by climate change.

What is for example the difference between a peatland in northern Scotland, a mixed forest in the Netherlands and arable field in Spain? The soils will likely vary in terms of temperature, moisture and fertilization. Measuring decomposition in many different kinds of soils will help the researchers of the Teatime4science project to understand the role of decomposition for global warming.

Many researchers on many different places on earth have tried to measure the decomposition. However, they used many different methods and materials in their experiments, which makes it impossible to compare results between all those experiments.
Another problem is that many methods for measuring decomposition rates require a lot of effort.

Sometimes, researchers simulate the effects of climate change by placing plastic cylinders over a piece of soil. These cylinders are called "open top chambers" and serve as mini-greenhouses which slightly increase soil temperatures. They compare soils inside those open top chambers to similar locations without the open top chambers. For instance, when they test the effect of warming on decomposition, researchers will compare the weight loss of plant material which is located under the plastic cylinder with the weight loss of material outside the cylinder. Since all other factors on the site are the same (such as the amount of rain) differences in weight loss can be attributed to an increased temperature due to climate change.

Recently, a new method was developed to investigate the decomposition. The new method is called *Tea Bag Index* and uses tea bags with plastic mesh bags. The tea inside the bags is plant material and decomposes just like all other plant material. By using tea bags, it becomes much easier to do experiments with exactly the same method. It will thereby become possible to compare the results. With use of the decomposition observed in the tea bags (i.e. the weight loss after 3 months) The Tea Bag index is calculated consisting of decomposition rate (k) and a stabilizing factor (S).

The Tea bag method

The tea bag experiment uses two types of tea: **green tea** and **red tea** (rooibos tea). Green tea is made from materials that are easily decomposed by microorganisms while red tea is woodier and therefore more difficult to decompose. By comparing the decomposition of these two different kinds of tea, it becomes visible that decomposition of a branch and a leaf differ.

Both tea types are buried for three months. Since the two tea types differ in material composition, the green tea with its easily degradable material will decompose faster than the red tea. Because of this, green tea will already have reached the second phase of decomposition after three months, and the remains of green tea consists of the recalcitrant material plus the *stabilized* material.

[1] In the photosynthesis, green plants use carbon dioxide, water and solar energy to produce oxygen and carbohydrates.

The red tea decomposes slower and after three months, it will still be in the first phase of decomposition *(see Figure 2).* In this way, the different types of teas are indicative of the different phases of decomposition of organic material.

Did you know......

1. Each cubic meters (m^3) of wood stores over 200 kg carbon.

2. The Scottish peatlands are important for sequestering carbon. Partly because there is a lot of peat, and partly because decomposition is very slow in peat, as the wet conditions do not provide decomposers with enough oxygen.

3. In the tropics, the degradation rate is very high and a fallen leaf is gone within a month. In a colder climate, as in northern Scotland, it takes more than ten years.

4. Degradation time for an orange peel is 2-5 weeks[2]

5. It takes at least 10 years for an ice cream stick of wood to decompose, and under certain circumstances, it may take millions of years before the stick has been totally decomposed[3].

6. In the last 30 years, the global average temperature, both on land and in the oceans, has increased by about 0.85 degrees Celsius[4].

7. The different scientific models to predict the temperature rise due to climate change says that the global temperature will increase by 1-4 degrees Celsius during this century. Differences between models are due to uncertainties of the estimates of how much human activity will increase (and how we think this affects, for example, the decomposition process).

TEA BAG EXPERIMENT – HOW IT WORKS!

In the Tea bag experiment you will make your own "mini-greenhouse" experiment by placing a cylinder of a PET bottle on top of half of the buried tea bags. The temperature in the soil will rise by some degree below the cylinders, and in this way we can study the greenhouse effect on decomposition. The tea bags with and without bottles are all buried in the same location.

Material

The following material are needed for the experiment.
You need mostly cheap and reusable materials. The only equipment you need is a scale (with at least 0.01 digits).

Research kit:

- 8 Lipton Rooibos tea bags
- 8 Lipton Green tea bags
- 2 soil thermometers (looks like small watch batteries) **NOTE!** They should remain in the plastic bags throughout the experiment
- Plastic tube with lid to send the dried soil samples in
- Form
- Return envelope for the soil samples and soil thermometers.

Other material:

Which you have to collect yourself

- 7 empty 1.5 L soda bottles. (To all use the same bottles we suggest you use water bottles that have uncolored, thin plastic, with a diameter of 10 or 11 cm. Suggestions are indicated on page 13).
- Saw or proper scissors
- A scale (0.01 digits). A scale can be bought online at amazon. Or local pharmacies and jewelers may have such scales.
- Waterproof marker pen, black
- Spade or spoon
- Sticks to mark where the tea bags are buried (such as barbecue sticks or straw)
- Transparent tape
- Ruler
- 4 plastic bags (1 liter)
- Hammer (may occasionally be required to take the soil sample)
- A warm and preferably sunny spot indoors where the tea bags and soil samples can dry when you have dug them up (such as a window sill)

On website (www.decolab.org/tbi) ready by June:

- Instruction film for how to dig down the tea bags
- Instruction film for how to take a soil sample
- Instruction film for how to use the digital scale

Method overview

You can divide the work between you and the students in the way that suits the students' age and educational purpose. We provided some suggestions for labour divisions between teachers (**T**) and students (**S**).

In the experiment, you will dig down a total of 12 tea bags - 6 red and 6 green - at three different locations *(see Figure 4).*

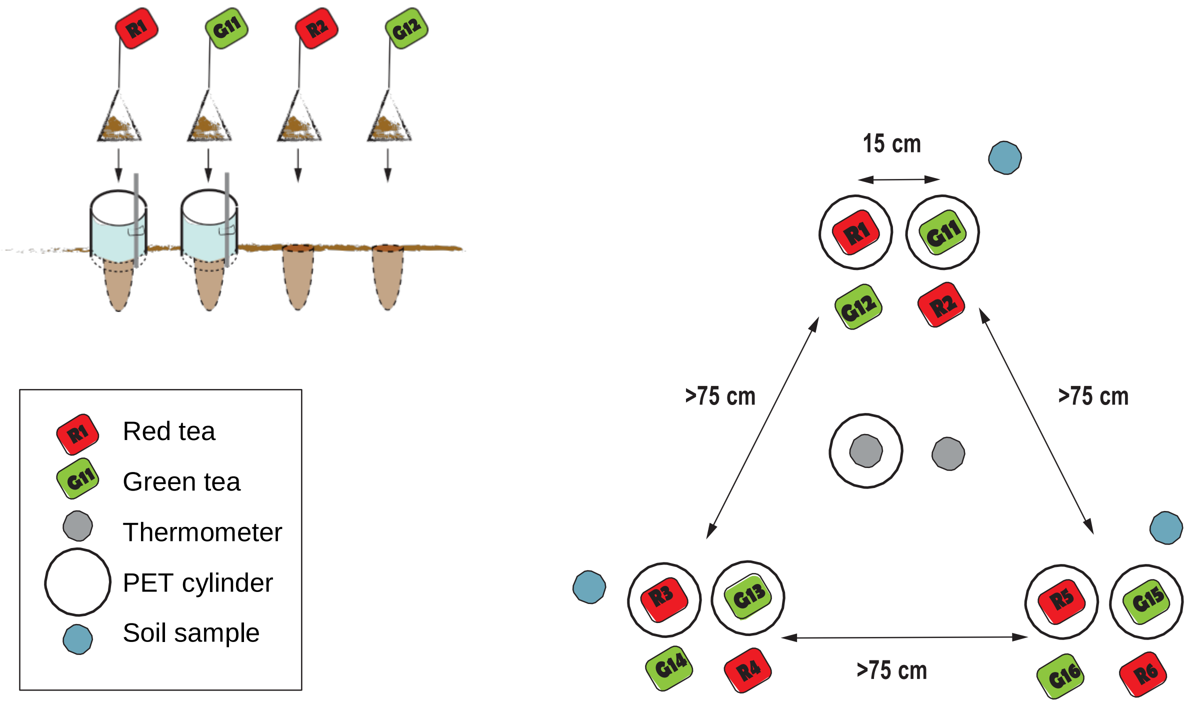


Figure 4: Experimental setup

At each location you dig down a bag of red tea *with* a PET cylinder and a bag of red tea *without* a PET cylinder; and a bag of green tea *with* a PET cylinder and a bag of green tea *without* a PET cylinder. In total you will dig down three sets of green and red tea with PET bottles and 3 sets of tea bags without PET cylinders (*see Figure 4*). A video showing how to bury the tea bags are available on YouTube (*check the Facebook group for updates)*

You have received four spare tea bags that can be used if something goes wrong. **NOTE!** *In case of mistakes, write down what happened and how you solved it*. The spare tea bags could also be used to bury an extra set if there are many students in you class (or you can make tea out of it after the experiment).

Next to the tea bags, 1) two thermometers should be buried (with and without PET cylinder) and 2) three soil samples should be taken at the same place as the buried tea bags *(see Figure 4).*
An instruction video on weighing and taking a soil sample are available on YouTube.

Spring (week 22–23)

Preparations

(Watch the instruction clips)

1. (T) Take 6 tea bags with green tea (Lipton Green Tea) and 6 tea bags with red tea (Lipton Rooibos tea) and the form to fill in the data for the experiment.

2. (T) On *the white side* of the label, number the red tea bags with R1-6 (or 1-8 if you also bury the two extra tea bags) and green tea bags with G11-16 (or 11-18) with a black, **water-resistant** marker. Use "**R**" for red and "**G**" for green tea. Since the white side of the label is made of plastic the label will remain. The green or red side is made of paper and will disappear.

3. (T/S) Using a scale, weigh all the teabags with an accuracy of at least 0.01 grams (two decimals shall be recorded in the form). Make sure the scale is placed on a stable, horizontal underground.

4. (T) Enter the weight of each tea bag in the column "Start Weight" in the form.

5. (T/S) Prepare seven 1.5 liter PET bottles by removing the top and bottom, above and below the label (10 cm) so that you get a plastic cylinder. Remember to remove the plastic label (*see Figure 5)*!

6. (T) Write down the numbers of the thermometers in the form.

7. (T/S) Bring barbecue sticks for supporting the plastic cylinders and to highlight where you bury the tea bags.

Figure 5: PET-bottle preparation.

Suitable bottles:

These bottles are suitable for the experiment. Choose one brand to make the seven plastic rings. Use only the part with the label to make the rings.

Lidl
Saskia 1.5L

Lidl
Freeway 2L

Aldi
River 1.5L

Spar
Sinas 1.5L

Available at most supermarkets:

Fanta 1.5L

Sisi 1.5L (Little to narrow)

Digging down:

1. (T) Choose a natural grassland[2] with low vegetation (less than 30 cm) and at least 2 x 2 meters uniform vegetation, where no fertilizer has been used recently. Also note that the tea bags and the sticks need to stay over summer without disturbance by people or animals.

2. (S) Look at Figure 4 when you do the following steps. Dig 12 holes, 8 cm deep, and place a tea bag in each hole, number the bags according to figure 4. The depth of the holes should be measured with a ruler. The distance between the four tea bags should be 15 cm. Keep the label above the ground. Put back the soil and press it firmly with your hands.

3. (S) Place the prepared PET cylinders over three of the green and three red tea bags, following Figure 4. Make sure that at least two sticks are taped to the bottle, for extra stability. Else, the bottle will be blown away by wind.

4. (S) Dig two holes of 8 cm deep close to where you buried the tea and place the thermometers in those holes. Close the holes and place a PET cylinder over the thermometer with the odd number. The thermometer with an even number should be buried without the PET cylinder.

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[2] For instance a meadow, grazed field, open spot in the forest. Don't dig down the tea in the forest itself, as the trees will provide too much shade. Too much shade will make the plastic cylinder function less well. An agricultural field is not suitable as those are often disturbed by humans or fertilized. A park or lane is therefore also less suitable, but can be used when more natural locations are not present.

5. (S) Mark the place where each tea bag and thermometer has been buried with a stick and attach the label of the bag to this stick. Draw a sketch to show how the tea bags and thermometers are buried. Name the three (or four) digging places as A, B, C (and optionally D).

6. (T/S) Fill in the form: date of digging down, the location (geographical position - *see Figure 6,* but you can soon use our website for it), what kind of environment the bags are buried in (meadow, field, forest) and (optional) which plant species are present at the location.

7. Save the form in a safe place and remember to put a reminder in your calendar or your phone that the tea bags and thermometers should be dug up again in the fall!

Geographic position

In addition to contact and address details, we need the latitude and longitude of the location of the tea. A simple way to determine your geographic position is to find the location of your tea bags on google earth. When you have found your location, you click on the button with the yellow pin ('add place mark'). A pin will appear that you can drag to your location. The GPS coordinates will be shown in a gray window.

Pay attention to put your GPS settings on decimal degrees. You can check this by clicking on 'Tools' followed by 'options'.

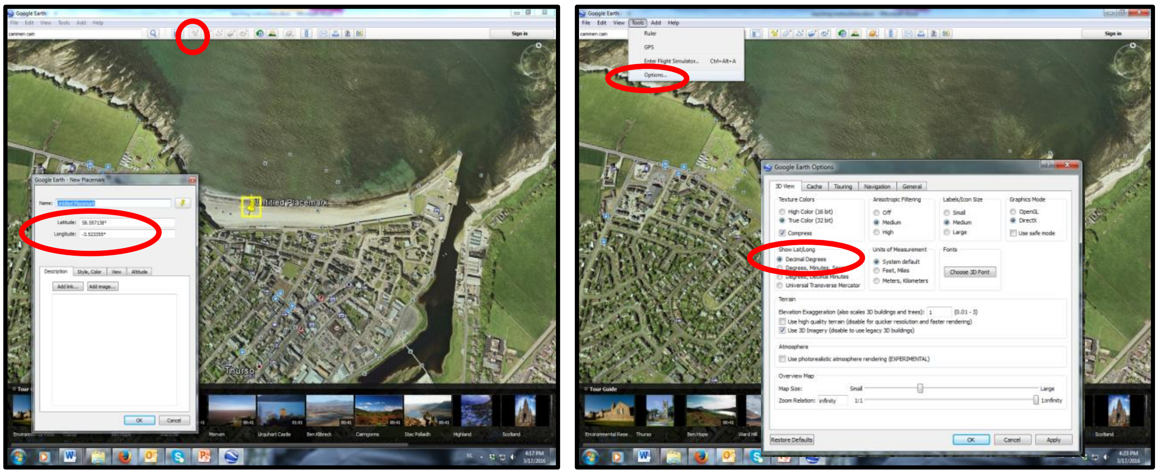

Figure 6: Instructions for finding your GPS location

Autumn (week 35–36)

Digging up the tea bags and soil sampling:

(Please take a look at the video clips)

Outdoor

1. (S) Week 35-36 the tea bags can be dug up. Do this CAREFULLY so that neither the labeling nor the tea bag is destroyed. Carefully remove soil and roots that are stuck to the tea bag. **NOTE!** *Do not use water to clean the bag, and write down if something goes wrong or if you see anything strange on the tea bags (fungus, roots grown into the bag, holes in the bag etc.)*
2. (S) Dig up the thermometers.
3. (S) Take a soil sample next to each group of holes where tea bags were buried (three soil samples in total), as described below.

Soil samples

a) Take the plastic tube and push it into the ground. If the ground is too firm, put a piece of wood on the tube to protect it, and then use a hammer to knock the tube into the ground.
b) Remove the tube from the ground and make sure it is completely filled with soil. Sometimes it may help to use a shovel or spoon and dig it up.
c) Press out all the soil from the tube into a plastic bag. Use one plastic bag for each soil sample.

In the classroom:

a) Weigh the three soil samples. (First tare the scale with an extra empty plastic bag, so that you only measure the weight of the soil in the bag). Write down the weight of the soil samples in the form.
b) Spread out the soil as in the instruction clip and let it dry indoors for three days on a warm and sunny place.
c) After three days, way the soil again. Write down the weight in the form. The difference between the initial weight and final weight is the moisture content of the soil.
d) Mix the dried soil samples and fill the white plastic bottle with it and send the bottle to the researchers (see paragraph 5 below).

Tea bags

1. (S) Let the tea bags dry indoors in a warm (and preferably sunny) place for at least three days, or longer, until they are completely dry.
2. (S) Carefully remove the remaining soil from the tea bags with your hands.
3. (T/S) With the form at hand, weigh one tea bag at a time. **Remove the label** prior to weighing, but leave the cord. Write down the weight of every tea bag.
4. (T/S) Fill in the rest of the form.
5. (L) Put the completed form, the thermometers and the plastic gutter with the soil sample in the stamped envelope provided with the equipment, and mail it to the researchers Judith and Iris so that they can analyze it.
6. Done! Now the scientists can analyze the results.

Optionally

1. (E) Calculate weight loss of tea and soil samples as a percentage of the starting weight. Calculate the mean values for each treatment (green/red tea, with/without PET bottle).
2. The tea bags (with string and label) should be sorted as other waste and not with the green waste because the tea bag is made of plastic.

TIPS AND TRICKS!

• For quality control, it may be recommended that the teacher weights all the tea bags him- or herself and then let the students weigh them again. It is also helpful if the teacher checks the weight of the tea bags recorded on the forms.

• Do not forget to remove the label from the PET bottle and to use clear tape to attach the sticks to the bottle.

• The tea bags must be completely dry before they are weighed.

• Remember to have the scale stable, horizontal surface.

• Broken tea bags cannot be used because weight loss are than not solely due to decomposition. Be careful during retrieving the bags! If the bag loses its entire string, it can still be used. In that case tie a new cord, *without a label*, to the tea bag and weigh it.

• Remember to mark the tea bags labels on the white side with a waterproof pen. Otherwise, the marking will be gone by the time the tea bags should be dug up!

• If you bury the tea bags in any order other than that shown in Figure 4, indicate this in the sketch you make in the form.

• Aim to have the tea bags buried for three months. This can vary between 65 and
100 days for the Tea Bag index to be calculated.

RELEVANCE FOR DIFFERENT SUBJECTS

Mathematics – Calculation of the results and statistical comparisons.

Sports – The practical outdoor part of the experiment can be upgraded to an orienteering or geocaching activity.

Biology – The area around the digging site can be used for teaching for example plant species, soil organisms or ecology.

Chemistry – It is possible to expand chemically on how the decomposition and/or the carbon cycle works to a molecular level (how does photosynthesis and burning work chemically, and how can energy be stored in organisms?). It also links to enzyme activity, and hypothesis building on why or how different environmental factors influence the decomposition.

General – The Tea bag experiment invites to discussions about how climate change affects our daily lives. Or on waste management. What will, for example, happen with all our waste? How long is the decomposition time for a plastic bag? Is it sustainable that we use materials that do not decompose naturally? Why do we have a plastic soup and not a paper soup?

FURTHER READING

Tea Bag Index Projects homepage: *http://www.decolab.org/tbi/*

Facebook:
Swedish project: *https://www.facebook.com/groups/tepaseforsoket/*
General Facebook site: *https://www.facebook.com/tea-bagindex*
Facebook site for questions: *https://www.facebook.com/groups/teatime4science/*

Additional information on decomposition: https://en.wikipedia.org/wiki/Decomposition

Movie on yearly global fluctuations of carbon dioxide:
http://www.vox.com/2014/11/19/7246067/nasa-animation-carbon-dioxide

How to measure climate: http://www.windows2universe.org/earth/climate/direct_measures.html

Information about soil types: *http://www.soils4teachers.org*

Soil fractions:
http://eisforexplore.blogspot.nl/2013/03/soil-density-column.html

Soil categories: *http://cmase.pbworks.com/f/ Soil+Texture+By+Feel.pdf*

Carboncycle (informativ sida):
http://epa.gov/climatestudents/basics/today/carbon-dioxide.html

Plant identification: http://kukkakasvit.luontoportti.fi/index.phtml?lang=en

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[3] **Hjärnkontoret svarar,** av Jacob Seth-Fransson. 2001. ISBN: 91-29-65441-6.

[4] **IPCC Rapport, Climate Change 2007: Synthesis Report.** (Valencia, Spain, 12–17 November 2007)

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Sarneel J. M. **Tea Time for Science.** Appendix A: Research program.

A **big** thank for your participation to you and your students!