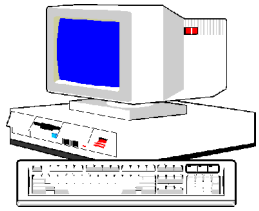
Agri-science Resources
for High School Sciences

Soil Chemistry



Chemistry

Science

Grade 10-12

Chemistry Classroom
Computer Lab

Teams of 2 or 3

DESCRIPTION

Soil is the top layer of the earth's crust in which organic matter grows. There are many components which determine a soil type such as pH, nutrient level and organic content. These factors can vary depending on the type of plant or crop which grows in the soil and also on geographic location. The best way to determine soil quality is by conducting a soil test. In this exercise, students will learn about soil and some of its components. Groups will collect soil to be analyzed and students will use the Internet to view their results.

READINESS ACTIVITIES

Students should:
- see what types of compounds their family uses to care for their lawn or garden

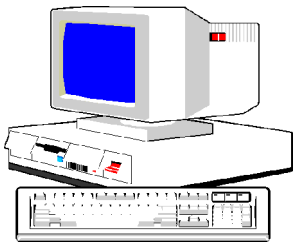
LEARNING OUTCOMES

Students will:
- learn various techniques that are used to modify the quality of soil
- develop computer skills in a soil analysis program
- examine the chemistry involved in soil science

MATERIALS

- Soil sampling bags
- Soil probe or shovel
- Bucket or container
- Sample information sheet

Soil Chemistry



Agri-science Resources for High School Sciences

Chemistry

Soil

Gardeners know that you can not grow vegetables just anywhere. The quality of vegetables grown depends on the condition of the **soil**. Soil is the top layer of the Earth's surface that is suitable for plant growth. Soil quality is a major concern for Prince Edward Island farmers because of it's importance to agriculture. Although it is often referred to as dirt or ground, there is a lot more to soil than meets the eye.

pH

One of the most important components of soil is the **pH**. The pH of soil can be modified by adding different chemicals. Soil pH indicates how **acid** or **alkaline** the soil is. The pH scale ranges from 0 to 14. Any substance with a pH near the lower end of the scale is very acidic. Substances in the upper range of the scale have a high alkalinity or are very basic. The pH of a soil is crucial because crops grow best in a narrow pH range which can vary among crops. For example, blueberries and a few types of flowers grow best when the pH is 5.5 or less. Potatoes, a more familiar crop, grow best with a soil pH range of 5.5 to 6.0. Most garden vegetables, shrubs, trees and lawns grow best when the soil pH is over 6.0 or 6.5. The range between 5.5 and 7.5 is favorable for two reasons. It allows sufficient microorganisms to break down **organic matter**. It is also the best range for **nutrient** availability. Organic matter and nutrients will be discussed later. Areas that were formerly covered by trees, such as Prince Edward Island, develop acidic soils. This helps explain how Prince Edward Island farmers can grow the best potatoes in the world.

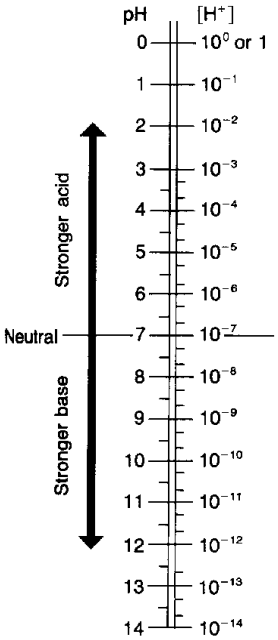
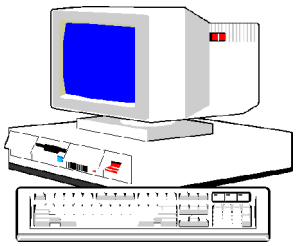


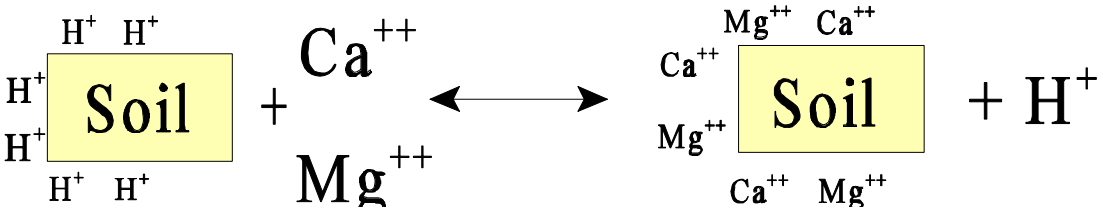
Figure 1. pH scale

source: Chemistry: International System of Units Edition

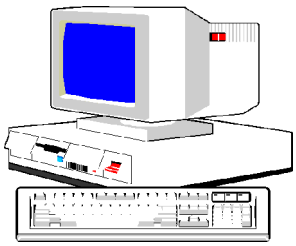


Liming

When farmers originally cleared the lands on the Island, the soil quality was adequate for growing potatoes. However, potatoes were not the only crop at that time. Therefore, farmers needed a way to increase the pH of the soil to make it suitable for other crops. The pH of soil can be increased by liming. This is why people sometimes spread white powder on their lawns or gardens. This white powder is **lime**. Calcitic limestone ($CaCO_3$) provides a good source of Calcium (Ca) and helps neutralize soil acidity. Dolomitic limestone functions similarly but also adds Magnesium (Mg). The best limestone will have the greatest calcium and magnesium content and will be ground into very tiny particles. The smaller particles allow the limestone to correct soil acidity more rapidly. The chemistry to liming is quite simple. Hydrogen ions (H^+) are attracted to soil and organic material which have a negative charge. When lime is applied, these hydrogen ions are exchanged for calcium or magnesium (Ca^{2+} or Mg^{2+}) ions which have a greater positive charge. This helps to neutralize the acidity of the soil. The free hydrogen ions are taken out of solution. This also helps to increase the pH. This reaction demonstrates the process of liming:



In some cases, the soil may have very high pH and need to be made more acidic. This can be done by using sulfur, aluminum sulfate, or ammonium sulfate.



Nutrients

Each year the soil undergoes a series of cycles in which materials are added and then taken away. Organic matter and nutrients, in various forms, are constantly being added to the soil. Nutrients are the minerals required by plants to survive. It is very important that plants receive all the required nutrients. There are a total of sixteen elements required for plant growth. Each is required in different amounts. The most important nutrients are called **macronutrients**. Nutrients which are essential, but only needed in small quantities are called **micronutrients**. Carbon, Hydrogen, and Oxygen are the big three macronutrients. These are obtained in almost unlimited amounts from the atmosphere and from the water around the plant. The other macronutrients are nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sulfur (S). These nutrients should be available for plant uptake from the soil. Micronutrients are obtained from the soil. They are boron (B), copper (Cu), chlorine (Cl), iron (Fe), manganese (Mn), molybdenum (Mo), and zinc (Zn). They are all essential because the absence of any one of these will cause the plant to grow poorly or develop disease.

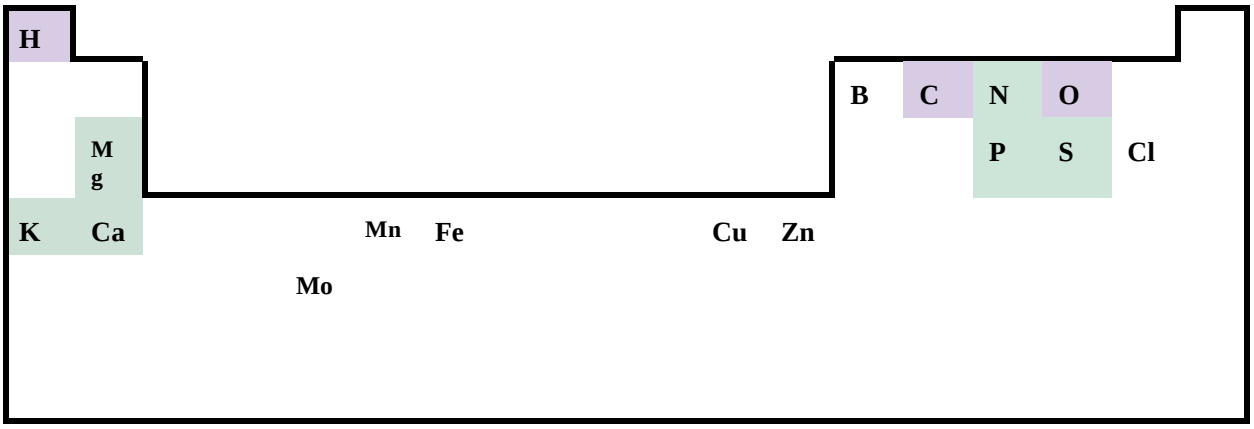
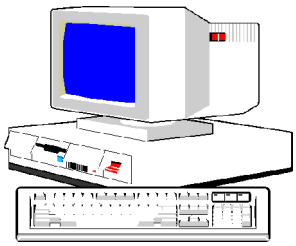


Figure 2. The sixteen essential nutrients indicating their position on the periodic table. The macronutrients are highlighted.



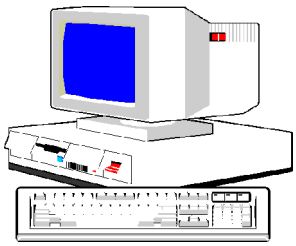
Organic Matter

Many pleasant drives in the country have been affected when the passengers of a car are hit with an unpleasant, but familiar odor. Many people complain about the smell without questioning why it exists. There is actually a very good reason for this practice. Although they are often given more unpleasant names, these animal wastes are known as organic fertilizers. These fertilizers have a very high content of organic matter. Organic matter is simply dead decaying matter that originated from a living source. It prevents nutrients from being lost from the soil by binding these nutrients. Therefore, the best soil for crop production will have a very high organic content. Most organic fertilizer originates from livestock such as cows, pigs, and poultry. Compost is also an organic fertilizer. Compost can be made up of grass clippings, table scraps, ashes, seaweed, and many other types of food products. Organic fertilizers contain high levels of Nitrogen and moderate levels of Phosphorus and Potassium. The nutrient content of organic fertilizer can vary according to the animal that produced it (agriscience text). The process of spreading organic fertilizers gives farmers the opportunity to rid themselves of accumulated livestock waste. It also provides farmers with a free source of fertilizer which is sometimes sufficient to meet the needs of the desired crop. Organic fertilizers are also less harmful to the environment. This may be one of the first recycling practices that ever developed.

APPROXIMATE AMOUNTS OF PLANT NUTRIENTS AVAILABLE FROM ONE TON OF MANURE

	Cattle	Sheep	Swine	Poultry	Horse
Nitrogen (lb)	10	28	10	30	14
Phosphorus (lb)	5	10	5	20	5
Potassium (lb)	10	25	10	10	14

Figure 3. The nutrients present in manure of different livestock animals.
(Source: Agriscience: Fundamentals & Applications)



Cation Exchange Capacity (CEC)

The **CEC** measures the extent to which soil can hold and exchange plant nutrient cations. The ability of soil to hold positively charged nutrients from being leached and lost from soil is important to maintaining soil fertility. Clay and organic matter have a negative charge. They allow the soil to hold these nutrient cations due to the attraction of charges. Soils with high clay or organic matter content will have a higher CEC. Sandy soils tend to have a lower CEC.

Buffering Capacity

This is the ability to withstand rapid pH fluctuation. The greater the **buffering capacity**, the greater the quantity of acid or base which must be used to alter the pH. Soil types having low buffering capacities include sandy soils with little clay or organic matter. Soils with a higher buffering capacity would have large quantities of mineral clay and organic matter. Therefore, a thick rich soil with a high buffering capacity would require more lime in order to raise the pH.

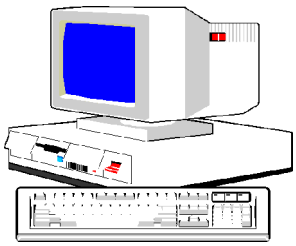
Fertilizer

Fertilizers can replenish the mineral nutrients depleted from the soil by natural means or during crop removal. Most fertilizers contain nitrogen (N), phosphorus (P), and potassium (K). The proportions of these elements are called the fertilizer grade. The fertilizer grade on a bag gives the percentages of each mineral by weight. For example, a bag of fertilizer labeled 10-10-10 contains 10 percent N, 10 percent P, and 10 percent K. In the common 80 pound bag of this grade, you would have 8 pounds of each nutrient. There are a variety of different grades of fertilizer. The cost varies according to the contents. The most appropriate grade of fertilizer depends on the desired crop, and the condition of the soil where the crop will be planted.

Exercise 1

In the following exercise you will need to know the names and formulas of several compounds used in soil chemistry. To determine the formula for the compound, use the following cations and anions:

Soil Chemistry



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Chemistry

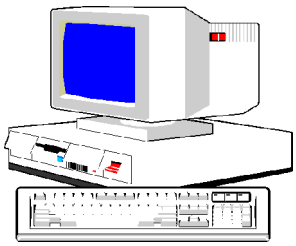
Cations:		Anions:	
	NO_3^- nitrate		NH_4^+ ammonium
	PO_4^{3-} phosphate		Ca^{2+} calcium
	SO_4^{2-} sulfate		Na^+ sodium
	O^{2-} oxide		K^+ potassium
	CO_3^{2-} carbonate		Mg^{2+} magnesium

Mix and Match

Write the letter next to the statement number which matches it.

__ 1. Calcium sulfate
__ 2. compound that is a good source of nitrogen and increases soil pH
__ 3. because the ions have opposite effects, this compound does not change soil pH
__ 4. contains two of the three nutrients in fertilizer
__ 5. a macronutrient obtained from the soil often often associated with an unpleasant odor
__ 6. a micronutrient which has an atomic number of 29
__ 7. used when soil has a very high pH and needs to be made more acidic
__ 8. macronutrient with an atomic mass of 24.305
__ 9. this compound contains three macronutrients which can be obtained from the atmosphere
__ 10. sometimes referred to as a metalloid
__ 11. potassium sulfate
__ 12. A micronutrient with a charge of - 1
__ 13. magnesium oxide
__ 14. contains both a macronutrient and a micronutrient
__ 15. used to lime acidic fields

a. $CaCO_3$
b. $K_2(SO_4)_2$
c. $Al_2(SO_4)_3$
d. Cu
e. Ca_2SO_4
f. S
g. chlorine
h. MgO_2
i. urea
J. KNO_3
k. Mn
l. calcium nitrate
m. $CaSO_4$
n. B
o. K_2SO_4
p. sodium sulfide
q. potassium fluoride
r. MgO
s. KSO_4
t. Mg
u. KCl
v. $MgSO_4$

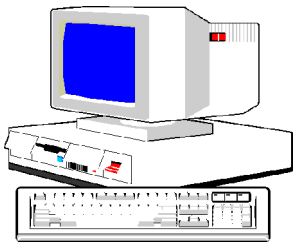


Exercise 2

Soil Test

The best way to learn if your soil needs to be limed or fertilized is by conducting a soil test. A soil test will give you an accurate description of many soil factors, including pH and nutrient levels. For example, if the pH of the soil is low, lime should be used. The amount needed can be estimated by considering the type of soil, the desired pH, and the form of lime that will be used. A soil test will also indicate how much fertilizer to use and the best grade for your soil.

In this lab exercise students will divide into groups of three or four. Each group will take a soil sample either from a group members backyard or a nearby field. The soil will be analyzed at the Soil and Feed Laboratory in Charlottetown. The Provincial Department of Agriculture and Forestry has an Internet program which will each group to examine their results. There are a few questions designed to help understand the program. If there any terms in the program that are unfamiliar, double click the term, and a clear explanation is given.



Taking a Soil Sample

- ✔ You need a pail or ice cream container, a small shovel or spade, and a sample bag.

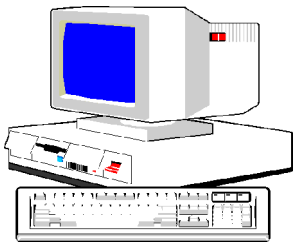
- ✔ Choose a few uniform spots in the field or yard and take a few small samples from each one. This will give a good representative sample of the test area.

- ✔ The soil should be sampled to a depth of about 6 inches (15cm). You need to dig enough soil for a 500 gram sample (roughly). Try not to include too much grass.

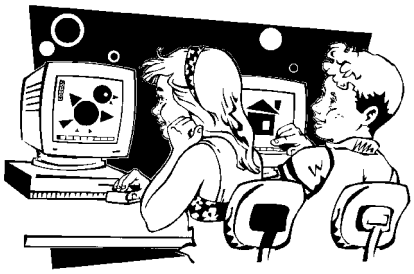
- ✔ Put all the soil samples in the container and mix it thoroughly.

- ✔ Use the soil sample bags provided by the Soils and Feeds Lab of the Department of Agriculture and Forestry. Fill the bag to the indicated level. The instructor will take this bag to the Soil and Feed testing lab in the bottom floor of the Research Station at 440 University Avenue, Charlottetown, Prince Edward Island.

- ✔ The sample will take about three or four working days to analyze. Then you can obtain your results on the Internet by using the username and password issued to you by the Soils and Feeds Lab.

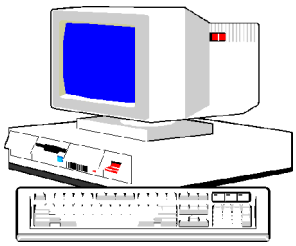


To Gain Access to the Soil Analysis Program:



- get on the world wide web by connecting to your server
- Find the Open Location command in the file menu
- Access the provincial government web site by typing **www.gov.pe.ca/daff/soilfeed**
- Open the site and the home page should appear. It is titled Soil and Feed Testing Laboratory

The page gives a brief description of the lab itself along with a great deal of useful information. Feel free to click on any subject that interests you. We will be focusing on Soil Testing. To see the results from your own soil sample go to Click here to view your results in the upper right hand corner of the page. Use the username and password that has been given to you to gain access to your file. Remember, we are focusing on soil testing, so you do not have to change anything on the next page, simply click View under Soil Test. Next a table labeled Soil Analysis will appear. This table lists the Date Sampled, an Accession Number, and the Number of Samples. Next you get a choice to click for your data. Begin by clicking View.



Questions

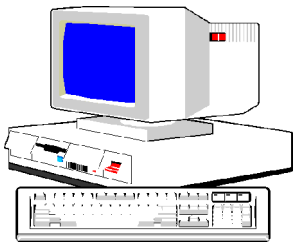
Use the results from your soil sample and the section "How to Interpret your soil test report" on the Homepage to answer the following questions.

1. What is the pH of your sample? Based on the pH value, would the sample area be suitable for growing potatoes?
2. Describe the soil ratings (H,M,L) for P, K, Ca, and Mg. Are any of these nutrients found in higher or lower amounts than the others?
3. Comment on the amount of N, P, and K that the program suggests is required. Based on what you have learned about fertilizer grades, what types of grades do you think would be most appropriate for your sample area?

Part II

The next set of questions apply to the demonstration samples which the Department of Agriculture and Forestry has made available to the public. Access this file with username:1383 and password: warps2stoop. Go to the example with five samples. Enter the View function.

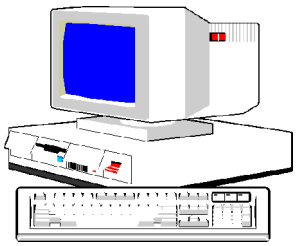
4. Of the five micronutrients shown in the analysis, which is the most abundant in ppm? Which is the least abundant?
5. What is the Cation Exchange Capacity (CEC) of the soil? What does this value indicate in terms of the organic content and texture of the soil? Consult the program if you are not sure.
6. Compare the Percent Base Saturation values to those presented in Table 2; "Ideal % Base Saturation". What values fall into the "ideal" bracket and which ones do not? What else does the % H indicate about the soil?



Next we will use the Fertilizer Fit Function. First, you need to change the crop in the first table to Lawn. This will give a more realistic comparison to your samples. Underneath the table, the ratio of N,P, and K required is given. Skip down to the section Summary of Individual Field Requirements.

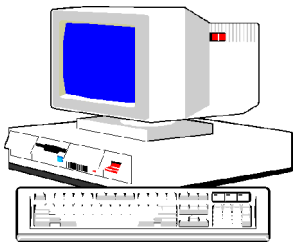
7. Of all the listed fertilizer grades listed, which grade has the largest application mass? Which grade has the smallest mass of application?
8. What grade is the most expensive? Which is the least expensive? Are there any trends in the price of fertilizer?
9. You have figured out the fertilizer you need, but when you go to the store, they only have the 10-10-10 grade. How much of this fertilizer will you need and how much will it cost? Use the force fit function.
10. Your parents decide they want to change this lawn into a potato field. You wonder if they have any idea how to do this. You decide to give them some help. Copy the nutrient requirements for an Established Lawn. Now change the crop to potatoes. How have the nutrient requirements changed? What will your parents have to do to the soil if they want to grow potatoes?
11. You decide that if your parents are growing potatoes, you are going to have your own pumpkin patch. What are the different nutrient requirements for pumpkins? Is there much work ahead of you to obtain a prize pumpkin?

This ends the lab on soil. Feel free to play around with the Internet program some more if you would like. Remember, it's free. When you do get your own lawn, hopefully now you've learned how to care for it properly.



Glossary of Terms

acid	material with a pH of less than 6.9
alkaline	material with a pH of more than 7.1
buffering capacity	the ability of the soil to withstand pH fluctuation
CEC	cation exchange capacity is the ability of a soil to hold and exchange plant nutrient cations
fertilizer	material that supplies nutrients for plants
lime	material that reduces the acid content of soil and supplies nutrients such as calcium and magnesium to improve plant growth
macronutrients	elements used in relatively large quantities
micronutrients	elements used in very small quantities
nutrients	substances necessary for the functioning of an organism
organic matter	dead plant and animal tissue that originates from living sources such as plants, animals, insects, and microbes
pH	measurement of alkalinity from 1 to 14
soil	top layer of the earth's surface suitable for plant life



Answer Key

Mix and Match:

1. m	6. d	11. o
2. l	7. c	12. g
3. n	8. t	13. r
4. j	9. i	14. u
5. f	10. n	15. a

References

Cooper, E.L. 1997. Agriscience: Fundamentals & Applications. 2nd. Ed. Delmar Publishers, Albany, New York.

Masterton, W.L., and C.N. Hurley. 1993. Chemistry: Principles and Reactions. 2nd.Ed. Saunders College Publishing, Fort Worth, Texas.

Wilbraham, A.C., D.D. Staley, C.J. Simpson and M.S. Matta. 1993. Chemistry: International System of Units (SI) Edition. Addison-Wesley Publishers Ltd., Don Mills, Ontario.