THE CHEMISTRY OF FERTILIZERS

GRADES 10-12

written by
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for the
California Foundation for Agriculture in the Classroom

in cooperation with the
California Department of Education
California Department of Food and Agriculture
California Farm Bureau Federation
Fertilizer Inspection Advisory Board
Fertilizer Research and Education Program

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TABLE OF CONTENTS

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The California Foundation for Agriculture in the Classroom is dedicated to fostering a greater public knowledge of the agricultural industry and seeks to enlighten students, educators, and leaders in the public and private sector about agriculture's vital, yet sometimes forgotten, role in American society and the effect all citizens have on agriculture's well being.

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INTRODUCTION

The Science Framework for California Public Schools emphasizes the need to make science education more meaningful to students so they can apply what they learn in the classroom to their daily lives. Since all students eat food and wear clothing, one natural connection between science and the real world is agriculture.

Agriculture is an enormous industry in the United States, especially in California. As more rural areas become urbanized and more challenges exist to maintain and improve the quality of the planet and feed the people of the world, it is extremely important to educate students about their environment and about agriculture.

Agriculture, today, is very dependent on general and analytical chemistry concepts. The nature of fertilizers and their interactions with soil, water and air greatly influence how and when fertilizers are used. Challenges facing agriculture are clearly illustrated in this unit as students make a fertilizer, analyze fertilizers for phosphate content and discuss fertilizer labeling. The lessons in this unit are structured to encourage students and teachers to "construct" their own knowledge about agriculture and the environment and provide enough background information to make the teacher feel confident in the subject matter.

The California Foundation for Agriculture in the Classroom is dedicated to fostering a greater public knowledge of the agricultural industry and seeks to enlighten students, educators, and leaders in the public and private sector about agriculture's vital, yet sometimes forgotten, role in American society and the effect all citizens have on agriculture's well being. Please contact the Foundation for assistance on the integration of agriculture into existing curriculum. Your comments on this unit or on other Agriculture in the Classroom resources are always welcome.

UNIT OVERVIEW

BRIEF DESCRIPTION

This unit, intended for use in high school chemistry classes, uses fertilizer science as a tool to apply chemistry concepts to real world situations. Life and earth science concepts are applied throughout the unit making the lessons appropriate for integrated science classes. Through a series of hands-on labs and activities, practice problems, discussions and writing assignments, students learn about fertilizer chemistry as they break compounds into ions, make a fertilizer and test various fertilizers for phosphate content. What nutrients are required by plants, how these nutrients are obtained and the issues related to fertilizers and the environment are addressed.

SCIENCE THEMES

- Systems and Interactions
- Stability
- Energy
- Scale and Structure

CONCEPTS

(Footnotes refer to specific pages in the 1990 California Science Framework for Public Schools.)

- Plants, as all matter, are made of chemical elements.1
- Soil and water are amended with nutrients so plants get the nutrients they require.
- It appears that plants require 17 essential chemical elements as nutrients which can only be absorbed in certain forms through root uptake or leaf absorption.[2]
- A fertilizer is any natural or manufactured material added to soil or water in order to supply one or more essential chemical nutrients to plants.[3]
- Fertilizers come in a variety of forms and mixtures of different chemical ions.
- Fertilizers are made in a variety of ways.[4]
- Fertilizers are made of elements and can be tested to measure the amounts of those elements.
- Fertilizers do not all contain the same percentages of each of the primary nutrients; fertilizers are prepared in different compositions so the consumer, farmer or home gardener, can apply only what is needed to the soil?
- The concepts relating to plant nutrient uptake are complex.[2]
- Though fertilizers are an important part of crop production, over-fertilization and misuse can be harmful to the environment. In order to be effective, fertilizers must be used properly?
- Chemistry learned in the classroom is applicable to the real world and affects the lives of all people, including farmers and consumers.6

- There are many career opportunities related to agriculture that do not directly involve production agriculture.

SEQUENCE OF ACTIVITIES

These activities can be used in a variety of sequences. Skim over the entire unit before beginning it with your students. Pick the sequence that will work best with your curriculum. A suggested sequence is described below.

1. Chemically Speaking - What's in a Plant?

2. A Chemical View of the World!

3. How to Determine the Percent of Available Nutrients in Fertilizers

4. Making a Fertilizer and Testing for Phosphates

5. A Letter to Your Grandfather!

EVALUATION

Several assessment tools are built into this unit. Evaluate each student's active participation in lab activities as well as in discussions. "A Letter to Your Grandfather" can be used as an evaluation tool. The changes that occur in the student's review of the "Chemically Speaking! - What's In A Plant?" assignment also can be included in student portfolios.

TIME REQUIREMENTS

General Time Frame

This unit is designed to cover a two week time span. Make sure you allow enough time for lab preparation and set-up. Honors and Advanced Placement classes may require less than two weeks.

Chemically Speakinq! - What's in a Plant?

1 twenty-minute session
1 ten-minute session at conclusion of unit

A Chemical View of the World!

1-2 forty-minute session(s) to complete poster
1 forty-minute session for presentations
1 forty-minute session to complete "Chemical Formulas and Available Ions in a Fertilizer"

How to Determine the Percent of Available Nutrients in Fertilizers

1 forty-minute session

Makinq a Fertilizer and Testina for Phosphates

2 hours of teacher preparation
2-3 forty-minute lab sessions

A Letter to Your Grandfather!

1 ten-minute session for introduction
3-4 nights to complete writing assignment
1 twenty-minute session for conclusion
Allow 1 week for students to research topic as homework.

MATERIALS LIST

Specific quantities of materials are listed at the beginning of each individual lesson. The following list provides you with an overview of what materials are necessary to complete the entire unit.

Balances
Beakers
Bunsen burners
Calculators
Chemicals
- Ammonium molybdate $(NH_4)_2MoO_4$
- Ascorbic acid
- Concentrated sulfuric acid
- K_2HPO_4 (potassium phosphate)
- KCl
- KH_2PO_4
- NH_4NO_3

Colored pencils or markers
Commercial fertilizer
Construction paper or butcher paper
Distilled water
Filter paper
Flasks
Graduated cylinders
Handouts--supplied in this unit
Periodic Tables
Plant--any type
Reference books--see Teacher Resource section
Ring clamps
Ring stands
Scissors
Scotch tape
Stirring rods
Stoppers
Test tubes
Test tube labels
Wire gauze

CHEMICALLY SPEAKING - WHAT'S IN A PLANT?

PURPOSE

The purpose of this activity is for students to relate the chemical elements they learn about in the classroom to the world of plants and production agriculture. Students will focus on the general chemical composition of plants and discover where the required elements come from. This focus activity assists the instructor in finding out what conceptions students have about the chemistry of plants, fertilizers and the environment and encourages the students to think about the topics before they learn more about them.

CONCEPTS

- Plants, as is all matter, are made of chemical elements.1
- Soil and water are amended with essential elements so plants get the nutrients they require.

MATERIALS

- Photographs of corn fields and forests (optional)
- One plant
- Copies of "Chemically Speaking - What's in a Plant?" handout (1 for each student)
- Various articles related to plant nutrient requirements and current issues associated with plant nutrient requirements (see Teacher Resource section)
- Periodic Table of the Elements

TIME

1 twenty-minute session
1 ten-minute session at the conclusion of the unit

BACKGROUND INFORMATION

This introductory lesson allows the students to think about what they already know about chemical elements that make up plants. Encourage your students to think for themselves and relate their thinking to their own experiences. This will make the unit more meaningful to each individual. After reading your students' responses to the questions, tailor your upcoming lessons to clarify misconceptions on the subject matter.

Research has shown that plants require 17 chemical elements, and they are required in certain forms. These elements will be discussed in more detail in upcoming lessons. Recently, at the University of California at Davis, the 17th essential element was identified as nickel. Perhaps other essential elements will be identified in the future. Information on nickel is not present in most books/references due to its recent discovery as an essential plant nutrient.

PROCEDURE

1. Show students a plant.

2. Ask the students to think of this plant in detail. What are the building blocks of this plant? What has to happen to keep this plant alive?

3. Explain the purpose of this focus activity to your students. (See Purpose and Background Information) If available, show the students photographs of corn fields and forests.

4. Have students complete the worksheet "Chemically Speaking - What's In A Plant?" Spend as much time on this lesson as you deem appropriate. Critical thinking and conceptualizing take more time for some students than for others.

5. Have students read several articles about plant nutrient requirements, fertilizers, etc. Have them complete question #7 of their worksheet. Choose articles from the Teacher Resources section of this unit or use articles you have acquired.

6. Discuss the students' answers to the questions. Perhaps you may choose to post different answers so that students can see them as they complete the unit. Save your students' worksheets for the end of the unit.

7. Complete the rest of this unit as indicated. Refer to this lesson when appropriate.

8. At the conclusion of this unit, return the questionnaires to the students. Have them look at their answers and prepare a written or oral explanation of how their conceptions of plant chemistry have been confirmed or have changed.

CONCLUSION

Plants require essential elements for proper growth and reproduction. Fertilizers can provide plants with these necessary elements.

VARIATION

Have students pretend they are a molecule that becomes absorbed into a plant. Have them discuss their journey in the plant and how they eventually are recycled back into the environment.

EXTENSION

Have students make up a lesson which explains, to a kindergarten class, how plants get nutrients from the soil. Arrange for selected students to teach their units to kindergartners.

Student Handout **Name**___________________

CHEMICALLY SPEAKING - WHAT'S IN A PLANT?

imagine walking through a forest or a field of corn stalks that stand taller than your head. Biologically speaking, it is relatively easy to visualize the life cycle of these plants ... seeds are planted, they sprout, continue to grow and then, at maturity, produce seeds so the cycle can begin again.

Now, think what must happen chemically to make this all happen!

Answer the questions below as thoroughly as you can. Take your time and come up with your best answers to these questions.

1. Take a look at a Periodic Table of the Elements. What elements do you think are essential for plant growth?

2. Where and how do you think plants get these elements?

3. Do you think there could be a problem if plants had too little or too much of their required nutrients? Explain.

4. Why do you think farmers and home gardeners use fertilizers?

5. What is your definition of a fertilizer?

6. Throughout this unit, you will learn more about the chemistry of plants. What is one thing you would like to personally learn about plants and the chemical elements they require?

7. Read the article(s) provided by your teacher. What are two important issues you think farmers, scientists and the general public must address and work on together?

A CHEMICAL VIEW OF THE WORLD!

PURPOSE

The purpose of this lesson is to understand the chemistry involved in how plants absorb nutrients.

CONCEPTS

- It is believed that plants require 17 essential elements which can be absorbed only in certain forms.2
- A fertilizer is any natural or manufactured material added to soil or water in order to supply one or more plant nutrients.[3]
- Fertilizers come in a variety of forms and mixtures of different chemical ions.

MATERIALS

For the Class:

- 1 copy of <u>The Western Fertilizer Handbook</u> as a reference
- "Elements Required By Plants" handout

For Each Group of Students:

- Markers or colored pencils
- Periodic Table of the Elements
- 11" X 14" piece of construction paper or butcher paper
- Various references on chemicals, specifically fertilizers
- "Elements Required By Plants" handout (optional)

For Each Student:

- "Chemicals, Chemicals Everywhere!" handout
- "Chemical Formulas and Available Ions In Fertilizers" handout

TIME

1-3 forty-minute session(s) to create and present the "element posters"

1 forty-minute session to read and complete "Chemical Formulas and Available Ions In Fertilizers"

BACKGROUND INFORMATION

Prior to this lesson, students will need to know how to use the periodic table, read chemical formulas and break compounds down into their ionic components.

A fertilizer is any type of substance added to the soil or water to increase the nutrients available to plants. Plants require 17 essential chemical elements. Three of the 17 elements -- carbon, hydrogen, and oxygen -- are taken primarily from air and water. The other 14 are normally absorbed from the soil or from the particles dissolved in water. Fertilizer is added to soil or water to make sure all essential nutrients are readily available in the appropriate forms. The

14 elements are divided into three groups: primary nutrients, secondary nutrients and micronutrients. These groups are based on the relative amounts required for plant growth, yet all are equally essential. Primary nutrients are needed in large amounts and are the three elements that make up the three numbers on fertilizer packages. These three elements are nitrogen, phosphorus and potassium (N-P-K). Secondary nutrients are needed in moderate amounts, but not in such quantity as the primary nutrients. The secondary nutrients are calcium, magnesium and sulfur. The final category, called micronutrients, are needed by plants in very small amounts, yet are critical for plant growth. They are zinc, iron, manganese, copper, boron, molybdenum and chlorine. Recently, University of California at Davis research indicated that nickel be added to the list of micronutrients. Studies are continuing to determine whether or not other micronutrients are needed by plants.

PROCEDURE

1. Briefly discuss how chemistry is a part of everyone's daily life. Pass out the handout titled "Chemicals, Chemicals Everywhere!" Discuss the chemical compounds and formulas with the students. Emphasize the picture of the fertilizer. Explain the three numbers on fertilizer labels (the first number is the percent nitrogen, the second number is the percent phosphorus and the third number is the percent potassium). Discuss that the emphasis the next few days will be on the chemistry of plant nutrients including fertilizers.

2. Ask the students what elements plants generally absorb from the air. Discuss that they are carbon and oxygen in the forms of CO_2 and O_2. Sometimes plants absorb other substances from the air such as sulfur and chlorine but the air is not the major source of these elements. Review that plants also absorb hydrogen and oxygen as H_2O in gaseous and liquid form. Review the basic equations for photosynthesis ($6CO_2 + 12H_2O$ + 673,000 cal $\rightarrow$ $C_6H_{12}O_6 + 6H_2O + 6O_2$) and respiration ($C_6H_{12}O_6 + 6O_2 + 6H_2O \rightarrow 6CO_2 + 12H_2O$ + energy) with your students. Explain the importance of these equations. If you desire, use an overhead transparency for this discussion.

3. Divide your class into 13 equal groups. Assign each group one of the essential plant nutrients (excluding C, H, 0). The elements are: nitrogen, potassium, phosphorus, calcium, magnesium, sulfur, zinc, iron, manganese, copper, boron, molybdenum and chlorine. (Nickel is excluded from this activity, due to it's recent discovery.) Having students draw the element names out of **a** hat randomizes the assignment. Have the students create an 11" X 14" poster with the information described below. They can obtain this information by researching this information in the <u>Western Fertilizer Handbook</u> and other sources. The teacher handout "Elements Required By Plants" may be useful if students have difficulty locating some of the information.

   The posters should include the following information:

   - Element name
   - Element symbol
   - Category - primary, secondary or micronutrient
   - Forms in which plants absorb the element
   - Functions of the element
   - Deficiency symptoms if element is not present or is in low supply
   - Toxicity symptoms if element quantity is too high

Other information the students should include in their brief oral presentation is described below. This information can be found in basic plant nutrient books in the school library.

- How does this element naturally exist in nature?
- If the soil does not have enough of this element, how do people provide it to plants?
- What environmental, including agricultural, issues might be associated with this element?

Example Calcium Poster:

Ca

Calcium

Secondary Plant Nutrient

Function: Essential to healthy cell walls

Absorbed as the calcium ion Ca^{2+}

Deficiency Symptoms:

1. Death of growing points
2. Abnormal dark green color
3. Weakened stems

Toxicity Symptoms:

1. Brown or white spotting on fruit

Points for Discussion:

Common manufactured fertilizers produced from phosphate rock contain absorbable calcium. Generally, a store-bought manufactured fertilizer contains enough calcium for household gardens. Calcium can also be obtained from lime and gypsum rock. Areas must be mined to get phosphate rock, lime and gypsum. Manures and irrigation water have some calcium. Soils high in calcium- are easier to till than those low in calcium.

4. Have each group report their findings to the class.
5. Display the posters around the room. Refer to the posters at appropriate times during this unit and in other appropriate discussions,
6. Complete the worksheet "Chemical Formulas and Available Ions in Fertilizers" with your students. An answer key is provided for your convenience.

CONCLUSION

Seventeen elements are required for plants to grow and reproduce. To be utilized by plants, each element must be in a certain ionic form. There are many issues and challenges associated with plant nutrient uptake, fertilizers, soil amendments and the environment.

VARIATIONS

1. Use fast growing seeds to set up a nutrient assay. Grow plants in complete and deficient media. See various science catalogs for kits that provide solutions to create nutrient deficiencies.

2. Use the CD rom "Plant Requirements" by Technical Publications to learn the importance of certain elements.

EXTENSIONS

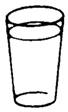
1. Have students research what legumes are and how they affect the usable nitrogen level in soil.

2. Obtain pictures or actual plants that exhibit deficiency symptoms. Incorporate the examples into student presentations.

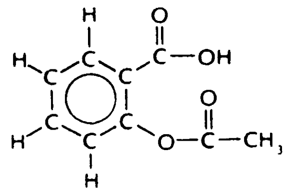
3. Have students research the importance of proper nutrients in hydroponic systems.

4. Build a fertilizer model using toothpicks and colored marshmallows or molecular model kits.

CHEMICALS, CHEMICALS, EVERYWHERE!
(Student Handout)

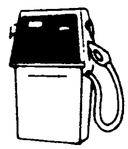

Water H_2O


Aspirin




Vodka CH_3CH_2OH


Odor of rotten eggs H_2S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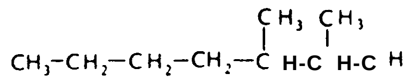
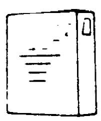
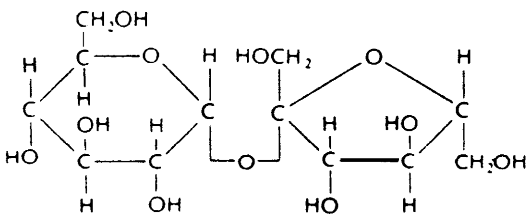
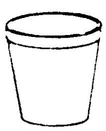
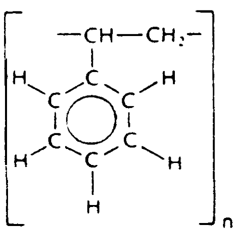

, others

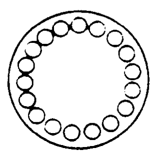

Sugar

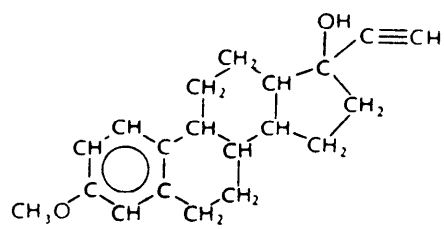



Fertilizer NH_4NO_3, K_2SO_4, NH_3, others


Styrofoam cup

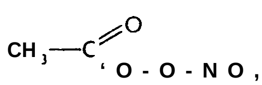



Birth control pills

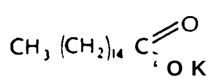



Smog

NO_2, NO, SO_2, O_3, CO, SO_3




Soap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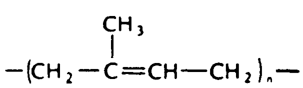
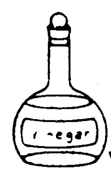
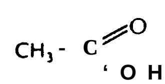
Automobile tire




Vinegar



ELEMENTS REQUIRED BY PLANTS
(Teacher Information)

I. Introduction

It is a known fact that humans require certain elements for healthy normal growth. When any of these elements are left out of the diet, the body develops definite symptoms which may be related to its shortage. Deficiencies of this sort present themselves in abnormalities in the growth of body tissues, especially the skin, hair, teeth and bones.

Plants also have elements which are absolutely necessary for their normal growth, and many of these are the same as those required by humans. Nutrient tests may be conducted with such plants as corn, beans, tomato and barley to enable students to observe symptoms which develop on plants due to the lack of a particular element.

In addition to carbon, hydrogen and oxygen -- which plants get from the air and water -- there are fourteen elements required by plants. These are usually divided into three classes:

Element Names	Class
NITROGEN PHOSPHORUS POTASSIUM	Primary Elements
CALCIUM MAGNESIUM SULFUR	Secondary Elements
BORON MANGANESE COPPER ZINC IRON MOLYBDENUM CHLORINE NICKEL	Micronutrient Elements (needed in minute amounts; excess may be toxic)

II. Functions of Elements in Plant Metabolism and Symptoms Related to Their Deficiencies

A. NITROGEN

Function - promotes rapid vegetative growth and gives plants a healthy green color.

Deficiency Symptoms - stunted growth, pale yellowish color starting at older leaves, burning of tips and margins of leaves starting at bottom of plant.

Absorbed - NO_3^-, NH_4^+

B. PHOSPHORUS

Function - stimulates early growth and root formation, hastens maturity, promotes seed production,makes plants hardy.

Deficiency Symptoms - slow growth, poor root development, spindly stalk, delayed maturity, purplish discoloration of leaves on certain plants, dying of tips of older leaves, poor fruit and seed development.

Absorbed - $H_2PO_4^-$, HPO_4^{2-}

C. POTASSIUM

Function - improves plant's ability to resist disease and cold, aids in the production of carbohydrates and proteins, an active part of enzyme systems.

Deficiency Symptoms - slow growth: margins of leaves develop a "scorched" effect starting on older leaves, weak stalk, shriveled seed or fruit.

Absorbed - K^+

D. CALCIUM

Function - aids in the movement of carbohydrates in plants, essential to healthy cell walls and root structure.

Deficiency Symptoms - terminal bud dies under severe deficiency, margins of younger leaves scalloped, blooms shed prematurely, weak stem structure.

Absorbed - Ca^{2+}

E. MAGNESIUM

Function - is an ingredient of chlorophyll, aids in the translocation of starch within plant, essential for the formation of oils and fats.

Deficiency Symptoms - yellowing of leaves between veins starting with lower leaves, leaves abnormally thin, tissue may dry and die, leaves have a tendency to curl upward.

Absorbed - Mg^{2+}

F. SULFUR

Function - aids in the formation of oils and certain proteins.

Deficiency Symptoms - lower leaves yellow-green, stems and roots small, entire plant tends to be pale.

Absorbed - SO_4^{2-}

G. BORON

Function - aids in the assimilation of calcium; amount required is extremely small.

Deficiency Symptoms - affects tip growth, cracked stems in celery, small heads in cauliflower.

Absorbed - BO_3^{3-}

H. COPPER

Function - promotes formation of Vitamin A; excess is very toxic.

Deficiency Symptoms - bleached appearance of leaves, die-back of new growth in citrus.

Absorbed - cu+, Cu^{2+}

I. IRON

Function - essential in the formation of chlorophyll and in the release of energy from carbohydrates.

Deficiency Symptoms - yellowing of leaves (young leaves first), veins remain green, affected leaves curl upward.

Absorbed - Fe^{2+}

J. MANGANESE

Function - acts as a catalyst in plant growth processes.

Deficiency Symptoms - chlorosis between veins of young leaves, dead spots in affected tissue, dwarf appearance of plant.

Absorbed - Mn^{2+}

K. MOLYBDENUM

Function - aids plant in using nitrogen.

Deficiency Symptoms - stunted and yellow in color (resembles nitrogen-deficient plant).

Absorbed - MoO_4^{2-}

L. ZINC

Function - aids in the formation of chlorophyll and carbohydrates.

Deficiency Symptoms - small chlorotic leaves ("Little-leaf" in citrus), reduced fruit formation, die-back of twigs after first year.

Absorbed - Zn^{2+}

M. **CHLORINE**

Function - stimulates manufacture of carbohydrates and chlorophyll, helps regulate water balance in plants.

Deficiency Symptoms - slightly wilted appearance.

Absorbed - Cl^{-}

N. NICKEL

Function - recently discovered to be an essential trace element; details on its function, deficiency symptoms, etc. are still being researched.

Student Worksheet **Name** ___________________

CHEMICAL FORMULAS AND AVAILABLE IONS IN A FERTILIZER

INTRODUCTION

Soil serves as a storehouse for plant nutrients and normally provides plants with the nutrients they require to grow and reproduce. Under most conditions, however, growth can be enhanced by the proper application of supplemental nutrients especially when plants are grown in areas where they are not naturally grown or when plants are grown in heavily farmed areas where nutrients are not replaced as quickly as they are removed. Nutrients are removed from the soil when crops are harvested for food. Thus, fertilizers are used to replenish the soil.

Nutrients can be added to soil in many ways. The earliest fertilizer materials were animal manures, plant and animal residues, ground bones and potash salts (wood ashes). These substances are still used to amend soils today. Three major developments in the nineteenth century were the forerunners of the modern fertilizer industry and promoted the mass production of fertilizers as we know them today.

- **1839-** The discovery of potassium salt deposits in German states.
- **1842-** The treatment of ground phosphate rock with sulfuric acid to form super phosphate.
- **1884-** The development of the theoretical principles for combining hydrogen and atmospheric nitrogen to form ammonia.

Fertilizers are categorized by how much of the primary nutrients they contain. A single nutrient fertilizer has one primary nutrient. A multinutrient fertilizer has two or more of the primary nutrients. The three numbers on a fertilizer label represent the percentages of nitrogen, phosphorus and potassium, in that order.

When fertilizers are incorporated into the soil, they are absorbed in their ionic forms. The compounds in the following list are used to form fertilizers or are fertilizers themselves. Read the chemical formulas and write their chemical names in the appropriate places on the chart. Break the compounds into their positive and negative ions and complete the remainder of the table.

	CHEMICAL FORMULA	CHEMICAL NAME	POSITIVE ION	NEGATIVE ION
1.	NH_4NO_3			
2.	$(NH_4)_2HPO_4$			
3.	$Ca(NO_3)_2$			
4.	$Ca(CN)_2$			
5.	$NaN0_3$			
6.	H_3PO_4			
7.	KCl			
8.	KNO_3			
9.	K_2SO_4			
10.	Cu_2O			
11.	$CuSO_4$			
12.	$FeSO_4{\cdot}7H_20$			
13.	MnS04			
14.	$MnCl_2$			
15.	Na_2MoO_4 H_2O			
16.	$ZnSO_4{\cdot}H_20$			
17.	Zn0			
18.	$ZnCl_2$			

Compare the ions in the chart above to the essential plant nutrient ions that plants absorb. Which of the chemical formulas contain ions that plant roots can absorb?

KEY

"CHEMICAL FORMULAS AND AVAILABLE IONS IN A FERTILIZER"

	CHEMICAL FORMULA	CHEMICAL NAME	POSITIVE ION	NEGATIVE ION
1.	NH_4NO_3	Ammonium Nitrate	NH_4^+	NO_3^-
2.	$(NH_4)_2HPO_4$	Diammonium phosphate	NH_4^+	HPO_4^{2-}
3.	$Ca(NO_3)_2$	Calcium nitrate	Ca^{2+}	NO_3^-
4.	$Ca(CN)_2$	Calcium Cyanamide	Ca^{2+}	CN^-
5.	NaN03	Sodium nitrate	Na^+	NO_3^-
6.	H_3PO_4	Phosphoric acid	H^+	PO_4^{3-}
7.	KCl	Potassium chloride	K^+	Cl^-
8.	KNO_3	Potassium nitrate	K^+	NO_3^-
9.	K_2SO_4	Potassium sulfate	K^+	SO_4^{2-}
10.	Cu_2O	Copper (II) oxide	cu+	O^{2-}
11.	cuSO4	Copper (II) sulfate	Cu^{2+}	SO_4^{2-}
12.	$FeSO_4 \cdot 7H_20$	Iron (II) sulfate	Fe+	SO_4^{2-}
13.	$MnSO_4$	Manganous sulfate	Mn^{2+}	SO_4^{2-}
14.	$MnCl_2$	Manganous chloride	Mn^{2+}	Cl^-
15.	$Na_2MoO_4\ H_2O$	Sodium molybdate	Na^+	MoO_4^{2-}
16.	$ZnSO_4 \cdot H_20$	Zinc sulfate	Zn^{2+}	SO_4^{2-}
17.	Zn0	Zinc oxide	Zn^{2+}	O^{2-}
18.	$ZnCl_2$	Zinc chloride	Zn^{2+}	Cl^-

HOW TO DETERMINE THE PERCENT OF AVAILABLE NUTRIENTS IN FERTILIZERS

PURPOSE

As consumers, students need to learn how to make educated decisions about the products they buy. This activity will teach students how to make knowledgeable decisions about the purchase of fertilizers. The students will learn how to calculate the amount of plant nutrients available in any given fertilizer and then compare the costs of fertilizers with regard to the amount of nutrients that are available to plants.

CONCEPTS

- All fertilizers do not contain the same percentage of each of the primary nutrients; fertilizers are prepared in different compositions so the consumer, farmer or home gardener, can apply only what is needed to the soil?
- Though fertilizers are an important part of crop production over-fertilization and misuse of fertilizers can be harmful to the environment?
- In order to be effective, fertilizers must be used properly.

MATERIALS

For the class:

- Commercial fertilizer labels (optional)
- Fertilizer label handout (optional)

For each student:

- "How to Determine the Percent of A Nutrient Available in a Fertilizer" worksheet
- Calculator
- Periodic Table

TIME

forty-minute session

BACKGROUND INFORMATION

Farmers decide what fertilizers to apply examining the soil type, soil quality and the plant crop requirements. First, the particular soil is tested to see what nutrients need to be added to the soil. The farmer then chooses fertilizer combinations that will best meet the needs of the particular situation. Manures, composts, crop rotation with legumes and manufactured inorganic fertilizers are options to be considered in an integrated approach to plant nutrient supplementation. Underfertilization reduces crop yield. Overfertilization can reduce crop yield and can be costly and dangerous to the environment. More and more research is being done to reduce the problems of groundwater contamination, salt deposition on soils, etc. The agriculture industry realizes that it must do its job in protecting and improving the quality of the environment. The current agricultural trend is to make agricultural ecosystems sustainable. This means that farmers replace the substances that are removed from an ecosystem when a crop is harvested. Organic and inorganic substances are used to do this.

Chemistry calculations play a big part in determining how much of an element is available in a fertilizer and in a particular soil. Farmers also need to analyze fertilizers in order to use the most cost efficient ones. As your students complete the worksheet, they will learn how to calculate the percentages of various nutrients in a fertilizer and determine the percent yield of different fertilizers. They will see how this information is useful to themselves as well as to major farming operations.

HOW TO DETERMINE THE PERCENT OF AN ELEMENT IN A COMPOUND

The percentage composition of a compound is a statement of the relative mass each element contributes to the mass of the compound as a whole. A chemist often compares the percentage composition of an unknown compound with the percentage composition calculated from an assumed formula. If the percentages agree, it will help to confirm the identity of the unknown. This type of calculation will be used in this activity.

Salt is composed of two elements, sodium and chloride, in a 1 to 1 ratio. The two elements are present in the same ratio by mass. Therefore, the percentage of sodium in any sample of sodium chloride would be the atomic mass of the element divided by the formula mass and multiplied by 100.

$$\frac{\text{mass Na}}{\text{mass NaCl}} \times 100 = \frac{23\ \text{amu}}{23\ \text{amu} + 35.5\ \text{amu}} \times 100 = \frac{23.0}{58.5} \times 100 = 39.3\%\ \text{Na}$$

It is just as easy to calculate the percentage composition of a compound, such as ethanol, where more than one atom of an element appears. The formula for ethanol is C_2H_5OH and its molecular mass is 46.1 amu. It can be seen that one ethanol molecule contains two carbon atoms with a combined atomic mass of 24.0 amu. Therefore, the percentage of carbon in the compound is:

$$\frac{24.0}{46.1} \times 100 = 52.1\%\ \text{c}$$

PROCEDURE

1. Review with your students how to determine the percent of an element in a compound and how to determine yield.

2. Complete the worksheet with your students.

CONCLUSION

Understanding the chemistry of fertilizers is an important part of agriculture. Home gardeners and farmers alike can benefit financially and environmentally if they use basic chemistry and mathematics before making decisions about which fertilizers to purchase and apply.

VARIATION

1. Before or after this activity, you might want to do the “How to Read A Fertilizer Label” lesson from the unit “The Interrelationships of Soil, Water and Fertilizers and How They Affect Plant Growth” available from the California Foundation for Agriculture in the Classroom. See the Teacher Resources section of this unit for ordering information.

EXTENSIONS

1. Using the fertilizer label handout provided or actual fertilizer labels, have students create realistic questions that classmates answer.

2. The CD rom "Plant Requirements" by Technical Publications allows students to apply a certain percentage of a nutrient to a crop and observe what happens. Have your students experiment with different quantities of nutrients on a variety of crops.

FERTILIZER LABELS

WARNING:
Harmful or fatal if swallowed.
Keep out of Reach of Children.

Disposal: Container will not contain toxic residues if empty. Remove any additional fertilizer before disposal.
Store in cool, dry place. Product will lose nutrient value over time.

Guaranteed Fertilizer Analysis Statement

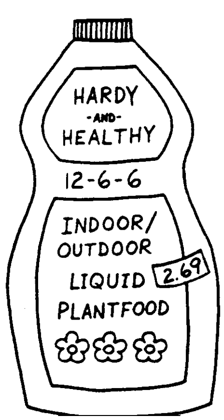
Total N 0%
5.6% Ammoniacle N
1.1% Urea N
1.3% Water Insoluble N
Available Phosphoric Acid (P_2O_5) .... **.12%**
Soluble Potash (K20) 4%
Calcium (Ca) 8.0%
Magnesium (Mg) 3.0%
Sulfur (S) **4.0%**
Boron (B) 0.02%
Iron (Fe) 0.4%
Manganese (Mn) 0.05%
Molybdenum (Mo) 0.0008%
Zinc (Zn) 0.05%

Warning: Keep out of reach of children.

Guaranteed Fertilizer Analysis Statement

Total N 17%
4.1% Ammoniacle N
8.9% Urea N
4.0% Water Insoluble N
Available Phosphoric Acid (P_2O_5) 23%
Soluble Potash (K20) ....*............ 6%

Derived from: Monoammonium phosphate, urea, methylene ureas, muriate of potash



Caution: Keep out of reach of children.
Harmful if swallowed.

Guaranteed Fertilizer Analysis Statement

Total N 12%
12% Urea N
Available Phosphoric Acid (P_2O_5) **6%**
Soluble Potash (K20) 6%
Iron (Fe) 0.5%
Zinc (Zn) 0.1%

Primary Nutrients from Urea and Potassium Phosphate

Trace Nutrients from Iron Sulfate and Zinc Sulfate

Directions: Add 1 Tablespoon per gallon of water. Apply to foliage and soil. Repeat monthly. Do not apply during heat of day.

Student Handout **Name**___________________

CHEMICAL COMPOSITION OF FERTILIZERS...PERCENTS AND PERCENT YIELD

1. Ammonium nitrate is used as a fertilizer; ammonia is also used as a fertilizer. Compute the percentage of nitrogen in each. If both cost the same amount per ton, which is the better buy in nitrogen content?

2. A farmer has two different fertilizers in her barn. One is K_2SO_4 and the other is KCl. The two fertilizers cost the same per ton, but she wants to use the one with the highest percentage of potassium. Which fertilizer should she use? Substantiate your explanation with numbers.

3. Most states mandate that "Guaranteed Fertilizer Analysis Statements" be printed in a standard format on all fertilizers. However, if the fertilizer label were not available, you might use something like the numbers below to determine whether or not substances were comparable in content. Determine whether or not the following samples are the same compounds.

   a 45.0 g sample containing 35.1 g Fe and 9.9 g SO_4
   215.0 g sample containing 167.7 g Fe and 47.3 g SO_4

   b. 75.0 g sample containing 20.5 g K and 54.5 g Cl
   135 g sample containing 67.5 g K and 67.5 g Cl

4. Calcium nitrate and ammonium nitrate are used as fertilizers. Compute the percent nitrogen in each. If calcium nitrate costs $225 per ton and ammonium nitrate costs $275 per ton, which fertilizer is more cost effective? (Hint: Determine the per pound cost of nitrogen for each compound.)

5. Animal manures are often used to add nutrients to soils. Assume that the average price for chicken manure is $15 per ton and contains 31 lbs of nitrogen per ton.

   a What percentage nitrogen does the manure contain?

   b. What is the cost per pound of nitrogen?

   c. Which is more cost effective--to apply chicken manure, calcium nitrate or ammonia nitrate? Explain.

   d. What are some issues, other than price, that might affect which of the fertilizers a farmer or gardener might choose to use?

6. "Super phosphate" fertilizer is made by treating phosphate rock, $Ca_3(PO_4)_2$ with sulfuric acid according to this equation.

   $$Ca_3(PO_4)_2 + 2H_2SO_4 \rightarrow Ca(H_2PO_4)_2 + 2CaSO_4$$

   If this reaction has a 52.5% yield, how much $Ca(H_2PO_4)_2$ could be obtained from 5.2 metric tons of phosphate rock?

7. Review the questions and answers in the problems above. How could this type of information help you as a home gardener? Why is it crucial that farmers understand how to do basic chemistry such as this?

KEY

CHEMICAL COMPOSITION OF FERTILIZERS...PERCENTS AND PERCENT YIELD

1. Ammonium nitrate is used as a fertilizer; ammonia is also used as a fertilizer. Compute the percentage of nitrogen in each. If both cost the same amount per ton, which is the better buy in nitrogen content?

Ammonium nitrate - NH_4NO_3 vs. Ammonia - NH_3

N		14.0067
H_4	4 x 1.0079 =	4.0316
N		14.0067
O_3	3 X 15.9994 =	47.9982
		80.0432

N		14.0067
H	3X1.0079=	3.0237
		17.0304

$$\%N = \frac{28.0134}{80.0432} \times 100$$

%N = 34.99 → 35%N
for Ammonium Nitrate

$$\%N = \frac{14.0067}{17.0304} \times 100$$

%N = **82.2%N**
for Ammonia

Ammonia (NH_3) is the better buy. It is applied as anhydrous ammonia, a colorless gas. The gas is injected into the soil, usually about 5 inches deep. While ammonia is the cheapest source of N, many safety precautions must be used in its application. Severe eye, nose, throat, lung and skin damage if the applicator comes into contact with the gas. Students should understand that factors other than price are considered in selecting nitrogen material.

2. A farmer has two different fertilizers in her barn. One is K_2SO_4 and the other is KCl. The two fertilizers cost the same per ton but she wants to use the one with the highest percentage of potassium. Which fertilizer should she use? Substantiate your explanation with numbers.

K_2SO_4

K2	2 X 39.0983 =	78.1966
S	=	32.06
O_4	4 x 15.9994 =	47.9982
		158.2548

KCl

K	39.0983
Cl	35.453
	74.5513

$$\%K = \frac{78.1996}{158.2548} \times 100$$

%K = 49.4%

$$\%K = \frac{39.0983}{74.5513} \times 100$$

%K = 52.4%

The farmer would get a better buy if KCl was used.

KEY (continued)

3. Most states mandate that "Guaranteed Fertilizer Analysis Statements" be printed in a standard format on all fertilizers. However, if the fertilizer label were not available, you might use something like the numbers below to determine whether or not substances were comparable in content. Determine whether or not the following samples are the same compounds.

   a. 45.0 g sample containing 35.1 g Fe and 9.9 g SO4
   215.0 g sample containing 167.7 g Fe and 47.3 g SO4

   $\%Fe = \frac{35.1}{45} \times 100 = 78\%$ $\quad\quad$ $\%SO_4 = \frac{9.9}{45} \times 100 = 22\%$

   b. 75.0 g sample containing 20.5 g K and 54.5 g Cl
   135 g sample containing 67.5 g K and 67.5 g Cl

   $\%Fe = \frac{167.7}{215} \times 100 = 78\%$ $\quad\quad$ $\%SO_4 = \frac{47.3}{215} \times 100 = 22\%$

   The compounds are the same.

4. Calcium nitrate and ammonium nitrate are used as fertilizers. Compute the percent nitrate in each. If calcium nitrate costs $225 per ton and ammonium nitrate costs $275 per ton, what fertilizer is more cost effective if you want to put on as much nitrogen as possible? (Hint: Determine the per pound cost of nitrogen for each compound.)

   First to solve this problem you need to find the %N in each material - similar to question #1.

$Ca(NO_3)_2$

Ca		40
N	2 X 14	28
0	6 X 16	96
		164

$\%N = \frac{28}{164} \times 100 = 17.1\%$

NH_4NO_3

N	2 X 14	28
H	4 X 1	4
0	3 X 16	48
		80

$\%N = \frac{28}{80} \times 100 = 35\%$

For every ton of calcium nitrate, only 17.1% is the desired, needed nitrogen. Therefore, for every 2,000 Ibs of calcium nitrate, only 0.171 X 2000) or 342 Ibs are actually nitrogen. For ammonium nitrate, 35% of the compound is nitrogen, so a ton of ammonium nitrate has (0.35 x 2000) = 700 Ibs of actual nitrogen.

To calculate which is more cost effective, you take the cost of each material per pound of actual N in each material -

KEY (continued)

cost of N in calcium nitrate = $\frac{\$225}{2000 \text{ lbs } Ca(NO_3)_2} \times \frac{2000 \text{ lbs } Ca(NO_3)_2}{342 \text{ lbs N}} = \frac{\$225}{342 \text{ lbs N}} =$ .658 = 66 cents per pound N

For ammonium nitrate, 35% of the compound is nitrogen or 700 lbs N for every ton of NH_4NO_3.

If ammonium nitrate is $275 per ton:

cost of N in ammonium nitrate = $\frac{\$275}{\text{ton of } NH_4NO_3} \times \frac{\text{ton of } NH_4NO_3}{700 \text{ lbs N}} = \frac{\$275}{700 \text{ lbs N}} =$ .039/lb of N

Ammonium nitrate = 4 cents per pound of N

The basic premise is that cost per ton of material and % N must be used to determine which N source is most cost effective. In this case, even though NH_4NO_3 costs more for a ton of material ($275 vs. $225/ton of material), it has a lot more N (35T N vs. 17.1% N in calcium nitrate). This high concentration of N spreads the cost out and makes NH_4NO_3 a cheaper source of desired N (4 cents per pound N vs. 66 cents per pound of N in $Ca(NO_3)_2$.)

This same theory applies to the consumer at the grocery store. Should you buy a whole chicken (with inedible bones and skin and neck, wings, etc.) for $1.50 per pound or buy boneless, skinless, all white meat chicken breasts for $2.50 per pound? Which one is the best buy of desirable, usable, edible chicken?

5. Animal manures are often used to add nutrients to soils. Assume that the average price for chicken manure is $15 per ton and contains 31 lbs of nitrogen per ton.

a What percentage nitrogen does the manure contain?

$\frac{31 \text{ lbs N}}{2000 \text{ lbs}} = .0155$ .0155 x 100 = 1.55% nitrogen

b. What is the cost per pound of nitrogen?

$\frac{\$15}{1 \text{ ton}} \times \frac{1 \text{ ton}}{2000 \text{ lbs}} \times \frac{2000 \text{ lbs}}{21 \text{ lbs}} = \$.484/\text{lb N} = 48¢$ per pound

c. Which is more cost effective--to apply chicken manure, calcium nitrate or ammonia nitrate? Explain.

Ammonium nitrate is more cost effective
chicken manure = 48¢ per pound
calcium nitrate = 66¢ per pound
ammonium nitrate = 4¢ per pound

KEY (continued)

d. What are some issues, other than price, that might affect which of the fertilizers a farmer or gardener might choose to use?

    safety
    ease of application
    reduced nitrogen loss to the environment
    effect on soil microbes
    effect on soil organic matter
    plant's need for other nutrients
    availability of nitrogen for immediate and/or delayed uptake by plants
    transportation costs

6. "Super phosphate" fertilizer is made by treating phosphate rock, $Ca_3(PO_4)_2$, with sulfuric acid according to this equation.

   $$Ca_3(PO_4)_2 + 2H_2SO_4 \rightarrow Ca(H_2PO_4)_2 + 2CaSO_4$$

   If this reaction has a 52.5% yield, how much $Ca(H_2PO_4)_2$ could be obtained from 5.2 metric tons of phosphate rock?

   $$5.2 \text{ metric tons} \times 0.525 \times \frac{\text{molecular mass of } Ca(H_2PO_4)_2}{\text{molecular mass of } Ca_3(PO_4)_2}$$

7. Review the questions and answers in the problems above. **How** could this type of information help you as a home gardener? Why is it crucial that farmers understand how to do basic chemistry such as this?

   Answers will vary.

MAKING A FERTILIZER AND TESTING FOR PHOSPHATES

PURPOSE

The purpose of this activity is for students to experience making a fertilizer and then to quantitatively test for a particular component, phosphate, in fertilizers.

CONCEPTS

- Fertilizers are made in a variety of ways.[4]
- Fertilizers contain elements and can be tested to measure the amounts of those elements.
- Fertilizers do not all contain the same percentages of each of the primary nutrients; fertilizers are prepared in different compositions so the consumer, farmer or home gardener, can apply only what is needed to the soil.[5]

MATERIALS

For each student:

"Making A Fertilizer" and "Phosphate Analysis of Fertilizers" worksheets

For the entire class:

"Making a Fertilizer":

- NH_4NO_3
- KH_2PO_4
- KCl
- Flasks-- 1 per team
- Stoppers to fit flasks
- Balances
- Filter paper
- Distilled water

"Phosphate Analysis of Fertilizers": (materials listed are for 30 students in teams of two):

- 20 g ascorbic acid
- 20 g commercial fertilizer having a 20% phosphate content
- 1 .O L of 10.0 ppm standard phosphate buffer solution (65 mL/team)
- 1 g potassium phosphate, di-basic (K_2HPO_4) for preparing standard phosphate buffer solution; fw= 174.18 as anhydrous K_2HPO_4 (see advance preparation)
- 300 mL ammonium molybdate-sulfuric acid reagent (see advance preparation)
- 7.5 g ammonium molybdate $(NH_4)_2MoO_4$ crystals for preparing reagent
- 150 mL conc. sulfuric acid for preparing reagent
- 10 liters distilled water
- 105 test tubes (19mm x 150mm)- 6 per team
- 15 test tube clamps
- 15 ringstands, ring clamps, wire gauze
- 15 500 mL beakers
- 15 250 mL beakers
- 15 10 mL graduated cylinders
- 15 5mL or 1 00-mL cylinders
- 15 500mL flasks
- 15 stirring rods
- 15 Bunsen burners
- balance with filter paper

TIME

2 class periods

BACKGROUND INFORMATION

Phosphate rock deposits are the basic source of all phosphate materials. The earth has many natural deposits of phosphate which are igneous or sedimentary in origin. The predominant phosphate mineral is francolite, a carbonate fluorapatite represented by the formula $Ca_{10}F_2(PO_4)_6 \cdot CaCO_3$. Most of the world's reserves now being mined are in North Africa, North America and Russia. The phosphate mines in the western states are located in Montana, Idaho, Utah and Wyoming. Florida, North Carolina and Tennessee also have phosphate rock deposits. Phosphate rock must be converted to a phosphate form which can be utilized by plants. Most phosphate rock contains 14 to 35 percent phosphate; therefore, it must be concentrated to process into fertilizers. One common method of doing this is by exposing the phosphate rock to sulfuric acid and water as shown in the simplified chemical equation below:

$$Ca_{10}F_2(PO_4)_6 + 10\ H_2SO_4 + 20\ H_2O \rightarrow 10\ CaSO_4 \cdot 2\ H_2O + 2\ HF + 6\ H_3PO_4$$

phosphate rock + sulfuric acid + water → calcium sulfate (gypsum) + water + hydrogen fluoride + phosphoric acid

PREPARATION:

THIS ADVANCE PREPARATION MUST BE PERFORMED BY INSTRUCTOR ONLY

STANDARD PHOSPHATE SOLUTION

The standard phosphate solution is prepared by dissolving 1.0 g K_2HPO_4 in a small volume of water and then diluting to 1000 mL in a volumetric flask. Mix. Take 20 mL of this solution and dilute to 1000 mL. This produces one liter of standard (10.0 ppm) phosphate solution.

AMMONIUM MOLYBDATE-SULFURIC ACID REAGENT

The ammonium molybdate-sulfuric acid reagent is prepared as follows.

- Dissolve 7.5 g of ammonium molybdate in 75 mL of distilled water. Cool the solution in an ice bath. Retain this solution for a later step.
- Slowly, while mixing, add 125 mL of ice-cold 18 M H_2SO_4 to 125 mL of ice-cold distilled water. *(Caution: Diluting concentrated sulfuric acid generates considerable heat, and may produce splattering if not added slowly with continual stirring. Perform this dilution with considerable care.)*
- Slowly, while mixing, add the cold sulfuric acid solution to the ice-cold ammonium molybdate solution. Keep the ammonium molybdate solution in an ice bath during this step. This makes up the **325 mL** reagent solution.

FERTILIZER "X

Buy a fertilizer that has a 20% phosphate content (N-P-K). This will be Fertilizer "X" in the lab.

PROCEDURE

MAKING A FERTILIZER

1. Discuss with students the different ways of producing fertilizers (See background information and also refer to the Western Fertilizer Handbook). Tell them that they will be making a simple liquid fertilizer.

2. Have students complete the lab.

3. Make sure your students save their fertilizers for the next activity.

PHOSPHATE ANALYSIS OF FERTILIZERS

1. Discuss the purpose of this activity with your students. (See purpose and background information as well as student lab.)

2. After reviewing safety precautions, have students complete the lab.

3. Discuss ways, other than colorimeters, of identifying ions in particular substances.

4. After the students have completed the experiments, relate their findings to the global agricultural picture. Center the discussion around the post-lab questions which emphasize the importance of colorimetric techniques, student connections to everyday observations of the color density of solutions and the practical significance of quantitative data to a farmer.

Lab Tips

- The actual value of phosphate, as phosphorus (V) oxide , P_2O_5, using 20-20-20 fertilizer is 20%.

- Fertilizer "X" will range between 17-25% phosphate (P_2O_5).

- The intensity of the color is affected by the length of time the solution is allowed to boil; some consistent method of heating must be agreed upon to insure comparable results throughout the class. The point at which the first “bump” of boiling occurs is an acceptable reference point.

- With a spectrophotometer, data can be collected and plotted to obtain an absorption curve for the phosphate standards. This curve can then be used to compare sample values with the standards. A wavelength of 610 nm gives optimum absorption for this experiment.

CONCLUSION

Fertilizers are made in a variety of ways and contain a variety of components in various concentrations. Fertilizers can be produced to contain certain ions that are required by plants in specific quantities and these ions can be measured using a variety of techniques including colorimeters. The chemical production and analysis of fertilizers is crucial to the viability of farmers as well as the environment.

EXTENSIONS

1. Have a discussion about phosphorus. Perhaps a fertilizer manufacturer representative and/or farmer can discuss some of this information with your students. Some possible questions are listed below.

   - Where does phosphorus come from?
   - How is phosphorus formed in nature?
   - Where are phosphate deposits located?
   - What soil types and weather conditions are needed for phosphorus deposit formation?
   - Are there phosphorus mines located in California?
   - What are some non-agricultural uses of phosphorus?
   - Once mined, how is phosphorus formulated for agricultural use?
   - What are the functions of phosphorus in plant and animal systems?
   - What quantity of phosphate rock is mined each year?
   - Is the phosphorus supply considered to be endless? If not, predict when human use will exceed phosphorus reserves.
   - What are alternatives to mining phosphate rock to obtain useful phosphorus?

2. Have students plant corn or wheat seeds. Water some with tap water, some with class-made fertilizers and some with store-bought fertilizers. Compare the results.

3. Prepare four different fertilizers--one without nitrogen, one without potassium, one without phosphorus, and one with all three. Use the fertilizers on plants and observe growth variations due to nutrient deficiencies.

4. Use the "waste" fertilizers from the experiment on school landscaping.

(Lab activities adapted from <u>ChemCom</u>, a high school chemistry book, with permission.)

Student Handout **Name** ___________________

MAKING A FERTILIZER

INTRODUCTION

All plants require certain nutrients in order to grow. However, the amount required varies from plant type to plant type. For example, asparagus requires approximately half as much nitrogen, 65% of the phosphorus and 50% of the potassium that almonds require. Therefore, an almond farmer will need to use a different composition fertilizer than an asparagus grower if nutrients are to be applied in the needed quantities. Proper application of appropriate fertilizers benefits farmers financially as well as protects soil, water and air quality.

Your group will formulate one of two liquid fertilizers. The two liquid fertilizers will have different compositions. As you complete the procedure, keep in mind how your research could benefit agriculture.

PROCEDURE

WEAR GOGGLES FOR THE PROCEDURE BELOW

1. Group A will produce a fertilizer as follows:

   a. Combine 7.1g NH_4NO_3, 4.8g KH_2PO_4 and 1.4g KCl with a mortar and pestle.
   b. Take 0.5g of mixture and put in 500 ml flask. Add enough water to produce 500 ml of solution.

   Group B will produce a fertilizer as follows:

   a. Combine 4.8g KH_2PO_4 and 1.4g KCl with a mortar and pestle.
   b. Put 0.5g of mixture into 500 mL flask. Add enough water to the mixture to produce 500ml of solution.

2. Save the fertilizer you prepared for the next activity!

3. Complete the “Let‘s Think About It” section.

LET'S THINK ABOUT IT!

1. Legumes, such as peas, beans and peanuts, have a unique mutualistic relationship with certain bacteria that live in nodules on the roots of these plants. The bacteria are able to convert atmospheric nitrogen (N_2), a form of nitrogen that plants cannot absorb, into ammonium ions (NH_4^+), a form of nitrogen that plant roots can absorb. For this reason, most legumes do not require nitrogen to be added to the soil in order to grow.

   Suppose you are a farmer. Last season you grew corn on a particular plot of land. You have decided to grow beans on the land this season. The bean plants will be tilled into the soil after harvest. They will not only add nitrogen back into the soil, they will also add organic matter which will make the soil more viable, thus improving water holding capacity, infiltration and tilth.

   Review the compositions of both fertilizers that your class made. Which fertilizer (A or B) should the farmer use on the beans, or does it matter? Explain your reasoning.

2. The fertilizer you made was a liquid. Fertilizers are also applied as solids and gases. Describe a situation where you think a solid or gaseous fertilizer would be a more appropriate form of fertilizer. How do you think gaseous and solid fertilizers are made? How are they applied to the soil?

Student Handout **Name** ___________________

PHOSPHATE ANALYSIS OF FERTILIZERS

INTRODUCTION

Most fertilizer packages list the percents (by mass) of the essential nutrients contained in the fertilizer. In this activity you will determine the mass and percent of phosphate ion in various fertilizer solutions. The method you will use, called a **colorimetric** method, is based on the fact that the intensity of a solution's color indicates the concentration of the colored substance. A chemical reaction will convert colorless phosphate ions (PO_4^{3-}) to colored ions. To determine the percent of phosphate ion present, you will compare the color of the unknown solutions to colors of solutions with known concentrations.

PROCEDURE

WEAR GOGGLES DURING THE PROCEDURE DESCRIBED BELOW!

Note: You will prepare the unknown fertilizer solution by diluting the fertilizer "X" by a factor of 50. This dilutes it enough for comparison with the color standards you will have. You will also dilute the fertilizers A and B you and your classmates prepared by a factor of 50.

1. Label 7 test tubes as follows: 10 ppm, 7.5 ppm, 5 ppm, 2.5 ppm, Fertilizer A, Fertilizer B, and X. (ppm=parts per million)

2. Complete these steps to prepare the unknown fertilizer "X" solution:

   a. Place 0.50 g of fertilizer "X" in a 400 mL beaker. Label the beaker "original."
   b. Add 250 mL of distilled water. Stir until the fertilizer is completely dissolved.
   c. Pour 5.0 mL of this solution into a clean dry 400 mL beaker labeled "dilute." Discard the remaining 245 mL of the "original" solution in the container provided by your instructor.
   d. Add 245 mL of distilled water to the 5.0 mL solution in the dilute beaker. Stir to mix.

3. Pour 20 mL of the diluted solution into the test tube labeled "X". Discard the remaining diluted solution in the container provided by your instructor.

4. Complete these steps to prepare the Class Fertilizer A .

   a Place 5.0 mL of fertilizer A in a clean, dry 400 mL beaker and to it add 245 mL of distilled water.
   b. Label the beaker "A".
   c. Pour 20mL of the "A" solution into the test tube labeled "A". Discard the remaining solution in the container provided by your instructor.

5. Complete the steps described in #4 above, with Class Fertilizer B.

6. In the tube labeled 10 ppm, place 20 mL of the standard 10 ppm phosphate ion solution provided by your teacher. Add solutions and water to the other three test tubes as listed below:

Concentration (ppm)	Standard 10 ppm phosphate solution (mL)	Distilled Water (mL)
10	20	0
7.5	15	5
5	10	10
2.5	5	15

7. Add 2 mL of ammonium molybdate-sulfuric acid reagent to each of the four prepared standards, the unknown (X), and the class fertilizers "A" and "B."

8. Add a few crystals of ascorbic acid to each tube. Stir to dissolve.

9. Prepare a water bath by adding about 200 mL of tap water to a 400 mL beaker. Place the beaker on a ring stand above a Bunsen burner. Place the 7 test tubes in the water bath.

10 Heat the water bath containing the test tubes until a blue color develops in the 2.5 ppm solution. Turn off the burner.

11. Allow the test tubes to cool briefly. Using a test tube holder, remove the test tubes from the water bath and place them numerically in a test tube rack.

12. Compare the color of the unknown solution with those of the standard solutions. Place the unknown "X" between the standard solutions with the closest matching colors. Do the same for the test tubes labeled "A" and "B."

13. Estimate the concentration (ppm) of the unknown solution and the two class solutions, "A" and "B", by comparing the solutions to the known concentrations of the color standards. (For example, if the unknown solution color falls between 5 ppm and 7.5 ppm color standards, you might decide to call it 6 ppm, or 6 g phosphate ion per 10^6 g solution). Record the estimated values of each of the substances by creating an easy to read table of your own creation.

14. Clean up the equipment and wash your hands thoroughly before leaving the laboratory.

CALCULATIONS

1. Calculate the mass of phosphate ion in the three fertilizers (X, A and B) using this equation. Place the numerical value of the unknown solution concentration (in ppm) in the blank.

$$\text{mass of } PO_4^{3-}(g) = \frac{\_\_ g\ PO_4^{3-}}{10^6 g \text{ solution}} \times 250g \text{ solution} \times 50$$

The factor of 50 in the calculation takes into account the 50-fold dilution of the fertilizer solution. By multiplying the calculated mass of phosphate by 50, the mass is adjusted back to its pre-diluted value. Record the calculated mass of the phosphate ion.

2. Calculate the percent phosphate ion (by mass) in the fertilizer sample. Record this value.

$$\% \ PO_4^{3-} = \frac{\text{mass of phosphate ion (step \#13)}}{\text{mass of fertilizer (0.50g)}} \times 100$$

QUESTIONS

1. Name two household products or beverages for which you can estimate relative concentrations just by observing their color intensity.

2. Instruments called colorimeters are often used for determining solute concentration. In this experiment, phosphate ions are the solute. Colorimeters measure the quantity of light that passes through an unknown sample and compares it with the amount of light that passes through a known standard solution.

   Colorimeters are used on tomato harvesters. A standard wavelength for the color red is set in the colorimeter. Tomatoes pass by the colorimeter as they are harvested. Tomatoes which do not have the appropriate color, such as green or yellow tomatoes, are identified by the colorimeter and are dropped out of line and dumped back into the field.

   What are the advantages of a colorimeter over the human eye? Why do you suppose tomato harvesters still need to have a few people on them to help sort out odd colored tomatoes?

3. Explain this statement: "The accuracy of colorimetric analysis depends on the care taken in preparing the standards." Your fertilizers "A" and "B" should have had 10% phosphate ion. How close were you to this number? Where do you think some error factors occurred in your experiment?

4. Techniques other than colorimetric techniques are used to determine the quantity of certain ions. How could a reaction that produces a precipitate be used to determine the concentration of an ion?

5. Why is it important for farmers to know exactly the percent composition of fertilizers they use?

6. What risks are involved in applying more nutrient to a soil than is actually needed?

7. If you were a farmer, what do you think you would do to make sure that you are applying the appropriate amounts of nutrients to the soil? What should scientists, agribusinesses, etc. do to help you carefully manage your land?

A LETTER TO YOUR GRANDFATHER!

PURPOSE

The purpose of this activity is to allow your students to apply the knowledge they gained to a new situation. Career opportunities in agriculture are also addressed.

CONCEPTS

- The concepts relating to plant nutrient uptakes are extremely complex.*
- Chemistry learned in the classroom is applicable to the real world and affects the lives of all people, including farmers and consumers.
- There are many career opportunities related to agriculture that do not directly involve production agriculture.

MATERIALS

For **each student:**

- 1 copy of the "A Letter To Your Grandfather" scenario

TIME

One lo-minute session to introduce the writing assignment
Two to three nights for students to complete their writing assignment at home
One 20-minute session to do the concluding activity

BACKGROUND INFORMATION

Statistics have shown that many jobs related to agriculture are left unfilled each year due to the lack of qualified applicants. It is estimated that 48,000 jobs related to agriculture are available each year. However, only 43,500 qualified people are put into the work force each year. Agricultural occupations do not include farming only. Only 1-2% of the United States population actually farms. Jobs left vacant include positions such as agricultural scientific researchers, attorneys, sales personnel, environmental inspectors, etc. The handout "Think About It" lists numerous career opportunities that relate to agriculture. Information on how to receive a copy of the handout can be obtained by writing the California Foundation for Agriculture in the Classroom.

PROCEDURE

1. Discuss the objectives of this activity with your students.

    a) You want them to review the knowledge they gained in the last few days and apply it to a new situation.
    b) You want them to see how chemistry fits into the real world in which they live.
    c) You want them to think about the challenges that face the environment today and how they can be overcome.
    d) You want them to think of career opportunities that are available related to the food we eat and the clothes we wear.

2. Explain to the students that this activity will be used as an evaluation tool to see what the students have learned.

3. Have the students complete this writing activity at home. Encourage students to do many rewrites of their letter and to proof them. You may even allow time in class for students to proof each other's work.

4. On the due date of the assignment, have students exchange their letters with one another to see what other students have written. Some students may wish to read their letters aloud to the class.

5. Return the "Chemically Speaking - What's in a Plant?" papers the students completed at the beginning of this unit. Have students re-read their answers and discuss which of their thoughts have changed and which have remained the same.

CONCLUSION

The students should conclude that chemistry plays a vital role in production agriculture and environmental quality. Many challenges exist in these areas, but with the aid of scientific research and technology they can be overcome.

VARIATIONS

1. Have the students complete this activity in small groups.

2. Have the students present a scientific paper on their research at a hypothetical conference titled "Chemistry and Agriculture".

Student Handout **Name** ___________________

A LETTER TO MY GRANDFATHER

Put yourself into the situation described below:

You have lived on a large farm all of your life. The land your family owns has been farmed since your great-great-grandparents moved west.

You have enjoyed the farming operation and feel your family is very successful. Your grandfather, however, thinks a little differently. He thinks that the family is currently successful but is concerned about food production in the future. He has seen tremendous changes in the agricultural industry over the years. He has lived through the Dust Bowl era, the changes in pest management, changes in fertilizer production and usage and has observed the drastic reduction of prime agricultural land as more houses and factories are built. He feels that the family farming operation must be updated and that the family must do its part to find out about current issues and trends in agriculture. He knows that if the soil, land and air are not properly taken care of, your family will not have a future in farming.

Knowing that you wish to continue the farming operation, your grandfather stated that you should attend a two day comprehensive chemistry conference on soil amendments and fertilizers. You hesitantly agree to go, not quite sure of how chemistry fits into farming.

Pretend that the labs, discussions and readings you did the past few days were part of this conference. As a farmer, you are amazed at how much the scientific researchers do for the world of agriculture and how many challenges are yet to be overcome.

Your task as a student is to assume the role of the young farmer. Choose one of the two assignments described below.

A) Write a letter to your grandfather explaining what you learned at this seminar. Act enthusiastic about the material you learned and about the crucial connections you see between farming and science. Discuss the challenges that face agriculture and the environment. Mention the different types of people you met at this seminar who spend their lives working to make agriculture a viable industry that protects the environment and provides safe and plentiful food.

B) After attending the conference, you decide to take action on a situation that exists on your property. Fifteen to twenty 100 pound bags of fertilizer were delivered to your farm during a rainstorm. The labels were destroyed, but the fertilizer is still salvageable. In an effort to save money and resources, you decide to determine the fertilizer content and then use the fertilizer appropriately. Write an explanation of how you would go about identifying the fertilizer - who you would contact, what tests they would do, etc. Also discuss specific reasons explaining why you want to identify and use this material rather than discard it.

Note: This assignment should clearly show your instructor how much knowledge you gained in the areas of chemistry, fertilizers and agricultural and environmental awareness.

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Nitrate Debate

Public concern over nitrates in groundwater has the Salinas Valley considering solutions.

by Caroline Mufford

Nitrogen, as every farmer knows, is essential to food and fiber production (to say nothing of profits), yet it is also a potential source of environmental stress. In some cases this stress can increase under drought conditions. Minimizing its leakage from the crop root system by avoiding overloading the soil with nitrate is the key to reducing the amounts of the substance moving to ground and surface waters. While nitrates in groundwater can hardly be described as a statewide problem, a California Department of Food and Agriculture (CDFA) Nitrate Working Group report warns, "Several regions of California have significantly high levels of nitrate in groundwater." The report calls for the establishment of local management programs in areas with high levels of nitrate sensitivity.

"Whether it's food safety, or environmental hazards, farmers and ranchers in this state have a different burden than in other states-that of being a good neighbor,'' says Merlin Fagan, natural resources director for the California Farm Bureau. "If they don't move swiftly to solve it, others will."

While the Environmental Protection Agency (EPA) estimates that only a small percentage of wells tested have nitrate contamination above the federal health advisory level of 10 parts per million, more farmers are seeking reassurance that responsible production agriculture will not contaminate water. As a result, ConAgra Technologies, along with Neogen Corporation, has introduced Agri-Screen Nitrate test to allow individuals to determine the nitrate levels in their water. A simple kit is used to test drinking, well and surface water as well as water from field runoff or tile drainage. (For information on the test call l-800-634-757 1.)

Monterey County, the "salad bowl" of the nation, is one of several areas that illustrates the complexities of concerns and problems associated with a nitrate pocket. Fields of celery, lettuce and other shallow-rooted vegetables dominating the landscape require high levels of nitrogen. Agriculture's visibility, growers and other community leaders say, makes it an easy target. Some public concerns are real and some overblown, but growers are realizing they must face them and find educational, political and agricultural solutions.

Monterey County has the most nitrate-contaminated drinking water in California. Of monitored wells, 48 percent show unacceptable levels of nitrate contamination, according to Monterey County Water Resources Agency (MCWRA) figures.

Matt Zidar, senior county hydrologist, says, "We have the largest number of small water systems in the state." The agency projected in its June 1988 report, ' 'Nitrates in Groundwater,' ' that ' 'Based on the trend of the last 10 years, the projected mean nitrate concentrations will exceed the drinking water standard in the year 2000 by 1.9 to 4.4 times in all unconfined subareas." This projection is based on 90 comparison wells. The drought, now in its fifth year, worsens contamination because of lack of "recharge" to

See Nitrate, Page11

Nitrate

Continued From Page I

aquifers, says Russ Jeffries, the mayor of Salinas. "If it had not been for not having any rain for the last five years, personally I don't think we'd even be talking about [nitrate contamination],*' says grower Sid Christierson of Major Farms.

Controversy over nitrates in Monterey revolves around money, but the underlying issues involve much more, including public health, real estate development, cleanup of drinking water, assignment of liability and responsibility for costs and the well-being of local agribusiness. For example, one local paper linked Monterey's high rate of birth-defect deaths (highest among California's 30 large counties) to nitrate pollution in groundwater.

On the Monterey Peninsula, a recent moratorium halted the drilling of new wells. The health department cites nitrate pollution as the reason, but growers consider it a no-growth ordinance in disguise. "If you know you have nitrate contamination on your property, there may be disclosure requirements before a property transfer," which could make properties unattractive to potential buyers, Zidar explains.

A major concern revolves around the imminent threat to the aquifer providing drinking water for Salinas, Monterey's largest city, with 106,000 residents. Jeffries says an aquifer on the valley's east side that is highly contaminated with nitrate is now migrating toward an aquifer feeding the city. "Most reports point fingers at growers, but there are several other points of nitrate contamination,' ' Jeffries says.

Zidar adds that nitrates in groundwater are almost impossible to trace. If scientists find this kind of contamination underneath a 30-year-old feedlot, for instance, they can make "an educated guess" that the nitrates come from feedlot animal waste, but the complexities of soil and water movement mean no one can be certain. Tracing the origin of the contamination is the first order of business in deciding liability for cleanup costs. ' 'Nitrate contamination can be handled by filtration or reverse osmosis of nitrate, but it is very expensive to do. Consequently, who is responsible for that cost of cleanup?'' Jeffries asks.

Direct costs due to nitrate mitigation for Salinas or other sites could include well relocation and/or deepening, wellhead treatment to remove nitrogen, and the importing of water for dilution. According to 1989 estimates by the Orange County Water District, the wellhead treatment process for nitrate removal costs about $375 per million gallons. In 1986, California's Department of Health Services says it received requests for remedial measures for nitrate of $48.7 million. Many water systems do not apply for funding, so total funds expended for nitrate mitigation may run higher.

Benny Jefferson, a grower of cauliflower, head lettuce, celery, and mixed lettuces, says many growers will have increased costs for their water systems. "The Monterey County Environmental Health Department is going to go around and check every single well. If you have two houses, and one is [inhabited by] an employee, then you are required to have a doublecheck valve," he explains. Cliff Sharpe, field operations manager with the Office of Drinking Water, adds that farm families with babies will want to check for nitrates in their property's well water. In California, Sharpe says, 600,000 to 1 million people depend on private wells for drinking water.

In response to these concerns, the Monterey County Board of Supervisors in October 1988 formed the Ad Hoc Salinas Valley Nitrate Advisory Committee, composed of local officials (including Jeffries), hydrologists, and ag community members. Members expect the report to go to the board this spring.

Jacques Franco, CDFA nitrate management coordinator, says statewide oversight of this contamination is easier than it is for local agencies. However, he says, nitrate contamination exists as a localized problem, varying widely among areas within counties. "It's a touchy subject because you are dealing with liability, particularly at the local level," Franco says. "In Monterey I've seen all sorts of funky manipulations to sanitize reports. Everybody there is under tough pressure to come up with the kinds of answers the constituency is willing to accept." For instance, he says, Monterey County is caught in a squeeze between state and local pressures. "The state board has power to adjudicate a basin. They have

See Nitrate, Page III

Nitrate

Continued From Page II

threatened the board of supervisors to do that if they don't clean up the groundwater. Some people say 'let them do it.' ''

The fertilizer industry has been pursuing nitrate management, according to Steve Beckley, executive vice-president of California Fertilizer Association. CFA helped set up a fertilizer sales tax to fund Franco's program through CDFA. "We want to make sure we (the fertilizer industry) are [not part] of the problem," Beckley says. Many factors contribute to nitrate contamination, and the complexities of Salinas Valley provide a good example. Backflow often gets fingered, but Jefferson, who serves on the nitrate committee, feels the issue is overblown. "Nitrate from wells is over-calculated as a problem in this county," he says. "No one injects more fertilizer than absolutely necessary.'' Christierson, who also is a member of the committee, agrees. "We're not going to put on any more fertilizer than we have to . . . Nobody in their right mind is going to run fertilizer down a well." UC Extension soils specialist Stuart Pettygrove says geologic source leaching from irrigation water has been incorrectly ruled out in Salinas.

Photographic evidence from the Monterey area shows, in fact, that active greenhouse operations may be among the highest sources of nitrate contamination, according to Gerald Snow, water quality analyst with MCWRA. Greenhouses historically use three to four times the nitrate as comparable root crops-Snow says they flush excess nitrogen.

For example, the nitrate level in Quail Creek, along which a greenhouse is located, often runs up to l,OOO-2,000 ppm.

Evidence also shows that long-running cattle feedlots may contribute high levels of nitrate. However, Snow contends, feedlots have improved their practices in recent years.

According to Snow, other nitrate "hot spots'' in Monterey County include an agrichemical dealer with poor handling practices (the dealer has since improved), a farm where nitrate fertilizers were siphoned down a well, numerous former dairies in the county, and even septic tanks. Sandy soils, irrigation and organic matter in the soil also affect nitrogen movement and levels.

Growers outside of Monterey County will not escape the issue, either, although groundwater-nitrate problems, hence political pressures, vary tremendously among counties. In Fresno County, groundwater nitrate values have tested above the maximum contaminant level (MCL) for years. Last surnmer, Fresno Extension advisors Dan Munk and Pedro Ilic found 100 ppm of nitrates in a well supplying household drinking water on a small farm. However, Munk says, at another farm two miles away, well water measured only 20-15 ppm. Small-farm and vegetable advisor Ilic says farmers he works with tend to over-fertilize. "The Valley has a serious problem with nitrate contamination," Ilic says, noting 60 years of continuous farming as a factor. "We all need to assume we contribute to the problem," he warns.

Sources for rising nitrate levels in California aquifers include greater numbers of people generating more sewage, the burning of fossil fuels, greater industrial sources and greater amount: c.f nitrogen fertilizer and livestock, CDFA's Nitrate Working Group says in its February 1989 report, "Nitrate and Agriculture in California."

Nationwide, concern over nitrates intersects other growing public concerns. Consumers want clean drinking water, local and federal governments seek to stop groundwater pollution, and everywhere urban interests seem to be rubbing against those of agriculture.

"Historically," says Franco, "EPA has directed state water quality agencies toward point-source problems. Most of the efforts have been put into these programs over the past 20 years. Nonpoint water problems are much more complicated, technically and politically."

"Nitrate is ubiquitous in the environment," says Pettygrove, of UC-Davis. "You can't trace it to a bag of fertilizer.'* According to the CDFA report, ''Fertilizer applications, when associated with porous soils and excessive application of irrigation water or in areas with shallow water tables, have contributed to the increase in groundwater nitrates. Additionally, areas within the state which are vulnerable are those where multiple plant-

See Nitrate, Page 1111

Nitrate

Continued From Page III

ings of high-nitrogen- requiring, low use–efficiency vegetable and truck crops are grown. The high nitrogen requirement and production of up to three crops a year make the total nitrogen applied several times the.normal application rate for most other systems."

Last year, Franco says, California initiated a "nonpoint source" nitrate unit in Sacramento, managed by Stan Martinson. "I think the pressure [on nitrates] is going to come," Franco says. On a federai level, the EPA released in November 1990 a five-year, $12 million study of drinking-water wells in the United States. EPA thus started an undoubtedly busy year of 'debate, as the lo-year-old Clean Water Act comes up for reauthorization this year. EPA found more than half the wells it tested were tainted with nitrates. But it found nitrate above the MCL in fewer than 3 percent of wells. The American Farm Bureau states: "Farmers and Farm Bureaus may be forced to defend themselves against headlines that talk about nitrate detections even though levels of O-3 ppm nitrate-nitrogen are considered natural background levels. EPA did not say how many detections were in this natural range."

The Salinas Valley experience suggests growers can prepare for increasing pressure over nitrates by educating themselves as well as the public; by political organizing, particularly at local or county levels; and by a score of agricultural approaches. For education, Ilic says Extension offices can guide growers to material, adding that new publications on nitrates are plentiful. For organizing, counties with high groundwater nitrates can consider the Salinas Valley report recommendations: ' 'A cooperative effort between numerous agencies and groups will be required. These may include the District, the County Agricultural Commissioner's Office, agribusiness interests, UC Extension Service, the Soil Conservation Service, Monterey County' Environmental Health Department, the Central Coast Regional Water Quality Control Board, the State Water Resources Control Board, and the CDFA."

Such a group could institute programs to locate abandoned wells and ensure containment of polluted water, for example. It also could set up a program to educate farm workers on fertilizer handling practices.

The CDFA report from the Nitrate Working Group also suggests establishment of local management programs in areas with high levels of nitrate sensitivity. It calls for immediate reduction of significantly high levels in several regions of California, and recommends CDFA facilitate these five actions: Identify nitrate-sensitive areas; list priority areas for nitrate control; set up nitrate management programs in these areas with local government and agriculture; develop best-management practices to incorporate in these local programs; and establish a research and demonstration project on nitrate control through irrigation, fertilizer, and manure management.

For agricultural approaches, "It's a different prescription for each soil and crop condition," Pettygrove says. Munk says one eggplant and tomato grower with high nitrate groundwater levels plans to forgo additional nitrate applications this year. Grower Jefferson says, "One of the most important things you can do is to make sun your injection point for fertilizer for a well is on the downstream side of your checkvalve." Monterey invites growers to begin with evaluation of their irrigation systems, since water use is integral to nitrate movement. The county has available a new mobile lab to offer free, no-obligation evaluations.

To growers who feel beleaguered over nitrates, Franco reminds them the same programs can be seen as environmentally motivated, "bottom-line enhancement. Energy savings, water savings and water quality-all these goals are aligned when you reduce water contamination from nitrate."

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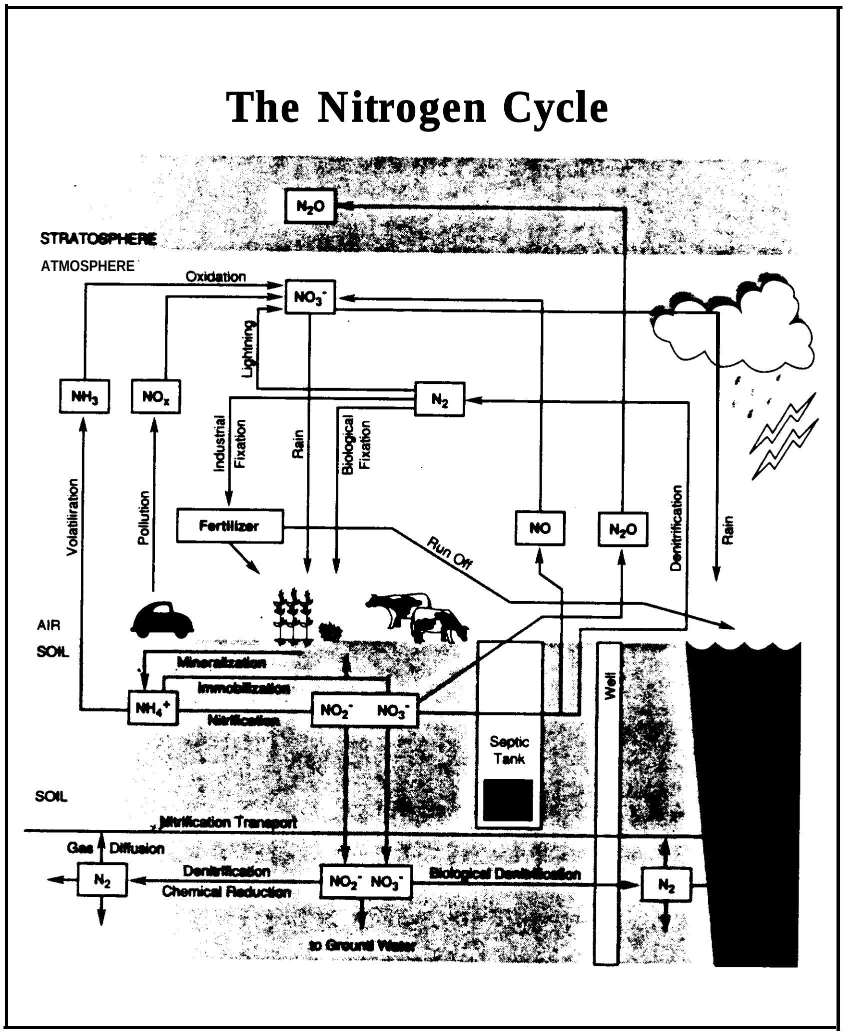
The Nature of the Nitrate Problem

In recent decades, environmental monitoring has revealed widespread and steadily increasing amounts of nitrate in California's vast underground water resource. The trend is associated with a growing population and with more intensive agriculture. Rising nitrate levels in groundwater are known to result from (1) manure generated by concentrated animal production; (2) fertilizer applied to crops and landscapes; (3) septic systems and sewage treatment plants; and *(4) fuel* combustion and industrial sources. All of these human activities produce nitrate, which is a soluble compound of nitrogen and oxygen. Nitrate also comes from natural sources – sediments and rocks, and natural fixation of nitrogen by plants and lightning. Nitrate can move with water down through the soil to enter the groundwater supply.



Adapted from: EPA Nitogen Action Plan, March 1991 draft

Although nitrate is a natural component of living systems, too much nitrate can cause problems – for human health and for the environment. One well-known potential threat is the relationship between high nitrate levels in drinking water and a rare infant disease called methemoglobinemia (blue-baby syndrome). In the stomachs of very young babies that have not yet developed normal acidity, nitrate can change to a related compound (nitrite) that interferes with the blood's oxygen-carrying capacity.

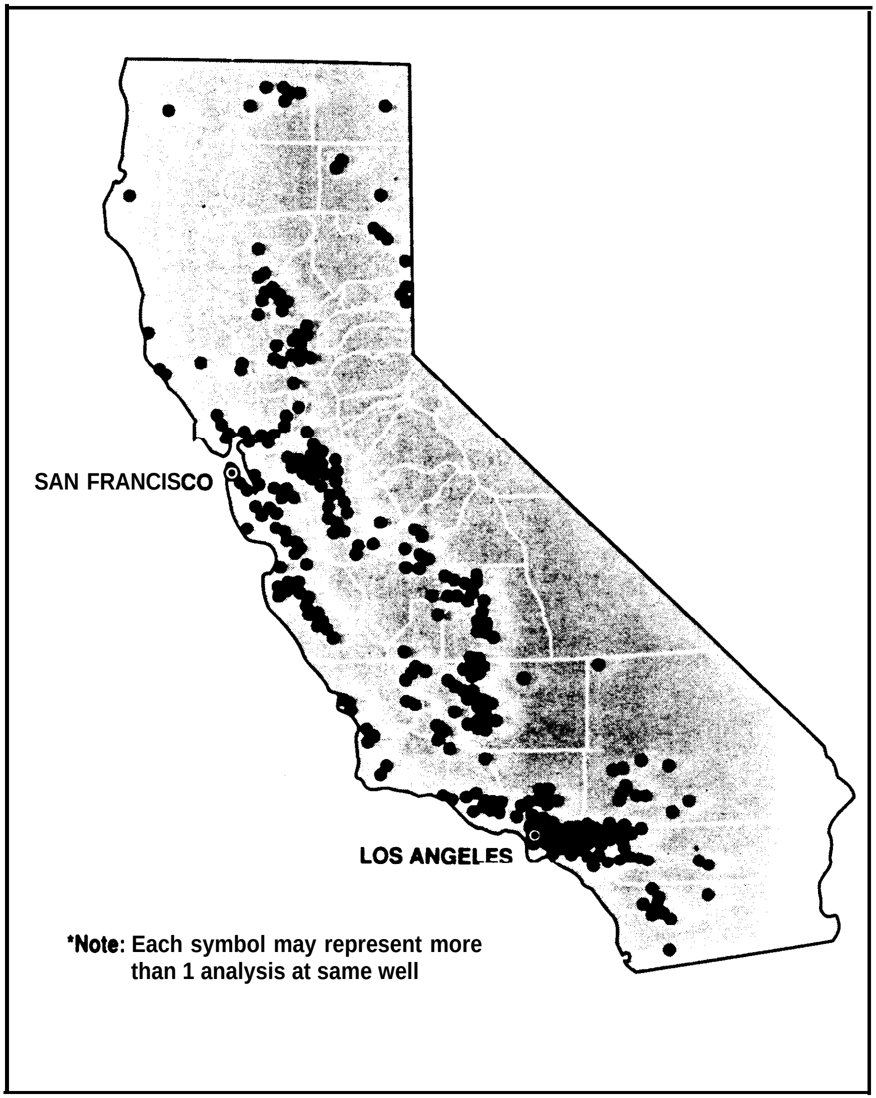
Cancer and birth defects also have been the subject of concern in relation to high nitrate drinking water, but no firm link has been established.

The current public health standard for acceptable drinking water in California is 44.3 milligrams/liter of nitrate (10 milligrams/liter of NO_3-N). *As shown on Map 1,* hundreds of wells in various areas of the state currently exceed this level.

There also is an economic dimension to the problem. When nitrate in a public water supply reaches or exceeds the 44.3 mg/l standard, costly measures are required. The well may have to be deepened or closed down, a different water source may have to be acquired for blending, or expensive water treatment may be required. For example, the Orange County Water District has estimated that wellhead nitrate treatment costs about $375 per million gallons. In 1986. public water systems in California applied to the State Department of Health Services for more than $48 million to correct nitrate violations. The total cost undoubtedly was even larger since many water agencies used other sources of funds to address the problem.

Excess nitrogen can also cause other economic and environmental problems such as oxygen-depleting algae growth in rivers and lakes, toxicity to aquatic life, increased calf abortion rates, and even loss of quality in fruit and other crops. These are often the result of inadequate manure, irrigation or fertilizer management.

Additional costs of nitrate in groundwater include land use restrictions, denial of loans for lack of a suitable water supply, and a reduced tax base. So the problem of increased nitrate levels in California's groundwater is both significant and persistent.



Map 1: Well Locations where nitrate levels have been recorded at 45 mg/1 or greater during the period 1975–1987*)

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CDFA Nitrate Working Group Report

In 1988, the Director of CDFA appointed a Nitrate Working Group to study the nitrate problem relating to agriculture in California. Scientists from the University of California, state agencies and industry participated. Meanwhile, the State Water Resources Control Board (SWRCB), in a report to the Legislature, reviewed the state-wide problem of nitrate in drinking water and evaluated existing programs.

The CDFA Nitrate Working Group's 1989 report, "Nitrate and Agriculture in California," also analyzed the problem on a state-wide basis. Using a computerized database that included 12 years of well testing results as well as groundwater information compiled by the SWRCB, the scientists reviewed and confirmed locations in the state where groundwater contains elevated levels of nitrate.

Their report also:

- Analyzed the mechanisms of nitrate movement through the soil. Since nitrate moves with water, the best way to slow the process is to reduce the amount of water that drains out of the crop root zone, especially percolation to groundwater.
- Reviewed the potential of fertilizer best management practices, the sources of nitrogen and the types of fertilizers, as well as application rates and methods.
- Looked at the problem of animal production in relation to nitrate pollution. Dairies. beef feedlots and poultry ranches are significant sources. Counties with most of these enterprises are San Bernardino and Riverside (the Chino area) and Imperial in the south; Merced, Stanislaus, Fresno, Kern and Tulare in the San Joaquin Valley; and Sonoma County on the coast.

The Nitrate Working Group report concluded with five recommendations. Those charges became the mission of CDFA's Nitrate Management Program (NMP), which later developed into the Fertilizer Research and Education Program (FREP). They are:

1. To identify nitrate-sensitive areas throughout California.
2. To prioritize those areas where action is most needed.
3. To organize voluntary nitrate management programs in high-priority areas in cooperation with local governments and agriculture.
4. To develop nitrate-reducing farming practices tailored to the high-priority areas and that fit into the management programs, in cooperation with growers and other government agencies.
5. To organize and support research and demonstration projects.

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Criteria For Nitrate-Sensitive Areas

The first step in implementing these recommendations was to decide which locations in the state should be given highest priority. Two conditions indicate an urgent problem: First, a high level of nitrate contamination in groundwater and, second, a population that depends on that water for drinking.

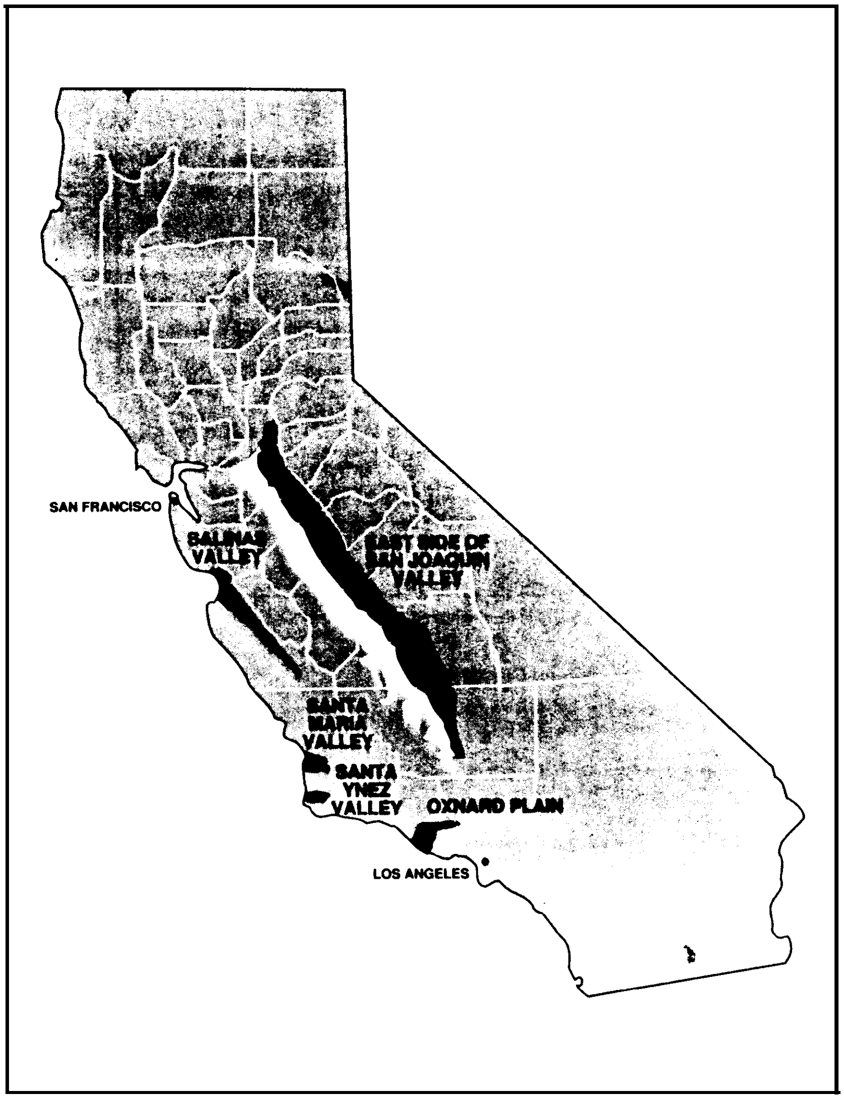
Those two conditions depend on various factors. University of California soil scientists originally listed five criteria for nitrate-sensitivity of an area:

Groundwater use. Nitrate concentration is critical if groundwater is used for domestic or animal drinking supplies. If it is used only for cleaning, cooling or irrigation of most crops, there is less concern.

Soil type. Sandy or other coarse-textured soils transmit water downward more rapidly, and nitrate with it. Also, these soils are less likely to create conditions in which nitrate turns to a gas and escapes from the soil (denitrification).

Irrigation practices. Inefficient irrigation systems that lead to large volumes of deep percolation increase the leaching of nitrate. Typically, these are surface flow systems with long irrigation runs. Well-managed sprinkler or drip systems, or surface flow systems with short runs, reduce the threat of nitrate leaching to groundwater.

Type **of crop.** Crops most likely to increase nitrate leaching are those that (1) need heavy nitrogen fertilization and frequent irrigation, (2) have high economic value, so the cost of fertilizer is relatively small compared to revenue produced (3) are not harmed by excess nitrogen and (4) tend to take up a smaller fraction of the nitrogen applied. Many vegetable, fruit, nut and nursery crops fit these criteria, and therefore have more potential for nitrate leaching. Those with less potential include field crops such as alfalfa, wheat and sugar beets.



Map 2: Generalized Map of Nitrate Sensitive Areas in California

Climate. High total rainfall, concentrated heavy rains and mild temperatures lead to more leaching of nitrates.

Two more criteria for nitrate-sensitivity were developed by FREP:

Distance from the root zone to groundwater. Less distance means a more immediate problem.

Potential impact. This depends on such factors as population density and availability of an alternate water supply.

These seven factors — groundwater use, soil and crop type, irrigation practices, climate, distance to groundwater, and potential impact-indicate the nitrate-sensitivity of an area. They determined where FREP's initial field activities were directed. In general, two regions of the state, the Central Coast valleys and parts of the east side of the Central Valley, fit the above criteria.*(See Map 2 on prior page).*

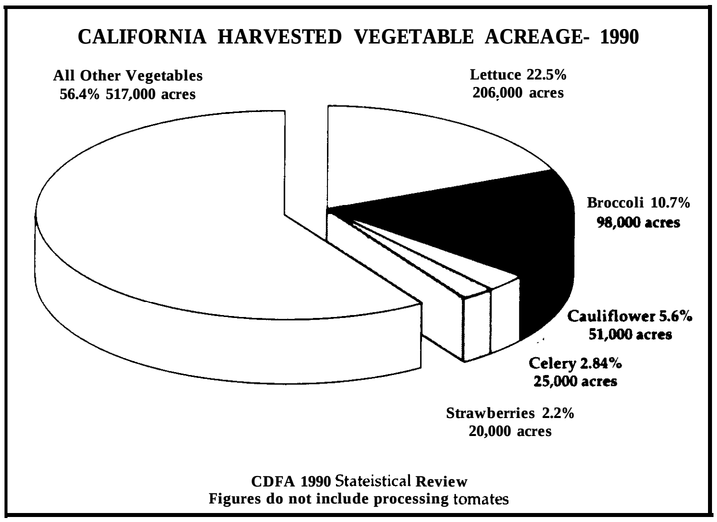


Chart 1:

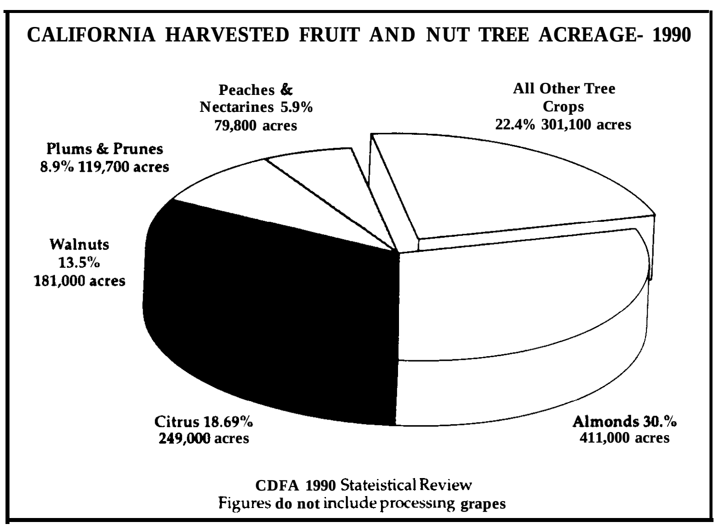


Chart 2:

The Central Coast valleys are major vegetable producing areas. In this region, irrigated vegetable fields are a potential source of groundwater contamination. The five major crops are lettuce, broccoli, cauliflower, celery and strawberries. These crops account for 43.6% of the vegetable acreage in California excluding processing tomatoes. *(See Chart 1 and Appendix 4).*

On the east side of the Central Valley, tree fruits and nuts are major crops, including almonds, walnuts, peaches and nectarines, plums and prunes, and citrus. These crops account for 77.6% of the total state fruit acreage. *(See Chart 2).* Almonds and citrus account for 8.2% of the acreage in California, yet use 12.5% of the total nitrogen fertilizer. (See *Appendix 4).*

Fruits and vegetables account for 27.9% of California harvested acreage yet use 41% of the total agricultural nitrogen fertilizer.

(The Los Angeles basin and surrounding areas where well measurements also indicate a groundwater nitrate problem are no longer a significant farming region. For that reason, FREP's agriculturally-oriented program is not very active there.)

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First Projects

Using the nitrate sensitivity criteria listed above, three areas were chosen to begin FREP field activities: the Salinas Valley in Monterey County, eastern Stanislaus and Merced Counties, and the Fall River Basin in Shasta County.

In these locations, working closely with growers, local governments, industry, UC Cooperative Extension. the Soil Conservation Service and others, FREP is helping to develop improved farming practices. These improved ways of fertilizing, irrigating and managing crops are designed to fit local resource and farming conditions and reduce nitrate leaching without impairing growers' profits.

Salinas Valley

This coastal farming region, which produces more than one-fourth of the nation's fresh vegetable crops. depends almost entirely on groundwater-not only for irrigation but also for domestic and industrial water use. About 150,000 people use Salinas Valley groundwater as a drinking water source.

According to a 1987 report by the Monterey Water Management Agency, almost one half of the wells sampled in unconfined aquifers of the Valley had nitrate levels above th44.3 mg/l standard. The report also points out that irrigated farms are currently a major source of that nitrate.

In late 1988, the Salinas Valley Nitrate Advisory Committee (NAC) was established by local authorities to develop plans to address the nitrate situation. FREP was invited to participate in this effort and helped implement a number of the committee's recommendations. With funds from the State Water Resources Control Board, the Monterey County Water Resources Agency, FREP, the lettuce industry, the federal government, UCD and UC Cooperative Extension, a number of projects are researching and demonstrating improved farming practices. These improved methods are designed not only to reduce nitrate pollution, but to promote more efficient fertilization and irrigation. Informing growers about the findings is a built-in part of these projects. (See ***Appendix*** *1).*

San Joaquin Valley

On the eastern side of the San Joaquin Valley. particularly in Stanislaus and Merced Counties. many farming areas are particularly sensitive to groundwater contamination from nitrate. The soils tend to be sandy or coarse, with little or no layering to restrict downward water flow. The tree crops grown in this area require high inputs of nitrogen but their nitrogen uptake efficiency is relatively low. Water delivery systems tend to be less efficient. which increases deep percolation. Throughout the San Joaquin Valley, dairying. with its associated problems of manure disposal, is a large and important industry.

FREP is cooperating with a team working on a proposed demonstration project on the east side of the San Joaquin Valley to help reduce nitrate contribution to groundwater from all agricultural sources. The cooperative project will include education, technical assistance and cost-share programs for dairymen and growers. UC Cooperative Extension and USDA agencies as well as the Regional Water Quality Control Board. Western United Dairymen's Association and local governments are participating. FREP also is supporting research to develop strategies to reduce potential nitrate leaching in almonds and peaches, and to improve plant nitrogen monitoring techniques in orchards. *(See Appendix I).*

Fall River Valley

This small farming region in northeastern California is not high in state-wide agricultural importance but was selected for a pilot project because of its small, confined aquifer and its unique combination of rural residences in close proximity to agricultural production. The Fall River Valley produces livestock. alfalfa, potatoes, grain and specialty crops such as strawberry plants. A recent survey of local wells showed that about 40 percent had nitrate levels in excess of 44.3 mgil.

To address the problem, the Fall River Resource Conservation District is working with a multi-agency team including the Regional Water Quality Control Board, UC Cooperative Extension, FREP. local government. and the California Department of Water Resources. A project proposal was approved and funded by the State Water Resources Control Board in early 1991. In the first phase, about 20 wells throughout the region are being monitored. Information is collected not only on nitrate levels but on patterns of land use, population, agriculture and geology. Nitrate data will be correlated with proximity of leachfields. type of agriculture. soil type and depth of n-ells. The second part of the project is developing best management practices. primarily. for potatoes and strawberries.

THE ROLE OF FERTILIZER

WHY FERTILIZE

Soils Need **Fertility** Maintenance. Soil is a natural body of finely divided rocks, minerals and organic matter. Sand, silt, clay and organic matter help provide tilth, necessary aeration and favorable water intake rates, but they seldom maintain adequate plant food to sustain continuous healthy plant growth.

WHAT IS FERTILIZER

There are 16 elements that are known to be essential for plant growth and development.

Fertilizers (also called plant food elements) are materials produced to supply these elements in a readily available form for plant use.

SOURCE		
AIR & WATER	SOIL & FERTILIZER	
Carbon	Nitrogen	Magnesium
Hydrogen	Phosphorus	Manganese
Oxygen	Potassium	Molybdenum
	Sulfur	Copper
	Zinc	Calcium
	Iron	Chlorine
	Boron	

Three of the sixteen essential elements, carbon, hydrogen and oxygen **are** taken primarily from the air and water. Oxygen and hydrogen are obtained by plants from water. Carbon and hydrogen are taken in by the leaves from the air. The other thirteen elements utilized by the plant must come from the soil or from added fertilizer materials.

Crop removal of these elements, plus leaching, volatilization and erosion causes the soil fertility to be continually reduced. Turf and landscape plants will have poor color (yellow-green to yellow), poor plant density-allowing weed invasion and low plant vigor which increases plants suseptibility to disease and insect damage.

Soil productivity can be maintained by well managed, scheduled applications of multiple element fertilizers.

WHY DOESN'T FERTILIZER HAVE 100% PLANT FOOD

A fertilizer **16-6-8 analysis adds up to 30% plant food or thirty pounds** per hundred pounds of material. ***What is the other 70%?***

It is not **a** filler; it is the way the plant food is chemically compounded so plants can utilize it.

Plants can't use elemental nitrogen (N), they only take up nitrogen when it is in the NO_3 or NH, form. This means that for each part of nitrogen you have three parts of oxygen with (NO_3) or 4 parts of hydrogen with (NH,). When nitrogen is in **a** compound which is available to plants, nitrogen is only part of the compound. The same is true with phosphorus and the other elements. Phosphorus is absorbed by plants as H_2PO_4—, HPO, = or PO,= depending upon soil pH.

If fertilizers were in the elemental form, they would be difficult to handle:

Elemental nitrogen (N) — **a** colorless inert gas that could drift off into the air.

Elemental **phosphorus (P) —** catches fire spontaneously when exposed to the air. It is actually poisonous to plants in concentrated forms.

Elemental **potassium (K) —** placed in contact with water it will catch fire, explode and decompose into a strong caustic solution.

FUNCTIONS OF THE 13 ELEMENTS OBTAINED FROM THE SOIL AND ADDED FERTILIZER

A. Primary Plant Food Elements

Nitrogen
Phosphorus
Potassium (Potash)

Plants rapidly utilize these elements **and unfertilized** soils normally cannot provide them in quantities needed for best plant growth.

Nitrogen (N)

1. Promotes rapid vegetative growth (leaf and stems) — hastening recovery after mowing and imparting vigor to the turf.
2. **A** vital element in the formation and function of Chlorophyll — the **key ingredient** imparting dark green color.
3. Synthesizes Amino Acids which in turn form protein.
4. Regulates the uptake of other nutrients.
5. Basic ingredient of vital compounds - Nucleic acid and enzymes.

Phosphorus (P)

1. Stimulates early root formation and **growth—gets plants off to a good start and forms** a root filter system in the soil to efficiently pick up

the other available plant nutrients and water. improves the strength and stamina of the plant.

2. Hastens maturity (conversion of starch to sugar).
3. Stimulates blooming and seed development.
4. Causes energy transformation and conversion processes in which sugars are converted to hormones, protein and energy to grow new leaves and fruit.
5. Forms nucleic acids (DNA and RNA).
6. Vital for photosynthesis (greening of plants).
7. Essential for cell division.

Potassium (K)

1. Aids in the development of **stems** and leaves.
2. Increases disease resistance and hardiness which helps wearability.
3. Strengthens cell walls, causing grass to stand up and reduces lodging.
4. Affects water intake by plant cells-plants with inadequate potassium may wilt in the presence of ample moisture.
5. Acts as a catalyst in Iron uptake.
6. Essential to the formation and translocation of protein, starches, sugar and oil-improving the size and quality of fruit, grains and tubers.

B. **Secondary Plant Food** Elements

Calcium Magnesium Sulfur	They are used in somewhat less quantities than the primary elements, but they are just as essential for plant growth and quality.

Calcium (Ca)

1. Calcium is an essential part of cell wall structure and must be present for the formation of new cells.
2. Deficiency of calcium causes weakened stems and premature shedding of blossoms and buds.

Magnesium (Mg)

1. **Essential for** photosynthesis (greening of plant).
2. Activator for many plant enzymes required in **growth process.**

Sulfur (S)

1. **A** constituent of three amino acids and is therefore essential in the formation of protein.
2. Helps maintain green color in plants.
3. Improves alkaline **soils.**
4. Helps compacted soils-making them loose and allowing better water penetration.

Sulfur Note-There are commonly two types of sulfur applied to plants and soils:
Sulfate Sulfur - SO,; Elemental Sulfur (S)

Sulfate Sulfur (SO,)

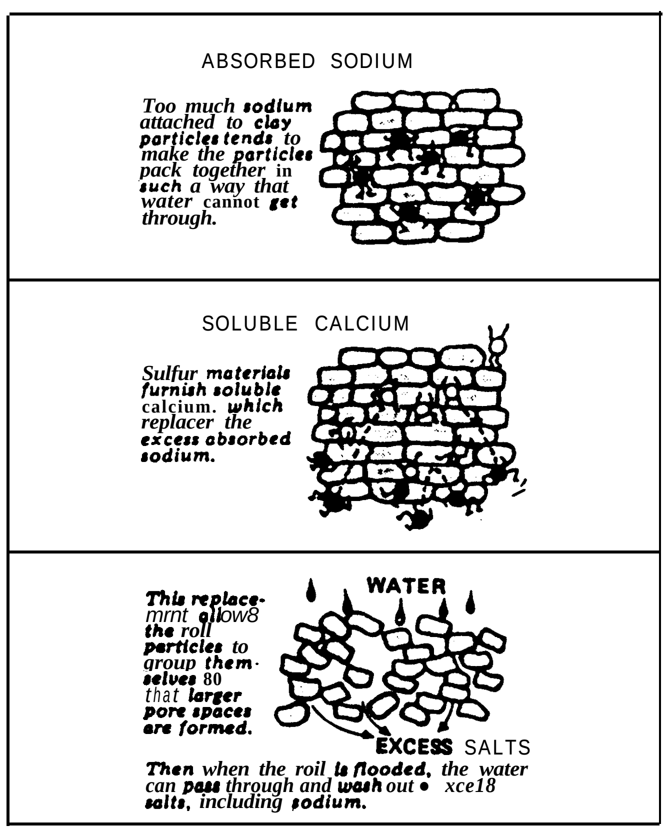
Sulfate Sulfur (SO,) is the form taken up for plant food. Many plants require as much sulfur as phosphate in their growth processes.

Sulfate Sulfur (SO,) is contained in gypsum ($CaSO_4$) and other sulfate fertilizers — Ammonium Sulfate, Ammonium Phosphate Sulfate and many turf fertilizers.

Gypsum ($CaSO_4$) will help reclaim alkali soils and make them loose and friable. Alkali soils contain sodium which causes soil to disperse, puddle and seal up. The **free calcium from** gypsum will replace the sodium on the clay particle and allow the sodium to be leached out of the soil.

It also causes the small soil particles to flocculate (join together in small crumbs), leaving space between them for air and water movement.

HOW **SULFUR & GYPSUM RECLAIMS SODIUM SOILS**



Elemental Sulfur (S)

Elemental Sulfur (S) will convert to sulfate sulfur in the soil. This reaction can be slow, depending upon the sulfur particle size and the soil conditions. Once it has converted to sulfate sulfur (SO,) it is available to the plant. If the soil contains calcium, it can form gypsum in the soil and be used for reclamation of alkaline soils.

Elemental sulfur will lower the pH of the soil at the location of the pellet as it converts to sulfate. (See the article on **Turf and Sulfur).**

C. Micronutrients: Iron, Zinc and Manganese

Even though micronutrients are used by plants in very small amounts, they are just as essential for plant growth as large amounts of primary and secondary nutrients. They must be maintained in balance in order for all nutrients and water to be used efficiently.

On turf grass there are three micronutrients that are particularly important in order to maintain green color and plant vigor:

Iron (Fe)

Yellowing of grass (Iron Chlorosis) is often due to iron **deficiency.** Iron is required for the formation of chlorophyll in the plant cell (causes turf to maintain **a** healthy, green color). It **serves** as a catalyst for biological processes such as respiration, symbiotic fixation of nitrogen and photosynt hesis.

Applications of iron can correct iron deficiency, but it may be iemporary in high pH soils, due to tie up with calcium. This may **require** acidification of the soil with elemental sulfur or the use of ammonium forms of nitrogen or some other acidification **agents. As** ammonium converts to nitrate in the **soil, it has an acidifying effect.** This acidifying effect makes iron and many other elements more available in high pH soils.

Zinc (Zn)

Zinc is an essential component of several plant enzymes. It is **a** part of auxins and controls the synthesis of indoleacetic acid which regulates growth compounds. Zinc also affects the intake and efficient use of water by plants.

Manganese (Mn)

Manganese serves as an activator for enzymes in plants. Without **Manganese, the** plants cannot use the iron which they have absorbed. It assists the iron in chlorophyll formation which causes yellowish turf to green up.

BACKGROUND AND EDUCATIONAL RESOURCES

"Ag Alert--A Weekly Newspaper on California Agriculture," California Farm Bureau Federation.

Available to Farm Bureau members, this weekly newspaper provides readers with articles on current issues in agriculture. Contact your local county Farm Bureau to order this publication.

Aariculture and Fertilizers, Oluf Chr. Bockman; Norsk Hydro, 1990.

This book provides readers with different perspectives about fertilizers and fertilizer use as well as detailed fertilizer science facts. Contact the California Foundation for Agriculture in the Classroom for information on how to order this book; (916) 924-4380.

Agriculture and the Environment: The 1991 Yearbook of Aariculture, United States Department of Agriculture; US. Government Printing Office, 1991.

This yearbook examines environmental concerns facing agriculture and indicates what the United States Department of Agriculture (USDA) is doing to address these concerns. This publication is made available by your local congressmen or can be ordered from the US. Government Printing Office.

Agriscience--Fundamentals and Applications, Elmer L. Cooper; Delmar Publishers, Inc., 1990.

This high school agriscience textbook presents general information taught in introductory high school agricultural science classes. It is a great reference to have for student research and teacher background information.

Alternative Agriculture, Committee on the Role of Alternative Farming Methods in Modern Production Agriculture, National Research Council Board on Agriculture; National Academy Press, Washington D.C., 1989.

This report examines in detail the scientific and economic viability of alternative agricultural systems, such as crop rotation and biological pest control, so that many challenges facing agriculture today can be overcome. To order this book, call 1-800-624-6242.

"Bottle Biology," Bottle Biology Program; University of Wisconsin-Madison, Department of Plant Pathology, 1630 Linden Drive, Madison, WI 53706; (608) 263-5645.

"Bottle Biology" is an inexpensive, motivating way to teach hands-on biology using one and two liter plastic bottles. Sign up to be put on their mailing list for newsletters.

California Farmer, Farm Progress Companies, Inc..

This colorful monthly magazine contains articles on current agricultural issues as well as editorials, classified ads, weather information and more. Write to P.O. Box 11375, Des Moines, IA 50340-I 375 for subscription information.

California Fertilizer Association's Lending Library of Motion Pictures, 1700 I Street, Suite 130, Sacramento, CA 95814; (916) 441-1584.

A variety of videos and slides discussing fertilizer use and water quality are available.

ChemCom: Chemistrv in the Communitv, Kendall/Hunt Publishing; Dubuque, IA, 52004-0539.

A high school chemistry book that emphasizes hands-on examples.

"Clear Facts About **Clean** Water," The Fertilizer Institute; 1990.

This pamphlet provides detailed information about water contamination, especially ground water, drinking water and nitrate contamination, To request a class set of these pamphlets, contact Amy Jo Matthews at The Fertilizer Institute, 501 Second Street NE, Washington D.C. 20002.

"Fast Plants," University of Wisconsin-Madison; Department of Plant Pathology-Fast Plants, 1630 Linden Drive, Madison, Wisconsin 53706; (608) 263-2634.

Rapid growing plants with many activities are available through this university. Ask to be put on their mailing list. "Fast Plants" can be ordered through Carolina Biological Supply at I-800-334-5551.

"Fertilizer--Perception and Reality" pamphlet, The Fertilizer Institute.

This pamphlet provides factual information on fertilizers and specifically addresses many of the perceptions associated with fertilizer use. For ordering information, write to The Fertilizer Institute, 501 Second Street NE, Washington D.C. 20002.

"Field's Of Gold" Video, California Foundation for Agriculture in the Classroom; 1601 Exposition Boulevard, Sacramento, CA 95815; (916) 924-4380.

This 28 minute historical video shows the relationships of agriculture with California history.

A Glossary of Farm Terms, United States Department of Agriculture; 1983.

This booklet provides definitions to hundreds of agricultural terms. This is a great reference to have available to students during reading or writing assignments. Order from Ag in the Classroom, USDA, Rm. 318-A, Administration Building, Washington, D.C. 20250.

"Improving Plant Production for Human Health and Environmental Quality" Handbooks, Potash and Phosphate Institute.

Five different comic book-type, easy to understand pamphlets provide the reader with information on various plant nutrients such as nitrogen, potassium and phosphorus. To order these booklets, write to PPI, Suite 410, 2801 Buford Hwy, NE, Atlanta, Georgia 30329.

Livina in the Environment, G. Tyler Miller, Jr.; Wadsworth Publishing Company, 1992.

This college-level environmental science textbook contains thorough, yet easy to understand, information about various factors that affect the environment. It also contains many short articles written by key authors that encourage the students to think on all sides of issues before making decisions.

Organic Soil Amendments and Fertilizers, David E. Chaney, et al.; Regents of the University of California, Division of Agriculture and Natural Resources, 1992.

This booklet is a guide to organic materials used to enhance soil quality and promote plant growth. To order, write to ANR Publications, University of California, 6701 San Pablo Avenue, Oakland, CA 94608-1239 or call (510) 642-2431.

Science Framework for California Public Schools Kindergarten Throuah Grade Twelve, Science Curriculum Framework and Criteria Committee; California Department of Education, 1990.

This document provides suggested guidelines for science education throughout California. All science educators should have a copy of the framework available to them. Themes and concepts are outlined, as well as guidelines on classroom management and teaching skills. Write to the Bureau of Publications, Sales Unit, California Department of Education, P.O. Box 271, Sacramento, CA 95802-0271 for ordering information.

Science Safety Handbook, California Department of Education.

This document provides the rules, regulations and procedures recommended for using and storing particular chemicals in the classroom. Write to the Bureau of Publications, Sales Unit, California Department of Education, P.O. Box 2731, Sacramento, CA 95802-0271 for ordering information.

Sunset-New Western Garden Book, Sunset Magazine Editors; Lane Publishing Company, 1989.

This easy-to-use gardening book, written for gardeners of the western United States, provides general information on soils, pest control, planting techniques, and fertilizing, plus problem solving tips and plant selection guides. Available at most bookstores; this is a must for your student and teacher reference library.

Seeds of Chanae, Herman J. Viola and Carolyn Margolis; Smithsonian Institute Press, 1991.

This beautifully illustrated book provides an overview of American agriculture in commemoration of Columbus' voyage to the New World.

"Soil Fertility Manual," Potash and Phosphate Institute; 1987.

This manual, written for farm advisors, provides basic agronomy concepts in an easy to understand manner. Soil components, fertilizers, and plant nutrient requirements are some of the key points discussed in this booklet.

Soil Science and Management, Edward J. Plaster; Delmar Publishers Inc., 1985.

This college-level soil science book provides detailed information on introductory soil science.

Western Fertilizer Handbook, Soil Improvement Committee and the California Fertilizer Association; The Interstate Printers and Publishers, Inc., 1990.

This well-organized book provides information on the nutrient requirements of plants and nutrient management strategies. Contact the California Fertilizer Association at (916) 441-1584 for ordering information. This should definitely be part of your reference library for use by teachers and students.

USEFUL ORGANIZATIONS AND COMPANIES

Ag Access
603 4th Street
Davis, CA 95616
(916) 756-7177

This bookstore specializes in agricultural information. Knowledgeable personnel can help you find the resource books you need. Write or call for a free catalog.

American Chemical Society
1155 16th Street NW
Washington DC 20036
(800) 227-5558

Request a catalog of materials and programs available for educators and students

California Association of Resource Conservation Districts
3830 U Street
Sacramento, CA 958 17
(916) 639-6251

This organization has many soil science activities for all grade levels, including a popular comic book titled "Amazing Soil Stories."

California Fertilizer Association
1700 I Street, Suite 130
Sacramento, CA 958 14
(916) 441-1584

This association has various videos and pamphlets on general and technical information of fertilizer manufacturing, application, safety and more.

California Foundation for Agriculture in the Classroom
1601 Exposition Blvd. FB 16
Sacramento, CA 95815
(916) 924-4380

The Foundation has a wealth of materials for educators, including a teacher resource guide that provides information on how to order free or low cost classroom materials which promote agricultural awareness. Educator workshops and conferences on integrating agriculture into the classroom occur several times a year. Be sure to get on the mailing list!

Delmar Publishers, Inc.
2 Computer Drive West, Box 15-015
Albany, New York 12212-5105

This company publishes a variety of agriculturally-related science books.

Discover Science
20417 Nordoff Street
Chatsworth, CA 91311
(818) 341-2535

This company sells a wide variety of chemicals and lab equipment.

The Fertilizer Institute
501 Second Street, NE
Washington D.C. 20002

This association has various videos and pamphlets on general and technical information of fertilizer manufacturing, application, safety and more.

Fertilizer Research and Education Program
California Department of Food and Agriculture
1220 N Street
Sacramento, CA 94271-0001
(916) 653-5340

Videos and other publications are available on the agronomically safe and environmentally sound use of fertilizers.

Fisher-EMD
4901 W. Lemoyne Street
Chicago, IL 60661
(800) 621-4769

Request a catalog from which you can order a wide variety of classroom materials, including chemicals and laboratory equipment.

Lab-Aids
17 Colt court
Ronkonkoma, New York 11779
(516) 737-I 133

This company has for purchase a variety of science kits for student use, as well as inexpensive "chemtrays."

NASCO West
1524 Princeton Avenue
Modesto, CA 95352-3837
(800) 558-9595

This company has classroom science and agricultural science educational supplies available for purchase. Request their science and/or agricultural sciences catalogs.

Potash and Phosphate Institute
Suite 401
2801 Buford Hwy, NE
Atlanta, GA 30329

This organization has colorful, easy to read booklets on potassium, phosphorus, nitrogen and other plant nutrients. Write for a list of other materials they have available.

Sargent-Welch
911 Commerce Court
Buffalo Grove, IL 60089-2362
FAX (708) 677-0624

This company sells a wide variety of chemicals, lab equipment and software.

University of California, Cooperative Extension

Cooperative extensions provide the public with general and technical information on various topics, including agricultural information. The Master Gardeners, Future Farmers of America (FFA) and 4-H programs are usually obtainable through this office. A pamphlet on current publications available from the U.C. Cooperative Extension is also available. Check your local phone book for your county's U.C. Cooperative Extension phone number and address (Listed under the name of your county.)

University of California Sustainable Agricultural Research and Education Program
University of California
Davis, CA 95616
(916) 752-7556

This department can answer specific questions you have about sustainable agriculture and current farming and gardening practices that are designed to enhance the environment.

Vernier Software
2920 SW 89th Street
Portland, OR 97225
(503) 297-5317

Request a catalog to review the various science software programs available.

GLOSSARY

Amendment-- any material added to soil to make it more productive; usually used for added materials other than fertilizers such as lime or gypsum; but a fertilizer is an amendment.

Anhydrous-- a dry substance; without water.

Buffer-- any substance or mixture of compounds that, added to a solution, is capable of neutralizing both acids and bases without changing the original acidity or alkalinity of the solution.

Chemical elements-- a collection of a single kind of atom.

Conservation-- to be cautious and moderate in the use of a resource, resulting in preservation.

Crop rotation-- the successive planting of different crops in the same field over a period of years to maintain or improve soil quality and reduce pest problems.

Denitrification-- a biochemical reduction of nitrates, ammonia and free nitrogen in soil; often done by microorganisms.

Ecosystem-- a system formed by the interaction of a community of organisms with their environment.

EPA-- Environmental Protection Agency; a governmental agency.

Fertilizer-- any substance added to soil or water to increase the nutrients available to plants.

Fertilizer Analysis-- the actual composition of a fertilizer as determined in a chemical laboratory using standard methods.

Gypsum-- hydrated calcium sulfate.

Holding capacity-- the amount of water/nutrients that a soil can hold before nutrients begin to leach out.

Hydroponics-- to grow plants, without soil, in a water nutrient solution.

Ion-- an electrically charged atom or group of atoms.

Infiltration-- to filter into or through; to move through the soil profile.

IPM-- Integrated Pest Management; a strategy used to reduce pests in a particular location by relying first on biological controls, treating pests only when economically necessary and to maintain crop yields while avoiding a negative impact on the environment.

Leaching-- downward movement of materials in solution through the soil. If fertilizers leach below the plant's roots, the plant cannot absorb the material. Leaching can lead to groundwater contamination.

Legume-- normally a plant that has pods whose seeds split into two; often helps with nitrogen fixation; examples include beans and alfalfa.

Macronutrients-- nutrients needed by plants in large quantities.

Manure-- solid animal waste products; can contain some straw or other animal bedding material.

Methemoglobinemia-- "Blue Baby Syndrome" caused by high nitrate intake in very young mammals which reduces the blood's ability to carry oxygen.

Micronutrients-- nutrients needed by plants in small quantities; usually less than several parts per million in a plant.. examples include boron, copper and zinc.

N-P-K-- Nitrogen/Phosphorus/Potassium; the three chemical elements that legally must be represented on a bag of fertilizer.

Nitrate-- the NO_3 form of nitrogen that is readily used by plants and is very leachable.

Nitrification-- to break down nitrogen compounds to nitrites and nitrates by bacterial action.

Nutrients-- elements needed by plants for proper growth.

Nitrogen-fixation-- conversion of N_2 to forms readily usable for plant growth.

Periodic Table-- a chart in which the chemical elements are arranged according to their atomic numbers; based on atomic weights and chemical characteristics.

Primary Nutrients-- nutrients needed by plants in large amounts; this includes nitrogen, phosphorus and potassium.

ppm (parts per million)-- a very small quantity; equivalent to one drop of water in a swimming pool.

Reduction-- in chemical terms, the gaining of electrons.

Secondary Nutrients-- nutrients needed by plants in medium quantities. Includes calcium, magnesium and sulfur.

Sustainable Agriculture-- an agricultural system that remains productive, economically viable and environmentally sound over a long period of time.

Tilth-- the act or operation of tilling the land.

USDA-- United States Department of Agriculture.

Yield-- the amount of product produced on one acre of ground.

FOOTNOTES

The following chapters and page numbers refer to the 1990 Science Framework for California Public Schools.

1. Chapter 5 A-l, pg. 118
2. Chapter 5 A-2, pg, 120
3. Chapter 3 B-l, pg. 51
4. Chapter 4 B-2, pg. 94
5. Chapter 5 C-4, pg. 142
6. Chapter 4 B-4, pg. 98