AP® ENVIRONMENTAL SCIENCE
2009 SCORING GUIDELINES

Question 1

(a) Support Councilwoman Smith's statement that nitrogen-based fertilizers cause other environmental problems by describing <u>one</u> such problem.

Two points can be earned for describing the cause and effect of one environmental problem not related to photochemical smog that is associated with the use of nitrogen-based fertilizers. One point can be earned for a description of an effect without a description of a cause.

Cause (1 point)	Effect (1 point)
Fertilizer enters surface waters or groundwater	• Increases algal blooms in surface waters • Decreases dissolved oxygen levels in surface waters • Promotes eutrophication in surface waters • Results in nitrate contamination of drinking water • "Blue baby syndrome"
Bacterial decomposition of fertilizer	• Produces nitrous oxide (N_2O), which increases global warming • Produces N_2O, which depletes stratospheric ozone
Production, transportation, and application of fertilizer	• Consumes fossil fuels, increasing habitat destruction during their extraction • Consumes fossil fuels, which produces carbon dioxide (CO_2) and increases global warming

(b) Identify a nitrogen-containing primary pollutant that contributes to the formation of photochemical smog. Describe how that primary pollutant forms and explain why Councilman Budd was wrong.

Three points can be earned: 1 point for identifying a nitrogen-containing primary pollutant; 1 point for describing how the selected primary pollutant is formed; and 1 point for explaining why Councilman Budd was wrong.

Primary Pollutant (1 point)	Formation (1 point)
Nitric oxide (nitrogen monoxide), nitrogen dioxide, or nitrogen oxides <u>OR</u> NO, NO_2, or NO_x	Nitrogen reacts with oxygen ($N_2 + O_2 \rightarrow 2NO$) or ($N_2 + 2O_2 \rightarrow 2NO_2$) or nitric oxide reacts with oxygen ($2NO + O_2 \rightarrow 2NO_2$) during: • High-temperature combustion • Combustion in automobile engines • Combustion in fuel-burning power plants • Burning of fossil fuels

One point can be earned for a statement explaining that nitrogen-based fertilizers do not release the air pollutants that cause photochemical smog.

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Question 1 (continued)

(c) Identify one secondary pollutant that is a component of photochemical smog and describe the following.

(i) How the secondary pollutant forms

(ii) ONE human health effect of the pollutant

(iii) ONE environmental effect of the pollutant

Four points can be earned: 1 point for the identification of a correct secondary pollutant; 1 point for describing how the selected secondary pollutant is formed; 1 point for a correct human health effect; and 1 point for a correct environmental effect.

Pollutant (1 point)	Formation (1 point)	Human Health Effect (1 point)	Environmental Effect (1 point)
Ozone OR O_3	• In the light-activated reactions of nitrogen oxides and volatile organic compounds (VOCs) or hydrocarbons • In the reaction of O_2 with O	• Respiratory problems • Impairs immune system • Eye irritation • Reduces crop yields, which may lead to poor nutrition or lack of food	• Damages plant tissues (cells, leaves, needles, stems, etc.) • Inhibits photosynthesis in plants • Suppresses plant growth • Increases plant susceptibility to diseases and pests • Causes respiratory problems in animals • Damages materials (rubber, paint, fabric, etc.) • Acts as a greenhouse gas and increases global warming
Peroxyacyl nitrates OR PANs	In the light-activated reactions of nitrogen oxides and volatile organic compounds (VOCs) or hydrocarbons	• Respiratory problems • Impairs immune system • Eye irritation • Reduces crop yields, which may lead to poor nutrition or lack of food	• Damages plant tissues (cells, leaves, needles, stems, etc.) • Inhibits photosynthesis in plants • Suppresses plant growth • Causes respiratory problems in animals

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Question 1 (continued)

Pollutant (1 point)	Formation (1 point)	Human Health Effect (1 point)	Environmental Effect (1 point)
Nitrogen Dioxide OR NO_2	In the reaction of nitrogen oxide (NO) with oxygen	• Respiratory problems • Impairs immune system • Eye irritation • Reduces crop yields, which may lead to poor nutrition or lack of food	• Reduces visibility, which also impairs photosynthesis • Increases plant susceptibility to diseases • Suppresses plant growth • Causes respiratory problems in animals
Nitric Acid OR HNO_3	In the reaction of nitrogen oxides (NO_x) with oxygen and water vapor	• Irritates eyes, nose, or throat • Damages lungs when inhaled • Reduces crop yields, which may lead to poor nutrition or lack of foo	• Causes loss of soil fertility • Leaches nutrients from soils • Releases toxic elements in soils • Causes plant damage or death • Increases susceptibility of plants to disease or drought • Causes loss of habitat • Causes injury or death of aquatic life • Causes loss of essential elements from aquatic ecosystems • Damages materials (limestone, marble, etc.)
Sulfuric Acid OR H_2SO_4	In the reaction of sulfur dioxide (SO_2) with oxygen and water vapor	• Irritates eyes, nose, or throat • Damages lungs when inhaled • Reduces crop yields, which may lead to poor nutrition or lack of food	• Causes loss of soil fertility • Leaches nutrients from soils • Releases toxic elements in soils • Causes plant damage or death • Increases susceptibility of plants to disease or drought • Causes loss of habitat • Causes injury or death of aquatic life • Causes loss of essential elements from aquatic ecosystems • Damages materials (limestone, marble, etc.)

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Question 1 (continued)

Pollutant (1 point)	Formation (1 point)	Human Health Effect (1 point)	Environmental Effect (1 point)
Nitrates, sulfates, or fine particulate matter OR PM 2.5	In the reaction of nitrogen oxides (NO_x) or sulfur dioxide (SO_2) with oxygen	• Irritates eyes, nose, or throat • Damages lungs when inhaled • Reduces crop yields, which may lead to poor nutrition or lack of food	• Causes loss of soil fertility • Leaches nutrients from soils • Releases toxic elements in soils • Causes plant damage or death • Increases susceptibility of plants to disease or drought • Causes loss of habitat • Causes injury or death of aquatic life • Causes loss of essential elements from aquatic ecosystems • Damages materials (limestone, marble, etc.)

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Question 1 (continued)

(d) Earth's natural nitrogen cycle occurs in several steps. Describe one chemical transformation that occurs in the natural nitrogen cycle and discuss the importance of that transformation to an ecosystem.

Two points can be earned: 1 point for a correct natural nitrogen-cycle chemical transformation and 1 point for a corresponding discussion of its importance to an ecosystem. A discussion point can be earned without a description of the chemical transformation.

Chemical Transformation (1 point)	Discussion (1 point)
Nitrogen is converted to ammonia, ammonium, or nitrate OR $N_2 \rightarrow NH_3$ or NH_4^+ or NO_3^-	• Converts atmospheric nitrogen into terrestrial nitrogen • Converts nitrogen to a biologically usable form • Provides plants with biologically available (fixed) nitrogen
Ammonia or ammonium is converted to nitrite, which is converted to nitrate (a description of only one of the steps is acceptable) OR NH_3 or $NH_4^+ \rightarrow NO_2^- \rightarrow NO_3^-$ NH_3 or $NH_4^+ \rightarrow NO_3^-$ $NO_2^- \rightarrow NO_3^-$ (a description of only one of the steps is acceptable)	• Provides plants with nitrates that can be taken up and used • Nitrates, along with ammonia and ammonium, are the most useful forms of nitrogen to plants
Nitrate, ammonia, or ammonium is converted to nitrogen-containing molecules (e.g., proteins, nucleic acids) OR NH_3 or NH_4^+ or $NO_3^- \rightarrow$ proteins or nucleic acids	• Converts nitrogen to proteins, nucleic acids, and other molecules essential to life
Nitrate is converted to nitrogen gas OR $NO_3^- \rightarrow N_2$	• Converts terrestrial nitrogen into atmospheric nitrogen to continue the cycle
Nitrogen-containing molecules (e.g., nitrates, urea, uric acid, proteins, nucleic acids) are converted to ammonia or ammonium OR NO_3^-, urea, uric acid, proteins or nucleic acids $\rightarrow NH_3$ or NH_4^+	• Converts the nitrogen in nitrogen-containing wastes and dead organisms back into biologically useful forms • Provides plants with nitrogen in a biologically usable form

(a) Nitrogen-based fertilizers cause eutrophication. These fertilizers runoff from land into bodies of water, where they promote excess algal growth. This algal growth, in turn, deprives the water below of dissolved oxygen, triggering fish kills. Normally, nitrogen compounds are needed nutrients, but in excess amounts, they cause this phenomenon, called eutrophication, in water.

(b) The class of nitrous oxide compounds, called NOX, constitutes a primary pollutant and cause of photo-chemical smog. NOX forms primarily through the burning of organic compounds, and is often emitted in car exhaust. Specifically, gaseous nitrogen is released, which bonds with atmospheric oxygen to form NOX compounds. Councilman Budd was wrong to propose a fertilizer ban because fertilizer contains nitrogen, but not in gaseous form. Thus, fertilizer does not contribute to smog formation; banning it would have no effect.

(c) Ozone (O_3) is a secondary pollutant and component of photochemical smog.

(i) Ozone forms when atmospheric oxygen (O_2) bonds with a single oxygen molecule. This single molecule could be available because of

ADDITIONAL PAGE FOR ANSWERING QUESTION 1

other pollutants that break apart the bonds in O_2.

(ii) Many people are sensitive to ozone. For people with respiratory conditions like asthma, ozone aggravates the condition and causes difficulty breathing.

(iii) Ozone is damaging to plants. It may impede the ability of photosynthetic plants to grow and photosynthesize.

(d) An important step in the nitrogen cycle is nitrogen fixation, where bacteria in the root nodules of certain plants converts atmospheric nitrogen (N_2) into nitrates. This transformation is vital to an ecosystem because nitrates are a nutrient in soil of key importance to the growth of many plants. Nitrogen fixation replenishes the nitrates in soil, allowing other plants to grow.

ADDITIONAL PAGE FOR ANSWERING QUESTION 1

1a) Councilwoman Smith's statement that nitrogen-based fertilizers can cause other environmental problems is true because fertilizers cause runoff of nitrogen into the water. The runoff of nitrogen pollutes water sources and can lead to eutrophication. By increasing the amount of nitrogen, there are algal blooms in bodies of water. The BOD content rises in the lake as the Dissolved oxygen level drops. The algal bloom blocks sunlight from the plants preventing them from doing photosynthesis. This kills the plants which in turn kills the fish.

1b) A nitrogen-containing primary pollutant that contributes to photochemical smog is nitric oxide. This pollutant forms from automobile emissions and also from smoke stacks at factories. As the nitric oxide is released from these sources, it pollutes the air and contributes to the formation of photochemical smog which is primarily made from nitric oxide. Councilman Budd was wrong because fertilizers are not the only source that contribute to the photochemical smog problem. Emissions from automobiles also release nitric oxide, which makes up a large part of the photochemical smog problem.

1c i) One secondary pollutant that is a component of photochemical smog is ozone. This pollutant forms by chemical reactions from automobile emissions. Ozone is produced mainly from chemical reactions from nitric oxide.

1c ii) One human health effect of ozone is it can cause lung cancer because ozone contributes to the photochemical smog that can cause lung problems in humans.

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ADDITIONAL PAGE FOR ANSWERING QUESTION 1

1c iii) One environmental effect of ozone is that ozone is a greenhouse gas that contributes to global warming. Ozone in the atmosphere reflects the sunlight back onto the planet to heat it. This causes global warming which will cause changes of biomes and climates of the world.

1d) In the nitrogen cycle, the last step is denitrification. In this step, nitrogen-fixing bacteria change the nitrates, nitrites, and ammonia back into N_2 which is released into the atmosphere. The last step of the cycle is important because without being changed back into N_2, the cycle would not be able to start over and therefore, would not be a cycle.

ADDITIONAL PAGE FOR ANSWERING QUESTION 1

(a) Councilwoman Smith is correct in stating that nitrogen-based fertilizers do cause other environmental problems other than photochemical-smog because nitrogen-based fertilizers can create runoff that run into nearby bodies of water like lakes, ponds, or rivers. Nitrogen runoff can cause eutrophication in these water which could lead to hypoxic or dead zones. This decreases the biodiversity in these waters because of the low levels of dissolved oxygen that do not meet the biological demand.

(b) No answer.

(c) One secondary pollutant that is a component of photochemical smog is ozone.

(i) No answer.

(ii) Ozone traps light ~~in the~~ therefore emitting more UV radiation into the earth. Excessive amounts of UV radiation can cause skin cancer like melanoma.

(iii) Because ozone traps light, ~~the~~ extra light ~~and radiation~~ begins to warm the earth thus causing the melting of glaciers and ice caps which makes the sea level rise. The melting of ice caps would mean habitat destruction for animals like penguins and polar bears and the rise in sea level could cause more storms and floods.

(d) One chemical transformation that occurs in the nitrogen cycle is nitrogen fixation in which nitrogen is turned into a usable form, (ammonia) for ~~vegetation~~ plants by bacteria. This is crucial because plants need nitrogen for natural ~~process~~ processes and can't use it in its basic form.

AP® ENVIRONMENTAL SCIENCE
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Question 1

Overview

This was a document-based question based on a mock newspaper article. The article reported an apparent misconception about the role nitrogen plays in the environment. In addition to refuting the statement of the city councilman, students were asked to demonstrate their understanding of the role nitrogen plays in the environment and their knowledge of the formation and effects of photochemical smog.

Sample: 1A
Score: 10

Two points were earned in part (a). One point was earned for stating that "[n]itrogen-based fertilizers cause eutrophication," and 1 point was earned for stating that "fertilizers runoff . . . into bodies of water."

Two points were earned in part (b). One point was earned for identifying "NOX" as a primary pollutant, and 1 point was earned for the explanation that the councilman is wrong. No point was earned for the description of the formation of "NOX" because the response does not indicate that nitrogen and oxygen react within car engines.

Four points were earned in part (c). One point was earned for identifying ozone as a secondary pollutant present in photochemical smog. One point was earned in part (c)(i) for stating that "[o]zone forms when atmospheric oxygen (O_2) bonds with a single oxygen molecule," 1 point was earned in part (c)(ii) for stating that ozone aggravates asthma, and 1 point was earned in part (c)(iii) for stating that ozone impedes photosynthesis in plants.

Two points were earned in part (d). One point was earned for stating that N_2 is converted to nitrates, and 1 point was earned for stating that nitrate is a nutrient in the soil.

Sample: 1B
Score: 8

Two points were earned in part (a). One point was earned for stating that fertilizers cause runoff of nitrogen into water, and 1 point was earned for stating that runoff of nitrogen "can lead to eutrophication."

One point was earned in part (b) for identifying nitric oxide. No points were earned for describing the formation of the primary pollutant, nor for the explanation of why the councilman is wrong.

Three points were earned in part (c). One point was earned for identifying ozone as a secondary pollutant present in photochemical smog. No point was earned in part (c)(i) for the incorrect description of the formation of ozone. One point was earned in part (c)(ii) for stating that ozone "can cause lung cancer," and 1 point was earned in part (c)(iii) for stating that "ozone is a greenhouse gas that contributes to global warming."

Two points were earned in part (d). One point was earned for stating that nitrates are changed into N_2. The incorrect identification of denitrifying bacteria as "nitrogen-fixing bacteria" was not penalized. One point was earned for stating that without changing the nitrate into N_2, "the cycle would not be able to start over."

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Question 1 (continued)

Sample: 1C
Score: 6

Two points were earned in part (a). One point was earned for stating that fertilizers can run off into bodies of water, and 1 point was earned for stating that "[n]itrogen runoff can cause eutrophication."

No points were earned in part (b).

Two points were earned in part (c). One point was earned for identifying ozone as a secondary pollutant present in photochemical smog. No point was earned in part (c)(i). No point was earned in part (c)(ii) because tropospheric ozone does not result in increased UV radiation. One point was earned in part (c)(iii) for stating that "ozone traps light" and radiation and warms the earth.

Two points were earned in part (d). One point was earned for stating that "nitrogen is turned into . . . ammonia," and 1 point was earned for stating that "plants need nitrogen . . . and can't use it in its basic form."