

2023



AP[®] Environmental Science

Sample Student Responses and Scoring Commentary Set 2

Inside:

Free-Response Question 3

- Scoring Guidelines**
- Student Samples**
- Scoring Commentary**

Question 3: Analyze an Environmental Problem and Propose a Solution Doing Calculations**10 points**

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- (a) **Describe** one environmental problem associated with the release of methane into the atmosphere. **1 point**

Accept one of the following:

- It traps heat effectively leading to climate change/global warming.
- The greenhouse effect is enhanced, increasing global temperatures/warming.
- It is a greenhouse gas, which leads to climate change/global warming.
- It is a greenhouse gas, which leads to melting ice/rising sea levels.

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- (b) **Describe** one factor that could affect the decomposition of the solid waste in a landfill. **1 point**

Accept one of the following:

- The amount of/percentage of organic material in the solid waste.
- The amount of/percentage of non-degradable material in the solid waste.
- Conditions of the landfill (such as concentration of oxygen, population of microbes/decomposers, temperature, moisture).
- Environmental conditions of the area (such as temperature, amount of rainfall, climate, weather, etc.).

-
- (c) **Propose** a solution to decrease the amount of methane released from landfills into the atmosphere. **1 point**

Accept one of the following:

- Incinerate waste.
 - Compost waste.
 - Recycle/reuse non-synthetic organic waste (paper, textiles).
 - Install/Use methane collection systems.
 - Burn off/Combust the methane coming from the landfill.
-

- (d)** **Justify** the solution proposed in part (c) by describing an additional advantage, other than decreasing the amount of methane released from landfills. **1 point**

Accept one of the following:

Solution proposed in part (c)	Justification of solution with additional advantage
Incinerate waste.	<ul style="list-style-type: none"> • Extends the lifetime of the landfill. • Reduces the amount of waste going to the landfill. • Can be used to generate electricity/heat. • Can generate income. • Reduces land area needed for landfills.
Compost waste.	<ul style="list-style-type: none"> • Extends the lifetime of the landfill. • Produces effective, inexpensive fertilizer. • Reduces land area needed for landfills.
Recycle/Reuse non-synthetic organic waste (paper, textiles, etc.).	<ul style="list-style-type: none"> • Reduces land needed for landfills. • Reduces energy/resources needed for new products. • Reduces trees cut for new paper.
Install/Use methane collection systems. Burn off/Combust the methane coming from the landfill.	<ul style="list-style-type: none"> • Can be used to generate electricity. • Can be used to heat buildings. • Can generate income. • Can be used as fuel. • Reduces the need for other energy sources.

- (e)** The average cow releases 150 liters of methane per day. **Calculate** the amount of methane that was released by all beef cattle raised in the United States in one year. **Show** your work. **1 point**

One point for the correct setup to calculate the amount of methane released in one year:

Accept one of the following:

- $\frac{150 \text{ L methane per day}}{\text{cow}} \times 31,200,000 \text{ cows (cattle)} \times \frac{365 \text{ days}}{1 \text{ year}}$
- $31,200,000 \times \frac{150 \text{ L}}{\text{cow}} \times 365 \text{ days}$
- $150 \times 31,200,000 \times 365$

One point for the correct calculation of the amount of methane released in one year: **1 point**

Accept one of the following:

- 1,708,200,000,000 L
- 1.7×10^{12} L

Total for part (e) 2 points

- (f)** A typical beef cow needs 11.8 kilograms of food per day and each hectare of cattle pasture produces 26.2 kilograms of grasses. **Calculate** the number of hectares of pasture that would be needed to support all beef cattle raised in the United States for one day. **Show** your work. **1 point**

One point for the correct setup to calculate the number of hectares of pasture to support cattle:

Accept one of the following:

- $\frac{11.8 \text{ kg}}{\text{cow}} \times \frac{1 \text{ ha}}{26.2 \text{ kg}} \times 31,200,000 \text{ cows (cattle)}$
- $31,200,000 \times \frac{11.8 \text{ kg}}{26.2 \text{ kg}}$
- $\frac{11.8}{26.2} \times 31,200,000$

One point for the correct calculation of the number of hectares of pasture to support cattle: **1 point**

Accept one of the following:

- 14,051,908
- 1.4×10^7
- 14.1 million

Total for part (f) 2 points

-
- (g)** The average American consumes 2,250 kilocalories of food per day. Beef cattle can produce 2.7 million kilocalories per hectare of land. Corn can produce 30.4 million kilocalories per hectare of land. **Calculate** how many more American people could be fed if 150 hectares of land was used to grow corn instead of raising beef cattle. **Show** your work. **1 point**

One point for the correct setup to calculate the change in the number of people:

Accept one of the following:

- $\frac{(30,400,000 \text{ kcal} - 2,700,000 \text{ kcal})}{1 \text{ ha}} \times \frac{1 \text{ person}}{2,250 \text{ kcal}} \times 150 \text{ ha}$
- $(30,400,000 - 2,700,000) \times \frac{1 \text{ person}}{2,250 \text{ kcal}} \times 150$
- $\left(\frac{30,400,000}{2,250} \times 150\right) - \left(\frac{2,700,000}{2,250} \times 150\right)$
- $\frac{(30,400,000 - 2,700,000)}{2,250} \times 150$

One point for the correct calculation of the change in the number of people: **1 point**

Accept one of the following:

- 1,846,667
- 1.8×10^6

Total for part (g) 2 points

Total for question 3 10 points

Important: Completely fill in the circle that corresponds to the question you are answering on this page.

Question 1

Question 2

Question 3



Begin your response to each question at the top of a new page. Do not skip lines.

- 3.) a) Methane causes global warming since it acts as a greenhouse gas and traps infrared radiation from the earth's surface. Thus, release of methane into the atmosphere ultimately warms the planet and has devastating effects such as more intense natural disasters.
- b) Solid waste in a ~~landfill~~ covered land fill does not have access to oxygen, which is usually used in decomposition. So, without oxygen, anaerobic decomposition occurs, ~~also~~ producing methane instead of CO₂.
- c) Trapping methane and burning it will lessen the amount of methane that reaches the atmosphere since it would turn into H₂O and CO₂.
- d) Burning methane can also produce ~~heat~~ ^{heat} energy, which could be potentially used to create electrical energy if it boiled water and ^{the} steam was moved to turn a turbine and a generator.

e)
$$\frac{31.2 \text{ million cattle} \times 150 \text{ L CH}_4 \times 365 \text{ days}}{1 \text{ day} \times 1 \text{ yr}} = 1.71 \times 10^{12} \text{ L of methane released in 2021 by beef cattle}$$

f)
$$\frac{31.2 \text{ million beef cattle} \times 11.8 \text{ kg feed}}{1 \text{ day} \times 26.2 \text{ kg feed}} = 1.41 \times 10^7 \text{ hectares of pasture to feed all US beef cattle for one day}$$

g) Beef: ~~$\frac{150 \text{ hectares}}{2.7 \text{ million kg}}$~~

Use a pen with black or dark blue ink only. Do NOT write your name. Do NOT write outside the box.

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Question 1

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Begin your response to each question at the top of a new page. Do not skip lines.

$$g) \text{ Beef: } \frac{150 \text{ hectares} \mid 2.7 \text{ million } \text{€} \mid 1 \text{ person}}{1 \text{ hectare} \mid 2250 \text{ € a day}} = 180,000 \text{ people fed}$$

$$\text{Corn: } \frac{150 \text{ hectares} \mid 30.4 \text{ million } \text{€} \mid 1 \text{ person}}{1 \text{ hectare} \mid 2250 \text{ € a day}} \approx 2,026,667 \text{ people fed}$$

$$2,026,667 - 180,000 = 1,846,667 \text{ more people would be fed}$$

if corn was grown instead of raising beef

Use a pen with black or dark blue ink only. Do NOT write your name. Do NOT write outside the box.

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Question 1

Question 2

Question 3



Begin your response to each question at the top of a new page. Do not skip lines.

3a). One environmental problem with releasing methane into the atmosphere is that it pollutes the air and can cause respiratory issues and decrease carbon dioxide levels.

3b). One factor that could affect the decomposition of the solid waste in a landfill is the need for fossil fuels which would increase solid waste.

3c). ~~Use materials that can be reused daily rather than being wasteful and throw everything away.~~ One example is stop the breeding of cows, since they create a lot of the waste we have that releases methane into our environment so by cutting down on their population growth can help decrease the amount of methane released from landfills into the atmosphere.

3d). By cutting down on the population of cows there is less risk of disease being spread into the meat market which makes it safer for everyone.

3e).

150 liters / day

365 days in a year

$$\text{liters of methane } 150 \times 365 \text{ days} = 54750$$

$$54750 \times 31.2 \text{ million beef cattle} =$$

$$1.7082 \times 10^{12} \text{ liters of methane}$$

~~any.~~



Page 5

Use a pen with black or dark blue ink only. Do NOT write your name. Do NOT write outside the box.



Important: Completely fill in the circle that corresponds to the question you are answering on this page.

Question 1

Question 2

Question 3



Begin your response to each question at the top of a new page. Do not skip lines.

3f).

11.8 Kilograms ^{Food} / day

26.2 Kilograms Grass / pasture

31.2 million beef cattle

$$31.2 \text{ million} \times 11.8 \text{ Kilograms of food} =$$

368160000

$$368160000 \text{ Kilogram hectare} / 26.2 =$$

14051908.4 Hectare
pastures needed

3g).

$$2,700,000 \text{ million} / 2,250 \text{ people} = 1200 \text{ people to be fed}$$

$$30.4 \text{ million} \times 150 = 4560000000 \text{ can be used for corn}$$

~~2700000000~~

$$4560000000 / 2,250 = 2026666.667 \text{ people}$$

$$2026666.667 - 1200 = 2025466.667 \text{ million more people can be fed when using corn instead of beef cattle}$$

Use a pen with black or dark blue ink only. Do NOT write your name. Do NOT write outside the box.

Important: Completely fill in the circle that corresponds to the question you are answering on this page.

Question 1

Question 2

Question 3

Begin your response to each question at the top of a new page. Do not skip lines.

3a The release of methane in the atmosphere contributes to global warming from the greenhouse effect.

b. Heavy rainfall can cause solid waste to decompose and make its way into groundwater.

c. Use amounts of the waste from the landfills as natural fertilizers.

d. This will improve agricultural outcomes.

e. $1 \text{ beef cow} \times \frac{150 \text{ L methane}}{\text{day}} \times \frac{31.2 \text{ mil. beef cows}}{\text{U.S.}} =$

$$\boxed{4.08 \times 10^9 \text{ L methane released.}}$$

f. $31.2 \text{ mil. cattle} \times \frac{11.8 \text{ kg food}}{\text{day}} \times \frac{1 \text{ hectare}}{26.2 \text{ kg grass}} =$

$$\boxed{14051908.4 \text{ pastures needed}}$$

g. $150 \text{ ha} \times \frac{2.7 \text{ mil kcal}}{\text{ha}} = 4.05 \times 10^8 \text{ kcal from cows}$

$150 \text{ ha} \times \frac{30.4 \text{ mil kcal}}{\text{ha}} = 4.56 \times 10^9 \text{ kcal from corn}$

~~$$4.05 \times 10^8 \text{ kcal} - 4.56 \times 10^9 \text{ kcal} =$$~~

$$4.56 \times 10^9 \text{ kcal} - 4.05 \times 10^8 \text{ kcal} = \frac{4.155 \times 10^9 \text{ kcal in corn}}{2250 \text{ kcal}}$$

~~$$4.05 \times 10^8 \text{ kcal} - 4.56 \times 10^9 \text{ kcal} =$$~~

$$= 1846666.7 \text{ kcal for Americans}$$

Use a pen with black or dark blue ink only. Do NOT write your name. Do NOT write outside the box.



Question 3

Note: Student samples are quoted verbatim and may contain spelling and grammatical errors.

Overview

This question focused on topics related to the methane formation and emissions in landfills and cattle, as well as food production efficiency between beef and corn cultivation.

In part (a) students were expected to demonstrate understanding that methane is a greenhouse gas that leads to climate change/global warming [Science Practice 1 Concept Explanation, Topic 9.3 The Greenhouse Effect, and Topic 9.4 Increases in the Greenhouse Gases].

In part (b) students were asked to describe one factor that could affect the decomposition of solid waste in a landfill. Students could describe the content/makeup of the waste itself, or conditions in the landfill that would affect decomposition [Science Practice 1 Concept Explanation and Topic 8.9 Solid Waste Disposal].

In parts (c) and (d) students were asked to propose a solution to decrease the amount of methane released from landfills into the atmosphere and justify that solution by describing an additional advantage other than decreased methane release. Students demonstrated their understanding of which types of solid waste would contribute to methane production or that methane collections systems would reduce the amount of methane released from a landfill. To justify their solution, students described the potential for electricity or heat generation with incineration and methane collection systems [Science Practice 7 Environmental Solutions and Topic 8.10 Waste Reduction Methods].

In parts (e), (f), and (g) students were asked to calculate, showing work, the amount of methane produced by all beef cattle in the United States, the number of hectares needed to support all beef cattle in the U.S., and the difference between how many people could be supported between corn cultivated land and land used to raise beef cattle [Science Practice 6 Mathematical Routines and Topic 5.7 Meat Production Methods]. While dimensional analysis based on unit cancellation is recommended, a setup point was earned for responses showing correct values and mathematical operations.

Sample: 3A

Score: 10

One point was earned in part (a) for describing “Methane causes global warming since it acts as a greenhouse gas” as an environmental problem associated with the release of methane. One point was earned in part (b) for describing “oxygen, which is usually used in decomposition” as a factor that could decrease decomposition of solid waste in a landfill. One point was earned in part (c) for proposing “Trapping methane and burning it” as a solution to decrease the amount of methane released from landfills. One point was earned in part (d) for justifying the solution in part (c) by describing “Burning methane can produce heat energy” as an additional advantage. Two points were earned in part (e). One point was earned for the correct setup, and 1 point was earned for the correct answer. Two points were earned in part (f). One point was earned for the correct setup, and 1 point

Question 3 (continued)

was earned for the correct answer. Two points were earned in part (g). One point was earned for the correct setup, and 1 point was earned for the correct answer.

Sample: 3B

Score: 4

No point was earned in part (a). No point was earned in part (b). No point was earned in part (c). No point was earned in part (d). Two points were earned in part (e). One point was earned for the correct setup and one point was earned for the correct answer. Two points were earned in part (f). One point was earned for the correct setup, and 1 point was earned for the correct answer. No points were earned in part (g).

Sample: 3C

Score: 3

No point was earned in part (a). One point was earned in part (b) for describing “Heavy rainfall can cause solid waste to decompose” as a factor that could decrease decomposition of solid waste in a landfill. No point was earned in part (c). No point was earned in part (d). No point was earned in part (e). One point was earned in part (f). One point was earned for the correct setup, but no point was earned for the answer. One point was earned in part (g). One point was earned for the correct setup, but no point was earned for the answer.