AP® ENVIRONMENTAL SCIENCE
2008 SCORING GUIDELINES

Question 2

(a) Calculate the volume, in m^3, of each of the following:

(Two points can be earned in each of parts (a)(i) and (a)(ii): 1 point for a correct setup, and 1 point for the correct answer.)

(i) The water infiltrated through the landfill per year

$$200 \text{ mm rain} \times \frac{1 \text{ m}}{1{,}000 \text{ mm}} = 0.2 \text{ m rain}$$

$$\frac{10{,}000 \text{ m}^2 \mid 0.2 \text{ m} \mid \text{50\% infiltrated water}}{\mid \mid \text{100\% water}} = \mathbf{1{,}000\ m^3}$$

(ii) The leachate that is treated per year

$$1{,}000 \text{ m}^3 \times 0.9\ (90\%) = \mathbf{900\ m^3}$$

Note: If the answer to (a)(i) is incorrect, then 0.9 times that answer still earns full credit in (a)(ii).

(b) Given that the cadmium concentration in the water draining from the landfill is 2.0 g/m^3, calculate the mass, in kg, of cadmium that is released into the surrounding soil per year.

(Two points can be earned: 1 point for the correct setup, and 1 point for the correct answer.)

Note: The student can either begin with the difference between the answers for (a)(i) and (a)(ii) or take 10 percent of the answer from (a)(i). Metric conversions do not necessarily have to be shown.

$$\frac{100 \text{ m}^3 \text{ drainage water} \mid 0.2 \text{ g Cd} \mid 1 \text{ kg}}{1 \text{ year} \mid 1 \text{ m}^3 \mid 1{,}000 \text{ g}} = \mathbf{0.2\ kg\ Cd/year}$$

(c) What is the annual cost of treating the leachate from the drainage system?

(Two points can be earned: 1 point for the correct setup, and 1 point for the correct answer.)

Note: The student must use the answer from (a)(ii).

$$\frac{900 \text{ m}^3 \text{ treatable leachate} \mid \$10}{\mid 1 \text{ m}^3 \text{ leachate}} = \mathbf{\$\ 9{,}000\ year}$$

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Question 2 (continued)

(d) Discuss TWO viable methods for reducing the amount of cadmium entering the municipal waste input.

(Two points can be earned: 1 point for a discussion of each viable method. Only the first two methods are scored.)

Category of Reduction	Method or Action
Disposal options	• Sort waste stream for cadmium-containing products (batteries, e-waste, paints and pigments, stabilizers, pesticides) headed to landfills • Deposit these materials at a dropoff site or recycling facility, or return to manufacturer
New/substitute technology or alternate materials	Avoid use of cadmium-containing products by: • using rechargeable batteries (e.g., lithium rechargeable) • applying new technology and/or alternate materials that do not use cadmium
Incentives and/or disincentives	• Place restrictions on disposal of materials that contain cadmium (batteries, e-waste, paints and pigments, stabilizers, pesticides) • Pass cradle-to-grave (RCRA) legislation • Provide rebate incentives for using cadmium-free products • Provide incentives for manufacturing cadmium-free products (e.g., research grants) • Place a deposit (payable on return) or surcharge on cadmium-containing products
Education	Make the public aware of (any one of the following): • concerns (health, environmental) associated with cadmium • methods of cadmium-containing product/battery reduction/recycling • availability of new/substitute technology

Question 2 (continued)

(e) Explain a shortcoming of ONE of the methods that you identified in part (d).

(One point is earned for an explanation that is linked to an accepted method described in part (d).)

Difficulty and/or expense identified with:

- educating the public about benefits of recycling waste that contains cadmium
- providing efficient systems for cadmium waste pickup (recycling/reuse)
- sorting
- achieving 100 percent cadmium removal from waste or 100 percent replacement
- safe disposal, new technology, and substitute material development
- enforcement/regulations/compliance
- recycling (e.g., energy requirements)
- determining if a product contains cadmium

I-2A

a.) i) $100\,mm/yr. = 50\%$ of $200\,mm/yr.$

$$\frac{1.0\times10^{2}\,mm \mid 1\,m}{\mid 1.0\times10^{3}\,mm} = 1.0\times10^{-1}\,m\ H_2O$$

$$(1.0\times10^{4}\,m^2)(1.0\times10^{-1}\,m) = \boxed{1.0\times10^{3}\,m^3\ H_2O/yr.}$$

ii.) ~~$(1.0\times10^{3})(.9)$~~

$$(1.0\times10^{3}\,m^3)(9.0\times10^{-1}) = \boxed{9.0\times10^{2}\,m^3\ \text{leachate}/yr.}$$

b.) $(1.0\times10^{3}\,m^3)(1.0\times10^{-1}) = 1.0\times10^{2}\,m^3$ leachate in soil

$$\frac{1.0\times10^{2}\,m^3 \mid 2.0\,g \mid 1\,kg}{\mid m^3 \mid 1.0\times10^{3}\,g} = \boxed{2.0\times10^{-1}\,kg\ cadmium}$$

c.) $9.0\times10^{2}\,m^3 \mid \frac{\$1.0\times10^{1}}{m^3} = \boxed{\$9.0\times10^{3}}$

d.) The city of Fremont municipal solid-waste landfill could enforce regulations that limited the amount of cadmium permitted in the landfill. For example, some items containing cadmium would be prohibited at the landfill & disposed of in another way or recycled. Another method includes the incineration of cadmium-containing waste.

e.) The incineration of cadmium-containing waste would ~~keep~~ release ~~cad~~ environmental particulate pollutants into the air, damaging the lungs & nerve tissue of those who breathe them.

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(a) (i) 50% of rainfall: (.5)(200 mm/yr) = 100 mm/yr infiltrated through the landfill

~~(.1 m rainfall)(10,000 m²)~~

100 mm = .1 m rainfall

(.1 m rainfall)(10,000 m² landfill) =
1,000 m³ water infiltrated per year

(ii) 90% of landfill water
(.9)(1,000 m³ water infiltrated through landfill) =
90 m³ leachate treated per year

(b) $\frac{2.0\ g}{m^3} = \frac{.002\ kg}{m^3}$ (.1)(1,000 m³) = 10 m³ in surrounding soil

$\left(\frac{.002\ kg}{1\ m^3}\right)(10\ m^3) = .02\ kg$ cadmium

(c) $\left(\frac{\$10}{m^3}\right)(90\ m^3) = \$900$ annual cost

(d) Cadmium entering the municipal waste input can be reduced by finding an alternative use for the cadmium. Usable cadmium could be stored and used instead of put into a landfill.
Cadmium entering the municipal waste input can be reduced by using a more efficient drainage system that would be able to drain more cadmium and

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ADDITIONAL PAGE FOR ANSWERING QUESTION 2

send it to be treated. This way, less cadmium would end up in the landfill.

(d) A shortcoming with making more efficient drainage systems is that they would be very expensive. This high economic cost might ~~not seem~~ make the public think that it's not really worth it to purchase more efficient drainage systems.

I-2C

(a) (i) volume of water infiltrated through the landfill:

$10{,}000\ m^2 \longrightarrow ?\ m^3$

$1{,}000\ m^3$

(ii) volume of leachate treated:

$\frac{90}{100} \times \frac{?}{10000}$

90% of $1{,}000\ m^3$ treated

$900\ m^3$ treated

(b) $2.0\ g/m^3$ cadmium

$?\ kg/m^3$ cadmium $\longrightarrow .0020\ kg/m^3$

(c) $.0020\ kg/m^3$ cadmium treated @ $\$10/m^3$ $\longrightarrow$ $\$200$ to treat the leachate

(d) Cadmium amounts could be reduced from the municipal waste input if there is somewhere else to put it. Instead of just putting it into a landfill or soil to decay, it could be filtered further into a more useful form. In addition, if the initial drainage system was better equipped, there would be less of a concentration to deal with in the municipal system.

(e) Either of the methods mentioned above would be both cost, and time consuming. Fixing/adding to the system requires a lot of money if it is done correctly. Many might complain about the cost, however, in the future the system would be more efficient and eventually pay for itself in the differences made.

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AP® ENVIRONMENTAL SCIENCE
2008 SCORING COMMENTARY

Question 2

Overview

The question assessed students' abilities to analyze environmental information from a schematic diagram as well as text. The outcome of these analyses should have been a correct computation of landfill values for infiltrated water, cadmium-containing leachate, cadmium released into surrounding soil, and the annual costs associated with treating the leachate. The question also measured students' abilities to recognize viable methods of waste-stream reduction for cadmium and the inherent shortcomings associated with the implementation of these methods.

Sample: I-2A
Score: 9

Part (a)(i): 2 points were earned—1 for the correct setup and 1 for the correct answer.

Part (a)(ii): 2 points were earned—1 for the correct setup and 1 for the correct answer.

Part (b): 2 points were earned—1 for the correct setup and 1 for the correct answer.

Part (c): 2 points were earned—1 for the correct setup and 1 for the correct answer.

Part (d): 1 point was earned for stating that the city "could enforce regulations," which leads to alternate disposal. Incineration is not a viable method.

Part (e): No points were earned. Since incineration is not viable, the shortcoming did not earn a point.

Sample: I-2B
Score: 5

Part (a)(i): 2 points were earned for the correct setup and the correct answer.

Part (a)(ii): 1 point was earned. The student makes computational errors that limit the score.

Part (b): No points were earned. The setup is nearly correct, but the computation of 10 m^3 of infiltration into the surrounding soil should equal 100 m^3. This incorrect volume leads to an incorrect calculation and final value.

Part (c): 2 points were earned. In this case, the student is not penalized a second time for the incorrect computation in part (a)(ii). The student earned 1 point for a correct setup (bringing down the answer from part (a)(ii) and multiplying by \$10/m^3). As a result, the answer also earned a point.

Part (d): No points were earned because "an alternative use for the cadmium" is not the same thing as an alternative to cadmium. The second method refers to cadmium already in the landfill.

Part (e): No points were earned because the shortcoming is linked to a nonviable method.

Sample: I-2C
Score: 3

Part (a)(i): 1 point was earned for the correct value.

Question 2 (continued)

Part (a)(ii): 2 points were earned for the correct setup and the correct answer.

Part (b): No points were earned.

Part (c): No points were earned. The student incorrectly applies the kg value from part (b).

Parts (d) and (e): No points were earned in part (d) because the first method is too vague and the second refers to cadmium already in the landfill. Part (e) does not link to a viable method in part (d).