Past-paper walk-through

Sewage Treatment ▪ 8.11

eXercise

Questions in this set

- 2024 Set 1 Q1
- 2017 Q1
- 2014 Q2

Reading the mark scheme

- **B1** a mark that stands on its own – the point is either made or not.
- **M1** a *method* mark: the right approach, even if the number is wrong.
- **A1** an *answer* mark, and it usually needs its M mark first.
- **C1** a working mark on the way to the answer.
- // separates answers the examiner accepts equally.
- **ecf** = error carried forward: a later part is marked on your own earlier answer.
- **owtte** = “or words to that effect” – the wording need not match.

Question 1

2024 Set 1 ▪ Q1

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Dissolved Oxygen and Biological Oxygen Demand in a Stream Ecosystem

[Diagram: a cross-section of a stream divided into five vertical zones (A through E) labeled left to right, with "Direction of Streamflow" arrow pointing right along the bottom axis. The y-axis (unlabeled numerically) ranges from "Low" at the bottom to "High" at the top, showing two curves: a solid line for "Dissolved oxygen" and a

Question 1

dashed line for "Biological oxygen demand". Common fish/macroinvertebrate species listed above each zone:

- Zone A: adult fish; mayfly, stone fly, and caddis fly larvae
- Zone B: blackfly and midge larvae
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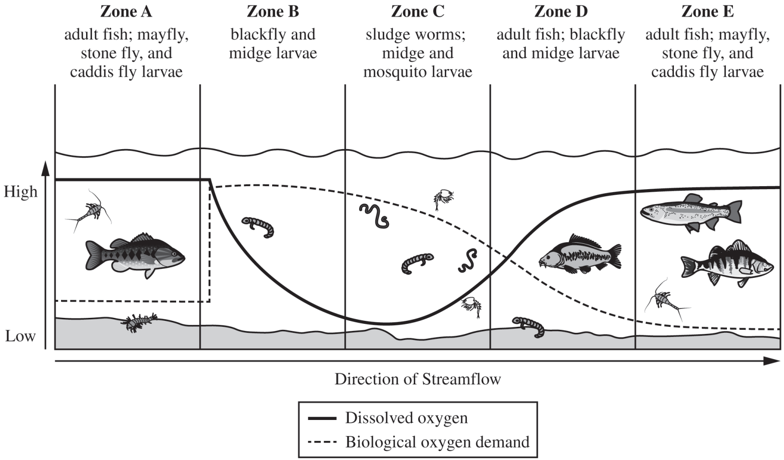
Question 1

Curve behavior: In Zone A, dissolved oxygen is High (solid line flat at top) and biological oxygen demand is Low (dashed line flat at bottom). Moving into Zone B, dissolved oxygen (solid line) drops sharply from High to Low while biological oxygen demand (dashed line) rises sharply from Low to High. In Zone C, dissolved oxygen remains Low (solid line near bottom) while biological oxygen demand remains High (dashed line near top), with the two curves close together at their extremes. Moving into Zone D, dissolved oxygen (solid line) rises back up from Low to High while biological oxygen demand (dashed line) falls back down from High to Low. In Zone E, dissolved oxygen is High (solid line flat at top) again and biological oxygen demand is Low (dashed line flat at bottom), mirroring Zone A.]

(a) Based on the information in the diagram, **identify** the zone with the lowest level of dissolved oxygen.

Question 1



Zone A
adult fish; mayfly, stone fly, and caddis fly larvae
Zone B
blackfly and midge larvae
Zone C
sludge worms; midge and mosquito larvae
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adult fish; blackfly and midge larvae
Zone E
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High
Low
Direction of Streamflow
Dissolved oxygen
Biological oxygen demand

Question 1

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Low. In Zone E, dissolved oxygen is High (solid line flat at top) again and biological oxygen demand is Low (dashed line flat at bottom), mirroring Zone A.]

(b) Based on the information in the diagram, **describe** the relationship between biological oxygen demand and dissolved oxygen.

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(c) Based on the information in the diagram, **identify** the zone where there is most likely point-source water pollution discharged into the stream.

The research team is interested in investigating the relationship between dissolved oxygen levels and macroinvertebrate species richness in the stream. Researchers counted the number of macroinvertebrate species in zones A, B, and C during the summer months. The researchers selected zone A to serve as the control in the investigation.

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(d) Identify the dependent variable in the researchers' investigation.

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(e) Identify a testable hypothesis for the researchers' investigation.

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(f) Describe the reason the researchers selected zone A to serve as the control in the investigation.

The researchers decided to repeat their data collection during the winter months.

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(g) Explain how the modification to collect data in the winter months could alter the results of the investigation.

Stream ecosystems are affected by point-source organic pollution in a variety of ways.

Question 1

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(h) Describe the effect that the introduction of raw sewage into the stream could have on the population of bacteria in the stream.

Question 1

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(i) Identify an abiotic factor other than dissolved oxygen and organic pollution that could also influence the population size of bacteria in the stream.

Question 1

2024 Set 1 ▪ Q1

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(j) Explain how persistent organic pollutants can affect higher trophic levels in an aquatic food web.

Solution 1

(a)

Mark scheme

- Zone C has the lowest level of dissolved oxygen (based on the diagram).

Solution 1

(b)

Mark scheme

- Biological oxygen demand (BOD) and dissolved oxygen (DO) are inversely related: as BOD increases, DO decreases (equivalently, as DO increases, BOD decreases).

Solution 1

(c)

Mark scheme

- Zone B is where point-source water pollution is most likely discharged into the stream (based on the diagram).

Solution 1

(d)

Mark scheme

- The dependent variable is the number of macroinvertebrate species (macroinvertebrate diversity / macroinvertebrate species richness) — the researchers measured this in response to dissolved oxygen level.

Solution 1

(e)

Mark scheme

- A testable hypothesis relates dissolved oxygen level to macroinvertebrate species number, e.g.: 'As dissolved oxygen levels increase, the number of macroinvertebrate species increases' (or the inverse: as DO decreases, species number increases; or a general statement of a direct/inverse relationship between DO and macroinvertebrate species number). A null hypothesis of no relationship is also acceptable.

Solution 1

(f)

Mark scheme

- Zone A was chosen as the control because it is upstream from the pollution/organic waste source, so it is not affected by (not impacted by) the discharge — its dissolved oxygen levels reflect conditions unaffected by the pollution, giving a baseline for comparison.

Solution 1

(g)

Mark scheme

- Collecting data in winter could alter the results because: (1) cold water holds more dissolved oxygen, which could increase the number of species; or (2) colder temperatures may fall below the tolerance range of some organisms, decreasing the number of species; or (3) lower light levels in winter reduce plant photosynthesis, which lowers dissolved oxygen and could decrease the number of species.

Solution 1

(h)

Mark scheme

- Raw sewage introduces nutrients (and/or organic matter) that increase the bacteria population (more food source), and/or raw sewage directly contains bacteria that increases the bacteria population size in the stream.

Solution 1

(i)

Mark scheme

- Any abiotic factor other than dissolved oxygen and organic pollution that affects bacteria population size, e.g.: temperature, pH, light/sunlight, turbidity/sediment, salinity, or nitrate/phosphate concentration.

Solution 1

(j)

Mark scheme

- Persistent organic pollutants (POPs) bioaccumulate/biomagnify in the tissues of organisms at higher trophic levels because those organisms consume prey that have already accumulated the pollutants, so pollutant concentration increases up the food web (often concentrating in fatty tissue); this can cause effects such as neurological toxicity in top predators.

Question 1

2017 ▪ Q1

Read the following article from the Fremont Daily Times and answer the questions that follow.
[Newspaper clipping, headed “Fremont Daily Times”, article title “Scientists Discuss Threats from Plastic Pollution”:] In testimony before the United States Senate Committee on Environment and Public Works, Dr. Duke Ewoldsen, an eminent toxicologist, discussed a new water pollutant that threatens aquatic life: microbeads. Ewoldsen noted that while posing a different threat than more conventional water pollutants such as nitrates, phosphates and PCBs, tiny beads of plastic contained in many products, especially cosmetics, now threaten plankton and small fish that ingest the particles because they mistake them for food. The microbeads cannot be digested and can fill or block the digestive tracts of the fish, leading to starvation. In addition, surfaces of these small spheres can adsorb organic pollutants such as PCBs and dioxin.

Question 1

When asked about steps to reduce this threat, Ewoldsen noted that the beads are so small that they are not easily removed by wastewater treatment plants and thus often enter aquatic ecosystems in wastewater discharges.

(a) Describe TWO effects that ingesting microbeads has on aquatic organisms.

Question 1

Fremont Daily Times

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(b) Dr. Ewoldsen states that nitrates pose different threats to aquatic ecosystems than microbeads do. Describe how nitrate levels can negatively affect water quality in some aquatic ecosystems.

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(c)(i) While wastewater treatment plants are ineffective at removing microbeads, they are very effective at removing large pieces of plastic waste and other pollutants. Identify one way large pieces of plastic are removed from wastewater during primary treatment.

(c)(ii) Prior to discharge, wastewater is often disinfected. Identify one technique commonly used to disinfect wastewater.

(c)(iii) Sludge or biosolids produced during the wastewater treatment process can be spread on agricultural fields. Identify one advantage and one disadvantage of this practice.

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(d)(i) Coastal ecosystems are threatened by other human activities in addition to wastewater disposal. Mangrove swamps are one such threatened ecosystem. Provide one reason why mangrove trees are being removed by humans.

(d)(ii) Identify one ecosystem service provided by intact mangrove ecosystems.

Question 2

2014 ▪ Q2

Like many communities, Fremont has a combined sewer system that collects both sewage and storm water. When storm water runs into storm drains that connect to the city's sanitary sewer system, the storm water and sewage flow together to the Fremont Wastewater Treatment Plant (FWTP). During a major storm event, however, the combined volume of storm water and sewage may exceed the plant's capacity, and the overflow bypasses the FWTP. The untreated overflow is discharged into Fremont Creek along with the treated waste.

Recently parts of Fremont received 5 cm of rain in 60 minutes. The storm caused widespread flooding in the northeast section of town. Especially hard hit was the Shoppes at Fremont shopping center.

Use the data from the table below to answer the questions that follow. Show all calculations.

Question 2

| Fremont Water Data | |—| | The shopping center's parking lot is 200 meters long and 100 meters wide. | | Fremont has an area of 10 km^2. | | Impervious surfaces cover 20 percent of Fremont's area. | | The FWTP typically treats $5{,}000$ m^3 of domestic sewage per day. | | The FWTP has the capacity to treat $10{,}000$ m^3 of combined sewage and storm water per day. |

(a) Identify TWO specific pollutants in storm-water runoff that degrade the quality of surface water.

Question 2

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Question 2

2014 ▪ Q2

Like many communities, Fremont has a combined sewer system that collects both sewage and storm water. When storm water runs into storm drains that connect to the city's sanitary sewer system, the storm water and sewage flow together to the Fremont Wastewater Treatment Plant (FWTP). During a major storm event, however, the combined volume of storm water and sewage may exceed the plant's capacity, and the overflow bypasses the FWTP. The untreated overflow is discharged into Fremont Creek along with the treated waste.
Recently parts of Fremont received 5 cm of rain in 60 minutes. The storm caused widespread flooding in the northeast section of town. Especially hard hit was the Shoppes at Fremont shopping center.
Use the data from the table below to answer the questions that follow. Show all calculations.
| Fremont Water Data | |—| | The shopping center's parking lot is 200 meters long and 100 meters wide. | | Fremont has an area of 10 km^2. | | Impervious surfaces cover 20 percent of

Question 2

Fremont's area. | | The FWTP typically treats $5{,}000$ m^3 of domestic sewage per day. | | The FWTP has the capacity to treat $10{,}000$ m^3 of combined sewage and storm water per day. |

(b) Calculate the volume of water (in m^3) that runs off the Shoppes at Fremont parking lot after a 5 cm rainfall event. Assume that all the water that falls on the parking lot runs off.

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(c) Calculate the volume of storm-water runoff (in m^3) generated in all of Fremont by the 5 cm rainfall event. Assume that only the impervious surfaces generate runoff.

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(d) Assume that all the runoff that you calculated in part (c) is captured by the storm sewers in one day. Calculate the volume of untreated water (in m^3) that bypasses the plant as a result of the storm. (Note that the plant still receives $5{,}000$ m^3 of domestic sewage per day.)

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(e) Describe TWO ways that the volume of storm-water runoff can be reduced.

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(f) Describe one environmental problem (other than pollution from runoff and from untreated sewage) that results from having extensive paved areas.