CheggSolutions - Thegdp

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## Environmental Engineering

### Design of Rapid Gravity Filters

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#### Given data:

**Population to be served** $(P) = 50,000$
**Average daily demand** $(D_a) = 180 \ \text{Lcd}$ (liters per capita per day)
**Filter operation rate** = $5000 \ \text{lit/hr/sqm}$
**Length to width ratio** = 1.5
**Maximum daily demand factor** = $1.8 \times$ average daily demand

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#### Step-by-Step Solution:

##### Step 1: Calculate the Total Average Daily Water Demand

Average daily demand for the entire population:

$$\text{Total Average Daily Demand} = P \times D_a \\ \text{Total Average Daily Demand} = 50,000 \times 180 \ \text{L/day} \\ \text{Total Average Daily Demand} = 9,000,000 \ \text{L/day}$$

**Explanation:** The total demand is calculated by multiplying the population by the average daily demand per person.

**Supporting Statement:** This step ensures the calculation of the average daily water demand for the given population.

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##### Step 2: Calculate the Total Maximum Daily Demand

Maximum daily demand with 1.8 times the average daily demand:

$$\text{Maximum Daily Demand} = 1.8 \times \text{Total Average Daily Demand} \\ \text{Maximum Daily Demand} = 1.8 \times 9,000,000 \ \text{L/day} \\ \text{Maximum Daily Demand} = 16,200,000 \ \text{L/day}$$

**Explanation:** The maximum daily demand is 1.8 times the average daily demand as given.

**Supporting Statement:** This provides the peak water demand scenario which the filters need to handle.

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##### Step 3: Convert Maximum Daily Demand to Liters per Hour

Converting the maximum daily demand to a flow rate in liters per hour:

$$\text{Maximum Demand per Hour} = \frac{\text{Maximum Daily Demand}}{24 \ \text{hours/day}} \\ \text{Maximum Demand per Hour} = \frac{16,200,000}{24} \ \text{L/hr} \\ \text{Maximum Demand per Hour} = 675,000 \ \text{L/hr}$$

**Explanation:** Dividing the daily maximum demand by the number of hours per day to find the hourly flow rate.

**Supporting Statement:** Critical to understand the hourly flow rate which is essential for filter design.

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##### Step 4: Calculate Required Filter Area

Using the operation rate for the filters:

$$\text{Required Filter Area} = \frac{\text{Maximum Demand per Hour}}{\text{Filter Rate}} \\ \text{Required Filter Area} = \frac{675,000 \ \text{L/hr}}{5000 \ \text{lit/hr/sqm}} \\ \text{Required Filter Area} = 135 \ \text{sqm}$$

**Explanation:** The area of the filters required is found by dividing the maximum hourly demand by the operational rate of the filters.

**Supporting Statement:** Determines the total effective filtration area required.

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Step 5: Determine Dimensions of Each Filter

Total area needed for two filters (since two filters are required):

$$ \text{Area per Filter} = \frac{135 \ \text{sqm}}{2} \\ \text{Area per Filter} = 67.5 \ \text{sqm} $$

Explanation: By dividing the total required area by the number of filters, the area per filter is calculated.

Supporting Statement: Necessary to find the area of one filter to establish the dimensions.

Step 6: Calculate Filter Length and Width

Given the relationship $\text{Length} = 1.5 \times \text{Width}$:

Let $\text{Width} = B$ and $\text{Length} = 1.5B$

$$ \text{Area} = \text{Length} \times \text{Width} \\ 67.5 = 1.5B \times B \\ 67.5 = 1.5B^2 \\ B^2 = \frac{67.5}{1.5} \\ B^2 = 45 \\ B = \sqrt{45} \\ B = 6.75 \ \text{m} \\ \text{Length} = 1.5 \times 6.75 \\ \text{Length} = 10.125 \ \text{m} $$

Rounding to practical dimensions:

$$ \text{Length} \approx 10 \ \text{m} \\ \text{Width} \approx 6.75 \ \text{m} $$

Explanation: Calculating the width using the area equation and then finding the length by multiplying the width with the given ratio.

Supporting Statement: Establishes the physical dimensions of each rapid gravity filter based on the calculated area and given length-to-width ratio.

Final Solution:

The dimensions of each rapid gravity filter required to treat water for a 50,000 population at specified demand rates are **Length = 10 m and Width = 6.75 m**.

Explanation: The final step consolidates all calculations into the specified design dimensions for practical application.

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