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# Targeting the Freshwater for Water Networks with Single Contaminant

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**Abstract**

This paper presents a new method to calculate the freshwater target for water using networks with single contaminant. The pinch point is determined by exploiting one of the features of water-pinch-analysis: freshwater is only necessary below the pinch. With the known pinch point, the calculation of the freshwater target becomes very simple, especially for the networks with many streams. The results obtained by this work agree with that obtained in the literature.

**Keywords:** Wastewater minimization, Freshwater target, Pinch point, Pinch analysis, Water networks

## 1. Introduction

Water is one of the key resources for the normal life and is used extensively in many industries. How to reduce water consumption has received many researchers' attention. Since Wang and Smith[1] presented water-pinch-analysis in 1994, many approaches have been proposed to calculate the freshwater target of water using networks with single contaminant till recently[2-6]. In the literature approaches, the pinch point and the freshwater target are determined simultaneously. Therefore, all the streams should be considered in detail either graphically or numerically in the calculation of the targets[2-6]. In this paper, by

incorporating the insights of water-pinch-analysis, we will propose a new approach to determine the pinch point before target calculation. One of the features of water pinch point is that freshwater is only necessary below the pinch point. This feature is used to identify pinch point of water-using systems with single contaminant. With the known pinch point, the calculation effort of freshwater target is reduced. The method proposed is simple and the results obtained in this work agree with that obtained in the literature.

## 2. The new method

In this paper, we will propose a new method to calculate the freshwater target for water-using systems. The pinch point will be determined first. This will simplify the calculation of the freshwater target, because the pinch point can divide the demand streams into below-pinch and above-pinch "sharply". The demand streams are the inlet streams of water-using units, and the source streams are the outlet streams. As pointed out by Liu *et al.*[7], freshwater and wastewater stream(s) are classified as source streams, as shown in Fig. 1.

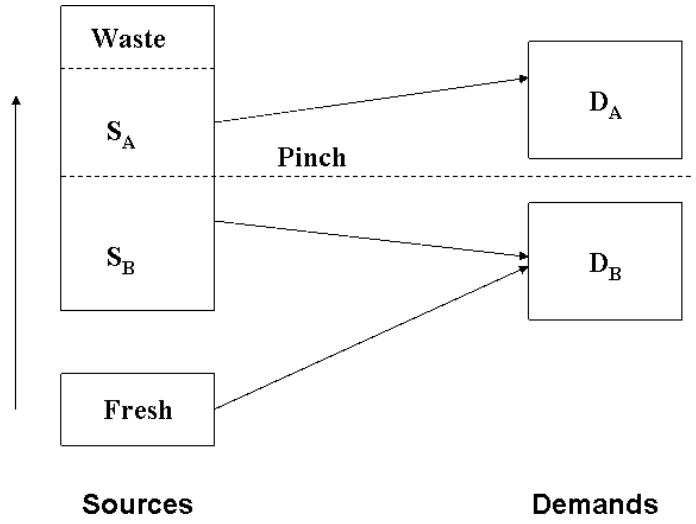


Fig.1. The illustration of the allocation of the source streams to the demand streams

### *2.1. Identification of the Pinch Point*

As indicated by Wang and Smith[1], for a water-using system, freshwater is only required below the freshwater pinch. This is one of the most important features of water-pinch-analysis. In this paper, we will use this feature to

identify the pinch point of water-using systems. We will arrange the demand streams and the source streams in the order of ascending concentration, respectively, because in this way, the targeting procedure for the freshwater requirement will be simplified.[3, 6, 7]

If there are a few streams with the same concentration, they will be lumped as a single stream. The total mass load of the streams will be taken as the lumped mass load at this concentration. Similarly, the lumped mass load of the source streams can also be determined.

A pinch point of a water-using system can be determined as follows:

(1) Satisfy each demand stream by the source streams in their concentration order;

(2) If the overall concentration of the source streams is greater than that of the demand streams, freshwater is required at this concentration; otherwise, freshwater is not required at this concentration;

(3) A pinch-source will be the source, which will satisfy one demand where freshwater is required, and satisfy another demand where freshwater is not required.

### *2.2. Calculation of the freshwater target*

When the pinch point of a water-using system is determined as above, the calculation procedure of the freshwater target can be simplified, because as shown in Fig.1, the pinch point can "sharply" divide the demand streams into below-pinch and above-pinch. Then, the freshwater target can be calculated as following procedure:

(1) calculating the flowrate of the demands and that of the sources according to their mass load and concentration below the pinch, respectively;

(2) calculating the target based on the flowrates of the demands and source below the pinch determined.

## 3. Case study

The case study example is taken from Olesen and Polley.[5] Table 1 lists the data of this example. Table 2 lists the generated data for this example. In Table 2, the demand streams and source streams are arranged in the ascending order of their concentration, respectively. The value of the mass load of the contaminant in the source $m_s$, and that in the demand $m_d$ and the flowrate $F_{max}$ for each process can be calculated from:

$$m_d = F_{max} \times C_{in,max} \qquad (1)$$

$$m_s = F_{max} \times C_{out,max} \quad (2)$$

$$F_{max} = m / (C_{out,max} - C_{in,max}) \quad (3)$$

The lumped mass load of the demand streams $M_D$ and that of the source streams $M_S$ at each concentration are also listed in Table 2. For example, there are three demand streams with the same concentration, 25 ppm, the lumped mass load for the demand at 25 ppm is 0.909 + 1.667 + 0.571 = 3.147 kg/h, as shown in Table 2.

Table 1. Data for the case study example taken from Olesen and Polley.[5]

| Demand | | | Source | | |
|---|---|---|---|---|---|
| No | F, t/h | C, ppm | No | F, t/h | C, ppm |
| 1 | 36.364 | 25 | 1 | 36.364 | 80 |
| 2 | 66.667 | 25 | 2 | 66.667 | 100 |
| 3 | 22.857 | 25 | 3 | 22.857 | 200 |
| 4 | 100 | 50 | 4 | 100 | 100 |
| 5 | 40 | 50 | 5 | 40 | 800 |
| 6 | 10 | 400 | 6 | 10 | 800 |

Table 2. Generated data for the case study example

| Demand | | | | Source | | | |
|---|---|---|---|---|---|---|---|
| F, t/h | C, ppm | $m_d$, kg/h | $M_D$, kg/h | F, t/h | C, ppm | $m_s$, kg/h | $M_S$, kg/h |
| 36.364 | 25 | 0.909 | | 36.364 | 80 | 2.909 | 2.909 |
| 66.667 | 25 | 1.667 | | 66.667 | 100 | 6.667 | |
| 22.857 | 25 | 0.571 | 3.147 | 100 | 100 | 10 | 16.667 |
| 100 | 50 | 5 | | 22.857 | 200 | 4.571 | 4.571 |
| 40 | 50 | 2 | 7 | 40 | 800 | 32 | |
| 10 | 400 | 4 | 4 | 10 | 800 | 8 | 40 |

Table 3 lists the allocation of the mass load of the contaminant from the source to the demand. For the demand of 25 ppm, the lumped mass load is 3.147 kg/h. This amount of mass load can be satisfied by the source at 80 ppm (the mass load is 2.909 g/h) and the source at 100 ppm (the mass load is 0.238

kg/h). The overall concentration of the source streams is higher than that of the demand stream. Therefore, freshwater is required when allocating the source streams to this demand. The allocation amount of the mass load, the concentrations of the demand and source streams, and the requirement of freshwater in this demand concentration are listed in Table 3. Similarly, the demand streams of 50 ppm (the mass load is 7 kg/h) and 400 ppm (the mass load is 4 kg/h) can also be satisfied by the source of 100 ppm as well, as shown in Table 3. When the source of 100 ppm is allocated to the demand of 50 ppm, freshwater is required. However, when the source of 100 ppm is allocated to the demand of 400 ppm, freshwater is not required.

Table 3. The allocation of the source to the demand

| $C_D$, ppm | $C_S$, ppm | $M_{i,j}$, kg/h | $F_{i,j}$, kg/h | Fresh Water Requirement |
|---|---|---|---|---|
| 25 | 80 | 2.909 | 36.364 | Yes |
| 25 | 100 | 0.238 | 2.381 | Yes |
| 50 | 100 | 7 | 70 | Yes |
| 400 | 100 | 4 | 40 | No |

Note: where $C_D$ and $C_S$ are the concentration of the demand and source, respectively, $M_{i,j}$ is the mass load allocated from the source to the demand, and $F_{i,j}$ is the flowrate of the source allocated to the demand.

From the data in Table 3, it can be seen that the pinch source is the source stream at 100 ppm, because it will be allocated to a demand whose concentration (50 ppm) is lower than that of the source, and to a demand whose concentration (400 ppm) is higher than that of the source.

Now, let us calculate the freshwater target based on the pinch point determined. Table 3 lists the amount of the mass load allocated from the source to the demand, and the amount of the flowrate of the source allocated to the demand. From the data, it can be calculated that the total amount of the source allocated to the demand below the pinch is: (36.364 + 2.381 + 70) = 108.745 t/h. From Tables 1 and 2, the total amount of the flowrate of the demand below the pinch is: (36.364 + 66.667 + 22.857 + 100 + 40) = 265.887 t/h. The freshwater target will be: 265.887 - 108.745 = 157.142 t/h. The result obtained is the same as that obtained by Olesen and Polley [5] and Manan et al.[4]

From the above example it can be seen that when calculating the freshwater target, it is only necessary to consider the allocation of the source to the demand below the pinch point. This reduces the calculation effort of the freshwater target, especially for the systems with many streams.

## 4. Conclusions

In this paper, a new targeting procedure for the freshwater requirement of water-using systems with single contaminant is proposed. The pinch point is determined based on one of the features of pinch point: freshwater is only required below the pinch point. Having known the pinch point, the calculation of the freshwater target will be simplified. This reduces the calculation effort, especially for the water-using systems with many streams. The results obtained in this work agree with that obtained in the literature.

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