SOLUTION FOR PROBLEMS IN CHAPTER 3

Problem 3.1 (tire-to-fuel process)

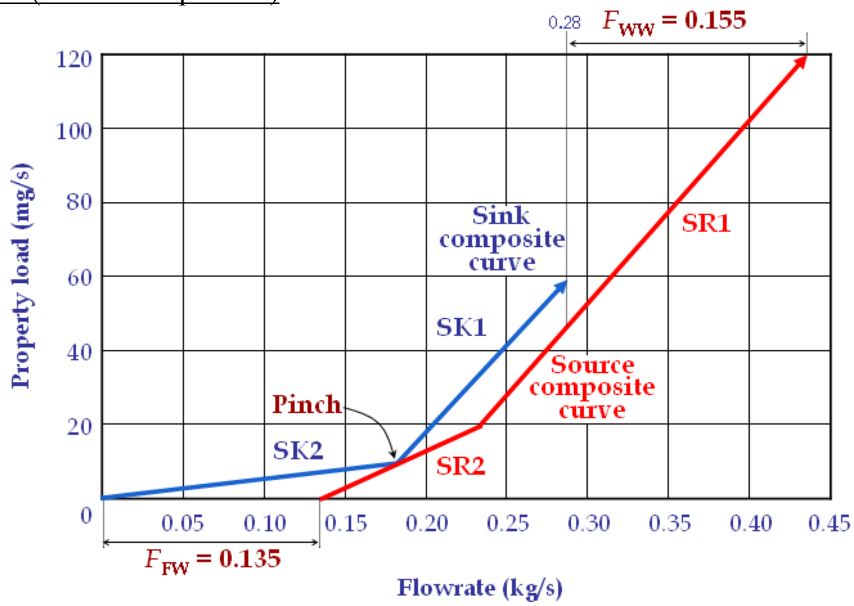


Figure S3.1 MRPD for Problem 3.1

Minimum flowrates for fresh water (F_{FW}) = 0.135 kg/s; and wastewater (F_{WW}) = 0.155 kg/s.

Problem 3.2 (textile plant)

Note: When plotting the sink composite curve, please note that sink SK3 has lower concentration than SK2, and hence is plotted prior to the latter.

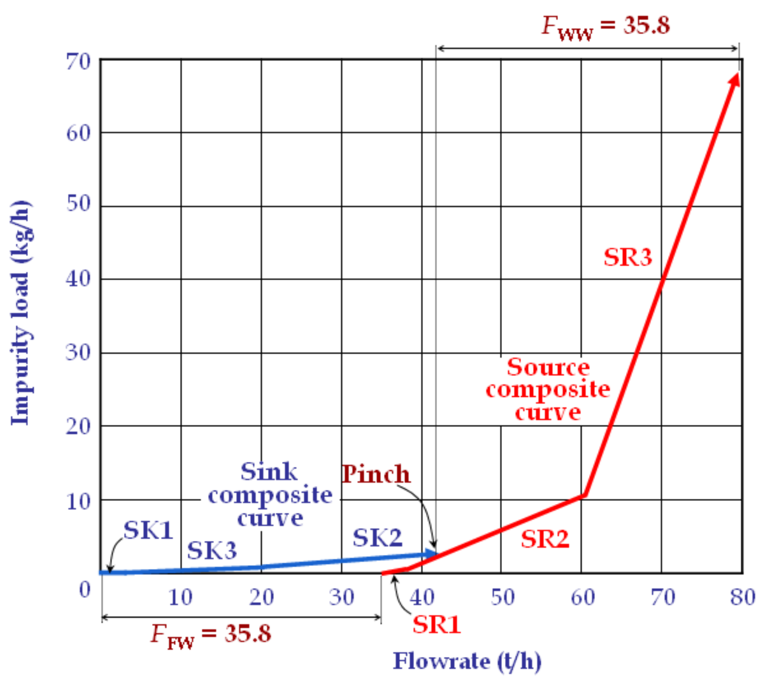


Figure S3.2 MRPD for Problem 3.2

Minimum flowrates for fresh water (F_{FW}) = 35.8 t/h; and wastewater (F_{WW}) = 35.8 t/h.

Problem 3.3

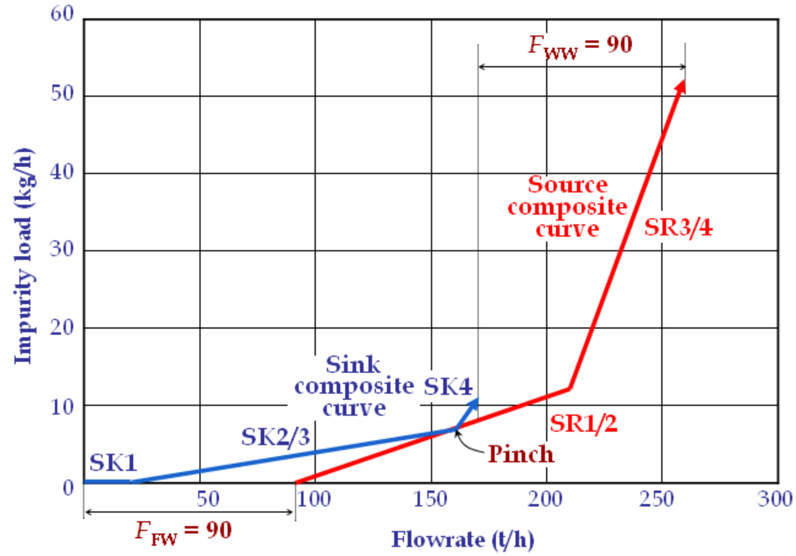


Figure S3.3 MRPD for Problem 3.3

Minimum flowrates for fresh water (F_{FW}) = 35.8 t/h; and wastewater (F_{WW}) = 35.8 t/h.

Problem 3.4 (Polley and Polley, 2000)

(a) Pure fresh water feed

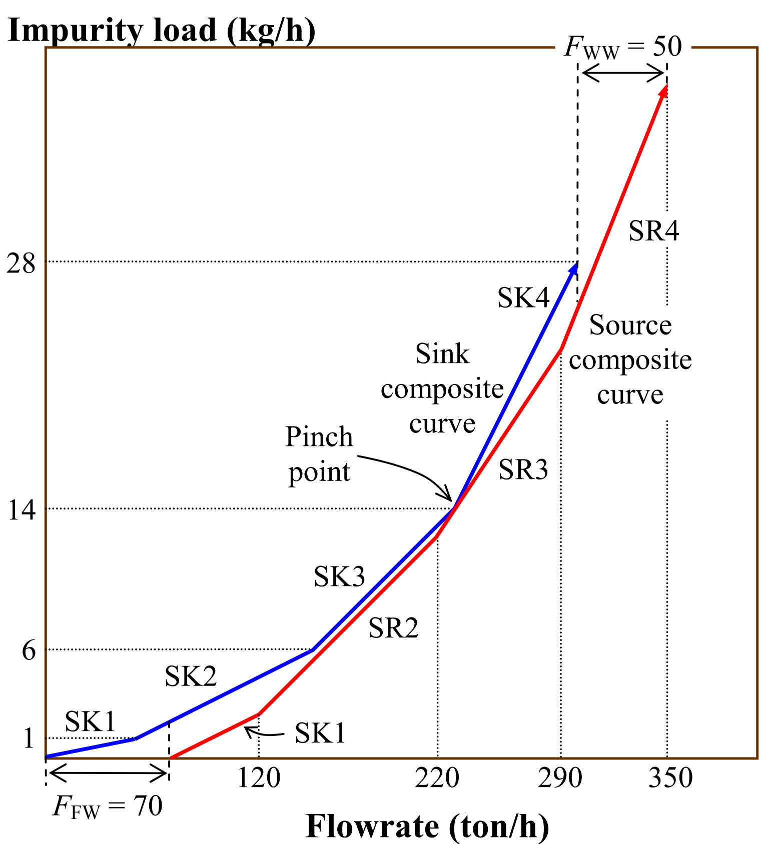


Figure S3.4 MRPD for Problem 3.4(a) (Foo, 2009)

Minimum flowrates for fresh water (F_{FW}) = 70 t/h; and wastewater (F_{WW}) = 5 t/h.

(b) Single impure fresh water feed, with 10 ppm impurity content

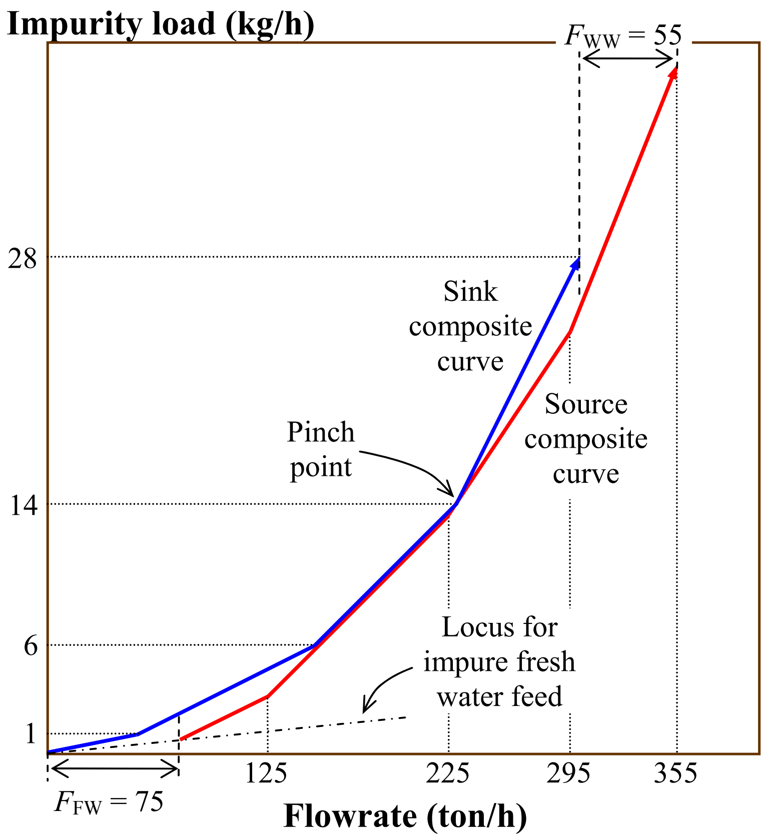


Figure S3.5 MRPD for Problem 3.4(b) (Foo, 2009)

Minimum flowrates for fresh water (F_{FW}) = 75 t/h; and wastewater (F_{WW}) = 55 t/h.

(c) Pure (0 ppm, \$1/ton) and impure fresh water feeds (80 ppm, \$0.2/ton).

In (a), the pinch concentration (when pure fresh water feed is used) for this problem is identified as 150 ppm. Hence, the prioritised cost for pure ($CT_{P,\,FW1}$) and impure fresh water sources ($CT_{P,\,FW2}$) are determined using **Equation 3.3** as:

$$CTP_{FW1} = \frac{\$1/\text{ton}}{(150-0)\,\text{ppm}} = \frac{\$6.667}{\text{kg impurity}};$$

$$CTP_{FW2} = \frac{\$0.2/\text{ton}}{(150-80)\,\text{ppm}} = \frac{\$2.857}{\text{kg impurity}}$$

Since the prioritised cost of the impure fresh water source is much lower than that of the pure fresh water source, the use of former should be maximised prior to the latter. Targeting using MRPD is shown in **Figure S3.6**. The fresh water flowrates for pure (F_{FW1}) and impure fresh water sources (F_{FW2}) are identified as 56.25 and 43.75 t/h respectively.

Operating cost for fresh water feeds are then calculated as:

$$56.25\ (1) + 43.75\ (0.2)\ =\ \$65/\text{h}$$

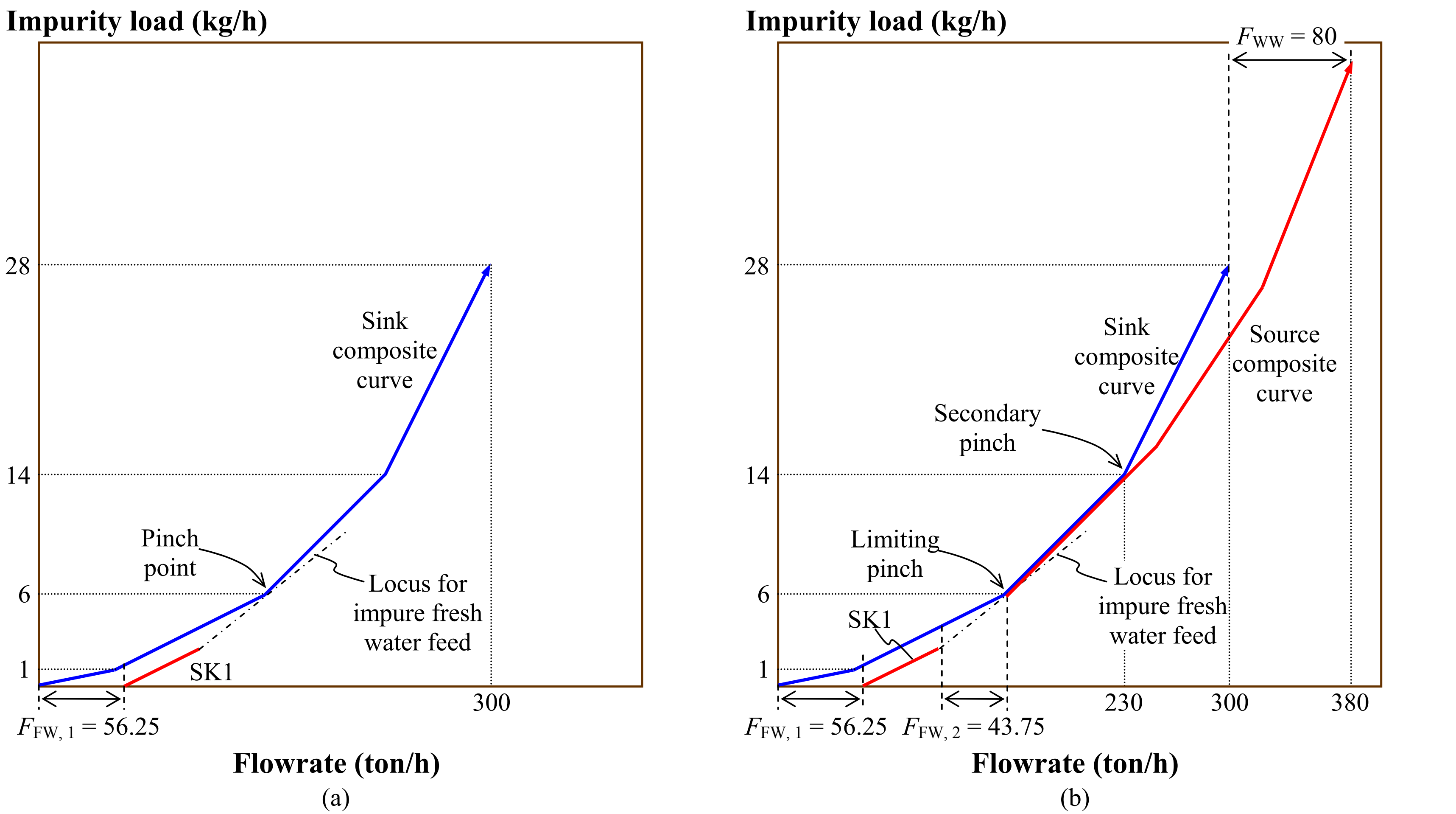


Figure S3.6 MRPD for Problem 3.4(c): (a) targeting for pure fresh fresh water feed; (b) targeting for impure fresh water feed (Foo, 2009)

Problem 3.5

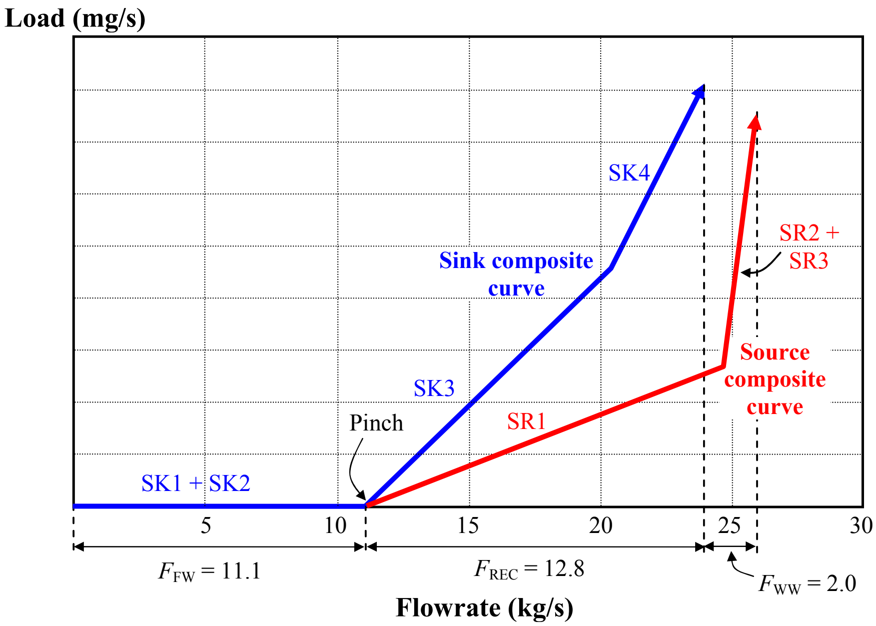


Figure S3.7 MRPD for Problem 3.5 (Foo, 2012)

Minimum flowrates for fresh water (F_{FW}) = 11.1 kg/s; and wastewater (F_{WW}) = 2.0 kg/s.

Problem 3.6

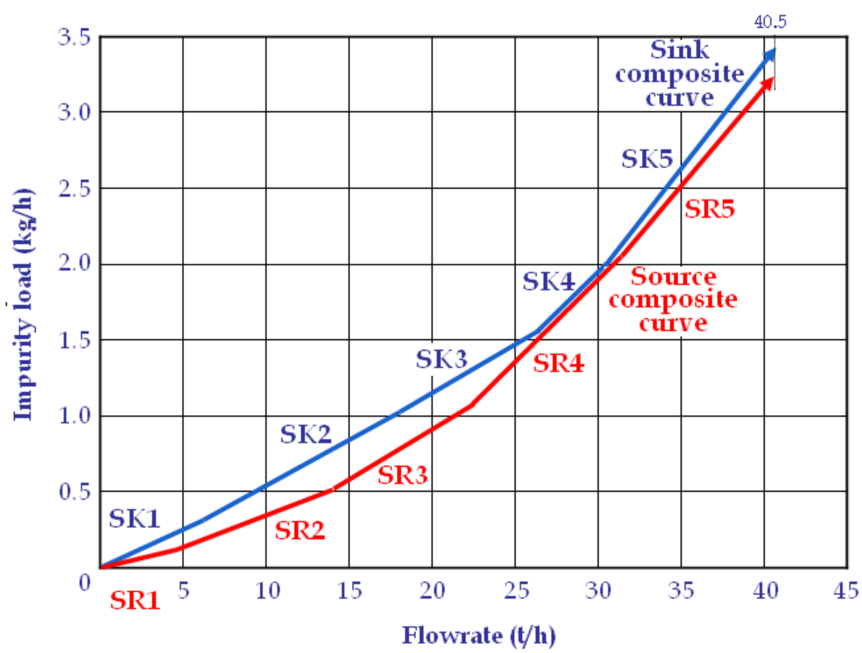
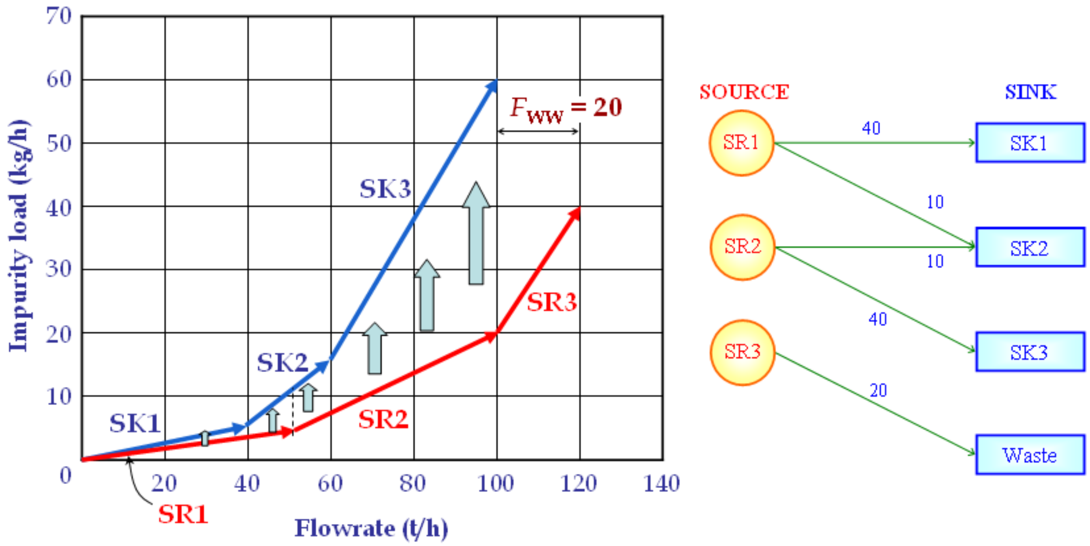


Figure S3.8 MRPD for Problem 3.6

Zero fresh resource and zero discharge network, i.e. no fresh water and wastewater flowrates.

Problem 3.7

Flowrate allocation for each water sink can be determined based on the horizontal distance of the segment. For instance, sink SK1 is allocated fully by source SR1; while SK2 receives water from both SK1 and SK2, with flowrate of 10 t/h respectively (see **Figure S3.9**). Similar approach is used for other sinks in **Examples 3.5** and **3.6** (see **Figure S3.10**).



(a) (b)

Figure S3.9 RCN for **Examples 3.5 -** zero fresh resource network

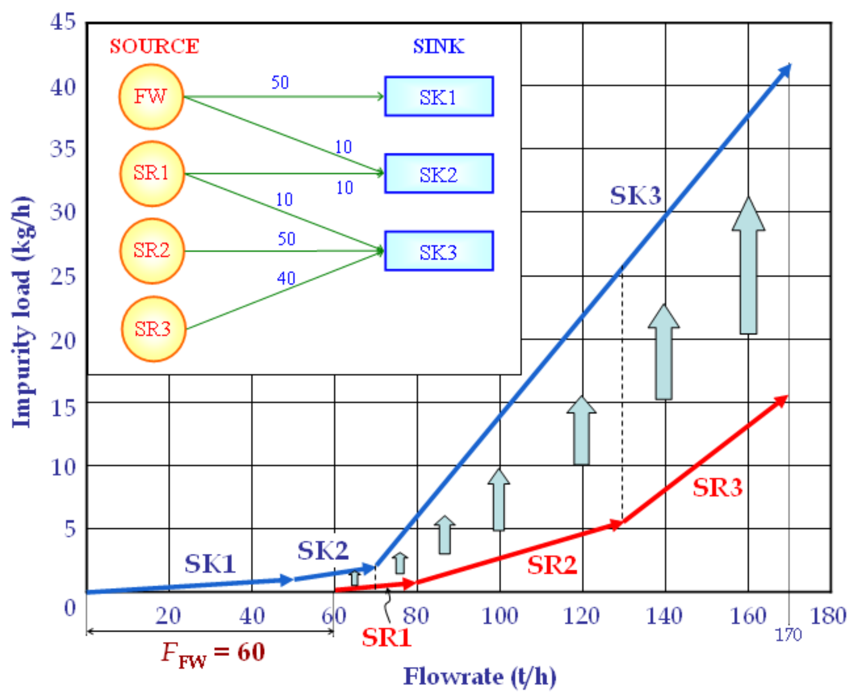


Figure S3.10 RCN for **Examples 3.6 -** Zero discharge network

Problem 3.8

Note: When plotting the sink composite curve, please note that source SR2 has lower concentration than SR1, and hence is plotted prior to the latter.

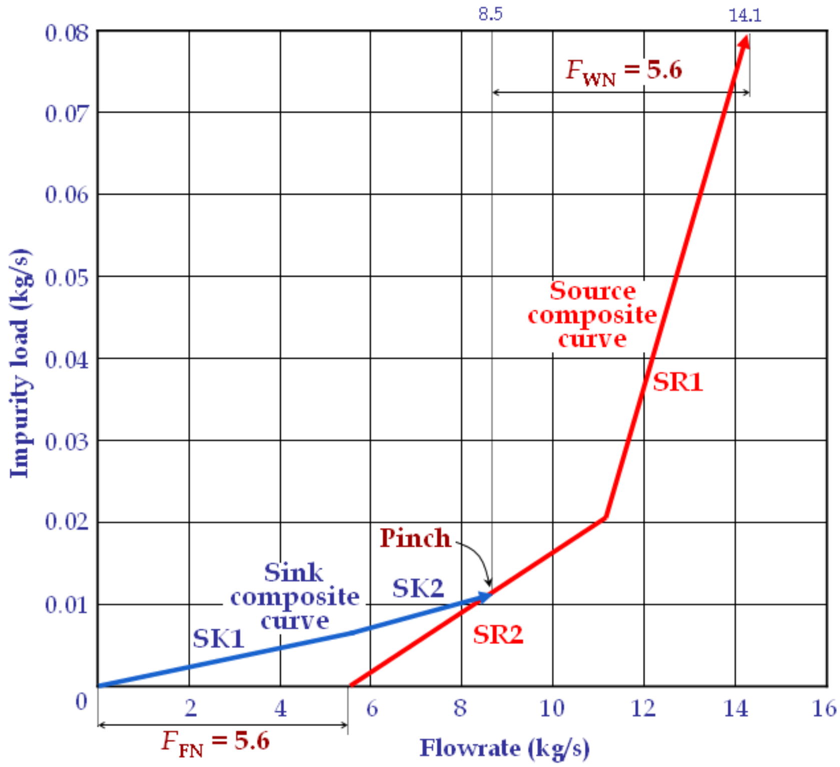


Figure S3.11 MRPD for Problem 3.8

Minimum flowrates for fresh nitrogen (F_{FN}) = 5.6 kg/s; and waste gas (F_{WN}) = 5.6 kg/s.

Problem 3.9

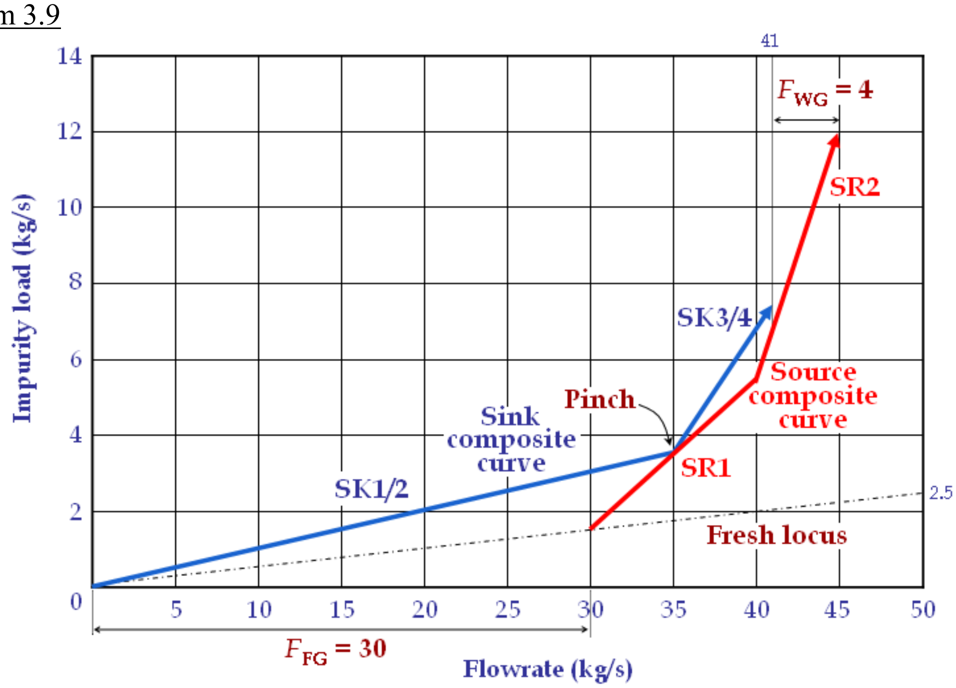


Figure S3.12 MRPD for Problem 3.9

Minimum flowrates for fresh oxygen gas (F_{FW}) = 30 kg/s; and waste gas (F_{WG}) = 4 kg/s.

Problem 3.10

Note: When plotting the sink composite curve, please note that source SR2 has lower concentration than SR1, and hence is plotted prior to the latter.

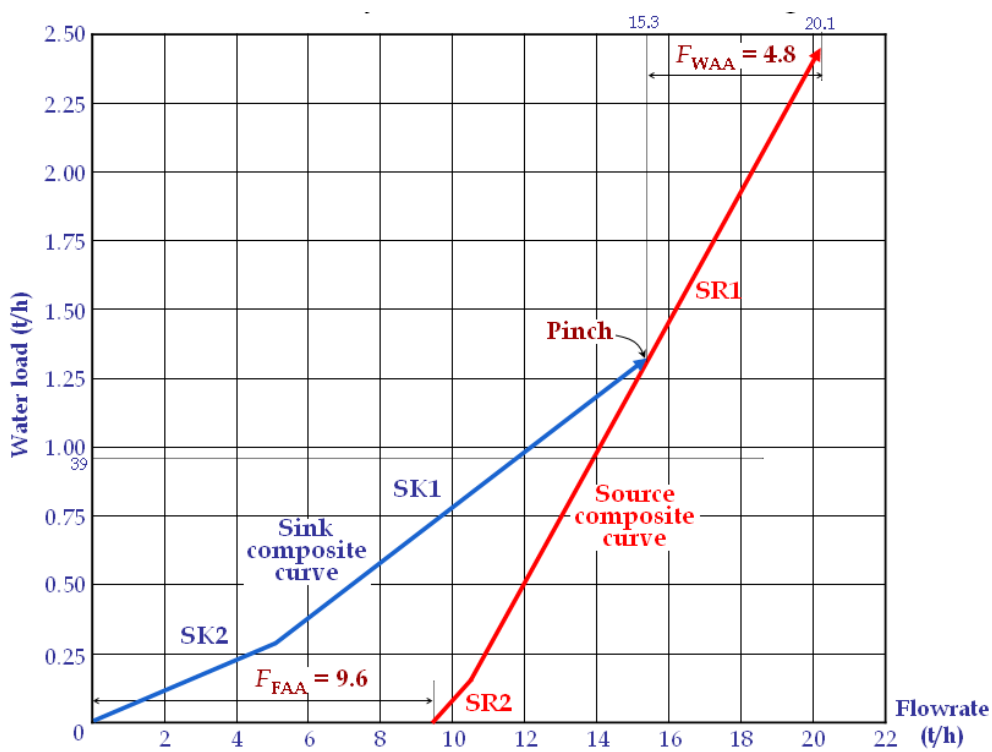


Figure S3.13 MRPD for Problem 3.10

Minimum flowrates for fresh acetic acid (F_{FAA}) = 9.6 t/h; and waste (F_{WAA}) = 4.8 t/h.

Problem 3.11

Since UPW has a resistivity of 18,000 kΩ/cm, which translates into the operator value of 0.000056 cm/kΩ. Hence a fresh locus is needed in the MRPD.

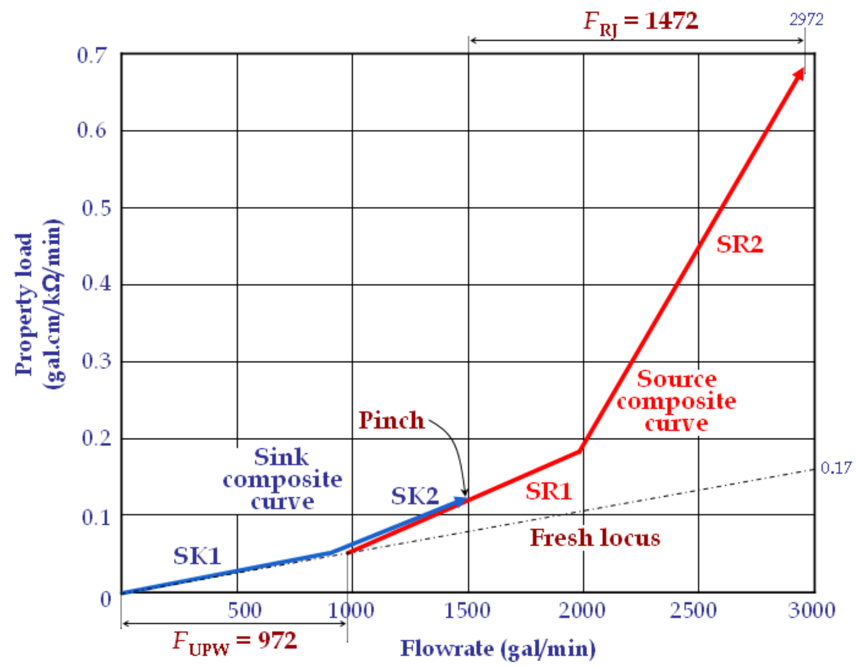


Figure S3.14 MRPD for Problem 3.11

Minimum flowrates for ultrapure water (F_{UPW}) = 972 gal/min; and reject streams (F_{RJ}) = 1472 gal/min.

Problem 3.12

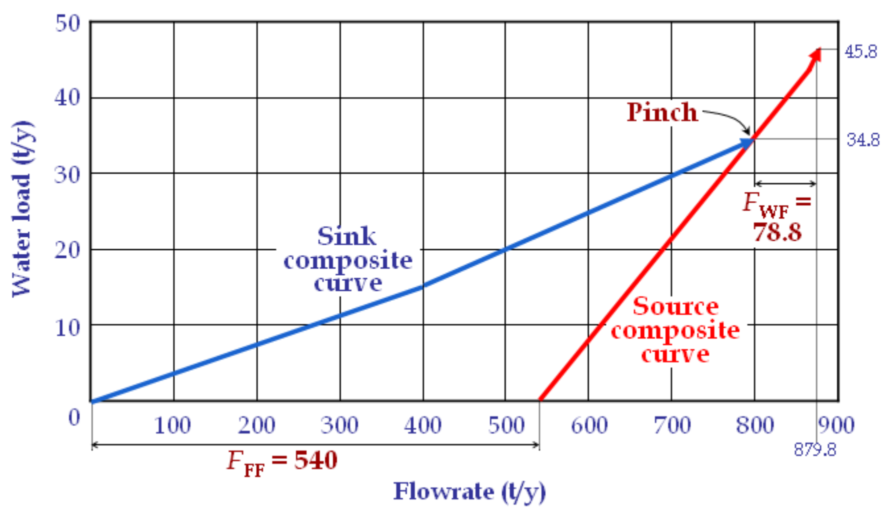


Figure S3.15 MRPD for Problem 3.12

Minimum flowrates for fresh fibre (F_{FF}) = 540 t/y; and waste fibre (F_{WF}) = 4 t/y.

References

Foo, D. C. Y. (2012). Resource Conservation through Pinch Analysis, in Foo, D. C. Y., El-Halwagi, M. M. and Tan, R. R. (Eds.) *Recent Advances in Sustainable Process Design and Optimisation*, World Scientific/Imperial College Press (in press).

Foo, D. C. Y. (2009). A State-of-the-art Review of Pinch Analysis Techniques for Water Network Synthesis. *Industrial & Engineering Chemistry Research*, 48 (11), 5125-5159.