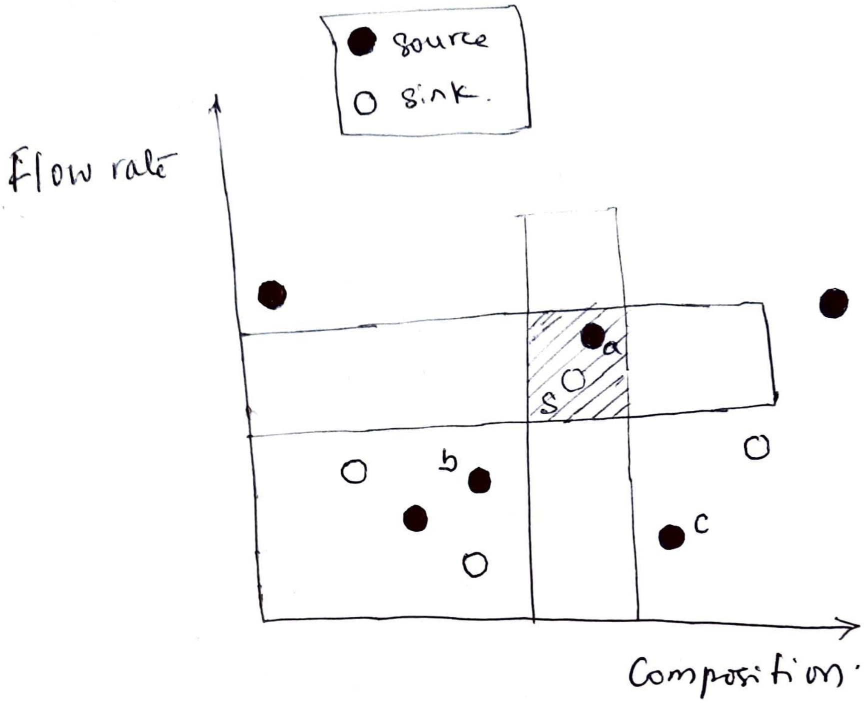
Source Sink Mapping diagram.

For each targeted species, a diagram called source-sink mapping diagram is constructed by plotting the flowrate vs composition. On the source sink mapping diagram, sources are represented by shaded circles and sinks are represented by hollow circles. The constraints on flow rate & composition are represented by horizontal and vertical bands. The intersection of these two bands provides a zone of acceptable load and composition for recycle. If a source (e.g., source a) lies within this zone, it can be directly recycled to the sink (e.g. sink S)

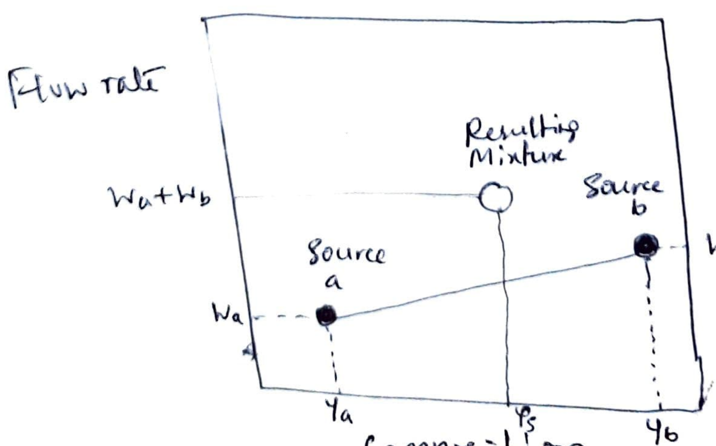
Moreover, the sources b and c can be mixed using the lever-arm principle to create a mixed stream that can be recycled to sink S.



Source Sink Mapping Diagram.

Lever arm principle :

Sources b and c can be mixed ~~by~~ using lever arm principle to create a mixed stream that can be recycled to sink S.



Mixing of sources a and b.

The lever arms can be determined based on material balance. Consider the mixing of two streams a and b shown in fig. The flow rates of the two sources are W_a and W_b and their composition are y_a and y_b. The mixture resulting from the two sources has a flow rate of $W_a + W_b$ and a composition y_s. The resulting flow rate and composition of the mixture satisfy the flow rate and composition constraints for the sink S.

A material balance for the targeted species around the mixing operation can be expressed as

$y_s (W_a + W_b) = y_a W_a + y_b W_b$.

Rearranging we get

$y_s W_a + y_s W_b = y_a W_a + y_b W_b$.

$y_s W_a - y_a W_a = y_b W_b - y_s W_b$

$(y_s - y_a) W_a = (y_b - y_s) W_b$.

$$\frac{W_a}{W_b} = \frac{(y_b - y_s)}{(y_s - y_a)}$$

$$\frac{W_a}{W_b} = \frac{\text{arm for a}}{\text{arm for b}}$$

where $(y_b - y_s)$ = arm for a

and $(y_b - y_a)$ = arm for b.

$W_a + W_b = y_b - y_s + y_s - y_a$

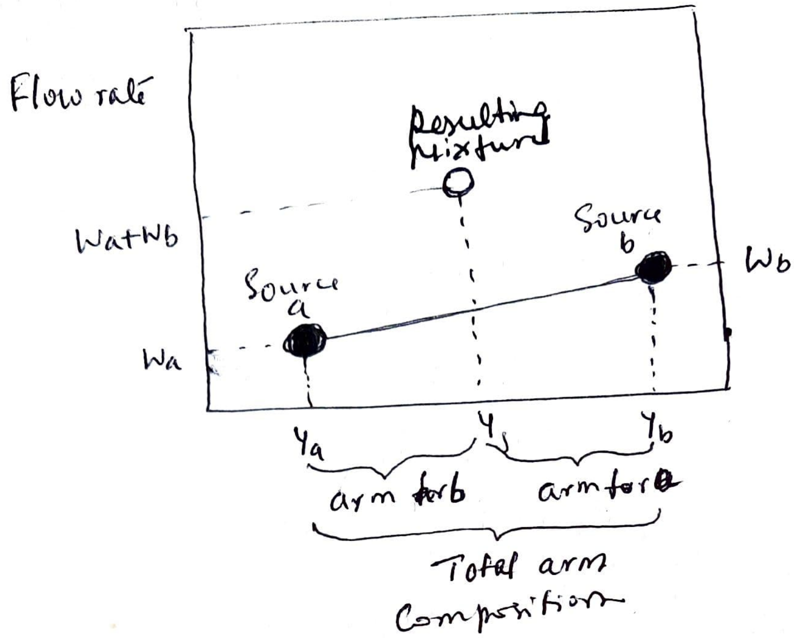
$= y_b - y_a$

IIIly $$\frac{W_a}{W_a + W_b} = \frac{\text{Arm for a}}{\text{Total arm}}$$

where the total arm is the sum of arm for a and arm for b

Total arm = $(y_b - y_a)$

Lever arm rule for mixing



The lever arms for the individual sources as well as the resulting mixture are shown in Fig. There are the horizontal lever arms, Arms can also be shown on the tilted line connecting sources a and b, In such cases ratio of arms will be exactly the same as the ratio of the horizontal arms because of angle similitude

SINK COMPOSITION RULE

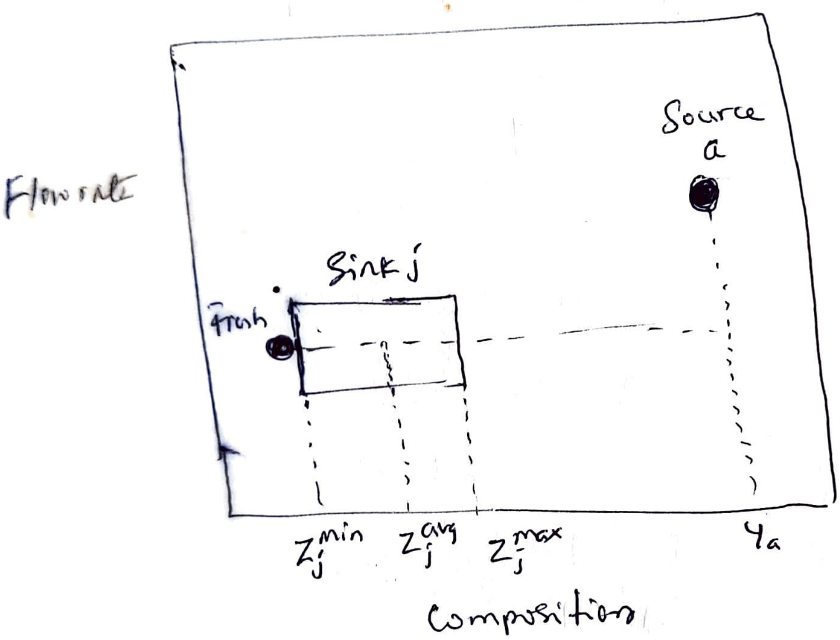
Consider a sink j shown in Fig. The composition bounds are $z_j^{min} \le z_j^{in} \le z_j^{max}$, Currently a fresh resource is used to satisfy the sink requirements, A process source a (e.g. waste stream) may be rerouted to sink j where a portion of the flow rate can be mixed with the fresh resource to reduce the consumption of fresh resource in the sink. In order to minimize the usage of the fresh flow rate satisfying composition constraints of the sink what should be the composition of the feed entering the sink? Should it be z_j^{min}, z_j^{max} or z_j^{avg}

According to lever arm rule

$$\frac{\text{Fresh flowrate used in sink}}{\text{Total flow rate fed to sink}} = \frac{\text{Fresh arm}}{\text{Total arm}}$$

i.e

$$\frac{\text{Fresh flow rate used in sink}}{\text{Total flow rate fed to sink}} = \frac{y_a - z_{\text{feed to sink}}}{y_a - y_F}$$

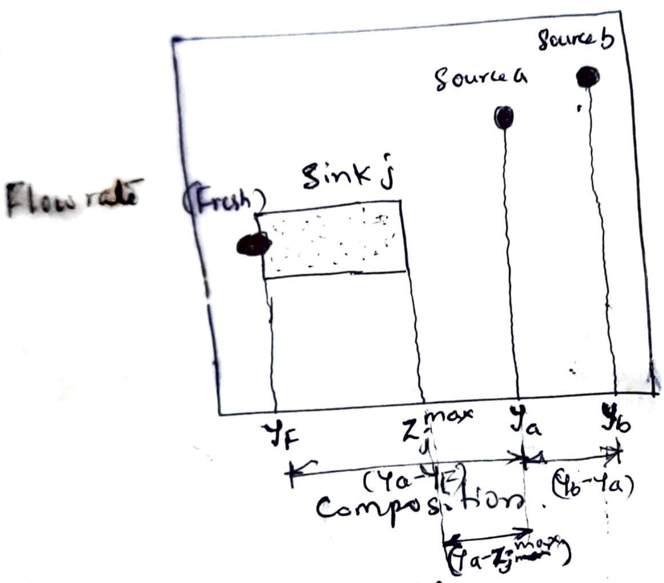


For a given requirement of total flow rate fed to the sink the flow rate of the fresh is minimized when $z_{\text{feed to sink}}$ is maximized. Hence the composition of the feed entering the sink should be set to z_j^{max}

Sink composition Rule:

When a fresh resource is mixed with process source(s), the composition of the mixture entering the sink should be set to a value that minimizes the fresh arm. For instance, when the fresh resource is a pure substance that can be mixed with the pollutant-laden process sources, the composition of the mixture should be set to the maximum admissible value.

Source Prioritization Rule.



A process sink currently uses a fresh resource. In order to reduce the fresh usage, two process sources are considered for recycle. Both sources have sufficient flow rate to satisfy the sink but their compositions exceed the maximum admissible composition to the sink. Yet, upon mixing with the fresh resource in proper proportions, both process sources can be fed to the sink. The question is which source should be used: a or b?

According to Fig.

Fresh arm when source a is used = $y_a - z_j^{max}$ ——— ①

z_j^{max} - composition of the mixture as described in the sink composition rule.

Fresh arm when source b is used $= y_b - z_j^{max}$ —— (2)

Arms given by eqn (1) and (2) are called absolute fresh arms

absolute fresh arm for a < absolute fresh arm for b.

Relative arm for $a = \frac{\text{Fresh arm}}{\text{Total arm}} = \frac{y_a - z_j^{max}}{y_a - y_F}$ —— (3)

Relative arm $= \frac{\text{Fresh arm}}{\text{Total arm}}$ Relative arm for $b = \frac{y_b - z_j^{max}}{y_b - y_R}$ —— (4)

Now evaluate the ratio of the two relative fresh arms.

$$\frac{\text{Relative fresh arm for a}}{\text{Relative fresh arm for b}} = \frac{\frac{y_a - z_j^{max}}{y_a - y_F}}{\frac{y_b - z_j^{max}}{y_b - y_R}}$$

$$= \frac{\frac{y_a - z_j^{max}}{(y_a - y_F)}}{[(y_b - y_a) + (y_a - z_j^{max})] / [(y_b - y_a) + (y_a - y_F)]}$$ —— (5)

$$= \frac{\frac{(y_b - y_a)}{y_a - y_F} + 1}{\frac{(y_b - y_a)}{(y_a - z_j^{max})} + 1}$$

But as can be seen from the figure

$(y_a - y_F) > (y_a - z_j^{max})$ —— (6 a)

hence $\frac{(y_b - y_a)}{(y_a - y_F)} < \frac{(y_b - y_a)}{(y_a - z_j^{max})}$ —— (6 b)

Combining ~~Combine~~ Eqn (5) and Eqn. (6b)

Relative fresh arm for a < Relative fresh arm for b

Source prioritization Rule: In order to minimize the usage of the fresh resource, recycle of the process sources should be prioritized in order of their fresh arms starting with the source having the shortest fresh arm.

~~Selection of Sources, Sinks and Recycle Routes.~~

Selection of Sources, Sinks and Recycle Routes.

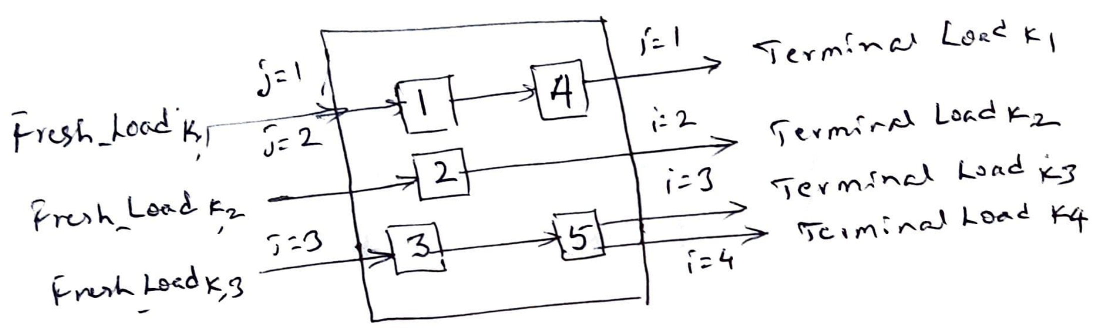


Fig 1. Process before recycle

In this process, three fresh streams (j = 1-3) carry the targeted species. The required input load of the kth targeted species in these streams is denoted by $Fresh\_Load_{K,j}$. The targeted species leave the process in four terminal streams; two of which (i = 1, 2) are recyclable (with or without interception) and the other two (i = 3, 4) are forbidden from being recycled. The total load from the four terminal streams is given by $Terminal\_Load_{K,1}$ + $Terminal\_Load_{K,2}$ + $Terminal\_Load_{K,3}$ + $Terminal\_Load_{K,4}$.

~~Fig 2.~~

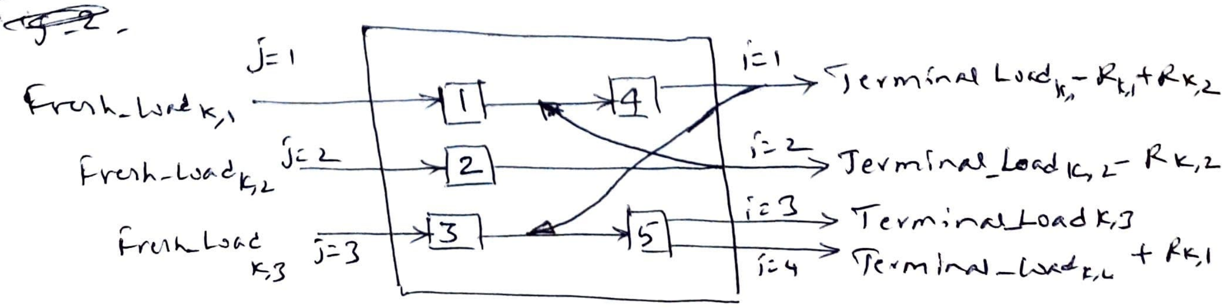


Fig 2. Process after Recycle to poor sinks.

Consider recycle from terminal streams to units that do not employ fresh resources as shown in Fig. 2. Let us recycle a load of $R_{K,1}$ from i=1 to the inlet of unit 5 and a load of $R_{K,2}$ from i=2 to the inlet of unit 4. Here, we are dealing with the case where recycle activities have no effect on Net-process K, the loads in the individual stream are simply redistributed with the total terminal load remaining the same (Terminal Load $_{K,1}$ + Terminal Load $_{K,2}$ + Terminal Load $_{K,3}$ + Terminal Load $_{K,4}$). Therefore in this case, sinks do not employ fresh sources of the targeted species are poor destinations for recycle.

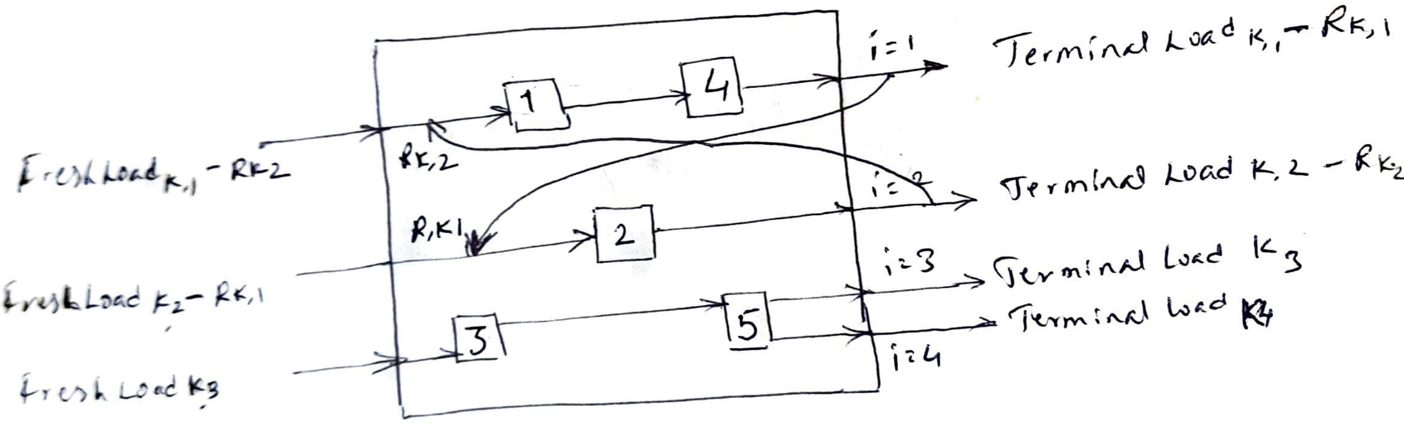


Fig 3. Recycle to proper sinks (Total terminal Load is reduced)

Consider recycle that reduce fresh loads (Fig 3). Let us examine the recycling of a load of $R_{K,1}$ from i=1 to the inlet of unit 2 and a load of R_{K2} from i=2 to the inlet of unit 1. There is net reduction of $R_{K,1} + R_{K,2}$ from fresh load $_{K}$. Therefore total terminal loads are reduced by $R_{K,1} + R_{K,2}$.

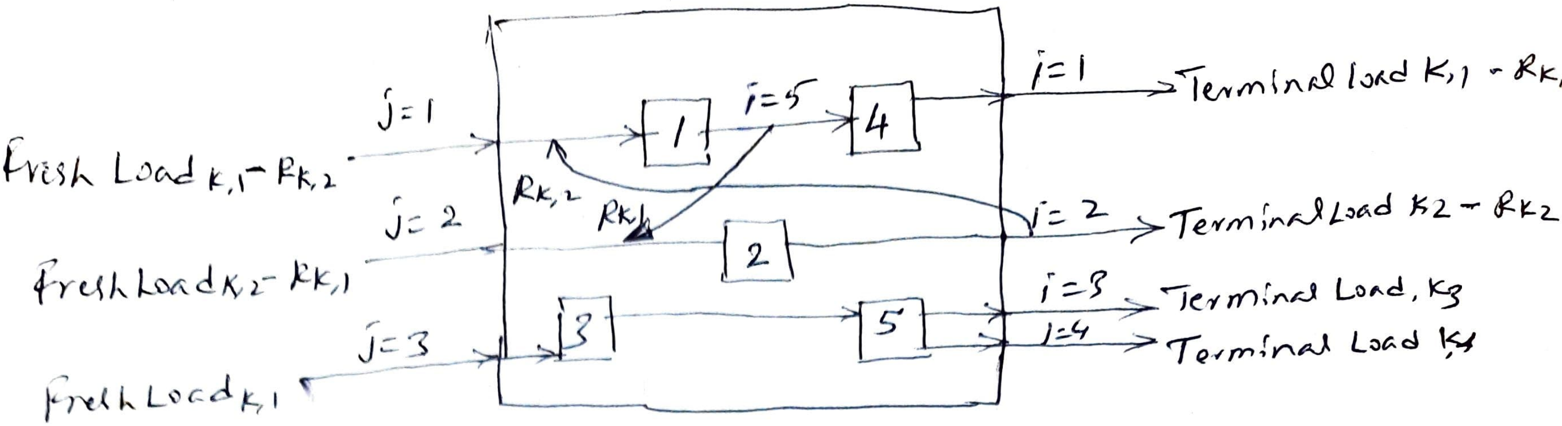


Fig 4 ; Recycle using inplant and Terminal loads.

The same effect can be accomplished (As in Fig 3) from recycling in plant resources (Fig. 4)

Conclusion:

The foregoing discussion illustrates that in the case where net generation/depletion of the targeted species is independent of stream rerouting activities, recycle should be allocated to sinks that consume the fresh resource. The recyclable sources may be terminal streams or inplant streams on the path on terminal streams. The result of such selection of sources and sinks lead to a reduction in both fresh consumption and waste discharge.