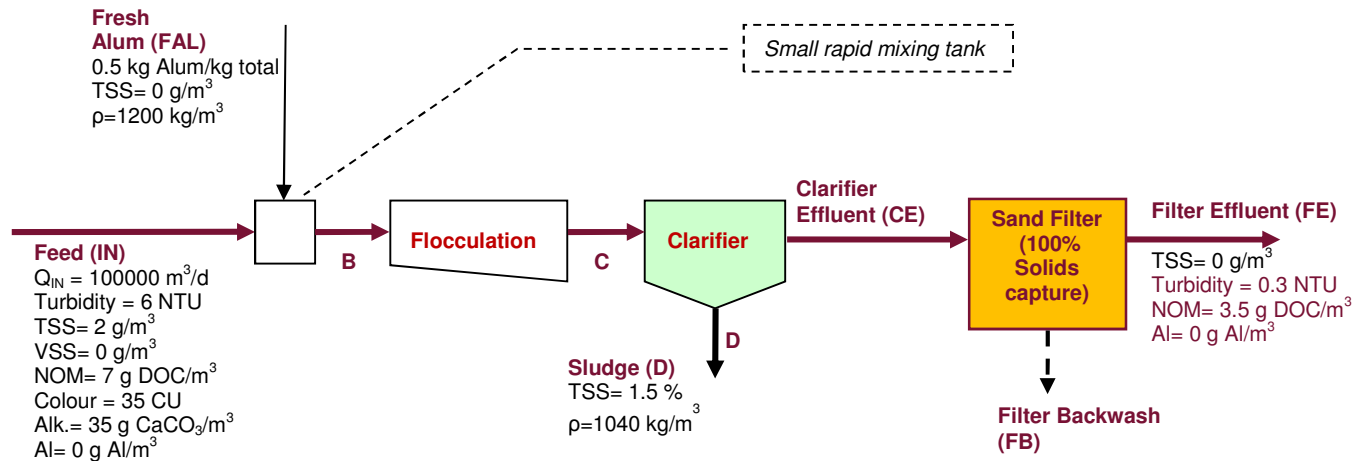


You are designing a water treatment plant for treating turbid river water. The plant consists of coagulation (rapid mix for uniform chemical dispersion), flocculation, sedimentation, sand filtration and chlorination.



During the high demand season the plant's average flow is 100000 m³/d, the average feed solids concentration is 2 g/m³, the average feed turbidity 6 NTU and the average influent dissolved organic carbon (DOC) of 7 g/m³. DOC is a measure of a measure of natural organic matter (NOM). Jar tests indicate that for the highest practical removal of the contaminants in the feed the required aluminum dose is equivalent to 32 g alum/m³ (alum = Al₂(SO₄)-14.3H₂O, MW=600) which is based on the feed flowrate. The combination of coagulation + flocculation + sedimentation achieves almost complete removal of the incoming solids (TSS_{CE} = 0.2 g/m³), 90 % removal of the incoming turbidity, and 50% removal of the feed of the DOC (all based on their concentrations in the clarifier effluent). Assume all of the alum reacts to form Al(OH)₃ flocs, which is removed through sedimentation and filtration. The DOC are removed by enmeshment and adsorption on the aluminum hydroxide flocs, assume its impact on solids generation is negligible. The sedimentation basin produces a sludge which contains all of the solids in the influent plus 95% of the Al(OH)₃ formed from the alum. The rest of the Al(OH)₃ is removed by the sand filter.

Determine:

- Determine the mass of alum added (kg alum/d)
- Determine the mass flowrate of stream "FAL" in kg/d.
- Determine the FSS formed via the coagulation reactions (g FSS/d)
- The volumetric flowrate of sludge stream "D" in m³/d.
- The volumetric flowrate of the clarifier effluent stream "CE" in m³/d.

Assume:

- That unless otherwise indicated that density of all streams is 1000 kg/m³
- The coagulant does not contain solids.

- 3) Assume that all of the aluminium (Al) added in the coagulant reacts via the above reaction which takes place in the mixing tank and flocculator.
- 4) The alum reacts to form Al(OH)_3 by the reaction

$$\text{Al}^{+3} + 3 \text{H}_2\text{O} \text{ ----- } \text{Al(OH)}_3 \downarrow + 3 \text{H}^+$$
- 5) 95% of the Al(OH)_3 are sufficiently large to be considered FSS created by the process. These FSS precipitates ends up in the clarifier sludge.
- 6) 5% of the Al(OH)_3 flocs formed are too small to: a) precipitate and be removed in the clarifier; and b) be considered FSS. However they manage to become large enough to be removed in the downstream sand filter.
- 7) The clarifier is a solids separations process, it does not separate dissolved species.
- 8) The DOC in the influent and effluents are considered to be dissolved substances (i.e., not suspended solids, so they do not count towards the FSS and the TSS).

Name	Formula	Molecular/Atomic Weight
Hydrogen	H	1
Sulfur	S	32
Oxygen	O	16
Aluminum	Al	27
Water	H_2O	18
Sulphate	SO_4	96
Sulphuric Acid	H_2SO_4	98
Alum	$\text{Al}_2(\text{SO}_4)_3 \cdot 14.3\text{H}_2\text{O}$	600
Aluminum Hydroxide	Al(OH)_3	78