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WASTEWATER MINIMIZATION IN PROCESS INDUSTRY THROUGH PINCH TECHNOLOGY: A CASE STUDY

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ABSTRACT

The paper emphasizes wastewater minimization in process industry, i.e. Fertilizer industry using pinch technology. An individual process constraint, which is to be easily incorporated, related to minimum mass transfer driving force, corrosion limitations, fouling etc. is allowed by the approach used. Targets are first set that maximizes water reuse. Only single contaminants are addressed. During target setting stage water regeneration opportunities are also identified which distinguishes between water reuse as well as recycling. Two simple design methods i.e. maximizing driving forces in the individual process and minimum number of water sources for each process are presented which allow targets both with as well as without regeneration to be achieved in design. The approach used is entirely conceptual.

INTRODUCTION

Before focusing on treatment of wastewater, attention should also be paid on reduction of wastewater generated. As reduction of wastewater, not only saves wastewater treatment cost, but also reduces the load on fresh water. Processes and their utility systems generate wastewater in any industry. Processes generate wastewater when it comes in contact with process materials in desalting, stream stripping and many other processes through out the refinery. Wastewater is also generated by the utility systems from boiler feed water, cooling tower, blow down etc. On excluding the possibility of making the fundamental changes to processes to reduce their water demand, there are three possibilities for reducing wastewater.

(a) Reuse - Reuse of wastewater can be done directly in other operations provided the level of previous contamination does not interfere with the process. Reuse might require blending of wastewater with wastewater from other operations.

(b) Reuse after regeneration - Regeneration of wastewater can be done by partial treatment to remove contaminants, which would otherwise prevent its reuse and then reuse in other operations. Again, reuse after regeneration might require blending with Wastewater from other operations and or fresh water.

(c) Recycling after regeneration - Regenerated of wastewater can be done to remove contaminants, which have buildup, and then the water is recycled. In this case water can re-enter the processes in which it has previously been used.

2) Water pinch - In view of rising fresh water costs and more stringent discharge regulations pinch analysis is helping companies to systematically minimize freshwater and wastewater volumes. Water pinch is a systematic technique for analyzing water networks and reducing water costs for processes. It uses advanced algorithms to identify and optimize the best water reuse, regeneration and effluent treatment opportunities. It has also helped to reduce losses of both feedstock and valuable products in effluent streams.

3) Process wastewater minimization - Today, reducing waste has become one of the greatest challenges faced by the process industries. Because water is one of industry's major waste products. The ability to reclaim wastewater for reuse is an important step toward overall waste reduction. Also excessive use of water in process industries is reported to be one of major cause for depletion of water table in the area.

METHODOLOGY

(a) Targeting Wastewater minimization for single contaminants

In any water using operation process material is contacted with water in order to reduce the level of a contaminant. The water in turn becomes contaminated. Lot of water is used in fertilizer industry. They are used in several processes, as boiler feed water, cooling tower etc. Presently the raw water consumption per ton of urea production is 6.78 $m^{3,}$ i.e. 6780 liter by IFFCO (Indian farmers fertilizers cooperative ltd.). IFFO Phulpur, which has two urea production units of 1500 MTPD and 2586 MTPD respectively. So water consumption per day can be of 10,170 B.L.P.D. and 17,533 B.L.P.D. respectively. As a result of this, large amount of wastewater is generated. Therefore minimization of fresh water requirement is need of the day.

To show the benefits of this technology we are taking three processes listed in the Table below. In practice in fertilizer industry water get contaminated through various processes and by several contaminants but here only ammonia contamination is considered. The inlet and outlet concentration of the contaminant in the process stream are specified by the process requirements, as is the mass of contaminant transferred. Specifying the inlet and outlet concentrations of water and the mass of contaminant transferred also specifies the water flow rate. Different water flow rates and contaminant concentrations can solve the same problem. In order to maximize the possibility of water reuse from other **operations** to this operation we should specify water, water with the highest possible inlet concentration. Then specifying the maximum possible outlet concentration minimizes the water flow rate at the maximum inlet concentration. This water profile will not necessarily be the profile we will use in the final design. It represents a limiting case. This is designated as limiting water profile. So limiting water profile of any process is a profile of water used in it having maximum inlet as well as outlet concentration. Any water supply line below this will meet the requirement of the process. The maximum inlet and outlet concentrations for the limiting water profile may be fixed by a number of possible considerations.

(I) Minimum mass transfer driving force

(II) Maximum solubility.

(III) Minimum flow rate requirements to avoid settling of solid materials etc.

In this study limiting water profile is used rather than using process fluids directly since we will ultimately apply the approach to different operations in which the mass transfer might be quite different in nature and constraints due to minimum mass transfer driving force, corrosion limitation etc. will vary. We need a way in which these operations can be treated on a uniform basis. The limiting water profile allows this to be achieved and provide us with the information we need.

Let us emphasize that the data in Table-1 represent limiting data, i.e. maximum inlet and outlet concentrations of contaminant. Also in Table-1 we assume that the mass transfer is a linear function of concentration. This is usually valid in dilute systems. However, if the behavior is significantly non-linear the approach can still be used by representing the non-linear process as a series of linear segments.
Assuming that fresh water is used in all the three process the network design will be as shown in Fig 1.

If we have to minimize the water flow rate overall, we must analyze how the water using processes behave in an overall sense. For this a limiting composite curve is constructed using the data given in Table 1. So the limiting composite curve represents how the total system would behave if there were a single water using process. The idea of concentration composite curve was first introduced by EL-Halwagi and Manousiouthakis (1989) and was adopted from the temperature enthalpy composite curves of Linnhoff *et al*. (1979) Here we will use the concentration composite curve in limiting water profile context. The limiting composite curve incorporates the process constraints directly.

The composite curve of the processes is plotted using the data given in

Table 1.

Fig 4 shows the water supply line matched against the limiting composite curve .The inlet concentration of the supply line is assumed to be zero, i.e. fresh water. By maximizing the outlet concentration of the supply line, fresh water use and hence wastewater generation are both minimized. The composite curve touches the limiting water profile both at zero concentration and a intermediate point. Each point where the supply line touches the limiting water profile creates a pinch in the design. In general there will normally be at least one pinch. At the pinch the driving force goes to the minimum since the minimum mass transfer driving forces have been built._

Design for minimum wastewater for single contaminants

El – Halwagi and Manousiouthakis (1989) adopted the pinch design method for heat exchanger networks of Linnhoff and Hindmarsh (1983) to the design of mass exchange networks. The method of El-Halwagi and Manousiouthakis (1989) involved mass exchange between a set of rich process streams and a set of lean streams. There are two different approaches possible that achieve different objectives, while both allowing minimum flow rate to be achieved in design. Applying both the methods for wastewater minimization :

Method - 1

Maximum driving forces

The limiting composite curve is first divided into vertical mass load intervals. Everywhere there is a change in slope on the limiting composite curve we create a boundary. Thus dividing the system into mass load intervals. Then network is designed to follow these mass load intervals .The grid diagram introduced by Linnhoff and Flower (1978) was used.

The composite curve is divided into vertical mass load intervals. Everywhere where there is a change in slope on the limiting composite curve boundary is created. Thus the system is divided into three mass load intervals. Grid diagram for water networks is designed using fig-5. In interval 2, process 2 and 3 exists, where as in interval 3 only process 3 exist. The conventional flow sheet for water network in shown in Fig. 5.

The fresh water enters both in process 1 and 2 of the interval 1, and its concentration reaches 1300 ppm at the end of his interval. This water enters interval 2, which contains process 2 & 3 and water reaches 2000ppm and at last this water enters in interval 3 consisting of process 3 only and exit out at 2980-ppm conc. The grid diagram of the water network is shown below fig-6 (a).). Design of water networks to achieve minimum flow rate often requires complex stream splitting arrangements and the method allows these to be generated.

This approach will always produce a design, which achieves the target minimum flow rate, it will also leads to design, which have some unnecessary complexity. To remove this complexity loops are identified. The loops are identified in grid diagram (fig-6 (a)), which are two in number and are shown in Fig.6 (b).

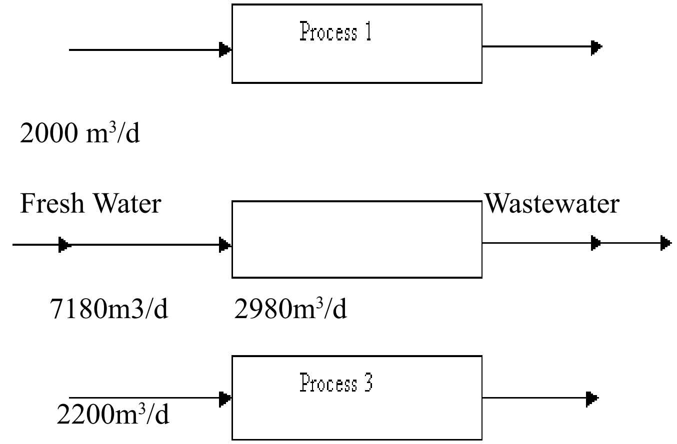

Fig. 1 Network design

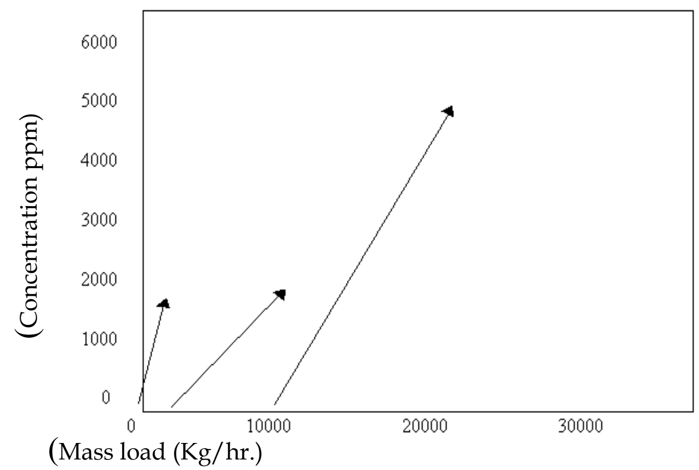

Fig. 2 Limiting water profile

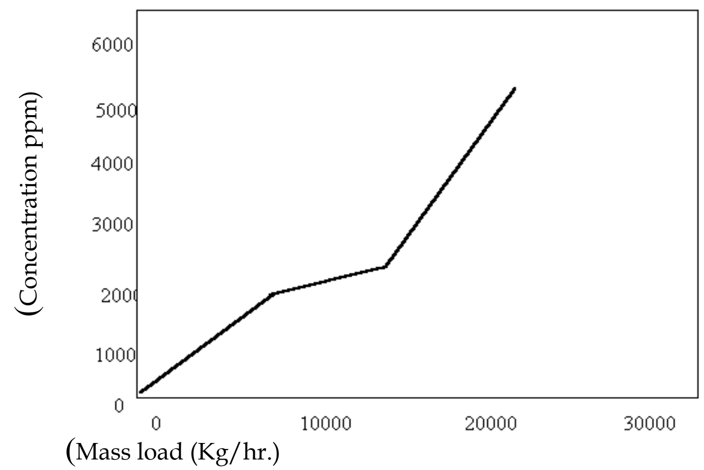

Fig.3 Limiting composite curve

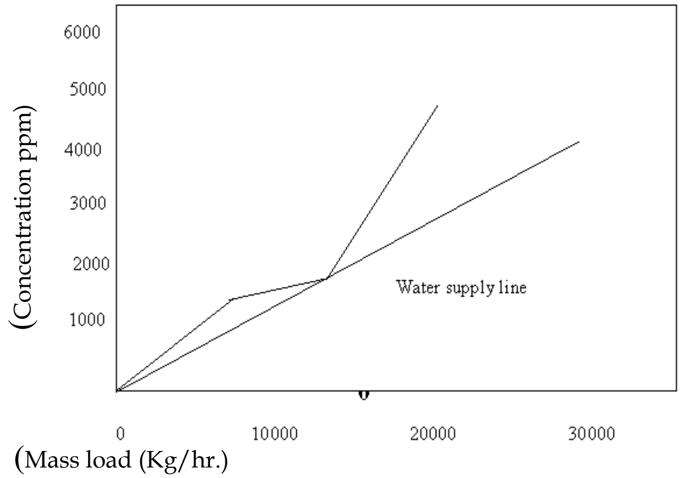

Fig. 4 Matching the water supply line

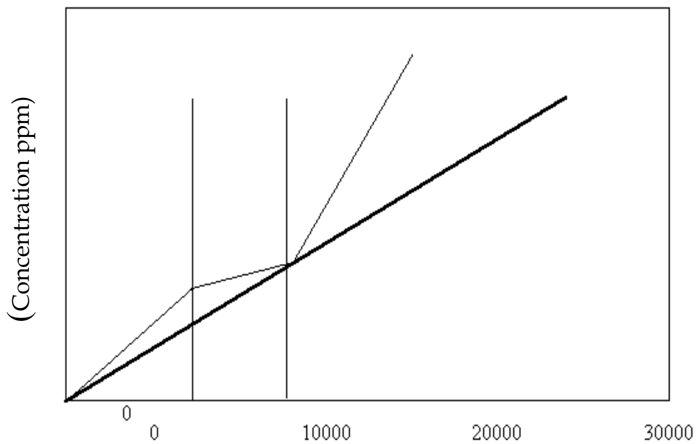

Fig. 5 (a). Conventional Flow Sheet

The loops away from pinch are broken first. Matching B-C by shifting the mass load can break the Loop 1, whereas matching D-E can break Loop 2. This causes a change in the concentration of the water supply line, but feasible concentration difference still exists. Thus, the network is simplified without changing the flow rate. Thus the final network grid diagram and flow sheet designed obtained will be as shown in figure 7(a) and 7 (b).

Method -2

Minimum number of water sources

When water networks are designed it is ensured that as few matches as possible are made. In this method a generalized alternative approach is used in designing of water networks which exploits bypassing and mixing to minimize the number of matches (i.e. minimize the number of water sources for

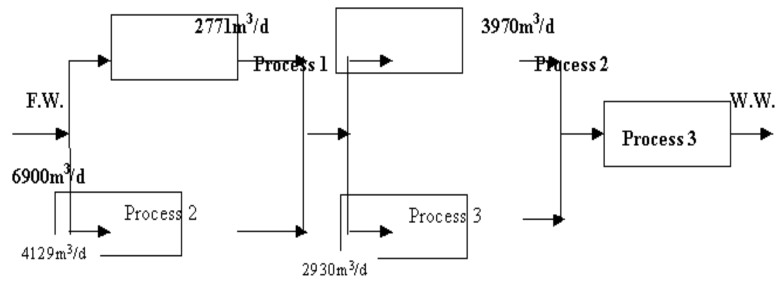

Fig-5 (b).

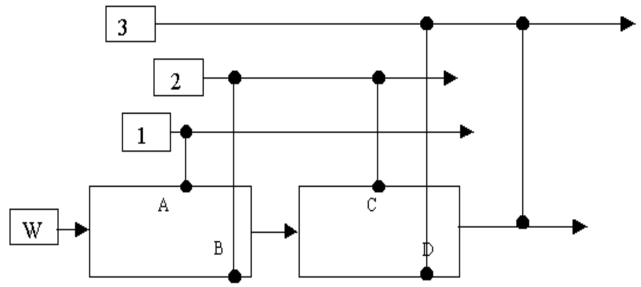

Fig-6 (a)

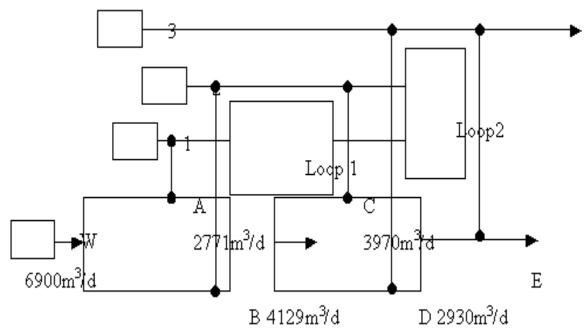

Fig.6(b)

Fig. 5 (b) Conventional Flow Sheet , **Fig. 6** (a) Grid Diagram ,
Fig. 6 (b) Loops in grid diagram

each operation). In this instead of following mass load intervals we follow concentration intervals to define matches (Fig. 8). In each match we only use sufficient water just to maintain network feasibility. Instead of following mass load intervals here concentration intervals are followed to define matches . In each match we only use sufficient water just to maintain network feasibility. Thus limiting composite curve is followed and we minimize driving forces in individual matches. If more water is available then any excess is bypassed to be mixed in later.

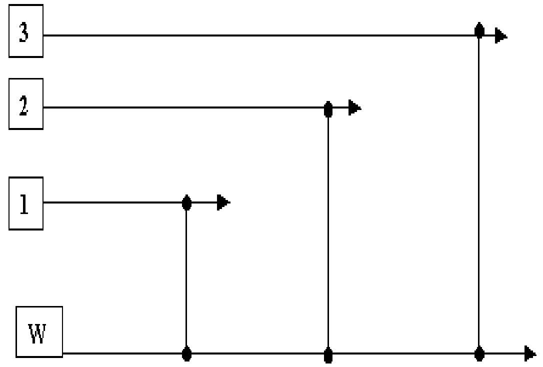

Fig.7(a)

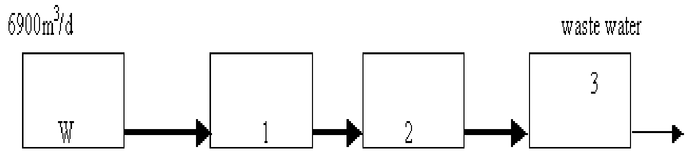

Fig.7(b)

Fig. 7 (a) Final network grid diagram
Fig. 7 (b) Final network flow diagram

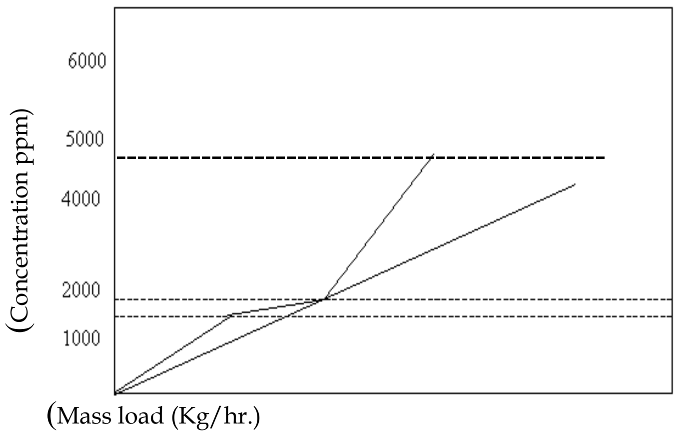

Fig. 8 Limiting composite curve

Dividing the curve according to the concentration intervals three intervals are found (Fig.8), first 0 to 1800 ppm, second 1800 to 2000 ppm, and third 2000 to 5000 ppm. In the first interval process one, second, as well as third exists. These are matched with fresh water .In each process as much as water is used to maintain feasibility i.e.1800ppm at the outlet .In interval second process 2 and 3 exists, in this water is split between these two to obtain 2000ppm at the outlet .In the interval three only process three exists. Minimum water is used in the process to maintain feasibility i.e.5000 ppm at the outlet and the

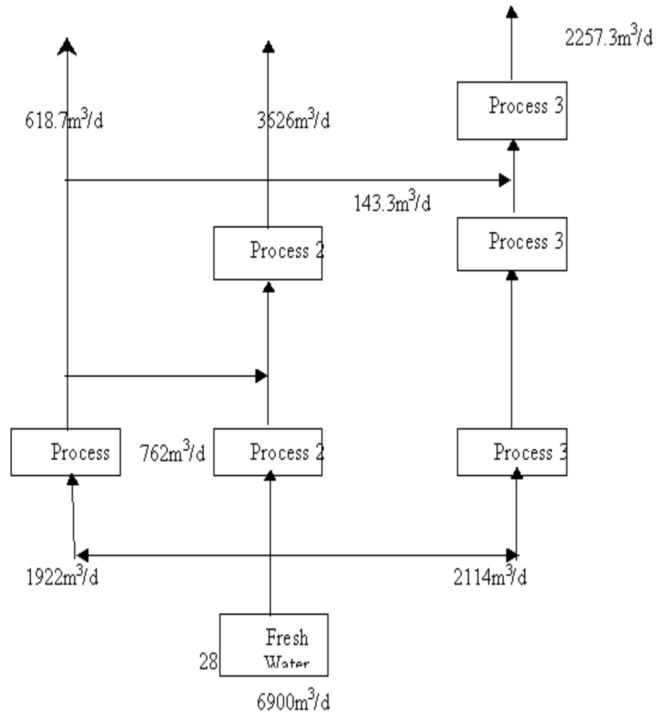

Fig .9 Limiting composite curve

reminder is bypassed to outlet. The resultant network design obtained from this method is given below (Fig. 9).

RESULTS AND DISCUSSION

This study is done takeing three processes of which inlet as well as outlet contamination concentration is known. The processes are ammonia process condensate, urea process condensate and floor washing. As a result of water networking 280 m3/day i.e. 4% reduction in fresh water consumption is obtained. It is seen that study carried out taking three processes results is reduction of 280 m3/day i.e. 4% as a result of which wastewater production will also be minimized. This will result in saving of treatment cost of waste-water as well as reduces load on fresh water.

This study is based on only three processes occuring in a fertilizer industry. There were several other processes also where contamination of water occurs. It is ncessary to estimate the contamination and mass load in all those process. There after in depth study is to be done to know the actual condition of the industry. The water involved in heat exchangers as coolant should also be incorporated in wastewater minimization as they are also part of wastewater. So energy conservation aspect should also be carried out to find the actual condition, as without that it will be no mean of doing wastewater minimiza-tion.

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