Introduction to Chemical Engineering

Chapter 03

Solving Engineering Problems
(*What Shall We Do?*)

3.1 Strategies for solving problems

Steps to solving problems

1. Define the problem.
2. List possible solutions.
3. Evaluate and rank the possible solutions.
4. Develop a detailed plan for the most attractive solution(s).
5. Re-evaluate the plan to check desirability.
6. Implement the plan.
7. Check the results.

3.1 Strategies for solving problems

Memo from supervisor (chapter 01):

ABC Chemical Company
Memorandum

From: Barbara Magelby, Supervisor, Chemical Process Group

We've just received information indicating that the company that has been disposing of our HCl byproduct is not doing well. We anticipate that they will be going out of business in 6-12 months. This puts us in a very dangerous situation, since we can't operate very long without disposing of that waste. Our marketing people have tried to find a potential buyer for the acid, but the byproduct is apparently not at an appropriate concentration or purity to be valuable to anyone in our local area.

One possibility to consider is treatment of the waste in order to be able to dispose of it in the lake next to our company site. However, at this point, no engineering analysis has been conducted on this or any other strategy.

Your assignment is to propose a strategy and design (with a cost analysis) for safely and legally disposing of the acid waste.

Please keep me informed of your progress.

3.1 Strategies for solving problems

1. Define the problem:

a. Many problems have taken longer than necessary to solve because they were not defined correctly.

b. For our problem, we are looking for a way to continue viable operation of our process without depending on the company that has been disposing of our acid waste.

c. From our company records,

average acid stream flow rate: 11,600 L/hr

average HCl concentration in the waste stream: 0.014 M

3.1 Strategies for solving problems

2. List possible solutions

a. Change our company process so that the acid is not produced.

b. Contract with another independent company to take the acid away.

c. Build giant holding tanks to store the acid for 10 years.

d. Discharge the acid to an evaporation pond built on the company site.

e. Discharge the acid into the lake next to the company site without treatment.

f. Treat the acid and discharge it into the lake.

3.1 Strategies for solving problems

3. Evaluate and rank the possible solutions:

a. Change our company process so that the acid is not produced.

: Alternative processes are usually not known or are extremely expansive.

b. Contract with another independent company to take the acid away.

: Transportation costs and profit for the independent company would be added.

: It would seem that we can do it more cheaply.

: No such company is presented in this analysis.

3.1 Strategies for solving problems

3. Evaluate and rank the possible solutions:

c. Build giant holding tanks to store the acid for 10 years.

: The required volume of such tanks would be

$$11600\ L/hr \times \frac{24\ hr}{1\ day} \times \frac{365\ days}{1\ yr} \times 10\ yrs = 1.0 \times 10^9\ L$$

: The volume occupied by each tank (10 m in diameter and 5 m in height) would be

$$Volume = \frac{\pi}{4} D^2 H = \frac{\pi}{4} (10\ m)^2 (5\ m) = 393\ m^3 = 393 \times 10^3\ L$$

: The 2587 tanks would be needed (a cost for building and maintaining).

: Not a sustainable solution and not suitable from an environmental perspective

3.1 Strategies for solving problems

3. Evaluate and rank the possible solutions:

d. Discharge the acid to an evaporation pond built on the company site.

: Need to construct the ponds making sure that no acid leaked into the ground water.

: Land would have to be available.

: Consider the average evaporation rate (> 11600 L/hr).

: Ensure that the amount of acid in evaporating water is smaller than limits.

: Dispose of the concentrated acid left as a result of the evaporation process

3.1 Strategies for solving problems

3. Evaluate and rank the possible solutions:

e. Discharge the acid into the lake next to the company site without treatment.

: Environmental responsibility

: Violation against the environmental protection laws

f. Treat the acid and discharge it into the lake.

: Neutralizing the acid in the stream with a basic solution

: Cooling the treated stream before final discharging to the lake

3.1 Strategies for solving problems

4. Develop a detailed plan for the most attractive solution(s):

Let's suppose that…

1) a preliminary analysis suggests that option (f) is the best option.

2) you have selected the strategy of neutralizing the acid by addition of sodium hydroxide to the waste stream.

$$\mathbf{HCl + NaOH \rightarrow H_2O + NaCl}$$

If the upper limit for dissolved solids in water is 1200 mg/L (= 1.2 g/L),

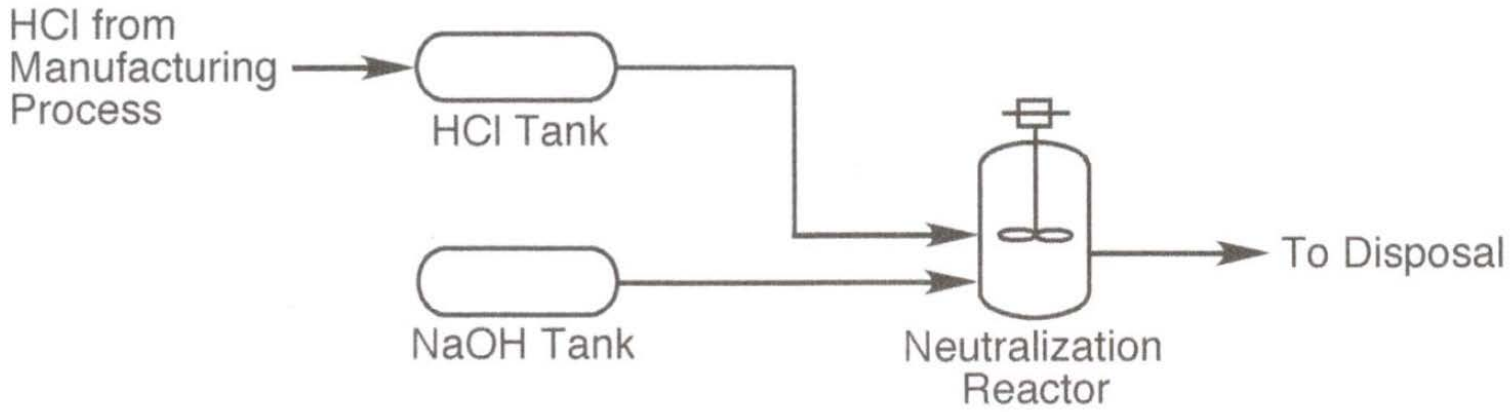
$$\frac{1.2\ g/L}{58.5\ g/gmol} = 0.02\ gmol/L > 0.014\ gmol/L$$ **(The final concentration cannot exceed.)**

Obviously, there is much more detail needed for the design of the acid-neutralization process.

3.1 Strategies for solving problems

4. Develop a detailed plan for the most attractive solution(s):

Process flow diagram (PFD) for acid neutralization concept



3.2 Ethical considerations in solving problems

- **Code of ethics** (http://www.aiche.org/about/code-ethics)
- **Safety**
- **Protecting the environment**
- **Avoiding harassment**
- **Ethical practice**

3.3 The use of teams in solving problems

3.3.1. Ingredients for a successful team

1. A clear mission or set of goals
2. A plan for attacking problems
3. Clearly defined roles
4. Clear communication
5. Well-defined decision procedures
6. Balanced participation
7. Established ground rules
8. Awareness of group processes

+ more ingredients for a successful team

1. Atmosphere that encourages contribution

   : positive reinforcement, friendship, trust, diplomacy, sensitivity to other's needs

2. Individual commitment
3. Individual dependability (follow-through)
4. Individual integrity

3.3 The use of teams in solving problems

3.3.2. Learning to work together

Stages of team development

1. Forming	Organization of the group, setting of rules and procedures, introductions of members and learning a little about each other.
2. Storming	Emergence of conflict caused by different perspectives, experiences, backgrounds and views. This is the time when most groups will fail.
3. Conforming	Coming to the agreement to disagree; tolerance of varying views and opinions and perspectives. Individuals accept the team, their roles on the team, and the individuality of the various team members.
4. Performing	Utilization of individual differences for the benefit of the group and the work of the group. Varying perspectives and differences are viewed as advantages rather than hindrances.

adapted from Scholtes, P.R., The Team Handbook for Educators, Madison, WI: Joiner Associates Inc., 1994.

3.3 The use of teams in solving problems

3.3.3. Diversity

Characteristic responses to a goal or task

Fact Finder	Precise, judicious and thorough, this mode deals with detail and complexity, seeking to be both objective and appropriate. Keen at observing and at gathering information, sometimes Fact Finders can be too judicious, seeming overly cautious as they wait for more data. *Keyword: probe*.
Follow Thru	Methodical and systematic, this mode is focused and structured, and brings order and efficiency. Follow Thru people are meticulous at planning, programming, and designing, and predictability is essential to their being. *Keyword: pattern*.
Quick Start	With an affinity toward risk, this mode is spontaneous and intuitive, flexible, and fluent with ideas. Quick Starters are deadline- and crisis-oriented. They need an atmosphere of challenge and change, and sometimes they can be impatient. *Keyword: innovate*.
Implementer	Hands-on, craft-oriented, this mode brings tangible quality to actions. Implementers have a strong sense of three-dimensional form and substance and the ability to deal with the concrete. *Keyword: demonstrate*.

adapted from Kolbe, K., The Conative Connection, Menlo Park, CA: Addison-Wesley Publishing Co., 1990.

3.3 The use of teams in solving problems

3.3.3. Diversity

Roles within a team structure

Leader/Coordinator	The leader is responsible for calling group meetings, handling or assigning administrative details, planning team activities, and overseeing preparation of reports and presentations.
Observer/Summarizer	This individual is responsible for observing the operation of the group and summarizing key issues.
Data Gatherer	This individual or group of individuals is responsible for gathering data needed for the team to accomplish its goals. Data gathering is typically accomplished between team meetings. It may take the form of gathering quantitative data or may consist of qualitative observations, and the like.
Devil's Advocate	Having a devil's advocate on the team is useful in probing and evaluating the work of the team. Formal recognition and use of this role turns what might be perceived as a negative contribution into a positive and important part of the total group effort.
Recorder	The recorder writes down the group's decisions and edits the group's report.