Cost of corrosion in fertilizer industry – A case study

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A detailed cost of corrosion survey has been undertaken in one of the oldest fertilizer factories in India producing ammonium sulphate and ammonium phosphate. The total direct cost of corrosion has been worked out as US $ 129,739. Due to use of corrosion resistant materials such as SS316L the annual cost of corrosion has been brought down considerably. It is further shown that approximately US $ 17,000 could be saved annually by opting for a high performance corrosion resistant system.

1 Introduction

India is the third largest producer and consumer of fertilizers in the world. The largest being China followed by USA. The fertilizer use in India has shown a consistent growth from 66,000 Metric Tones (MT) of plant nutrients in 1951–52 to 18.07 10^5 MT in 1999–2000. The fertilizer consumption in India has increased from 1 kg per hectare in 1950–51 to about 106 kg per hectare in 1999–2000 [1]. At present, there are 66 large shed fertilizer units in the country manufacturing a wide range of nitrogenous, phosphatic and complex fertilizers. Of these, 39 units produce urea, and 20 units produce DAP and complex fertilizers. 7 units produce low analysis nitrogenous fertilizers. This also includes seven major urea plants where operations had been suspended/discontinued for reasons of safety, feedstock limitation, non-viability or/and financial constraints. Another 9 units manufacture ammonium sulphate. Besides, there are about 80 small and medium scale units producing single super phosphate [2]. The total installed capacity of fertilizer production in the country was 120.58 10^5 MT of nitrogen and 52.31 10^5 MT of phosphate as on 31.1.2002.

Fertilizer industry is one of the major agrochemical industries, playing an important role in meeting the food grain requirement of increasing population. Corrosion is one of the major problems in fertilizer plants due to the presence of a wide spectrum of corrosives as raw materials like natural gas, naptha, fuel oil, coal, rock phosphate, sulphur, sulphuric acid, nitric acid, phosphoric acid etc. Due to wide variety of raw materials, corrosive materials and corrosive atmosphere prevailing at various stages of productions, the fertilizer industry is loosing crores of rupees due to corrosion and its control. It would therefore be of interest to carry out a systematic corrosion auditing in fertilizer industry so as to highlight the impact by collecting and analyzing the data on the amount spent towards mitigation of corrosion. Present value method has been adopted for estimating the cost of corrosion.

2 About the industry

Systematic corrosion auditing was carried out in one of the oldest large-scale fertilizer units in India. The industry was setup in 1943. It started production of ammonium sulphate with an installed capacity of 10,000 MT nitrogen in 1947. The second stage of expansion was completed in 1962. The third stage of expansion was completed in 1965 with setting up of a new ammonium sulphate plant.

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Finished products of this plant are ammonium sulphate and ammonium phosphate. Intermediary products are sulphuric acid, oleum, SO_2 gas and phosphoric acid. Carbon dioxide gas is the by-product of this unit.

2.1 Phosphoric acid plant

This plant was commissioned during 1966 and its current capacity of production is 100 Tonnes Per Day (TPD). The phosphoric acid plant is a wet process using rock phosphate + sulphuric acid. Based on the information provided by the competent authorities of this plant the approximate item wise expenditure with regard to corrosion related activities is given below:

- Every year US $ 3,261 (Rs. 1.5 lakhs) is being spent towards discharging, cleaning and patch repair of single tank reactor.
- Due to attack of acid fume, patch repair work is being carried out in the filter feed tank at a cost of US $ 1,087 (Rs. 0.50 lakh) once in a year.
- Due to suction vacuum, the adhesion of rubber lining to tray is affected. Every year replacement of filter tray is being carried out at a cost of US $ 2,717 (Rs. 1.25 lakh).
- Regular patchwork say once in a year is being carried out in the return acid tank at a cost of US $ 543 (Rs. 0.25 lakhs).
- Pumps and pipelines in this plant are corroded severely. Every year US $ 5,435 (Rs. 2.5 lakhs) is being spent towards replacement of corroded parts of pumps and pipelines.
- Due to acid fumes and prevailing environmental conditions in this area, the concrete supporting structures, handrails, and staircases are corroded. Every year US $ 2,717 (Rs. 1.25 lakhs) is being spent for application of gunniting in the concrete structures.
- Every year, all the machinery equipments, vessels, tanks and pipelines in this plant are cleaned and given an anticorrosive paint at a cost of US $ 7,609 (Rs. 3.5 lakhs).

2.2 Ammonium phosphate plant

Here two plants are producing 20:20 grade of ammonium phosphate having capacities of 150 and 300 TDP respectively. The 150 TPD capacity plant was installed in 1972 and 300 TPD capacity was installed in 1966. Based on the information provided by the competent authorities of this plant the approximate item wise expenditure with regard to corrosion related activities is given below:

- The blunger is being regularly patch welded at a cost of US $ 3,261 (Rs. 1.5 lakhs) per year.
- The fume fan is subject to severe erosion – corrosion and is being replaced once in a year at a cost of US $ 1,087 (Rs. 0.5 lakh).
- The parts of dryer discharge conveyor are being repaired and replaced every year at a cost of US $ 2,717 (Rs. 1.25 lakhs).
- Scrubber parts are also corroded and being repaired once in a year at a cost of US $ 1,087 (Rs. 0.50 lakh).
- Repair work is being carried out in the parts of bagging unit every year at a cost of US $ 3,261 (Rs. 1.5 lakhs).

Due to acid fumes and prevailing environmental conditions in this area, the concrete supporting structures, handrails, and staircases are corroded. Every year US $ 4,348 (Rs. 2 lakhs) is being spent for application of gunniting in the concrete structures.

Every year, all the machinery equipments, vessels, tanks and pipelines in this plant are cleaned and given an anticorrosive paint. The expenditure in this regard is US $ 10,870 (Rs. 5 lakhs).

2.3 Ammonium sulphate plant

Ammonium sulphate is produced under two streams (a) Oxime Ammonium Sulphate (OAS) and (b) Lactum Ammonium Sulphate (LAS). This plant was installed during 1990 and its current capacity of production is 682 TPD. Based on the information provided by the competent authorities of this plant the approximate item wise expenditure with regard to corrosion related activities is given below:

In the ammonium sulphate plant, most of the equipments are made of SS 316L. Therefore there is no corrosion problem in the equipments. However, all the supporting structures (handrails, platform, staircase, structure, skirting for the equipments and platform supporting) made of carbon steel are corroded severely.

- Every year US $ 10,870 (Rs. 5 lakhs) is being spent towards application of protective coatings in these support structures. In addition, completely corroded structures are replaced once in a year at a cost of US $ 3,261 (Rs. 1.5 lakhs).
- In the bagging unit, due to traces of ammonium sulphate, the conveyor is corroded severely. Once in a year nearly US $ 3,804 (Rs. 1.75 lakhs) is being spent towards replacement of corroded portions.
- Nearly 55 pumps are used in this process. Casing, impeller of all the pumps is of stainless steel. Bearing brackets are of mild steel. Once in two years, such brackets are replaced at a cost of US $ 5,435 (Rs. 2.5 lakhs).
- All the exposed reinforced concrete structures are corroded in this plant. Nearly US $ 3,261 (Rs. 1.5 lakhs) is being spent once in a year for repairing the concrete structure by gunniting.

2.4 Oleum plant

As an intermediary product, oleum is produced during the production of sulphuric acid. Current capacity of production is 220 TPD. Based on the information provided by the competent authorities of this plant the approximate item wise expenditure with regard to corrosion related activities is given below:

- In the oleum plant, pipelines are replaced every year at a cost of US $ 3,804 (Rs. 1.75 lakhs) due to corrosion.
- Patch repair work is being carried out once in a year in the storage tanks as well as the tower at a cost of US $ 1,087 (Rs. 0.50 lakh).
- Every year cooler tubes are corroded severely. US $ 2,717 (Rs. 1.25 lakhs) is being spent towards replacement of corroded cooler tubes.
- Due to the prevailing atmosphere, the concrete structures are corroded severely. Every year US $ 4,348 (Rs. 2 lakhs) is being spent towards repairs as well as gunniting.
- Every year US $ 7,609 (Rs. 3.50 lakhs) is being spent towards maintenance painting for all the structures, pumps, and tanks in this plant.

2.5 Sulphuric acid plant

There are two plants producing sulphuric acid. The first plant was commissioned during 1965 and it was recommissioned during 1981. Its current capacity of production is 380 TPD. The second plant was commissioned during 1988 and its production capacity is 175 TPD. In addition this plant is producing sulphur dioxide acid with a capacity of 375 TPD. Based on the information provided by the competent authorities of this plant the approximate item wise expenditure with regard to corrosion related activities is given below:

- Steam coils at the various pits (melting, cleaning, mixing and precoating) are replaced every year at a cost of US $ 65,217 (Rs. 30 lakhs).
- Every year, patch welding of the boiler shell is done to avoid leakage due to corrosion. The cost of patch welding is US $ 3,804 (Rs. 1.75 lakhs).
- The SO_2 and SO_3 ducts are damaged severely due to corrosion. Once in 3 years US $ 10,870 (Rs. 5 lakhs) is being spent towards replacing the ducts.
- Once in two years, patch welding is required at the converter shell at a cost of US $ 5,435 (Rs. 2.50 lakhs).
- In the acid cooler (Acid Drying Tower (ADT), Intermediate Absorption Tower (IAT) & Final Absorption Tower (FAT)) tubes are replaced every year at a cost of US $ 9,783 (Rs. 4.50 lakhs) due to leakage.
- Once in a year patch repair works are being carried out in the acid storage tank at a cost of US $ 5,978 (Rs. 2.75 lakhs).
- Generally, all the pipelines in this plant are replaced once in 3 years at a cost of US $ 7,609 (Rs. 3.5 lakhs).
- Every year maintenance painting work is being carried out at acid storage, furnace, supporting structures, acid circulating tower; blower, pumps and pipelines (water, acid & air) at a cost of US $ 8,696 (Rs. lakhs).
- Reinforced concrete structure in the sulphuic acid plant undergoes severe corrosion due to acid fumes. Once in a year US $ 4,891 (Rs. 2.25 lakhs) is being spent towards maintenance work as gunniting.

3 Corrosion auditing

As can be seen from the foregoing a fertilizer industry normally spends every year quite a considerable amount towards mitigation of corrosion. Therefore in the present study, the cost of corrosion has been analyzed by considering the following

- As per the Income Tax Act, fertilizer industry has to pay 35% of the net income as tax (*t*). This factor has been taken into account while computing the cost of corrosion.
- An interest rate (I) of 6.25% has also been considered.

Data generated for cost of corrosion in various plants are shown in Table 1. This table depicts annual expenditure, present worth factor, tax credit, present value, annual cost factor and equivalent annual cost in that order.

The total annual direct cost of corrosion in this fertilizer industry is around US $ 129, 739 (Rs. 60 lakhs) as shown in Table 1. This figure is based on expenditure (cash outflow) of corrosion related activities of the industry such as painting, maintenance, replacement and structural corrosion. The pattern of distribution is shown in Fig. 1, which indicates that more than 50% of expenditure goes towards replacement of corroded parts.

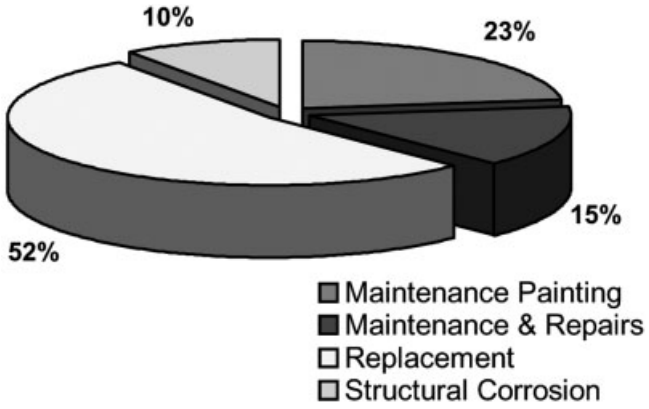

Fig. 1. Pattern of distribution of corrosion expenditure in a typical fertilizer industry

4 Comparison with previous data

Central Electrochemical Research Institute (CECRI) [3] had carried out a cost of corrosion survey in the same industry during 1976–77. The data collected at that time are compared with the present data in Table 2. The annual cost of corrosion as arrived at during 1976–77 is US $ 116,381 (Rs. 24.44 lakhs). Taking into account an annual inflation rate 9% (inf1) for the year 1976–77, the projected cost of corrosion for the year 2002–03 works out to US $ 1.09 million (Rs. 2.3 crores). Actual annual cost of corrosion as arrived at in this survey carried out during 2002–03 US $ 129,739 (is Rs. 60 lakhs). Therefore this comparison clearly brings out the fact that the authorities over these years have given greater attention to improved corrosion control methods including the use of corrosion resistant materials i.e. SS 316L in a big way.

5 Potential savings due to an alternative high performance paint system

Every year, this industry spends a considerable amount towards painting to protect the equipments. The existing paint scheme at the factory consists of the following:

a. Alkyd undercoat
b. Alkyd primer
c. Aluminium painting and
d. Silicone resin (for high temperature)

This is a conventional decorative painting system and therefore it needs renewal every year at a cost of US $ 56,848 (Rs. 26.15 lakhs) which includes surface preparation as well as labour costs (i.e. 25% of the painting cost). The total surface area for painting is 1,70,000 m^2.

As per the available information from "Depreciation – Guidelines and Rules" (Rev. Proc.62-21) issued by Internal Revenue Service of the U.S. Treasury Department as publication No. 456 (7–62) in July, 1962, the estimated life of the equipments in Chemical and Allied products industry is 11 years. Therefore in the present study, the potential savings has been analyzed by considering a life period of 11 years for equipments in the fertilizer industry. Annual expenditure of existing painting system has been worked out taking into consideration an inflation rate of 4% (inf2) for the year 2002–03.

Table 1. Equivalent annual cost of corrosion for various plants

Expenditure details	Period of occurrence	Expenditure Amount (U.S. Dollars)	Present worth factor $\frac{1}{(1+I)^n}$	Tax credit (1 − t)	Present value (U.S. Dollars)	Annual cost factor $\frac{I\,x\,(1+I)^n}{(1+I)^n-1}$	Equivalent annual cost (U.S. Dollars)
A. PHOSPHORIC ACID PLANT							
Discharging, cleaning & patch repair work at single tank reactor.	Annual	3,261	0.94	0.65	1,992	1.06	2,112
Patch repair work at filter feed tank	Annual	1,087	0.94	0.65	664	1.06	704
Replacement of filter tray	Annual	2,717	0.94	0.65	1,660	1.06	1,760
Patch repair work at return acid tank	Annual	543	0.94	0.65	332	1.06	352
Replacement of corroded pumps	Annual	5,435	0.94	0.65	3,321	1.06	3,520
Application of gunniting in the concrete structures	Annual	2,717	0.94	0.65	1,660	1.06	1,760
Protective painting	Annual	7,609	0.94	0.65	4,649	1.06	4,928
B. AMMONIUM PHOSPHATE PLANT							
Patch repair work at blunger	Annual	3,261	0.94	0.65	1,992	1.06	2,112
Replacement of fume fan	Annual	1,087	0.94	0.65	664	1.06	704
Repair & replacement of dryer discharge conveyor	Annual	2,717	0.94	0.65	1,660	1.06	1,760
Repair work at scrubber areas	Annual	1,087	0.94	0.65	664	1.06	704
Repair work at bagging unit	Annual	3,261	0.94	0.65	1,992	1.06	2,112
Application of gunniting for concrete structures	Annual	4,348	0.94	0.65	2,657	1.06	2,816
Protective coatings	Annual	10,870	0.94	0.65	6,641	1.06	7,040
C. AMMONIUM SULPHATE PLANT							
Protective coatings	Annual	10,870	0.94	0.65	6,641	1.06	7,040
Replacement of carbon steel supporting structures	Annual	3,261	0.94	0.65	1,992	1.06	2,112
Replacement of conveyor parts	Annual	3,804	0.94	0.65	2,324	1.06	2,464
Replacement of pump parts	Once in two years	5,435	0.89	0.65	3,144	0.55	1,729
Application of gunnitng in concrete surfaces	Annual	3,261	0.94	0.65	1,992	1.06	2,112

On the other hand, if a high performance corrosion resistant painting scheme is adopted, a maintenance free life of more than 11 years can be ensured. Specifications and total cost of proposed painting system is shown in Table 3. The annual costs of maintenance painting for the two systems are compared in Table 4. It can be seen that an annual saving of US $ 17,151 (Rs. 7.88 lakhs) is achievable by application of an corrosion resistant painting system in place of the existing system.

Table 1. Continues

Expenditure details	Period of occurrence	Expenditure Amount (U.S. Dollars)	Present worth factor $\frac{1}{(1+I)^n}$	Tax credit (1 − t)	Present value (U.S. Dollars)	Annual cost factor $\frac{I\,x\,(1+I)^n}{(1+I)^n-1}$	Equivalent annual cost (U.S. Dollars)
D. OLEUM PLANT							
Replacement of pipelines	Annual	3,804	0.94	0.65	2,324	1.06	2,464
Patch repair works at storage tanks & towers	Annual	1,087	0.94	0.65	664	1.06	704
Replacement of cooler tubes	Annual	2,717	0.94	0.65	1,660	1.06	1,760
Application of gunniting for concrete structures	Annual	4,348	0.94	0.65	2,657	1.06	2,816
Protective coatings	Annual	7,609	0.94	0.65	4,649	1.06	4,928
E. SULPHURIC ACID PLANT							
Replacement of steam coils	Annual	65,217	0.94	0.65	39,848	1.06	42,239
Patch repair works at boilers	Annual	3,804	0.94	0.65	2,324	1.06	2,464
Replacement of SO_2 & SO_3 ducts	Once in 3 years	10,870	0.83	0.65	5,864	0.38	2,228
Patch repair works at converter	Once in 2 years	5,435	0.89	0.65	3,144	0.55	1,729
Replacement of acid cooler tubes	Annual	9,783	0.94	0.65	5,977	1.06	6,336
Patch repair works at tanks	Annual	5,978	0.94	0.65	3,653	1.06	3,872
Replacement of pipelines	Once in 3 years	7,609	0.83	0.65	4,105	0.38	1,560
Maintenance painting	Annual	8,696	0.94	0.65	5,313	1.06	5,632
Application of gunniting works to concrete structures	Annual	4,891	0.94	0.65	2,989	1.06	3,168
						Total Equivalent Annual Cost	$ 129,739

I = interest rate 0.0625
n = year
t = 0.35

6 Cost of corrosion

The annual direct cost of corrosion for this plant is US $ 129,739 (Rs. 60 lakhs). During 2002–03, this plant had 33% of share of total production of ammonium sulphate and 8.4% of share of total production of 20:20 in India. Therefore the total direct cost of corrosion for fertilizer industry in India engaged in producing ammonium sulphate and 20:20 comes to US $ 923,913 (Rs. 425 lakhs).

7 Conclusion

Corrosion auditing has been carried out in a large-scale fertilizer industry in India since 1943. By using present value method it has been shown that the annual direct cost of corrosion in the particular industry works out to US $ 129,739 (Rs. 60 lakhs). By extrapolating this figure to the total production of ammonium sulphate and 20:20 in India, the total annual direct cost of corrosion in this sector works out to US $ 923,913 (Rs. 425 lakhs). It is also shown that by opting for high performance corrosion resistant system an annual savings of US $ 17,151 (Rs. 7.88 lakhs) is achievable. It is further shown that the present value of annual direct cost of corrosion is very much less than the projected figure based

Table 2. Comparative data for different periods

Heads of expenditure	1976–1977 Value (U.S. Dollars)	2002–2003 Value (U.S. Dollars)
Painting cost	58,810	29,565
Maintenance & Repair cost	11,143	19,087
Replacement cost	30,952	68,413
Structural corrosion cost	15,476	12,652
Total cost of corrosion	116,381	129,717
Inflation factor $(1 + \text{inf } 1)''$	9,39	Not applicable
Cost of corrosion for the year 2002–03	1,092,818	129,717

Inf1 $= 0.09$
$n = 26$ year

Table 3. Specifications and total cost for the proposed corrosion resistant painting system

Paint specification	Film thickness (microns)	Cost per liter Amount in		Coverage per litre (m^2)	Total litre required	Total cost Amount in	
		U.S. Dollar	Indian Rupees			U.S. Dollar	Indian Rupees
Epoxy primer	55–60	3	135	8	21,250	62,364	28,68,750
Epoxy under coat	100–110	4	190	5	34,000	140,435	64,60,000
Epoxy top coat	100–110	4	190	5	34,000	140,435	64,60,000
Polyurethane finish coat	30–35	6	275	12	14,167	84,694	38,95,925
					Total painting cost	427,928	1,96,84,675
					Surface preparation & labour cost (25% of total painting cost)	106,982	49,21,169
					Total cost	534,910	2,46,05,844

Table 4. Comparison of existing painting system with proposed corrosion resistant painting system

Year	Expenditure cost (Amount in U.S. Dollar)	Inflation factor $(1 + \text{inf2})''$	Value (Amount in U.S.Dollar)	Total value (Amount in U.S. Dollar)	Annual cost factor $\frac{\text{inf2}}{(1+\text{inf2})'' - 1}$	Equivalent annual cost (Amount in U.S. Dollar)
A. Existing painting system						
1	56,848	1.000	56,848			
2	56,848	1.040	59,122			
3	56,848	1.082	61,487			
4	56,848	1.125	63,946			
5	56,848	1.170	66,504			
6	56,848	1.217	69,164			
7	56,848	1.265	71,931			
8	56,848	1.316	74,808			
9	56,848	1.369	77,800			
10	56,848	1.423	80,912			
11	56,848	1.480	84,149	766,670	0.074	56,734
B. Proposed high performance corrosion resistant coating system						
1	534,910	1	534,910	534,910	0.074	39,583
					Annual savings in U.S. Dollar	17,151

Inf2 $= 0.04$
$n =$ year

on an earlier survey carried out during 1976–77. Obviously due to increased corrosion awareness and due to use of corrosion resistant materials such as SS 316L, the annual cost of corrosion has been brought down considerably.

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