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Feature Article

SOLUTIONS TO CORROSION CAUSED BY AGRICULTURAL CHEMICALS

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ABSTRACT

Corrosion is the deterioration of materials by chemical interaction with their environment. The consequences of corrosion are many and varied. The effects of these on the safe, reliable and efficient operation of equipment or structures are often more serious than the simple loss of a mass of metal. The two main reasons for replacing machinery or equipment include upgrading old equipment and substituting them because of wear and corrosion. Discussions with people in this sector placed corrosion costs in the range of five to ten percent of the value of all new equipment. Furthermore, many commercial chemicals are used on farmlands, grain and silage preservatives, pests and weed control, and as proprietary acid solutions for cleaning dairy equipment. In addition to these, farm wastes and slurries contain many chemicals. On the whole, these various chemicals frequently damage farming machinery and ancillary structures. The aim of this discussion is to proffer suitable solutions to corrosion occurring due to actions of these agricultural chemicals.

Key Words: Agriculture, machinery, corrosion, chemical

INTRODUCTION

Agriculture gives rise to livestock, poultry, or other animal specialties, their products and crops including fruits and green house or nursery products. The two main reasons for replacing machinery or equipment include upgrading old equipment and replacement because of wear and corrosion. Discussions with people in this industrial sector resulted in an estimate of corrosion costs in the range of five percent to ten percent of the value of all new equipment [1] Corrosion is the deterioration of materials by chemical interaction with their environment. The term corrosion is sometimes also applied to the degradation of plastics, concrete and wood, but generally refers to metals. The most widely used metal is iron (usually as steel) and the following discussion is mainly related to its corrosion. The consequences of corrosion are many and varied and the effects of these on the safe, reliable and efficient operation of equipment or structures are often more serious than the simple loss of a mass of metal. Failures of various kinds and the need for expensive replacements may occur even though the amount of metal destroyed is quite small [2]. Some of the major harmful effects of corrosion can be summarized as follows:

1. Reduction of metal thickness leading to loss of mechanical strength and structural failure or breakdown. When the metal is lost in localized zones so as to produce a crack, very considerable weakening may result.
2. Hazards or injuries to people arising from structural failure or breakdown (e.g. bridges, cars, aircraft).
3. Loss of time in availability of profile-making industrial equipment.
4. Reduced value of goods due to deterioration of appearance.
5. Contamination of fluids in vessels and pipes (e.g. beer goes cloudy when small quantities of heavy metals are released by corrosion).
6. Perforation of vessels and pipes allowing escape of their contents and possible harm to the surroundings. For example a leaky domestic radiator can cause expensive

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damage to carpets and decorations, while corrosive seawater may enter the boilers of a power station if the condenser tubes get perforated.

7. Loss of technically important surface properties of a metallic component. These could include frictional and bearing properties, ease of fluid flow over a pipe surface, electrical conductivity of contacts, surface reflectivity or heat transfer across a surface.
8. Mechanical damage to valves, pumps, etc, or blockage of pipes by solid corrosion products.
9. Added complexity and expense of equipment, which needs to be designed to withstand a certain amount of corrosion, and to allow corroded components to be conveniently replaced [3-4].

On the other hand corrosion is one of the most important problems in agricultural machinery. It is not considered by most manufacturers. This problem causes a decrease in agricultural machinery's life. Many factors have effects on corrosion. Our aim in this paper is to discuss the chemical effect of corrosion on agricultural machinery.

CORROSION BY AGRICULTURAL CHEMICALS

Many commercial chemicals are used in farming, including fertilizers, grain and silage preservatives, chemicals for pest, disease and weed control, and proprietary acid solutions for cleaning dairy equipment. Farm wastes and slurries can also be significantly corrosive.

Fertilizers

Fertilizers are chemicals given to plants with the intention of promoting growth. They are usually applied either via the soil or by foliar spraying. Fertilizers typically provide in varying proportions the three major plant nutrients (nitrogen, phosphorus and potassium) and the secondary plant nutrients (calcium, sulphur, magnesium, iron, etc).

Some fertilizers are more corrosive than others, especially if they decompose or react to produce aggressive substances such as ammonia or hydrogen sulphide; if chloride ions are present (including potassium or ammonium chloride), or if acidic conditions prevail. For example, dihydrogen ammonium phosphate or ammonium nitrate can lead to increased corrosion via hydrolysis to acids (i.e. a fall in pH).

The relative ratios of the essential plant nutrients can influence the corrosiveness of compound liquid fertilizers, there being some evidence that the greatest effects occur with fertilizer solutions containing about 15% nitrogen, especially when half the free nitrogen is derived from urea and half from ammonium nitrate. Some typical reactions for liquid fertilizers are given on **Table 1**. If fertilizers are kept dry, then no corrosion occurs, but being hygroscopic they can pick up moisture and hence may become corrosive. The hygroscopic point – the relative humidity (RH) at and above which moisture is absorbed – varies from one compound to another and the lower its value the more corrosive the fertilizer is likely to be. Ammonium nitrate starts to absorb moisture at 60% RH, while certain phosphates absorb moisture only above 90% RH. Moisture initially causes caking of the fertilizer, which can increase its abrasive properties [5].

***Table 1**. Corrosive reactions of liquid fertilizers [5]*

Liquid fertilizers	*Chemicals*	*Reactions with steel*
Nitrogenous solutions	Ammonium nitrate, urea	Slow reaction with steel, can be more rapid at weds and bolt holes, etc.
Phosphate solutions	Ammonium phosphate	Tends to be less reactive, form a protective phosphate coat which can protect metal from subsequent attack by nitrogenous solutions, unless acid conditions prevail

Galvanizing of steel is generally beneficial in resisting corrosion, as can be noted from the results of laboratory tests, where metal was immersed in shallow pools of solution for 500 hours at ambient temperatures (**Table 2**). Carbon steel is often used to contain fertilizers because it is cheap, but adequate surface cleaning, preparation and coating are necessary. Type 304 Stainless Steel has shown overall benefit for liquid fertilizer service over three-year service tests. Penetration figures for tanks exposed for 2 years to commercial liquid fertilizers are given on **Table 3**. [5]. Large fertilizer storage tanks should be constructed of materials, which are resistant to corrosion, puncture, or cracking.

***Table 2**. Steel corrosion rates in fertilizers determined laboratory tests at ambient temperature [5]*

Fertilizer	***Equivalent thickness loss after first year (µm)***	
	Mild steel	*Galvanized steel*
Ammonium nitrate:		
Saturated solution	1,250	250
63% solution	380	280
Ammonium nitrate and chalk:		
Saturated solution	815	330
%67 solution	1,070	340
Compound fertilizers(0,24,24)		
Saturated solution	200	60
Controls in clean water	60	20

Silage

Silage is fermented, high moisture forage to be fed to ruminants, cud-chewing animals like cattle and sheep. It is fermented and stored in a structure called a silo. In many countries, the plant material is colleted, chopped into pieces about 13 mm long and packed into the storage. Silage undergoes anaerobic fermentation, typically beginning about 48 hours after the silo is filled. The fermentation is essentially complete in about two weeks. Also the fermentation process releases a liquid. The amount of liquid can be excessive if there is too much moisture in the crop when it is ensiled. Silo effluent contains nitric acid (HNO_3) making it corrosive. It also can be a contaminant of lakes and streams, because of the high nutrient content, and would lead to algae blooms. Silage effluent is potentially one of the most damaging effluents produced by agriculture. There are specific storage instructions to prevent silage leakage. Silage effluent is also very acidic and therefore the storage structures must be resistant to corrosion and acid attack. Modern steel silos, both galvanized and glass-coated, are virtually always designed for silage and grain storage. Their adaptation is primarily one of installing aeration equipment, modifying unloading if necessary, and making provision for aeration air discharge in the top of normally sealed units. Older style steel silos, especially those that show severe corrosion in the lower sections and/or those that have not been used for a number of years, should be viewed with extreme caution as safe grain or silage storages. Corrosion on a very thin metal wall can markedly reduce the metal area remaining to sustain the storage load.

***Table 3**.Material performance in commercial liquid fertilizers after 2 years service tests [5]*

Material	***Penetration (µm)***
304 stainless steel	0,253
Carbon steel	282
5052 aluminium	132

Besides tower silos are prone to corrosion damage, primarily by the organic acids that are produced during the process of ensilage. The most acidic and corrosive environment is claimed to exist within silos containing whole crop maize silage, which ferments readily and rapidly to produce acids with typical concentrations in solution of 2% lactic acid and 0.5% acetic acid and with the pH as low as 3.6. Lactic acid is regarded as the stronger acid and, if oxygen is present also, then secondary fermentation can occur, giving silage, which is predominantly butyric acid, thus yielding a higher pH value. Furthermore, temperatures inside silos can be as high as 30°C, so corrosion rates inside tend to be higher than those on the external walls. In practice, the contact time for acids on machinery, e.g. on augers and balers, is low, so corrosion rates are usually less than 1 mm/year (on mild steel). During storage, acid-treated grain has little effect, the major precaution needed being to minimize the risk of concentration in local areas such as crevices, or where stagnant pools of liquid can collect. Propionic acid is highly corrosive, but little damage should occur if correct precautions are taken, such as the complete removal of the acid-treated grain from the silo after use, washing with water, and avoidance of contact of treated grain with unprotected machinery. A particular problem with organic acid additives is their paint-stripping properties, but compositions modified, for example, by the addition of a caution to produce complex acid salts, are significantly less corrosive and less liable to strip paint. Materials that have given good service for silos are aluminium (over 10 year's life), and vitreous enamelled steel, which is particularly easy to clean and maintain. Plastic coatings are liable to surface damage, and crevice corrosion can occur if adhesion is lost.

Galvanized steel may deteriorate in contact with silage juices and slurries, but is resistant to silage vapours. The order of preference for metals of construction for storage vessels is: aluminium (best), galvanized steel, mild steel. The combination of abrasion and acid attack is also especially destructive to concrete because acids react with lime; covering of floors with plastic sheeting, or with an acid-resisting coating such as chlorinated rubber or epoxy paint, provides protection [5]

The intensification of animal husbandry has increased the problems of handling manure, and much equipment has been developed to cope with the large quantities involved. Enhanced corrosion in crevices and awkward corners can be avoided at the design stage by the use of round-section tankers and other equipment. Slurry is a mixture of dung and urine, and farmyard manure is slurry composted with litter, i.e. straw or wood shavings, etc. Both ferment to release moisture, ammonia and carbon dioxide. The corrosive constituents in slurry and FYM are urea, uric acid, ammonia and ammonium salts, and naturally excreted chloride and the mixture is corrosive towards steel structures and machinery that are poorly protected and maintained. **Table 4** shows steel corrosion rates in farmyard manure in laboratory tests at ambient temperature. Besides, corrosion associated with wastes in contact with steel and concrete is given on **Table 5**.

Table 4. *Steel corrosion rates in farmyard manure in laboratory tests at ambient temperature [5]*

Manure	***Equivalent metal thickness loss after 1 year(µm)***	
	Mild steel	*Galvanized steel*
Poultry	167	160
Cattle	199	95
Controls in clean water	60	20

Table 5. *Corrosive reactions of wastes [5]*

Wastes	***Chemicals***	***Reactions with steel and concrete***
Silage effluent	Lactic acid Acetic acid Butyric acid	Such acids in sufficient concentration will react with lime in cement; concrete subject to such acids should be designed to a medium workability mix
Milk wastes	Lactic acid	Any steel surfaces need suitable protection
Slurry	Varies from neutral to slightly acid	Special precautions are not normally needed

Slurries and manures

The design of farm manure storage should be carried out in accordance with regulatory requirements. In addition to being designed correctly, all manure storage facilities should be inspected regularly for any signs of corrosion, surface breakdown, cracking of concrete and fractured pipes.

Herbicides and pesticides

A herbicide is a pesticide used to kill unwanted plants. Besides, selective herbicides kill certain target while leaving the desired crop relatively unharmed. Some of these act by interfering with the growth of weed and often based on plant. Herbicides are widely used in management of landscape turf and in agriculture. Most herbicides are applied as water-based sprays using ground equipment. Besides, herbicides can also be applied aerially using helicopters or airplanes, and can be applied through irrigation systems ('*chemigation*')

During the last decade there has been intensive development of chemicals used for crop protection, and corrosion by herbicides and pesticides can be significant under certain conditions, especially if harmful species concentrate in local areas. Copper-bearing fluids such as Bordeaux mixture – made from copper sulphate, water and lime – can, for example, be aggressive to aluminium or to zinc (as on galvanized steel), a feature associated with incompatible metals[6] Glasshouse structures has shown that 'zinc drip' can become significant if such fluids are used. This attack is particularly harmful on new structures with fresh galvanizing. Intense waterline attack has been reported in steel drums containing 50% aqueous TCA (sodium trichloroacetate) weed killer within nine months. Heavy attack was noted for aluminium, galvanized steel, various brasses and copper, but tinned steel and molybdenum containing stainless steel (Type 316) were resistant. Nitrophenolic compounds, of general formula 2,4-dinitro, 6-alkyl phenol, commonly used as weed-killers, have corroded steels and irons used in spraying equipment, whether in aqueous or oleaginous dispersion. Inhibitors such as 0.7% sodium dichromate (for TCA) and 1.5% furfural (for 2,4-dinitro) have been useful; surface coverage by oil has also inhibited waterline attack. Certain insecticides, such as chlorodane, are particularly corrosive and acidic (pH = 2) and aqueous solutions of sodium arsenide and DDT in salt water have been found to be aggressive to common metals like carbon steel, galvanized steel, copper and aluminium. Of the more common materials, stainless steel is reported to be the most resistant for use with herbicides and pesticides and aluminium is satisfactory in all but aqueous sodium arsenide. Insecticides dissolved in kerosene or fuel oil are not aggressive[5].

All of equipment used to apply pesticides should be constructed with materials that resist corrosion. Fiberglass and stainless steel resist corrosion caused by most chemicals, as do plastic coatings; however, durability of these materials is reduced if cracks or chips in the coating develop and expose the base metal to corrosive forces. Untreated metal can be used for applying non-corrosive pesticide solutions but precautions should be taken to prevent rust and scale. All tanks should be constructed to prevent leaking and rupture. Nozzles are constructed from many different materials, each with different characteristics in terms of resistance to corrosion, abrasion, or reaction with spray mixtures. Selection of nozzle types should be made by balancing the characteristics of the construction materials against the cost of the different nozzles. For example, brass nozzles are relatively inexpensive but wear quickly if exposed to abrasive materials. Aluminium nozzles resist corrosion by some pesticide spray mixtures but are readily corroded by some fertilizers. Stainless steel nozzles will not readily corrode and resist abrasion but cost substantially more than brass nozzles. Plastic nozzles may resist both corrosion and abrasion but may swell when exposed to certain solvents in pesticide formulations. Tungsten carbide and ceramic nozzles are most highly resistant to abrasion and corrosion but are usually the most expensive.

Dairy farming

Dairy farming is a class of agricultural, or more properly an (animal husbandry) enterprise raising female cattle for long term production of milk which may be either processed on site or transported to a dairy for processing and eventual retail sale. Generally stainless steels are widely used for dairy equipment; so in most cases corrosion in this area is relatively uncommon. Specific problems arise with cleaning and sterilization of associated buildings and machinery, there being particular need to protect mild steel supporting structures from milk wastes; lactic acid, for example, can remove 1.25 mm of steel in one year. Chlorine-containing agents (sodium hypochlorite, etc) are potentially corrosive to all constructions metals encountered in the dairy industry, and efforts should be taken to minimize any local build-up of chloride ions which can destroy or weaken naturally forming protective films on the metal surface. Under certain conditions tensile stress, temperatures above 70^{o}C some stainless steels may crack by stress corrosion when in contact with chloride ions [5].

CONCLUSION

All agricultural equipments require coating that resists wear and corrosion in their applications. For this reason corrosion must be prevented by adopting some reusable-friendly methods. Besides, certain inhibitors can be used for corrosion protection in agricultural applications. Corrosion control and prevention can be accomplished by keeping equipment clean and dry after each use, applying corrosion-resistant materials or materials with a corrosion allowance, applying external coatings (paints) or internal lining systems, or using cathodic protection. Strategies for maintaining and optimising inspection programmes for agricultural equipment (i.e. minimising safety concerns for fertilizer tanks) with a high corrosion risk need to be developed. Development of new and improved inspection techniques is required to ensure the integrity of agricultural equipment.

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