Chelating Agents

VERSENE™, VERSENEX™, AND VERSENOL™
Effective, Economical Metal Ion Control

Product Overview and Selection Guide
Almost any aqueous system can be affected by uncontrolled metal ions

Uncontrolled metal ions in your product or process can eat away profits by causing scaling, chemical degradation, discoloration, precipitation, emulsion instability, rancidity, and a host of other problems. In products, soluble metal ions accelerate chemical reactions which reduce quality, consumer appeal, shelf-life, and ultimate value. In processes, uncontrolled metal ions hamper process efficiency and increase equipment downtime.

Since trace amounts of soluble iron, copper, manganese, calcium, and other metals occur naturally in many raw materials, the potential for scaling and undesirable metal-catalyzed reactions is widespread. These metal ions are normally found in processing water, and can also be introduced during processing.

**Food and beverage products are vulnerable to metal-catalyzed spoilage and discoloration**

Even in concentrations as low as 0.05 ppm, metal ions can cause spoilage, rancidity, discoloration, off-odors, off-flavors, and shortened shelf-life in foods. Metal ions also catalyze the oxidative degradation of fats and oils. Emulsified products are particularly sensitive. In products such as salad dressings, mayonnaise, sauces, and spreads, as little as 0.5 to 1.0 ppm copper or iron can lead to color changes, off-flavors, and emulsion instability.

Another familiar example is the discoloration of white potatoes which begins when iron in the potato reacts with phenolic compounds during cooking. In canned seafood, naturally high levels of copper, zinc, tin, and iron combine with organics to cause discoloration, off-flavors, and off-odors. Uncontrolled metal ions also lead to problems in food processing equipment by causing scaling.
Cleaning and laundering products can be rendered ineffective by metal ions in hard water
Metal ions have long plagued formulators of soaps, detergents, and cleaning formulations. One of the major challenges is producing formulations that provide good cleaning performance and rinsability when used with hard water. Metal ions can also reduce shelf-life and cause cloudiness in liquid cleaning products and detergents. In combined detergent and disinfectant formulations, metal ions can inhibit germicidal performance.

Without provisions to control metal ions, these products can also exhibit poor detergency and lathering characteristics when used with hard water.

In pulp and paper processing, metal ions reduce bleaching efficiency and cause brightness reversion
Traces of heavy metals, which occur naturally in wood fibers and processing water, work against the best efforts of pulp and paper mills to produce brighter, whiter papers. Uncontrolled, these metal ions reduce the effectiveness of hydrosulfite and hydrogen peroxide bleaches used to brighten pulps. As a result, it takes more bleach to achieve and maintain the desired level of brightness. Because bleach chemicals are relatively expensive, pulp and paper mills have long worked to control metal ions through chelation chemistry.

Metal ions cause scaling and sludge deposits in water systems
Wherever water is used as a processing or heat exchange medium, metal ion reactions can lead to problems – boilers, heat exchangers, wood pulp digesters, processing equipment and evaporators are just a few examples. Scaling on interior surfaces of equipment is the major problem. Scaling can reduce heat exchange efficiency and increase equipment downtime. Scaling caused by soluble calcium, magnesium, or iron is the most common problem.

Dow chelating agents provide an effective, economical solution to metal ion problems
Chelating agents (also known as sequestering agents) can inhibit undesirable metal-catalyzed reactions by forming complexes with the metal ions. The resulting structure, called a chelate, deactivates the metal ion and prevents it from reacting with other components of the system.

Of the different types of metal ion control agents in use today, Dow chelating agents produce the most stable complexes with metal ions and generally provide the most effective control of metal ion problems. Dow products are aminopolycarboxylic acids available as VERSENE™ EDTA, VERSENOL™ HEDTA, and VERSENEX™ DTPA chelating agents (generically referred to as EDTA, HEDTA, and DTPA). Although often more expensive than other materials on a per-pound basis, Dow chelating agents are frequently the least costly option for metal ion control due to their effectiveness at remarkably low concentrations. Unique advantages of Dow chelating agents include predictable performance, high thermal stability, chemical stability, pH stability, and resistance to bacterial or mold breakdown.

Metal ions shorten shelf-life and hamper performance in personal care products
Metal ion reactions can seriously affect the quality, performance, consumer appeal, and shelf-life of personal care formulations. Oil-in-water emulsions such as creams, lotions, deodorants, and ointments are subject to metal-catalyzed oxidation and rancidity. In shampoos and soaps, metal ions can cause turbidity and reduce shelf-life.

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How Dow chelating agents control troublesome metal ions

**Dow locks problem ions in a highly stable complex**
Soluble trace metals in aqueous systems exist as positively charged ions. Each of these ions has a fixed number of reactive sites. Most metal ions have either four or six reactive sites. EDTA, DTPA, and HEDTA have six, eight, and six metal-complexing sites respectively, enabling one molecule to interact with all the reactive centers of a metal ion. NTA has four metal complexing sites, enabling one molecule to interact with the majority of the reactive centers of a metal ion.

Figure 1 illustrates how VERSENE™ EDTA can block up to six reactive sites on a metal ion, completely deactivating the ion. Equally important, the intrinsically strong, five-membered ring structures in this complex are highly stable even under heat, light, and pH extremes. This can translate into trouble-free processing and better protection for products, even in adverse conditions. By comparison, other metal ion control agents, such as phosphates and citrates, may form relatively weak complexes with metal ions and can’t always provide the protection you need.

**Effective at remarkably low concentrations, Dow chelating agents can help you reduce operating and material costs**
Because they are so efficient, Dow chelating agents can often provide the protection you need at much lower concentrations than citric acid, phosphates, or other competitive metal ion control agents. A dramatic example is in treating frozen potatoes to inhibit after-cooking darkening. In this application, 20 times less VERSENE EDTA is required for protection than sodium acid pyrophosphate (SAPP).

**Excellent heat and pH stability make Dow chelating agents compatible with most aqueous systems and processes**
The complexes formed by many other types of chelating agents can break down during processing and storage of products, releasing metal ions to cause undesirable reactions. Long-chain phosphate molecules also tend to hydrolyze and break down in aqueous systems, particularly at elevated temperatures. In contrast, Dow chelating agents are stable up to, and beyond, 400°F (204°C).

In addition, many chelating agents function within a restricted pH range. Figures 2 and 3 show that EDTA complexes of iron and copper retain their stability over a wider pH range than citric acid and pyrophosphate complexes, making Dow chelating agents compatible over a wide range of processing, storage, and use conditions.

**Higher stability means more reliable protection for your product or process**
One measure of the efficiency of metal ion control agents is the conditional stability constant of the complex they form with a metal ion. The higher the stability constant, the stronger the complex formed and the more efficiently the metal ions are controlled. Figures 2 and 3 compare the conditional stability constants of complexes formed by VERSENE EDTA, citric acid, and pyrophosphate with iron and copper ions. In each case, EDTA forms the most stable complex. In practical terms, the higher stability of EDTA complexes means better protection for your product or process.

Figure 1: VERSENE EDTA surrounds and immobilizes problem ions in a stable ring structure called a “chelate”
This illustration shows how the EDTA molecule can block up to six reactive sites on a metal ion, completely deactivating the ion. The highly stable ring structures contribute excellent pH, heat, and light stability to these complexes.
These graphs show the EDTA complexes of iron and copper remain stable at high pH levels and are much more stable than citric acid and pyrophosphate complexes. In addition, the EDTA complexes retain their stability over a wider pH range.
Table 1: Common Symptoms of Undesirable Trace-Metal Reactions In Your Product or Process

<table>
<thead>
<tr>
<th>APPLICATION</th>
<th>TYPICAL SYMPTOMS</th>
<th>BENEFITS OF USING DOW CHELATING AGENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food &amp; Beverage</td>
<td>Canned seafood products&lt;br&gt;Dressings, sauces, spreads&lt;br&gt;Canned beans&lt;br&gt;Beverages&lt;br&gt;Potato products&lt;br&gt;Pickled vegetables</td>
<td>Discoloration&lt;br&gt;Rancidity&lt;br&gt;Off-odors/off-flavors&lt;br&gt;Precipitation&lt;br&gt;Loss of clarity&lt;br&gt;Deterioration of texture&lt;br&gt;Crystal formation&lt;br&gt;Shortened shelf-life</td>
</tr>
<tr>
<td>Cleaning Products</td>
<td>Heavy-duty laundry detergents&lt;br&gt;Hard surface cleaners</td>
<td>Poor performance in hard water&lt;br&gt;Poor foaming characteristics&lt;br&gt;Poor rinsability&lt;br&gt;Haze formation or precipitation&lt;br&gt;Poor shelf-life&lt;br&gt;Discoloration&lt;br&gt;Rancidity&lt;br&gt;Need to reduce phosphate levels&lt;br&gt;Hard water stains&lt;br&gt;Bathtub ring&lt;br&gt;Dishwater spots</td>
</tr>
<tr>
<td>Personal Care Products</td>
<td>Creams, lotions&lt;br&gt;Oils&lt;br&gt;Bar and liquid soaps&lt;br&gt;Shampoos&lt;br&gt;Hair preparations</td>
<td>Poor performance in hard water&lt;br&gt;Poor rinsability&lt;br&gt;Haze formation or precipitation&lt;br&gt;Oxidation, rancidity, or off-odors&lt;br&gt;Viscosity shifts&lt;br&gt;Poor shelf-life&lt;br&gt;Degradation of texture or appearance</td>
</tr>
<tr>
<td>Pharmaceuticals</td>
<td>Drug stabilization&lt;br&gt;Antimicrobial booster&lt;br&gt;Antioxidant&lt;br&gt;Preservative</td>
<td>Poor drug performance in presence of hard water</td>
</tr>
<tr>
<td>Pulp &amp; Paper</td>
<td>Mechanical pulp bleaching&lt;br&gt;Chemical pulping&lt;br&gt;Reduction of brightness reversion&lt;br&gt;Chemithermomechanical pulping</td>
<td>Poor performance of hydrogen peroxide or hydrosulfite bleaches&lt;br&gt;Problems meeting brightness needs&lt;br&gt;Excessive bleach usage&lt;br&gt;Process scaling&lt;br&gt;Brightness reversion in finished paper</td>
</tr>
<tr>
<td>Water Treatment</td>
<td>Boilers&lt;br&gt;Heat exchangers&lt;br&gt;Evaporators&lt;br&gt;Filter cloths&lt;br&gt;Glass-lined kettles</td>
<td>Scale deposits&lt;br&gt;Frequent shut-downs for cleaning&lt;br&gt;Reduced heat transfer efficiency</td>
</tr>
<tr>
<td>APPLICATION</td>
<td>TYPICAL SYMPTOMS</td>
<td>BENEFITS OF USING DOW CHELATING AGENTS</td>
</tr>
<tr>
<td>-------------</td>
<td>------------------</td>
<td>---------------------------------------</td>
</tr>
</tbody>
</table>
| Metalworking | Surface preparation  
               Metal cleaning  
               Metal finishing and plating       | Drag-in and contamination of succeeding plating baths  
                                         Poor rinse solution performance at elevated temperatures  
                                         Oxidation of cleaned iron or steel during storage  
                                         Streaking after pickling  
                                         Rough deposits, reduced efficiency, dulling, and unsuitable metal deposition during plating | Improved product performance in hard water  
                                                                 Improved rinsability  
                                                                 More consistent performance  
                                                                 Improved high-temperature performance |
| Textiles    | Preparation  
               Desizing  
               Scouring  
               Bleaching  
               Dyeing     | Poor performance of hydrogen peroxide bleach  
                                         Fabric contaminated with deleterious materials  
                                         Dye shade change                                | Deactivates metal ions that interfere with hydrogen peroxide performance  
                                                                 Less need to overbleach to ensure specified brightness level  
                                                                 Water soluble Dow chelating agents are ideal for metal ion control in textile processes  
                                                                 Dye shade stability                               |
| Agriculture | Chelated micronutrients  
               Herbicides             | Poor performance of herbicides in hard water  
                                         Plant problems associated with micronutrient deficiencies  
                                         Micronutrient deficiencies in animal feeds | VERSENOL™ AG Fe is a ready-to-use micronutrient that supplies the trace metal iron, which is vital to the metabolism of plants and animals  
                                                                 Excellent water solubility makes metal chelants more readily utilized by plants than the inorganic forms of metals  
                                                                 Stabilizes herbicides when formulated or mixed with hard water |
| Polymerization | Styrene-butadiene polymerization  
                            PVC polymerization  
                            Stabilization of polymer systems | Poor uniformity in polymerization rates  
                                         Polymer buildup on reactor walls  
                                         Coarse, off-grade polymer  
                                         Polymer breakdown and discoloration  
                                         Heat and light instability in polymer systems | Stable polymerization rates  
                                                                 Reduced polymer buildup in reactors  
                                                                 Improved suspending agent performance  
                                                                 Better polymer stability and shelf-life |
| Photography | Developers  
               Bleaches               | Scaling in photoprocessors  
                                         Deposits or scratches on film  
                                         Silver retention                        | Reduced scaling  
                                                                 Less downtime for scale removal  
                                                                 Higher quality prints and negatives  
                                                                 Enhanced silver recovery  
                                                                 Increased longevity of prints and negatives |
| Oilfield Applications | Drilling  
                                Production  
                                Recovery       | Formation plugging due to iron precipitation during acidizing and fracturing processes  
                                         Scaling on well casings from brines normally coproduced with oil  
                                         Scale buildup, precipitation, and plugging in enhanced oil recovery operations | Prevents plugging, sealing, precipitation by deactivating metal ions  
                                                                 Effective over wide temperature and pH range |
| Scale Removal & Prevention | Boilers  
                                 Evaporators  
                                 Heat exchangers  
                                 Filter cloths  
                                 Glass-lined kettles | Scale deposits  
                                         Reduced heat transfer efficiency  
                                         Reduced flow rates                      | Removes existing scale deposits  
                                                                 Works in combination with other materials to prevent scale formation |
Choose from many different VERSENE™, VERSENOL™, and VERSENEX™ products to meet your needs

Dow offers a broad range of Dow chelating agents to meet specific needs. These products include general purpose and specialty VERSENE EDTA products as well as VERSENOL HEDTA products and VERSENEX DTPA products.

**Unsurpassed quality and consistency**

Quality is the standard achieved by products that give you exactly what you want, every time. That’s the standard set by top management for Dow chelating agents. It serves as the driving force behind the people who make and distribute Dow products.

At the heart of this program is a dedicated quality assurance plan that helps us maintain the highest possible quality and consistency for Dow chelating agents. Every aspect of production and distribution is carried out according to a formalized quality control plan which documents each action that must be taken to meet predetermined product specifications.

In textile manufacturing, Dow chelating agents are used to improve hydrogen peroxide bleach performance and to provide dye shade stability.

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**Table 2: Typical Properties**

<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>PRODUCT AVAILABILITY</th>
<th>COMPOSITION</th>
<th>APPEARANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>VERSENE 100 chelating agent</td>
<td>NLPEIMA</td>
<td>Tetrasodium ethylenediaminetetraacetate</td>
<td>Amber, light</td>
</tr>
<tr>
<td>VERSENE 100 XL</td>
<td>NLPEIMA</td>
<td>Tetrasodium ethylenediaminetetraacetate</td>
<td>Amber, light</td>
</tr>
<tr>
<td>VERSENE 100 LN</td>
<td>NLPE</td>
<td>Tetrasodium ethylenediaminetetraacetate</td>
<td>Amber, light</td>
</tr>
<tr>
<td>VERSENE Diammonium EDTA chelating agent</td>
<td>NLP</td>
<td>Diammonium ethylenediaminetetraacetate</td>
<td>Light, straw-colored liquid</td>
</tr>
<tr>
<td>VERSENE Tetraammonium EDTA chelating agent</td>
<td>NLP</td>
<td>Tetrasodium ethylenediaminetetraacetate</td>
<td>Light, straw-colored liquid</td>
</tr>
<tr>
<td>VERSENE 220 Crystals chelating agent</td>
<td>NLPEIMA</td>
<td>Tetrasodium ethylenediaminetetraacetate tetrahydrate</td>
<td>White crystalline powder</td>
</tr>
<tr>
<td>VERSENE Na Crystals chelating agent</td>
<td>NLPEIMA</td>
<td>Disodium ethylenediaminetetraacetate tetrahydrate</td>
<td>White to off-white powder</td>
</tr>
<tr>
<td>VERSENE Acid chelating agent</td>
<td>NLPEIMA</td>
<td>Ethylenediaminetetraacetic acid</td>
<td>White powder</td>
</tr>
<tr>
<td>VERSENE NA Disodium EDTA chelating agent</td>
<td>NLPEIMA</td>
<td>Disodium ethylenediaminetetraacetate dihydrate</td>
<td>White to off-white powder</td>
</tr>
<tr>
<td>VERSENE CA chelating agent</td>
<td>NLPEIMA</td>
<td>Calcium disodium ethylenediaminetetraacetate dihydrate</td>
<td>White to off-white powder</td>
</tr>
</tbody>
</table>
EDTA (ethylenediaminetetraacetic acid)-Based Chelating Agents

Our EDTA (ethylenediaminetetraacetic acid)-based chelating agents are the workhorses of our chelating agent product line. The leading product in this lineup is VERSENE™ 100 chelating agent, a general purpose product that is widely used to control common multivalent metal ions to pH 12, iron to pH 8, and water hardness ions above pH 4.

Other products in this series make the basic EDTA chemistry available in diammonium, tetra-ammonium, disodium, and acid forms. Physical forms include liquids, powder, and crystal forms. VERSENE NA Disodium EDTA and VERSENE CA chelating agents are food and pharmaceutical grade EDTA products.

1 The data provided for these properties are typical values, intended only as guides, and should not be construed as sales specifications.
2 N = North America; L = Latin America; P = Pacific; E = Europe; I = India; M = Middle East; A = Africa
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<table>
<thead>
<tr>
<th>CHELATION VALUE</th>
<th>% ASSAY</th>
<th>MOLECULAR WEIGHT</th>
<th>SPECIFIC GRAVITY (@25/25° C)</th>
<th>BULK DENSITY</th>
<th>pH (1 WT% AQUEOUS SOLUTION)</th>
</tr>
</thead>
<tbody>
<tr>
<td>102 (mg as CaCO₃ per g)</td>
<td>39 wt% as Na₂EDTA</td>
<td>380.2</td>
<td>1.3</td>
<td>10.6 lb/U.S. gal 1270 kg/m³</td>
<td>11 - 12</td>
</tr>
<tr>
<td>102 (mg as CaCO₃ per g)</td>
<td>38 wt% as Na₂EDTA</td>
<td>380.2</td>
<td>1.27</td>
<td>10.5 lb/U.S. gal 1260 kg/m³</td>
<td>11 - 12</td>
</tr>
<tr>
<td>102 (mg as CaCO₃ per g)</td>
<td>39 wt% as Na₂EDTA</td>
<td>380.2</td>
<td>1.3</td>
<td>10.6 lb/U.S. gal 1270 kg/m³</td>
<td>11 - 12</td>
</tr>
<tr>
<td>137 (mg as CaCO₃ per g)</td>
<td>40 wt% as (NH₄)₂EDTA</td>
<td>328.2</td>
<td>1.2</td>
<td>10 lb/U.S. gal 1200 kg/m³</td>
<td>4.6 - 5.3</td>
</tr>
<tr>
<td>130 (mg as CaCO₃ per g)</td>
<td>38 wt% as (NH₄)₂EDTA</td>
<td>362.2</td>
<td>1.17</td>
<td>9.8 lb/U.S. gal 1170 kg/m³</td>
<td>9.0 - 9.5</td>
</tr>
<tr>
<td>219 (mg as CaCO₃ per g)</td>
<td>99.0 wt% as Na₂EDTA·4H₂O 83.2 wt% as Na₂EDTA 64.0 wt% as H₂EDTA</td>
<td>452.2</td>
<td>—</td>
<td>45 lb/cu ft 720 kg/m³</td>
<td>10.5 - 11.5</td>
</tr>
<tr>
<td>267 (mg as CaCO₃ per g)</td>
<td>99.0 wt% as Na₂H₂EDTA·2H₂O 89.4 wt% as Na₂H₂EDTA 77.7 wt% as H₂EDTA</td>
<td>372.2</td>
<td>—</td>
<td>61 lb/cu ft 977 kg/m³</td>
<td>4.3 - 4.7 (5 wt% solution)</td>
</tr>
<tr>
<td>339 (mg as CaCO₃ per g)</td>
<td>99 wt% as H₂EDTA</td>
<td>292.24</td>
<td>—</td>
<td>54 lb/cu ft 870 kg/m³</td>
<td>2.5 - 3.0 (saturated solution)</td>
</tr>
<tr>
<td>267 (mg as CaCO₃ per g)</td>
<td>99.0 wt% as Na₂H₂EDTA·2H₂O 89.4 wt% as Na₂H₂EDTA 77.7 wt% as H₂EDTA</td>
<td>372.24</td>
<td>—</td>
<td>61 lb/cu ft 980 kg/m³</td>
<td>4.3 - 4.7 (5 wt% solution)</td>
</tr>
</tbody>
</table>

Already a calcium chelate of EDTA

| 97.0 – 102.0 wt% as CaNa₂EDTA·2H₂O 91.2 wt% as CaNa₂EDTA | 410.26 | — | 40 lb/cu ft 640 kg/m³ | 6.5 - 7.5 |

Dow Chelating Agents | January 2018
DTPA (diethylenetriaminepentaacetic acid)-Based Chelating Agents

We offer DTPA (diethylenetriaminepentaacetic acid)-based chelating agents under the trademark VERSENEX™. These products should be considered for use when: 1) the chelant will be used in the presence of oxidizers such as peroxide; 2) when metal chelates of greater stability or solubility are sought; or 3) when VERSENE™ 100 chelating agent has shown limited utility.

HEDTA (N-(hydroxyethyl)-ethylenediaminetriacetic acid)-Based Chelating Agents

VERSENOL™ 120 and VERSENOL 120E chelating agents are the trisodium salts of N-(hydroxyethyl)-ethylenediaminetriacetic acid. They have some unique properties that make them worth considering for use: 1) to control iron at pH 8 – 10; and 2) under more acidic conditions (i.e. low pH) where other chelants are less soluble.

Agricultural Micronutrients

VERSENOL AG micronutrient is a chelated micronutrient that is more readily utilized by plants than are inorganic forms of metals; therefore, less metal is required in the chelate form. This chelating agent is designed to provide trace amounts of iron. VERSENE Acid is a base chelant for micronutrient formulation.

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1 The data provided for these properties are typical values, intended only as guides, and should not be construed as sales specifications.

2 N = North America; L = Latin America; P = Pacific; E = Europe; I = India; M = Middle East; A = Africa

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<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>PRODUCT AVAILABILITY</th>
<th>COMPOSITION</th>
<th>APPEARANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>VERSENEX 50 chelating agent</td>
<td>NL</td>
<td>Pentasodium diethylenetriaminepentaaacetate</td>
<td>Light straw-colored liquid</td>
</tr>
<tr>
<td>VERSENEX 80 chelating agent</td>
<td>NLPEIMA</td>
<td>Pentasodium diethylenetriaminepentaaacetate</td>
<td>Light straw-colored liquid</td>
</tr>
</tbody>
</table>

| Table 3: Typical Properties1 of DTPA (diethylenetriaminepentaacetic acid)-Based Chelating Agents |

<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>COMPOSITION</th>
<th>APPEARANCE</th>
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</thead>
<tbody>
<tr>
<td>VERSENOL 120 chelating agent</td>
<td>NLPEIMA</td>
<td>Trisodium N-(hydroxyethyl)-ethylenediaminetriacetate</td>
</tr>
</tbody>
</table>

| Table 4: Typical Properties1 of HEDTA (N-(hydroxyethyl)-ethylenediaminetriacetic acid)-Based Chelating Agents |

<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>COMPOSITION</th>
<th>APPEARANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>VERSENE Acid chelating agent</td>
<td>NLPEIMA</td>
<td>Ethylenediaminetetraacetic acid</td>
</tr>
<tr>
<td>CHELATION VALUE</td>
<td>% ASSAY</td>
<td>MOLECULAR WEIGHT</td>
</tr>
<tr>
<td>-----------------</td>
<td>------------</td>
<td>------------------</td>
</tr>
<tr>
<td>97 (mg as CaCO₃ per g)</td>
<td>40.9 wt% as Na₅DTPA</td>
<td>503.1</td>
</tr>
<tr>
<td>80 (mg as CaCO₃ per g)</td>
<td>40.2 wt% as Na₅DTPA</td>
<td>503.1</td>
</tr>
<tr>
<td>120 (mg as CaCO₃ per g)</td>
<td>41 wt% as Na₃HEDTA</td>
<td>344.2</td>
</tr>
<tr>
<td>—</td>
<td>4.5 wt% as Iron</td>
<td>334.0</td>
</tr>
<tr>
<td>339 (mg as CaCO₃ per g)</td>
<td>99 wt% as H₄EDTA</td>
<td>292.24</td>
</tr>
</tbody>
</table>
Selecting the correct Dow chelating agent

The three-step method discussed below should be a fast and useful technique to determine chelating agents requirements for controlling polyvalent metal ions. It should also be helpful in making quantitative estimates which can be converted into initial process economic estimates. However, unless you are experienced in making the choice of a Dow chelating agent and in determining chelating agent requirements for commercial use, consultation with Dow Technical Service and Development personnel is recommended.

Three-Step Method
Use of the method requires first determining:

- Problem metal ion or ions
- Other metal ions present
- pH of solution
- Concentration of metal ion or ions

**Step One: Select Chelating Agent**
Using the Metal Ion Control Chart (Figure 4), select the most suitable material. In most applications, VERSENE™ 100 chelating agent should be considered first. Note: Since calcium and magnesium (hardness metal ions) are not chelated below a pH of 4.0, no chelating agents are specified. Above pH 4.0, VERSENE 100 is usually the chelant of choice, although NTA should be considered as an alternative for chelation of hardness ions above pH 9. For ferric (Fe$^{3+}$) ion control above a pH of 8.0, refer to VERSENOL™ 120 and/or Triethanolamine 99.

**Step Two: Determine Metal Ion(s) to Be Chelated**
Using the Metal Chelate Selectivity Displacement Series (Table 6), determine the metals to be chelated. The metal ions are listed in order of chelation: Fe$^{3+}$ before Cu$^{2+}$; Cu$^{2+}$ before Ni$^{2+}$, etc. Note: If Ca$^{2+}$ is the problem metal ion and Cu$^{2+}$ is present, Cu$^{2+}$ must be inactivated first.

**Step Three: Determine Quantity Required**
From Table 7 (Parts of Chelating Agent Required to Chelate One Part of Metal), determine the amount of chelating agent needed to control a unit weight of metal [4.7 grams VERSENE 100 for 1 gram Pb$^{2+}$].

Table 8 (Conversion Factors, Chelating Agent Equivalents, page 14), will then be useful to estimate the amount of Dow chelating agent required.

Answers obtained by the three steps should be checked on a limited or laboratory basis. Final adjustments can then be made so the optimum quantity of chelating agent will be used in commercial processes.
<table>
<thead>
<tr>
<th>METAL</th>
<th>NAME</th>
<th>VERSENE™ 100</th>
<th>VERSENEX™ 80</th>
<th>VERSENOL™ 120</th>
<th>DIAMMONIUM EDTA</th>
<th>TETRAAMMONIUM EDTA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al³⁺</td>
<td>Aluminum</td>
<td>36.1</td>
<td>46.4</td>
<td>30.9</td>
<td>27.1</td>
<td>28.5</td>
</tr>
<tr>
<td>Ba²⁺</td>
<td>Barium</td>
<td>7.1</td>
<td>9.1</td>
<td>6.1</td>
<td>5.3</td>
<td>5.6</td>
</tr>
<tr>
<td>Cd²⁺</td>
<td>Cadmium</td>
<td>8.7</td>
<td>11.1</td>
<td>7.4</td>
<td>6.5</td>
<td>6.8</td>
</tr>
<tr>
<td>Ca²⁺</td>
<td>Calcium</td>
<td>24.3</td>
<td>31.2</td>
<td>20.8</td>
<td>18.2</td>
<td>19.2</td>
</tr>
<tr>
<td>Co³⁺</td>
<td>Cobalt</td>
<td>16.5</td>
<td>21.2</td>
<td>14.1</td>
<td>12.4</td>
<td>13.1</td>
</tr>
<tr>
<td>Cu²⁺</td>
<td>Copper</td>
<td>15.3</td>
<td>19.7</td>
<td>13.1</td>
<td>11.5</td>
<td>12.1</td>
</tr>
<tr>
<td>Fe³⁺</td>
<td>Iron (Ferric)</td>
<td>17.5</td>
<td>22.4</td>
<td>14.9</td>
<td>13.1</td>
<td>13.8</td>
</tr>
<tr>
<td>Fe²⁺</td>
<td>Iron (Ferrous)</td>
<td>17.5</td>
<td>22.4</td>
<td>14.9</td>
<td>13.1</td>
<td>13.8</td>
</tr>
<tr>
<td>Ga³⁺</td>
<td>Gallium</td>
<td>14.0</td>
<td>18.0</td>
<td>12.0</td>
<td>10.5</td>
<td>11.0</td>
</tr>
<tr>
<td>In³⁺</td>
<td>Indium</td>
<td>8.5</td>
<td>10.9</td>
<td>7.3</td>
<td>6.4</td>
<td>6.7</td>
</tr>
<tr>
<td>Pb²⁺</td>
<td>Lead</td>
<td>4.7</td>
<td>6.0</td>
<td>4.0</td>
<td>3.5</td>
<td>3.7</td>
</tr>
<tr>
<td>Mg²⁺</td>
<td>Magnesium</td>
<td>40.1</td>
<td>51.5</td>
<td>34.3</td>
<td>30.1</td>
<td>31.6</td>
</tr>
<tr>
<td>Mn²⁺</td>
<td>Manganese</td>
<td>17.7</td>
<td>22.8</td>
<td>15.2</td>
<td>13.3</td>
<td>14.0</td>
</tr>
<tr>
<td>Hg²⁺</td>
<td>Mercury</td>
<td>4.9</td>
<td>6.2</td>
<td>4.2</td>
<td>3.6</td>
<td>3.8</td>
</tr>
<tr>
<td>Ni²⁺</td>
<td>Nickel</td>
<td>12.2</td>
<td>21.3</td>
<td>14.2</td>
<td>12.4</td>
<td>13.1</td>
</tr>
<tr>
<td>Pd⁰</td>
<td>Palladium</td>
<td>9.2</td>
<td>11.8</td>
<td>7.8</td>
<td>6.9</td>
<td>7.2</td>
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<tr>
<td>Sc³⁺</td>
<td>Scandium</td>
<td>21.7</td>
<td>27.8</td>
<td>18.5</td>
<td>16.3</td>
<td>17.1</td>
</tr>
<tr>
<td>Sr⁰</td>
<td>Strontium</td>
<td>11.1</td>
<td>14.3</td>
<td>9.5</td>
<td>8.3</td>
<td>8.8</td>
</tr>
<tr>
<td>Th⁴⁺</td>
<td>Thorium</td>
<td>4.2</td>
<td>5.4</td>
<td>3.6</td>
<td>3.2</td>
<td>3.3</td>
</tr>
<tr>
<td>Ti³⁺</td>
<td>Titanium</td>
<td>20.4</td>
<td>26.1</td>
<td>17.4</td>
<td>15.3</td>
<td>16.1</td>
</tr>
<tr>
<td>TiO²⁺</td>
<td>Titanium Oxide</td>
<td>15.3</td>
<td>19.6</td>
<td>13.0</td>
<td>11.4</td>
<td>12.0</td>
</tr>
<tr>
<td>V³⁺</td>
<td>Vanadium</td>
<td>19.1</td>
<td>24.6</td>
<td>16.4</td>
<td>14.3</td>
<td>15.1</td>
</tr>
<tr>
<td>V²⁺</td>
<td>Vanadium</td>
<td>19.1</td>
<td>24.6</td>
<td>16.4</td>
<td>14.3</td>
<td>15.1</td>
</tr>
<tr>
<td>VO³⁺</td>
<td>Vanadium Oxide</td>
<td>14.6</td>
<td>18.7</td>
<td>12.5</td>
<td>10.9</td>
<td>11.5</td>
</tr>
<tr>
<td>Y³⁺</td>
<td>Yttrium</td>
<td>11.0</td>
<td>14.1</td>
<td>9.4</td>
<td>8.2</td>
<td>8.7</td>
</tr>
<tr>
<td>Zn²⁺</td>
<td>Zinc</td>
<td>14.9</td>
<td>19.1</td>
<td>12.8</td>
<td>11.2</td>
<td>11.8</td>
</tr>
</tbody>
</table>
Typical Use of Three-Step Method

Problem
Both calcium and copper ions have been identified to be problems in a textile processing step. There are 3 ppm of copper and 20 ppm of calcium in the system. The questions: Which Dow chelating agent should be used...and how much?

Solution
Because Ca and Cu ions must be controlled and system pH in the textile plant is 8, use of the Metal Ion Control Chart (Figure 4, page 12) suggests VERSENE™ 100 chelating agent as the product of choice.

Because Ca and Cu ions must be chelated, use of Table 6 (page 12) indicates that the Cu ion must be inactivated first, and then the Ca ion.

By use of Table 7 (page 13), it is apparent that 15.3 parts of VERSENE 100 product are required to chelate one part of the Cu ion, and 24.3 parts of VERSENE 100 are required to chelate one part of the Ca ion. Therefore, 15.3 times 3 ppm of copper = 45.9 ppm VERSENE 100 required to chelate the copper, and 24.3 times 20 ppm of calcium = 486 ppm of VERSENE 100 required to chelate the calcium: a total of 531.9 ppm of VERSENE 100. Often a 10% excess is used to account for fluctuations in the system.

Judgement on volume requirement for a process is dependent on volume throughput of the system to be treated. Assistance in determining specific amounts of chelating agent required for a particular system is available from Dow. For further information, please contact The Dow Chemical Company.

Use of Table 8 suggests that 248 ppm of VERSENE 220 Crystals could be utilized in replacement of the 532 ppm of VERSENE 100 product, if that were desirable.

<table>
<thead>
<tr>
<th>TO REPLACE ONE POUND OF:</th>
<th>VERSENE 100</th>
<th>VERSENE 220 CRYSTALS</th>
<th>VERSENE ACID</th>
<th>VERSENEX™ 80</th>
<th>VERSENOL™ 120</th>
<th>VERSENE NA₂ CRYSTALS</th>
</tr>
</thead>
<tbody>
<tr>
<td>VERSENE 100</td>
<td>—</td>
<td>0.466</td>
<td>0.301</td>
<td>1.28</td>
<td>0.880</td>
<td>0.395</td>
</tr>
<tr>
<td>VERSENE 220 Crystals</td>
<td>2.15</td>
<td>—</td>
<td>0.646</td>
<td>2.73</td>
<td>1.83</td>
<td>0.849</td>
</tr>
<tr>
<td>VERSENE Acid</td>
<td>3.32</td>
<td>1.55</td>
<td>–</td>
<td>4.24</td>
<td>2.83</td>
<td>1.31</td>
</tr>
<tr>
<td>VERSENEX 80</td>
<td>0.784</td>
<td>0.365</td>
<td>0.236</td>
<td>–</td>
<td>0.667</td>
<td>0.310</td>
</tr>
<tr>
<td>VERSENOL 120</td>
<td>1.18</td>
<td>0.548</td>
<td>0.354</td>
<td>1.50</td>
<td>–</td>
<td>0.465</td>
</tr>
<tr>
<td>VERSENE Na₂ Crystals</td>
<td>2.53</td>
<td>1.18</td>
<td>0.761</td>
<td>3.23</td>
<td>2.15</td>
<td>–</td>
</tr>
</tbody>
</table>

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METAL SIGNATURE™ analytical service
The METAL SIGNATURE analytical service from Dow is an exclusive lab service that provides you with a detailed profile of the metal ions present in your product or process. You’ll also get the results of lab studies which determine the type, amount, and addition point for Dow chelating agents to achieve optimum effectiveness and economy. All you need to do to initiate the service is provide us with basic information about your process, plus samples of your product or process water at key points in your process.

The sophisticated PIMIC™ modeling service
Another unique service available from Dow is the PIMIC modeling service using the predictive and interpretive metal ion control computer program. With specific data about your system, this computer model helps us predict and optimize the behavior of different chelating agents in the system. The result is a valuable data package that can minimize your laboratory work and help you determine the best route to take to solve your problem. The powerful PIMIC modeling service was developed by Dow researchers and is available only from Dow.

Expert technical support
In addition to valuable lab services, we also provide dedicated technical service support for Dow chelating agents. Qualified technical specialists who understand your process technology and can quickly help you find the best solution to metal ion problems are just a phone call away. Our more than 50 years of experience in metal ion control have provided us with a large data base of information covering almost every conceivable application. Don’t hesitate to take advantage of this significant resource.

Our excellent distributor network
Our network of national and independent distributors offers the advantages of local inventories, convenient quantities, and individual service tailored to your needs. The Dow Chemical Company has a fundamental concern for all who make, distribute, and use our family of chelant products, and the environment we share. This concern is the basis for our Product Stewardship philosophy, by which we assess all available information on our products and then take appropriate steps to protect employee and public health and the environment. In addition, Dow is committed to implementing the guiding principles and management practices of the chemical industry’s Responsible Care® Initiative, which includes Product Stewardship as one of the Management Practices. As part of our Product Stewardship effort, information such as Material Safety Data Sheets and this brochure are provided to assist our customers in handling our chelant products in a safe and responsible manner.

Contact Dow for up-to-date information and samples of Dow chelating agents
Contact Dow for more information on our chelating agents as well as samples for your developmental work. Contact information for your region is on the back cover of this brochure. If you have questions, a technical representative will be glad to assist you.

For detailed information on safety and handling considerations for Dow chelating agents, we provide Material Safety Data Sheets (MSDS) for each product. MSDS are available on request, and are included with each product order.

We also offer brochures and technical data sheets on the complete range of applications for Dow chelating agents. These include materials on foods and beverages, cleaning products, personal care products, pharmaceuticals, pulp and paper processing, water treatment, metalworking solutions, textile processing solutions, agricultural micronutrients, polymerization, oilfield applications and scale removal and prevention.
Why Dow chelating agents should be your first choice for metal ion control

- Provide reliable protection for the quality, shelf-life, and value of your products
- Improve processing efficiency
- Reduce scale formation
- Effectively dissolve inorganic scales
- Improve bleach performance
- Prevent metals from reacting with your process or product
- Improve product performance in hard water
- Soften process water
- Keep metal ions in solution
- Form more stable complexes than other metal ion control agents
- Offer unique thermal, light, and pH stability
- Effective at low concentrations, helping you reduce ingredient costs
- A long history of success in a broad range of applications

Why Dow is your best source for metal ion control solutions

- Unsurpassed quality and consistency in every Dow product
- Different product chemistries and many physical forms for formulating versatility
- The exclusive METAL SIGNATURE™ analytical service
- The sophisticated PIMIC™ computer modeling service
- Expert technical support
- Comprehensive technical and application literature
- Complete metal ion control systems tailored to your needs
- Global production facilities and our excellent distributor network

Why not find out more about how Dow chelating agents can help you protect the value of your products and/or the efficiency of your processing? We’ll be happy to answer your questions, provide additional literature, and send samples of Dow chelating agents for your evaluation. Call today. The sooner you get started formulating with Dow chelating agents, the sooner you’ll start getting more reliable, cost-effective protection against detrimental metal ion reactions.

For more information, complete literature, and product samples you can reach a Dow representative at the following numbers:

- U.S., Canada, Mexico: 1-800-447-4369  www.versene.com
- Latin America: +55 11 5188 9222
- Europe: +31 11567 2626
  Toll-free +800 3 694 6367*
- Asia-Pacific: +60 3 7965 5392
  Toll-free +800 7776 7666*

*(Toll-free service not available in all countries.)

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Product Overview and Selection Guide

Chelating Agents