

How Chelating Resins Behave

By Peter S. Meyers

Chelating resins are gaining acceptance as the best available technology for the removal of transition and heavy metal cations from ground water and from plating rinse waters. These specialty ion exchange resins are capable of removing metals selectively in the presence of other ions such as calcium, magnesium and sodium. This paper describes the various types of chelating resins that are commercially available, discusses the conditions under which they will and will not work, and explores the input requirements necessary to optimize a system design.

Solution Chemistry

The chemistry of plating rinsewaters is particularly interesting, because the potential number of types of solutions and the individual chemistry of these solutions is very large.

Two basic concepts must be firmly grasped by users of ion exchange, in order to be successful in these types of applications.

1. All chelating resins are cation exchangers, at least with respect to their chelation properties. Chelating functionality is created by Lewis base activity. Chelating functional groups do not exchange for anions or for anionic complexes. Because many metals form complexes with various other

Editor's Note: This "Best Paper" award-winner was presented at the AESF/EPA Conference during AESF Week '98, Orlando, FL. The complete text can be found in the conference proceedings.

chemicals, it is extremely important to know something about the composition of the other ions in the feedwater besides the metal of interest.

2. The process of ion exchange represents a dynamic equilibrium between the liquid solution and the solid resin. The equilibrium is predictable only when the liquid composition is predictable. Chelating resins operate well with a relatively narrow inlet composition, with respect to pH. If the liquid composition changes rapidly, the equilibrium between the liquid and resin also change rapidly. This may result in poor performance or a complete unloading of metals previously exchanged onto the resin.

Unfortunately, many plating shops combine all of their rinsewaters into one large waste tank and then treat the waste simultaneously. Although this is not impossible to do, it can complicate the situation with respect to the resin. A chelating resin will always work better when there is good control of the composition of the wastewater leading to the ion exchange column, and when the conditions of operation are relatively constant.

Complexing agents that are frequently encountered in plating operations include cyanide, chloride, ammonia, EDTA and other liquid chelants. Most cyanide complexes can be readily destroyed by chlorination, and this process is routinely practiced. Any excess chlorine must be removed ahead of the ion exchange column to prevent oxidative damage to the resin. Certain cyanide complexes, ferrocyanide in particular, do not oxidize readily. Ammonia complexes are generally cationic in nature. In many cases, these complexes are removed

by chelating resins, although not as completely as the bare metal cation. Chloride complexes are not often seen in plating rinsewaters, because these types of complexes do not form until the chloride concentration is quite high. In attempts to treat plating baths with chelating resins, however, the formation of these complexes is very important. Chelants such as EDTA combine with metallic cations to form very stable anionic complexes. Metals that are EDTA-complexed are not available for removal by cation exchange. In cases where the pH is elevated (as following hydroxide precipitation), the metals that remain in solution are dominantly hydroxide complexes. These anionic complexes are not available for removal by cation exchange resins. In these cases, it is necessary to reduce the pH to insure that the form of the metal is cationic.

General Behavior Of Chelating Resins

Although we often consider chelating resins to be selective for a particular metal, they are actually selective for groups of ions. A cation resin has some selectivity for all cations. This is important, because even an iminodiacetate chelant, which is considered nonselective for calcium, does exchange for calcium and can be converted to the calcium form. A resin that is extremely selective for an ion, such as copper in the presence of sodium, will usually be less selective for copper in the presence of calcium. Furthermore, the resin will be selective not only for copper, but also for other divalent transition metals.

True chelants depend on ligand bonding between the metal and the resin. These types of ligand bonds are "sprung" by high concentrations of acid. No true chelating resin can operate in a highly acidic environment.

A true chelant has one or more chela, which form a ligand bond with the metal. The term ligand refers to the interaction between the resin (a Lewis base) and the metal cation (a Lewis acid). A ligand, or complex bond, is the result of stabilizing the charge balance between the resin, which has an exposed electron pair, and the metal, which is in search of electrons to provide atomic stability. Commercial chelating resins possess not only chelating functionality, but also ion exchange functionality. They capture metal cations by a combination of ion exchange and chelation. The stability of the chelated complex depends on the nature of the ion exchange functionality built into the resin, the ionic charge, the hydrated radius of the metal cation and on the influence of other ions in the solution.

Definitions

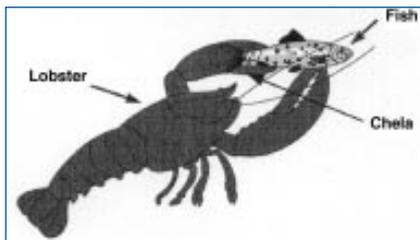
Chela—Gr. The pincer-like claw of a crab, lobster or scorpion.

Ligand—The chemical term for an electron pair donor (Lewis base) when it forms a bond with a metal cation.

Chelating resin—Ion exchange resins that have ligands that can bond with metal cations. The ligands may be in addition to or in place of conventional ion exchange sites.

Selectivity—The preference of an ion exchange material for a particular ion. Selectivity is always relative to a particular operating condition.

Chelating Lobster



Because of the relatively bulky exchange groups of chelating resins and the stability of the chelant bonds, a chelating resin's rate of exchange is limited. They cannot operate at high flow rates without a significant loss of capacity and increase of metal leakage. Optimum flow rate is around 0.5–1.0 gpm/ft³. Flow rates higher than 2.0 gpm/ft³ cause a chelating resin's performance to suffer and will probably lead to disappointing results.

Ion Exchange Selectivity

Ion exchange selectivity refers to the equilibrium constant between the solid resin phase and the mobile liquid phase. It is manipulated mathematically in the same fashion as solubility products for various salts in solution. However, so-called selectivity constants for ion exchange resins are not true solubility products, and they vary with the dynamic conditions of the process. The most significant of these variables is pH. Although we use ion exchange selectivity as a working tool to predict the general behavior of chelating resins, we also must understand that the solution variables have a profound effect on the observed selectivity. For this reason, we will briefly present the basic equations and then move onto a more practical description of how chelating resins are used.

What Makes a Chelating Resin Selective?

Ionic charge (valence)—Most chelating resins prefer divalent ions to monovalent or trivalent ions, because the chelant group has two "chela" (claws).

Hydrated ionic radius—When the size of the hydrated radius of the ion closely fits the space between the "chela," the resin is very selective for that particular ion.

Ligand bonding—Nitrogen (and oxygen) can possess an exposed electron pair, making them Lewis bases (electron pair donors). Metals that are Lewis acids form ligands with Lewis bases.

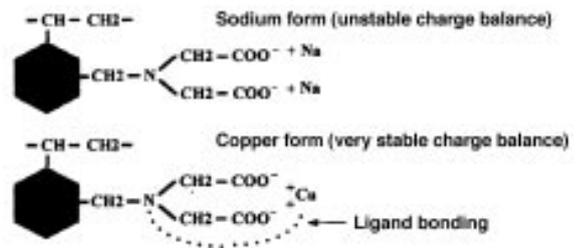
Relative Selectivities of Iminodiacetate Chelants

Ion	"K"	Ion	"K"
H ⁺		Co ⁺⁺	7
Na ⁺	0.00001	Cd ⁺⁺	15
Ca ⁺⁺	1	Hg ⁺⁺	2800
Cu ⁺⁺	2300	Pb ⁺⁺	1200
Ni ⁺⁺	57	Zn ⁺⁺	17
Fe ⁺⁺	4		

Equilibrium Equation Using the Selectivity Constant

$$K_{Ca}^{Cu} = \frac{[RX - Cu]^2 [Ca^{+}]^2}{[RX - Ca]^2 [Cu^{+}]^2}$$

Iminodiacetate Chelant SIR-300



where "K" is the equilibrium constant that describes the relationship between the ionic concentrations in the resin and in the water. Ionic concentrations are generally described in molarity.

Descriptions of Various Chelants & Their General Areas of Use

There are three types chelating resins that are commercially available and in general use. They are the iminodiacetate chelant, such as SIR-300, the aminophosphonic chelant, such as SIR-500, and the picolyamine chelant, such as Dow 4196. Other chelants, such as the pyridine chelant and the amidoxime chelant, are less commonly used. In addition to the true chelants, there are several other selective resins available that are sometimes employed in metal removal. These include weakly basic polyamine resins and the natural zeolites. Conventional ion exchange resins, such as weak acid cation and strong cation resins, are also used.

Chelating Resins

True chelating resins

- Iminodiacetate (SIR-300)
- Aminophosphonic (SIR-500)
- Picolyamine (DOW 4196)

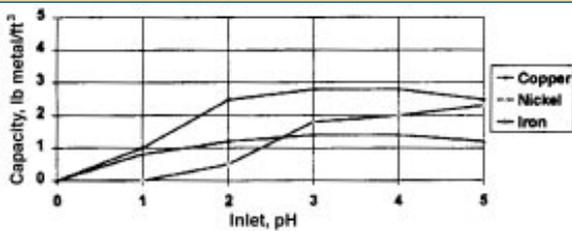
Other selective resins

- Thiol (SIR-200)
- Thiuronium (SIR-400)
- Exhausted weak base (WBMP & SIR-700)
- Natural zeolites (SIR-600, greensand & others)
- Weak acid cation resins (WACG & WACMP)

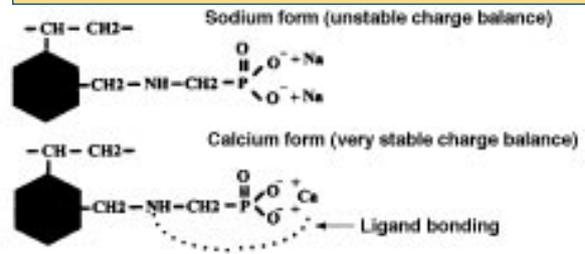
Iminodiacetate Chelant (SIR-300)

This type of chelating resin has a functional group that consists of two carboxylic acid groups, attached to a nitrogen atom, bonded to the resin's polymer structure. The carboxylic acid groups exchange with various cations in exactly the same manner as

Capacity of SIR-300 Various Metals (at saturation)



Aminophosphonic Chelant SIR-500



weak acid cation resins. In addition, the nitrogen atom provides the Lewis base necessary to form a ligand bond with the metal cation. Metals are removed by a combination of ion exchange and chelation. Most commercially available iminodiacetate chelants contain single carboxylic acid groups in addition to the double carboxylic groups. When an iminodiacetate resin is protonated (meaning that the carboxylic acid groups are attached to hydrogen ions), the charge balance of these exchange groups is very stable. Under this condition, the carboxylic groups are not available for exchange with any cations, and only the limited chelating capability of the resin is available. At a pH below approximately 2, the nitrogen atom is stabilized by the presence of hydrogen ions, and the resin has no capacity whatsoever for any other cations. As the pH increases, the nitrogen is first destabilized, then one of the two paired carboxylic acid groups is destabilized, and finally, both of the carboxylic acid groups are destabilized.

The strongest chelation occurs when one of the paired carboxylic groups and the nitrogen atom enter into the ion exchange reaction with the metal, such that half of two exchange groups are used to capture the metal.

This behavior sets up the following scenario with respect to pH.

Below a pH of 2, the resin has no selectivity for metal cations and is regenerated. Between a pH of 2 and approximately 4.5, half of the diacetate group is destabilized, and the resin reaches peak efficiency. Above pH of 4.5, the other half of the diacetate group is destabilized, and the resin becomes more selective for monovalent ions. Above a pH of approximately 9, almost all the exchange groups are destabilized. The resin's selectivity for monovalent ions

increases to the point where the removal of divalent metal cations is not preferred.

Iminodiacetate Chelant (SIR-300) Operating Limits

Dissolved Solids

- Unaffected by sodium and other Group IA metals (except hydrogen)
- Practically unaffected by calcium and other Group 2A metals
- Selectivity is affected by other complexing agents
 - EDTA blocks exchange entirely for many metals
 - Ammonia affects exchange significantly
 - Chloride has a minor effect on selectivity

pH

- Optimum pH is usually slightly acidic
- Selectivity is lower at high pH
- Loses selectivity below pH of approximately 2.0

The usefulness of the iminodiacetate chelant is in slightly acidic solutions for removal of divalent transition metals. The resin, under these conditions, is relatively nonselective for alkaline metals such as calcium and magnesium. Divalent metal cations such as copper, nickel, cadmium, and zinc can be removed very selectively. SIR-300 is useful in the treatment of plating wastes following hydroxide precipitation with lime or caustic, if the pH is reduced to the proper level.

Iminodiacetate Chelant (SIR-300) Criteria for Selection

- Removal of divalent Group IV (transition) metals
- High TDS background (>1000 ppm)
- Significant calcium concentration present (\geq metal concentration)
- pH is slightly acidic (optimum pH is approx. 4)

Aminophosphonic Chelant (SIR-500)

This chelant is quite similar in structure to the iminodiacetate chelant, with the exception that the carboxylic groups are replaced by phosphonate groups. The differences between the aminophosphonic and iminodiacetate chelant are rather subtle. The aminophosphonic chelant has a relatively higher selectivity for the alkaline metals than does the iminodiacetate chelant. The phosphonate groups do not destabilize, therefore, this resin remains more selective at elevated pH. In most applications, the aminophosphonic and iminodiacetate resins can be interchanged with each other without any observable difference in performance. The notable exceptions are operation at high pH, where the aminophosphonic resin maintains its high selectivity, and the iminodiacetate loses selectivity. In high-calcium environments, the aminophosphonic resin is less selective for other metals than is the iminodiacetate resin.

The aminophosphonic resin is primarily used in brine softening, where its selectivity for alkaline metals, such as calcium, is advantageous. It is also useful in plating wastes, where the pH cannot be reduced into the acidic range necessary for an iminodiacetate chelant. A word of caution is needed here, however, because many metals form anionic complexes at high pHs, thereby removing them from the exchange equation.

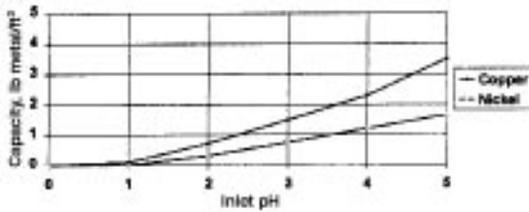
Aminophosphonic Chelant Operating Limits

Dissolved Solids

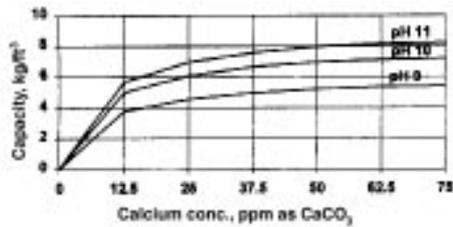
- Unaffected by sodium
- Moderate selectivity for calcium and other Group 2A metals

* Dow 4196, Dow Chemical Co.

**Capacity of SIR-500
Copper & Nickel (at saturation)**



**Capacity of SIR-500
For Calcium**



- Selectivity is affected by other complexing agents
 - EDTA blocks exchange entirely for many metals
 - Ammonia affects exchange significantly
 - Chloride has a minor effect on selectivity

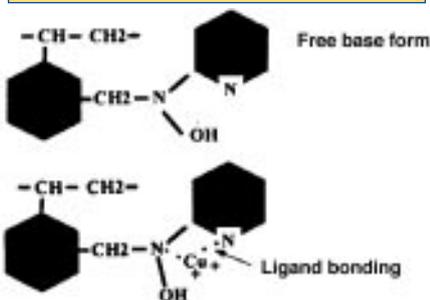
pH

- Optimum pH is usually significantly basic
- Selectivity is lower at low pH
- Loses selectivity below pH of approximately 4.0

**Aminophosphonic Chelant
Criteria for Selection**

- Removal of divalent Group IV (transition) metals in the absence of calcium and other Group 2A metals
 - High TDS background (>1000 ppm)
 - pH is slightly acidic to significantly basic

Picolylamine Chelant



- Removal of calcium and other Group 2A metals from saturated brine
 - pH is basic (optimum pH is approx. 11)
 - Temperature is slightly elevated (140–160 °F)

Picolylamine Chelant

Unfortunately, the picolylamine used in making this resin is very expensive and is available from only a few manufacturers.* This resin is much more expensive than competitively priced chelants, such as SIR-300 and SIR-500.

The picolylamine chelant is significantly different. It is a weakly basic anion resin. In use, it has no ion exchange capacity for metals. It works

solely by its chelating properties. The picolylamine chelant contains two nitrogen atoms that can form ligand bonds with metals. It has very strong chelation properties. It also has the advantage of being able to operate into a relatively low pH range (roughly pH of 1). The useful range is still limited, however, because at extremely low pHs, the exposed pair of electrons on the nitrogen atoms become stabilized by hydrogen ions.

The picolylamine resin has successfully been used to treat acid plating baths. Because of its high cost, it is seldom used in treating rinsewaters.

**Picolylamine Chelant
Operating Limits**

Dissolved Solids

- Unaffected by sodium
- Low selectivity for calcium and other Group 2A metals
- Selectivity is affected by other complexing agents
 - EDTA blocks exchange entirely for many metals
 - Ammonia affects exchange significantly
 - Chloride has a minor effect on selectivity

pH

- Optimum pH is usually significantly acidic
- Selectivity is lower at alkaline pH
- Loses selectivity above pH of approximately 8.0

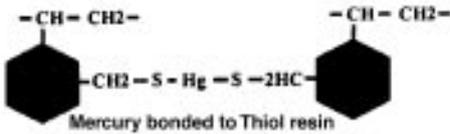
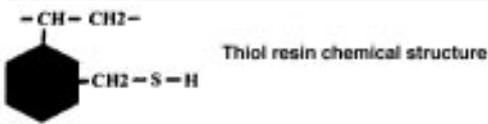
Thiol & Thiuronium Functional Resins—SIR-200 & SIR-400

These resins depend on the sulfur atom built into the functional group of the resin. The thiol-based resin, SIR-200, has an “SH” group. The thiuronium has the sulfur atom sandwiched between two carbon atoms.

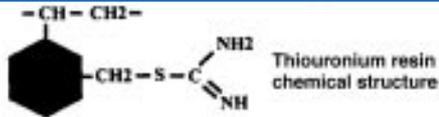
The thiuronium resin is a weak acid cation exchanger. The thiol resin is also very weakly acidic. Both resins, however, are so weakly acidic that the question of whether they are actually ion exchangers is controversial and problematic. Either the chelation with the sulfur atom is so strong that it cannot be broken by conventional chemistry, or the metal actually precipitates onto the sulfur atom.

Free Details: Circle 112 on reader service card.

Thiol Functionality Resin SIR-200



Thiouronium Functionality Resin SIR-400



In either case, regeneration of metals off of these resins is, at best, extremely difficult and most probably impossible. There is a close parallel between sulfide solubility and selectivity of these resins for various cations.

Their primary use has been in mercury removal from waste streams and for precious metal removal. In mixed wastes, where other metals are present that also form insoluble sulfide precipitants, these metals must be removed prior to the use of the sulfur-based chelants. Otherwise, the resin loads up with the tramp metals and becomes exhausted prematurely. Because of their relative inability to be regenerated, the sulfur-bearing chelants have very limited usefulness.

Thiol & Thiouronium Resins Criteria for Selection

- Primary use is removal of trace levels of mercury from wastewater
- Resin can also be used to remove noble metals, as well as other metals that form insoluble sulfide precipitants
- Due to the resins' relatively indiscriminant removal of most transition and heavy metals and the unlikelihood that regeneration will be successful, the practical applications for these resins are generally limited to removal of mercury

Natural Zeolites

The natural zeolites, such as clinoptilolites, SIR-600 and manganese greensand, have interesting properties that make them selective for certain classes of metals. The clinoptilolite type of zeolite is extremely selective for cesium and also shows significant selectivity for ammonia. Zeolites have crystalline structures that possess ion exchange functionality. They also possess holes or tunnels in their crystalline structure that allow them to capture ions with the proper atomic geometry. Clinoptilolite is exceptionally selective for cesium, because the atomic dimensions of a cesium ion is precisely the right size to fit in the crystalline tunnels. Ammonia is also close to the optimum size.

Clinoptilolite is used for cesium removal from radioactive wastewaters, as well as for ammonia removal from water where high levels of sodium are not present. It is not selective for any divalent cations and has no chelating functionality.

Natural Zeolites Criteria for Selection

- Primary uses
 - Removal of cesium from radioactive waste
 - Removal of ammonia from water against moderate levels of sodium
- Some Zeolites are used as redox media for the removal of iron and manganese
- Zeolites are generally stable in oxidizing environments and at moderate pH, but dissolve at very high or low pH

Manganese greensand has catalytic properties that are generally enhanced by the addition of a manganese dioxide coating. This media is primarily used for its redox properties, particularly in the precipitation of iron and manganese.

Conventional Ion Exchange Resins

We include a brief discussion of conventional resins because there are certain cases where they can be used. Most combined wastewaters have too high a total dissolved solids for

conventional cation exchange resins. This is because the selectivity for metals, as compared to sodium, is not much greater than unity. In order to remove the metals, it is necessary to also remove the sodium. This limits the throughput capacity of the resin to the point where it is not practical. There are quite a few systems out there, however, that mistakenly employ this technology and, frankly, they do not work very well, if at all.

TDS Limits of Various Resins Used for Metals Removal

Strong cation resin (hydrogen form)	500 ppm
Strong cation resin (sodium form)	1,000 ppm
Weak cation resin (sodium form)	10,000 ppm
Chelating cation resin (sodium form)	no limit
Mixed-bed resin	500 ppm

Cation exchange can be useful for recycling and recovering individual rinsewaters if the total dissolved solids are not too high. In these cases, the make-up water to the rinse tanks should be deionized to prevent the addition of unwanted ions that will have to be taken out later, along with the metals.

Weak acid cation resin has been overlooked in many applications, because its useful pH is limited to greater than 4 and, when in the hydrogen form, it has very little capacity for metals. In the sodium form, however, and at neutral-to-alkaline pH, weak acid cation resin has exceptionally high selectivity for divalent metals of all kinds. In some cases, this selectivity is even higher than that of chelating resins. Unfortunately, weak acid resin cannot distinguish between alkaline metals such as calcium and transition metals such as copper. In cases where calcium can be excluded from the wastewater by means of softening the make-up and where the TDS is not extremely high, however, the high capacity and relatively low cost of weak acid cation resin make it an attractive alternative to chelating resins.

The Case for Weak Acid Cation Resin

- If all water is softened to remove hardness ions, then the waste will contain only monovalent cations along with the metal contami-

nants. In this case, sodium form weak acid cation resin will have far higher capacity for metals than any of the chelating resins.

- pH must be neutral to alkaline and the TDS must be less than approximately 10,000 ppm.

Operational Considerations

When considering any type of ion exchange in a waste application, it is important to consider the two types of fouling that will prevent any ion exchange system from functioning well. We call these the “sponge effect” and the “plastic bag effect.”

The sponge effect comes from resin’s relatively good filtration characteristics. In chelating beds that remain in operation for very long periods of time, there is a tendency for suspended solids to become trapped by the resin bed and to build up in the spaces between the resin beads. The solids become a sponge and can interfere with the resin’s ability to function in two ways.

They can plug up the bed and cause channeling, interfering with the physical flow of liquid through the resin. The consequences can be very dramatic.

Either the bed completely plugs up, or the water flows through channels in the bed and does not get treated.

During the regeneration phase, if the sponge is not removed, then the chemical used in the regeneration process becomes trapped in the sponge, along with a portion of the metals. During the next service cycle, the regenerants and metals then leach out of the sponge.

The plastic bag effect is when the resin beads become coated by a foreign substance, most notably organic molecules that have limited solubility, such as oils and polymers. These organic molecules are routinely used as fluxes and have the same general effect on the resin.

They coat the resin beads with a “plastic bag” that prevents the exchange of ions. This phenomenon affects both the service cycle and the regeneration cycle. Not only do the metal ions not get removed properly during service, they also do not get cleaned off the resin bed properly during regeneration. The net result is a failure of the ion exchange system to function.

All organic-based ion exchange resins are susceptible to oxidation.

There are several types of chemical attack that occur. The general effect, however, is that the functional ion exchange groups are destroyed, thereby lowering the capacity of the resin. The polymer structure of the resin can also be attacked, resulting in swelling, softening and eventual dissolving of the resin. The consequence is that the resin is completely ruined.

It is prudent to include dechlorination and, possibly, carbon filtration in front of the ion exchange resin to remove oxidants and to adsorb organic molecules. It is important to remember that the capacity of carbon for adsorption is limited, and carbon beds must be changed regularly to maintain their effectiveness.

Chelating Resins’ General Operating Limits Part 1

Flow rates & bed depths

- All chelating resins are very flow-sensitive
 - Optimum flow is ~1 gpm/ft³
 - Significant loss of capacity occurs above 2 gpm/ft³
- Deep beds always work better than shallow beds

- 4 to 6 ft deep beds are ideal
- 2 ft deep beds are marginal
- Surface flow rates should not exceed about 12 gpm/ft²
- Pressure loss across the bed should not exceed 20 psi

Part 2

Sensitivity to inlet contaminants

- Chlorine (and other oxidants)
 - Poor. All organic ion exchangers are sensitive to oxidation (including chelating resins). Inlet chlorine should be < 0.1 ppm (preferably zero ppm).
- Suspended solids
 - Poor. Because of extremely long run lengths normally produced by chelating resins, they are susceptible to fouling by suspended solids. Inlet turbidity should be as low as possible (1 ppm is too high).

Part 3

Sensitivity to inlet contaminants

- Organic molecules
 - Polar and non-polar solvents are of no consequence. They do not harm chelating resins; however, in some cases, solvents can complex with metals and prevent them from being removed by the resin.
 - Polymers and other long chain molecules (particularly if they are only partially water-soluble) will coat the resin beads and prevent the exchange of ions.

Part 4

Sensitivity to inlet contaminants

- pH
 - All chelating resins are stable from pH < 0 to >14; however, their useful operating range is much narrower. This useful range is different for each type of chelating resin. Some chelants (notably, those with Thiol-based functionality) are inactivated at high pH.
- Temperature
 - All chelating resins are stable to at least 140°F. In general, capacity increases with increasing temperature.

Regeneration

Regeneration of chelating resins is almost always accomplished in a two-step process.

First, the resin is stripped of its contaminants by use of acid. The chelating groups are stabilized by the hydrogen ions and cannot form ligand bonds under this condition. The resin becomes non-selective for metals, and they are carried out of the resin bed along with the spent acid. The resins must be neutralized prior to use, because they are not selective in the acid form. Neutralization is accomplished by passing a basic solution through the resin. Most commonly, the base is sodium hydroxide or ammonia.

The regeneration sequence consists of some type of backwash to (hopefully) clean suspended solids out of the resin bed. This is followed by acid injection. Hydrochloric acid is most commonly used, although in some cases sulfuric acid can be employed. The amount of acid required must include an excess to insure that the pH is low enough to spring the chelant bonds and to regenerate the ion exchange groups. In addition, acid can help to dissolve precipitants that may have formed in the resin bed. When sulfuric is used, there is a potential for precipitation of metal sulfates. In practice, the chelants that are regenerated with sulfuric acid have far more problems caused by precipitation than those regenerated with hydrochloric acid. After the acid is rinsed from the resin bed, the resin is neutralized with caustic and then rinsed to quality.

Typical Regeneration Schedule

Backwash

- 50% bed expansion for 15–20 min

Acid injection

- 5–8 lb/ft³ of HCl at 5% concentration for 40–60 min

Acid rinse

- Approx. 40 gal rinsewater at any convenient flow and time

Caustic neutralization

- 2–4 lb/ft³ of NaOH at 5%, then air-mix and soak 30 min

Final rinse

- Until conductivity and pH are acceptable for process use

In the case of the iminodiacetate chelant, it is important not to neutralize with too much caustic. At high pH, this resin does not have good selectivity for metals. Although in most ion exchange applications it is not proper to add chemicals and mix them with the resin, in the case of the chelating resin, this method works rather well.

What is Needed for a Successful Chelating Bed Design?

In order to determine if a chelating resin will be successful, it is necessary to have relatively detailed information about the solution to be treated. It is surprising how often a system is put in place without any knowledge of the inlet metal concentration or the effluent requirement. It would seem obvious that these two pieces of data were invariably necessary. Yet, that hasn't always been the case.

In addition to the relative inlet and outlet metal concentrations, it is imperative that the pH and total dissolved solids of the solution be known and controlled. In cases where these parameters vary, it is necessary to know the relative range and to keep it as narrow as possible. It isn't always necessary to be exact, but it is a relatively small ballpark.

Because of the potential for fouling, it is necessary to know something about the level of suspended solids, the presence or absence of oxidants, the temperature of the solution and the presence or absence of organic contaminants. It is not usually necessary to know exactly what organic molecule might be present. We can generally group these by type and effect on the resin. For instance, solvents such as alcohol, ketones and even low molecular weight hydrocarbons have no effect on ion exchange resins. Polymers, partially water-soluble fluxes and oils of any kind, are generally very bad for resin.

The presence or absence of complexing ions (such as chloride, ammonia, EDTA and cyanide) need to be known because they change the nature of the metals in solution, and may put them in a form where removal by cation exchange is not possible.

The type of process generating the wastewater is often quite useful, because, in many cases, there is relevant experience with ion exchange from previous attempts to use it, both successful and unsuccessful. If the process is well known, the applicability of ion exchange is probably well known, and the need to thoroughly study the characteristics of the water is less important. Where no previous knowledge is available, it is helpful to perform either a lab scale column study to determine how well ion exchange will work, or to do a plant trial with a small pilot scale system.

There is no substitute for trying it out, as all the theory in the world is useless if the dynamics of the solution are not completely understood.

What Do We Need to Know?

In order to determine if a chelating resin is appropriate technology, it is necessary to know the basic details of the water to be treated.

- TDS (or conductivity) with min and max, if variable
- pH and temperature with min and max, if variable
- Basic inorganic analysis of ions (Ca, Mg, Na, Cl, SO₄)
- Presence or absence of oxidants
- Presence or absence of complexing agents
- Level and type of organic molecules
- Level of suspended solids

Conclusion

The use of chelating resins to remove metal cations is a remarkably effective tool that can be used to prevent the discharge of metals into the environment. Chelants can reduce the metal content of wastewater to practically nondetectable levels. Their use, however, may require a readjustment in the way that the wastewater from a plating shop is handled, and a careful segregation of incompatible streams.

General Limits of All Chelants

- All chelants are flow-sensitive and cannot be operated at high space velocities (low EBCT)
- They have a relatively narrow chemistry range in which they work well
- They are expensive compared to conventional ion exchange materials
- They are susceptible to fouling due to extremely large volume throughputs

For any specific application, it is helpful to consult an ion exchange specialist with previous experience in your particular situation.

Why Not Use a Chelating Resin?

- If it is not possible to carefully control inlet chemical composition, particularly pH and TDS, then chelating resins will probably not perform to expectations.
- If the TDS (and hardness) are low enough to permit other ion ex-

changers to function, then they are likely to be far less expensive to use.

Ion exchange can be a plater's best friend—if it is employed properly and the conditions are understood for how it can be used. Ion exchange can also be the plater's worst enemy if the system is put in with the mistaken assumption that it will remove any metal, from any stream, at any time. These systems are certain to fail. P&SF

About the Author

Peter Meyers is technical manager for

ResinTech Inc., Cherry Hill, NJ. His responsibilities include providing technical assistance to customers, managing laboratory operations and overseeing process and production applications. His 20 years of experience ranges from many types of makeup demineralization, polishers and softeners, to process design and hardware operation. A graduate of MT San Antonio College in California, he has written numerous papers on ion exchange and holds several patents related to water treatment.