CIMCOOL® Technical Report

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THE EFFECTS OF WATER IMPURITIES ON WATER-BASED METALWORKING FLUIDS

Water is the major ingredient in a water soluble metalworking fluid mix. It may amount to as much as 90-99% of the mix as used. Therefore, its importance in product performance can not be ignored.

Corrosion, residue, scum, rancidity, foam, excess concentrate usage, or almost any metalworking fluid performance problem can be caused by the quality of the water used in making the mix. Untreated water always contains impurities. Even rain water is not pure. Some impurities have no apparent effect on a metalworking fluid. Others may affect it drastically. By reacting or combining with metalworking fluid ingredients, impurities can change performance characteristics. Therefore, water treatment is sometimes necessary to obtain the full benefits of water soluble metalworking fluids.

Water Quality

Water quality varies with the source. It may or may not contain dissolved minerals, dissolved gases, organic matter, microorganisms, or combinations of these impurities that cause deterioration of metalworking fluid performance. The amount of dissolved minerals, for example, in lake or river water (surface water) depends on whether the source is near mineral deposits. Typically, lake water is of a consistent quality, while river water varies with weather conditions. Well water (ground water), since it seeps through minerals in the earth, tends to contain more dissolved minerals than either lake or river water. Surface water, however, is likely to contain a higher number of microorganisms (bacteria and mold) and thus need treatment.

Some metalworking plants use well water and have detailed information on its composition. Most, however, use water supplied by a municipal water works, which maintains daily or weekly analyses of the water. To estimate the effect of water on a metalworking fluid mix, measurement of the following provide sufficient data in most cases:

- **Total hardness as calcium carbonate**
- **Alkalinity "P" as calcium carbonate**
- **Alkalinity "M" as calcium carbonate**
- **Chlorides**
- **Phosphate**
- **Sulfate**
- **pH**

Total Hardness

Of the water analysis results, total hardness has perhaps the greatest effect on the metalworking fluid mix. Hardness comes from dissolved minerals, usually calcium and magnesium ions reported in parts per million (ppm) and expressed as an equivalent amount of calcium carbonate ($CaCO_3$). The ideal hardness of water for making a metalworking fluid mix ranges from 80 to 125 ppm. The term "soft" is used for water if it has a total hardness of less than 100 ppm or the term "hard" if total hardness exceeds 200 ppm.

Soft Water

When the mix water has a total hardness of less than 75 ppm, the metalworking fluid may foam -- especially in applications where there is agitation. Foam causes problems when it overflows the reservoir, the machine, the return trenches, etc. Foam may also interfere with settling type separators (since it suspends swarf and prevents settling), obscure the workpiece, and diminish the cooling capacity of a water-based metalworking fluid.

Soluble oil and semi-synthetic products, typically, foam more readily in soft water. After exposing a metalworking fluid to chips, dirt, and tramp oil for a few days, foam tends to dissipate. If it must be eliminated immediately, inspect the system for physical conditions that contribute to excessive foam. Sharp turns or drops in fluid flow, high pressure nozzles, malfunctioning pumps, etc., could be responsible. If not, foam depressants, chemical water hardeners, antifoam, or oil are useful to decrease the foam.

Hard Water

Hard water, when combined with some water soluble metalworking fluids, promotes the formation of insoluble soaps. The dissolved minerals in the water combine with anionic emulsifiers in the metalworking fluid concentrate to form these insoluble compounds that appear as a scum in the mix. Such scum coats the sides of the reservoir, clogs the pipes and filters, covers machines with a sticky residue, and may cause sticking gages.

Because soluble oils typically have the least hard water stability, hard water has a more obviously detrimental effect on them. Separation of the mix is apparent in severe cases, and is characterized by an oil layer rising to the top of a fresh mix.

Semi-synthetics and synthetic metalworking fluids may not be visibly affected by water hardness. Some are formulated with good hard water tolerance. However, dissolved minerals react with ingredients other than emulsifiers. In these reactions, the metalworking fluid ingredients change or are tied up and, consequently, the product never attains peak performance.

Dissolved mineral content increases in a metalworking fluid mix with use. After a 30-day period, the amount in the mix can increase three to five times the original amount. This results from the "boiler effect" that exists in a metalworking fluid reservoir. That is, water evaporates and leaves dissolved minerals behind. Then, makeup (usually 3-10% per day) introduces more with each addition, and they continue to accumulate. Therefore, even with water that has very low dissolved mineral content initially, dissolved minerals can build up rapidly and cause problems.

Water Treatment

There are two processes that are commonly used in treating hard water: water softening and demineralization.

<u>Water Softening</u> - In this process, the water passes through a zeolite softener. The softener exchanges calcium and magnesium ions (positively charged ions which are largely responsible for hardness) for sodium ions. In effect, water that was rich in calcium and magnesium ions becomes rich in sodium ions. The total amount of dissolved minerals has not decreased, but sodium ions do not promote the formation of hard water soaps. Corrosive, aggressive negative ions are not removed by the zeolite and can continue to build up in the metalworking fluid mix, and lead to corrosion problems or salty deposits. Thus, the use of "softened" water is not recommended with water soluble metalworking fluids.

<u>Demineralization</u> - Deionizers or by reverse osmosis units are used to demineralize water. Deionizers *remove* dissolved minerals. This is done selectively or completely, depending on the type and number of resin beds through which the water passes.

It is not necessary to obtain pure water for metalworking fluid mixes. A hardness level of 80-125 ppm is suitable. Usually a two-bed resin deionizer produces water of sufficiently high quality, as opposed to a more expensive mixed-bed deionizer needed to obtain pure water.

Reverse osmosis removes dissolved minerals by forcing water through a semipermeable membrane under high pressure. Typically, this process removes 90 to 95% of the dissolved minerals.

pH

pH is an expression that is used that indicates whether a substance is acidic, neutral, or alkaline. A pH of 7 is neutral, between O and 7 is acidic, while 7 to 14 is alkaline (basic). Water in the United States normally varies from 6.4 to 8.9 in pH, depending on the area and source of water.

The buffering ability of a metalworking fluid is far greater than that of any clean water supply. pH adjustments to the water are rarely needed.

Alkalinity

Two kinds of alkalinity exist in water: "P" alkalinity and "M" alkalinity.

"P" alkalinity is the measure of the carbonate ion ($CO_3^{=}$) content and is expressed in ppm calculated as calcium carbonate. This is sometimes referred to as *permanent alkalinity* and, as such, is not changed by boiling as is the "M" alkalinity.

"M" alkalinity is the measure of both the carbonate ion content ("P" alkalinity) and the bicarbonate ion (HCO_3^-) content. This value is also expressed in ppm, calculated as calcium carbonate. It is referred to as *total alkalinity* and *temporary alkalinity*. This is because its value can be lowered to that of "P" alkalinity by boiling.
Metalworking fluids typically perform best when the pH is between 8.8 and 9.5. They require a certain amount of alkalinity for good cleaning action, and corrosion and rancidity control. If pH and total alkalinity become too high,

however, pitting and staining of nonferrous metals may occur. Skin irritation is another possible problem. Currently, there appears to be no satisfactory treatment for alkaline water, so careful product selection is critical.

Chloride

When chloride (Cl^-) ion content is high (above 50 ppm) in the water used in making metalworking fluid mixes, it is more difficult for the product to prevent rust. Richer concentrations of the metalworking fluid mix may counteract the effect of chloride sometimes. In others, excessive chloride ions must be removed from the water prior to use by demineralizing.

Sulfate

Sulfate ($SO_4^=$) ions also affect the ability of a metalworking fluid to prevent rust, though not as much as chloride ions. In addition, they can promote the growth of bacteria. If sulfate ion content exceeds 100 ppm, richer concentrations of the metalworking fluid mix may improve corrosion and rancidity control.

Phosphate

Phosphate ($PO_4^{\equiv}$ and others) ions contribute to total alkalinity and stimulate bacterial growth, leading to problems of skin irritation and rancidity, respectively. If phosphate ions are found in the mix water, they should be removed by demineralization to prevent these problems.

Table 1 (on next page) lists these and other frequently encountered water impurities. It also describes their effects, and the problems they may cause if present in sufficient quantities.

Choice of Water Treatment

The chemistry of the water as determined by a water analysis, water quantity needs, water quality requirements, and economics (capital and operating costs) are considerations in selecting suitable water treatment.

Softening of hard water eliminates the scum that forms in some metalworking fluid mixes, but increases the possibility of rust problems.

We recommend demineralization by deionizers or reverse osmosis. Deionizers, typically, are lower in capital costs than reverse osmosis units, but higher in operating costs. Deionizers can provide higher quality water; however, resin beds must be regenerated frequently. If not regenerated frequently, water quality deteriorates and the resin beds also serve as an excellent environment for massive growth of bacteria. Reverse osmosis units do not require regeneration, but do require membrane replacement in time, depending on the water quality fed into the units. Pretreatment systems, prior to either the deionizing or reverse osmosis unit usually lengthen membrane life.

With either method of demineralization, foam can be a problem when initially charging a metalworking fluid system. To avoid foam, the initial charge could be made with untreated water (except in cases where dissolved mineral content is excessive) and subsequent makeup could be mixed with the demineralized water. Chips, grinding grit, and debris eventually would add impurities to the initial charge, but the amount is not significant when compared to using untreated water daily for makeup.

Many of our customers treat poor quality water before using it in metalworking fluid mixes. The benefits vary, depending on the water quality before treatment and the type of metalworking fluid that is used.

One customer, for example, who uses soluble oil in a Hoffman Vacu-matic reports that demineralized water has eliminated several problems that seemed to occur no matter what metalworking fluid he used.

Composition of his water, furnished by the city, varies widely in dissolved minerals content because of frequent changes in processing by the municipal water works. After passing this water through a mixed-bed deionizer, however, he obtains water with zero hardness.

The cost of demineralization roughly equals the amount that saved in reduced usage of soluble oil concentrate. In addition, filter media consumption reduced, while fluid filtration improved significantly. Demineralized water has also decreased additive usage and a corresponding incidence of skin irritation. Likewise, the amount of residue on machines is less, and it is more fluid in nature.

This customer concludes that the benefits of using demineralized water are well worth the investment. Also, he has water of a consistent quality, which eliminates one major variable when looking for the source of any metalworking fluid performance problem. ■

Water Impurities
Table 1

IMPURITY	EFFECT	PROBLEMS
Calcium (Ca^{++}) Magnesium (Mg^{++})	Precipitate soaps, anionic surfactants, anionic emulsifiers, corrosion inhibitors, and microbicides from the mix.	Product imbalance Product instability Rancidity Poor filtration Unsatisfactory production Residue in parts and/or machines Short product life
Sodium (Na^{+}) in the presence of sulfate	Chemically aggressive and tends to reduce pH value.	Mix instability Poor ferrous corrosion control
Carbonate ($CO_3^{=}$) Bicarbonate (HCO_3^{-})	Decrease chemical stability and increase total alkalinity	Residue on parts and/or machines Dermatitis Product imbalance Unsatisfactory production Short product life
Chloride (Cl^{-}) over 50 ppm	Promotes Corrosion	Poor corrosion control Product imbalance Short product life
Sulfate ($SO_4^{=}$) over 100 ppm	Similar to chloride in effect. Also promotes growth of sulfate-reducing bacteria.	Same as chloride, plus rancidity
Phosphates ($PO_4^{\equiv}$ and others)	Contribute to total alkalinity and stimulate microbial growth.	Dermatitis Rancidity Mold growth