Is Plain Water Washing Effective Enough?

Chloride, Sulfate, and Nitrate Salts on Bridges and Their Removal

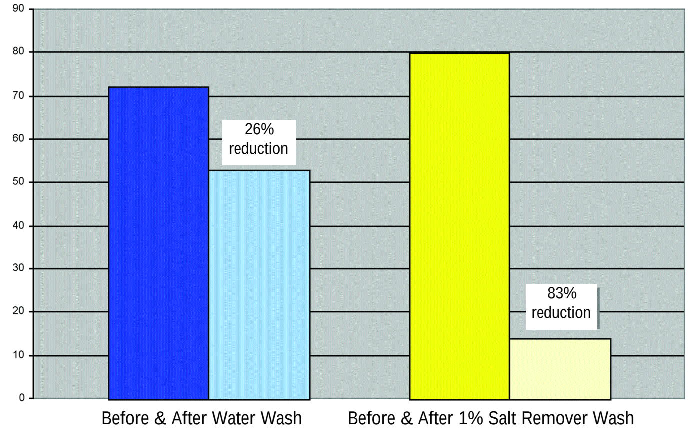
I-270 in Collinsville, IL, one of the bridges in the Illinois Department of Transportation study. Photos courtesy of the authors

By James Johnson, CHLOR*RID International, Inc. and Gary Kowalski, Illinois Department of Transportation

Though the coatings industry has widely acknowledged that salts other than chlorides, such as sulfates and nitrates, contribute to premature coating failure, little if any actual field data have been gathered. Less is known about the degree of contamination in these various environments, or if standard washing practices are effective at removing them. Early in 2001, to address these issues, research began on existing salt contamination levels on highway bridges in Illinois. The data were collected through field testing locations representing the diversity of environments across Illinois. Chloride, nitrate, and sulfate salt concentrations were measured.

The scope of the research was three environments: urban, suburban, and rural. Each was to include two bridge structures as close to each other as possible in proximity, condition, and use. One in each pair was to be washed with water alone; the second in each pair was to be washed with water and a chemical salt remover. In all, six bridges were to be tested for salt contaminants before surface preparation and after the pressure washing. All bridges were undergoing maintenance repainting during the testing so our testing had to be coordinated with the contractor's schedule.

Fig. 2: IL DOT District 1 Bridge Test & Research Project
District 1 Wash Results



The existing coating was in acceptable condition for overcoating; power tool cleaning was specified with blasting only being done at the beam ends under the joints. Washing was a preliminary step before power tool cleaning. The tests were performed over corroded areas before power tool cleaning.

Field testing was performed with a commercially available salt test kit that contains the materials needed to extract and analyze chlorides, sulfates, and nitrates from steel surfaces. The kit contains a bottle of pre-measured extract solution for each individual test. After the surface was sampled, the solution was returned to the bottle for analysis. Analyses were done on site but away from the work zone.

Fig. 1: Deicing salts have run down an open joint on the I-80 bridge, causing corrosion.

Test Sites

Urban—District 1

Two of the bridges are in District 1 on Interstate-80 in Joliet and required special testing considerations. Interstate-80 at this location is a heavily traveled roadway in an urban environment. The structures are two individual bridges built side by side and to the general public appear as a single bridge. Between the two bridges is an open joint where deicing salts have run down for some time (Fig. 1). The two beams on either side of this joint have suffered heavy corrosion because of the exposure to deicing salts. The water-only wash was performed on the east-bound bridge, and water with the chemical salt remover additive was used on the west-bound bridge. These structures also differed from the others in that there are three lanes under the bridges: an entrance lane, a driving lane, and a passing lane. Sampling was performed over the approximate center of each lane.

Table 1: Overall Average prior to Wash (urban)

Chlorides	47.34 µg/cm^2
Nitrates	15.67
Sulfates	8.20
Total salt	71.68

Table 2: Overall Average after Water Wash (urban)

Chlorides	36.78 µg/cm^2
Nitrates	11.03
Sulfates	4.17
Total salt	52.86

Fig. 3: Corrosion was mainly on the underside of the District 7 bridge on I-57.

Table 3: Overall Reduction by Water Wash (Urban)

Chlorides	22%
Nitrates	29%
Sulfates	50%
Total salt	26%

Table 4: Overall Average prior to Wash (Urban)

Chlorides	55.61 µg/cm^2
Nitrates	14.57
Sulfates	9.97
Total salt	80.08

Table 5: Overall Average after 1% Salt Remover Wash (Urban)

Chlorides	9.37 µg/cm^2
Nitrates	2.25
Sulfates	1.77
Total salt	13.50

Table 6: Overall Reduction by Salt Remover Wash (Urban)

Chlorides	84%
Nitrates	85%
Sulfates	82%
Total salt	83%

Table 7: Overall Average prior to Wash (Rural)

Chlorides	23.50 µg/cm^2
Nitrates	16.70
Sulfates	5.90
Total salt	46.10

Table 8: Overall Average after Water Wash (Rural)

Chlorides	11.70 µg/cm^2
Nitrates	7.90
Sulfates	0.40
Total salt	20.00

Table 9: Overall Reduction by Water Wash (Rural)

Chlorides	50%
Nitrates	52%
Sulfates	93%
Total salt	56%

In all, 144 surface samplings were retrieved, yielding 144 test results each for chlorides, sulfates, and nitrates.

Tables 1–3 show the salts found before and after water washing and the percent reduction in salts after washing. All washing was performed with a 3,000 psi (200 bar) pressure washer and tap water from local sources. The tap water was not analyzed. All test results are reported in micrograms per square centimeter (µg/cm^2). All levels should be rounded to nearest µg/cm^2. Tables 4–6 show the salts found before and after water wash with salt remover and the percent reduction in salts after washing. The results are graphed in Fig. 2.

Rural—District 7

The next two bridges are in District 7 on Interstate-57, south of Effingham, IL. Interstate-57 at these locations has a moderate level of traffic. The two structures are approximately one mile apart and subject to almost identical conditions (e.g., they are basically the same interstate route, have the same traffic flow, are treated with salt, and are subject to the same environmental conditions).

These two structures had very little visible corrosion. It was limited to the undersides of the bottom beam flanges (Fig. 3). The contractor set constraints that limited sampling in the passing lane. One would expect the driving

Table 10: Overall Average prior to Wash (Rural)

Chlorides	31.20 µg/cm^2
Nitrates	10.00
Sulfates	8.00
Total salt	49.20

Table 11: Overall Average after Salt Remover Wash (Rural)

Chlorides	8.30 µg/cm^2
Nitrates	3.90
Sulfates	2.40
Total salt	14.60

Table 12: Overall Reduction by Salt Remover Wash (Rural)

Chlorides	74%
Nitrates	61%
Sulfates	70%
Total salt	70%

lane to have the highest levels of contamination because it gets more traffic, more salt spray, and more exhaust emissions from the trucks. While meaningful data were gathered regarding wash reduction rates of the salts, it should be noted that the salt levels over the passing lanes before washing were significantly lower than expected. Forty surface samplings were retrieved, yielding 40 test results each for chlorides, sulfates, and nitrates.

Tables 7–9 show the salts found before and after water wash and the percentage reduction in salts after washing. Tables 10–12 show the salts found before and after water wash with salt remover added and the percentage of salts reduced by washing with the salt remover. The results are graphed in Fig. 4.

Suburban—District 8

The third pair of bridges is in District 8 on I-270 in Collinsville, IL. Interstate-

Fig. 4: IL DOT Bridge Test & Research Project
District 7 Wash Results

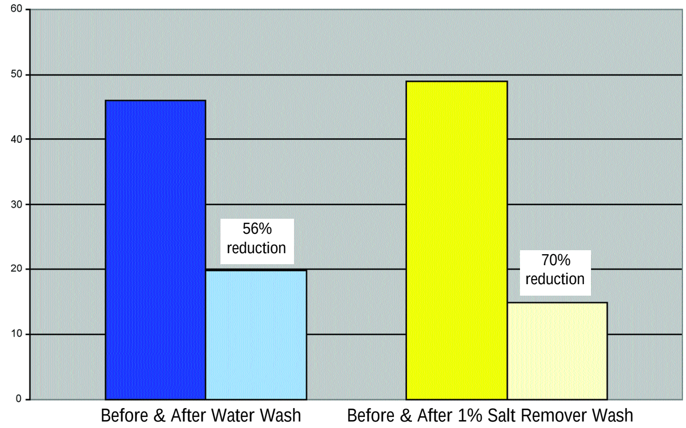


Fig. 5: IL DOT Bridge Test & Research Project
District 8 Wash Results

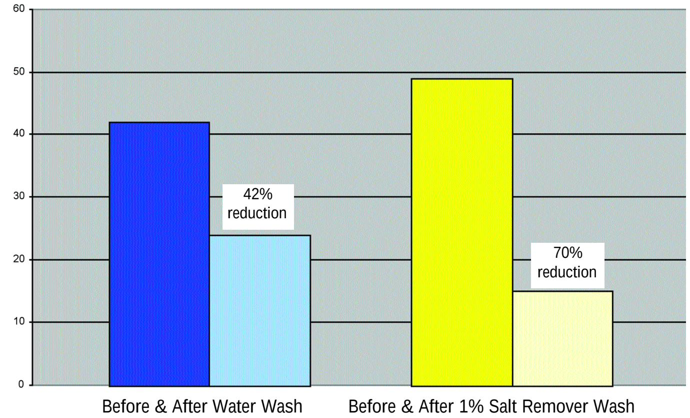


Table 13: Overall Average prior to Wash (Suburban)

Chlorides	18.92 µg/cm^2
Nitrates	7.60
Sulfates	15.59
Total salt	42.11

Table 14: Overall Average after Water Wash (Suburban)

Chlorides	10.60 µg/cm^2
Nitrates	6.15
Sulfates	7.65
Total salt	24.40

Table 15: Overall Reduction by Water Wash (Suburban)

Chlorides	44%
Nitrates	19%
Sulfates	51%
Total salt	42%

Table 16: Overall Average prior to Wash (Suburban)

Chlorides	31.20 µg/cm^2
Nitrates	10.00
Sulfates	8.00
Total salt	49.20

270 at this location is a fairly heavily traveled route in a suburban environment. The two bridges are also only one mile apart and subject to almost identical conditions. The existing lead paint was to be prepared in a typical manner: a 3,000 psi (200 bar) pressure wash, power tool cleaning per Illinois-modified SSPC-SP 3 over the entire surface, and coating application. The main areas of corrosion were the webs of the fascia beams and the undersides and top sides of the bottom flanges (photo, p. 48). Eighty surface samplings were retrieved, yielding 80 test results each for chlorides, sulfates, and nitrates.

Tables 13–15 show the salts found before and after water wash and the percentage reduction in salts. Tables 16–18 show the salts found be-

Table 17: Overall Average after Salt Remover Wash (Suburban)	
Chlorides	8.30 µg/cm^2
Nitrates	3.90
Sulfates	2.40
Total salt	14.60

Table 18: Overall Reduction by Salt Remover Wash (Suburban)	
Chlorides	74%
Nitrates	61%
Sulfates	70%
Total salt	70%

fore and after water wash with salt remover added and the percentages of salts reduced after washing. The results are graphed in Fig. 5.

Field Test Results

A summary of the average of all six bridges shows the following in units of µg/cm^2.

	Pre-Wash	Water Wash	Salt Remover Wash
Chlorides	33 µg/cm^2	20 µg/cm^2	8 µg/cm^2
Nitrates	13	8	3
Sulfates	10	4	2
Total salt	56	32	13

Conclusions

This research has shown that sulfates and nitrates exist as contaminants in significant levels in all the environments sampled. Before field testing, we expected sulfate levels to be much higher based upon the proximity of power plants, diesel exhaust, and other industrial emissions. Because the sulfate ion is more readily solubilized in water than the chloride ion when reacted with the metal surface, it is possible that naturally occurring moisture or rain has kept the levels down. The sulfate ion, in the presence of chlorides and nitrates, was found to be more readily removed than either the chlorides or nitrates. Given that chloride and nitrate ions are more reactive, these are expected to react preferentially with free metal ions and concentrate in the crevices and troughs of micropits of the surface profile. The sulfate ion, although less water soluble, has a significantly lower bonding strength to the metal substrate compared to the other two ions. If that is the case, then existing levels will vary with seasons and the ability of the rainwater to reach those contaminated surfaces.

We also anticipated that nitrate levels would be very low because contaminant sources, such as fertilizer plants, were not abundant. Further research beyond this study suggests that the cause of the nitrate contamination could be from nitrous oxide exhaust emissions from vehicles or that it could be a by-product of lightning. The U.S. Environmental Protection Agency (EPA) has reported that such vehicle emissions are a direct cause of acid rain. Nitrous oxide from exhaust emissions reacts with oxygen and moisture in the air and produces nitric acid.

It is widely known and documented in the scientific community that acid rain consists of dilute solutions of sulfuric acid and nitric acid. When fossil fuel, such as coal, is burned, the sulfur within the coal produces sulfur dioxide in the emissions. The same process generates sulfur dioxide when diesel fuel with a sulfur content is burned, emitting sulfates in the exhaust gases. When the H_2O portion of acid rain evaporates, the sulfates and nitrates are left behind and are deposited on surfaces.

Lightning has been scientifically researched for many years. It is well documented that lightning causes naturally occurring nitrogen in the air to be converted into acid rain in the form of dilute nitric acid. Some industries, such as the automotive industry, are very aware of these phenomena and take protective measures. New vehicles are often transported and stored with plastic film applied to protect the paint finish. Because exhaust emissions and lightning are common nationwide, nitrate contamination may well be far more common than is generally thought.

The results also demonstrate that pressurized water washing of coated surfaces may leave a substantial quantity of soluble salt on the surface. Salt removal was enhanced with the addition of the chemical salt remover. It was accomplished economically by incorporating it into procedures that had been established previously. One additional step was incorporated into to the washing process already in place. This had little impact on the contractors' work routine. The additional cost to add the salt remover in this research project is estimated at less than $0.10 per square foot. This number was reached by dividing the material cost by the square feet washed. Assessing the cost was not part of the study, but was of interest to the state.

Because one goal of the research was to determine the effectiveness of current procedures, no attempt was made to influence the contractors' work practices. In observing the actual work procedures as they were being performed, we thought that lower levels of soluble salts could be achieved if the pressure washer operator were to pay closer attention to operational parameters. Examples are keeping the pressure washer nozzle perpendicular to, and within 18 inches of, the work surface. Eighteen inches was the distance called for in the old specification.

Note: The Illinois Department of Transportation has since updated its bridge painting specifications, with more emphasis on the contractor's responsibility for quality control, and is requiring testing for salts (after final surface preparation) and limiting chlorides to 7 µg/cm^2 after abrasive blast cleaning.