Hydrogen sulphide (H₂S) generation in municipal wastewater treatment plants has always been present. It causes corrosion in the form of sulphuric acid attack of portland cement concrete in sewer collection/treatment systems. Gaseous H₂S condenses on aerated, wet concrete surfaces; is metabolised by sulphur-oxidising bacteria or SOB; and is oxidised to form dilute sulphuric acid (H₂SO₄).

Through the late 1970s, it was commonplace to periodically encounter H₂S concentrations as high as 10–15 ppm within sewer pipe crowns and other headspaces in conveyance/treatment structures. In such cases, acidic attack of concrete caused a gradual loss of hydrated cement paste. Occasionally, during periods of unusually low sewer flows and elevated ambient temperatures, such as during periods of low rainfall in hot months, even higher H₂S concentrations (30–50 ppm) were encountered for short periods of time. When frequent, these higher H₂S levels accelerated the corrosion of the concrete to the point where up to 1/4 in. (12 mm) or more of concrete was lost in a year.

In general, however, the H₂S levels encountered in headspaces were below 10 ppm in most municipal sewer system locations prior to the 1980s and 1990s. There were obvious exceptions to this in some larger regional systems. Average gaseous H₂S concentrations for most systems in the 1970s were approximately 2 to 7 ppm in pipe crowns and pump station headspaces. The average H₂S concentration resulted in concrete corrosion, but it was very gradual. One of the major reasons for the relatively low H₂S concentrations was the presence of heavy metals, which reduced aqueous sulphide levels in the wastewater.

Following the passage of the U.S. Clean Water Act in 1980, industrial pre-treatment was mandated to reduce or eliminate the presence of heavy metals from wastewater discharges. As such, all industrial plants putting metals such as zinc, lead, iron, mercury, chromium, and copper into their effluent were required to pre-treat the effluent (for removal of heavy metals) before sending it on to municipal wastewater treatment agencies. (In Europe, regulations also exist governing the discharge of heavy metals into wastewater systems. The most recent European legislation is the Integrated Pollution Prevention and Central Regulations (EC/61/96), which prohibit discharging heavy metals and other pollutants into watercourses, including sewers.)

This general trend toward higher H₂S concentrations has promoted much higher concrete corrosion rates in domestic treatment plants (especially in larger regional plants) than witnessed in the past. This has resulted in several significant changes in exposure conditions that must now be considered when selecting protective coatings or linings for concrete protection in domestic wastewater treatment systems. Coating systems that were effective in protecting concrete from H₂S and associated sulphuric acid attack in the past are failing dramatically in these newer, more severe environments.

For example, for many years, prior to the late 1980s, relatively thin-film (20 mils [500 microns] dry film thickness) coatings based on coal tar epoxy and amine-cured epoxy formulations provided effective corrosion protection of concrete for up to 10–12 years, as long as proper surface preparation and application practices were implemented. This included proper filling of “bug holes” and air voids in the concrete substrate with surfacers or thixotropic fillers compatible with the coatings such that relatively pinhole-free films could be provided. In recent years, these same coating materials have severely failed prematurely (within 6 months to 2 years). The failures were caused by both insufficient acid resistance and inadequate resistance to permeation by gases, mainly H₂S. Some thicker film coatings and linings (up to 1/4 in. [3 mm] thick) based on polyester, epoxy, and polyurethane resins
have also failed under these relatively new and more adverse exposure conditions related to higher sulphide generation.

Based on extensive inspection in domestic and combined industrial/municipal wastewater systems, it is the belief of this author that there are four pertinent exposure condition factors that have changed in large domestic wastewater systems. These changes are directly associated with the relatively recent increase in sulphide production. The main objectives of this article are to identify and illustrate these changes with respect to selecting coatings and linings for future long-term corrosion protection of concrete in large, regional municipal wastewater treatment plants.

**Changes in Exposure Conditions**

The four major changes affecting exposure condition severity are the following.

- Stronger sulphuric acid concentrations related to higher H$_2$S concentrations
- Greater rates of H$_2$S and other gas permeation of coatings due to more constant and higher concentrations of H$_2$S and covered headspaces
- Greater sulphur-oxidising bacteria (SOB) colonisation resulting in thicker scum layers. These layers serve as anaerobic substrates for sulphur-reducing bacteria (SRB) colonisation in which increased sulphide production occurs directly over coatings and linings. This process feeds the SOB additional sulphides directly on top of the protective coating, resulting in more aggressive acid concentrations.
- Sulphuric acid formation is more constant due to the higher and more constant H$_2$S presence. Where H$_2$S production was once much lower in sewer systems, the availability of H$_2$S as nutrition for SOB at any given headspace surface was erratic over time. With increased H$_2$S production, SOB are provided with a more constant source of nutrition. Hence, H$_2$SO$_4$ formation is more constant.

**Stronger Sulphuric Acid Concentrations**

The formation of H$_2$SO$_4$ in these municipal wastewater systems begins with bacterial sulphide production, which is followed by bacterial metabolism of H$_2$S to form the acid.$^1$

In large regional wastewater treatment structures where H$_2$S concentrations have been measured to average over 30 ppm annually, surface pH measurements on concrete have typically been in the 1.5–2.5 range.

Gaseous H$_2$S levels have generally risen in most wastewater treatment plants since 1980 from less than 10 ppm to as high as several hundred ppm. In conjunction with this, surface pH values are now commonly measured to be in the range of 1.0 and lower. In order of magnitude, this means that sulphuric acid concentrations have risen from 1–1.5% solutions to as high as 7%. This rise in sulphuric acid concentration requires that the coatings and linings selected for protecting concrete in wastewater treatment systems be reassessed. Over the past five years, several amine-cured epoxy and coal tar epoxy coating failures observed have been due to inadequate sulphuric acid resistance in large regional wastewater treatment applications.

**Increased Permeation of Coatings/Linings by Water Vapour, H$_2$S, and Other Gases**

Because odour control has become so important in waste treatment collection and treatment systems, many newer headspaces have been created by adding covers to structures such as clarifiers. These enclosed spaces combined with higher H$_2$S concentrations have increased the volume and pressure of gases to which protective coatings are exposed on a routine basis. Many coatings that provided long-term performance and protection in the past have failed within a year or two under these changed conditions. For instance, in two large waste treatment plants in the northeastern USA, amine-cured epoxy coatings up to 30 mils (750 microns) in dry film thickness (dft) failed due to blistering. Both failures occurred within 18 months of application and both were in new treatment facilities. Both failures occurred in headspaces where gaseous H$_2$S levels had frequently been measured over 100 ppm. Both coating projects included the application of epoxy surfacers to fill bug holes and air voids, and both projects included pinholing testing of the cured coatings to ensure pinhole-free films. Each of these failures involved permeation of the coatings by H$_2$S and other acid gases.

One of the most effective ways to assess a coating’s permeability is to evaluate its water vapour transmission in accordance with ASTM E96, Standard Test Methods for Water Vapor Transmission of Materials. While water vapour is the best penetrator of organic films or membranes, it also aids the penetrating ability of other molecules such as H$_2$S and CO$_2$. Both of the epoxy coatings from the failures discussed above had vapour permeance values between 0.35 and 0.41 perms (grains of moisture/hr/ft$^2$ in Hg). These values are typical for thin-film epoxy coatings. Similar coatings...
with similar properties had provided effective corrosion protection in wastewater treatment structures in the past for up to 8–10 years. In the case of the two failures cited, pH testing on unbroken blister constituents (most had been broken due to calcium sulphate formation under the coating related to H₂SO₄ attack of the cement paste) revealed values between 4.0 and 5.0. This clearly indicated that permeation of the coating occurred from the tank side. The pH of the concrete would be well above 7.0. All coatings are permeable on the molecular level, and molecules such as H₂O, H₂S, and CO₂ penetrate the film through the intermolecular spaces or voids in them. Permeation is driven by many factors including the concentration of gases, the absorption capacity of the coating or lining, headspace pressure, other physical properties of the barrier, and thermal gradient effects. For instance, where the effluent and headspace temperatures are higher than the concrete substrate temperatures, penetration will be enhanced toward the concrete substrate due to thermal gradient effects.

Due to higher H₂S concentrations and to more constant H₂S and other gas exposures, coatings selected in the future generally must provide lower permeability ratings than were required in the past.

**Stronger Sulphur-Oxidising Bacteria Colonisation**

The SOB tend to thrive in the scum layers close to the aerated surface where sufficient dissolved oxygen is available for their metabolism. Beneath the SOB-active regions, the scum layer becomes sufficiently thick and dense enough to become anaerobic. It is in these underlying regions that SRB are also established using the SOB-evolved regions as a substrate. The SRB produce sulphides that come in direct contact with the coated surface and provide additional sulphides for the SOB above.

It is this author’s belief that this condition promotes more aggressive concrete corrosion as well as more aggressive acidic exposure conditions for protective coatings.

**More Constant Sulphuric Acid Exposures**

Because sulphide production and gaseous H₂S concentrations are routinely higher in sewer system headspaces than in the past, the higher H₂SO₄ concentrations previously discussed are also present on a more constant basis. This undoubtedly accelerates the corrosion of concrete and contributes to earlier breakdown of protective coatings.

It is important to recognise that the chemical resistance of protective coatings is generally a function of chemical concentration, temperature, and length of exposure duration. This is why the chemical resistance data for polymer resin-based coatings are typically reported according to temperature, chemical solution concentration, and time of exposure (for example, no effect after exposure to 10% H₂SO₄ after 7 days at 75 F [24 C]).

The major point here is that many coatings can resist a particular chemical exposure for periodic durations of time. How-
ever, the same coatings will break down under sustained, long-term exposure to the same concentration of the same chemical solution at the same temperature. The axiom applies to large wastewater collection and treatment systems today. As an example, a coating is unaffected by exposure to H₂SO₄ at 10% at 75 F (24 C) after 7 days but is degraded severely after 6 months in the same exposure. The end result is that more chemical-resistant coatings will be required to achieve long-term corrosion protection.

**Major Material Selection Criteria Recommended**

Due to the changes in municipal wastewater system exposure conditions discussed above, material selection guidelines or criteria are presented herein for future consideration when coatings are selected for protecting concrete exposed to aerated and closed headspaces.

A. Improved H₂SO₄ resistance
B. Lower permeability
   1. Water vapour transmission
   2. Water absorption
C. Increased film thickness
D. Resistance to bacterial action
E. Successful field performance history
F. Optimum adhesion
G. Other selection criteria

Suitable applications may include the following.

- Headworks
- Covered primary clarifiers
- Grit chambers
- Effluent trenches or channels
- Crowns of pipes
- Pump station wet walls
- Diversion troughs or channels
- Manhole structures

The major material selection criteria to consider will differ somewhat between new construction and rehabilitative concrete corrosion protection. In new construction, ambient conditions and cleanliness of surfaces will be more easily controlled to ensure proper application and curing of certain coating or lining systems. In rehabilitative cases, products that provide more tolerance to moisture and other existing site conditions are more attractive.

**Improved H₂SO₄ Resistance**

Resistance to sulphuric acid of at least 10% concentration at 90 F (32 C) for a minimum of two years’ constant exposure is suggested as a requirement. This criterion should not be superseded by resistance of a coating to higher concentrations of H₂SO₄ over a shorter period of time. Generally, the experience in sewer systems has shown that if no detrimental effects related to acid resistance are observed in a coating in a particular constant exposure condition for two years, they are not observed at lower solution concentrations after
two years. The 10% concentration is conservative. Testing reported by Redner, Hsi, and Esfandi of the County Sanitation Districts of Los Angeles County and by others supports this recommendation.2

The criterion should be that no detrimental effects such as blistering, chemical degradation, or embrittlement are acceptable. Minor gradual loss of film thickness and colour changes in the coating or lining can be accepted provided no other deterioration occurs, the film thickness loss is predictable, and the film is sufficiently thick for the predictable service life.

**Lower Permeability**

Two key criteria are recommended for lower permeability coatings and linings.

*Water Vapour Transmission*

Testing in accordance with ASTM E96, Method E should be used to evaluate coatings for resistance to permeability by H2O vapour, H2S, CO2, and other gases in wastewater systems. Because polyvinyl chloride (PVC) linings at a minimum thickness of 30 mils (750 microns) have the longest and best performance history in high H2S sewer environments, the water vapour transmission values for PVC should be taken as the baseline. Cast-in-place, anchored PVC sheet linings
have performed well for at least 30 years where exposed to H₂S gas concentrations routinely over 30 ppm and when constantly exposed to 100% relative humidity. This is not to suggest that PVC linings are the only material choice, but rather that low permeability values similar to PVC linings should be considered when selecting coatings and linings.

Some coating manufacturers and engineers will argue that moisture vapour or water vapour transmission will reach equilibrium provided good adhesion is obtained. This is true for more homogenous substrates such as carbon steel. However, the adhesion of coatings to concrete substrates is never as uniform as the adhesion of coatings to steel substrates due to the heterogeneous nature of concrete. Establishing the uniformity of substrate profile achievable with steel substrates is not possible with concrete substrates. Also, concrete is a far more permeable and absorptive substrate than steel. Due to ir-

### Table 1: Characteristics of Coatings that Failed by Blistering

<table>
<thead>
<tr>
<th>Generic Coating Types</th>
<th>Average DFT mils (microns)</th>
<th>Average Tensile Pull Adhesion per ASTM D 4541 psi (kPa)</th>
<th>Time in Service Prior to Blistering Failure (Months)</th>
<th>Water Vapour Permeance perms</th>
<th>Average H₂S (Gaseous) Concentration Exposure (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cycloaliphatic amine-cured epoxy</td>
<td>19 (475)</td>
<td>350 (2,400)</td>
<td>14</td>
<td>0.54</td>
<td>35</td>
</tr>
<tr>
<td>Coal tar epoxy</td>
<td>28 (700)</td>
<td>375 (2,600)</td>
<td>12.5</td>
<td>0.62</td>
<td>37</td>
</tr>
<tr>
<td>Polyester glass flake-filled</td>
<td>36 (900)</td>
<td>400 (2,800)</td>
<td>15</td>
<td>0.160</td>
<td>50</td>
</tr>
<tr>
<td>Straight amine-cured epoxy glass flake-filled</td>
<td>12 (300)</td>
<td>400 (2,800)</td>
<td>10</td>
<td>0.021</td>
<td>42</td>
</tr>
<tr>
<td>Vinyl ester</td>
<td>32 (800)</td>
<td>375 (2,600)</td>
<td>13</td>
<td>0.018</td>
<td>50</td>
</tr>
<tr>
<td>Elastomeric polyurethane</td>
<td>29 (725)</td>
<td>350 (2,400)</td>
<td>11</td>
<td>1.76</td>
<td>32</td>
</tr>
</tbody>
</table>
The average water vapour permeance for 30-mil-thick (750-micron-thick) PVC is 0.002 perms (following ASTM E96, Method E). It is, therefore, suggested that a key selection criterion for coatings in potentially high H2S exposures be a water vapour permeance of no greater than 0.002 perms at 30 mils (750 microns) in thickness as determined by ASTM E96, Method E.

**Water Absorption**

Testing for water absorption in accordance with ASTM D570, Standard Test Method for Water Absorption of Plastics, should also be used to evaluate coatings or linings for improved re-

<table>
<thead>
<tr>
<th>Property or Field Characteristics</th>
<th>Requirement</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile strength (ASTM D412)</td>
<td>&gt;2,000 psi (&gt;14 MPa)</td>
<td>Based on experience of successful coatings/linings</td>
</tr>
<tr>
<td>Elongation (ASTM D638) to failure</td>
<td>&gt;200%</td>
<td>Based on experience of successful coatings/linings</td>
</tr>
<tr>
<td>Abrasion resistance (ASTM D1044 Taber Abraser)</td>
<td>&lt;50 mg loss; 1,000 gm load; 1,000 cycles; 14-day cure prior to test</td>
<td></td>
</tr>
<tr>
<td>Coefficient of thermal linear expansion (ASTM D696)</td>
<td>As low as possible relative to concrete</td>
<td>Concrete CTLE is generally 5.5 x 10^-4 in/in/F. Evaluate based on similar field performance also.</td>
</tr>
<tr>
<td>Ability to bridge active existing concrete cracks</td>
<td>Will be based on tensile strength or elastomeric elongation properties</td>
<td>Many products may meet all but this criterion, which requires cracks to be treated separately with appropriate sealant.</td>
</tr>
<tr>
<td>Moisture tolerance for application and cure</td>
<td>Any improvement in moisture tolerance is an advantage for these applications.</td>
<td>Environmental control will often be necessary for products to perform successfully.</td>
</tr>
<tr>
<td>Ambient condition tolerance</td>
<td>The more tolerant coatings are to lower substrate and air temperatures and to higher relative humidities, the more attractive they are for these applications. Suggested requirement is min. temp. 50 F (10 C) substrate max. 90 F (32 C). Maximum relative humidity = 85%</td>
<td>Environmental control will often be necessary for products to perform successfully.</td>
</tr>
<tr>
<td>Ease of ability to achieve pinhole-free coating/lining</td>
<td>The easier, the better</td>
<td>Property is needed because of typically difficult working conditions in systems.</td>
</tr>
<tr>
<td>Complete cure time and recoat limitations</td>
<td>The shorter the complete cure time is for return to service, the better. The shorter the minimum recoat, the better.</td>
<td>These requirements must be balanced against other criteria, compliances, and ultimate successful performance.</td>
</tr>
<tr>
<td>Degrees of difficulty for sealing around and onto penetrations</td>
<td>The less difficult this is, the better the system is.</td>
<td>Being able to apply the system from the concrete onto metallic pipes or mechanical penetrations is very advantageous. Balance this against performance overall and available access duration.</td>
</tr>
<tr>
<td>Product has compatible concrete repair products.</td>
<td>As stated</td>
<td>Repair is better for schedule when reblast cleaning is not required. However, deep repairs may necessitate this. Repair product cure times are essential here.</td>
</tr>
<tr>
<td>Product’s ability to be applied on overhead/vertical surfaces without sagging</td>
<td>As stated</td>
<td>This is obvious but is often overlooked.</td>
</tr>
<tr>
<td>Adhesion to metal substrates such as ductile iron and carbon steel (ASTM D4541)</td>
<td>&gt;500 psi (&gt;3 MPa)</td>
<td>Product will often have to terminate onto metallic penetrations or mechanical components that interrupt the concrete surface.</td>
</tr>
<tr>
<td>VOC compliance</td>
<td>The US EPA established 450 g/L (3.7 lb/gal.) for most industrial maintenance coatings.</td>
<td>The requirement also is important for safety in confined spaces.</td>
</tr>
<tr>
<td>Flash point</td>
<td>100 F (38 C) or higher</td>
<td>It will be very unusual for headspace temperature to be greater than 90 F (32 C), but this issue must be reviewed case by case for safety in confined spaces.</td>
</tr>
</tbody>
</table>
sistance to permeation. Again, following the proven long-term success of PVC linings under high H₂S gas exposure, it is recommended that the water absorption range for PVC be used as a basis for selecting coatings and linings for reduction of permeability under the severe wastewater conditions defined above. The water absorption rate for PVC at 30 mils (750 microns) thick is 0.1 to 0.5% in 24 hours. Hence, it is recommended that another important selection criterion be that the material have a water absorption of no greater than 0.5% in 30 days following 14 days of cure in accordance with ASTM D570.

Both the low water vapour permeance and low water absorption criteria will ensure that the coatings/linings used will be sufficiently resistant to permeation by water vapour, H₂S, CO₂, etc., to avoid failures related to such penetration to the substrate. It is well known that a low water absorption and low water vapour transfer rate increase a coating’s resistance to ionic passage, reduce the likelihood of osmotic blistering, and improve the coating’s dielectric strength. These are all positive attributes for increasing a coating’s or lining’s service life under these newer, more aggressive exposure conditions. With respect to water absorption and equilibrium achieved through desorption when good adhesion has been provided, it must again be emphasised that concrete substrates are very different from steel substrates. Concrete is a much more porous substrate than steel. This fact, combined with the irregularity of surface profile and non-uniformity of adhesion possible for coatings on concrete, means that such equilibrium is far more difficult to achieve.

The author performed failure analyses on six domestic wastewater projects where permeation with subsequent blistering was the mechanism of failure. In all cases, the coatings had been 20 to 35 mils (500 to 875 microns) dft with tensile pull adhesion values averaging 350 psi (2,400kPa) or greater. The coatings were all pinhole tested prior to placement in service. All had properly cured. All had generally good film quality. All were applied over epoxy or acrylic surfacers to fill air voids, etc. The coating types included amine-cured epoxy (two), coal tar epoxy, polyester, vinyl ester, and elastomeric polyurethane. One of the amine-cured epoxies and the polyester coating were glass flake-filled. All six coatings failed in headspaces such as pipe crowns. All six systems mainly failed due to permeation and blistering after 12 to 15 months in service. The average reported gaseous H₂S concentrations were between 25 and 50 ppm based on periodic monitoring (grab samples). The reported water vapour permeance values for these six products are listed in Table 1 on p. 47.

Table 1 shows that water vapour transfer rates for these six different products are all well above the criterion suggested by this article. Incidentally, there are many products besides PVC sheet linings that meet the recommended criteria. For example, one 60-mil-thick (1.5-millimeter-thick) amine-cured epoxy had a water vapour permeance of 0.0024. One 1¼-inch-thick (3-millimeter-thick) vinyl ester mortar lining had a permeance value of 0.0014 and a water absorption of 0.4% in 30 days.

There are, of course, other factors to consider when assessing the permeability of coatings and linings. One important factor has to do with the fact that such physical properties as water vapour transmission and water absorption are typically based on laboratory-prepared and -tested samples. Achieving the same physical properties for a product on large surface areas under more adverse field conditions may not always be possible. This is why actual in-service performance and various field characteristics of materials must also be addressed by the selection criteria. These issues are addressed later in this article. Other factors include thermal gradient effects, conditions for curing, ensuring good adhesion to the substrate, and additional application-related considerations.
Increased Film Thickness

Field experience indicates a high probability of failure for coating systems having total dry film thicknesses of 30 to 35 mils (750 to 875 microns) or less. Conversely, coating/lining systems over 50 mils (1,250 microns) in thickness, especially those having low permeability and sufficient chemical resistance, have had a higher degree of success in domestic wastewater headspace applications.3

Thicker systems might increase the opportunity for improved film quality, i.e., fewer pinholes. They can do so by allowing better coverage over rough, irregular, and porous concrete substrates. Also, water absorption percentages and water vapour permeance values may generally be lower over time than thin film systems due to the intermolecular distance through which penetrants like water must travel. Furthermore, such thicker linings or coatings might help to close off discontinuities related to entrapped air escaping from the concrete. This, of course, assumes that the products have relatively low permeability properties.

Based on the experience described above, it is recommended that linings selected for the applications pertinent to this article have a dry film thickness of no less than 50 mils (1.2 mm). This dfth criterion must be qualified relative to the substrate profile following surface preparation. The 50-mil (1.2-millimeter) thick system should be applied over a sub-


strate profile similar to 60–80 grit sandpaper. Any profile depth which is greater should be filled using an appropriate surfacer or mortar compatible with the coating or lining system or by more of the coating/lining system itself.

Resistance to Bacterial Action
With higher sulphide production in today’s large domestic wastewater systems, there is greater SOB colonisation. Hence, the resistance of the coating or lining to bacterial action or breakdown is more important than ever. The best way to insure this is to select coatings or linings that have a bacterial oxygen demand not less than 700 ppm. This is not a new criterion for coatings and linings used in sewer headspaces, but rather is a criterion that should invariably be checked to avert bacterial attack problems in the corrosion protection system.

Successful Field Performance History
Another suggested criterion for material selection is that all candidate coatings or linings must have performed well under similar exposure conditions for over five years. The critical issues there are similar exposure conditions and verification of performance over time. Similar exposure conditions should be carefully assessed for the application in question. The following data should be identified.
• H₂S concentration—The average should be based on periodic measurements over the past year or two with another 50 ppm added to the average to be conservative. This will help to assure performance under excursion conditions. If no average can be identified, select the highest H₂S concentration value available under warmer summer and/or low rainfall conditions, whichever is higher. Use that concentration as the criterion value.

• Surface pH—Measure the surface pH in the scum layer at the top of the waterline in the headspace to be protected. Take several measurements to obtain an average. Use that pH value to assess prior field performance of the candidate product. Most domestic wastewater agencies will be willing to provide you with such data or will take measurements to obtain such data. This also should be conservatively evaluated. Take the lowest pH data available for your field performance evaluation.

• Other data—Determine if the reference projects include degrees of turbulence in wastewater flow similar to those of your application. Always be careful to determine that good reported performance over time was, in fact, verified by recent reinspections.

Optimum Adhesion
As previously discussed, any product’s physical properties and performance are directly impacted by the quality of its adhesion to the concrete substrate. So a good adhesion capability must be included in any material selection criteria. Generally, a tensile pull adhesion value equal to or greater than 350 psi (2,400 kPa) will serve a coating’s or lining’s performance well under typical domestic wastewater applications. This should be measured using portable adhesion testers in accordance with ASTM D4541, Standard Test Method for Pull-off Strength of Coatings Using Portable Adhesion Testers. Of course, all other properties being equal, the better the adhesion is, the better the coating or lining performance will be. This means the surface preparation must provide sufficient and uniform surface profile and a high degree of substrate cleanliness, and it must remove soluble contaminants such as chlorides, sulphates, and sulphides.

Other Selection Criteria
The criteria presented above cover the major changes in material selection considerations recommended by this article. There are, of course, many other important criteria for any concrete protection project in domestic wastewater system headspaces. However, these criteria have always been critical. These other major recommended criteria are presented in Table 2 on p. 49.
Summary

In summary, the major material selection criteria recommended by this article include:

- resistance to 10% H₂SO₄ at 90 F (32 C) for a minimum of two years,
- water vapour permeance value of 0.002 perms at 30 mils (750 microns) per ASTM E96, Method E,
- water absorption of no greater than 0.5% in 30 days following 14 days of cure (ASTM D570),
- dry film thickness of 50 mils (1,250 microns) or greater over substrate profile or anchor pattern equivalent to 60–80 grit sandpaper,
- biological oxygen demand of not less than 700 ppm,
- successful field performance of at least five years under similar exposure conditions as delineated herein,
- tensile pull adhesion of coating/lining to properly prepared concrete of no less than 350 psi (2,400 kPa) per ASTM D4541, and
- careful evaluation of the other normal material selection criteria described under Table 2.

These recommended material selection criteria are specifically qualified for wastewater treatment headspaces where gaseous H₂S concentrations frequently average 25 ppm or higher and attack-region surface pH values are below 3.0, where periodic excursions for several weeks each year reach average H₂S concentrations of 50 ppm or greater, or where surface pH volumes below 3.0 are measured. Similarly, these recommended criteria pertain to conditions where H₂S concentrations are unknown, but where surface pH measurements give values typically below 3.0. These recommended selection criteria are conservative but are based on the proven performance of PVC linings and other coating/lining materials under the higher sulphide production levels present in today’s regional wastewater collection/treatment systems.

At H₂S gas concentrations of 5 ppm and lower, concrete degradation due to sulphuric acid attack is not a significant problem. At concentrations between 5 and 25 ppm, there are insufficient data available to establish material selection criteria other than past performance histories of various products. For the exposure conditions defined above, the present article attempts to provide the reader with specific material selection criteria that will ensure the successful corrosion protection of concrete in domestic wastewater collection systems and treatment plants.

References


Also Consulted: CRC Handbook of Chemistry (1990), pp. 494–499.