By Matthew Wirth, MWC

Using Science When Solving Water-Quality Issues

Water professionals are asked to solve water-quality issues. The task requires sound science and engineering to accomplish solutions that are reliable, maintainable, and environmentally responsible. Within the water industry, technologies are evolving, offering new and better ways of achieving results while conserving water and reducing solids waste to drain. This is all well and good, but as professionals, we must review the science tied to the solution and consider the hypothesis used in drawing the conclusions that were in turn used to prove results.

To be useful in science, a hypothesis (such as a manufacturer's claim) must be testable and falsifiable. "Falsifiable" means there must be a possible negative answer to the hypothesis. In other words, it must be possible to subject the hypothesis to a test that generates evidence for or against it. It must also be possible to make observations that would disprove the hypothesis if it were false. There is no room for "I believe," "I think," "testimonials show," and "I feel." Function trumps feeling, meaning science is quantitative, not qualitative.

Therefore, real science is "testable, measurable, observable, scalable, and repeatable."[1] If the technology prescribed for a water-quality solution lacks testability, measurability, observability, scalability, or repeatability, it is not actual science and is not a solution; it is faith or assumption and has no place in developing water-treatment answers. Before using a new application, system, technology, and/or great idea, look very closely at the research and claims for signs of falsifiable results.

What Is a Law of Nature?

Scientific laws are principles used to predict the behavior of the natural world. Chemistry, physics, thermodynamics, and hydraulics follow the laws of nature and are scientific law. Water-system design uses these disciplines to predict physical outcomes and develop solutions that meet the requirements of being TMOSR (testable, measurable, observable, scalable, and repeatable.) Scientific laws are well supported by observations and/or experimental evidence.

The laws of science are constant and unchanging. Mother Nature has no room for pseudoscience or exaggerated claims. It is real or it is not. Scientific laws refer to rules, frequently written as equations, for how nature will behave under certain conditions. Unfortunately, some of the new "scientific theories" relating to water treatment take liberties with natural law and make claims that are not measurable or testable.

Scientific theories are overarching explanations of how nature works and why it exhibits certain characteristics. Theories explain why we observe what we do, and laws describe what happens. If a technology claims to be a change in scientific law, it must be TMOSR: testable, measurable, observable, scalable, and repeatable. If science is none of these, then it is not actual science; it is faith and unusable in solving real water-quality issues.

Where to Look for Real Science

Membrane technology, ion exchange, filtration, and separation all offer operating conditions founded in research and development using science. They state conditions of performance based on scientific findings using an identified challenge water and environmental conditions. Membrane elements are affected by total dissolved solids (TDS), temperature, and pressure. The effect of these conditions on the permeate production is clearly explained in the conditions of operation. Ion exchange offers charts and curves describing capacity, throughput, and leakage performance related to temperature, brining levels, and influent TDS. Filtration and separation are subject to multiple physical conditions, and the effectiveness is provided and limits are identified. If a technology does not offer its conditions of operation and expected effectiveness, beware.

Any technology that states a result that is not testable is not real. If water passes through a device and the influent and effluent test exactly the same, then what happened? In industrial and high-purity systems used in health care, production and process require validation by industry, state, and/or federal regulatory agencies. The system must treat to a performance specification for removing impurities to a defined level, and the components must satisfy a level of compliance, i.e., NSF 61, sanitary, or the system cannot be used.

Water-quality standards include, but are not limited to, Type III primary grade water for simple washing and rinsing; Type II purified water for laboratory use, rinsing instruments, and other applications requiring reverse osmosis (RO)/distilled water; and ASTM Type I ultrapure water for highly sensitive applications, such as semiconductor and pharmaceutical production. There is no reason to design and place any system—residential, commercial, industrial, etc.—that cannot be validated to a standard acceptable to the end-user. It must have a predictability of outcome and be sustainable, reliable, maintainable, and environmentally responsible to be considered professional work.

One example of a nontestable solution is the no-salt softener. Basic water knowledge defines hard or soft water based on its makeup of mineral salt. Water with elevated calcium, magnesium, and other cationic divalent mineral salts is called hard water. A water softener, using cationic ion-exchange resin, replaces the hard minerals for sodium, and the water becomes soft. The water tests as soft, and the resin offers a measured capacity. If a device allows the hard minerals to pass through without changing the levels of hardness, then the water tests the same at the inlet and outlet, and the device is not softening the water. Further explanations are moot points; the water is soft, or it is hard.

If a pass-through device claims to alter calcium, then ask this question: Based on peer-reviewed, objective criteria, what is the driving mechanism that takes a soluble calcium ion to an insoluble calcium carbonate?[2] According to the solubility rules, the bicarbonates are soluble, so calcium bicarbonate is soluble in water. It dissociates in water and produces calcium ions, which are the cause of hardness. In researching a no-salt softener, do you find the technology falsifiable? How did the bicarbonate become carbonate?

Stochiometrics

O_2 Required = Xf + Xm + Xhs				
where,	Reaction Factor	Fe (iron) mg/l (ppm)	Mn (manganese) mg/l (ppm)	H_2S (sulfide gas) mg/l (ppm)
Xf = Fe Reaction Factor	0.14	7		
Xm = Mn Reaction Factor	0.29		0.8	
Xhs = H_2S Reaction Factor	0.49			2
			Theoretical O_2 Demand	2.192

Another example is oxidation using ambient air or ozone. Claims of systems operating over a broad pH and removing high amounts of iron, manganese, and/or hydrogen sulfide gas (H_2S) can be true. The caveat to this is does the water possess an oxygen reduction potential (ORP) to achieve the stated results? The greatest iron filter, using the greatest catalytic media built to function at prescribed flow rates and throughput, fails if the ferrous iron, manganous manganese, and hydrogen sulfide cannot be oxidized and reduced to a filterable state because the water is trending toward anoxic (low oxygen). The water analysis gives the stoichiometric calculations that dictate the ORP requirement. This process is not one-size-fits-all. One must do the work to ensure the results are accurate and measurable. Or, are the calculations proving the treatment plan is falsified?

Testable and Measurable

"NSF was founded in 1944 as the National Sanitation Foundation to help standardize sanitation and food safety at a time when the United States had no national sanitation standards. NSF is an independent, global organization that facilitates the development of standards, and tests and certifies products for the food, water, health sciences, and consumer goods industries to minimize adverse health effects and protect the environment. The history of drinking water treatment standards goes back to 1970, when President Richard Nixon established the Environmental Protection Agency to address the extent of contaminants existing in our drinking water. As Americans began drinking more water, the demand for home water filters increased. The industry grew quickly, and the market became flooded with low-quality, ineffective, and sometimes toxic products. NSF facilitated the development of the first American National Standard for filtration in 1973 followed by additional standards throughout the 1980s and today."[3]

Water professionals should look for recognized product certifications and understand what the NSF standards include. When looking for a solution for a Level I contaminant, NSF 53 and 58 test RO systems and filtration for removal percentages of contaminants based on a challenge water.

An RO NSF 58 certification states that a tested RO system will remove the contaminants listed in the certification document. The claims under NSF/ANSI 58 testing for an RO system will give a reduction percentage based on the contaminants the manufacturer requested in the test based on a developed challenge water. The challenge is a solution mixed in the laboratory containing the contaminants at a predetermined level. There are no throughputs with this testing. Nothing states how long the system will perform or how many gallons will pass through the system before requiring maintenance. RO is a crossflow device with a permeate and concentrate flow that sheds separated solids to drain—it cleans itself.

CLAIMS AVAILABLE UNDER NSF/ANSI 58

Standard NSF/ANSI 58 includes test procedures to verify various claims that can be made for your RO system, including:

- Required
  - TDS (total dissolved solids) reduction
- Optional
  - Cyst reduction
  - Hexavalent and trivalent chromium reduction
  - Arsenic reduction
  - Nitrate/nitrite reduction
  - Cadmium reduction
  - Lead reduction
  - Barium reduction
  - Turbidity reduction
  - Fluoride reduction
  - Copper reduction
  - VOC reduction
  - Asbestos reduction
  - Perchlorate reduction
  - Radium 226/228 reduction
  - Selenium reduction
  - Pentavalent arsenic reduction

The NSF/ANSI 53 certification differs from the NSF/ANSI 58 in that it states a throughput. NSF 53 is for dead-end filtration and adsorption. It, too, is tested with a challenge water, and the manufacturer states how many gallons/liters can pass through the filter and still remove the chosen contaminant.

Say the manufacturer orders a test run on PFAS for 5,000 gallons at a determined flow rate. The testing lab mixes the challenge water and runs 5,000 gallons through the filter at two gallons per minute (gpm). If, at the end of the test, the water passing through the filter is still at the manufacturer's claimed level, it passes for a designated percent of PFAS.

One very important factor to note is that the certification is for 50 percent of the gallons put through the filter during testing. In other words, the certified throughput of this filter that produced 5,000 gallons of water at 2 gpm is 2,500 gallons at 2 gpm. The reduction of tested gallons offers a safeguard to give time for the filter exchange.

It's important to know the test method of the solution prescribed and to base the continuing maintenance on the level of protection required. An NSF 58 device requires an ongoing water-testing program with scheduled filter, sanitation, and membrane changes. NSF 58 is measurable for a reduction result but carries no usage volume (throughput). An NFS 53 solution requires throughput monitoring and scheduled filter change prior to exhaustion. NSF 53 is measurable for both reduction results and throughput.

If the solution for health concerns being considered has no NSF/ANSI certification or other third-party performance certification, is it appropriate? Water professionals don't guess, and they don't mess around with people's welfare. Test and verify. Real solutions are observable, scalable, and repeatable. Is installing an NSF 58 solution a workable plan? Yes or no? Will an NFS 53 solution offer the monitoring to ensure in-time replacement? Yes or no?

Conclusion

Working through a solution and testing it against falsifiable results offers a scientific approach to placing systems and technologies. Technical professionals must determine if a solution stands up against proper scrutiny using real science and sound engineering. This is the pledge that professionals make to their customers when they act as advisors and solve water-quality challenges. WCP

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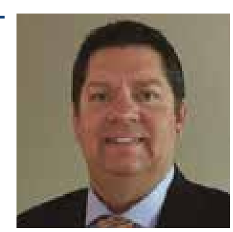
About the author



Matthew Wirth is a water professional with 42 years of experience working at multiple levels in the water industry. The scope of his experience includes heavy industrial and commercial systems to public and private well applications, both customer direct and nationwide distribution. In addition to his work as frontline field support (including design, application, and service troubleshooting), Wirth is an approved trainer for several industry organizations and state CEU programs and an author for trade periodicals. He holds a Water Conditioning Master license in the state of Minnesota and a bachelor's degree in organizational management and communication from Concordia University in Saint Paul, Minnesota. He received his engineering training at the South Dakota School of Mines and Technology in Rapid City, South Dakota. Wirth is the general manager of the Pargreen Sales Engineering-Water Division in Chicago, Illinois. He can be reached at (630) 433-7760.