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Water 4.0: The Past, Present, and Future of the World's Most Vital Resource by David Sedlak (Yale University Press; 332 pages; 2014)

Like the pipes that deliver clean water to urban dwellers but remain out of sight, the past narrative and future trajectory of urban water development often remains shrouded in obscurity. In *Water 4.0*, environmental engineering professor David Sedlak sheds light on the past, present, and future of the world's most vital and, strangely, taken for granted resource: water. Usually, most people have no need to know the hidden world of water. Scientists and engineers manage water without interruption. Only when crisis occurs is the public forced to recall water's necessity. According to Sedlak, water is on the verge of making itself known again. Technology used in our water systems is becoming outdated. Water systems built in the nineteenth century and then retrofitted with twentieth century technology may not be up to twenty-first century challenges. Sedlak brilliantly and entertainingly presents the amazing, yet rarely discussed history of urban water development. Although he suggests an array of possible solutions to the looming crisis, his solutions only provide vague guidance. The result is that, instead of proposing a specific way forward, he creates more concerns and unanswered questions.

Since many of the challenges in water development repeat themselves, recalling water development's history illuminates its current state. Sedlak presents a fascinating overview of the developments in urban water management, starting with Water 1.0 and moving towards his suggested Water 4.0. Sedlak gives credit for Water 1.0 to the Romans. As Rome's population grew, so did its need for water. In order to meet this demand, Roman engineers designed the first complete water system. The system imported water, distributing it to homes and public spaces through a network of pipes; and once used, water was exported back to the environment. But with the collapse of the Roman Empire, cities no longer had the engineers and armies necessary to maintain a complete public water system. Europe took on a rural character and individuals resorted to gathering water in buckets.

Water 2.0 concerned the purity of incoming drinking water. Growth in industry and population in the United States caused river contamination. This resulted in outbreaks of cholera and typhoid fever. In response, American bacteriologists began running water through sand filters. While sand filters produced only modest results, engineers noticed that a film formed on the sand—what is now known as biofilm. Engineers observed that biofilm consumed water borne pathogens. Applying this discovery, engineers created filters that relied on both biofilm and sand to purify water. Thus, Water 2.0 was born and the

results were staggering. Not only did the new filtration systems reduce cholera and typhoid fever, it also contributed to increased life expectancy.

Water 3.0 focused on contaminated water. Under Water 1.0 and Water 2.0, cities had simply piped contaminated water back into rivers. This practice made down-stream consumers and wildlife the recipient of untreated runoff. To treat wastewater, engineers again pressed microbes into service. Unfortunately, even this method had its problems. Microbes need time to break down harmful matter. Due to varying volumes of water, which created fluctuations in velocity, cities experienced bottlenecking in the treatment process. The answer, Sedlak explains, was to ensure that sewage flows at a constant rate. Engineers did this by creating holding ponds. These ponds consolidated water and regularized the rate at which contaminated water passed through filters. This process allowed microbes to purify harmful waste before being piped back into rivers.

Sedlak's examination of urban water's history begs the question: what direction does Water 4.0 need to take? Reflecting on Water 1.0, Water 2.0, and Water 3.0, Sedlak observes that even though key features like filtration and sewage have been added to modern water systems, cities still use the same centralized model developed by Rome. The problems posed by Water 3.0, however, are ongoing. Sedlak says that most urban water infrastructures are outdated. For the most part, pipes installed before and after World War II need replacement.

Peering into the future, Sedlak believes that Water 4.0 will be forced to assume one of two paths. First, Water 4.0 could pick up where Water 3.0 left off and continue on the current trajectory created by Rome by replacing pipes as they deteriorate. This approach will address problems more gradually. But this solution might only be a Band-Aid, a temporary fix, where perhaps a cure is needed. Sedlak explains that in the long run, the quick fix of pipe replacement may only put off radical infrastructure changes needed to finally settle the approaching crisis. Ultimately, it may be more expensive.

The second, more radical approach involves decentralizing Rome's centralized model. Under a decentralized water system, each household becomes more self-sufficient. This involves capturing rainwater from roofs, using efficient appliances, and reusing water. This strategy will enable cities to abandon plumbing and sewer systems. Water will be managed holistically and the environment will be integrated into the conveyance and treatment of water. This approach, Sedlak points out, depends on the particular circumstances of each city's water issues.

While Sedlak proves skillful at telling the history of urban water development, his analysis falls short at *Water 4.0*. Instead of exploring the well-documented problems and solutions of the crystalized past, Sedlak's analysis begins to encounter problems that are still waiting for answers. Overall, he does not propose a definitive solution. Lacking guidance, readers may begin to wonder whether Sedlak dodges the bullet with a case-by-case, circumstance specific approach because there is no readily available systemic solution.

The solutions Sedlak does offer seem less than satisfying. On the one hand, gradual pipe replacement seems to merely delay expensive comprehensive upgrades. On the other hand, the solution of decentralization seems like a viable option. But on further examination, one may wonder whether the proposal represents progress or rather just the decomposition of a system that cannot be maintained. This possibly stems from the fact that many of Sedlak's suggested solutions amount to shifts in individual attitude and practice rather than technological or engineering advancements. Although both solutions seem less than satisfying, a water crisis appears inevitable and these solutions must be considered.

In sum, *Water 4.0* contains important and interesting lessons in the history of water development and provides more than ample fodder for thought. Although Sedlak's proposed solutions are less than satisfying, he deserves praise for a clear exhibition of the problems. Sedlak skillfully raises awareness of an ultra important issue in a fascinating, page-turning way. *Water 4.0* is an enlightening book and should be read by all beneficiaries of clean urban water.

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