The Half-Life of Policy Rationales

How New Technology Affects Old Policy Issues

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Avoiding the Grid

Technology and the Decentralization of Water

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Traditional Water Facilities

During the twentieth century, American communities depended mainly on public utility monopolies for their water supplies.[1] Textbook expositions of "natural monopoly" might suggest to an unsuspecting reader that such local monopolies evolved in a free market (Musgrave and Musgrave 1993, 51–53; Rosen 1988, 322–25; Stiglitz 1993, 411–60; a summary of the argument may be found in this volume's introduction). However they may have originated, monopoly waterworks practices are now so entrenched that nearly all local governments have them and hardly anyone gives the matter a second thought. Water is so essential to a community's life and well-being that few seriously consider leaving its delivery to the vagaries of free enterprise in a market economy that has even the slightest possibility of high prices, conspiracy, and segmentation. So, to preempt such an outcome, the public has allowed municipal water and sewage works to be monopolized under political control. The costs and revenues of government-operated utilities tend to become commingled with the other costs and revenues of government. Taxes cover any operating deficits and debt service, and even if the water is metered, the patrons pay a rate that bears little relation to water's actual cost or value. As a result, municipal utilities have little incentive to conserve, and payment for the system is left to the vagaries of politics.

Once utility operations are taken over by the government, the real cost of the water supplied is buried in arcane municipal funding and accounting practices. In the new city of Rancho Palos Verdes, California, for example, the local franchised water monopoly charges the householder from \$3 to \$4 per 1,000 gallons delivered, depending on his monthly usage as metered plus a surcharge based on the size of his meter. In addition, the householder's share of the county property tax is about \$13 per year per \$1,000 of assessed valuation, with about 10 percent going to the various water supply, sewerage, and drainage agencies. This levy adds about \$1 per 1,000 gallons (25 to 33 percent) to the average household's direct cost of water.

Political monopoly arrangements are generally assumed to be in the public interest. Accordingly, their privileges by law and taxation are rarely questioned. But is a monopoly really inevitable in providing a community's water supply? It might seem so by looking only at the bargains in metered charges for raw tap water.

Is the political administration of communitywide waterworks really desirable? What are the real costs of the buried assets, wasted resources, environmental insults, immunity from liability, and postponement of progress? The answers to these questions depend in part on the state of relevant technologies.

A Qualified Laissez-Faire Regime

To address the question of whether technology is enhancing the case for free enterprise, we need to specify what laissez-faire would mean in the delivery of water. Assume that it is possible to remove all but a residue of constraints left over from preexisting government operations. We might then have a "qualified" laissez-faire regime applicable to the community's water business. Such a qualified laissez-faire regime might be characterized as having

- Free entry into and exit from any and all businesses subject to contractual commitments freely entered into.
- No regulation of pricing, product quality, or operations.
- No guarantees of return on capital invested or protection against operating losses from any cause whatsoever.
- Equal and fair access to government rights-of-way and reasonable easement rights.
- Equal and fair access to all government-controlled water-related facilities for any and all purveyors of water. Those facilities would

> include lakes, rivers, canals, bays, beaches, aqueducts, aquifers, and the like, as well as such government-sanctioned privileges as easements, eminent domain powers, and other exclusive or subsidized access to government-controlled rights-of-way.

The difference between a qualified laissez-faire policy and a fully laissez-faire regime for water supply and delivery is that the latter would have no government-held resources, eminent domain powers, or regulations.

Which community utility paradigm benefits the populations served more—government or free enterprise? Some actual historical experience in less developed regions of the world seems to contradict the conventional wisdom favoring politically monopolized water utilities. In the less developed countries where political government has been relied on exclusively to provide utilities, these places are notoriously deficient, almost without exception, in hygienic water supplies accessible at affordable cost to the general public. Recent experience has found private enterprise to be decidedly superior to a traditional government monopoly in bringing water accessibility, quality and service to a community (Cowen and Cowen 1998).

Policy and technology are mutually dependent. Private ownership is motivated, flexible, and forward looking. According to the economic historian Werner Troesken, "about 20 percent of all private water companies had installed filters by 1899. Only 6 percent of all public companies had installed filters by 1899" (1999, 946). Private enterprise uses more technology, but outside our window we find a water sector dominated by government. Although many water supply and treatment technologies are available "on the shelf," few are widely used. Indeed, the implementation of technological advancements by political jurisdictions moves so slowly as to be imperceptible. Fully 100 years after bell-and-spigot cast-iron pipe was developed, the municipal water bureaucracy in Philadelphia still used bored logs, and the city was hit by a typhoid epidemic lasting for 50 years while its officials pondered a relatively newer innovation called filtration (see Steel 1947, 3). We can only speculate how, under an alternative regime, currently underutilized technologies might be used more efficiently, but such is the task at hand.

In a qualified laissez-faire environment, a private enterprise producing and distributing water to a community would have to be innovative. It could not rely on price protection, taxes, or assessments to cover its operating deficits or obtain certain traditional economies of scale available to government-controlled central facilities. It could not be compelled to connect unlimited numbers of customers to large central plants by networks of pipelines. Without the ability to resort to eminent domain powers to condemn and traverse property lines, centralizing facilities under a privately owned monopoly would be difficult. However, a laissez-faire rendering of community utilities would not be restricted to a centralized approach but would also allow a decentralized, *on-site* approach. Rather than examine the notion of competing private water grids, therefore, we will explore the viability of on-site water systems.

The On-Site Alternative

On-site utilities operated as private enterprises can be economic units of significant size. Even though they are generally deprived of the economies of scale available to central utilities under political administration, they can serve major realty operations like multiple-tenant income properties under undivided ownership without any multiple transits of property boundaries.

The on-site approach allows an entrepreneur to compensate significantly for scale-related costs by providing opportunities to minimize initial and recurring costs. On-site utilities offer an incentive for recycling valuable materials, thereby avoiding additional transportation costs and adding value in the form of by-products. In addition, by using new technologies for the intensive treatment of wastewater on the site, additional potable water can be made available to consumers without further exploiting natural resources. By avoiding such development costs, the initial costs facing a new homeowner would be sharply reduced, and the transaction costs associated with permitting and connecting to existing utility networks might be eliminated altogether.

Localizing waste treatment on the site where the waste is produced could significantly curtail the volume of water used and the sewage to be removed and collected at some large, remote treatment site. A community's dependence on large-scale public works for reservoirs, pumping stations, water lines, sewerage, and treatment plants could, therefore, be minimized if not eliminated altogether. Realty operators and homeowners using on-site utilities would have no reason to deal with public utility commissions, city public works departments, county utility districts, sanitation districts, consolidated sewer works, groundwater recharge agencies, waste recovery and recycle agencies, metropolitan water districts, and standby water reserves. Avoiding the politics, uncertainties, and strings-attached might, alone, be an enormous cost savings.

The on-site utility approach would not rely on the regimentation of property owners. Technological developments have now matured to the point that on-site utility arrangements can be competitively marketed, economically constructed, and reliably operated. Such facilities can offset all the so-called market-failure problems, real or imagined, used to justify central utility monopolies. Technological means are now available to support a full spectrum of affordable on-site water services.

The Cogeneration Factor

Cogeneration refers to the utilization of a single source of energy to "cogenerate" a multiplicity of utility functions. For example, fuel oil may be burned in a heat engine (such as a diesel) to generate electric power, and the otherwise wasted heat generated in the process may subsequently be used to produce hot water, space heating and cooling, and water treatment as by-products.

Let us assume that our laissez-faire regime would also permit the on-site supply and delivery of electricity on an entrepreneurial basis (a scenario explored by the chapter by Wayne Crews and me in this volume). Heating and cooling as well as other energy uses like water supply and waste disposal could be packaged to obtain significant additional cost reductions and profit opportunities. An integrated on-site utility systems scenario is appealing because it can combine a variety of domestic energy uses in a cogeneration hierarchy to maximize energy utilization and service potential.

The technologies that make integrated energy systems practical in domestic residential applications are not esoteric but are actually quite familiar to engineers. However, their use thus far has been limited to larger-scale commercial and industrial applications for which the cost of obtaining building and operating permits from local political authorities is smaller in relation to prospective gains from the installation.

An Alternative to Turning up the Heat: Closing the Windows

Water that is found in nature can have such widely varying properties that some sources of it may even be overlooked. Thus, Coleridge's Ancient Mariner anguished, "Water, water, every where, Nor any drop to drink."

On a raft cast adrift on the ocean, a shipwrecked mariner may not stop to consider that the medium supporting him is 96.5 percent pure water. For him, it may as well be concrete unless he is prepared to extract the potable quantities he needs to drink in order to survive. How much does he need, and how can he extract it? The "how much" depends on how he behaves and how he uses the crude water supply he finds at hand. The "how to extract it" involves physics and engineering. In any case, although the answers to both questions may not be common knowledge, they are not complicated.

The shipwrecked mariner's essential intake of pure water for metabolic purposes depends on the water content of his diet as well as the rate of water loss from his skin, gut, and kidneys. If he suffers from colic, his infected bowel will pretty surely doom him to death by dehydration. If he is exposed to tropical summertime sunshine and air temperatures, his skin will lose more water to the air than he may find suitable to drink. However, if he understands that he can immerse himself in the aqueous medium that his raft is floating in and allow his skin to mitigate this loss, he can subsist on substantially less drinking water.

Similarly, conditioning the air of buildings can reduce the residents' essential water consumption requirements by reducing their transpiration losses. Moreover, the water transpired by the inhabitants of buildings can be recovered by condensation on the air conditioner cooling coil surfaces where it must be condensed to maintain a comfortable equilibrium in the ambient humidity level.

Hierarchy of Water Qualities

The details of and the possible choices among the many kinds of water-refining technologies are manifold, and most are beyond the scope of this chapter (see Ingram et al. 1969). Complicating this matter further is the question "what for?" Obviously, getting drinkable water from seawater is a problem different from getting suitable supplies for firefighting or lawn irrigation—or from getting drinking water in turn from such supplies. Indeed, it may be appropriate to apply different standards of water quality to a community's various water uses (see *Treating Farmstead* 1972). A hierarchy of standards can facilitate significant economies in serving the common demands for utilities without threatening public health and safety.

The value of a water-quality hierarchy is exemplified in the chemical engineering technology known as *continuous countercurrent decantation* (Perry 1941, 1600). Countercurrent washing and rinsing procedures are used in pulp mills, plating plants, and other water-intensive industries to conserve water consumption per unit of output. The electroplater knows, for example, that to rinse a given batch of his product to a certain level of cleanliness in the highest-quality water available to him requires a volume of water that is 100 times greater than the volume of parts. He finds that he can clean the same quantity of parts to the same level of cleanliness by rinsing the dirtiest parts in the dirtiest water and progressing in a countercurrent manner from dirtiest to cleanest in successive steps. As a result, he finds he needs only a tenth as much water for the job. The analogous household situation might be to use dishwashing, laundry, and bath rinse water as toilet-flushing water. Thereby, the most stringent cleaning stage (dishes, persons, clothing, etc.) is accomplished in the "cleanest" water, and the least stringent wash (the toilet bowl) uses the same water after it has leached out, dissolved, and entrained the solid wastes from the antecedent operations.

Nonetheless, the traditional pattern of public utility service is burdened with a single quality standard for all domestic water supplies because the political establishment is obliged to provide water to all users for all purposes through a common piping system. If the quality supplied is adequate for the most demanding purposes, most of the water will have been treated beyond necessity. The greater part of the treatment outlays will have been inappropriate, if not outright wasted. At the same time, the small fraction that is destined for heath-sensitive usage will most likely be undertreated.

Typically, municipal utility systems serve a mosaic of users connected in common via piping networks run in dedicated rights-of-way and easements from an exclusive provider. In the case of water supply and sewage, the provider is usually the political establishment itself.

An all-purpose system will be held liable for personal injury from infection or toxicity, because it must provide water quality that is safe for the most biologically and physically sensitive uses and users, even though the least sensitive uses comprise the bulk of the community's demand for water. Furthermore, all users are served by an extensive piping network that is vulnerable to infiltration by the pathogens and toxins that reside in the subsurface environment through which the pipes must pass. Moreover, because the political establishment is obliged only to serve all alike, the people most vulnerable to waterborne disease cannot be any better protected than the least vulnerable.

Treatment Processes

It is clear that those water treatment technologies applicable to all-purpose central utility systems will differ from those that will be most effective and economical in an on-site setting. The mission of the conservative administrators of central utility systems is to satisfy the public's thirst for water without complaint. But the only approach available to them is establishing a sufficient quantity and quality of water in a reservoir and then attempting to maintain that quality as the water flows from the reservoir throughout the system all the way to the end users. The administrators focus on technology advancements in pipe materials, piping practices, bulk treatment facilities, chemical methods, and the like. The gradual introduction of plastic pipe, "hot-tapping" tools, horizontal-drilling machines, and chemical agents with residual bacteriostatic properties has helped maintain the status quo in community services provided by central plants, notwithstanding the significant growth in population and groundwater pollution in recent years. However, these technologies have nothing to do with water quality and quantity improvement.

Small-scale and on-site utilities marketed, constructed, operated, and managed by entrepreneurs represent bona fide alternatives to the traditional water service monopolies. Private ownership of water treatment facilities demands a degree of specialization that is alien to bureaucratically administered central plants. Private ownership in a laissez-faire environment demands profit-seeking management under which the owner/provider is personally liable for damages. Therefore, the most appropriate technologies for this approach must be both economical and reliable. Although true private enterprise is relatively rare in the field of community utilities, there is, nevertheless, an inventory of assorted technologies waiting to be used in individual and on-site utility systems.

In recent years, various new water treatment techniques have been advanced and perfected. Some are new processes using existing materials. A few are old processes refined with the application of new materials and apparatus. Others use new processes involving new materials, processes, and apparatus. The most common of these processes, each of which has its virtues and limitations, are listed next, presented in approximate descending order of the severity of water treatment performed and the rigor of quality control attainable. The quantity and quality of energy used by these processes are approximately in the same order when the chemicals and controls required to implement them are taken into account.

Distillation: Nature's own method of water purification and recycling. Distillation is a thermal process. It is the oldest, most complete, and most reliable method available for extracting pure water from raw sources. During the past thirty years, significant refinements have been made in the methods and means for large-scale recovery from saline-water sources like the ocean. One example is given at the end of this treatment (Lowi 1983). Small distilling units of varying design, size, and energy efficiency have been developed and available since about 1970 for household, laboratory, and marine applications.[2]

Deionization: Inorganic ion separation by chemical means. This is a relatively recent advancement of the old-fashioned "zeolite" cation (positively charged ion) exchange process in which certain natural minerals called *zeolites* arranged in porous granular beds substitute sodium ions for calcium and magnesium ions in a stream of water flowing through the bed. Such ion substitution improves soap solubility and has become known popularly as *water softening*. New ion exchange resins have been developed since World War II using new methods of chemical synthesis. By combining these new materials in the same bed, both anions (negative ions) and cations can be captured to remove virtually all ionizable material from water, including most dissolved polar solids and liquids. This process is widely used in research laboratories to prepare mineral-free water. Like all related though less severe ion exchange processes, including water softening and chelation, deionization requires consumable chemicals for regeneration.[3]

Electrodialysis: The process of using an ion-selective membrane to demineralize water. Electrochemical technology developed after World War II produced ion-selective membranes or electrodes capable of demineralizing water as with ion-exchange resins but without any chemical regeneration. In the early 1960s, anticipating cheap electric power from atomic energy, electrodialysis was seen to offer an improvement in the economics of large-scale water demineralization. Like a storage battery, electroplating bath, or other electrochemical cell operation, electrodialysis requires large quantities of expensive direct-current electricity.

Reverse osmosis: A physical membrane process for the partial separation of dissolved solids in water. The selective permeation of larger molecules in solution, whether or not ionized, can be accomplished with a thin film of certain plastic materials, provided that sufficient pressure is applied in excess of and in opposition to the osmotic pressure of the solution. Membrane and cell construction have developed rapidly in recent years to reduce the cost and improve the durability and range of separation. Some products are available at reasonable cost for undersink installation in a household to purify tap water using service pressures only. These are now widely available through water-conditioning services (see www.culligan.com). Purification of exceptionally mineralized water requires somewhat higher pressures than available from domestic service, which calls for pumping and expensive membrane support. A less expensive alternating current is used to drive the pumps.

Chelation: Selective inorganic ion modification. Selective ion exchange such as the softening processes for reducing "hardness" (increasing soap effectiveness) is familiar and used in many households. Numerous advancements have been made since the early 1900s, and many products and systems are now widely available through water-conditioning services like Culligan. However, there are many other applications for chelating agents in water such as increasing the solvation in laundry machines or forming filterable precipitates and flocculating and coagulating them for clarification purposes. Chelation involves the use of disposable chemicals.

Anaerobic digestion: A culture of anaerobic organisms used to reduce the mass and concentration of dissolved and suspended organic materials in aqueous wastes. Certain bacteria are cultivated in a body of aqueous waste containing digestible organic material. These anaerobes obtain their metabolic oxygen from chemically bound oxygen in the material in solution rather than from air. Since organic ash is formed as a result of biotic digestion, the process is analogous to submerged incineration. Subsequently, the ash can be flocculated, coagulated, precipitated, and settled using chemical aids (see Chelation). This is the type of treatment process that takes place in common septic tanks. The process requires periodic sludge removal and possibly inoculation and culture boosting.

Aerobic digestion: A culture of aerobic organisms used to reduce the mass and concentrate the bulk of aqueous organic waste. A stream of aqueous organic waste is treated by aeration to allow air-breathing microbes to digest the organic material, reducing it to filterable inorganic solids and gases like carbon dioxide and water. This process is carried out in aeration ponds, cascades, and trickling filters. A trickling filter is like a cooling tower but is usually constructed as a porous rock pile. This process requires pumping power, filtration, and sludge removal. It is generally known in the municipal sanitation field as *secondary treatment*.

Filtration: A solids-laden stream of water is passed through a porous solid medium that presents a large surface area to the fluid. A bed of so-called sharp river sand through which water is made to flow represents perhaps the oldest engineered water treatment process. Beds of activated carbon particles (charcoal) are used to trap odorous chemicals like chlorine and sulfur compounds as well as inert particles. Diatomaceous earth, the filter medium of preference for swimming pools, is used to improve clarity and remove sediments. Silver-bearing materials may be included in the media to improve bacteriostasis. Some filters may be reconditioned by back flushing to remove trapped material. Others require replacement of the filter media themselves. Filters have been produced in myriad forms ranging from whole-house units to cartridges fitted to the faucet (see www.culligan.com).

Disinfection: Live microscopic and possibly pathogenic organisms are killed in solution. Dousing water-containing microorganisms with molecular chlorine, ozone, or other chemicals that liberate these molecules in solution denatures the live organisms, rendering them nonpathogenic. The effective level of concentration of the disinfectant varies with the organism and the chemical. Irradiation of the infected water stream with ultraviolet radiation of certain wavelengths also is effective, both from the generation of ozone in situ and by direct germicidal radiation. The effectiveness of any of these methods of disinfection depends to a large degree on prior filtration to reduce competition from noninfectious matter and to improve clarity.

All these processes have been investigated at one time or another under government auspices, usually with significant involvement in the research by the various, grant-funded, nonprofit universities and government laboratories. Rarely have private businesses with vested interests in the results, such as realty enterprises, participated in this work. Nevertheless, the greater usage of these water treatment technology developments is to be found outside government utility establishments that rely on exclusive, single-purpose central stations serving an extended geographical area in which there is diverse ownership and activity.

The appropriate technical approach for establishing and maintaining engineered and managed energy systems on an entrepreneurial basis is likely to be as integrated and flexible as possible. A wide assortment of technologies are considered in order to minimize costs and liabilities while maximizing marketable benefits because the entrepreneur has no access to taxes or other noncommercial sources of funds to cover his operating deficits or his liabilities for damages. Self-containment combining all appropriate technologies carries a high premium for private enterprise because of the high cost of transporting bulk commodities like water and aqueous wastes from a distance and across property lines. The integration of utility services on site leads to technical divergence in utility practices from those that now dominate centralized systems.

Application to a Typical Community Situation

The Existing Problem

In a front-page article, the *Pahrump Valley* (Nevada) *Times* highlighted a common problem with Nevada tap water, stating that "75 to 80 community water systems in this state are contaminated with arsenic and as much as $525,000,000 will be required to remedy the situation" (June 9, 2000). The article went on to state that to finance an unspecified government remedy to this so-called toxic contamination problem, water rates might have to be quintupled in the near future.

The use of the word *contamination* implies blameworthy human mischief calling for government action to protect property owners and the public from injury. However, what is actually happening to the public water supplies in Pahrump and other Nevada communities is a natural local environmental phenomenon, and one that has long been familiar to geologists and hydrologists.

Instead of sensationalizing the matter, the *Pahrump Valley Times* might have simply informed its readers what a fine solvent water is and how it naturally leaches soluble elements and salts from local mineral deposits existing in and around the local aquifer that is the source of their supply. As a result, readers might have learned that their tap water could very well contain unsavory concentrations of salts and elements because the soil in the state of Nevada is exceptionally rich in arsenic as well as silver and other heavy metals. Then, they might have informed their readers of alternative, more wholesome sources of water available, indicating that some of these might even be available at the local supermarket for mere pennies a gallon. They might have pointed out that still other alternatives might be available delivered at the door or produced on-site with available appliances at an adequate level of reliability and affordable cost. So informed, the public might realize that they have in their own hands technically and economically feasible alternatives to the proposed government action.

The minerals in community water sources such as Pahrump's were present long before the water was tapped for human use. And since it was tapped from the ground, generations of consumers have used it in ignorance of its chemical composition. Until recently, almost all water consumers and many waterworks managers had no better idea of water quality than what they could surmise from its color, odor, and taste. Even so, by the beginning of World War I, waterborne diseases were already on the wane, largely as a result of improving personal hygiene practices like hand washing, cooking, bottling, and canning.

The government's actual technical prospects for cleaning up the general water supply to cooking-and drinking-quality standards are quite unrealistic. While it might technically fulfill its promise to purify the water to wholesome levels at the reservoir, whether it could do so without excessive cost to the taxpayers is another question. Maintaining reservoir quality as the water passes through antiquated delivery systems buried in public easements and in defective piping embedded in private buildings is an unrealistic expectation. The Romans were doing about as well two thousand years ago without the benefit of spectroscopy, bacteriology, chlorination, and PVC pipe. Nowadays, new technology makes central utility practices mimicking the Romans anachronistic.

A New Approach: Public Water as a Bulk Commodity

The proliferation, elaboration, and refinement of water treatment and reuse technologies make it timely to look at public water supplies from a wholly new perspective. Technical information, products, and services available directly to water consumers are rapidly expanding and increasingly accessible via the Internet.[4] Countertop and undersink appliances integrate filtration, reverse osmosis, or distillation with ultraviolet radiation and refrigeration for continuous antisepsis. Some of the water purification appliances combine hot and cold dispensers. Such products are readily available and becoming better and cheaper every day.

Curiously, the water treatment technologies and products that are practical and economical for in-home and on-site applications are already more sophisticated than those found in most central plants. Moreover, high-quality, germ-free, and palatable water is widely distributed in bottles at supermarkets at low retail prices. So, instead of depending on the government to do the impossible, to treat the community's whole water supply as a refined commodity, more and more people are taking their water supply into their own hands and becoming healthier in the process.

It is a fact that the great bulk of the water in a mixed-use community is for cooling, sanitation, firefighting, and landscaping purposes. Since none of these uses is for persons, a communitywide water supply might better be considered as just a bulk commodity, a raw material supplied to consumers for further processing for particular needs as they wish. Consumers might use such a supply directly out of the pipe or ditch for sanitation and landscaping purposes and then refine only a small part, as needed, for cooking, drinking, and bathing.

On-Site Refining

To minimize the dependence on instant access to municipal water supplies or receding water tables of whatever quality, a homeowners' association or individual homeowners could either install their own engineered treatment system and storage tanks or else convert their septic tanks and drain fields to such. They could then maintain an inventory of bulk water to be replenished at will using various economic sources, whether they be city water mains, tank trucks, rainstorm runoff catchments, or reclaimed water from certain prior uses like laundry and bathing.

Water is already commonly refined in the home. For example, many households use water softeners to improve the cleaning power of their laundry water using less soap. Then they install reverse-osmosis or distillation units to remove the excess minerals in their cooking and beverage water. Charcoal filters are commonly installed at the tap to improve the hygiene and taste of the water they use for drinking, cooking, and ice making. Modern refrigerators are connected to a source of filtered and sometimes also demineralized water under pressure to operate the ice and chilled-water dispensers.

Distillation is the ideal process for preparing water for personal consumption because it is a complete and reliable method of water purification regardless of raw water quality or composition. Nevertheless, distillation appliances are not yet common in households, even though they can be designed for permanent installation and connected to plumbing like a water heater or made into a cord-connected countertop appliance like a coffeepot. Both types are available on the market, and neither requires any particular skill or talent to install and operate successfully.[5]

A properly designed distiller can produce pharmacologically pure water inexpensively.[6] The energy required to evaporate a pound of cold tap water at sea level is about a third of a kilowatt-hour (Keenan 1936). If the water can be evaporated and subsequently condensed back into liquid form without a significant loss of steam or heat, the production of a gallon of pure water in a simple still would consume about 3 kilowatt-hours of electricity. At prevailing domestic electricity rates, the energy cost would be about $0.30 per gallon. That gallon of genuine distilled water may be purchased in a supermarket for about $2.50. The retail price for a gallon of bottled water of lesser purity ranges from about $0.50 from a coin-operated dispenser up to $2.00 on the beverage shelf, container included.

Pharmacological purity is the water purity required to prepare solutions for safe intravenous injection. To be pharmacologically pure, water may contain no more than 2 parts per million (ppm) total dissolved solids.[7] By contrast, the total dissolved solids carried in most public water supplies ranges from 100 to 5000 ppm and has been increasing year by year as subsurface aquifers, lakes, and streams are drawn down and replaced by drainage laden with sewage, fertilizers, insecticides, solvents, detergents, and the like (*Environmental Quality 1982*). However, to put this situation into some kind of meaningful perspective, recall that seawater contains approximately 35,000 ppm of total dissolved solids (Sverdrup et al. 1942).

Managing an Inventory

To gain independence and safety in their lifestyle in regard to their water supply, homeowners will face, among other things, some plumbing changes in their household drainage piping to inventory raw water and recover gray water. Although local building codes, laws, or regulations may prohibit such changes in many locations at the present time, such restrictions would not exist in a free-enterprise regime. Be that as it may, if homeowners recognize the realities of their hierarchy of uses, they can learn to create a bulk water supply separate and distinct from their particular end-use water needs. They can segregate and store relatively large volumes of so-called gray water, the residue of their most voluminous usage, like dishwashing, laundry, and car washing. Recovered gray water is satisfactory for most sanitary flushing and landscaping purposes. Where it is not, only minor treatment is required, depending on the amounts and kinds of soaps, bleaches, conditioners, and detergents used in the household. With additional treatment, such water may also be used in swimming pools, wading ponds, fish ponds, and the like, in which case the household may already have abundant raw water storage capacity on site.

Sanitary flushing produces relatively small volumes of "black water." Low-flush toilets can reduce the volume of black water by an appreciable fraction and increase the concentration of organic waste being transported by a comparable amount. This not only conserves water and reduces sewage volume; it also enables greater efficiency in subsequent waste-treatment processing. (Black water can even be eliminated from the household altogether by the use of chemical toilets or waterless earth closets; see www.envirolet.com).

Black-water drains contain relatively large fractions of solid organic waste. Such drains may be intensively treated to produce a smaller volume of safely reusable water, resulting in a comparable amount of septic aqueous waste. This liquid waste may, in turn, be de-watered by evaporation in a pond and then composted for use as organic fertilizer, or it can be stored in a septic tank for microbial digestion. The clarified and disinfected water may be decanted for gray water makeup. The sludge may be composted or disposed off-site via sewerage if a connection already exists or hauled off by a vacuum truck if not. On the basis of the solid-waste content, kitchen garbage disposers are also black-water dischargers. Accordingly, their drains should be piped in common with toilets to simplify the subsequent collection, treatment, and disposal of fluidized solid waste.

Households would acquire and maintain an inventory of gray water by recovering as much as they can of the water they use. The water used for metabolic consumption and outdoor plant irrigation is difficult to reclaim, however, because most of it ends up evaporating into the air, percolating into soil, or fluidizing organic waste for subsequent transportation off-site. To make up for these various losses, householders must periodically replenish their raw water inventory. Inventorying water on-site is the key to improving a community's water supply.

Recycling gray water involves the familiar technologies of filtration and disinfection as a minimum. That portion of the gray water to be used for metabolic and bathing purposes is best extracted by distillation to ensure the removal of those organic contaminants in domestic water supplies that are as readily absorbed into the body through the skin as through the gut. By such means, the water for the household's most sensitive uses would be far purer than that flowing from the ordinary kitchen tap today. Indeed, today's tap water is laden with toxic chloramines that are formed in the basic water supply by chemical reactions between the dissolved organic compounds and the chlorine dose applied at the central plant for disinfection prior to distribution (McDaniel 1972). But germs can grow in distilled water as well or better than in tap water without residual chlorine compounds. To deal with this dilemma, the John Ellis Company developed its Electron Water/Air Machine (www.johnellis.com). Various companies offer ozonation and ultraviolet irradiation treatment products for this purpose as well.[8]

Even those who might not care to treat their own water have readily available alternatives. A growing number of enterprises cater profitably to householders.[9] No doubt, many more such enterprises will form in the future.[10] Whether or not such water is of the purity achieved by distillation, such commercially refined water nevertheless meets the needs of discriminating consumers. Doubtless in time such products will be prepared by distillation, if only to minimize liabilities.

A Specific Implementation for Pahrump

How would the on-site utility scheme work out in the case of Pahrump, a community still using individual septic tanks? First, to protect the health of their neighbors as well as their own, Pahrump residents would install gray-water storage tanks or convert their existing septic tanks into cisterns with separate black-water clarifiers. They would want to abandon the use of haphazard drain fields, which, though legal in many areas, run a high risk of exposing the neighborhood to infectious and toxic materials. Once established, the inventory of gray water would be recycled after being treated and rendered aseptic and clear by local trickling filters.[11] After sediment filtration in sanitary diatomaceous earth, the clarified water would be disinfected by ozonation or ultraviolet irradiation. Chlorination should be used only if the amount of dissolved reactive organic materials is minimal and there are no aesthetic objections to the residual gas, which is toxic in relatively low concentrations. Consumers could then subject that part of the water destined for more personal use such as cooking, drinking, and bathing to a more intensive treatment like distillation. Or they could obtain such refined water on the market, as many households already do for their cooking and drinking needs.

The water inventory contained in the cistern would consist of recovered gray water, possibly a smaller amount of recovered black water, and imports of doubtful quality from external sources such as a municipal water system. As already noted, some replenishment would be required from time to time because of local water losses. The heaviest losses would come from landscape irrigation, but here again, technological advances in the form of drip irrigation and underground soakers are dramatically reducing the amounts of water required for gardening and general landscaping.[12] Drip watering requires less than 30 percent of conventional sprinkling. Drip has been found to reduce plant stress from over- and underwatering, resulting in earlier production and up to 49 percent faster growth. Healthier and more beautiful plants are cultivated with up to 84 percent greater yields of flowers and fruit. Drip also reduces weed growth by watering only the base of the desired plants and eliminating water runoff. Subsurface soaking feeds only the roots. Both prevent excessive soil moisture, expansion, and erosion. Whatever makeup water of sufficient quality and quantity that remains to be obtained may come from the public water system. If not available from that source, it could be trucked in by private water companies like General Water Club of Southern California.

Developments in Distillation Technology

Since we have cited distillation as a key component in the on-site approach to community water supplies, we should discuss the state of the art of that technology.

Distillation is the most comprehensive and reliable method of water treatment known. Although various other water treatment processes are less energy intensive, they are somewhat more specialized than distillation in their community applications. When water recycling, inventory, and reuse is contemplated, distillation is essential because it is the only fail-safe method of producing pure water from almost any available source.

Whereas many different and ingenious engineering methods have been devised for boiling-type distillation, many applications have certain economic disadvantages, including the need for descaling heat-exchanger surfaces and for high-temperature heat. Mineral-scale deposits must be removed periodically to maintain thermal performance, and such maintenance is labor intensive. While boiling at lower temperatures may reduce scaling, this requires subatmospheric pressures entailing the use of costly pressure vessels, which must be manufactured and transported from factory to site at some expense.

Supplying heat at high temperatures for boiling-type distillation typically uses high-pressure steam. Such heat is expensive because it requires sophisticated steam-generation equipment with licensed and unionized operators around the clock. In addition, steam commands a higher value for generating power than for heating.

Curiously, these disadvantages are absent in nature's distillation process in which water evaporates from the surface of the ocean at ordinary atmospheric pressure and condenses back again as rain without ever approaching the boiling point. Mineral-scale deposits are nowhere in evidence. This scale-free, natural-distillation phenomenon sharply contrast with the experience with conventional water distillers on naval vessels at sea, a comparison that led to the conception of an all-direct-contact, vapor-staged, multieffect process called *absorption distillation* (Lowi 1983).

The object of this innovation was to devise a suitable process and apparatus for large-scale seawater desalination to support a mixed-use real estate development on a seacoast location having good accessibility to everything but municipal or other suitable water supplies. However, an unanticipated result of this new development in distillation technology was to make the cogeneration of water in integrated, on-site utility systems economically attractive.

By perfecting the means for carrying out partial evaporation and condensation in the presence of a noncondensable medium such as air, which is the absorption distillation technique, a number of advantages could be realized and drawbacks avoided while retaining the basic virtues of distillation. For example, absorption distillation is carried out in a structure very similar to an ordinary and familiar cooling tower. In fact, a cooling tower is representative of the evaporative portion of the absorption distillation apparatus. A similar tower located adjacent to the evaporative tower is used for direct-contact condensation, which is essentially a spray dehumidification process.

Some salient attributes of the absorption distillation process and apparatus include the following:

- Site-constructed facilities using only locally available building materials can be scaled to suit any size application and modularized for flexible uprating to suit future growth.
- An all-direct-contact heat and mass transfer arrangement eliminates scaling, corrosion, expensive construction materials, and expensive pumping and piping machinery.
- A nonboiling evaporation process carried out in stages entirely at atmospheric pressure eliminates expensive, fabricated pressure vessels and uses low-level heat input to heat water without boiling.
- The low-level heat requirement facilitates the operation on waste heat from electric power generation plants without penalty to them, thereby inviting cogeneration arrangements.
- The bona fide distillation process implemented provides a robust and reliable separation of water from contaminants ranging from radioactive salts to septic organic matter.
- Concurrent aerobic digestion of organic matter as a result of the intimate contact of the raw water with the oxygen in the transport medium (air) reduces the residual mass of that form of contamination to inert mineral ash.

Experimental results support these attractive characteristics of absorption distillation (see Lowi 1983). By using economical energy and facilities, this innovation in distillation technology can provide the comprehensive water treatment needed to facilitate integrated, on-site utility systems. The economic advantage of absorption distillation over other distillation methods is attributable to its low-cost construction and effectiveness in utilizing low-grade heat.

Conclusion

This chapter has touched on the extensive range of water treatment techniques and complex combinations of them that are accessible to private enterprise for providing on-site utilities. It questioned the natural-monopoly arguments justifying single-purpose, indefinitely expandable, centralized water, sewer, and power grids under political jurisdiction.

Progress invariably depends on the introduction and application of new technology, which always brings change and risks. Government is bound to be conservative because it must be seen to be avoiding taking risks with the commonwealth it controls. Hence government is not only noncompetitive; it is antiprogressive.

Entrepreneurial activity in this arena of community service can accelerate technological initiative combined with financial responsibility. The value of such alternatives is clearly illustrated in the case of Pahrump, Nevada. The residents of Pahrump would be well advised to look at their water situation from a fresh technological perspective before they agree to government projects that, with very questionable chances of success, may in the near future quintuple their water rates.

Unlike centralized municipal utility bureaus, proprietary on-site utilities are inclined to use a wide assortment of technologies, especially for serving the community's water demands. This approach recognizes a quality hierarchy in serving various uses. Emphasizing the economies of water reuse on site, the on-site approach substantially reduces the demand for water supplies from the environment as well as the overall burden of aqueous waste disposal into the environment.

The existence of proprietary utility systems like the on-site alternatives described depends on the existence of a qualified laissez-faire social environment. Such dependence implies a substantial independence of regulation by municipal and county governments, which have long relied on their ability to grant or withhold permission to connect to "the grid" as a major tool for controlling land development and generating revenues. So the challenge of engaging in the utility business under present circumstances should not be minimized. But this challenge is political, not technological or economic.

When researchers consider the recent technological advancements in the provision of utilities, they will realize it is not nature that creates monopolies. As technologies overcome previous limits, decentralized and competitive water systems will become more attractive and economical. Technological advancements in water supply and delivery would allow the natural competition of many substitutes and alternatives, if permitted by law.

NOTES

1. Most nineteenth-century waterworks were privately provided. See Crocker and Masten 2000. On the history of private waterworks in London, see Tynan 2000.

2. See "Home Appliance Makes Pure Drinking Water," *Waterwise Catalog*, www.waterwise.com, *Popular Science* Magazine Showcase, December 2000, 107. Another example is the 1997–98 catalog for the Cole-Parmer Instrument Company, Vernon Hills, IL, 1997-98 Catalog, 1318–25, www.coleparmer.com.

3. Also see the Chelation section; *Engineers Catalog*, Culligan International Company, Northbrook, IL, 1973; and www.culligan.com for an extensive, up-to-date selection of domestic water treatment products and services.

4. See the product and service catalogs at www.culligan.com, www.waterwise.com, www.envirolet.com, www.watergeneral.com, www.filterdirect.com, www.puritywater.com, www.johnellis.com, www.clearwater-az.com, www.ecosoft-engineering.com.

5. *Home Appliance Makes Pure Drinking Water*, Waterwise Catalog, www.waterwise.com.

6. Brochure for *Quench* Portable Water Distillers, Terraqua, Inc., San Pedro, CA 1972.

7. U.S. Pharmacopeia, ISBN 1889788031, Bk. & Suppl. ed., January 1, 2000.

8. The *1999 Regional Industrial Buying Guide* of the Thomas Regional Directory Company lists hundreds of sources of such water treatment products. See www.thomasregional.com.

9. See product and service listings in the Product Showcase section of any issue of *Popular Science* or *Popular Mechanics*.

10. The *Los Angeles Times*, Saturday, June 3, 2000, advertised on p. C3 an offer to residents of Southern California by the General Water Club to dial 800-440-4048 to arrange to have quality drinking water delivered to their home in unlimited amounts for $10 a month.

11. A trickling filter consists of a porous bed of rock in which water is contacted by a countercurrent of air to promote the aerobic digestion of organisms and to remove the resulting ash.

12. James Dulley, "Update Bulletin No. 598," James Dulley List, P.O. Box 54987, Cincinnati, OH 45254; www.dulley.com. (The Web site lists manufacturers and suppliers of various types of drip watering systems and components.)

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