CHAPTER III

Eighteenth and Early Nineteenth Centuries

The quest for pure water in the eighteenth century was keen but the quarry was small. Many and various ideas and experiments on water treatment in Great Britain, France, Germany and Russia, and a few instances of practical achievements, are reviewed in this chapter. French adventures in patenting and promoting filters appear in Chap. IV, "Four Centuries of Filtration in France." Late eighteenth century developments in England and Scotland are found in Chap. V, "British Contributions to Filtration." America did not join the hunt, except incidentally, until the nineteenth century, and did not get into full cry until after the Civil War. Specialized means of water treatment appearing for the first time or in new form in the eighteenth century are given only passing mention in this chapter. They appear under their proper heads in later chapters.

In 1703, the Parisian scientist La Hire (1) presented before the French Academy of Sciences a plan for providing a sand filter and rain-water cistern in every house. He proposed an elevated cistern covered with matting to prevent freezing and also to exclude light that would otherwise foster "a greenish kind of moss" on the water surface. Rain water passed through river sand and stored underground, he said, would keep for years without spoiling and was usually the best water for drinking, washing, bleaching and dyeing, because "it is not mixed with any salt of the earth as all spring waters usually are." This is perhaps the earliest written recognition that spring waters, in their long passage through the earth, may take up objectionable mineral salts.

The long-held theory that sea water could be freshened by filtration was exploded in 1711 by the Italian oceanographer, Marsigli (2), when he reported that sea water was not made drinkable by filtering it fifteen times through superimposed vessels filled with clay and sand. Rochon (3), who cites the experiment of Marsigli, also reports an experiment made by Nicollet and Réaumur. They used a zigzag glass

tube 1,000 fathoms or 6,000 ft. long, filled with sand but, says Rochon, the water came out as salty as when it was put in.

Boerhaave, noted Dutch physician and chemist, in *Elements of Chemistry* (4), first published in Latin in 1724, said that putrid water could be cured by boiling, with the addition of acid, and that spirit of vitriol would prevent putrefaction. Only one boiling of putrid water, he thought, would destroy the animals that generated spontaneously in the water, sending them to the bottom with other impurities. Then by adding a small quantity of strong acid the water would be made fit for use. This method, Boerhaave said, had given excellent service under the equator and between the tropics "where the waters putrefy horridly" and breed large quantities of insects, yet must be drunk.

Dr. Stephen Hales, writing in 1739 (5), reported experiments he had made to determine the ratio of vitriol necessary, as a small excess might be dangerous. He found that three drops of oil of sulfur in a wine quart (¾ U.S. gal.) preserved "water from stinking for many months . . . the purer the water the less the acid spirit" [required]. He had been informed that the Dutch, to prevent water from stinking on long voyages, put into it spirit of vitriol. He also noted a statement in the *History of the Academy of Sciences* (1722) that fresh water had been kept from putrefying and breeding insects by fuming the cask with burning brimstone.

Various Reports on Filtration

Advanced ideas on water purification were recorded by the scientist Plüche in a popular work called *Spectacle de la Nature,* first published in 1732 (6). He reported that rivers fouled by the filth of cities were improved by sedimentation and by exposure to the sun, and said it was customary to let muddy river water stand in earthenware vessels a few days, in which time it settled and became clear as crystal. "Several" used copper cisterns with sand in them "through which by an artificial kind of filtration [the water] clarifies sooner and with equal safety, provided the sand it drains through be often wash'd, and the vessel [be] well tinned within to secure it from verdigrease." This is the first clear-cut recognition found on record of the slowness of sedimentation compared with filtration. It is also the first contemporary record of the need for occasional cleansing of sand in filters and for protecting copper containers from the verdigris that gave

Amy, a few years later, so much concern. It shows, too, the customary use of sedimentation and the less common use of sand filtration in 1732. A passing remark by Amy, in 1750, carries the use of household sand filters in Paris back another two centuries, or to about 1550.

Extensive use of filtering stones early in the eighteenth century is shown in a paper by Dr. Abraham Vater (7) describing the filtering stone of Mexico and comparing it with other stones then in use.

The earliest mention of filters in English and French encyclopedias is in the fifth edition of Chambers (1741) (8), which describes filtration through sand and pulverized glass and by ascent through cotton. The seventh edition of Chambers (1751–52) is a little more explicit.

In striking contrast to Chambers, Diderot's *Encyclopédie* (9), which featured science and industry (volumes pertinent to this discussion published in 1756–57), took up filters for use in pharmacy and manufacturing (*filtration en grande*); described stone filters used extensively in Japan; and devoted a page to *fontaines domestiques,* as the household filters then widely used in Paris were called. Although in 1757 the household filters were of many kinds, most of them appear to have been of sand, inclosed in copper vessels, the sand resting on and being covered with perforated copper plates. The article illustrated in detail and highly commended Amy's filter (see Chap. IV).

Ten years later Croker's *Complete Dictionary of Arts and Sciences* (10) defined "filter" as a strainer of filtering paper or bag of woolen or linen cloth. A page was devoted to depuration in pharmacy by decantation, by despumation or percolation through strainers of flannel, linen, cloth or paper and "by the attraction of a pendant thread." The first edition of the *Encyclopedia Britannica* (1771) had only this sentence on filtration: "Filter or filtre, in chemistry, a strainer commonly made of bibulous or filtering paper in the form of a funnel, in order to separate the gross particles from water and render it limpid."

Six British Questers for Pure Water

In the brief period, 1753–69, a half dozen English and Scotch questers for pure water came on the scene: Doctors Lind, Home, Butler, Rutty, Heberden, Percival and Buchan.

Lind on Supplying Water for Seamen.—James Lind, Scotch physician and naval surgeon, gave much attention to the purification of water for use on sea and land in *A Treatise on Scurvy* (11), first pub-

lished in 1753, and in *An Essay on the Most Effectual Means of Preserving the Health of Seamen in the Royal Navy* (12), which appeared four years later. Both these books were pioneers in their field.

One method of at least delaying putrefaction of water at sea mentioned by Lind was that of fuming the casks with burning brimstone; another was that of adding a little oil of vitriol. A common and a good practice of curing putridity was that of throwing a little salt into water while it is being boiled and removing the "thick feculant unwholesome scum" that rises. This should always be done, he asserted, when peas or oatmeal are boiled. Another method of curing water that is putrid and stinking was that of taking the bungs out of the casks, shaking the casks or pouring the water from one vessel to another. Safer for common use than applying vitriol or salt is adding juice or extract of lemon. Acid, he explained, will precipitate the earthy particles in the water together with "various animalcules with their sloughs, now destroyed by boiling."

The stone filter sometimes used on ships to soften and clarify water, Lind said, was "very proper" if the water did not abound with "vitriolic or marine salts" but it could never yield enough water for a ship's company. "Sand," he added, "is the finest body for separating these heterogeneous particles from water." There followed a description of a multiple filter from "the ingenious essay of Sir Francis Home on the Dunse Spaw" (published in 1751). This seems to have been based on the filter described by Porzio in his book of 1685 (see Chap. II).

Lind elaborated on filtration through sand, and several other methods, in *An Essay on the Most Effectual Means of Preserving the Health of Seamen in the Royal Navy* (1757) (12). Bad water, next to bad air, he said, is a frequent cause of sickness, especially near the torrid zone. Where the water found on shore is bad, the ship's casks should be filled with rain water, if possible; or, if fuel is available on shore, sea water may be distilled, "which will prove as wholesome as that of the Thames." He gives, in a footnote to the revised edition of 1762, the substance of a paper read before the Royal Society, dated April 26, 1762. He advised digging a pit on shore to find water. If the water thus found were foul or impure, the pit should be made deep and large, its bottom and sides lined with large stone and then sand and gravel thrown in. By this means the water "will often become in 24 hours clear, soft and wholesome." If not, then a filter could

be constructed by placing a small cask inside a large one, both headless; then putting sand and gravel in the small cask and in the concentric space between the two casks. Water poured on the sand of the inner cask will pass down through the inner cask and up through the outer cask where it may be drawn off through a cock.

When the surface sand of the inner filter became "loaded with the gross impurities of the water," it could be replaced with fresh sand. For private use, a large funnel could have a bit of sponge inserted in its narrow part, sand placed above that, then a piece of flannel and finally sand again. The materials had to be changed when they became fouled.

Other practices mentioned by Lind were: Toasted biscuit put into the water of the St. Lawrence River prevented fluxes in Sir Charles Saunders' fleet—about 4 lb. of burnt biscuit were used to a hogshead of water. Powdered ginger for the same purpose was mixed with water for troops in Canada, with resulting benefit. Vinegar in small quantity "is an excellent corrector of unhealthy waters"; also cream of tartar. Most notable of all is an early instance of the use of lime in water purification described by Lind:

> At Senegal, where the Water is extremely unwholesome, unquenched Lime has been used to purify it. . . . But water cannot be thus purified in a Ship, because I find [note the personal pronoun] that it must be exposed in a very wide mouthed Vessel for many Days, and sometimes Weeks, before it looses the Taste of the Lime: much of it also is expended, by daily removing the Scum; and it will sometimes require boiling. (12)

Home and the Appearance of Water Softening.—Dr. Francis Home, Scotch physician, experimenter and writer, contributed greatly to the knowledge of water softening in *Experiments on Bleaching* (13). His book was published in 1756 but apparently the experiments were made earlier. His studies appear to have included the first scientific experiments on water softening ever made and he seems to have been the first to suggest that softening be applied to city water supplies.

Butler and Soap Lye for Purification.—Dr. Thomas Butler (14) wrote in 1755 that if a wine glass of the strongest soap lyes were added to 15 gal. (Imp.) of sea water, and the water distilled, 12 gal. of fresh water generally would be produced. To keep fresh water sweet, he recommended putting ¼ lb. avoirdupois of "fine clear white pearl ashes" into 100 gal. of fresh water.

Rutty's Mineral Waters.—Dr. John Rutty, in his thick quarto treatise, *A Methodical Synopsis of Mineral Waters* (1757) (15), has a chapter on "Common Waters." He notes the "great importance in building a town to chuse a proper situation with regard to the quality of springs." Common spring waters, if not immoderately hard, may be softened by standing a few days, those at Henly, England, and divers others requiring only two days' exposure to become "fit to wash with." One method of softening was to put into the water an alkaline salt. Rutty mentions adding two or three drops of oil of sulfur per quart of water to keep river water from putrefying, and cites Dr. Butler's plan of using pearl ashes, and a proposal by a Dr. Alston to put a pound of quicksilver in a hogshead of water. In a long chapter on "Alum as an Ingredient in Mineral Water," Rutty says he had "found many spring waters to become more limpid upon the admixture of alum." In Kent, muddy pond water was cleared by throwing into it a little alum. Dr. Rutty quotes Churchill's *Collection of Voyages and Travels* as relating that a certain yellow or red river water in China was cleared and made drinkable by putting a little alum into a jar of it and shaking it about.

Heberden's Pump Waters.—Dr. William Heberden, in his discussion of London pump waters (1767) (16), took up softening, sedimentation and coagulation followed by filtration and distillation. Softening could be effected by boiling, which would free water of "most of its unneutralized limestone and selenite" but increase "saline matter." Limestone, either "loose" or "united to the acids," could be precipitated by adding salt of tartar—10 to 15 grains per pint! Heberden said that, although Prospero Alpino reported (*De Plantis Aegyptis Liber,* Venice, 1592) that powdered almonds were rubbed on the inside of jars containing Nile water as an aid to sedimentation in Egypt, he could not find it of any use. The common people of England, Heberden stated, successfully used alum to purify muddy water, 2 or 3 grains dissolved in a quart of water making the dirt very soon flocculate and then slowly precipitate. Subsequent filtration made the water fit for use. Such a small addition of alum "will hardly be supposed to make the water unfit for any purpose." No earlier suggestion for coagulation followed by filtration nor concern over the use of alum has been found. Distillation was given more space by Dr. Heberden than any other method of water treatment. To free the distillate from burnt

taste, it could be let stand or boiled in an open vessel or air could be forced into it, as suggested by Dr. Hales. The wholesomeness of distilled water could hardly be doubted, Heberden thought, if it were recollected that Nature distilled all the fresh water in the world.

Percival's Well Waters.—Thomas Percival described (1769) (17) some experiments on treating hard and in some cases polluted well waters at Manchester, England. Hard water, first well boiled, then filtered through stone, was rendered "tolerably pure, potable and salutary and at the same time better adapted to a variety of culinary uses."

Buchan and Purification of Municipal Supplies.—In *Domestic Medicine* (1769) (18), by Dr. William Buchan of Edinburgh, is found the first positive statement that water should be purified, if need be, before it is supplied to great towns. After saying that many diseases may be caused or aggravated by bad water, and that, once a supply had been procured at great expense, people were unwilling to give it up, he wrote that the common methods of rendering water clear by filtration, or soft by exposing it to the air, etc., were so generally known that it was unnecessary to spend time in explaining them. What the common methods of filtration so well known in 1769 were, Dr. Buchan did not tell. So far as has been found, no city water supply had been filtered up to that time.

Infiltration

In a French book on rural economy (1767), Jean Bertrand, pastor at Orbe, Switzerland (19), discussed retention of water in ponds and its aeration and natural filtration through rocks and sandy earth. He said he had no doubt that nature could be imitated by passing water through an artificial bank of sand. Filtration, he believed, would be of inestimable advantage to a city supplied with water that caused goiter or had other defects. A suitable means of correcting chalky and viscous waters, he reported, was to pass them through green branches of fir trees pressed into a pond above or just below its outlet.

Pits near the tidal reaches of the Senegal River, West Africa, were seen by J. P. Scotte, M.D., about 1776 (20). During the rains, Dr. Scotte wrote, the water of the river is fresh, but very thick and troubled. In dry months the river is salt, because the low stage of the river permits the backing up of water from the sea. Where a pit is dug into the sand, water "filtrates from all sides and gathers up to the level of

the river." Although brackish, this infiltrated water was used by the garrison and the inhabitants of the town.

Lowitz's Studies of Charcoal

The efficacy of powdered charcoal in preventing or removing bad tastes and odors from water, and incidentally in clarifying it, was established experimentally by Johann Tobias Lowitz in 1789–90 and detailed in a paper read before the Economics Society of St. Petersburg in 1790 (21).

Lowitz (1757–1804) was born at Gottingen, Holland, son of the German astronomer, George Moritz Lowitz, who became director of the Gottingen Observatory. The son was an eminent member of the Imperial Academy of St. Petersburg and a professor of chemistry.

In 1785, Lowitz showed that charcoal would decolorize brandy. The studies on charcoal centered on water for use on long voyages, but spring waters were also considered.

Addressing himself first to prevention rather than cure of tastes and odors, Lowitz said water free from heterogeneous particles is not subject to putrefaction, but, owing to its dissolving powers, it is difficult to preserve it long in a pure state. To keep it pure on shipboard it should be stored in vessels of glass or earthenware. This being impracticable, wooden casks were used. Such casks impart a great quantity of mucilaginous and extractive matters, which, in a state of division, furnish innumerable living creatures, the decomposition of which causes putrefaction. Clean casks are essential because the smallest quantity of corrupted matter left in them acts as a ferment which causes the water to putrefy. Therefore he advised that the casks be washed with hot water and sand, or any other substance capable of removing the mucilaginous particles. The clean casks having been filled with water, a small amount of vitriolic acid should be poured in, then powdered charcoal stirred in to nullify the acid taste. Six drams of powdered charcoal would deodorize and clarify three pints of water, provided 24 drops of vitriolic acid were also used. One cask of powdered charcoal would deodorize and clarify 34 casks of water; but more would be required to cure bad taste. Water drawn from the cask should be passed through a filtering bag, apparently filled with charcoal.

Spring waters having a hepatic or liver taste, said Lowitz, should be filtered through a bag half filled with powdered charcoal, but unless

it was loaded with mucilaginous particles, use of acid would be unnecessary.

The influence of Lowitz's paper was strong for many decades. His suggestions on the use of charcoal for filters, either alone or with other media, gained particular eminence.

Filter Ships

Porzio's plan for filter boats adjacent to army camps, published in Vienna in 1685 (see Chap. II), was simplified and put into effect during the siege of Belgrade on the Danube, in 1790. The German technical encyclopedist Feldhaus (22) credits the Austrian Surgeon General, Mederer von Wuthwehr, with transforming putrid into potable water by boring holes in the bottom of old transport ships, putting in successive layers of cannon balls or coarse gravel, coarse sand, fine wood ashes and fine sand. It was claimed that the water issuing through these filters was as clear as that from artesian wells.

Cavallo on Water Purification

Tiberius Cavallo, F.R.S., who was born in Naples in 1749 but settled in England before 1775, published a treatise on natural philosophy in 1803 (23) and an essay on preserving and purifying water in 1807 (24). In the treatise he described filtration "as a finer species of sifting [through] the pores of paper, or flannel, or fine linen, or sand, or powdered glass, or porous stones," and said that filtration would remove suspended but not chemically combined matters—that is, mud but not salt—from water.

In the essay he stated that animal, vegetable and earthy substances might be eliminated from water by sedimentation, either before or after fermentation. Thames water, after standing in casks a few days, fermented and "stinks intolerably." It became covered with scum, yielding inflammable gas which might be lighted by a candle. But when fermentation had decomposed animal and vegetable substances, which took a few days, the components flew off in the air or fell to the bottom of the casks, leaving the water sweet and clear. He taught that most stagnant waters may be purified by filtration and water putrid with animal or vegetable matter may be purified by agitating in it powder of freshly made charcoal, then filtering it. Charcoal mixed with sand (in filters) purifies muddy and stinking waters, but the charcoal powder must be renewed frequently. Or, he suggested,

a pound of quicklime may be added to 1 gal. of water, letting it stand for six to eight hours, stirring at intervals, and then filtering and exposing it to the atmosphere, with frequent agitation, for a few hours. According to Cavallo, sea water may be made drinkable by freezing or by distillation, but never by passing it into wells dug on the seashore—"no human art could ever effect it by filtration." Distillation will purify hard water; but if the water contains "volatile ingredients, and expecially the putrid effluvia of animal and vegetable bodies," quicklime should be added.

Cavallo described a filtration "machine" which was either a cask, open at both ends, or an earthenware chimney pot, placed in a tub or cistern; both vessels were filled to about three-quarters of their height with sand which had been repeatedly washed in boiling water to free it from clayey or saline particles. Muddy water poured upon the sand in the inner vessel would descend through it, then rise up through the sand outside. But double filtration, downward then upward, as has been seen, was not a new method. Municipal supplies are not mentioned by Cavallo.

CHAPTER III

Eighteenth and Early Nineteenth Centuries

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CHAPTER IV

Four Centuries of Filtration in France

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