THE HISTORY OF DESALINATION BEFORE LARGE-SCALE USE

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Summary

Desalination is generally considered by the layman (and indeed by many specialists) to be a relatively new technology, only recently put into practice. However, it has a rich and lively history and many of the difficulties addressed and insights developed by the early practitioners are still valid today. Anyone working in the field would be remiss not to look backward from time to time, not only for guidance but for the sheer pleasure of discovering his professional ancestors.

1. Introduction

1.1. The History of Science and Technology

The history of science and technology is an academic field which is often bypassed by students of either history or of science and technology. The reasons are several, but certainly include the fact that students of political or social history may feel ill-prepared to cope with its technical content and that students of science and technology already have an overladen schedule of courses they must take to advance in their professions. This is unfortunate but understandable. For a first-rate presentation of these issues, the reader is referred to Conant (1960) in his Horbit Lecture on the History of Science or to the introductory pages of the major works on the subject by Partington (1962) and by Sarton (1948).

Here, we are not addressing the history of science and technology so much as we are the history of a technology, desalination in this case. And to understand this technology fully, we must appreciate that it is a cumulative experience. Far more than in non-technical endeavors, one step builds upon the preceding step and empowers the following step. And yet even that point is not the primary reason to consider its history. We do not study it in order to be better at solving today's problems, although it may have some modest benefit. The reason was best put by Sarton (1948): "*The main value of the history of science to the philosophically minded scientist, the scientist who wishes to understand the indebtedness of his knowledge, lies in its moderating influence. Retrospective views enable him to keep his balance between dogmatism on one hand, and ultieffec and discouragement on the other. They help him to be patient*" *and* "*Above all, the history of science teaches humility*".

To this it may be added that the history of desalination can teach us not only humility, but pride as well. Some of the greatest names in science and technology have turned their hands to our task or to parts of it over the years. Those who have chosen to make it their profession may be allowed a bit of pride in serving with them.

1.2. The Organization of this Chapter

Desalination, like all technologies, did not develop linearly over time. There were periods of rapid growth, but there were also periods of inactivity. The latter were usually the result of a lack of either "tools" (e.g. scientific understanding or supporting

technical development) or of a strong motive or opportunity. The periods of activity and growth occurred when both the tools and the motive coincided. In earlier times, there was also the problem of communication. Advances in one region were not rapidly or reliably transmitted to other regions or even within a single region among the interested parties.

This chapter is organized into sections in chronological order and named to reflect the major influencing factors. It must be understood that the dates that separate one section from another are fuzzy and arbitrary and that some factors of activity cross these boundaries. Subsections break the activities of the period into groups of common activities, also arbitrarily chosen but with the intent of instructing.

2. Desalination in Antiquity

2.1. First References

One cannot tell when humanity first became frustrated at its inability to drink salt water and began to consider the matter of salt water purification. However, some of the earliest writings suggest that even in earliest times, it was a matter of some interest.

In China, according to the books *Huai Nan Wan Bi Shn* (*c*. 200 BC) and *Qi Min Shn* by Jia Si-Xie (*c*. AD 540), people would concentrate their wine by immersing the leaves of Guan-Pu grass in it. The leaves were more permeable to and adsorptive of water than alcohol and, therefore, the wine was strengthened (S. Wang, personal communication). In addition, during the same period in China, Guan-Pu leaves were used to concentrate brines to make pickling solution.

Similarly, in China, approximately 2000 years ago there were reports of desalting using specially woven bamboo sheeting and earthenware filters. Their method of employment is unclear, but it might have involved the formation of a dynamic gel layer on the "sieving surface" (S. Wang, personal communication). However, other regions were also suggesting desalination by filtration through earthen vessels. Unfortunately there is no first-hand substantiation of these legends.

In the Bible, there is the observation that "*for He maketh small the drops of water: they pour down rain according to the vapor thereof; which the clouds do drop and distil upon man abundantly*" (Job xx: xx).

In the Bible it is also written that

and they went three days in the wilderness, and found no water. And when they came to Marah, they could not drink the waters of Marah for they were bitter. … And the people murmured against Moses, saying, What shall we drink? And he cried unto the Lord; and the Lord shewed him a tree, which when he had cast into the waters, the waters were made sweet (Exod. Xx: xx).

(This reference to water treatment with vegetable products is similar to but different from that of the Guan-Pu leaves in China. In the biblical instance, the plant material

took up the salt rather than the water.)

In his *Meteorologica*, Aristotle (384-322 BC) wrote that "*Salt water when it turns into vapour becomes sweet and the vapour does not form salt water again when it condenses*" (Forbes 1948). He further speculated that

"Some again believe that the sea is, as it were, the sweat of the earth which it sweats out when the sun heats it: which is the reason why it is salt because sweat is salt. Others suppose that the earth is the cause of its saltiness: just as water strained through ashes becomes salt, so the sea is salt because the earth with this property is mixed with it"- (Nebbia and Menozzi 1966).

And so we see in the above an early consideration of a hydrological cycle.

Aristotle was also among the first of many to report that "*If one plunges a water-tight vessel of wax into the ocean, it will hold, after 24 hours, a certain quantity of water, that filtered into it through the waxen walls, and this water will be found to be potable, because the earthy and salty components have been sieved off*" .

Such a claim was to be reported repeatedly through the ages and was also published by Democritus (*c.* 500 BC) (Underwood 1935; Nebbia and Menozzi 1966). Although this may suggest a reverse osmosis type of mechanism at work, it is more likely just an attractive myth. [See also the later comments by Della Porta (1535) and Lucas (1756)]. Firstly, to overcome the natural osmotic pressure of seawater, such a "waxen vessel" would need to withstand great pressures. Neither a waxen vessel nor an unglazed earthenware vessel, perhaps coated with wax, would be likely to do so. Secondly, such a vessel would need to be lowered to and retrieved reliably from a depth of approximately 500 m. It is doubtful that the technology existed at the time for such an undertaking. Yet the concept was too attractive to be dropped and persisted for centuries.

2.2. The Dawn of Science and First Applications

During the first century, Pliny the Elder (AD 23-79) wrote his extensive *Natural History* summarizing the knowledge of the period and his personal views thereof (Jones 1963). He commented freely on many aspects of water and suggested which river and spring waters may be the most wholesome to drink. His comments on seawater purification are limited but include the following statements. "*But the nitrous and salty-acid streams that in the desert flow to the Red Sea are made sweet within two hours if pearl barley is added, and the barley itself they eat*". (Again a reference to using a plant product for purification.)

Because those at sea often suffer from failure of fresh water, I shall describe ways of meeting this difficulty. If spread around a ship, fleeces become moist by adsorption of evaporated sea water, and from them can be squeezed water which is fresh. Again, hollow wax balls, let down into the sea in nets, or empty vessels with their mouth sealed, collect fresh water inside. But on land sea water is made fresh by filtering through clay.

Pliny's writings must be interpreted as reporting things that he had been told or had read

of rather than things that he had personally observed. However, it is interesting that he repeats the story of the wax balls much as Aristotle had written. The story of the fleeces occurs repeatedly through the years and was used by the United Kingdom Atomic Energy Commission a number of years ago as inspiration for the drawing shown in Figure 1 (Howarth 1984).

Figure 1. Condensing Steam in Sponges.

During the first and second centuries AD, Alexandria was the scene of experimentation on distillation by Maria the Jewess, Cleopatra, and others (Badger 1926). While seawater was not the specific subject of their investigations, the skills and concepts were passed on to subsequent generations. Particularly important was the design of equipment for evaporation and condensation, including the alembic vessel which has come to be one of the more popular "logos" of chemistry. Alexandria was also the home of Hero whose steam-powered "aeropile", while only a toy, demonstrated the potential of steam as a useful tool.

Alexander of Aphrodisias commented *c*. AD 200 that "*sailors at sea boil sea water and suspend large sponges from the mouth of a bronze vessel to imbibe what is evaporated. In drawing this off the sponge, they find it to be sweet water*" (Forbes 1948).

This method of collection of steam also appears in the "steaming cotton-padded jacket" approach reportedly (S. Wang, personal communication) used hundreds of years ago in China.

Alexander further built upon the hydrological cycle suggested by Aristotle by stating in his *Natural Problems* that "*Some say that the origins of the saltiness of the sea is the earth itself. The water, in fact, running through the ground, takes its same properties*" (Nebbia and Menozzi 1966). St Basil, writing in the fourth century, commented upon

having been shipwrecked on a desert island and being saved by the seamen placing sponges over pots of boiling seawater to condense and collect the steam (Huber 1898). (This is the first time that the method of the fleeces or sponges is supported by an eye-witness account.)

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Bibliography and Suggestions for further study

Adams B A and Holmes E L (1935) *J. Soc. Chem. Ind.* **54**, 1-6.

Al Zubaidi A A J (1987) Seawater desalination in Kuwait - a report on 33 years experience. *Desalination* **63**, 1-55.

Ali A Y (1989) *The Meaning of The Holy Qur'an*. Amana Corporation.

Al-Masudi A A-H (1XXX) *Muruj Athahab wa Ma'adin al-Jawhar*, Vol. I. Beirut: Dar al-Andalus.

Anon (1941) *Naval Machinery*. Annapolis, MD: US Naval Institute.

Anon (1983) *Resources from Seawater*. Japan: Society of Sea Water Science.

Anon (1985) A new steam age? *Chemical Business* 9.

Anon (1989) *Meeting Malta's Demand for Fresh Water*. Malta: WaterWorks Department.

Badger H L (1926) *Heat Transfer and Evaporation*. New York: Chemical Catalog Company.

Badger W L and McCabe (1936) *Elements of Chemical Engineering*. New York: McGraw-Hill.

Baker M N (1981) *The Quest for Pure Water*, Vol. 1. Baltimore: American Water Works Association.

Bechhold Z (1907) *Physik. Chem.* 60, 257.

Bilkadi Z (1995) The oil weapons. *Aramco World* 46(1), 20-27.

Billiter J (1936) The elimination of salts from water. *J. Electrochem. Soc.* 70, 409-422.

Birkett J D (1984) A brief illustrated history of desalination - from the Bible to 1940. *Desalination* 50, 17-52.

Birkett J D (1993) The 70 years of desalination development prior to 1928. *The Next Breakthrough in Seawater Desalination*. Curacao: KAENV.

Birkett J D (1995) Desalination development during the industrial revolution. *IDA World Congress on Desalination and Water Sciences*. Abu Dhabi, UAE.

Birkett J D (1997) The 1861 de Normandy desalting unit at Key West. *International Desalination and Water Reuse Quarterly* **7**(3), 53-57.

Bronowski J (1973) *The Ascent of Man*, 448 pp., 11th edn. Boston: Little, Brown and Company.

Browne C A (1933) Origins of sugar manufacture in America. *J. Chem. Ed.* 323-330.

Carlson G (1921) Vapor compression system of evaporation. *Chem. and Met. Eng* 24(15), 645-647.

Chapman W (1759) An account of the distilling waters fresh from sea-water by wood-ashes. *Philosophical Transactions of The Royal Society of London* 50(II), 635-639.

Conant J B (1960) History in the education of scientists. *American Scientist* 48, 528-543.

Consolazio W V and Pace N (1944) Drinking water from sea water. *US Nav. Institute. Proc.* 70, 971-979.

Crank R K (1900) Six-Day Trial … Lillie … Dry Tortugas. *Am. Soc. Naval Eng.* 3, 85-99.

Dawson P M (1904) Stephen Hales, the physiologist. *Johns Hopkins Hospital Bulletin* 15, 232-237.

Deacon M (1971) *Scientists and the Sea, 1650-1900*, 445 pp. London: Academic Press.

Deerr N (1943) Evolution of the sugar cane mill. *Trans. Newcomen Soc.* XXI, 1.

Deerr N (1950) *The History of Sugar*, Vol. II. New York: Chapman and Hall.

Defoe D (1720) *Life Adventures and Pyracies of the Famous Captain Singleton*. Oxford: Basil Blackwell.

Dobry A (1936) Les perchlorates comme solvants de la cellulose et ses derives. *Ull. Soc. Chim. France* 5(II), 312-318.

Donnan F G (1911) Theorie der Membrangleichgewichte und Membranpotentilae … *Zeit. fur Elektrochemie und Angewandte Physikalische Chemie* 17, 572-581.

Doren C V (1938) *Benjamin Franklin*. New York: Viking Press.

Dutrochet R J H (1827) Nouvelles Observations sur l'Endosmose et l'Exosmose … *Annales de Chemie et de Physique* 35, 393-400.

Elder A N et al. (1934) Purification of substances by electrodialysis. *Ind. Eng. Chem. Anal. Ed.* 6, 65-66.

Elford W J (1937) Preparation of membranes graded porosities. *Trans. Farad Soc.* 33, 1095-1106.

Ellis C B (1954) *Fresh Water from the Ocean*. New York: Ronald Press Company.

El-Saie M H A (1965) Water production experience of the city of Kuwait. *First Int. Symp. on Water Desalination*. Washington.

Ferry J (1936) Ultrafilter membranes and ultrafiltration. *Chemical Reviews* 18, 373-455.

Fick A (1855) Uber Diffusion. *Poggendorff's Annalen der Physik und Chemie* 94, 59-86.

Fleischmann C L (1849) *Annual Report of Commissioner of Patents, for the Year 1848*. US House of Representatives.

Forbes R J (1948) *A Short History of the Art of Distillation*. Leiden.

Gans R (1913) *Centr. Mineral. Geol.* 22, 728.

Gilbert F W (1968) *Experimental Investigation of Steady-state Characteristics of Flashing Salt Solutions in Open Channel Flow between Two Submerged Orifices at Low Pressures*. Connecticutt: University of Connecticutt.

Glover B (1995) *Brewing for Victory: Brewers, Beer, and Pubs in World War II*. London: Lutterworth Press.

Goeldner R W (1983) More on MSF parenthood. *Water Desalination Report* XIX(35), 1-2.

Graham T (1829) Notice of the singular inflation of a bladder. *Quarterly Journal of Science* (II), 88-89.

Graham T (1833) On the law of the diffusion of gases. *London and Edinburgh Philosophical Magazine and Journal of Science* II, 175-190, 269-276, 351-358.

Graham T (1866) On the absorption and dialytic separation of gases by colloidal septa, part I. *The London, Edinburgh and Dublin Philosophical Magazine and Journal of Science* XXXII, 401-420.

Griessbach R (1939) *Angew. Chem.* 52(215).

Hales S (1739) *Philosophical Experiments: Containing Useful and Necessary Instructions for Such as Undertake Long Voyages at Sea*. London.

Harding J (1883) Apparatus for solar distillation. *Proc. Inst. Civ. Eng.* 73, 284-288.

Hawkins R (1868) *Observations in his Voyage into The South Sea in the Year 1593*. London: Hakluyt

Society.

Holmyard E J (1928) *The Works of Geber*. London: J. M. Dent and Sons.

Honig P (1963) *Principles of Sugar Technology*, Vol. 3. Amsterdam: Elsevier.

Howarth J (1984) *Product Literature for P and B Evaporators*. Derby: Aiton, Ltd.

Huber (1898) Uber die Mittel fur Herstellung genussfahigen Wassers aus Meerwaser. *Marine Rundschau* IX(11), 1045-1057, 1129-1136, 1369-1380, 1551-1560, 1687-1714.

Jones W H S (1963) *Pliny - Natural History*, Vol. VIII. London: William Heinemann Ltd.

Juda W and McRae W (1950) Coherent ion-exchange gels and membranes. *J. Am. Chem. Soc.* 72, 1044.

Kahn D (1967) *The Codebreakers*, 467 pp. New York: Macmillan.

Katz W (1977) *Address to Conference, San Diego*. National Water Supply Improvement Association.

Kolodin M V (1975) *Global Problems of Desalination*. Moscow: Znanye Publishers.

Latham A (1961) Experience with hand-cranked distiller.

Leitner G F (1960) Sea water conversion - byproduct of power. *Am. Power Conf.*

Lister M (1684) *Philosophical Transactions of The Royal Society of London* XIV, 493-494.

Lock C G W, Newlands B E R and Newlands J A R (1888) *Sugar: A Handbook for Planters and Refiners*. London: E. and F. N. Spon.

Lonsdale H K (1982) Growth of membrane technology. *Journal of Membrane Science* 10, 81-181.

Lorgna A M (1786) *Nuove Sperienze Intorno Allo Dolcificazione*, Vol. 3. Verona: Mem.diMatica. … Verona. 375-405.

Lucas C (1756) *An Essay on Waters*, Vol. I. London: Millar.

Lyle O (1947) *Efficient Use of Steam*. London: His Majesty's Stationery Office.

Mangold E and Kolliodzschr C K (1939) 86, 93.

McBain J W and Kistler S S (1931) Ultrafiltration for colloidal constituents. *J. Phys. Chem* 35, 130-136.

McCulloch R S (1847) *Investigations in Relation to Cane Sugar*. US Senate.

Meyer K H and Straus W (1940) Sur le passage du courant membranes selectives. *Helv. Chim. Acta* 23, 795-800.

Nachod F C (ed) (1949) *Ion Exchange*. New York: Academic Press Inc.

Nebbia G and Menozzi G M (1968) Early Experiments on water desalination by freezing. *Desalination* 5, 49-54.

Nebbia G and Menozzi G N (1966) Aspetti storici della dissalzione. … *Acqua Ind.*, 41-42, 3-20.

Needham J et al. (1980) *Science and Civilization in China*, Vol. 5. Cambridge: Cambridge University Press.

Nollet J A A (1752) Recherches sur les causes du Bouillonnement des Liquides. *Histoire de l'Academie Royale des Sciences* 57-104.

Ogata N (1993) Recent advances in salt manufacturing in Japan. *Seventh Symposium on Salt*. Elsevier.

Ohno M (1993) Technical progress of salt production in Japan. *Seventh Symposium on Salt*. Elsevier.

Padover S K (1943) *The Complete Jefferson*. New York: Duell, Sloan and Pierce.

Partington J R (1962) *History of Chemistry*, Vols 2-3. London: Macmillan.

Patten H E. and Waggaman W H (1908) Adsorption by soils. *Bureau of Soils - Bulletin*, Vol. 52, (ed. M. Whitney) Washington: Government Printing Office.

Porta G B D (1658) *Natural Magick*, English edn. Vol. X. Naples.

Reader W J (1957) *The Weir Group - A Centenary History*. London: Weidenfeld and Nicolson.

Rose C D (1983) Current design and applications of marine evaporators. *Soc. Nav. Archt. Mar. Eng., New York Section*. New York.

Sarton G (1948) *Introduction to the History of Science*, Vols 1-3. Baltimore: Williams and Wilkins.

Schmeltzer J E (1940) Engineering features of the maritime commission. *Trans. Soc. Nav. Arcts.* 332-370.

Shneiderov A J (1958) Saline water conversion research in the USSR. *Symp. Saline Water Conver.* Washington.

Silver R S (1947) Temperature and pressure phenomena in the flow of saturated liquids. *Proc. Roy. Soc.*

Silver R S (1962) Review of distillation processes. *Symp. Fresh Water from the Sea*. Athens: Elsevier.

Silver R S (1987) *Glasgow Engineering Contribution to the Production of Fresh Water from Seawater*, 41 pp. Glasgow: University of Glasgow.

Smith E C (1938) *A Short History of Naval and Marine Engineering*, 376 pp., 1st edn. Cambridge: Cambridge University Press.

Svedberg T (1928) *Colloid Chemistry*, 2nd edn. New York: Chemical Catalog Company.

The G H (1996) *Drinking Water from the Sea*. Curacao: WEB.

Thompson H S (1850) *J. Roy. Agr. Soc. Eng.* 11, 68.

Tiger H L et al. (1946) Desalting sea water - a practical chemical method. *Ind. and Eng. Chem.* 38, 1130-1137.

Tuley C (1957) Ship distilling unit development, U.S. Navy. *Symp. on Saline Water Conversion*. Washington: NSA-NRC.

Tuley C B (1955) A new design for steam operated distilling unit. *BuShips Journal* 19-29.

Tuwiner S B (1962) *Diffusion and Membrane Technology*, 420 pp. New York: Reinhold Publishing Corp.

Underwood A J V (1935) Historical development of distilling plant. *Trans. Inst. Chem. Eng.* 13, 34-62.

Van Linschoten J H V (1884) *Voyage to the East Indies*, Vol. I. London: Hakluyt Society.

Van't Hoff J H (1887) Die Rolle des osmotischen Druckes in der Analogie zwischen Losungen und Gasen. *Z. Physik.Chem.* 1, 481-508.

Watson B M (1976) *History, Status and Future of Distillation Processes*. US Department of Interior.

Watson P D (1934) Decrease of salts by electrodialysis. *Ind. Eng. Chem.* 26(6), 640-645.

Watson W (1753) An account of Mr Appleby's process to make sea-water fresh; with some experiments therewith. *Philosophical Transactions of The Royal Society of London* 48(1), 69-71.

Way J T (1850) *J. Roy. Agr. Soc. Eng.* 11, 313.

Webre A L and Robinson C S (1926) *Evaporation*. New York: Chemical Catalog Company.

Wilson J (1870) *Naval Hygiene*. Washington: Government Printing Ofice.

Ziadeh N A (1955) Early Arab-Islamic Culture. *Arab Perspectives* 4, 28-29.