Influence of Technological Revolutions on Salt Production

Salt, Safety and the Environment

Keywords: Salt history, Technological revolutions, Civilizations.

Abstract

A comprehensive documentary research was carried out, the result of which is presented in this document, which analyzes the relationship between technological revolutions and salt production throughout history. In order to locate the different innovations in salt production during the technological evolution of different civilization processes and sociocultural formations, the theoretical framework the model developed by Darcy Ribeiro in his book: *The Civilizational Process,* was used.

The Technological Revolutions that influenced the development of salt production in the history of humanity were: Agricultural Revolution (8000 BCE.), Urban Revolution (5000 BCE.), Irrigation Revolution (2000 BCE.), Metallurgical Revolution (1000 BCE.), Pastoral Revolution (600 BCE.), Mercantile Revolution (1500), Industrial Revolution (1800), Thermonuclear Revolution, and Information and Communication Technologies (ICT) (current era). The ICT concept was not developed by Ribeiro, so other sources such the Organization for Economic Co-operation and Development were consulted to include it due to the great influence that information systems have today and their relationship with the salt industry.

The first records on salt production correspond to China in 6000 BCE. during the Agricultural Revolution. Subsequently the salt activity had a prominent role until the Metallurgical Revolution in Egypt, Persia, Greece, Rome, as well as in Mesoamerican and Inca civilizations in Latin America. The Mercantile Revolution with the invasion and colonization of America marked the insertion point of the American Continent in the world economy. From 1492 the production of salt in this region underwent several transformations in its productive, legal and tax organization under the dominion of Europe.

Europe played a leading role in world production and trade of salt until the Industrial Revolution. From this period the salt production began to be linked more actively with other industrial processes. At the end of the 19th century, the main salt companies of Europe and the United States were founded. Those companies exercised the world leadership in salt production and trade in the past century. In the 20th century the main salt companies in China, Latin America and Australia began operations.

At the present time, the United States hegemony in world salt production has decreased due to the expansion of the European salt industry and the steady growth of the economy and salt industry in China. The technological evolution and its impact on the production, trade and diversification of salt as an input of other industrial processes were analyzed in this research. With this we have been able to appreciate the complexity and importance that this activity has had in the history of humanity until the present time.

Introduction

We will analyze the technological revolutions and their influence in the production of salt in the history of the humanity.

Agricultural Revolution (8000 BCE)

It began in Mesopotamia and Egypt. It expanded to India (6000 BCE), China (5000 BCE), Europe (4500 BCE), tropical Africa (3000 BCE) and America (2500 BCE).

Tribes of nomadic hunters and gatherers began to cluster in agricultural villages and started to domesticate animals. (RIBEIRO, p.35).

Traces of salt crops were found in China at Yuncheng Lake, Shanxi (6000 BCE). (KURLANSKY P. 18).

In Halle, Germany, 3500 BCE to 900 CE, there was salt production (MULTHAUF p.46).

In Egypt from 3000 BCE they used salt to cure meat, fish and ham. They exported salted fish to Libya and Ethiopia for salt-preserving properties (KURLANSKY pp. 36, 41).

In America in 2500 BCE agricultural villages that cultivated tubers or cereals were first formed. The Tupinambáes of Brazil exploited the salines in the environs of the Bay of Guanabara (RIBEIRO p.49).

Urban Revolution (5000 BCE)

Began irrigation agriculture, copper and bronze metallurgy, numbering and the calendar. First collectivist rural states: Mesopotamia (before 4000 BCE.), Egypt (4000 to 3000 BCE.), India (2800 BCE) and China (before 2000 BCE). Primitive rural states: Phoenicia (2000 to 1000 BCE), Etruscans (9th century BCE), Athens (6th century BCE) and Rome (before the 3rd century BCE) (RIBEIRO, pp.35, 63).

Nomadic Pastoral Headquarters: Hyksos in Egypt (1700 BCE), Hittites in Syria and Cyprus (1600 BCE), Achaeans in Peloponnesus and Crete (1200 BCE), Huns in Central Asia (200 BCE), Teutons in Central Europe (300 AD) Vandals in Germany and Poland (400), Visigoths in Europe (400) (RIBEIRO p. 63).

Figure 1. Huang Di, the Yellow Emperor

Salt production in China in 3000 BCE and the first war for salt during the reign of the "Yellow Emperor" Huandi (2698-2598 BCE) (KURLANSKY, pp. 36, 18).

In Greece salt was exchanged for slaves. It was also analyzed by philosophers such as Democritus, Empedocles and Aristotle in *the origin, salinity and evaporation of the sea* (ARISTOTLE, pp. 303-324).

In Rome, Ancus Marcius (641-616 BCE) ordered the construction of salt pans of Ostia for the production and distribution of salt, and to avoid relying on the Etruscans (KURLANSKY, p. 63. MULTHAUF, pp. 26-27).

From 8th century BCE the Via Salaria was the first great Roman road to transport salt being 242 km in length. The distribution of salt in the seas was one of the causes of the Punic Wars (264-146 BCE). Scipio was ordered to destroy Carthage and sprinkle salt to sterilize the land (KURLANSKY, pp.62-63).

In Colombia the Chibcha culture (1000 CE) had great ability to produce and distribute salt (KURLANSKY, p. 203).

Irrigation Revolution (2000 BCE)

It emerged in Mesopotamia (Acadian and Babylonian Empire, 2350 BCE and 1800 BCE), Egypt (Middle and New Empire, 2070 BCE and 1750 BCE), China: Dynasties Chou (1122 BCE), Ch'in and Han (220 BCE), Tang 618 BCE), Ming (1368 CE) and Ch'ing (1644 CE), India (Maurya and Gupta Empire, 327 BCE and 320 BCE). In America the Maya Empire (2000 BCE-900 CE), Aztec (1325-1521) and Inca (1200-1533) (RIBERIO, p. 77).

Innovations in hydraulic engineering, copper metallurgy, bronze, ceramics and new techniques in pulleys. Ideographic writing, numeric notation, weight systems, accounting measures, localization of arable land, collection and distribution of food and educational institutions. The empires had a monopoly of raw materials such as salt (RIBEIRO, p.80).

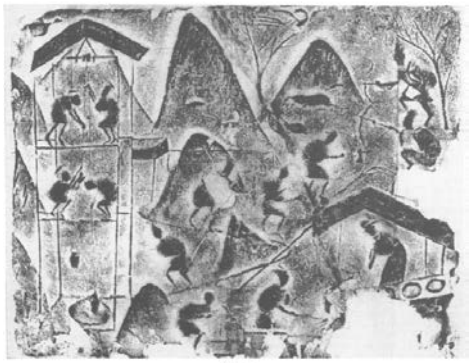

Figure 2. Salt production in Szechwan, China in Han Dynastie (RUDOLPH, R.C.)

In the Zhou dynasty in China (1122 BCE) the first document on salt production and trade was made. In 450 BCE Yi Dun used metal casseroles to evaporate brine for the first time in the world. In the Ch'in Dynasty (221 BCE) they used ancient writings (Guanzi, 300 BCE) to manage salt production. (KURLANSKY, pp. 30-31).

Figure 3. Men Preparing Fish, Tomb Puyemré (WILKINSON)

In India the Gupta Empire exerted a tax on salt (HIGHAM, p.121).

In America, the Mayas used salt for birth control, epilepsy, and labor pain. They even obtained salt from plants (KURLANSKY, p.204, THOMPSON).

The Aztec empire had warehouses with salt and food taxed from other cultures. (EWALD, p.22). Uixtocíuatl was the Aztec goddess of salt. (CASO, p. 62).

In the Inca empire, the mindalá exchanged products such as gold, silver, salt, coca leaf, chili, and hallucinogens (SALAZAR, WÖRRLE, p. 76).

Metallurgical Revolution (1000 BCE)

Assyrian civilization (12th to 7th century BCE), Achaemenian (6th to 8th century BCE), Hellenic (5th to 1st century BCE), Carthaginian (6th to 2nd century BCE), Roman (1st to 4th century CE) and Byzantine 6th To 10th century CE) (RIBEIRO p. 88).

Manufacture of tools, weapon and metal parts. Coin minting and adjustments in transport vehicles. Improvements to the phonetic alphabet and decimal numbering. Construction of hydraulic machines such as windmills, aqueducts and cranes.

In Rome the salt was guarded by legions who received their payment in salt to conserve foods and to exchange it (*salarium*: payment of salt). Magnus Aurelius Cassiodorus (485-585 CE) emphasized the importance of salt in *Variarum Libri* (IORGA, p. XII).

In the rest of Europe in Hallstatt period (900-400 BCE) they produced salt in Nauheim, Hesse, Vic-Lorraine and southern England. In La Tene period (450 BCE -1 CE) in Schwabish Hall, Württemberg. Gallo-Romans produced salt on the French Atlantic coast, southern England and the Netherlands at Salins and Reichenhall (MULTHAUF, p.46-47).

Pastoral Revolution (600 BCE)

Some pastoral leaders took advantage of the use of iron. Began the "despotic Salvationist empires" (RIBEIRO, p.96)

The Sassanian Persians dominated Iran, Mesopotamia and India (3rd to 7th century CE) and Asia Minor. In the 7th century Islam emerged and spread to the Middle East, North Africa, Mediterranean islands, Iberian Peninsula, Upper Asia, India, Indonesia, China, tropical Africa and Eurasia. Other Salvationist Despotic Empires: Ottoman Civilization (1460 CE) and Timurida (1530 CE) (RIBEIRO, p.97).

The Holy Roman Empire (962-1806) and the Byzantine (1025-1453) adopted similar characteristics as a mirror-strategy against Islam.

The salt mines of Ostia were exploited by Byzantium, then by Islam without any technological innovation (KURLANSKI, p. 80).

Salt taxes were implemented in the Caliphate of Cordoba (750 to 1031) and the Sultanate of Delhi (1300-1526) under the rule of the Timurid Empire.

The production of salt was made with the organization of successive empires. Greco-Roman forms of slavery, monopolies and imperial concessions were adopted for their production and trade.

In 1273 Rudolf I of Germany promoted the royal monopoly on salt production and trade in much of Central Europe (KURLANSKY, p. 169). In 1348 the Crown of Castile decreed their royal rights over salt (MULTHAUF, p. 32).

Origin of the *Gabelle*.

The term *gabelle* is derived from the Italian *gabella* (a duty), itself originating from the Arabic word *qabala* (to receive).

The gabelle was a very unpopular tax on salt in France. It was originally an indirect tax that was applied to agricultural commodities. However, from the 14th century , the gabelle was limited and solely referred to the French crown's taxation of salt.

We can find the origin of the gabelle in France in the 13th century, when a salt tax was created in Provence and in the saltworks of Marseille. It then spread throughout France during the Hundred Years' War. There were exceptions and impositions until 1386 when it became permanent (MULTHAUF, pp. 29-30, KURLANSKY, p. 226).

Mercantile Revolution (1500)

Advances in navigation and production of fire arms. Spain formed the first colonial world empire and Russia carried out a mercantile colonization towards Eurasia. The "mercantile capitalism" was generated in Holland (1609), later in England and France (RIBEIRO, p.114).

In 1550 the use of coal for the production of salt is started in Germany (MULTHAUF, p.101).

In 1670 a salt deposit in Cheshire was found and England is positioned as an exporting power (MULTHAUF, p.52).

In Germany the royal councils had specialists (*cameralists*) in laws, administration and technology. G.H. Zincke (1742) was a leading cameralist who analyzed trade, quality and inputs in salt production. Later the title of *Salinist* was created (MULTHAUF, pp. 113-115).

Figure 4. Reichenhall Saltworks, 1771 (VON STUBENRAUCH)

In 1789 Louis XVI ordered to increase the *gabelle* to the salt. Social discontent overflowed and the French Revolution broke out (KURLANSKY, p. 234). The *gabelle* was abolished in 1790 and was reestablished in 1805 to finance Napoleon's wars (MULTHAUF, p. 31).

In Mexico in 1555 Bartolome de Medina developed a technological innovation that required salt for silver amalgamation (Patio process).

In 1603 and 1609 Spain issued Royal Decrees for salt taxes. In 1635 they were applied to finance the Barlovento Navy.

In 1654 the dutch were expelled from Brazil and the salt production control was reestablished, boosting the dry meat industry until the eighteenth century.

In 1710 the *Revolta do sal* (MONTEIRO) occurred in Brazil and in 1762 another rebellion happened in Colima, Mexico. Both were in protest of taxes and corruption in the distribution of salt.

Joao VI fled to Brazil in 1808 due to the expansion of Napoléon. This provided incentives for the production of Brazilian salt (DIÓGENES).

In Chile, Manuel de Amat and Juan Ignacio Molina conducted research on geography and salt production in 1761 and 1788 (AMAT, pp. 425-458, MOLINA).

The increase in silver production in Mexico at the end of the 18th, with the participation of salt in that sector, contributed greatly to the financing of European industrialization (RIBEIRO, p. 117).

In 1801 Alexander von Humboldt conducted a research on salt production at the Zipaquirá mine in Colombia. He commented on the less productive saltworks of Germany (Berchtologaden, Schwabisch-Hall and Hallein) and the best installed ones (Tirol, Fraunhosen and Schonebeck). He identified similarities of Zipaquirá with the mines of Aragon, Tyrol, the Carpathians, Wieliczka and Hallein.

Von Humboldt raised the importance of modernizing saltworks as Germany, Prussia and Berne did, and commented on the rational use of wood and social impact on communities (VON HUMBOLDT).

Industrial Revolution (1800)

It began in the mid-18th century in England. The technological development will be divided in: Steam engine, Electrical energy and oil.

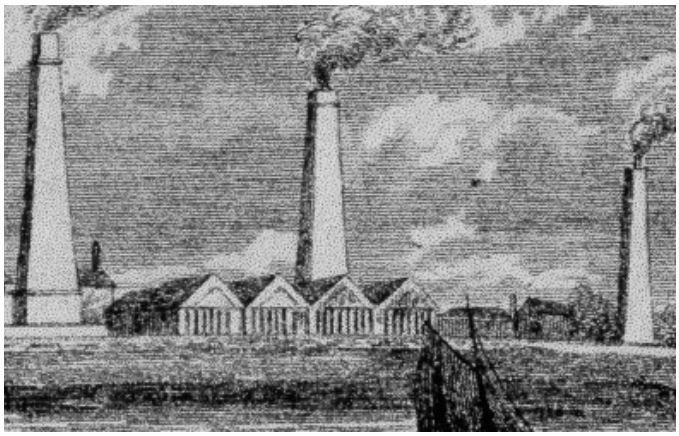

Figure 5. Garston Saltworks (1790's)

The steam engine

The invention of the steam engine contributed to the use of the water pumps and charge elevators that facilitate the production of coal.

The use of the steam locomotive and the steamboat allowed to transport large quantities of salt by land and sea. Salt production and trade increased.

At the end of the 18th century the German government decreed that the Schönebeck salt mine would have a steam engine built by Oberbergrath Bükling. In 1799 the first machine of this type was installed in Königsborn (MULTHAUF, p.134).

In 1887 Joseph Duncan installed the first vacuum salt process in Silver Springs, New York (KURLANSKY, p. 328).

Since the mid-19th century in Mexico they applied new brine evaporation techniques and used windmills as a source of wind energy (EWALD, pp. 123-125).

From the 19th century in Chile began an installation of railways and sea routes of steamships to connect the main salt production centers (VERA).

In the 1930's, the first vacuum salt plant was built in Mexico.

Electrical energy

At the end of the 19th century the use of electrical energy began on a larger scale. In 1930 came the process of producing salt by electrodialysis to desalt the sea water. It was introduced in Japan in 1965 with 57 thousand tons of salt produced by electrodialysis. Seven years later it increased to 1.12 million tons (MULTHAUF, p. 295).

Production of soda and salt

In France in 1792 a technological innovation in the production of artificial soda using salt to make sodium carbonate was developed. The *gabelle* had been demolished in France and in England this tax was also repealed. With this the chemical industry increased with salt at an accessible price (MULTHAUF, p.153).

The artificial soda industry was the first big consumer of salt. In the mid-19th century it covered 17% of the national consumption of salt in England and 15% in France. Fifty years later it increased to 65% in France, 61% in Great Britain and 43% in Germany. In 1900, half of the national salt consumption in the United States was to produce soda (MULTHAUF, p. 289).

Petroleum: Neptune yields to Vulcan

The use of petroleum and other fossil fuels like natural gas began in the 20th century in the United States, England and France.

The world production of salt by solar evaporation (sea salt) decreased when new technologies appeared: Rock Salt Mining, Solution Mining (Vacuum salt or Electrodyalisis).

For example: In Italy in 1897, 93% of the salt production was by solar evaporation and in 1965 this had decreased to 34%. In France in 1896, 63% was sea salt and in 1965 it was reduced to 18% (MULTHAUF, p.294).

Some variations that had the production of salt in some countries.

Period	USA	UK	Germany	France	Russia
1875-1890	+ 280%	+ 12%	+ 73%	+ 54%	+ 103%
1890-1925	+ 236%	- 2 %	+ 70%	+ 67%	-35%
1925-1960	+ 244%	+ 198%	+ 160%	+ 160%	+ 642%

Table 1. Percentages of increase in salt production (MULTHAUF, p.289)

Salt March

On 12 March 1930 Mahatma Gandhi and 78 people started the Salt March in India. They walked more than 300 kilometers and culminated on April 6 accompanied by a crowd on the coasts of the Indian Ocean.

The Salt March fractured the British colonial system and awakened the people of India to organize on the road to their independence, which they would reach in 1947.

Thermonuclear Revolution and Information and Communication Technologies - ICT- (Current era)

In 1942 the United States built the first nuclear reactor and detonated the atomic bomb in World War II. Subsequently, nuclear energy was used for electrical, thermal and mechanical energy.

The ICT (devices, networking components, applications and systems) began to integrate in the 1980's. This technologies has been used by the salt industry in trade, transportation, information, systems and others.

During the 20th century, national and international associations of salt companies were founded in America, Europe, Asia and Africa. In 1914 the Salt Institute was founded in the United States. In 1957 the European Committee for the Study of Salt was founded in France, later changed its name to European Salt Producers' Association (EU Salt) and in 2004 it moved to Brussels, Belgium.

Figure 5. Salt production in USA and Chile (K+S)

Currently in the world around 40% of salt is produced by solar evaporation of seawater or inland brines, 26% by mined rock salt and 34% by solution mining (ROSKILL).

Year	Million Tons
1900	12.2
1950	48.1
2000	195

Table 2. World salt production (KELLY).

In 2016 world salt production was 255 million tons (BOLEN, p.141). Approximately 50% was used by the chemical industry, 15% was used for road salt for deicing, 11% was used in food industry and table salt. Other uses (water softening, animal feed, industrial and medical uses) account for the remaining 24%. (IHS MARKIT)

Iodized salt. A public health triumph

From the 20th century salt is the most commonly used vehicle to prevent iodine deficiency disorders (IDD): perinatal mortality and mental retardation, preventable brain damage in childhood, goiter. It was first introduced in the 1920s in the United States and Switzerland (WHO, p.2).

In 1990 the United Nations World Summit for Children adopted a plan action that includes the virtual elimination of IDD by the year 2000.

In 2000 The Global Network on Sustained Elimination of IDD was formed by: ICCIDD (Iodine Global Network –IGN- today), WHO, UNICEF, Salt Institute, EuSalt, Kiwanis International, Micronutrient Initiative, Emory University, US CDC (IGN). In 2013, UNICEF reported more than 35 million newborns were unprotected from the lifelong consequences of brain damage associated with iodine deficiency (UNICEF).

Universal salt iodization has been the most widely used strategy to control and eliminate IDD. In 2013 UNICEF estimated that 75% of all households consumed adequately iodized salt.

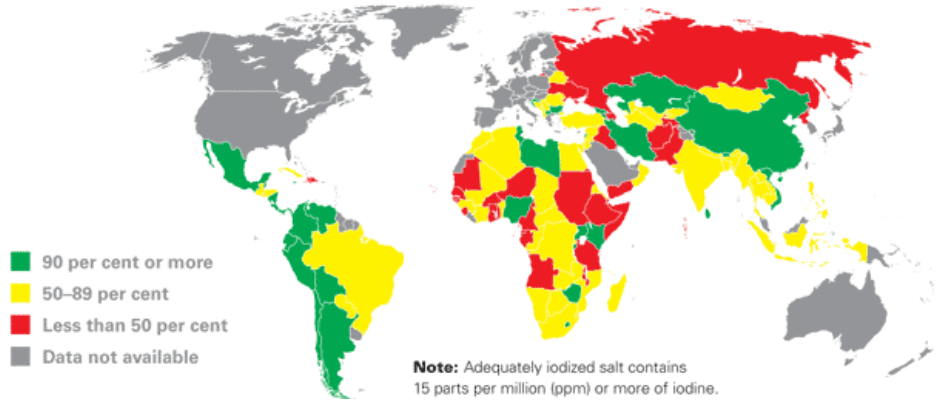

Figure 4. Percentage of households consuming adequately iodized salt, 2000–2006 (UNICEF).

Countries where IDDs were a public health problem were reduced from 110 in 1993 to 25 in 2015 (IGN).

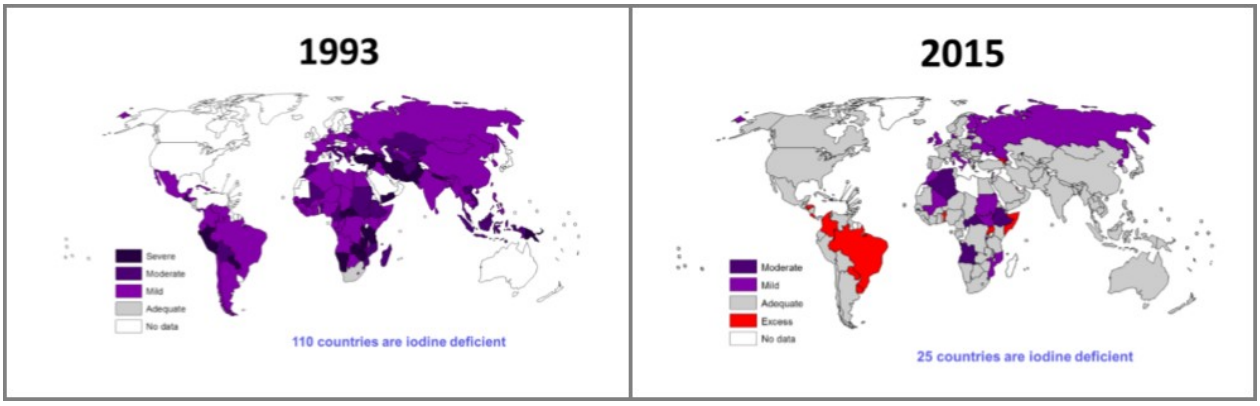

Figure 5. Map of Countries with Iodine Deficient, 1993 and 2015 (IGN)

CONCLUSIONS

Technological revolutions influenced the increase in salt production and its link with different aspects of human activity in all regions of the world.

Salt production was initially used for meet the human needs of food, food preservation, some medicinal and other applications. It also had a relevant role in the economy as a source of tax revenue and trade.

For many centuries the main technologies applied in the production of salt were by solar evaporation, cooking and manual extraction of mineral deposits. The turning point was from the Industrial Revolution with the use of new energy sources and production methods such as vacuum salt and electrodialysis.

Other industries have also emerged that have required large amounts of sodium chloride for their production processes. As well as the development of road infrastructure, this demands a large volume of this mineral for deicing roads during the winter.

Another aspect of great importance in the public health is the contribution of the salt added with iodine to prevent the IDD. This contribution has been fundamental for the development of different communities and deserves to be communicated, instead of transmitting through ICT and traditional media partial and aggressive messages against salt, by associating it in a simplistic way as if it were the main risk factor of cardiovascular diseases.

In this age of fake news, post-truth and media battles we must make an effort to talk and listen to the other. It is necessary to find a common and inclusive language between international health agencies and the salt industry.

During a conversation with an esteemed teacher, she told me that salt was like air. We do not realize its importance until we begin to notice its absence in our life. That is why I wish for a long life to this precious mineral.

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