EGTOP/2021

EUROPEAN COMMISSION
DIRECTORATE-GENERAL FOR AGRICULTURE AND RURAL DEVELOPMENT

Directorate B. Quality, Research & Innovation, Outreach
B.4. Organics

Expert Group for Technical Advice on Organic Production

EGTOP

Organic sea salt and other salts for food and feed
Final Report

The EGTOP discussed this technical report at the plenary meeting of June 16, 2021.

About the setting up of an independent expert panel for technical advice

With the Communication from the Commission to the Council and to the European Parliament on a European action plan for organic food and farming adopted in June 2004, the Commission intended to assess the situation and to lay down the basis for policy development, thereby providing an overall strategic vision for the contribution of organic farming to the common agricultural policy. In particular, the European action plan for organic food and farming recommends, in action 11, establishing an independent expert panel for technical advice. The Commission may need technical advice to decide on the authorisation of the use of products, substances and techniques in organic farming and processing, to develop or improve organic production rules and, more in general, for any other matter relating to the area of organic production. By Commission Decision 2017/C 287/03 of 30 August 2017, the Commission set up the Expert Group for Technical Advice on Organic Production.

EGTOP

The Group shall provide technical advice on any matter relating to the area of organic production and in particular it must assist the Commission in evaluating products, substances and techniques which can be used in organic production, improving existing rules and developing new production rules and in bringing about an exchange of experience and good practices in the field of organic production.

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All declarations of interest of Permanent Group members are available at the following webpage: www.organic-farming.europa.eu

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EXECUTIVE SUMMARY

In addition to the general production rules laid down in the Regulation (EU) 2018/848, the following rules shall apply to the organic production of food grade salt and salt for feed obtained from the sea, from rock salt deposits, from natural brine or from salt lakes. It does not apply to salt from origins other than those mentioned above, notably to the salt which is a synthetic product of chemical reactions, or is made from effluents from chemical industry, other industries and seawater desalination plants, or is a by-product from potash flotation.

Organic salt shall be consisting predominantly of sodium chloride as defined in Codex Alimentarius Standard 150-1985 for food grade salt. By way of derogation, the level of sodium chloride may be lower in case provisions of Union law or provisions of national law compatible with Union law, define this level differently (for example: Salt flower/Fleur de sel/Flor de sal, sal marina virgen, sel gris, sal marinho tradicional).

Food and feed additives, processing aids and non-organic agricultural ingredients, if authorised for organic production in the acts adopted on the basis of Article 24 (2)(a) and (b) of Regulation (EU) 2018/848, are authorized for production of organic salt, in accordance with restrictions and specifications included.

For cleaning, descaling and disinfection of process equipment, surfaces which are in contact with organic salt only the following products shall be used:

(a) cold water and hot water for cleaning;
(b) acetic acid, formic acid, diluted hydrochloric acid, and sodium carbonate for descaling;
(c) hot water and steam for disinfection.

Practices, processes and treatments in organic salt production, which are allowed and prohibited are specifically reported in the pertinent section of this report.

The production of salt is considered as organic production provided that the seawater and salty waters quality corresponds to clean seawater or clean water according to Article 2(1)(h) and (i) of Regulation (EC) 852/2004.

For salt obtained from the sea, rock salt deposits, natural brine or salt lakes, in order to be considered an organic product, a conversion period of at least two years before the first harvest shall be required.

The production of organic, in-conversion and non-organic salt in the same production unit is permitted.

Products, substances and techniques that reconstitute properties that are lost in the production or storage of organic salt, that correct the results of negligence in the production of organic salt, or that otherwise may be misleading as to the true nature of products intended to be marketed as organic salt, shall not be used.

1. TERMS OF REFERENCE

In the light of the most recent technical and scientific information available to the experts, the group is asked to address the following list of items and assess which measures in line with the rules laid down in Regulation (EU) No 2018/848 could be proposed for organic sea salt and other salts for food and feed.

Review of production methods

Salt may be produced from salty water or from rocks. Numerous processes exist and include different techniques (collect, separation from water -sun, wind, heat, vacuum- purification, grinding, sorting, cutting, drilling, blasting, refining, …).

The salt sub-group shall describe each production process separately and evaluate its compatibility with the objectives and principles of organic production mentioned in Chapter II of Regulation 2018/848. Where relevant, comparison with existing production rules of agricultural product laid down in Chapter III of this Regulation shall be done to evaluate the compatibility with the objectives and principles of organic production.

Composition and contamination

Salt for food and feed correspond to sodium chloride (NaCl), depending of its origin and the method of production, additional elements and contaminants are also present in the final product.

The salt sub-group shall list the different elements and contaminants that may be present in the final product for each type of production. The salt sub-group shall establish the concentration range of those elements and contaminants for each type of production/origin.

The potential source of contamination shall also be listed for each type of production (e.g.: water, pollution, cross-contamination,…).

Salt additives

Additives in conventional food grade salt are authorised at EU level and listed in Regulation (EC) 1333/2008[1].

The salt sub-group shall describe the function for each authorised additive in food and list the additives normally used in salt for feed.

Organic salt

Based on the analyses foreseen under points 1, 2 and 3, the salt sub-group shall suggest production rules applicable to organic production of salt and its final composition (including minimum and maximum thresholds s). The organic production rules should identify a positive and a negative set of production techniques, products and substances used.

In accordance with the Regulation 2018/848, the salt sub-group will evaluate in particular the following elements:

- The distinction between natural and non-natural production techniques (whereas 10);
- The contribution of salt production to the development of rural areas (whereas 10);
- The contribution to protection of the environment and climate (Art 4(a));
- The encouragement of short distribution channels and local production in the various areas of the Union (Art 4(f)
- The contribution to a non-toxic environment (Art 4(d));
- The respect for nature's systems and cycles (Art 5(a));
- The preservation of natural landscape elements, such as natural heritage sites (Art 5(b));

[1] Regulation (EC) No 1333/2008 of the European Parliament and of the Council of 16 December 2008 on food additives (OJ L 354, 31.12.2008, p. 16)

- The responsible use of energy and natural resources, such as water, soil, organic matter and air (Art 5(c));
- The production of a wide variety of high-quality products that respond to consumers' demand for good that are produced by the use of processes that do not harm the environment and human health (Art 5(d);
- The adaptation of the production process to take account of the regional differences in the ecological balance, climatic and local conditions

The salt sub-group will also provide their views in particular on:

- The possibility to split into clearly and effectively separated production units and the resulting requirements (Art 9(2) and (7));
- The necessity and condition to comply with a conversion period (Art 10);
- The specific requirements for collection, packaging, transport and storage of products (Annex III).

In setting organic salt production rules, a particular attention will be done on water in the framework of the Directive 2000/60/EC of the European Parliament and of the Council.

2. CONSIDERATIONS AND CONCLUSIONS

2.1. General consideration

The members of the permanent EGTOP Group wish to acknowledge the salt experts of the subgroup, namely Lidia ALDEGUER MORALES, Franz GOETZFRIED, Louis MERLIN and Andrea SIEBERT, for their valuable contribution to this technical advice. They provided an impressive amount of information on the different production methods, composition, contaminants and additives, in addition to constructive considerations on possible organic salt production rules. This report includes a selection of the documents they provided for the discussion.

2.2. Production rules applicable to organic production of salt

2.2.1. Scope

In addition to the general production rules laid down in the Regulation (EU) 2018/848, the following rules shall apply to the organic production of food grade salt and salt for feed obtained from the sea, from rock salt deposits, from natural brine or from salt lakes. It does not apply to salt from origins other than those mentioned above, notably to the salt which is a synthetic product of chemical reactions, or is made from effluents from chemical industry, other industries and seawater desalination plants, or is a by-product from potash flotation.

2.2.2. Composition

(a) Organic salt shall be consisting predominantly of sodium chloride as defined in *Codex Alimentarius* Standard 150-1985 for food grade salt[2].

(b) By the way of derogation from point above, the level of sodium chloride may be lower in case when the provisions of Union law or provisions of national law compatible with Union law[3,4] define this level differently (for example[5,6,7,8,9]: Salt flower/*Fleur de sel/Flor de sal, sal marina virgen, sel gris, sal marinho tradicional).*

(c) Organic salt may comprise natural secondary products, which are composed mainly of calcium, potassium, magnesium and sodium sulphates, carbonates, bromides and calcium, potassium, magnesium chlorides.

(d) Natural contaminants may not be present in the final product at levels higher than maximum levels as defined in *Codex Alimentarius*[10,11] for contamination and toxins in food and feed or as defined in the European[12] and national legislation, whichever is stricter.

(e) The levels of natural secondary products referred to in point (c) shall be in line with the European legislation in case such legislation is established for salt for food and

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2 *Codex Alimentarius*, Standard for Food Grade Salt. Codex Stand Number 150-1985,

3 Commission Implementing Regulation (EU) 2020/1668 of 10 November 2020 specifying the details and functionalities of the information and communication system to be used for the purposes of Regulation (EU) 2019/515 of the European Parliament and of the Council on the mutual recognition of goods lawfully marketed in another Member State.

4 Regulation (EU) 2019/515 Of the European Parliament and of the Council of 19 March 2019 on the mutual recognition of goods lawfully marketed in another Member State and repealing Regulation (EC) No 764/2008.

5 Real Decreto 1424/1983, de 27 de abril, por el que se aprueba la Reglamentación Técnico-Sanitaria para la obtención, circulación y venta de la sal y salmueras comestibles.

6 Ministère de l'Économie, des Finances et de l'Industrie: Décret no 2007-588 du 24 avril 2007 relatif aux sels destinés à l'alimentation humaine.

7 Portaria nº 72/2008, de 23 de Janeiro 2008

8 2326. Pravilnik o kakovosti jedilne soli, stran 7498. Uradni list RS, st 46/2018 z dne 6.7.2018

9 NN 70/2019, n. 1472 - Ministarstvo poljoprivrede

10 *Codex Alimentarius*, Standard for contaminants and toxins in food and feed. Codex Stand Number 193-1995,

11 Codex Alimentarius, Standard for Food Grade Salt. Codex Stand Number 150-1985,

12 Revision Reg. (EC) 1881/2006 (Cd and Pb)

feed.

(f) When placing on the market, the sodium chloride content of organic salt for feed shall be indicated on the label as required by current legislation[13,14].

(g) Natural contaminants may not be present in organic salt for feed at levels higher than the maximum levels defined in Directive 2002/32/EC on undesirable substances in animal food.

2.2.3. Use of certain products and substances

(a) Food and feed additives, processing aids and non-organic agricultural ingredients, if authorised for organic production in the acts adopted on the basis of Article 24 (2)(a) and (b) of Regulation (EU) 2018/848, are authorized for production of organic salt, in accordance with restrictions and specifications included.

(b) Specifically, the use of the following anti-caking agents in fine-grained organic salts with a grain size not coarser than 2 mm is allowed in organic salt production:
   1. E 535 Sodium ferrocyanide in organic salt for food and feed;
   2. E 551b Colloidal silica in organic salt for food;
   3. E 170 Calcium carbonate in organic salt for food;
   4. E 504 Magnesium carbonate in organic salt for food.

(c) Specifically, the following processing aids are allowed in organic salt production:
   1. Nitrogen or air as blankets for solution mining;
   2. calcium hydroxide, sodium hydroxide, sodium carbonate, carbon dioxide (flue gases from natural gas firing, which were prior subjected to wet washing) for brine treatment (softening);
   3. sodium hydroxide for the regulation of the pH of brine;
   4. calcium sulphate (gypsum) from natural origin as seed crystals in brine;
   5. vegetable oils, only when derived from organic production, as anti-foaming agent.

(d) Specifically, the following processing aids are not allowed in organic salt production:
   1. diesel as blankets for brines;
   2. flocculants for brine treatment (softening) such as polyacrylamides;
   3. anti-foaming agents such as polydimethylsiloxane or vegetable oils.

(e) The addition of iodine salts in organic salt production is allowed provided that their use is “directly legally required”, in the meaning of being directly required by provisions of Union law or provisions of national law compatible with Union law, with the consequence that salt cannot be placed at all on the market as food for normal consumption if iodine was not added. The maximum and minimum levels used are to be calculated as iodine (expressed as mg/kg) and shall be established by the national health authorities in the light of the local iodine deficiency situation. These levels shall be in line with the European legislation in case such legislation is established for salt with iodine.

2.2.4. Cleaning and disinfection products

For cleaning, descaling and disinfection of process equipment, surfaces which are in contact with organic salt only the following products shall be used:

(d) cold water and hot water for cleaning;

(e) acetic acid, formic acid, diluted hydrochloric acid, and sodium carbonate for descaling;

(f) hot water and steam for disinfection.

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13 Regulation (EC) No 2017/2279

14 Regulation ((EC) No 767/2009

2.2.5. Practices and restrictions

(a) The use of the following practices, processes and treatments in organic salt production is permitted:

1. direct supply of sea water to produce organic sea salt;
2. direct supply of salt spring water or salt lake water for salt obtained from natural brine;
3. supply of crystallized salt from underground or on-surface mining;
4. use of water or non-saturated brine to dissolve rock salt by solution mining in the underground, or by dissolution on surface;
5. physical-thermal evaporation and crystallization processes for the production of organic evaporated salt [multiple effect evaporation (MEE), mechanical vapour recompression (MVR), recrystallization and flash evaporation];
6. rock salt mining by mechanical cutting with mechanical techniques, like roadheaders and continuous miners, or by drilling;
7. mechanical harvesting with agricultural equipment in the crystallisers;
8. manual harvesting in the crystallisers, including salt flower only from the surface of the brine in the crystallisers;
9. drying of salt with direct solar energy or with hot air. Where possible, the use of energy shall be limited to energy from renewable sources;
10. washing, centrifugation, nano-filtration;
11. sieving, sorting, crushing and grinding by mechanical means;
12. compaction by mechanical means;
13. optical and magnetic sorting of salt;

(b) The use of the following practices, processes and treatments in organic salt production is prohibited:

1. rock salt mining by using explosives;
2. addition of oxygen scavengers to brine;
3. disposal of sludge from brine treatment and natural water-insoluble substances from rock salt dissolution, except in underground salt mines or brine caverns;
4. disposal of undiluted mother liquor (“bittern”) from sea salt crystallizer ponds to the sea;
5. use of steam with volatile boiler chemicals (oxygen scavengers, ammonia) for direct heating of brine;
6. use of biocides in cooling water systems, whereby the cooling water can come into direct contact with brine;
7. production of evaporated salt in open pans (pan salt), whereby the natural brine or seawater is heated with electricity, live steam or flue gas from gas, oil, wood and coal-fired systems;
8. use of plastic liners as the contact layer of the bottom of the evaporation and crystalliser ponds;
9. addition of colouring agents to seawater to increase absorption of sunlight;
10. production of solar salt from brine, which is made by solution mining or by dissolving rock salt on surface;
11. construction and maintenance of ponds for sea salt and solar salt production with contaminated material such as soil;
12. direct drying of salt with flue gas from oil, wood and coal-fired systems;
13. upgrading of rock salt with the following processes:
    i. *flotation,*
    ii. *electrostatic separation,*

iii. *thermoadhesive separation,*
iv. *heavy media separation.*

2.2.6. Environmental aspects

(a) Organic salt production techniques shall prevent or minimise any contribution to the contamination of environment, should contribute to biodiversity preservation and sustainable use of resources, as well as have almost zero ecological footprint.
(b) The operator shall provide environmental assessment to the control authority or control body. The content of the environmental assessment shall be based on Annex IV to Directive 2011/92/EU[15] of the European Parliament and of the Council.
(c) By the way of derogation from point (b), operators with a production lower than 500 tons of organic salt shall not be obliged to provide environmental assessment to the control authority or control body. These operators have to make sure that the size of the saltworks meets the requirements of the corresponding ecosystem[16]
(d) The operator shall provide a sustainable management plan proportionate to the production unit. Business operators shall draw up as part of the sustainable management plan a waste reduction schedule to be put in place at the commencement of operations. Whenever possible, the use of energy shall be limited to energy from renewable sources.
(e) In particular, the operator must take measures to maintain or increase biodiversity in the area of the production unit.

2.2.7. Water quality

(a) Water quality levels shall be adequate to ensure the development and survival of characteristic biocenosis of sea saltworks, which are intrinsically necessary for sea salt production. Specific regulation enforcement[17,18] shall protect and guarantee symbiosis between the ecosystem and the activity and the objectives of saltworks.
(b) The production of salt is considered as organic production provided that the seawater and salty waters quality corresponds to clean seawater or clean water according to Article 2(1)(h) and (i) of Regulation (EC) 852/2004.
(c) Contaminant control measures in the final product as established in agreed regulations (Codex Alimentarius Standards)[19,20] shall apply to ensure both the quality of the organic salt and the quality of its natural source.

2.2.8. Location

(a) Operations shall be situated in locations that are not subject to contamination with products or substances not authorised for use in organic production, or with pollutants that would compromise the organic nature of the product.
(b) Salt production shall not be considered as organic when practiced at locations or in areas designated by competent authorities (or certification bodies) as locations or

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15 Directive 2011/92/EU of the European Parliament and of the Council of 13 December 2011 on the assessment of the effects of certain public and private projects on the environment (OJ L 26, 28.1.2012, p. 1).

16 The appropriate size of saltworks to meet environmental and production requirements - Bernard Moinier- General Secretary, European Salt Producers Association (ESPA)

17 *Birds Directive* – Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds.

18 *Habitat Directive* – Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora (Natura 2000)

19 *Codex Alimentarius*, Standard for Food Grade Salt. Codex Stand Number 150-1985,

20 *Codex Alimentarius*, Standard for contaminants and toxins in food and feed. Codex Stand Number 193-1995,

areas which are unsuitable for such activities.

(c) Vegetation surrounding the production unit should not be treated with any products other than those allowed in organic production.

2.2.9. Conversion rules

(a) For salt obtained from the sea, rock salt deposits, natural brine or salt lakes, as defined in point 1, in order to be considered an organic product, a conversion period of at least two years before the first harvest shall be required.

(b) Where the production unit has been contaminated with products or substances not authorised for use in organic production of salt, the competent authority (or certification body) may decide to extend the conversion period for the production units concerned beyond the period referred above.

(c) No previous period may be retroactively recognised as being part of the conversion period, except where:

1. the operator's salt works and surroundings were subject to measures which were defined in a programme implemented pursuant to Regulation (EU) No 1305/2013 for the purpose of ensuring that no products or substances other than those authorised for use in organic production have been used on those salt works and surroundings; or
2. the operator can provide proof that the salt work and surroundings, for a period of at least three years, have not been treated with products or substances that are not authorised for use in organic production.

2.2.10. Organic, in-conversion and non-organic production at the same holding

(a) The production of organic, in-conversion and non-organic salt in the same production unit is permitted.

(b) Where organic, in-conversion and non-organic products, in any combination, are prepared, processed or stored at the same holding, the operator shall:

1. inform competent authority or, where appropriate the control authority or control body, accordingly;
2. carry out the operations continuously until the production run has been completed, separately in place or time from operations performed on any other kind of product (organic, in-conversion or non-organic);
3. store organic, in-conversion and non-organic primary and final products, before and after the operations, separate by place or time from each other;
4. keep available an updated register of all operations and quantities processed for organic, in-conversion and non-organic production, including information on additives used and practices, processes and treatments applied in non-organic salt production;
5. take the necessary measures to ensure identification of lots and to avoid mixtures or exchanges between organic, in-conversion and non-organic products;
6. carry out operations on organic or in-conversion products only after suitable cleaning of the production equipment.

2.2.11. Misleading nature of products

(a) Products, substances and techniques that reconstitute properties that are lost in the production or storage of organic salt, that correct the results of negligence in the production of organic salt, or that otherwise may be misleading as to the true nature of products intended to be marketed as organic salt, shall not be used.

2.2.12. Obligation of operators

(a) Operators producing organic salt shall establish and update appropriate procedures based on systematic identification of crucial production steps.
(b) The application of the procedures referred above shall ensure that the produced organic salt comply with this Regulation at all times.

3. ANNEX I - DESCRIPTION OF DIFFERENT SALT ORIGINS, SALT PRODUCTION METHODS, COMPOSITION AND CONTAMINANTS

1. DEFINITIONS AND CONTEXT

1.1 Definitions

Brine: concentrated saline water
Salinity*:* There are different methods to measure salt concentration. In this document, salinity is expressed in grams of NaCl per litre of saline water (g/l). The Baumé scale (º Be) is still used in the salt industry; conversion tables are available in *Tables T.1.*
Salt: in the context of this paper, salt and sodium chloride are synonymous. Pure salt is composed of 40% sodium and 60% Chloride, by weight.
Saltmarshes: Intertidal wetland with specific saline ecosystem. Equivalent to coastal mangrove belts in tropical areas.
Saltworks: a place or plant where salt is produced and/or processed.
Solar evaporation: concentration and crystallization of saline waters by sun and wind.
Solar saltworks: a set of connected pools, in which seawater is left to evaporate to obtain salt; usually situated in saltmarshes.
Sea salt: salt obtained in open-air saltworks after the solar evaporation of seawater.
Rock salt: salt obtained from the surface or underground mining of halite deposits.
Vacuum salt: salt obtained from saturated brine in vacuum evaporative crystallizers.

1.2 Context

Humans have produced salt for 8.000 years with different methods based on crystallisation through natural evaporation or heating systems from seawater or natural saline water; and extraction of rock salt. Most of the multiple socio-technical systems of salt production developed over centuries, still exist almost unchanged.
During the 19th and 20th centuries, industrialization impacted the salt sector with new, capital-intensive technologies. Huge solar saltworks appeared, based on mechanical pumping and mechanical harvesting. Rock salt extraction benefited from the improvement of mining methods. Salt from solution mining has its own specific economy, the salt produced is less valuable than the subterranean caverns created where oil and gas can be stored, turning them in strategic assets in the global energy economy[i, ii]. Consequently, the salt sector is of interest not only to salt producing companies but also to oil and gas corporations. Today, high-tech salt plants owned by large conglomerates and producing more than a million tons a year, co-exist with traditional small-scale producers.
Nowadays, the salt sector is driven by major factors far from food and feed. "*Today, salt is the largest mineral feedstock consumed by the world chemical industry*"[iii]. Over 280 million tons of salt are currently produced worldwide per year, a 500% increase since 1950[iv]. Of this, over 65% goes to chemical industry (PVC, etc.) and road de-icing[v]. Growing demand for highly purified salt for industrial uses led to the development of purification processes resulting in salts over 99% NaCl. With just 8% of the total consumption in the European Union[vi], salt for food and feed accounts for only a minor fraction of the salt industry's volume. The artisanal salt market, though, is an exception, with nearly 100% of its production

volume being consumed for food.
In Europe, Africa and South America, few small-scale saltworks survived the 20tht century, leaving vast coastal areas to abandonment, with heavy socio-economic and environmental impacts. In the 1980’s, however, small salt producers from the French Atlantic coast started to highlight their traditional sea salt and *fleur de sel*, setting off the *gourmet sea salt market* and creating economic opportunities for artisanal producers. Private eco-labels accompanied the rebirth of artisanal solar saltworks and created private, “*para-organic*” standards. Major salt companies also have developed *gourmet brands*. Today, numerous *gourmet salts* are on the shelves, many of them claiming certain traditional, manual or ecological qualities.
Europe does not have public statistical data on salt production, uses and trade on its territory. World and EU’s most reliable figures come from USA’s administration and from private agencies. With these reserves, EU salt production is slightly below 50 million tons per year, making EU the third top salt producer behind China and India but ahead of the USA (see *Annex A.1*). EU salt consumption for food and feed is estimated 3,7 million tons per year[vii] .
A conservative estimation of European artisanal hand-harvested salt currently produced comes to 50.000 to 60.000 tons per year[viii] , with potential for growth. The world top private salt production company has been from Germany until 2020, China salt companies could take back the lead.

2. ORIGINS

The main origins for salt are seawater, rock salt deposits, natural brine and salt lakes. A flow chart with the different types of salt depending on the origin and the techniques used for their production is in (*Annex A.2.*).

2.1. Sea water

The *water of seas and oceans* is known to contain all natural chemical elements (see *Table T.2.* and *Figure F.1.* and *F.2*), most of them present in small to tiniest quantities. Salinity of seawater (3.5% average) comprises all dissolved elements and varies with location and depth. Sodium chloride is the most important compound in terms of concentration, with about 28 g/L.

2.2. Rock salt deposits

Rock salt deposits are the result of evaporation and crystallization of ancient seas throughout geological times. Rock salt is in fact ancient sea salt, formed many millions of years ago and which has undergone geological processes. Rock salt deposits can be underground or on surface. In Europe, rock salt deposits are the main source for salt production (see *Annex A.1*). These are of different quality, sometimes the rock salt can be used directly as salt for food and feed, sometimes the rock salt is not fit for human consumption and requires purification. Rock salt is extracted through dry mining (solid salt extraction) and can also be redissolved to be processed into evaporated salt on the surface of the mine. On the coasts of the Mediterranean and the Atlantic the hot climate allows the solar evaporation of mined brines. (*see 3.3.2.*)

2.3. Natural brine

Saline waters result from the circulation of water in underground or surface geologic deposits of salt. This is explained by the geological phenomenon called natural diapirs: in the subsurface, brine deposits can arise through the natural dissolution of rock salt with groundwater that passes through the upper layers of rock and then through the layers of salt.
Salt springs (see *Figure F.3*) correspond to the case of brine deposits that emerge naturally to the surface. In Europe, natural saline waters mostly come from springs. Such springs are irregularly distributed in Europe, with over 500 historical salt production systems from saline

springs found in Spain[ix] and high densities of saline springs in Portugal, Romania or Poland[x]. These natural brines show an average salinity greater than the ocean or sea (200-250 g/L).

2.4. Salt lakes

These develop as a result of high evaporation rates in an arid climate with a lack of an outlet to the ocean, due to the existence of brackish marshes occupying a tectonic depression that are fed by channels, streams, groundwater, and surface water.
Salt lakes (see Figure F.4.) have a salinity greater than seawater; however, subject to seasonal changes: For most of the year, the lakes are very shallow. During wintertime, part of the salt is dissolved in the fresh water introduced to the lake by precipitation and surface runoff. During the summer, the lake dries up exposing a thick salt layer of 30 cm on average in August.
Salt lakes are used worldwide in solar salt production.

2.5. Other origins

The Standard for food grade salt (*STAN-CODEX 150-1985*) does not apply to salt from other origins, notably to salt which is a by-product of chemical industries. Therefore, the following by-products cannot be used as starting material for the production of salts for the food and feed sectors:
Salt formed during *chemical reactions* (chemical industry, flue gas treatment in waste incineration plants), *by-product rock salt from potash flotation*, and *effluents from seawater desalination plants*.
Significant amounts of organic substances (contaminants as residues of amines, processing aids as essential pine oil) can be found in such by-products.

3. PRIMARY PRODUCTION METHODS

There are two main methods to produce salt:

- Extraction of rock salt deposits:
  – Solid extraction through classical mining techniques
  – Dissolution of underground deposits by solution mining followed by evaporation
- Concentration and crystallization of saline water through evaporation
  – Solar evaporation in open-air ponds (“solar salt”, by sun and wind)
  – Evaporation through heating and/or vacuum techniques

3.1. Solid rock salt extraction techniques

Underground salt deposits are extracted by means of the following techniques:

3.1.1. Cutting, drilling and blasting

This technique begins by cutting slots at the base of the rock face using specialized equipment. A series of carefully sited holes are then drilled into the rock face. Alternatively, big holes can be drilled directly into the rock. Subsequently, the holes are charged with low emission explosives and the face is blasted to break the salt into large rocks. The most commonly used explosive is ***ANFO*** (*ammonium nitrate/fuel oil mixture*) in the form of loose prills. The typical consumption of explosives is between 100 and 200 grams per ton of salt.

3.1.2. Continuous mining

Continuous miners or roadheaders are used for the cutting extraction of the rock salt. It produces smaller lumps of rock than with techniques mentioned in *3.1.1*. It bores into the salt, extracting lumps that are then crushed into smaller pieces.
Sometimes both extraction techniques are used side by side in a mine.
The raw salt is transported by trucks, bucket loaders and conveyor belts to the secondary processing lines or plants. Different purification processes can be used to purify solid salt (*see*

5.4) and depending on its final use, salt can be further processed, including crushing, sieving, sorting and compaction (see *point 5*).
Rock salt production is a dry process and consumes water only for dedusting, if necessary, and for dissolving additives (sees *Annex A.3*).
Residues (natural impurities calcium sulphate and clay, salt dust) resulting from the processing of rock salt are deposited in the mine cavities.
To avoid subsidence, the rooms and columns in underground mines have to be sufficiently dimensioned. If necessary, empty chambers in mines are stabilized by backfilling with wastes, e.g., fly ash from municipal waste incinerators.

3.2. Brine extraction techniques

3.2.1. Natural brine extraction

Concentrated brines are the result of underground brine discharge from the quaternary layers of salt deposits. Between the chambers in which the enclosed brine is produced and extracted, pillars of considerable size are left behind to maintain stability of the rock.[xi] Natural brine is extracted by pumping to the surface.
In case of natural salt springs, brine emerges naturally to the surface.
The obtained brines are processed further to crystallized salt (see below *3.3.3, 3.4, 3.5 and* 3.6.)

3.2.2. Solution mining

It can be defined as mining of underground salt using one or more drilled wells to dissolve the minerals with water that is injected into the underground salt layer to create highly saturated brine. The production of brine by solution mining requires large amounts of water, which is pumped into the underground rock salt deposits. Depending on the structure of the rock salt deposit, solution mining creates caverns in the salt layer or extraction chambers in mines (e.g., Alps).
The main stages are: drilling and construction of the borehole, injection of water and dissolution and pumping out the saturated brine. (See *Figure F.5*)
Several pipes are installed in the borehole in a telescope-like arrangement. Water is injected into the inner pipe string to dissolve the salt. The brine which this produce is displaced to the surface through the inner annulus or reverse.
In brine extraction from caverns a protective fluid (***blanket***) is injected into the outer annulus to prevent uncontrolled upward solution of the salt formation. This can be a hydrocarbon such as *diesel fuel* or even *nitrogen* or *compressed air* (see *point 4*).
"Cavern shape and the upward rise of the cavern roof is today controlled by an inert fluid blanket pumped in and maintained at the top of the zone of active brine creation. Early solution wells did not use this blanket technology"[xii]
Caverns that are out of operation are kept full of brine to prevent subsidence; they can also be used, if possible, to store natural gas, oil, and hydrogen, produced with renewable energy.
The obtained brines are processed further to crystallized salt (see below *3.3.3, 3.4* and *3.5*)

3.3. Solar evaporation techniques

3.3.1. Sea water concentration and crystallisation

Seawater salinity is around 3,5% (approx. 35g of sea salt per litre) with local variations. This salinity is approximately composed of the following dissolved substances: Chloride (Cl, around 55% of total salts), Sodium (Na, around 31%), Sulphates (around 7,7%), Magnesium (around 3,7%), Calcium (Ca, 1,2%), Potassium (K, 1,1%) as well as various diluted organic and inorganic substances (including metals and trace elements). See *Table T.2 and T.3.*
Salt from seawater is a very abundant resource with an estimated 3,2x1017 tons of salt to

compare to current yearly world production of 250-300 millions of tons. In *Annex A.4*, there is a diagram showing the production flowchart for salt from sea water.

Sea salt production is close to agriculture (See *Annex A.5.*), with a cycle of weather-dependent production and a seasonal work schedule.

Sea saltworks consist of a series of successive, interconnected shallow ponds where seawater is naturally evaporated to concentrate and crystallise salt. Their ground must be impermeable, in order to avoid losses of brine or intrusion of freshwater. According to the process, the ponds are divided into two basic groups:

1. *Evaporating ponds:* where seawater is concentrated up close to saturation point and which feeds the crystallizers continuously with the required saturated brine required (nurse pond). They cover almost 90% or more of the saltworks production area.
2. *Crystallization ponds or crystallizers* consist of the ponds where salt crystallizes, via further evaporation of the brine. Crystallizers cover 10% or less of the saltworks.

a. Sea water movement

There are two main ways of getting sea water into sea salt production system: by gravity or by pumping. In pre-industrial times, saltworks were created in saltmarshes where tidal range is important, allowing a gravity-fed water management still in use. Where low tide range or unfavourable coastal layout makes gravity-fed systems impossible, saline waters are pumped to feed the salt ponds. The necessary energy firstly came from human or animal power, later from windmills and steam power and is nowadays provided by electricity or fossil fuel. See *Annex A.6*.

According to the weather conditions, the salt producer carefully manages the movements of saline water from one evaporation pond to the other. The movement of waters is slow, allowing sedimentation of the heavy particles.

b. Natural evaporation

Water evaporates mostly in summer, and the rate of brine evaporation depends on the prevailing microclimate of the region, particularly wind action, air temperature, humidity and sunshine. The absorption of solar energy in the evaporation ponds is favoured by two natural phenomena:

- At low salinity: dark pond's floor; the mud and/or the halophilic bacterial mat contribute to this dark bottom.
- At high salinity: opaque and coloured waters. When salinity increases, halophile life develops. A frequent and favourable development is a high density of the micro-alga *Dunaliella salina*, which gives a pink to orange colour.

Different techniques have been used to maximize the absorption of sun energy in the evaporation ponds including artificial dying of the ponds floor to darken them[xiii,xiv]

c. Concentration and fractional crystallisation

Fractional crystallisation is the crystallisation of the different dissolved minerals, each at a specific density (fractional crystallisation of seawater, see *Table T.3)*. As seawater concentrates and exceeds 100g/l, the first crystallisations of $CaCO_3$ and $CaSO_4$ (Gypsum) occur. Careful brine management ensures that most calcium compounds precipitate in the last evaporation ponds, before the concentrated brine is fed into the crystallisers.

d. Biology of sea salt ponds

Sea saltworks in the European Union countries are situated in saltmarshes, salt meadows and salt steppes protected as Special Areas of Conservation under *Directive 92/43/EEC*[xv] and as

Special Protection Areas under the *Directive 09/147/EU*[xvi]. EU members countries contracted to the international ***Ramsar Convention*** for the protection of wetlands, and almost all their sea saltworks are protected by the rules implementing this Convention at the local level. Furthermore, in several countries, saltworks are legally protected either as ***Natural Reserves*** or ***Natural Regional Parks***.

Most organic components present in sea water do not survive the concentration process. Instead, halophile populations develop: hypersaline bacteria and algae, unicellular organisms and aquatic invertebrates. They are fundamental elements of the food chain for aquatic species including fish, cephalopods, bivalves and other invertebrates and a wide range of water birds including threatened species. Vegetation is characterised by site-specific plant communities with halophilic biota and including many endemic species. The distribution of all these species varies according to the physical and chemical characteristics of water and substrate (especially salinity) (See *Figures F.6 to F.10*)

Biological management of the saltworks aims at creating a biological equilibrium of the ponds, in order to enhance salt yields and quality. Measures include development of the bacterial mat, turbidity control with plankton eating macro-zooplankton[xvii] or favouring the production of unicellular algae (e.g., *Dunaliella salina*) and autotrophic bacteria (e.g., *Halobacterium*), species responsible for the red colour of the water in the most concentrated salt ponds.

The presence of all these species has proven to contribute to evaporation and salt crystallization, which is why their symbiosis is essential for the salt production activity. Bacterial bio-precipitation of salt even allows for early salt crystallisation in under-saturated saline waters[xviii].

Nitrogen plays an important role for the biological equilibrium in the salt ponds, which is why in the past, the use of fertilizer has been recommended in sea salt production. Nowadays, by knowledge of the authors, no such practice has been observed anymore in Europe.

e. Natural crystallisation

In the crystallisation ponds, there are two specific crystallisation zones within the brine, corresponding to two supersaturated zones:

- <u>*Surface layer:*</u> the contact surface between air and water is where evaporation happens, creating a thin layer of supersaturated brine. This is where *fleur de sel* originates, a specific NaCl hopper crystallisation, in which the crystal cannot grow upwards and forms a typical inverted pyramid. Surface tension keeps the crystal floating until it is harvested or drowned by wind waves or air humidity. Drowned crystals pursue their development within the brine, where they turn into coarse salt crystals, adopting their typical cubic shape.
- <u>*Bottom layer*</u>: The saltiest brine is heavier and sinks to the bottom. This is where the classical sea salt with its cubical shape crystallises. There are two variants of immersed crystallisation:

– Free grain crystallisation. The brine is moved daily and / or harvesting is done frequently, preventing the bottom crystals from agglomerating. This coarse salt is typically artisanal (see *point 3.3.2.*).

– Block crystallisation or cake. During several months of crystallisation, the salt deposits on the bottom of the crystalliser pond. The aggregated crystals form a compact, hard layer of salt, the salt cake.

f. Harvesting

Harvesting usually takes place in summer, between June and October. The salt is harvested manually or mechanically by means, sometimes of specific agricultural equipment (harvesters, dumpers…). Harvesting methods depend on the size and configuration of the crystallizers, their surface, and how the salt has been deposited:

- Manual harvesting: Salt can be harvested manually. Throughout the world, there is a wide diversity of tools and methods for manual harvesting of the crystals, as coarse salt (free grains) or as compact salt layer (cake*). Fleur de sel* is always harvested manually when it is floating at the surface of the brine. See *Figures F.11*. to *F.14.* See also *Figure F.15* to *F.17*.
- Mechanical harvesting: The salt in large surface crystallizers precipitates to the bottom and aggregates there over time, forming a hard compact layer (cake). The thickness of the salt layer varies from one site to another, and, at a given site, from one year to another, depending on weather conditions. Harvest is done when the salt layer has reached a sufficient size, normally once at the end of the summer production period. Excess brine is removed, and the salt deposited harvested by machinery. Harvested salt is poured into trucks or transported by a conveyor belt. See *Figures F.18 to F.20.*

A salt floor can be made from a tough layer of "lost" salt cake, which is kept from one year to the other. A thin cleavage plane will separate the salt-floor from the new salt. The salt floor allows the circulation of the machinery necessary (harvesters) for harvesting.
In most big-scale saltworks, the salt is immediately washed and/ or centrifuged after mechanical harvesting (*see point 5*).

g. Maintenance of the ponds

The successive evaporation and crystallisation ponds (bottom and dikes) and the water regulating structures are carefully maintained during the whole year. Their conservation is regulated by specific legislation in many countries. Plant growth on the dikes close to crystallizers is controlled by mechanical treatment, in order to ensure free access to the ponds, to prevent obstacles to the wind and to mitigate foreign bodies in the salt.
When the salt of each crystallization pond is harvested mechanically, it is necessary to restore its soils, in order to prepare the new production cycle and limit the amount of impurities. The soil unevenness is removed by means of a levelling blade pulled by a tractor. For maintenance works in artisanal saltworks see *point 3.3.2*.

h. Storage in salt piles

Salt can be stored continuously during the harvesting in the outside, in salt stockpiles (*see Figure F.21*), which allows for natural drying. The area dedicated to the salt storage is arranged and maintained to avoid pollution. During outdoor storage, the content of soluble impurities and the moisture are reduced.
After storage, depending on its final use, sea salt can be sold or further processed, including centrifugation, washing, drying, grinding and/or sieving (*see point 5*).

3.3.2. Particularities of artisanal sea salt production

Artisanal salt extracted from seawater by solar evaporation has been produced for centuries in Europe. Nowadays, its production is mainly situated along the coastlines of France, Portugal, Spain, Italy, Croatia, Slovenia and Greece with a wide variety of traditional saltworks resulting in specific landscape (see *Annex A.7*). It is reliable in evaporative areas where rain periods are scarce or at least predictable. In Europe, the geographical limit for a fully solar-based salt production is in the South of Brittany, in France. North of there, solar evaporation is only partial and is either used only to pre-concentrate the brine, which is then evaporated further by heating, or is replaced completely by artificial evaporation methods.
Artisanal sea salt is produced by traditional manual techniques, without machinery involved,

in a small-scale production. Artisanal salt has points in common with other solar sea salt production methods (*see point 3.3.1.):*

- Controlled circulation of sea water in different ponds.
- Natural evaporation (only by wind and sun) to concentrate salt and produce saturated brine.
- Crystallisation after evaporation of saturated brines.

The following points, however, are specific and distinguishing for artisanal sea salt production (see flow chart in *Annex A.7*):

a. Movement and gradual concentration of seawater

Each year, prior to production, the artisanal sea salt producers remove the muds from the crystallizers' bottom to spread them on the surrounding dikes. Usually, they use manual tools but may also evacuate the muds using pumps.

Occasional heavy works may be necessary in the artisanal salt ponds for the maintenance of ponds, dikes or water management facilities. These works can be done manually or mechanically but must not dig deeper than the original bottom levels, in order to preserve the traditional gravity-driven saline water flow.

In Atlantic artisanal saltworks, the evaporation ponds feed the crystallizers on a daily or weekly basis to compensate their evaporation and maintain a constant water level. However, due to the shallowness of the ponds, strong winds or algae easily disturb the water circulation. The concentration process in the evaporation ponds needs careful monitoring, manual removal of algae and/or an increase of the water level. On the contrary, in case of heavy rains, the salt pond manager may need to remove excess water, usually by evacuating the less concentrated and lighter top layer.

In many costal zones, salt accumulates naturally in the soil of inter-tidal areas. Salt can be produced by collecting this salted soil, leeching it and evaporating the resulting brine. This *leeching technique* is one of the most ancient salt production methods, which existed in almost all continents, including Europe. It is still used today by salt producers in some countries, especially in West Africa and South America.

b. Natural salt crystallisation

In artisanal saltworks, salt crystallises naturally, only by sun and wind, in small open-air ponds.

The crystallisers' size is rather small, from 25 (e.g., Ile de Ré, FR) and 50 square meters (e.g., Algarve, PT) to 100 square meters (e.g., Guérande, FR). In the French artisanal salt ponds, brine and crystals are moved daily to prevent the agglomeration of coarse crystal grains (free grain method). In Portuguese artisanal salt ponds, crystals grow for one to four weeks and agglomerate in a fragile salt crust.

Depending on the geographical area, fresh brine is usually added from daily to weekly to compensate evaporation and maintain a constant layer of brine.

c. Harvesting

In artisanal salterns, the brine remains in the crystallisers during the harvest.

In European artisanal saltworks, coarse salt and *fleur de sel* are harvested by hand, with specific manual tools, frequently during the production period.

Coarse sea salt is gathered manually within the brine, which is used to ease the harvest and clean the salt. Gathering is mostly done with wooden raking tools and happens regularly during the production period. Reflecting the risk of rain, the harvesting frequency ranges from

daily to weekly or more. Hand-harvested salt is sun-dried. It is neither washed after harvest nor centrifuged and keeps its natural composition and sharp cubic crystal shape.
Fleur de sel is a sea salt, which is skimmed manually off the brine (see point 3.3.1.f.). Skimming is done with specific tools just below the surface, without touching the pond's floor. The floating fragile crystals get drowned easily by wind waves or air humidity and are therefore harvested on a daily basis. *Fleur de sel* is preferably produced in rather small ponds, as bigger ponds promote the formation of waves, which will drown the crystals. Cloudy, humid weather prevents their formation. As *Fleur de sel* is obtained from floating surface crystals, it features as unique characteristics a pyramidal crystal shape, a low density and exceptional friability. Like coarse salt, it is sun-dried and not subject to washing or centrifugation.
Artisanal sea salts are scanned for impurities and, depending on their intended use, can be further processed (grinding, drying; s*ee point 5*).
In European countries, most artisanal salt producers use similar methods with local variations. See Figures *F.11* to *F.17*.

3.3.3. Concentration and crystallisation of continental brines and salty waters

Solar salt production starts with natural brine (*see 3.2.1*), with brine from solution mining (*see 3.2.2*), or with brine produced by dissolving surface rock salts deposits. Solar salt is also produced with strong brine from salt lakes *(see 2.4.)*. In open ponds, brine concentrates by action of sun and wind, and salt crystallises in the ponds. The starting salinity of the brines is high, so there is usually no need for pre-concentrating it in evaporation ponds. The main difference among all these brines is their salinity, which requires more or less stages in the concentration step.
In *Annex A.8*, there is a diagram showing the production flowchart for these brines and salty waters, salt springs and saline lake salts.
The bottom of the ponds is made of earth, with or without plastic liners, or of concrete. The harvest can be manual or is carried out with mechanical equipment (bucket loader, mobile harvesters, trucks, etc.).
Depending on its final use, the salt can be further processed, including centrifugation, washing, drying, grinding, sieving and compaction (*see point 5*).
Partial solar methods: sometimes, thermal and solar evaporation is used in combination, insofar as the brine is first concentrated by heat and power generation (gas engines) and only then led into the evaporation ponds.

3.4. Vacuum evaporation techniques

The basic processes for vacuum salt production are brine purification, evaporation, and crystallisation.

a. Brine purification

The raw brine, depending to its origin, contains not only sodium chloride, but also a number of other components, among which the most problematic are sulphates, chlorides and carbonates of calcium and magnesium. They are usually removed from the brine (*softening*) to achieve a higher NaCl percentage and to avoid scale formation in the heat exchangers and the processing equipment. These treatments of the brine require the use of *processing aids (See point 4*).
Different purification processes may be applied: purification with Lime or Caustic Soda and Soda Ash, continuous brine purification process (with flocculation additives agents such as anionic polyacrylates), gypsum slurry process, mother liquor concentration and nanofiltration.
Secondary soluble salts**,** such as *magnesium and potassium compounds*, found in the raw

brine can be purified by means of chemical treatment, usually by a sequence of precipitation reactions in solution, that transform the soluble salts into salts that are little or not at all soluble in saturated brines and thus can be eliminated. Calcium can be eliminated by means of chemical reagents or carbon dioxide in the form of combustion gas.
Some of these processes (e.g., continuous brine purification) require that the brine is kept at temperatures among 80 and 100 ºC.
If the quality requirements for the evaporated salt allow, the softening of the raw brine can be omitted, and gypsum sludge can be added to the brine instead (gypsum seeding method). This also helps to prevent incrustations in the evaporation plant.
Impurities insoluble in heated brine can only be separated from it mechanically: e.g., by decantation using sedimentation agents (*flocculation additives*). (See *Figure F.22 and F.23*)

b. Vacuum techniques
Vacuum evaporation is the process of evaporating a liquid at a lower temperature than normal one by reducing the pressure of the liquid containing vessel. A liquid boils at a temperature at which its vapor pressure is equal to the pressure of the vessel. The lower the vessel pressure, the lower the temperature at which the liquid boils.
Evaporated salt is also known as **vacuum salt** or pure dried vacuum salt (PDV salt). It is normally produced in closed evaporators by concentrating brine heat alone or in combination with a vacuum process. See Flowchart in *Annex A.9.* The brine obtained from the dissolution of salt deposits (or the seawater or other salty water) is transported via pipeline to a vacuum salt production facility.
In evaporator systems most of the water evaporated from the brine is recovered and reused to dissolve the salt in solution mining. These techniques also guarantee lowest possible energy consumption. Nevertheless, the production of evaporated salt consumes a multiple of primary energy compared to the production of rock salt and solar salts. The CO_2-eq emissions depend on the share of renewable energies in the total energy consumption for salt production. (*see Annex A.6).*
Mother liquor from evaporated salt production is discharged into rivers, lakes, or the sea. As with the mother liquor (”bittern“) from sea salt production, the main component is chloride.
These are some of the most used current evaporation techniques:

- **MEE: Multiple effect process**[xix]

It is a heat-driven technology used when **steam** is an inexpensive energy source for the process. It consists of several evaporators connected in series. The first effect is heated by live steam, and the following stages are heated by the vapours of the corresponding upstream unit. The boiling point of the brine is reduced in each stage with the aid of a vacuum pump. The vapour of the last stage enters a cooling water system, and the brine feed is preheated with condensate from the evaporators.
Optimal energy consumption efficiency depends on **preheating**: the steam should be generated by a counter pressure steam turbine or a gas or steam turbine cogeneration unit. Where a cogeneration system is not feasible, the overall efficiency can be improved by thermal vapour recompression (TVR, ejector) See *Figure F.24.*

- **TVR: Thermal vapour recompression process**[xx]

Motive steam is used to compress part of the vapour produced in an evaporation effect from a low evaporation pressure and temperature level to the heating pressure of the first evaporation effect. In this way, the heat energy included in the first effect can be used again for heating. This technology can easily be combined with MEE. See *Figure F.25.*

- **MVR: Mechanical vapor recompression process**[xxi]

Contrary to TVR, no motive steam is required. Electrical energy is used for compressing vapours from the evaporator which can be reused as heating medium of heat exchanger.
Vapour-recompression forced-circulation evaporators consist of a crystalliser with one or several heating loops, a compressor, a vapour scrubber, and a preheating system. Recompression evaporators, although electricity-intensive, are more energy-efficient than multiple-effect evaporators and are generally considered the BAT (Best Available Technology). See *Figure F.26.*

- **Recrystallisation**[xxii]

Recrystallisation within the vacuum techniques is a purification process, in which crystallised salts are dissolved in diluted brine from the process or a clean solvent giving hot concentrated brine, which is led into several flash crystallisers working on different pressure levels. Supersaturation is achieved in the vacuum crystallisers by simultaneous evaporation and adiabatic cooling on the brine feed, subsequently the production of crystallised salt starts.
The salt suspension is removed from the crystallizer via an elutriation column and subsequently supplied to the salt debrining plant. Highly pure salt (usually >99.9%), such as pharmaceutical grade or reagent grade components is obtained.
This process does not need softening of brine, only mechanical brine treatment See *Figure F.27*.

- **Flash evaporation or flash crystallisation**[xxiii]

Flash evaporation or flash crystallisation is used as a means to cool brine without the use of heat exchange. The hot brine is introduced into a vessel that operates at low pressure (and temperature), where it is flashed under controlled conditions.
Usually, forced circulation or Draft Tube Crystallisers are used for this operation. The flash generates vapours, which are conducted to a condenser. The evaporation concentrates and cools the process feed, and combined with the lower end temperature, causes the precipitation of the produced crystals. See *Figure F.28.*

- **Combined techniques**

Above-mentioned techniques can be combined depending on the specificities of the brine material, product and site characteristics.

3.5. Open-pan techniques

A variant of evaporated salt is **pan salt** (see flow chart in *Annex A.10*). This salt is made in open pans while the brine is heated. Seawater, natural brine, brine from solution mining, or brine obtained by dissolving crystallised salts, untreated or softened, are used as the starting material.
In the past, salt has been extracted by heating the brine in pans operating at normal atmospheric pressure, known as open pans. The grainer or open-pan process uses open, rectangular pans with heating devices to evaporate the water in the brine. The grainer process, similar to the historic process of open pan boiling, consumes a lot of energy and is more efficient when waste steam is available or where waste lumber products provide an inexpensive source of heat.
A variation of the pan technique still in use is the Alberger process, which results in a combination of flakes and cubic crystals of salt. The pans are shallow, circular units with external heating units rather than heating coils.
If brine from solution mining or brine from surface-dissolved crystallised salt is evaporated in open ponds or open pans, a lot of water is required (see *Annex A.6*).

To a small extent, pan salt is still today produced by these methods also in artisanal salt production (see *3.6*).

3.6. Other artisanal methods

Aside from solar evaporation of seawater in traditional saltworks (*see 3.3.2.*), there is a variety of other salt production methods still or again in use in EU member countries, which can be done in an artisanal way.
Artisanal salt is generally understood as a distinctive product made in small batches or quantities. Typically, this salt is locally sourced or comes from traceable regions and is manufactured (at least partially) by hand.
However, the term *artisanal* is not specifically harmonised by Regulation 1169/2011. Member States can regulate the term *artisanal* for food products provided it complies with Article 34, Treaty on the Functioning of the European Union (TFEU). National regulations on the term artisanal by more Member States may result in different laws, which might generate obstacles to the proper functioning of the internal market. Provided a regulation of the term artisanal for food products is deemed necessary, the term should be regulated on EU level[xxiv.]
Many producers in this segment aim at the gourmet salt market and claim to be “artisanal”, based on the size of business (small-scale, often family-run operations) and the manual work involved in the production process. This “hand-harvesting”, however, mainly consists in retrieving the salt extracted from the boiling pans or vacuum evaporators and is thus to be distinguished from the manual gathering of artisanal sea salt described in *point 3.3.2.*
Geographically, Britain and Ireland act as a hinge between southern European solar and northern European thermal saltmaking by using mixed solar and thermal methods[xxv] . Due to climate conditions, thermal evaporation processes in small-scale operations were historically typical for saltmaking in Scandinavian countries (e.g., Denmark and Iceland) and Russia, having seen a renaissance in the “gourmet salt” scene lately (see 1.2.).
Aside from seawater, the salts described in this point are also produced from natural brine from salt springs (e.g., in Spain, Portugal, Romania, *see 2.3.*). Natural brine from streams and lakes is also used for small-scale artisanal production, though to the knowledge of the authors, not in Europe.
These inland saltworks use solar evaporation, generally in small ponds that are fed with the brine via horizontal plots or eras. When there is no sufficient level ground for the eras, these can be arranged in terraces (e.g., in Spain and Portugal). The brines are already nearly at saturation point (about 200/L). In other places, the brine can also be channelled from the salt spring into a thermal evaporation process, usually an open-pan method (e.g., in Morocco).
The actual techniques used for the production of “other artisanal salts” do not differ from the primary production methods described in *point 3.4 and 3.5*, relying almost exclusively on open or closed pan boiling and vacuum evaporation. Where climate conditions allow, both techniques are also found in combination with solar evaporation for the pre-concentration of seawater to (low salinity) brine.

- **Pan house process**: Seawater or natural brine is boiled in “pan houses”, which consist of large iron or steel pans, built into a structure with built-in flues. Where in the past, these were mostly fuelled with coal or firewood, heating is nowadays done by electricity, firewood (locally sourced, e.g., in Denmark), gas and geothermal energy (e.g., in Iceland). The process can be controlled by inserting two or more boiling steps and varying the heat and duration, in order to produce different types of salt: rapid boiling results in fine-grained salt suitable for use in food preparation, slow simmering produces large crystals.

- **Alberger process**: As described in *3.5*, this is a variation of the pan technique, in which flat circular pans with external heating flues are used, by which both flaky and cubic crystals can be obtained, depending on the management of the boiling process. This technique is applied by some small salt producers in Europe (e.g., in Iceland and Ireland). These producers use geothermal and electrical energy for heating.
- **Vacuum evaporation**: As described in *3.4 and 3.5.*, seawater or natural brine is channelled, sometimes filtered, into evaporator pans where it is boiled in a sealed system under a vacuum. By varying the parameters (pressure, temperature, time), different salt crystal types can be obtained. Lately, a few small-scale producers from northern European countries such as Ireland and Germany, came to apply this technology for their salt production.

- **Other methods,** used in the past, especially in Britain, Holland and Denmark are "leeching" followed by open-pan heating (*see 3.3.2.a*) and "selnering" (burning salt-impregnated peat, leaching the salt from the ashes, and boiling the strong brine). Both methods are of mere historical interest in Europe, but leeching is still used by several thousand producers in South America and West Africa.

4. PROCESSING AIDS

The production of sea salt, as well as the production of solar salt and pan salt that do not start with brine from solution mining, do not require processing aids. The same goes for the production of rock salt with cutting technique (continuous mining).
The extraction of rock salt by drilling and blasting requires as explosive *ammonium nitrate*.
The use of a protective fluid (*blanket)* is essential for solution mining. The use of blankets ensures a controlled development of the brine caverns. If *diesel oil* is used, suitable technical concepts are required to avoid the discharge of *diesel oil* with the raw brine. If technically and economically possible, it is recommended to use blanket gas (e.g., *air, nitrogen*) instead of *diesel oil*.
Evaporated salt needs precipitation agents and flocculants for brine treatment. The raw brine must be softened to achieve a subsequent undisturbed and energy-efficient crystallization process. This treatment removes magnesium, calcium and sulphate from the brine with lime milk, caustic soda, soda ash, and flue gas. Magnesium precipitates as magnesium hydroxide, calcium as calcium carbonate and calcium sulphate. Calcium can be eliminated by means of chemical reagents or with carbon dioxide, available in the form of combustion gas. Flue gases from oil firing should not be used to prevent contamination (dust, oil, dioxins, polycyclic aromatic hydrocarbons, etc.) of the brine. Only flue gases from natural gas firing, which were prior subjected to wet washing, are acceptable for this purpose.
If the quality requirements for the evaporated salt allow, the softening of the raw brine can be omitted, and gypsum can be introduced as seed crystals together with brine into the evaporators to avoid scaling with calcium sulphate on the metallic surfaces.
If necessary, an anti-foam agent is injected into evaporators to avoid foaming of the brine during evaporation.
For a list of commonly used processing aids please see *Table T.4*.
All used processing aids fulfil a certain technological purpose during extraction or processing and should not be detectable in the final product when correctly applied.

5. Secondary processing steps

5.1. Washing

Salt is transported to a washing plant where most of the impurities are removed. In some plants, a simple washing process is needed to remove all solid impurities from the salt (water insoluble substances) along with secondary salts (solutions of magnesium or potassium compounds). See *Figure F.29.*

5.2. Centrifugation

Salt can be centrifuged to remove some of the water it contains. The salt-brine mixture is drained and centrifuged to reduce salt moisture. Once salt is centrifuged, it's transported by conveyor belts to the pile or the facility.

5.3. Drying

Drying can happen by solar energy only (*see 3.3.1*) or by application of thermal energy (heating) and is a processing technique to comply with some food salt characteristics required by national food grade salt regulation (e.g., RD 1424/1983 in Spain) and to avoid incompliance with industry needs.

In thermal drying processes, salt is dried with hot air, which is normally heated indirectly in heat exchangers with steam. If the drying process of the salt occurs in a manner, whereby the crystallised salt comes into direct contact with the flue gases of a firing system, appropriate measures must be taken to prevent the entry of pollutants into the salt. For example, suitable measures include the usage of natural gas in the firing system.

5.4. Sieving and grinding

Grinding and sieving are commonly used in post-production process to comply to specific demands on calibration. The processes are classical: mechanical grinding (mill), mechanical sieving (moving grid).

5.5. Purification methods

Depending on the quality of the salt, different purification processes may be applied. The following are some of the methods used to purify solid salt:

a. Flotation**:** The final product quality attainable by separation depends on removal of the impurities by flocculation and *foaming additives* (e.g., *sulphate fatty acids* to eliminate anhydrite from fine rock salt). Attention must be paid to the residual flotation reagents.

b. Electrostatic separation: Preheated salt is fed to a rotating metal roll which a corona-producing electrode is placed. The salt and anhydrite/clay particles are charged but only the conducting anhydrite/clay particles can lose their charge. The charged non-conducting salt is separated moving attached to the surface of the roll. The disadvantage of this separation technique is its high power consumption.

c. Thermoadhesive process: it consists in exposing crude salt to radiant heating which selectively heats the impurity particles. The heated particles are removed by adhesion to a heat-sensitive coating on a conveyor belt.

d. Removal of impurities: Often used for sea salt, it can be done by manual picking, detection of harmful particles is usually done by metal detection, magnetic equipment, laser scanning, optical recognition with air flow rejection, or a combination of the afore-mentioned techniques.

5.6. Compaction

For special applications (e.g., food: pretzel salt / feed: lick stones), salt can be mechanically compacted on hydraulic presses.

6. Composition and contaminants

6.1. Chemical composition

The leading substance in salt is Sodium Chloride (NaCl). The main natural secondary components in **sea salt** are gypsum (hydrated calcium sulphate) and magnesium salts. Lime (hydrated calcium carbonate) and, potassium salts may also be present, though in lower quantities.

The main natural secondary components in **rock salts** are anhydrite (calcium sulphate) and water-insolubles (clay, silicates). **Evaporated salts** can have an extremely high purity. Natural secondary components of rock salts are largely removed by the production processes (solution mining, brine treatment), and only traces of sulphates are present in these salts. Water-insoluble components remain in the caverns during solution mining.

The requirements of Codex Alimentarius for food grade salt have been incorporated into national law and guidelines by some Member States[xxvi,xxvii,xxviii]. Other regulations of Member States should be taken into account in relation to the content of NaCl, particularly in some types of sea salt and of secondary mineral components. A summary of typical compositions of different salts and its legal requisites is included in *Table T.5*.

A harmonized quality standard for food grade salt does not exist in the EU. Private certification standards for artisanal sea salt exist in some Member States. Standards and existing legal regulations related to salt are listed here:

- **Standard for food grade salt (Codex/Stan 150-1985)**: "*This standard applies to salt used as an ingredient of food, both for direct sale to the consumer and for food manufacture. The content of **NaCl** shall not be less than 97% on a dry matter basis, exclusive of additives.* The standard states that salt *from origins other than those mentioned in Section 2 (obtained from the sea, from underground rock salt deposits or from natural brine), particularly the salt which is a by-product of chemical industries"* is not allowed as food grade salt.

- **Spanish legislation: RD 1424/83:** modified with regard to unrefined sea salts, as follows: *"The sodium chloride content must not be less than 97 per cent of the dry matter, excluding additives, with the exception of **virgin sea salt and flower salt,** which may contain at least 94 per cent. For virgin sea salt and salt flower, the defect in sodium chloride shall not result from increased insoluble residues".*

- **French legislation: Décret n°2007-588 du 24 avril 2007:** This national law states that the *"sodium chloride content of food grade salt must not be less than 97 per cent of the dry matter, excluding additives, with the exception of **grey sea salt** which may contain at least 94 per cent"*

- **Portuguese legislation: DL 350/2007 and Portaria 72/2008:** states that salt for food and feed must contain at least 90% of sodium chloride, that table salts and artisanal salts from seawater must contain at least 94% NaCl and that the NaCl content in table salt from salt springs must be at least 97%.

- **Croatian legislation: NN 70/2019, n. 1472:** modified with regard to unrefined sea salt and fleur de sel, which is now allowed to contain less than 97% NaCl (unrefined sea salt: ≥95%, fleur de sel ≥92%).

- **Slovenian legislation: Uradni List RS, st. 46/2018, 7498:** modified with regard to unrefined sea salt, which is now allowed to contain less than 97% NaCl (unrefined sea salt: ≥95%).

A summary of national legal regulations on salt in EU Member States is included in *Table*

6.2. Contaminants

6.2.1. Physical contaminants

A physical contaminant is a impurity, contamination or foreign matter/substance ("foreign body") present in food or feed. Sharp or large foreign bodies can cause injury if consumed inadvertently. An added risk is that a foreign object could be carrying a biological or a chemical contamination. In Codex Alimentarius, foreign bodies independently of their nature are referred to as "Insoluble Matter" (*CODEX STAN 150*).
Typically, insoluble matter makes up less than 0.5% of the raw salt's composition. In Spain, the Royal Decree 1424 affirms that Insolubles present in salt must not exceed 5 gram per kilogram (0.5%) and states explicitly that the missing Sodium Chloride in *Sal marina virgen* (i.e., 97-94=3%) is not the result of a higher amount of insoluble matter.

- ***Natural impurities****:* The presence of lumps of soil, sand, plant or insect parts and, rarely, animal hair, occurs mainly due to the salt production open air. In general, these impurities are not harmful, except the risk of choking in the rare case of exceptionally large impurities and hair. Natural impurities are removed in secondary processing, in order to eliminate potential hazards, to comply with industry requirements for purity and to meet consumer expectations for quality and purity.
- ***Environmental physical contamination:*** Foreign bodies from the environment consist mainly in plastic materials, namely microplastic (<5mm), and litter, due to pollution of sea water, soils (sand, sediments) and, to a lesser extent, air. Larger particles of plastic and associated litter, which are still detectable by optical recognition, are removed in secondary processing. The majority of microplastics, however, consists in particles smaller than 1mm, with a considerable fraction of nano-sized particles, and is neither detectable nor removable by secondary cleaning procedures. Ongoing research aims at combining detection methods such as optical, fluorescence and electron microscopy with subsequent infrared and Raman spectroscopic methods[xxix].

The ubiquity of environmental microplastic and its potential hazards has been investigated by numerous authors and the presence of microplastics in salt has been demonstrated by a variety of scientific studies in the past five years[xxx]. According to a study carried out at the University of Alicante[xxxi], the microplastics content in salt from marine and non-marine environments is very similar. Several scientific publications mention of non-marine origin like honey and sugar[xxxii], beer[xxxiii] and even drinking water[xxxiv].
These findings, however, are based on simple particles counts, without regard to particle size, shape and specific plastic materials. Furthermore, there is currently no existing determination standard for assessing micro and nanoplastics in food, neither for laboratories nor scientifically nor on the regulatory level. There are several analytical techniques (FT-IR, µ-RAMAN, Py-/TDS-GC-MS) to detect and measure microplastics, with different results according to the product (matrix). Depending on the analytical technique used, the sample preparation could be different. The studies published so far do not take into account these facts.
Considering the small amounts of salt ingested, most authors see the hazards of microplastic in salt not in singular injuries but in accumulation effects due to the constant intake, combined with the suspected role of microplastics acting as vectors that carry harmful chemical contaminants into the organism. Both effects are not fully understood and still being investigated. At the request of the German Federal Institute for Risk Assessment (BfR), the EFSA Panel for Contaminants in the Food Chain has delivered a statement on the presence of microplastics and nanoplastics in food[xxxv]. The report concluded that there are insufficient data on the occurrence, toxicity and fate of these materials when ingested, to carry out a full

risk assessment.
The European Commission's Group of Chief Scientific Advisors published on 30 April 2019 its Scientific Opinion[xxxvi]. One of its recommendations is to promote improvement in "detection, measurement and analysis, and risk/impact assessment methodologies of microplastic pollution". Once sufficient scientific information is available, EFSA will be requested to perform a risk assessment on potential hazards health effects related to presence of micro and nano-plastics in feed and food. After the EFSA report, the EC will set regulatory measures, if necessary.
Currently, post-production inspection and manual picking at the secondary processing stage is common good practice to remove and reduce microplastic particles in salt (see *point 5*).
The occurrence of any contamination with foreign bodies should be controlled and mitigated by the application of Good Manufacturing Practices (GMP) at the primary production stage and by the implementation of an HACCP system (HACCP: Hazard Analysis and Critical Control Points) in secondary processing, obligatory for any EU-based food processor since 2006.
Both approaches include preventive measures, instructions, procedures, monitoring of critical control points and staff training.

6.2.2. Chemical contaminants

Naturally occurring contaminants in the salt are metals and heavy metals, usually contained in low concentrations. Many metal elements, such as iron and copper, are present in food and essential for human and animal life since they play an important role in biological systems. These elements can, however, produce toxic effects when their intake is excessively elevated. Heavy metals, like mercury, arsenic, lead and cadmium, are non-essential and toxic, as they accumulate in living organisms[xxxvii].
Codex Alimentarius STAN 150 on food grade salt regulates the content of ***copper*** as a natural contaminant (≤ 2 mg/kg salt). With regard to heavy metals, food grade salt must comply with the maximum levels for ***mercury, lead, arsenic*** and ***cadmium***, defined in *Codex General Standard for Contaminants and Toxins in Foods and Feeds* (STAN 193-1995). Furthermore, salt for feed must comply with Directive 2002/32/EC on undesirable substances in animal food, which sets limits for the afore-mentioned heavy metals as well as for other inorganic substances, such as Nitrites, and also, for toxins and organic compounds[xxxviii] (See *Table T.7*).
Some information on heavy metal levels of food grade salt in the literature shows that they are contained in extremely low concentration[xxxix].
In alpine rock salt, the natural arsenic content can sometimes be above the limit value of the Codex Alimentarius. Rock salts sometimes contain traces of natural inclusions of gaseous hydrocarbons. These can be noticed by a slight odour of mineral oil.
For vacuum salt, the content of some heavy metals (e.g., lead) can be reduced by production processes (brine treatment).
In sea salt marshes .it may be necessary to prevent the growth of allergenic plant species (an allergen is a chemical hazard). This is done by mechanical treatment, as the requirements for the protection of wetlands do not allow for chemical treatment
Usually, salt does not contain other chemical contaminants.

6.2.3. Biological contaminants

Salt in general is not prone to microbiological contamination during production.
Sea salt shows a higher microbial load than rock salt, consisting of bacteria, algae and fungi. They either tolerate or require high salt concentrations (halotolerant, halophilic) and are important for biodiversity. Generally, they are not pathogenic, due to the high salinity and low water activity found in salt.

Pathogenic bacteria such as *Clostridium spp., Vibrio spp., Staphylococcus aureus, Escherichia coli, Streptococcus* and *Salmonella spp.* only encounter favourable conditions for growth in brines of low salinity, not in salt. The same goes for moulds and yeasts.
Regulation (EC) Nº 2073/2005 lays down the microbiological criteria for certain microorganisms and the rules to be complied with by food business operators when implementing the general and specific hygiene measures referred to in *Article 4 of Regulation (EC) No 852/2004.*
There **is no microbiological requirement at European level for food grade salt**. The only reference to be found is on *Listeria monocytogenes*: *Regulation (EC) No. 365/2010* states that *according to scientific evidence, presence and survival of L. monocytogenes in salt is unlikely in normal circumstances. Therefore, food grade salt should be added to footnote 4 of Chapter I of Annex I to Regulation (EC) Nª 2073/2005, which provides for the ready to eat foods in which regular testing of L. monocytogenes is not required.*
In Spain, R.D 135/2010, repealed article 13.1.6 of R.D. 1424/1983 concerning the microbiological composition of food. In Portugal, Portaria nº 72/2008 establishes the microbiological criteria for table salt and salt for food industries. See *Table T.5.*
In sea saltworks, as required for the protection of wetlands only mechanical treatment can be used to control the surrounding vegetation.

7. Added substances

7.1. Technological additives

a. <u>Food additives</u>

Regulation (EC) Nº 2018/848 states that the use of food additives and processing aids in organic production should be limited to the minimum (*Article 7.b*)
The list of additives allowed in food grade salt is included in different **<u>European regulations</u>**. Codex also indicates the additives allowed in food grade salt (summary in *Table T.8).*

- Regulation (EC) No 1333/2008 of the European Parliament and of the Council of 16 December 2008 on food additives (Current consolidated version: 28/10/2020)
- Regulation (EU) nº 1129/2011 of 11 November 2011 amending Annex II to Regulation (EC) nº 1333/2008 of the European Parliament and of the Council establishes the Union list of food additives (Current consolidated version: 21/11/2013)
- Commission Regulation (EU) No 380/2012 of 3 May 2012 amending Annex II to Regulation (EC) No 1333/2008 of the European Parliament and of the Council as regards the conditions of use and the use levels for food additives containing aluminium
- Commission Regulation (EU) 2015/1739 of 28 September 2015 amending Annex II to Regulation (EC) No 1333/2008 of the European Parliament and of the Council and the Annex to Commission Regulation (EU) No 231/2012 as regards the use of the ***iron tartrate*** as an anti-caking agent in salt and its substitutes.
- General Standard for Food Additives Codex Stan 192 – 1995 (2019)

Sodium chloride tends to absorb water at a relative humidity of over 75%, leading to secondary crystallization and the formation of clumps and blocks of salt (caking). Caked salt is difficult to use and to dose evenly. The addition of anti-caking agents prevents the clumping process.
The need to use anticaking agents depends on the salt's grain size and moisture content, as well as on packaging size, storage conditions and the storage period. The use of anticaking agents is normally necessary in fine salts, of any origin, with less than 1 mm grain size. Coarse salts can rather be used without anticaking agents.
Ferrocyanides, carbonates and silica substances are in use as anticaking agents for fine salts, of which ferrocyanides are considered the most effective. The other substances are less effective, i.e., require higher dosage levels. Carbonates and silica substances tend to

segregate. In order to not affect the salt's taste when used in high amounts, the added quantities are regulated. *E 500 Sodium carbonate (soda)* is only used in combination with ferrocyanides. It helps to raise the pH of the salt, which prevents the formation of Prussian blue from ferrocyanide under acidic conditions.

Iron tartrates are novel anti-caking agents, on which scientific reports state:

"*It's is therefore concluded that iron tartrate at ppm level is an effective anticaking agent for edible salt. Its anticaking mechanism is the inhibition of the recrystallization process of salt* crystals" ·

In relation to additives used in food grade salt, the ***EFSA Panel on Food Additives and Nutrient Sources added to Food*** has provided different scientific opinions (Food and feed additives are revised every few years for safety reasons):

- ***Scientific opinion re-evaluating the safety of silicon dioxide (E 551) as a food additive***. The Panel concluded that from the available database, there was no indication for toxicity of silicon dioxide (E 551) at the reported uses and use levels but stated also that the EU specifications for silicon dioxide (E 551) were insufficient to adequately characterize silicon dioxide used as a food additive[xl]. The Panel recommended that:

– *The EC considers lowering the current limits for toxic elements (arsenic, lead, mercury and cadmium) in the EU specifications for silicon dioxide (E-551) in order to ensure that the food additive will not be a significant source of exposure to these toxic elements in food.*

– *The EC considers revising the current EU specifications for E-551 to include characterization of particle size distribution of particles in the nanoscale present in silicon dioxide (E 551) used as a food additive.*

- ***Scientific opinion re-evaluating the safety of sodium ferrocyanide (E 535), potassium ferrocyanide (E 536), and evaluating the safety of calcium ferrocyanide (E 538) as food additives***[xli]. The Panel concluded that:

"Ferrocyanides (E 535–538) are of no safety concern at the current authorised use and use levels".

Sodium Ferrocyanides is currently allowed as anti-caking agents in organic production, in accordance with Annex VI of Regulation 889/2008.

IFOAM basic standards do not allow ferrocyanides as anticaking agents for salt to be used for organic food. In the US, anticaking agents are not listed within the permitted additives allowed of the US NOP Regulations, according to §205.605: *"Non-agricultural (non-organic) substances allowed as ingredients in or on processed products labelled as "'organic"' or "'made with organic (specified ingredients or food group(s))"*. Traditionally, anticaking agents other than ferrocyanides have been used for salt in the USA compared to Europe.

Some private national organic standards prohibit the use of any additives in salt (e.g., Certiplanet/Portugal, Intereco/Spain, Nature et Progrès/France), whereas others restrict their use (e.g., Demeter/Germany). See *Table T.9.*

b. Feed additives

Technological additives (anti-caking agents) and nutritional additives can be added to rock salt, evaporated salt, and solar salt for animals. Several lists of additives allowed for feed are included in different **European regulations**. (Summary in *Table T.10*):

- ***Regulation (EC) No 1831/2003*** of the European Parliament and of the Council of 22 September 2003 on additives for use in animal nutrition (Current consolidated version: 26/07/2019). (European Union Register of Feed Additives pursuant to Regulation (EC) No 1831/2003 Annex I: List of additives (Released date 13.10.2020) Edition 08/2020.

- ***Commission Regulation (EC) No 1810/2005*** of 4 November 2005 concerning a new authorisation for 10 years of an additive in feedstuffs, the permanent authorisation of certain additives in feedstuffs and the provisional authorisation of new uses of certain additives already authorised in feedstuffs (Current consolidated version: 19/07/2017)
- ***Commission Implementing Regulation (EU) 2016/896*** of 8 June 2016 concerning the authorisation of iron sodium tartrates as a feed additive for all animal species
- ***Commission Regulation (EU) 2016/896*** of 8 June 2016 authorised **1i534 Iron tartrates** as an anticaking agent in salt for all animal species with a maximum recommended dose of 106 mg of iron sodium tartrates/kg NaCl.
- ***Commission Regulation (EC) No 889/2008*** of 5 September 2008 laying down detailed rules for the implementation of Council Regulation (EC) No 834/2007 on organic production and labelling of organic products with regard to organic production, labelling and control (Current consolidated version: 07/01/2020)

In relation to additives used for feed in salt, the ***EFSA Panel on Additives and Products or Substances in Animal Feed (FEEDAP)*** has provided a scientific opinion on sodium tartrates:

- *Scientific Opinion on complexation products of sodium tartrates with iron (III) chloride for all animal species and categories*[xlii]. The FEEDAP Panel concludes that:

"*The additive has the potential to be efficacious as an anticaking agent when used in salt at the minimum proposed concentration of 3 mg iron /kg salt (equivalent to 26 mg Fe TA/kg salt on a dry matter basis*"

7.2. Minerals, Vitamins, Amino Acids and Micronutrients

a. ***Salt for food***

Regulation (EU) 848/2018 states in *Part IV: Processed food production rules that in the processing of food, the following products and substances may be used:*

"2.2.2.(f) minerals (trace elements included), vitamins, amino acids and micronutrients, provided that:

(i) their use in food for normal consumption is 'directly legally required', in the meaning of being directly required by provisions of Union law or provisions of national law compatible with Union law, with the consequence that the food cannot be placed at all on the market as food for normal consumption if those minerals, vitamins, amino acids or micronutrients are not added"

In the ***Codex Standard for Food Grade Salt CX STAN 150*** is laid down in section 3.3:

"Food grade salt shall be used when salt is used as a carrier for food additives or nutrients for technological or public health reasons."

In Europe, salt is used as a carrier for iodine, fluorine, and folic acid (Vitamin B_9). EU member states regulate the addition of these nutrients to food grade salt on a national basis. The ***Regulation (EC) No 1924/2006*** of the European Parliament and of the Council of 20 December 2006 on nutrition and health claims made on foods already exist.

To prevent iodine deficiency in their populations, member states are free to authorise the iodization of salt on a mandatory or voluntary basis. European researchers investigating iodine deficiency disorders (IDDs) under the umbrella of the "Euthyroid" project (ID: 634453) called on policymakers, public health officials and scientists to ensure IDD prevention strategies are implemented across Europe. WHO recommends all food-grade salt used in household and food processing to be fortified with iodine, as a safe and effective strategy for IDD prevention and control.

It is well known that fluoride controls caries effectively. Therefore, fluoride is added to table salts in some member states. The fluoridation of salt in each case is always on a voluntary basis.

Some companies have been approved for addition of the vitamin B_9 to table salt. An adequate

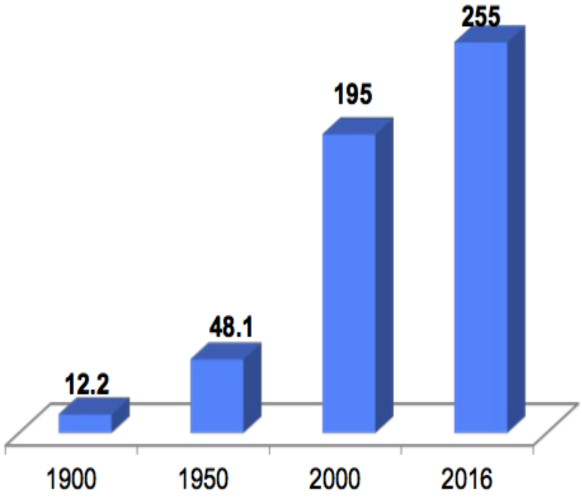
supply with this vitamin (folic acid) during early pregnancy has shown to reduce the incidence of Spina bifida or neural tube defects (NTD).
In *Table T.11,* the minerals and vitamins used for fortification of rock salt and evaporated salt for food are listed, together with the permitted additives.
Member States authorise the iodisation of salt on a mandatory or voluntary basis. The fortification with fluoride and vitamin B_9 is always voluntary. The levels of fortification are different in the member states. See *Table T.12.*
b. ***Salt for feed***
From the category *"nutritional additives" in* ***Regulation (EC) No 1831/2003*** of the European Parliament and of the Council of 22 September 2003 compounds of trace elements and vitamins are added to salt, especially for the salt, which is used to produce salt licks for animals.
Commission Regulation (EC) No 889/2008 of 5 September 2008 for organic feed production lists salt as an ingredient and the compounds of trace elements which can be used as additives. The following vitamins are added to salt which is used to produce salt licks for animals: *E, A, D3, B1, B2, B6, B12, niacin, calcium pantothenate, folic acid, β-carotene*. Most vitamins are produced synthetically. Some vitamins can currently only be produced by GMO.

8. Cleaning and disinfection products
For cleaning of process equipment and surfaces in contact with salt, only cold or hot water is used.
Disinfection in salt facilities is normally not necessary. However, if it is necessary in exceptional cases, hot water and food-grade disinfectants are used for disinfection.
In vacuum salt facilities it is necessary that deposits (calcium sulphate, calcium carbonate) that have formed in processing and storage equipment are removed from time to time. *Acetic acid, formic acid, diluted hydrochloric acid* and *sodium carbonate* are used for this descaling.
In vacuum salt facilities it is necessary that deposits (calcium sulphate, calcium carbonate) that have formed in processing and storage equipment are removed from time to time. Acetic acid, formic acid, diluted hydrochloric acid and sodium carbonates are used for this descaling.

4. ANNEX II – TABLES AND FIGURES

A.1. Salt production

These statistics shows the worldwide salt production from **2000** to **2018**. In **2018**, worldwide production of salt amounted to **285,6 million tons** (255 million tons in 2016). In that year, China was the leading salt producer worldwide with the production of **58 million tons**.

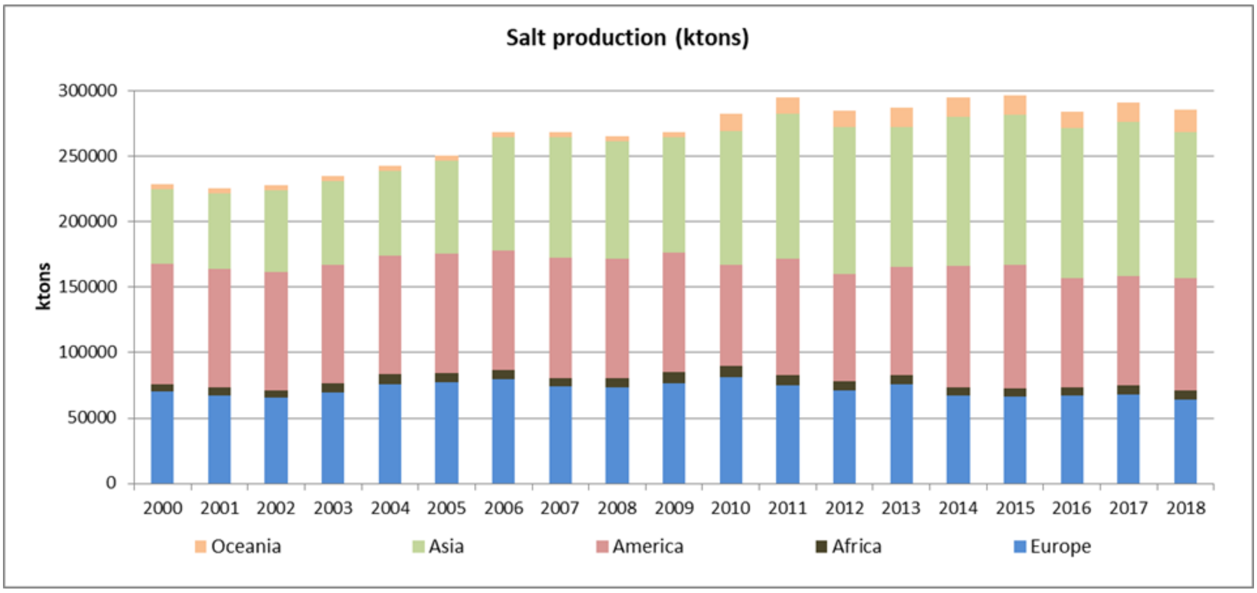


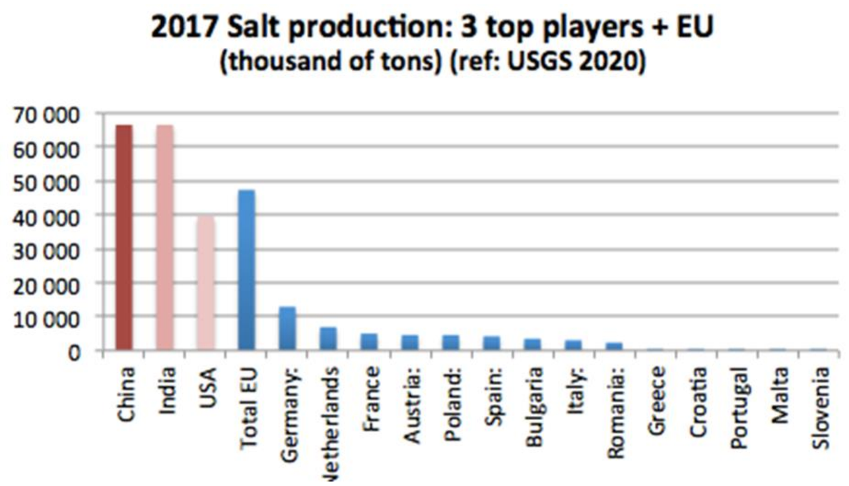
Source: Influence Technological Revolutions on salt production, Moreno Sergio A., Asociación Mexicana de la Industria Salinera, World Salt Symposium 2018 cited in MORENO 2018

Salt production (ktons)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Africa	5729	5793	5729	6974	7145	6813	7136	6798	7471	8545	8193	8078	7568	7746	6681	6467	6577	6816	7158
America	91626	90445	90475	90694	90564	91164	91264	91435	90901	90674	77796	88693	81563	82137	92494	93961	82983	83555	85860
Asia	57445	57991	62234	64212	65207	70766	86319	92060	89908	88276	101723	110653	112214	107214	113646	114597	114696	118041	111641
Europe	70069	67552	65375	69359	76097	77520	79820	73986	73271	76880	81356	74938	70917	75419	67022	66457	67034	68204	63700
Oceania	4037	3921	3806	3938	3906	3921	3934	3942	4005	4035	13183	12872	12546	15016	15187	15247	12573	14805	17599
Total	**228907**	**225700**	**227620**	**235178**	**242920**	**250185**	**268474**	**268221**	**265556**	**268409**	**282252**	**295235**	**284807**	**287532**	**295030**	**296730**	**283863**	**291421**	**285958**

Source: World-Mining-Data, C. Reichl, M. Schatz, G. Zsak, Volume: 31, Minerals Production, Vienna 2016 - *http://www.euromines.org/mining-europe/production-mineral#Salt*





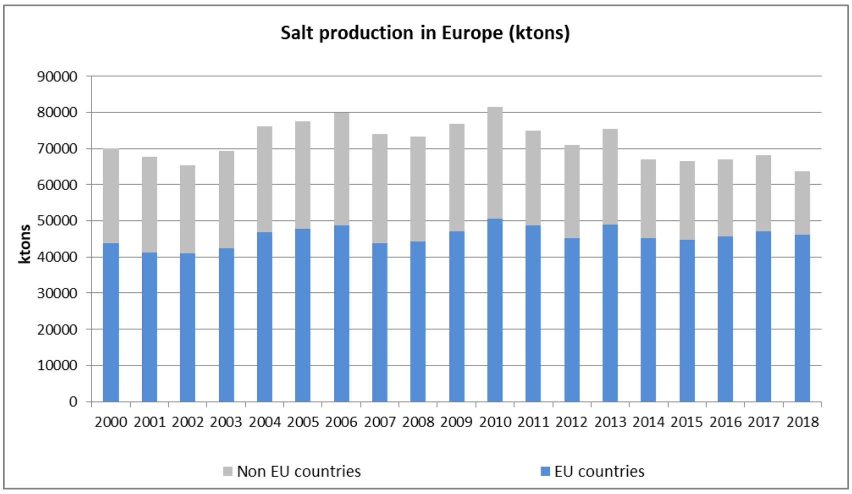
Source: USGS advanced data release of the annual tables, October 2020

European salt production represents approximately **22%** of world salt production (EU members: 16%), **70 million tons** per year, on average.

Salt production in Europe (ktons)

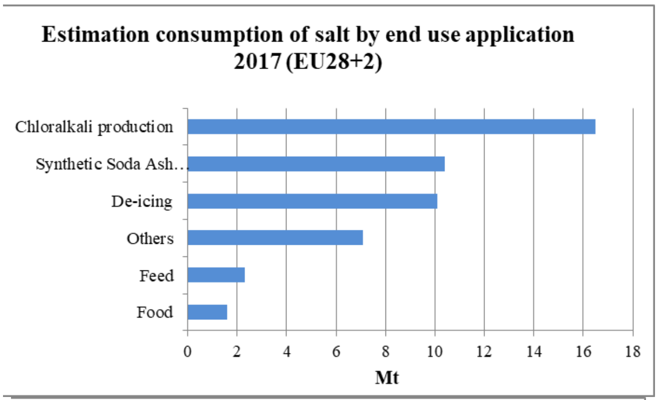
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
EU countries	43838	41327	40968	42320	46745	47811	48681	43889	44218	46960	50536	48744	45104	48917	45135	44798	45553	47011	46046
Non EU countries	26232	26225	24407	27039	29352	29709	31139	30098	29052	29920	30820	26194	25812	26502	21887	21660	21481	21194	17654
Europe	**70069**	**67552**	**65375**	**69359**	**76097**	**77520**	**79820**	**73986**	**73271**	**76880**	**81356**	**74938**	**70917**	**75419**	**67022**	**66457**	**67034**	**68204**	**63700**

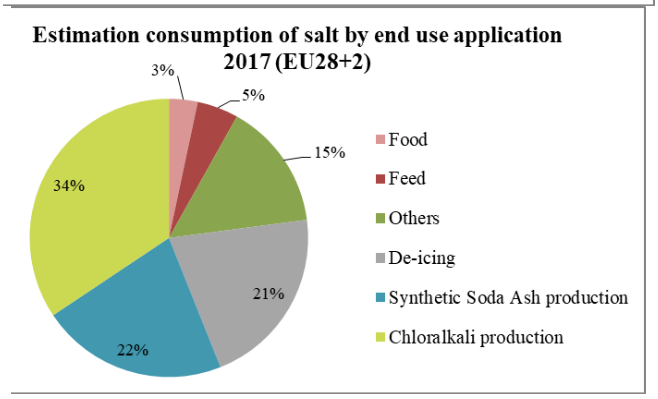
Source: World-Mining-Data, C. Reichl, M. Schatz, G. Zsak, Volume: 31, Minerals Production, Vienna 2016 **-** *http://www.euromines.org/mining-europe/production-mineral#Salt*



Worldwide, around **40%** of salt is produced by **solar evaporation of seawater** or **inland brines**. The balance is approximately divided between **mined rock salt (26%)** and brine extracted by **solution mining (34%)**[xliii]**.** Solution mined salt in EU28+2[xliv] is the main form in which salt is produced **(+60%).** Rock salt accounts for up to **30%** and the other **10 %** is sea salt[xlv].

Direct and indirect uses of salt number about 14.000, grouped into several macrocategories. The estimated salt consumption in EU 28+2 broken down by end use is:

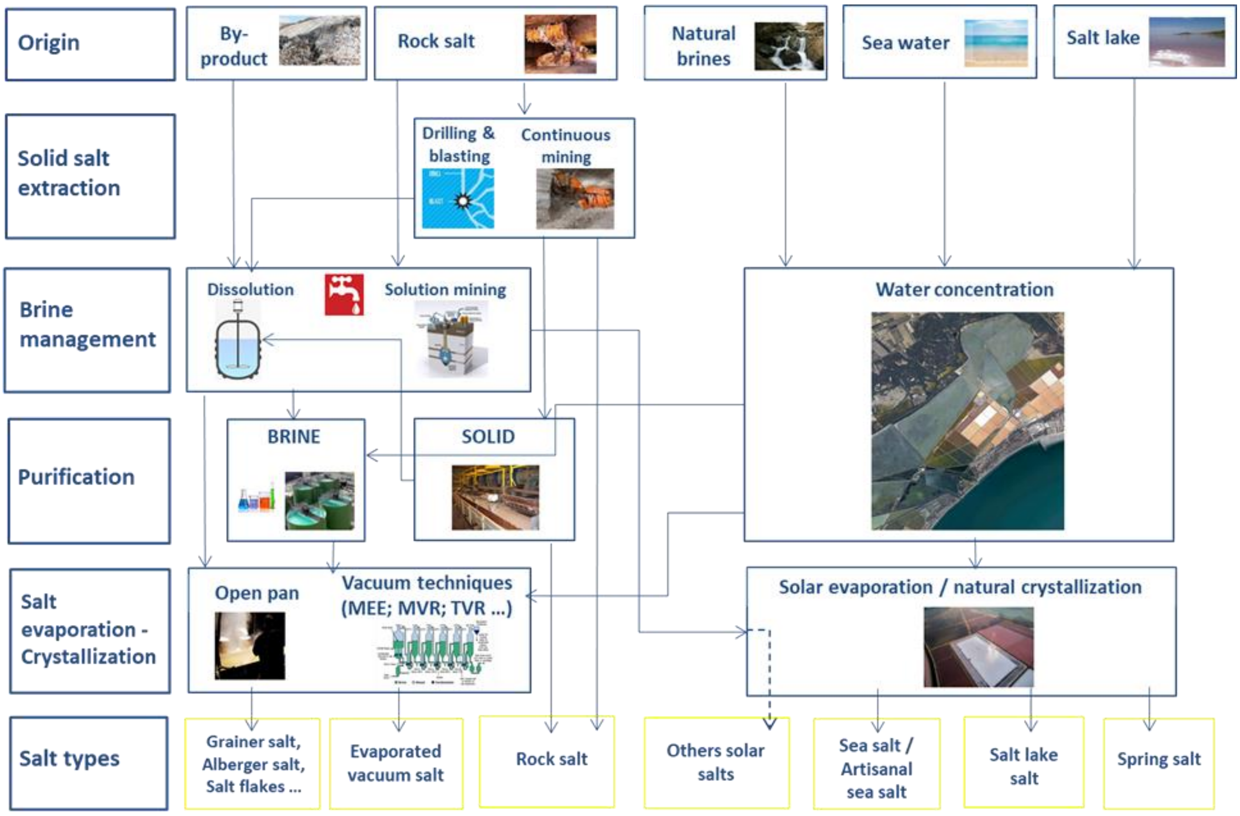




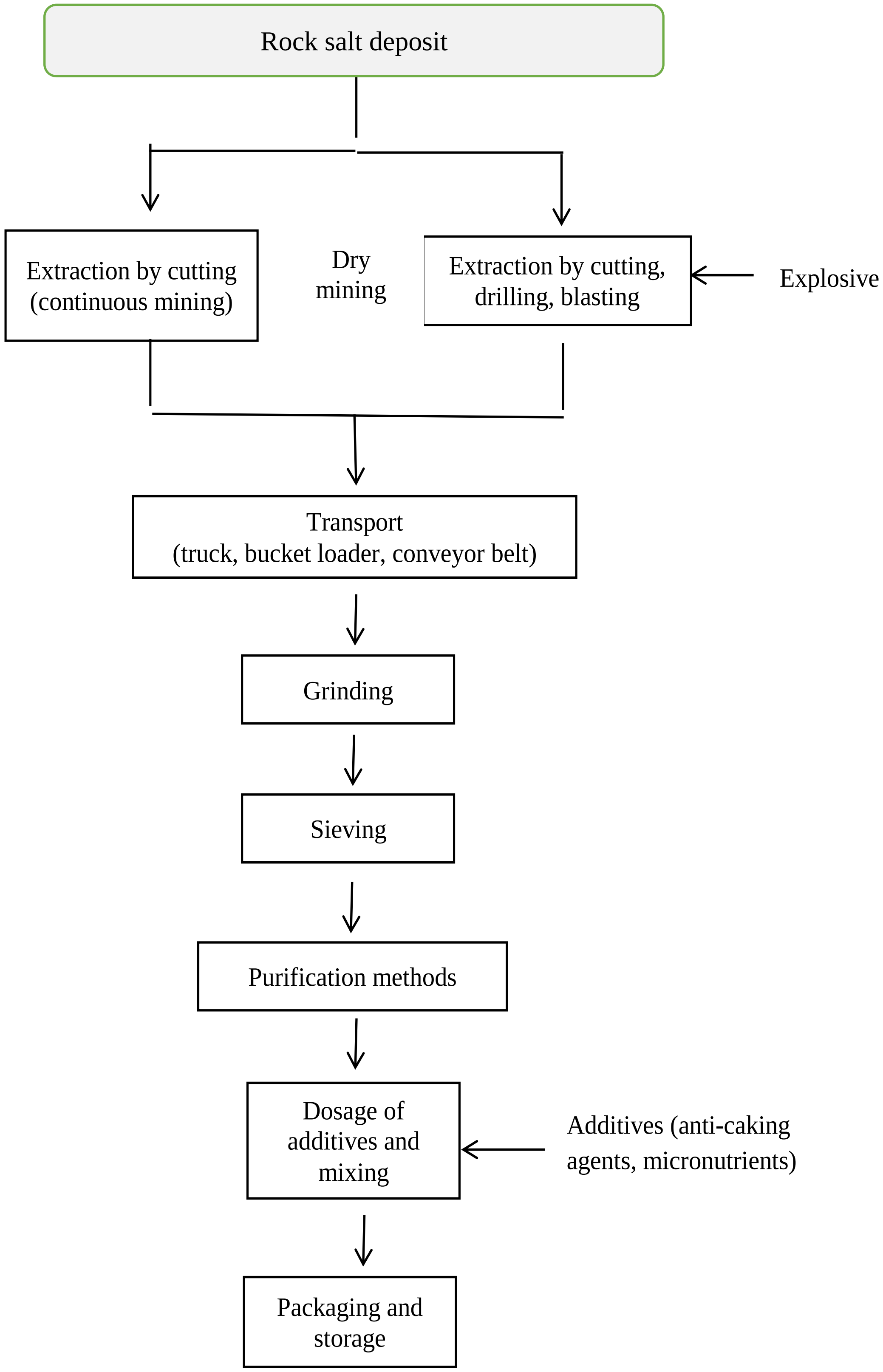
Source: Roskill - Review of the socio-economic impact of salt production in Europe (July 2017)

In EU countries[xlvi], around **3,7 Mt** (8%[xlvii] of 46[xlviii] Mt) **are needed for food** and **feed consumption**.

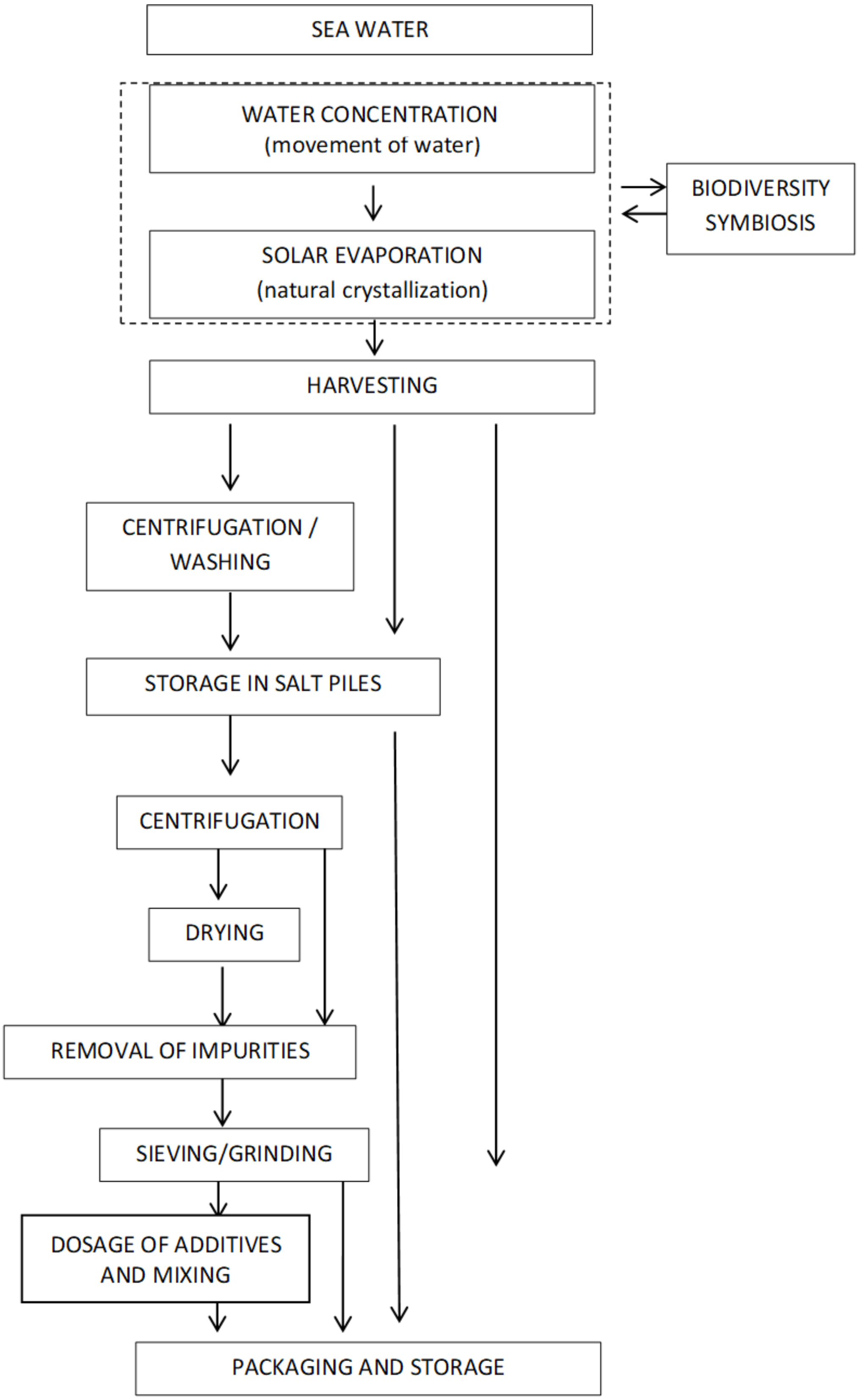
A.2. General flow chart



A.3. Rock salt flow chart



A.4. Sea salt flow chart



A.5. Organic rice production

Organic rice production rules are set out in Annex II in the *Regulation (EU) 2018/848*. Sea salt production is close to agriculture with a cycle of weather-dependent production and a seasonal work schedule.

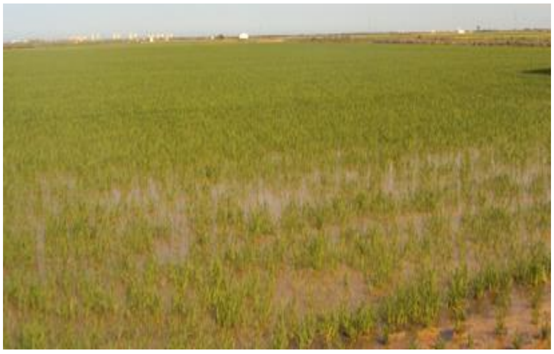
Rice production may be localized in areas with salinity such as deltas and marshes belonging to or close to Natural Parks. The following photos show pictures of the rice production process[xlix].

Fanqueo

This first part of rice production consists of mixing the stubble and scrap of the previous crop with the mud of the marshes

Drying and ploughing

In the second phase, marshes are dried to plough the land.



Fertilized

The next step is to fertilize the marshals and prepare them for sowing the seeds

Flooding and Sowing

The marshals are flooded, and the machines sow the land

Treatments

To prevent weeds from harming the crop, various treatments are performed before the rice plants bloom.

Harvesting

The harvesting machines separate the grain from the straw. Rice, once dried, is stored in silos for further processing.

A.6. Energy

With regard to the energy consumption of salt production, the data available is scarce, scattered and sometimes contradictory. The following table resumes the available data from several sources.

The production of sea salt, rock salt and solar salt consumes little primary energy compared with evaporated salts (see tables and figure). The process of crystallization by evaporation caused by sun and wind occurs with no energy consumption, which implies no CO_2eq-emmissions. Solar salt production is, per se, a sustainable activity, especially due to its efficiency[l] and low fossil energy requirements[li] in case of sea salt and natural brine salt.

In vacuum plants among 220-450 kwh/ton salt is the primary energy consumption. That value greatly depends on the technology (MEE, MVR or combinations). MEE installations for evaporated salt production are mainly driven by steam (more than 600 kg steam/ton of salt) and MVR consume mainly electricity (about 160 kwh/ton salt).

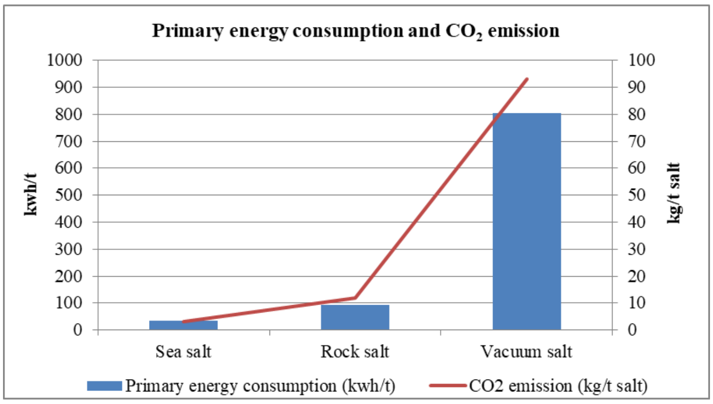
CO_2 emissions depend strongly on the energy mixture used (electricity, nuclear power, fossil fuels, renewables, etc.): In one example a value of 93 kg CO_2/ton of salt is given for the German mixture versus 12 kg CO_2/ton of salt for rock salt and 3 kg CO_2/ ton of salt for sea salt[lii].

<table>
<tr><th colspan="2"></th><th>Primary energy consumption (MJ/t salt). Mean values[liii]</th><th>Primary energy consumption (kwh/t salt) Estimation[liv]</th><th colspan="3">Electricity consumption (kwh/t salt)</th><th colspan="2">Vapour consumption (kg/t salt)</th><th>CO2 - Emission (kg/t salt)[lv]</th></tr>
<tr><td colspan="2">Sea salt</td><td>35 (10 kwh/t)</td><td>----</td><td colspan="3">----</td><td colspan="2">----</td><td>3</td></tr>
<tr><td colspan="2">Rock salt</td><td>93 (26 kwh/t)</td><td>----</td><td colspan="3">----</td><td colspan="2">----</td><td>12</td></tr>
<tr><td rowspan="3">Vacuum salt</td><td>Open pans</td><td>----</td><td>----</td><td colspan="3">----</td><td colspan="2">6000[lvi]</td><td>----</td></tr>
<tr><td rowspan="2">MEE/MVR</td><td rowspan="2">803
(223 kwh/t)</td><td rowspan="2">450</td><td>MEE (6)</td><td colspan="2">MVR</td><td>MEE (6)</td><td>MEE (3)</td><td rowspan="2">93</td></tr>
<tr><td>30[lvii]</td><td>155[lviii]</td><td>160[lix]</td><td>620[lx]</td><td>630[lxi]</td></tr>
</table>

----- No data available

MEE (3) and MEE (6) in the table refer to Multi-effect evaporators with 3 and 6 effects, respectively.

Data of primary energy consumption are transcribed from the original source and also given in kwh/t for comparison.



These tables were provided by Mr.Goetzfried, based on personal evidence and informal communication, and was therefore disputed within the group, with other group members objecting to the lack of data source.

Water footprint of salt production (*References not available*)	
Salt	**Water consumption (Liter/t salt)**
Rock salt	0-20
Evaporated salt • Solution mining, rock salt, natural brine (MEE, MVR, Recrystallization)	100-750
Evaporated salt (pan salt) - Natural brine - Brine from solution mining, or from dissolving crystallized salts on surface	10-100 3,000
Solar salt • Natural brine • Brine from solution mining or from dissolving crystallized salts on surface	10-100 3,000

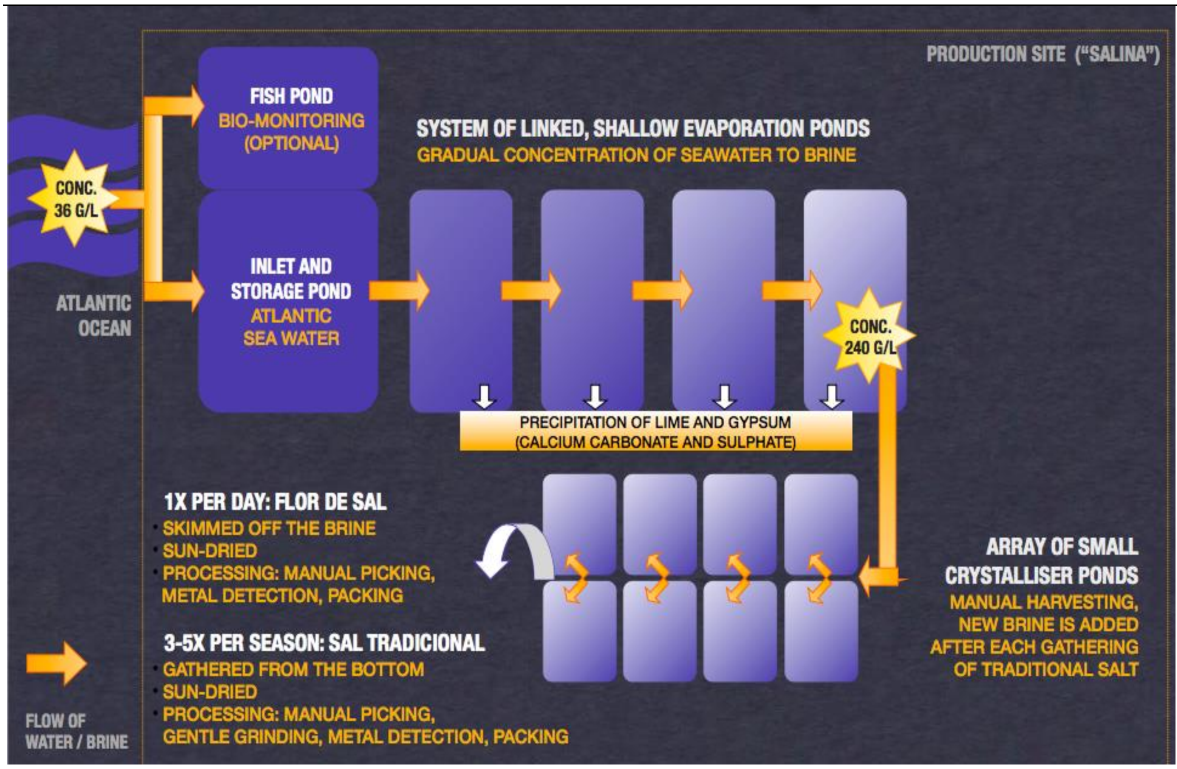
1. Energy consumption of salt production (“cradle-to-gate”). (*References not available*)

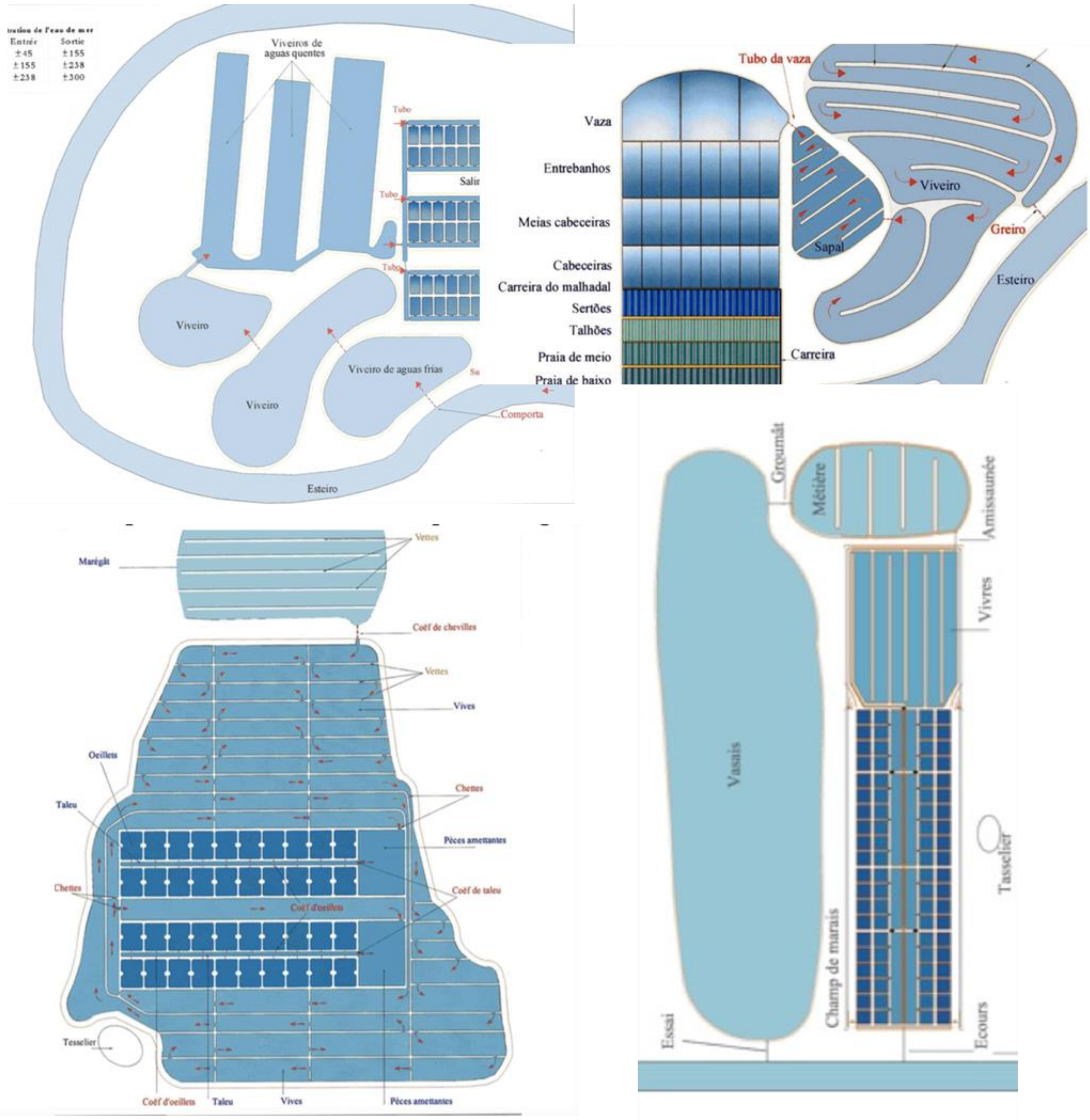
Rock salt (vertical shaft, mix cutting/blasting)	Electricity 15 kWh/t NaCl; Diesel 0.5 l/t NaCl
PDV salt (MEE, MVR, Recrystallization)	Electricity 30 – 160 kWh/t NaCl; Steam 75 - 800 kg/t NaCl
Solar salt and **sea salt** (dried with hot air/flue gas)	Electricity 10 kWh/t NaCl; Steam for hot air 50 - 75 kg/t NaCl (alternative: gas for direct drying with flue gas); Diesel 0.25 l/t NaCl

2. Carbon footprint of salt production („cradle-to-gate) (References not available)

Salt	**CO_2-eq (kg/t salt)**
Rock salt	9-15
PDV salt (MEE, MVR, Recrystallization)	18-160
Evaporated salt (pan salt) – Natural brine/waste heat – Live steam (gas), etc.	1.5 ≥900
Solar salt (without cogeneration, dried with hot air), • Solution mining • Brine from dissolving rock salt on surface	5-10 10-20
Sea salt - Wet - Dried (hot air, flue gas)	1.5 5-10

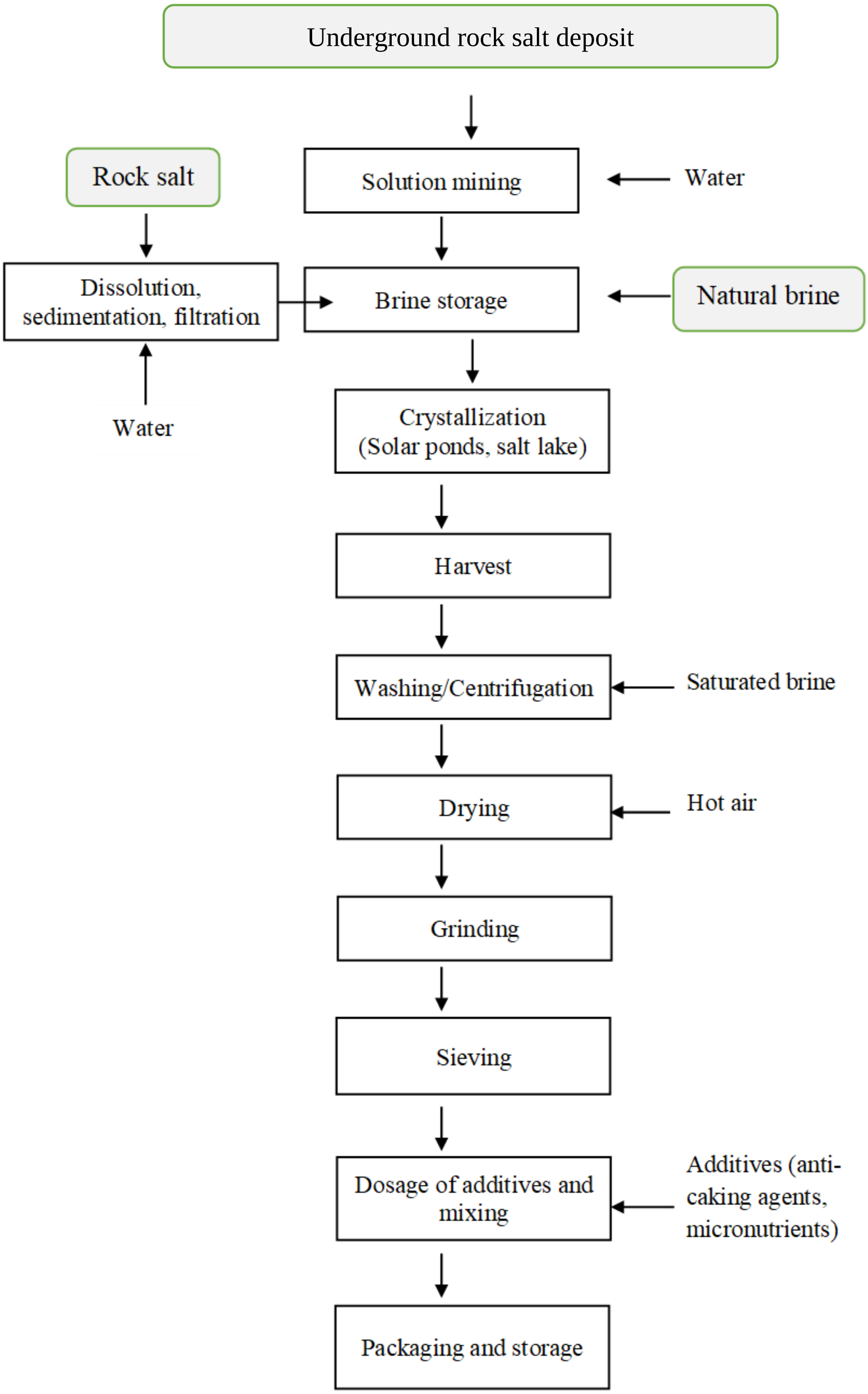
A.7. Artisanal flow chart



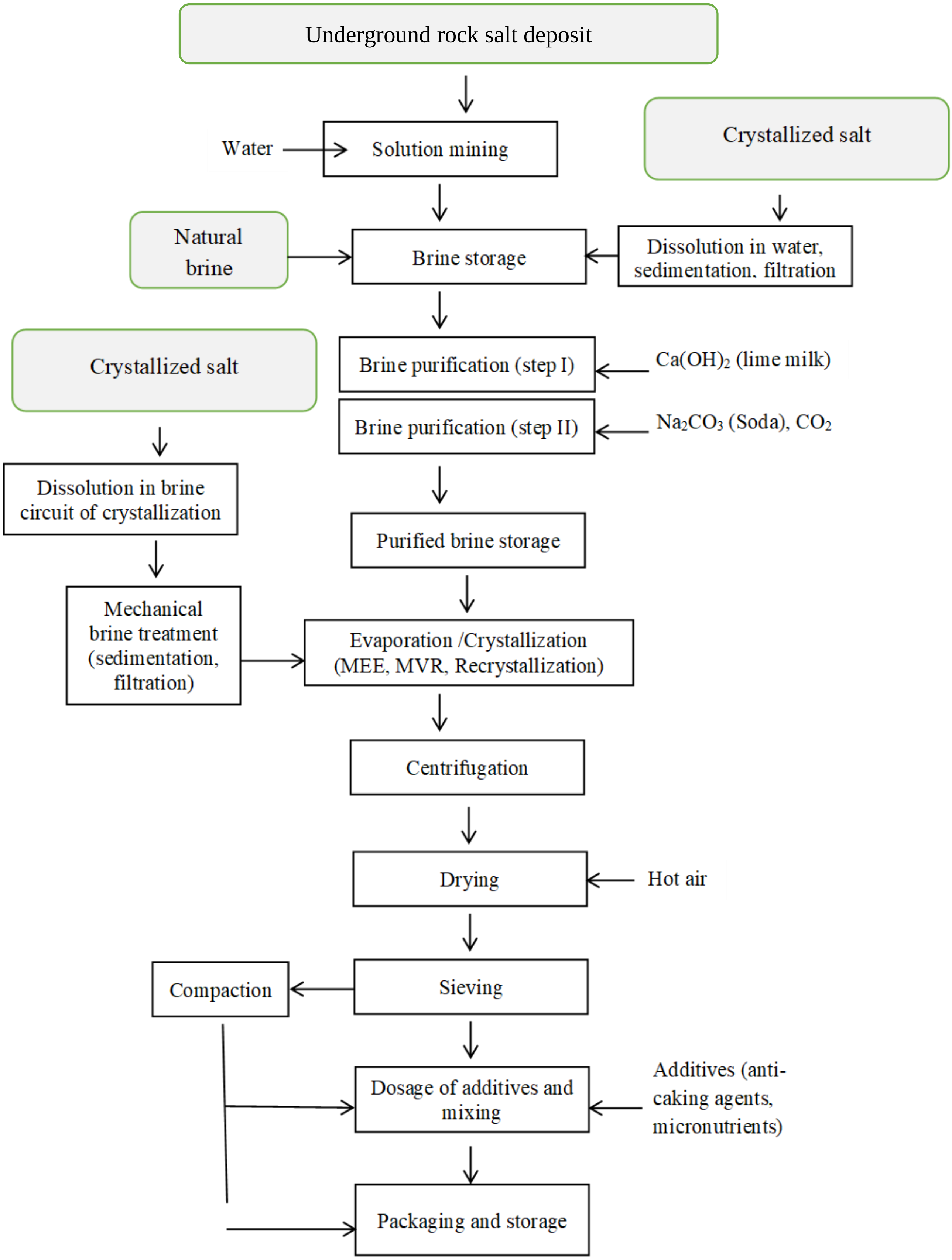


Different typicial layout of traditional saltworks in Portugal and France
From DELBOS Genevieve, Programme Interreg III B Sal/Sel de l'Atlantique 2004-2007
Revalorisation de l'identité des marais salants de l'Atlantique. Récupération et promotion des potentiels biologique, économique et culturel des zones côtières humides. 2006

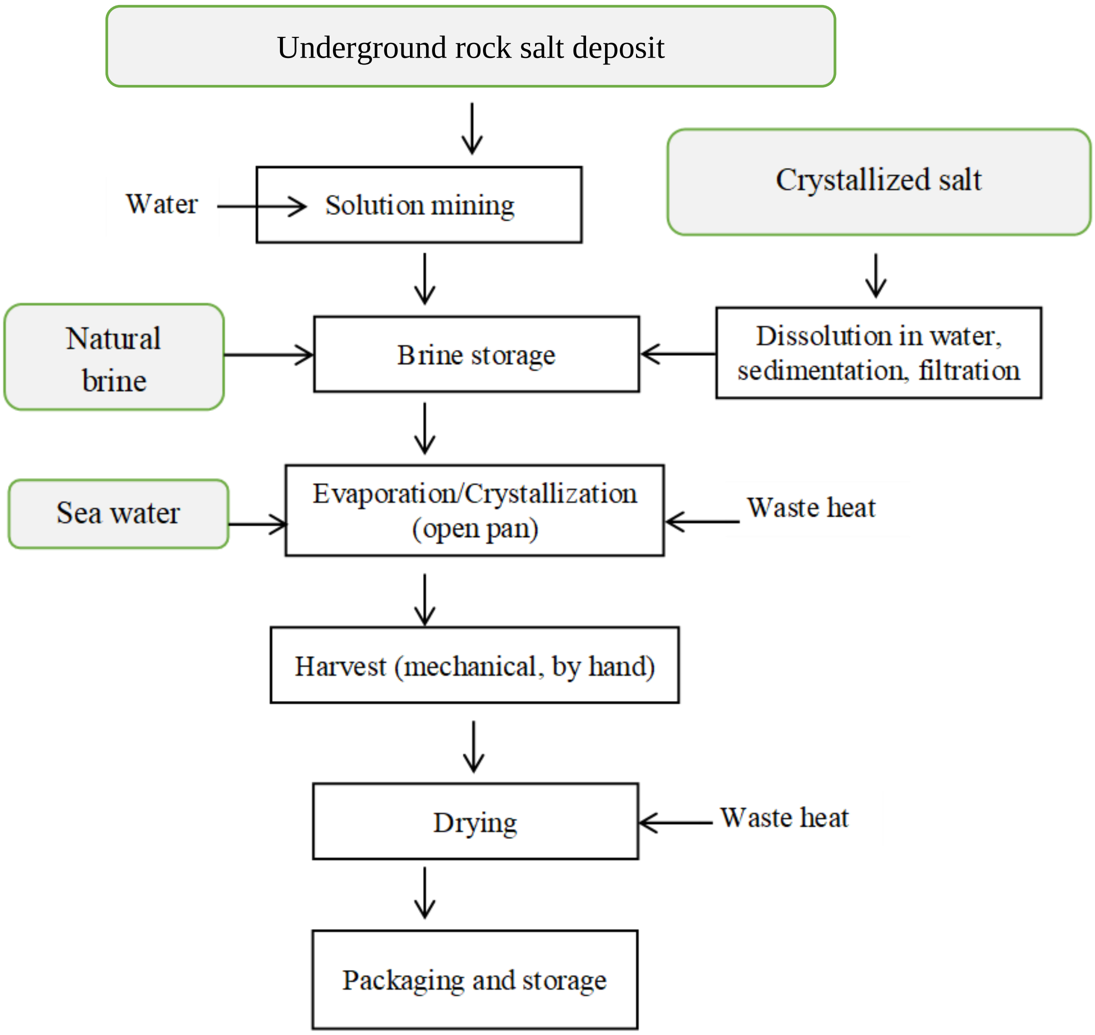
A.8. Solar salt (brines and salty waters) flow chart - Concentration and crystallisation of continental brines and salty waters



A.9. Vacuum salt flow chart



A.10. Open pan salt flow chart



TABLES

Brine Strength				Pound/Gallon Brine		Gram/Liter Brine		Freezing Point*	
Salometer Degree	Specific Gravity	Baume Degree	NaCl % Weight	NaCl	Water	NaCl	Water	°F	°C
0	1.000	0.0	0.00	.000	8.328	.0	998	+ 32.0	0
2	1.004	0.6	0.53	.044	8.318	5.3	996	+ 31.5	- 0.2
4	1.007	1.1	1.06	.089	8.297	10.6	995	+ 31.1	- 0.5
6	1.011	1.6	1.58	.133	8.287	16.0	993	+ 30.5	- 0.8
8	1.015	2.1	2.11	.178	8.275	21.4	991	+ 30.0	- 1.1
10	1.019	2.7	2.64	.224	8.262	26.8	990	+ 29.3	- 1.5
12	1.023	3.3	3.17	.270	8.250	32.3	988	+ 28.8	- 1.8
14	1.026	3.7	3.70	.316	8.229	37.9	986	+ 28.2	- 2.1
16	1.030	4.2	4.22	.362	8.216	43.4	985	+ 27.6	- 2.4
18	1.034	4.8	4.75	.409	8.202	49.0	983	+ 27.0	- 2.8
20	1.038	5.3	5.28	.456	8.188	54.6	981	+ 26.4	- 3.1
22	1.042	5.8	5.81	.503	8.175	60.3	979	+ 25.7	- 3.5
24	1.046	6.4	6.34	.552	8.159	66.1	977	+ 25.1	- 3.8
26	1.050	6.9	6.86	.600	8.144	71.9	976	+ 24.4	- 4.2
28	1.054	7.4	7.39	.649	8.129	77.7	974	+ 23.7	- 4.6
30	1.058	7.9	7.92	.698	8.113	83.6	972	+ 23.0	- 5.0
32	1.062	8.5	8.45	.747	8.097	89.5	970	+ 22.3	- 5.4
34	1.066	9.0	8.97	.797	8.081	95.4	968	+ 21.6	- 5.8
36	1.070	9.5	9.50	.847	8.064	101.4	966	+ 20.9	- 6.2
38	1.074	10.0	10.03	.897	8.047	107.5	964	+ 20.2	- 6.5
40	1.078	10.5	10.56	.948	8.030	113.5	962	+ 19.4	- 7.0
42	1.082	11.0	11.09	.999	8.012	119.6	960	+ 18.7	- 7.4
44	1.086	11.5	11.61	1.050	7.994	125.8	957	+ 17.9	- 7.8
46	1.090	12.0	12.14	1.102	7.976	132.0	955	+ 17.1	- 8.3
48	1.094	12.5	12.67	1.154	7.957	138.2	953	+ 16.2	- 8.8
50	1.098	12.9	13.20	1.207	7.937	144.5	951	+ 15.4	- 9.2
52	1.102	13.4	13.73	1.260	7.918	150.9	949	+ 14.5	- 9.7
54	1.106	13.9	14.25	1.313	7.898	157.2	946	+ 13.7	- 10.2
56	1.110	14.4	14.78	1.366	7.878	163.7	944	+ 12.8	- 10.7
58	1.114	14.8	15.31	1.420	7.858	170.1	941	+ 11.8	- 11.2
60	1.118	15.3	15.84	1.475	7.836	176.7	939	+ 10.9	- 11.7
62	1.122	15.8	16.37	1.529	7.815	183.2	936	+ 9.9	- 12.3
64	1.126	16.2	16.89	1.584	7.794	189.8	934	+ 8.9	- 12.8
66	1.130	16.7	17.42	1.639	7.772	196.5	932	+ 7.9	- 13.4
68	1.135	17.2	17.95	1.697	7.755	203.7	929	+ 6.8	- 14.0
70	1.139	17.7	18.48	1.753	7.733	210.0	926	+ 5.7	- 14.6
72	1.143	18.1	19.00	1.809	7.710	216.7	924	+ 4.6	- 15.2
74	1.147	18.6	19.53	1.866	7.686	223.5	921	+ 3.4	- 15.9
76	1.152	19.1	20.06	1.925	7.669	230.6	918	+ 2.2	- 16.5
78	1.156	19.6	20.59	1.982	7.645	237.4	916	+ 1.0	- 17.2
80	1.160	20.0	21.12	2.040	7.620	244.4	913	- 0.4	- 18.0
82	1.164	20.4	21.64	2.098	7.596	251.5	911	- 1.6	-18.6
84	1.169	21.0	22.17	2.158	7.577	258.5	908	- 3.0	- 19.4
86	1.173	21.4	22.70	2.218	7.551	265.7	905	- 4.4	- 20.2
88	1.178	21.9	23.23	2.279	7.531	272.9	902	- 5.8	- 21.0
**88.3	1.179	22.0	23.31	2.288	7.528	274.1	901	- 6.0**	- 21.0**
90	1.182	22.3	23.75	2.338	7.506	280.1	899	- 1.1	- 18.5
92	1.186	22.7	24.28	2.398	7.479	287.4	896	+ 4.8	- 15.0
94	1.191	23.3	24.81	2.459	7.460	294.7	893	+ 11.1	- 11.6
95	1.193	23.5	25.08	2.491	7.444	298.4	892	+ 14.4	- 9.8
96	1.195	23.7	25.34	2.522	7.430	302.1	890	+ 18.0	- 7.8
97	1.197	23.9	25.60	2.552	7.417	305.08	888	+ 21.6	- 5.8
98	1.200	24.2	25.87	2.585	7.409	309.6	887	+ 25.5	- 3.6
99	1.202	24.4	26.13	2.616	7.394	313.4	886	+ 29.8	- 1.2
99.6	1.203	24.5	26.29	2.634	7.386	315.6	885	+ 32.3†	+ 0.2†
100	1.204	24.6	26.40	2.647	7.380	317.2	884	+ 60.0 ‡	+ 15.5‡

The above table applies to brine tested at the temperature of 60°F
For brine tested at a warmer or colder temperature than 60°F see Table of Salometer Corrections
* Temperature at which freezing begins, ice forms, brine concentrates, and the feezing point lowers to eutectic
** Eutectic point, for brines stronger than eutectic, the temperatures shown are the saturation temperatures for sodium chloride dihydrate
Brines stronger than eutectic deposit excess sodium chlorid as dihydrate when cooled, and freeze at eutectic
† Transition temperature from anhydrous salt to dihydrate
‡ Saturated brine at 60°F

Above data courtesy of Morton Salt

Table T.1. Baume scale. Sodium Chloride Table for 60°F (15.5°C)[lxii]

Element	**Concentratión (mg/l)**	**Element**	**Concentratión (mg/l)**	**Element**	**Concentratión (mg/l)**
Chlorine	19.000	Iron	0,01	Krypton	0,0003
Sodium	10.500	Aluminum	0,01	Neon	0,0001
Magnesium	1.350	Molybdenum	0,01	Cadmium	0,0001
Sulfur	885	Selenium	0,004	Tungsten	0,0001
Calcium	400	Tin	0,003	Xenon	0,0001
Potassium	380	Copper	0,003	Germanium	0,00007
Bromine	65	Arsenic	0,003	Chrome	0,00005
Carbon	28	Uranium	0,003	Thorium	0,00005
Strontium	8	Nickel	0,002	Scandium	0,00004
Boron	4,6	Vanadium	0,002	Lead	0,00003
Silicon	3	Manganese	0,002	Mercury	0,00003
Fluorine	1,3	Beryllium	0,001	Gallium	0,00003
Argon	0,6	Titanium	0,001	Bismuth	0,00002
Nitrogen	0,5	Antimony	0,0005	Niobium	0,00001
Lithium	0,17	Cobalt	0,0005	Thallium	0,00001
Rubidium	0,12	Cesium	0,0005	Helium	0,000005
Match	0,07	Cerium	0,0004	Gold	0,000004
Iodine	0,06	Yttrium	0,0003	Protactinium	2 x 10E-9
Barium	0,03	Silver	0,0003	Radio	1 x 10E-10
Indian	0,02	Lanthanum	0,0003	Radon	0,6 x 10E-15
Zinc	0,01				

Table T.2. Elements in sea water[lxiii]

Brine stage (hypersaline)	Mineral precipitate	Salinity (‰)	Degree of evaporation	Water loss (%)	Density (gm/cm^3)
Supersaline	Bittern salts K–Mg salts	variable	> 60 X	~99	> 1.29
Supersaline	Halite (NaCl)	> 350	> 11 X	> 90	> 1.214
Penesaline	$CaSO_4$ ± halite	250–350	7–11 X	85–90	1.126–1.214
Penesaline	$CaSO_4$ (gypsum/anhydrite)	140–250	4–7 X	75–85	1.10–1.126
Mesohaline or vitahaline	Alkaline-earth carbonates	35–140	1–4 X	0–75	1.04–1.10
Normal marine	Seawater	35	1 X	0	1.04

Table T.3. Successive salt precipitations throughout the evaporation / concentration of seawater[lxiv]

	Sea salt	**Rock salt** (drilling and blasting)	**Evaporated salt**	**Evaporated salt** (Pan salt)	**Solar salt**	**Technological purpose**
Ammonium nitrate (NH_4NO_3)*	-	✓	-	-	-	Explosive for salt extraction by drilling and blasting
Nitrogen	-		✓	✓	✓	Blanket for solution mining
Air	-		✓	✓	✓	
Diesel	-		✓	✓	✓	
Lime milk ($Ca(OH)_2$)	-	-	✓	-	-	Precipitation agent for brine treatment (softening)
Caustic soda (NaOH)	-	-	✓	-	-	
Sodium carbonate (Na_2CO_3)	-	-	✓	-	-	
Carbon dioxide (CO_2)	-	-	✓	-	-	
Polyacrylamides	-	-	✓	-	-	Flocculant for sedimentation of sludge during brine treatment (softening)
Gypsum ($CaSO_4x2H_2O$)	-	-	✓	-	-	Seed crystals
Polydimethylsiloxane	-	-	✓	-	-	Anti-foam agent to avoid foaming in evaporators

*with 0% to max. 10% mineral oil.

Table T.4. Processing aids

	Sea salt	Artisanal sea salt (inc. fleur de sel)	Rock salt	Evaporated salt: Vaccum salt	Evaporated salt: Pan salt	Solar salt	Codex Aliment. Stan 150	RD 1424/83 (Spanish legislation)	Décret n° 2007-588 (French legislation)	(Portugal legislation) Decreto-Lei n° 350/2007	(Portugal legislation) Portaria n° 72/2008 – Table salt: Sea salt inc. traditional + flor de sal	Portaria n° 72/2008 – Table salt: Salt from spring water	Portaria n° 72/2008 – Salt for food industries: Sea salt	Portaria n° 72/2008 – Salt for food industries: Salt from spring water	Portaria n° 72/2008 – Salt for food industries: Rock salt	Decreto 31gennaio 1997, n. 106 (Italian legislation)	Uradni List RS, st. 46/2018, 7498 (Slovenian legislation): Table salt	Uradni List RS, st. 46/2018, 7498 (Slovenian legislation): Unrefined sea salt + fleur de sel	NN 70/2019, n. 1472 (Croatian legislation): Table salt	NN 70/2019, n. 1472 (Croatian legislation): Unrefined sea salt + fleur de sel	Non-EU: VLpH of 16.12.2016, 10.1. (Swiss legislation)
% Sodium chloride (NaCl)*	97-99,7	92-99	97-99,5	≥99,7	98,5-99	99-99,5	≥97	≥ 97 (virgin sea salt + flor de sal ≥ 94)	≥ 97 (grey sea salt ≥ 94)	≥ 90	≥ 94	≥ 97	≥ 90	≥ 90	-	≥ 97	≥ 97	≥95	≥ 97	≥95, (Fleur de Sel ≥92)	≥ 97 (sea salt: no regulation)
% Sulfate (SO4)	≤1,3	≤1,4	0,35-1,4	<0,1	0,75-1,1	≤0,6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% Calcium (Ca)	<0,2	<0,2	0,14-0,6	<0,01	0,2-0,35	≤0,3	-	-	-	-	-	-	-	-	-	-	-	≥0,1 (unrefined sea salt)	-	-	-
% Magnesium (Mg)	<0,5	<0,9	<0,1	<0,01	≤0,05	≤0,1	-	-	-	-	-	-	-	-	-	-	-	≥0,2 (unrefined sea salt)	-	-	-
% Potassium (K)	<0,1	≤0,5	<0,1	<0,01	≤0,05	<0,05	-	-	-	-	-	-	-	-	-	-	-	-	-		-
% Water insoluble	<0,1	<0,05-0,4**	<0,1-1,5	<0,01	<0,03	<0,1	-	≤ 0,5	-	-	-	-	-	-	-	≤ 0,5****	≤ 0,5****	≤ 0,5****	-	-	≤ 1
% Moisture	< 5 (wet), < 0,2 (dry)	≤8 (fleur de sel), ≤5 (other)	0,1-0,5	<0,1	0,1-0,3	2-6 (wet), 0,2 (dry)	-	≤ 5, ≤ 0,5 (table salt)	-	-	≤ 8 flor de sal / ≤ 6 traditional sea salt	≤ 4	≤ 8	≤ 4	-	-	≤ 7	≤7 (unrefined sea salt), ≤10 (fleur de sel)	≤5 (sea salt), ≤0,5 (other salt)	≤ 7	≤ 3, if >3: to be declared on label
% MgO	< 1	-					-	≤ 2 (curing salt)	-	-	-	-	-	-	-	-	-	-	-	-	-
mg/kg Nitrites, nitrates and ammonium salts	< 10	<5***					-	≤ 20	-	-	-	-	-	-	-	-	-	-	-	-	-
Nº col mesophile bact.		19-26/g					-	-	-	-	< 100/g	< 100/g	< 100/g	< 100/g	< 100/g	-	-	-	-	-	-
Nº col. halophile bact.		25-30/g					-	-	-	-	< 100/g	< 100/g	< 100/g	< 100/g	< 100/g	-	-	-	-	-	-
Nº col. coliform bact.		0					-	-	-	-	Absence	Absence	Absence	Absence	Absence	-	-	-	-	-	-
Nº Streptococcus faecalis		0					-	-	-	-	Absence	Absence	Absence	Absence	Absence	-	-	-	-	-	-
Nº col. E.Coli		0					-	-	-	-	Absence					-	-	-	-	-	-

* dry substance ** depending on geographical location and salt type *** summarised values (nitrites <1,6/nitrates<2,2) **** and insolubles ≤0.3 in 0,1M hydrochloric acid

Artisanal sea salt: For determination of values for NaCl, Sulfates and Moisture, analytical data of 40 salt samples from Atlantic and Mediterranean waters (FR, PT, ES, TUN) was used. For Insolubles, data from 86 samples from Atlantic and Mediterranean waters (FR, PT, ES, TUN) was used. For the remaining parameters, data from 25 samples from Atlantic waters (PT, ES) was used. (sample data range from 7/2016 to 10/2020). Obtained values were cross-checked with available data on Mediterranean artisanal salts from Italy (Cervia, Trapani), Croatia (Pag, Nin) and Slovenia (Piran), based on internet research.

Sea salt: Average value of Mediterranean sea salt samples analyzed in the last 5 years

Other salts: missing data source

Table T.5. Typical composition of sea salts, rock salt, evaporated salts, and solar salt for human and animal nutrition (%)

Member State	Legal reference
Austria	Österreichisches Lebensmittelbuch, Kapitel B 21, Speisesalz
Croatia	NN 70/2019, n. 1472: PRAVILNIK O SOLI
France	Ministère de l'Économie, des Finances et de l'Industrie: Décret no 2007-588 du 24 avril 2007 relatif aux sels destinés à l'alimentation humaine.
Germany	There is no legal reference, but several official sources state that *"table salt must contain > 97% NaCl, < 2% Calcium and Magnesium, <4ppm heavy metals, <1,6ppm Iron and <1ppm Arsenic[lxv]".*
Italy	DECRETO 31 gennaio 1997, n. 106
Portugal	Decreto-Lei nº 350/2007 estabelece o quadro legal relativo à produção e comercialização do sal destinado a fins alimentares
	Portaria n.º 72/2008 Define as normas técnicas, as características e as condições a observar na produção, valorização e comercialização do sal alimentar
Slovenia	Uradni List RS, st. 46/2018, Pravilnik o kakovosti jedilne soli, stran 7498.
Spain	Real Decreto 1424/1983 por el que se aprueba la Reglamentación Técnico-Sanitaria para la obtención, circulación y venta de la sal y salmueras comestibles.

Table T.6: National requirements for food grade salt in some EU member states

	Sea Salt	Artisanal sea salt	Rock salt	Vaccum salt	Solar salt	Codex Alimentarius Limits	Directive 2002/32/EC Max. level
Arsenic (As)	< 0,5	<0,05	<0,1	<0,01-0,02	≤0,1	≤0,5	≤2
Copper (Cu)	< 0,5	<0,1	<0,1	<0,01-0,1	≤1,0	≤2	-
Lead (Pb)	< 0,5	<0,1 - <2**	<0,5	<0,01-0,3	≤0,5	≤1***	≤10
Cadmium (Cd)	< 0,05*	<0,05	<0,01	<0,005-0,01	≤0,1	≤0,5	≤2
Mercury (Hg)	< 0,05	<0,05	<0,05	≤0,002	≤0,1	≤0,1	≤0,1
Nitrites, nitrates	<10	<5				-	≤15****

* Limit of Quantification (LOQ)
** Depending on geographical location
***Excluding salt from marshes for which: Pb ≤2
**** Nitrites only, for feed with 12% humidity and with some exceptions, see original source

Artisanal sea salt: For determination of values, analytical data of 25 samples from Atlantic waters (PT, ES) was used. (sample data range from 7/2016 to 10/2020). Values were cross-checked with available analytical data on Atlantic and Mediterranean artisanal salts from France, Italy, Croatia and Slovenia, based on internet research.

Sea salt: Average value of Mediterranean sea salt samples analyzed in the last 5 years

Other salts: missing data source

Table T.7. Contaminant concentrations and limits in salts for human and animal nutrition (mg/kg)

			FOOD								
			Regulation (EC) No 1333/2008 of the European Parliament and of the Council of 16 December 2008 on food additives (Current consolidated version: 28/10/2020)			Commission Regulation (EU) No 1129/2011 of 11 November 2011 amending Annex II to Regulation (EC) No 1333/2008 of the European Parliament and of the Council by establishing a Union list of food additives (Current consolidated version: 21/11/2013)			GENERAL STANDARD FOR FOOD ADDITIVES CODEX STAN 192-1995 (2019)		
Category number	E-number	Name	Maximum level (mg/l or mg/kg as appropiate)	Footnotes	Restrictions / exceptions	Maximum level (mg/l or mg/kg as appropiate)	Footnotes	Restrictions / exceptions	Year adopted	Max Level	Notes
12.1.1	Salt										
	E 170	Calcium carbonate	*quantum santis*			*quantum santis*			*2006*	*GMP*	
	E 338-452	Phosporic acid - phosphates - di-, tri-, and polyphosphates	10 000	(1) (4)		10 000	(1) (4)		(338; 339(i)-(iii); 340(i)-(iii); 341(i)-(iii); 342(i)-(ii); 343(i)-(iii); 450(i)-(iii),(v)-(vii), (ix); 451(i),(ii); 452(i)-(v); 542) 2006	8800 mg/kg	(33)
									(432-436) 2006	*10 mg/kg*	
	E 535-538	Ferrocyanides	20	(1) (57)		20	(1) (57)		(535, 536, 538) 2006	*14 mg/kg*	*(24) (107)*
	E 500	Sodium carbonates	*quantum santis*			*quantum santis*					
	E 504	Magnesium carbonates	quantum santis			quantum santis			*2006*	*GMP*	
	E 511	Magnesium chloride	quantum santis		only sea-salt	quantum santis		only sea-salt			
	E 530	Magnesium oxide	quantum santis			quantum santis			*2006*	*GMP*	
	E 534 [1]	Iron tartrate	110	(92)							
	E 551-559 [2]	Silicon dioxide - silicates	10 000		Period of application: until 31 January 2014	10 000		Period of application: until 31 January	*(551) 2006*	*GMP*	
									(552) 2006	*GMP*	
	E 551-553	Silicon dioxide - silicates	10 000		Period of application: from 1 February 2014				*(553) 2006*	*GMP*	
	E 554	Sodium aluminium silicate	20 mg/kg carry over in cheese	(38)	Only for salt intended for surface treatment of ripened cheese, food category 01.7.2 Period of application: from 1 February 2014				*2013*	*GMP*	*(6) (254)*
	E 470	SALTS OF MYRISTIC, PALMITIC AND STEARIC ACIDS WITH AMMONIA, CALCIUM, POTASSIUM AND SODIUM							*2006*	*GMP*	(71)

[1] Commission Regulation (EU) 2015/1739 of 28 September 2015 amending Annex II to Regulation (EC) No 1333/2008 of the European Parliament and of the Council and the Annex to Commission Regulation (EU) No 231/2012 as regards the use of the iron tartrate as an anti-caking agent in salt and its substitutes

[2] Commission Regulation (EU) No 380/2012 of 3 May 2012 amending Annex II to Regulation (EC) No 1333/2008 of the European Parliament and of the Council as regards the conditions of use and the use levels for aluminium-containing food additives

(1)	The additives may be added individually or in combination
(4)	The maximum level is expressed as P_2O_5
(38)	Expressed as aluminium
(57)	The maximum level is expressed as anhydrous potassium ferrocyanide
(92)	Expressed on dry matter

(6)	As aluminium
(24)	As anhydrous sodium ferrocyanide.
(33)	As phosphorus
(71)	Calcium, potassium and sodium salts only
(107)	Except for use of sodium ferrocyanide (INS 535) and potassium ferrocyanide (INS 536) in food-grade dendridic salt at 29 mg/kg as anhydrous sodium ferrocyanide
(254)	For use in salt applied to dry salted cheeses during manufacturing only

Table T.8: List of additives authorised for food grade salt

Private Certification Standard Organization	Certification Scope	Reference
Nature et Progrès (France)	• Artisanal and hand-harvested salt • Concentration process of seawater by natural evaporation • Gravity fed water management • Ponds' bottoms are natural, crystallisers' ponds are in clay. • Any additive is prohibited • -Salt washing and refining are prohibited	Cahier des Charges Sel Marin 2012
Intereco (Spain)	– Food grade salt – Only salt produced by solar evaporation of natural brines (sea water, salt spring water and salt lake water) – The use of additives is not allowed, except those included in Annex VIII of Regulation (EC) 889/2008	RT/INTERECO/04 DE SAL ECOLÓGICA Diciembre 2018 Rev. 1
Certiplanet (Portugal)	– Production and preparation of **traditionally obtained salts** from seawater (including flor de sal), spring salt water, salt lakes and solar rock salts – No artifical drying – No additives, no fortification allowed	Caderno de Especificações 2014 – Sal OT-057-04 Rev. 4
Sativa (Portugal)	• Production and preparation of artisanal sea salt	Referencial Kiwa Sativa para o SAL MARINHO ARTESANAL

Table T.9.a. Some private organic certification standards for salt

Private Certification Standard Organization	Regulation Scope	Reference
Bio Austria (Austria)	– Food grade salt, general used for food processing.	Produktionsrichtlinien 2020
Demeter (Germany)	– Food grade salt (sea salt, evaporated salt, rock salt; – preferably without anti-caking agent, or with E 170 Calcium carbonate; – without iodine and fluoride.	Betriebsmittellliste 2020, Verarbeiter-Richtlinie 2020
Bioland (Germany)	– Food grade salt – with or without iodine; – anti-caking agents E 170 Calcium carbonate and E 504 Magnesium carbonate.	Richtlinie für Verarbeitung
Naturland (Germany)	– Food grade salt (sea salt, evaporated salt, rock salt); – with or without iodine; – anti-caking agent E 170 Calcium carbonate.	Richtlinie für Verarbeitung

Table T.9.b. Some regulations on salt use in food and feed production, issued by organic certifiers

		FEED							
		Commission Regulation (EC) No 1810/2005 of 4 November 2005 concerning a new authorisation for 10 years of an additive in feedingstuffs, the permanent authorisation of certain additives in feedingstuffs and the provisional authorisation of new uses of certain additives already authorised in feedingstuffs (Current consolidated version: 19/07/2017)			**Commission Implementing Regulation (EU) 2016/896 of 8 June 2016 concerning the authorisation of iron sodium tartrates as a feed additive for all animal species**			**Commission Regulation (EC) No 889/2008 of 5 September 2008 laying down detailed rules for the implementation of Council Regulation (EC) No 834/2007 on organic production and labelling of organic products with regard to organic production, labelling and control** (Current consolidated version: 07/01/2020)	
E-number	**Name**	**Species or category of animal**	**Other provisions**	**End of period of authorisation**	**Species or category of animal**	**Other provisions**	**End of period of authorisation**	**Substance**	**Description, conditions for use**
E-535	Sodium Ferrocyanide	All species or categories of animals	Maximum content: 80 mg/kg NaCl (calculated as ferrocyanide ion)	Without a time-limit				Sodium ferrocyanide	Maximum dose rate of 20 mg/kg NaCl calculated as ferrocyanide anion.
E-536	Potassium Ferrocyanide	All species or categories of animals	Maximum content: 80 mg/kg NaCl (calculated as ferrocyanide ion)	Without a time-limit					
E-551 b	Colloidal silica							Colloidal silica	
1i534	Iron sodium tartrates				All animal species	1. The additive shall be used only in NaCl (sodium chloride) 2. Minimum recommended dose: 26 mg of iron sodium tartrates/kg NaCl (equivalent to 3 mg iron/kg of NaCl) 3. Maximum recommended dose: 106 mg of iron sodium tartrates/kg NaCl	29 June 2026		

Table T.10. List of additives authorised for feed

Micronutrient	**Additives**	**Concentration range of fortification (mg/kg)**	**Function**
Iodine	– Sodium iodide – Sodium iodate – Potassium iodide – Potassium iodate	5-75	Iodine deficiency disorders (IDD) prevention
Fluoride	– Sodium fluoride – potassium fluoride	90-310	Caries control
Vitamin B_9	– Folic acid	80-120	Reduction of the incidence of spina bifida or NTD

Table T.11. Some minerals and vitamins used for fortification of salt

Country	Legal status	Permitted iodine source	Iodine content (mg/kg salt)	Appli-cations	Market share of house-hold salt (%)	Iodisation of feedstuffs
Albania		KI	25	R	56	N
Austria	C	KI, KIO_3	15-20	R, B, F	95	Neg.
Belgium	V	KI, NaI, KIO_3	6-45	R, B, F	10	Y
Bosnia	C	KI	5-15	R	37	Y
Bulgaria	C	KIO_3	22-58	R, B, F	90	N
Croatia	C	KI, KIO_3	25		90	Y
Czech Republic	C	KI, KIO_3	20-34		90	Y
Denmark	C	KI	8-13	R, B		
Finland	V	KI	20	R	>90	Y
France	V	NaI	15	R	55	Y
Germany	V	KIO_3	15-25	R, B, F	84	Y
Greece	V	KI	50	R	18	N
Hungary	C	KIO_3	15		10-50	Y
Ireland	V	KI	25	R		N
Italy	V	KI, KIO_3	30	R, B, F	3	N
Lithuania	V	KI, KIO_3	10-40		12	Y
Luxembourg	V	NaI, KIO_3	10-25			Y
Macedonia	C	KIO_3	20-30		100	Y
Netherlands	V	KI, NaI, KIO_3	20-50 househ. 45-85 bakers	R, B, F	60	
Norway	V	KI	5			Y
Poland	C	KI, KIO_3	20-40	R	90	N
Portugal	V	KI	11	R, F		N
Romania	C	KIO_3	15-25	R, F	25	Y
Slovakia	C	KI	15-35		85 (imports;	Neg.
Slovenia	C	KI	5-15			Y
Spain	V	KI, KIO_3	60	R	16	
Sweden	V	KI, NaI	50	R		Y
Switzerland	V	KI, KIO_3	20-30	R, B, F	94	Y
Turkey	C	KIO_3	20-40		64	N
United Kingdom	V	KI	10-22		2	Y
Yugoslavia (Serbian Rep.)	C	KI, KIO_3	12-18	R,F	73	N

V: voluntary. C: compulsory.
KI = Potassium iodide, NaI = Sodium iodide, KIO_3 = Potassium iodate.
R = retail, B = bread, F = processed food. processed food
Y = yes, N = no, Neg. = negligible.
Void cases: no information available.

Table T.12. Regulations governing universal salt iodisation (USI) in some European countries in 2014 and market shares of iodised household salt[lxvi]*. (Some of these regulations have changed during the last years).*

FIGURES

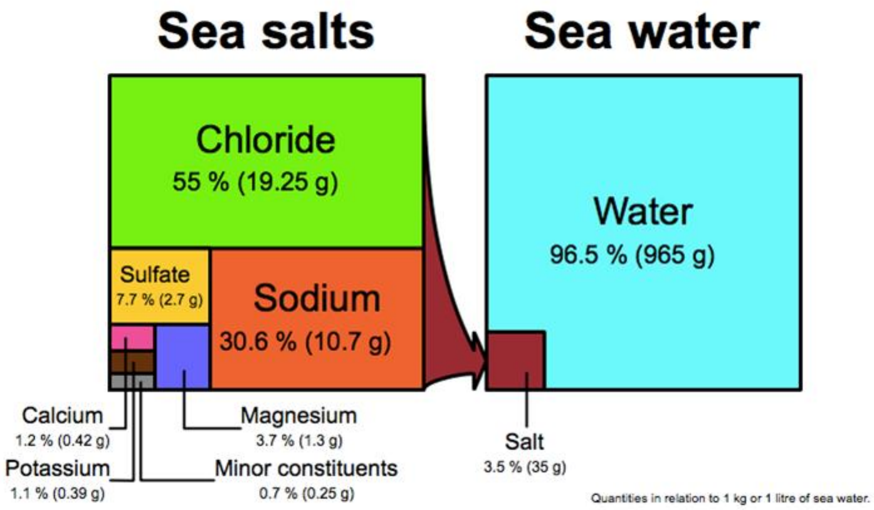


Figure F.1. Composition of sea salt and sea water

Figure F.2. Sea saltworks

Figure F.3. Salt spring

Figure F.4. Salt lake

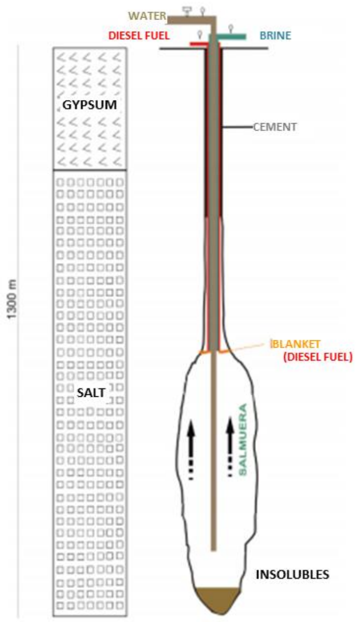


Figure F.5. Solution mining process[lxvii]

Figure F.6. Cormorant

Figure F.7. Egret

Figure F.8. Flamingos

Figure F.9. Limonium

Figure F.10. Reedbeds

Figure F.11. Ile de Ré: coarse salt is moved with water pushed with the simoussi (Merlin 2020)

Figure F.12. Salt is then pulled up on the dry clay (Merlin 2020).

Figure F.13. Tavira, Algarve: after drying, coarse salt is taken out of the saltern (Siebert 2009)

Figure F.14. Castro Marim, Algarve: coarse salt is pulled on a side of the pond (Siebert 2005)

Figure F. 15. Crystalliszer pond with floatting fleur de sel in Noirmoutier, FR

Figure F.16. Harvesting of fleur de sel (FR)

Figure F.17 Flor de Sal skimmed off in a crystalliser, Eastern Algarve, Portugal

Figure F.18. Mechanical sea salt harvesting in SP

Figure F.19. Mechanical sea salt harvesting in SP

Figure F.20 Mechanical salt harvest in Gruissan, FR

Figure F.21. Salt in piles

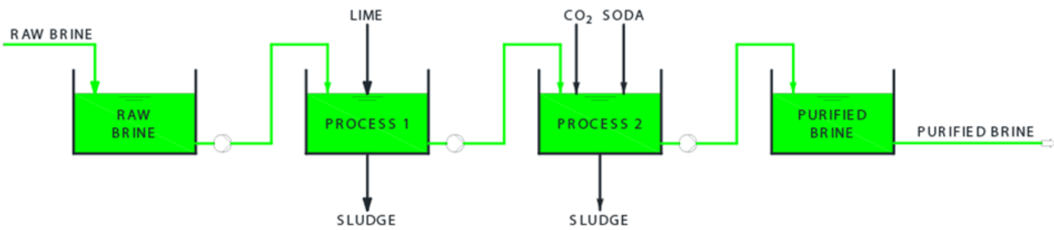


Figure F.22. Flow diagram of raw brine treatment[lxviii]

Figure F.23: Brine purification plant[lxix]

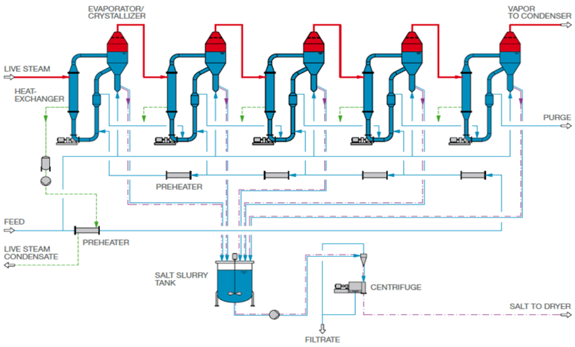


Figure F.24. MEE: Multiple effect process[lxx]

Figure F.25. TVR: Thermal vapor recompression process[lxxi]

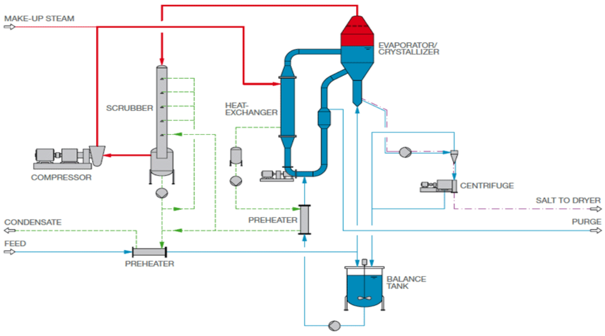


Figure F.26. MVR: Mechanical vapor recompression process [lxxii]

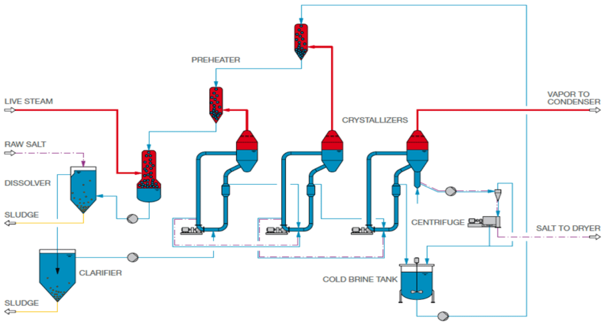


Figure F.27. Recrystallization[lxxiii]

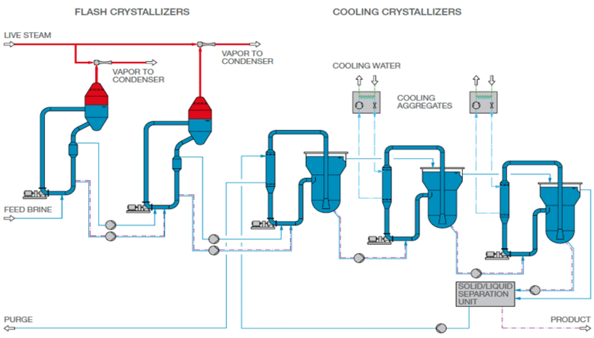


Figure F.28. Flash evaporation or crystallization[lxxiv]

Figure F.29. Sea salt washing facility, from Sedivy Vladimir, processing of salt for human and industrial consumption, 2009 i www.solutionmining.org consulted in December 2020

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[lxvii] El domo salino de Pinoso, Joan A. Cerdá, Mª del Mar Fresno, Mª Antonia Gómez3

[lxviii] https://www.sepwin.ch/en/applications/sodium-chloride/raw-brine-treatment.php

[lxix] https://www.sepwin.ch/en/applications/sodium-chloride/raw-brine-treatment.php

[lxx] Source: Evatherm AG, Othmarsingen/CH

[lxxi] https://www.gea.com/en/products/tvr-heated-evaporation-plants.jsp

[lxxii] Source: Evatherm AG, Othmarsingen/CH

[lxxiii] Source: Evatherm AG, Othmarsingen/CH

[lxxiv] https://www.sepwin.ch/en/technology/process-design/#anchor_faf826e4_Accordion-2-Thermal-Vapour-Recompression