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Upgradeability of Solar, Rock and Vacuum Evaporated Salts

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This presentation is broadcasting on Salt Partners YouTube channel under the following link: https://youtu.be/af14NWpmO9A

10th World Salt Symposium 2018, Park City, Utah, USA

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Salt Partners build HYDROSAL salt purification plants.

Interested parties usually ask: I have salt with the following analysis... How can your HYDROSAL process purify my salt?

I say: I don’t know.

Surprising, isn’t it? Now, let me explain why.

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Salt purification prior to dissolution in electrolytical brine

Way back in 1979, Krebs Swiss incorporated a Salins du Midi salt washing unit in a chloralkali plant built for MISR Chemicals in Egypt

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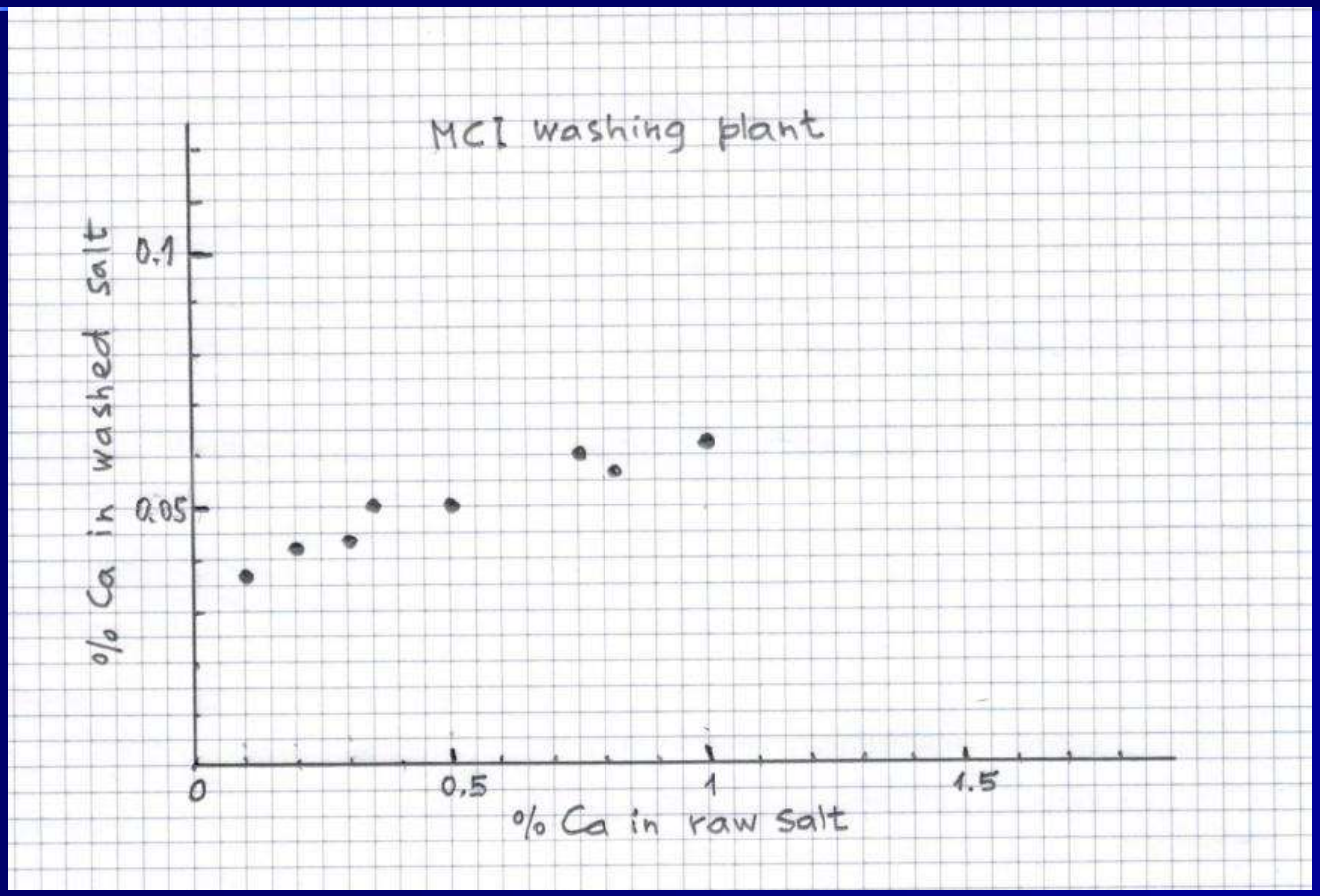
I was evaluating the washing plant performance



Fist week of operation

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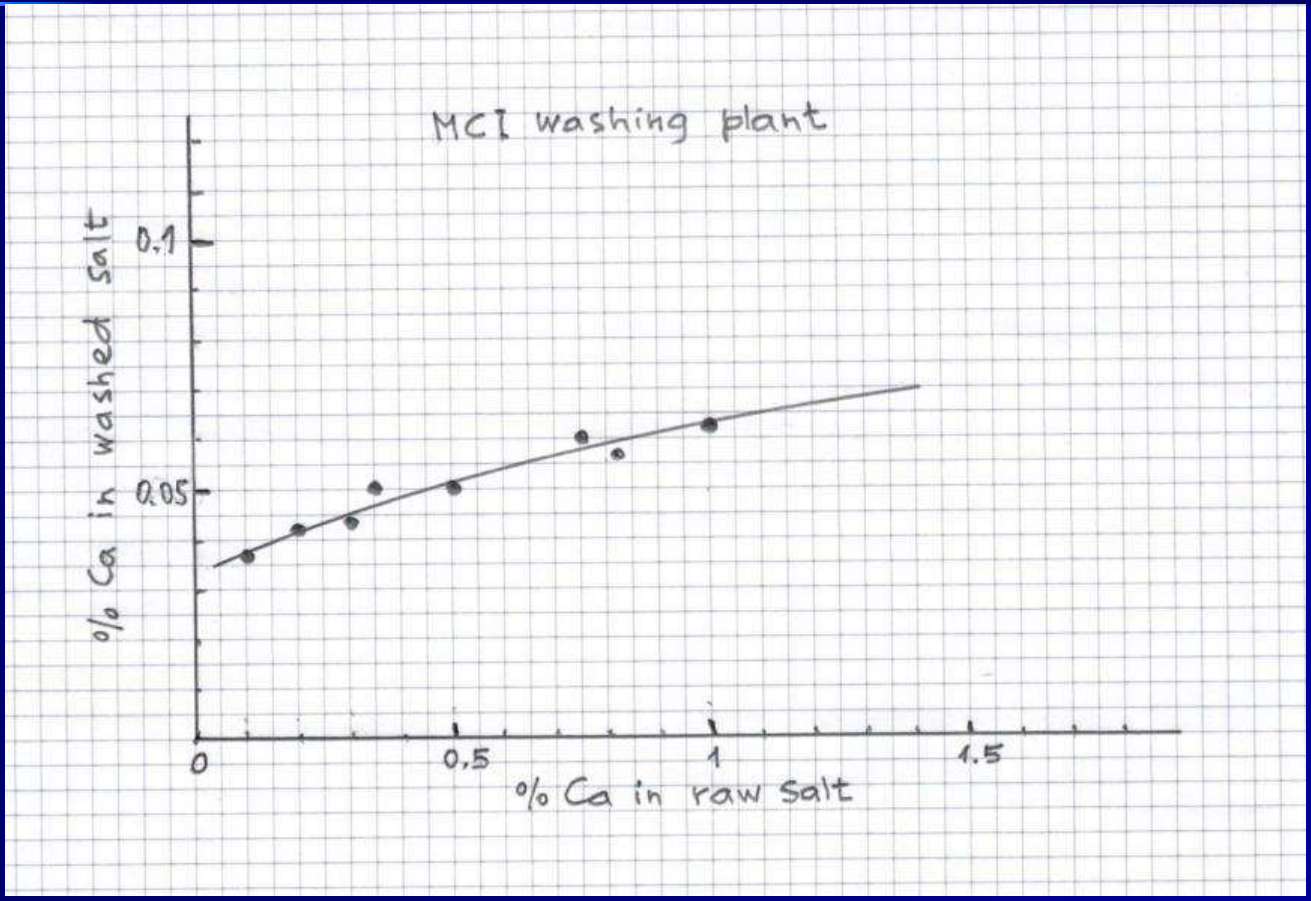
Evaluation of washing plant performance



The data fitted a nice regression curve

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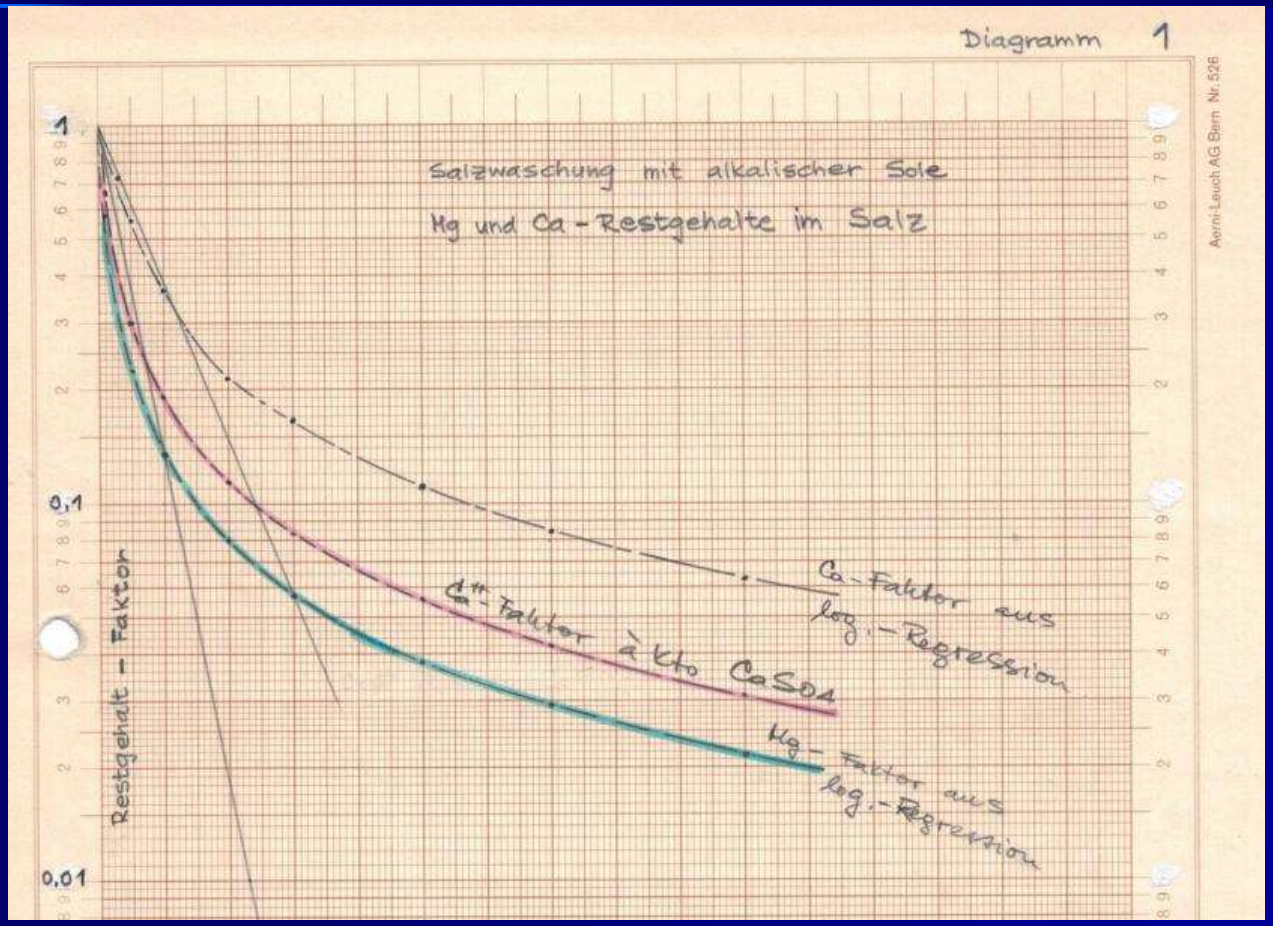
Evaluation of washing plant performance



I created a digram to predict washed salt purity as a function of raw salt analysis

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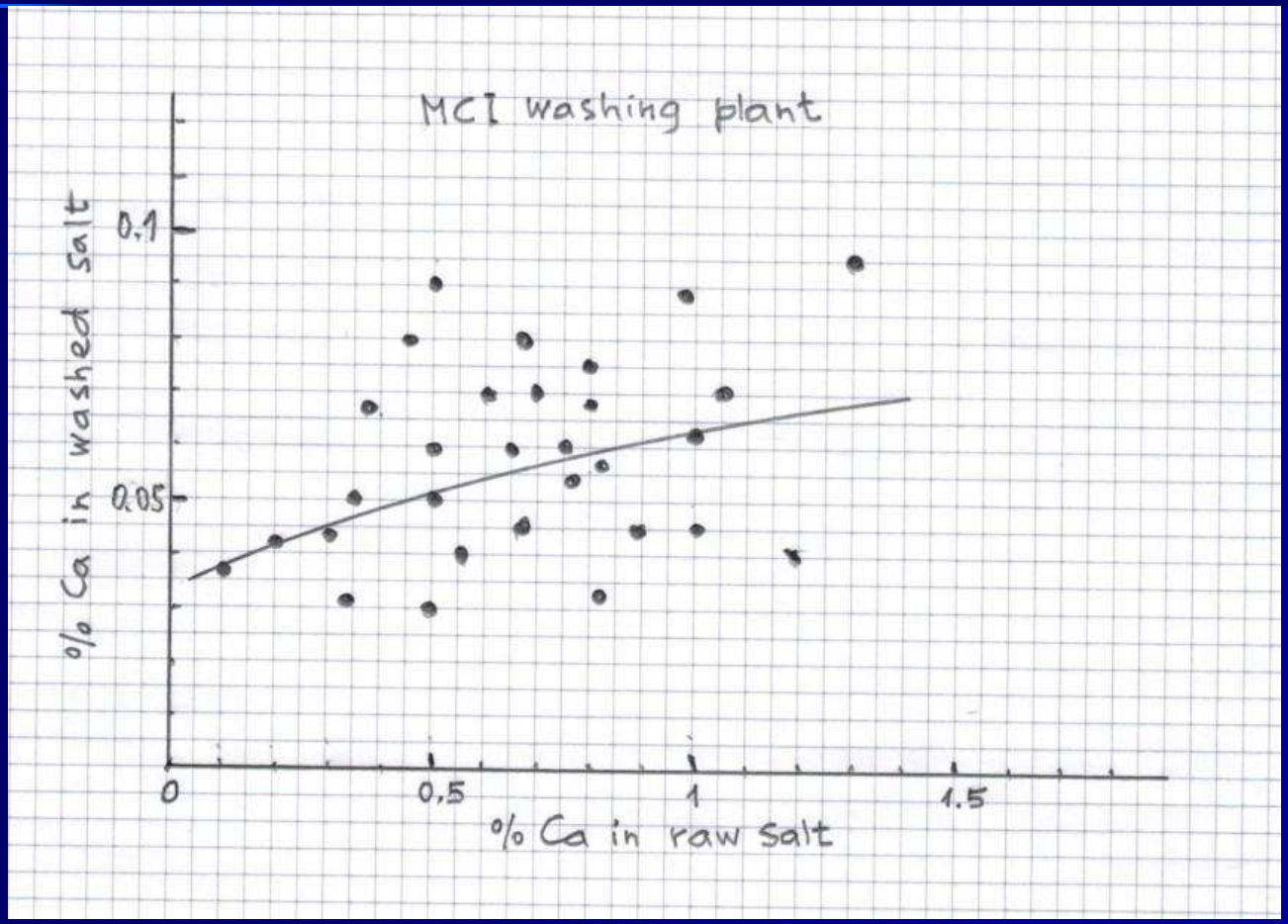
Evaluation of washing plant performance



The data received in the following days didn't fit the curve

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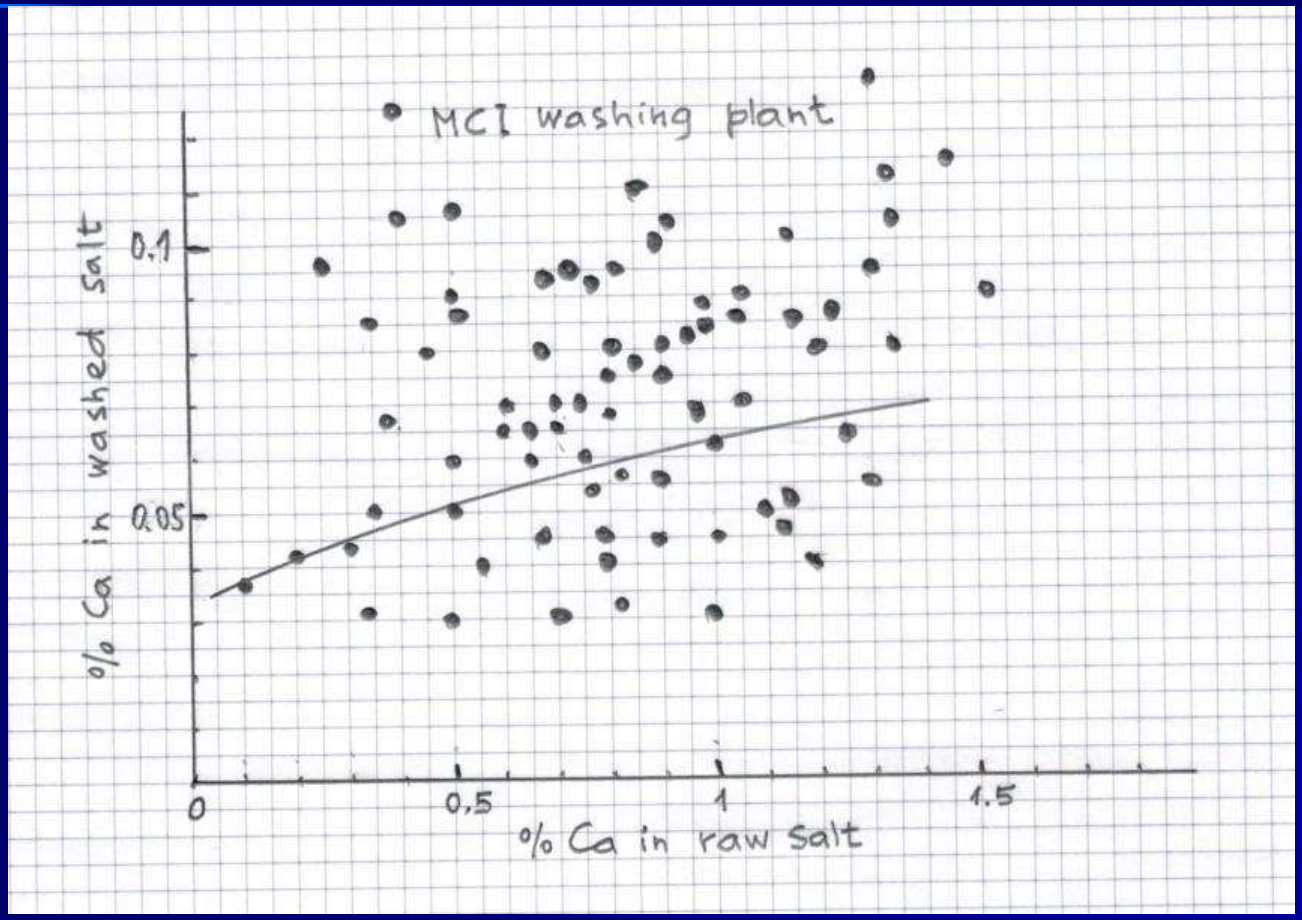
Evaluation of washing plant performance



The data received in the following weeks showed that the attempt to predict washed salt purity using regression curve was a failure.

I had to seek another solution.

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Parameters of impurity removal from salt

On what parameters can a salt purification process depend?

- **Nature of impurities**
- **Phase equilibria of brine components**
- **Structure of salt crystals**
- **Salt and brine contact time**
- **Unit operations**
- **etc.**

I had to learn the salt purification basics.

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Nature of the most common impurities in salt

	Rock salt	Sea salt	Lake salt	Brines
CaSO4	0.5 – 2%	0.5 – 1%	0.5 – 2%	Saturated
MgSO4	Traces	0.2 – 0.6%	Traces	Traces
MgCl2		0.3 – 1%	Traces	
CaCl2			Traces	
Na2SO4			Traces	
KCl			Traces	
NaBr			Traces	
Insolubles	1 – 30%	0.1 – 1%	1 – 10%	

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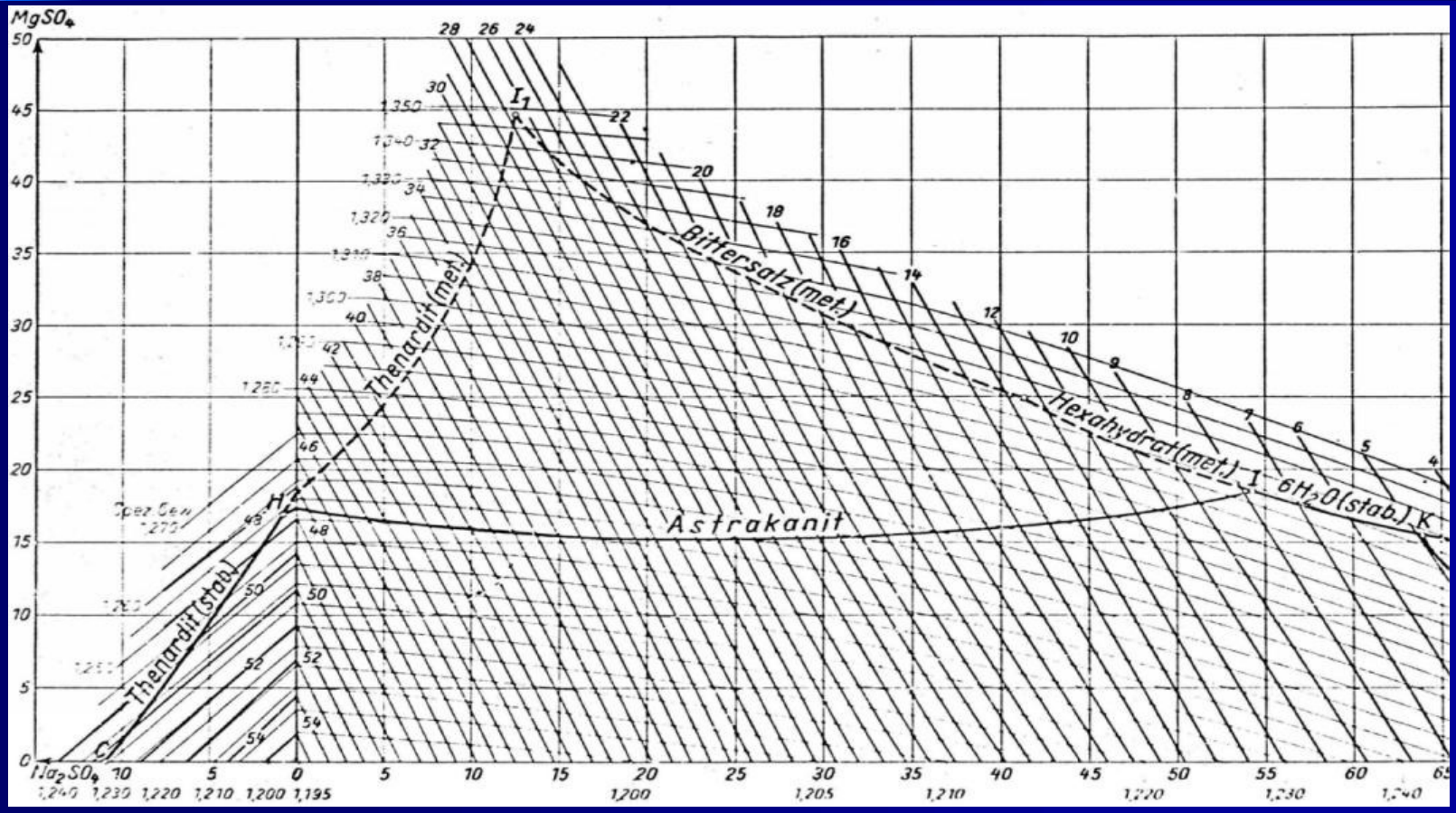
Phase equilibria of Na–Mg–Cl–SO4–H2O system



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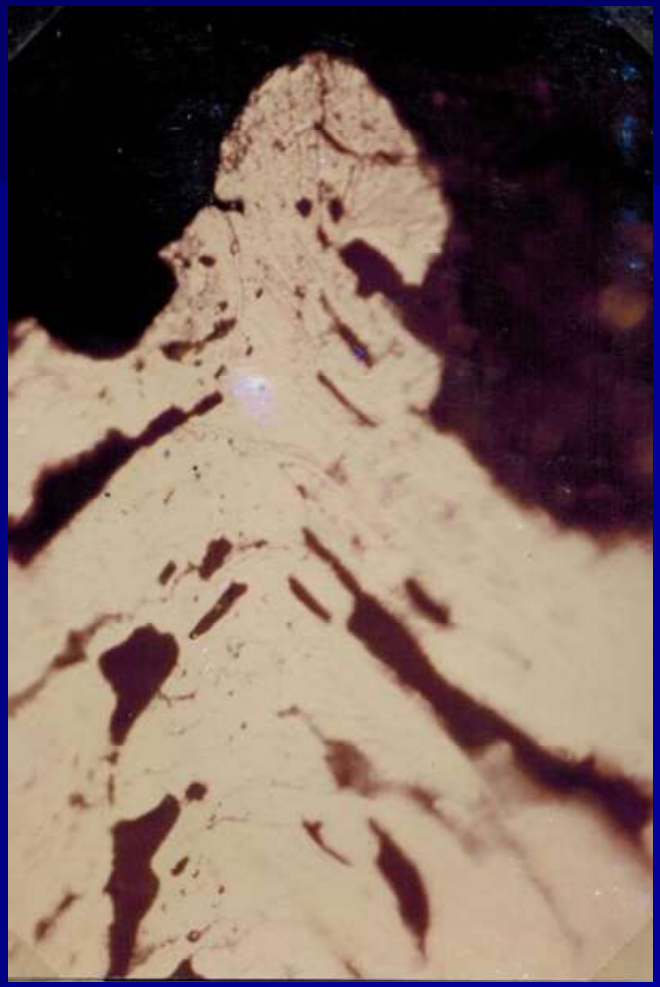
Nature of salt crystals

Broken solar salt crystal



Reflecting light reveals cavities and crevices

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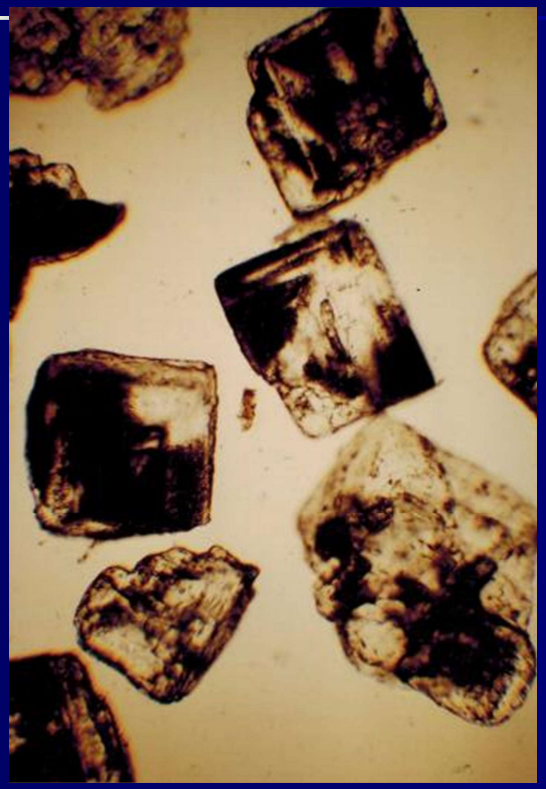
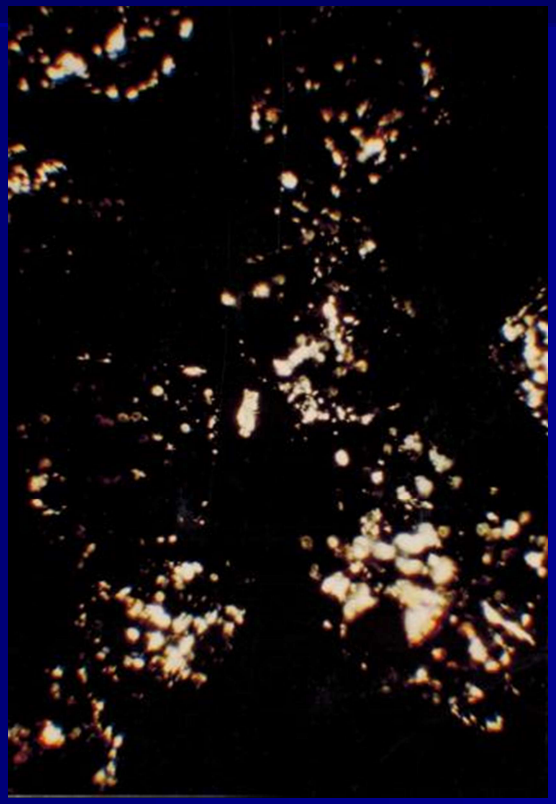
Polarised light makes salt and impurities visible



Solar salt crystals in normal light



Solar salt impurities in polarised light

Solar salt crystals and impurities in phase shifted polarised light

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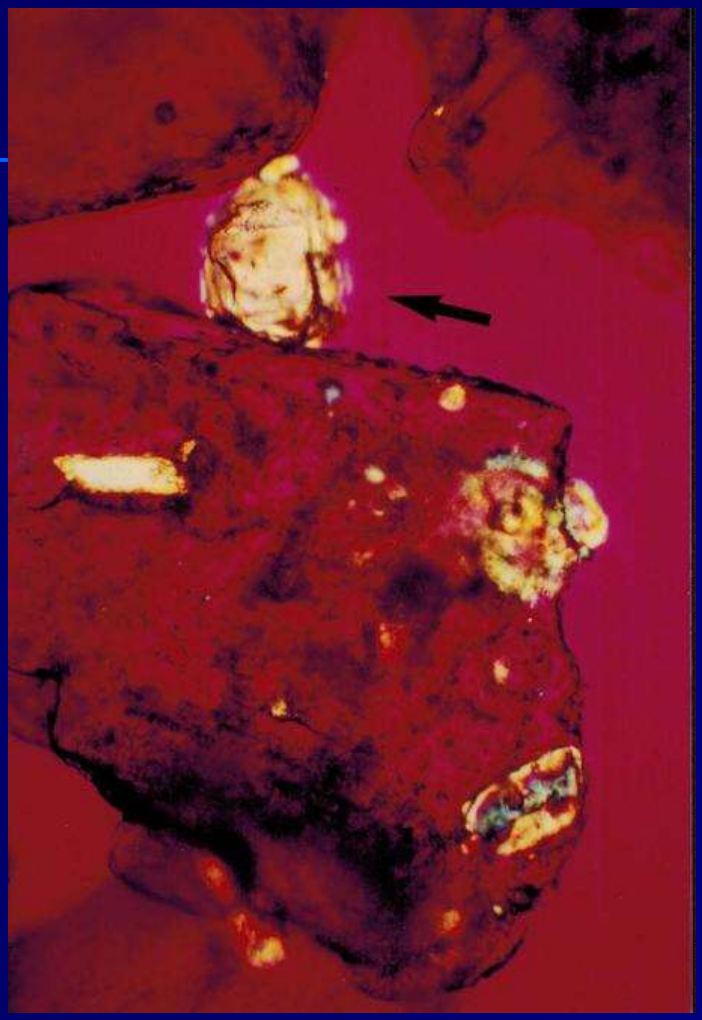
Magnesium impurities in salt



Astrakanite $Na_2Mg(SO_4)_2 \cdot 4H_2O$

Bitter salt or Epsomite $MgSO_4 \cdot 7H_2O$

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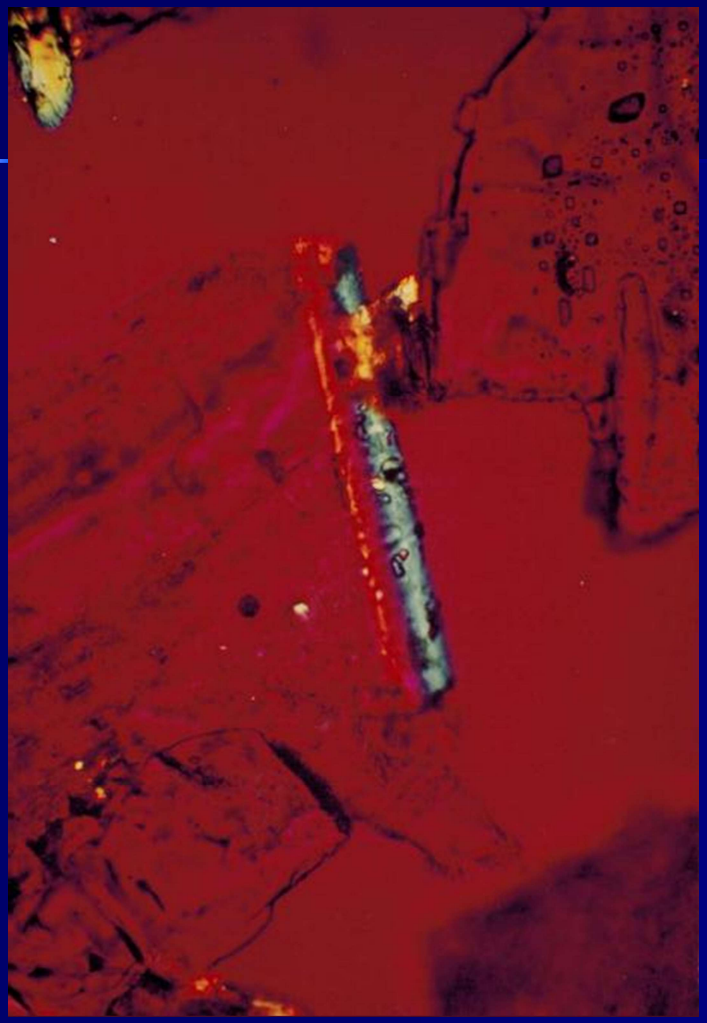
Gypsum in salt



Crystals break where gypsum is

Gypsum falls out from broken salt crystals

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Elutriation versus washing

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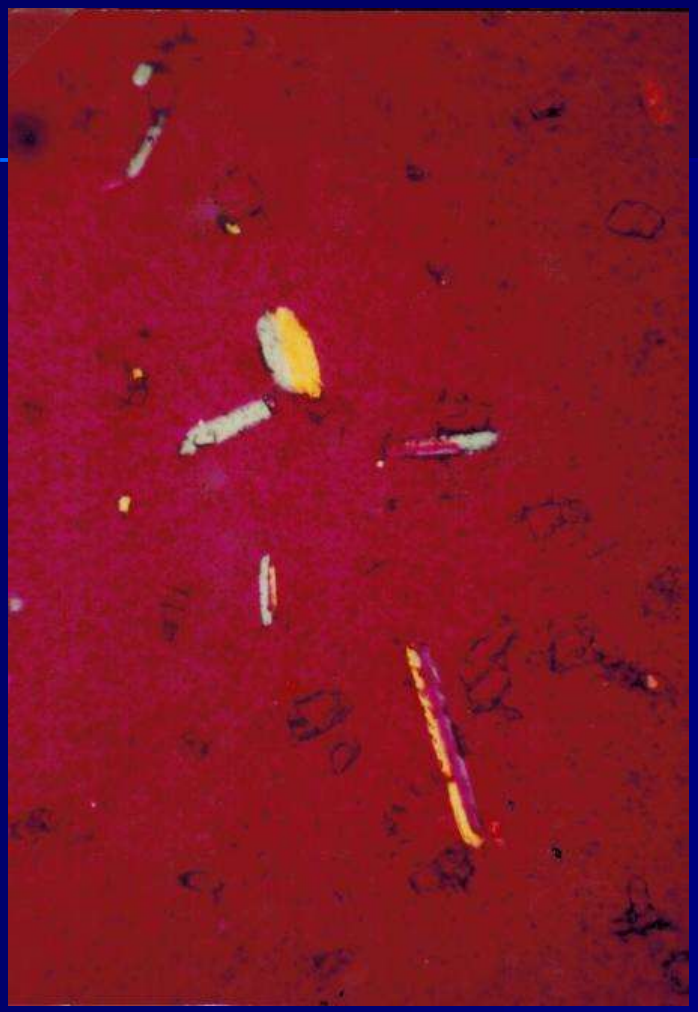

Gypsum removal by elutriation

Excessive washing dissolves salt leaving only gypsum and insolubles

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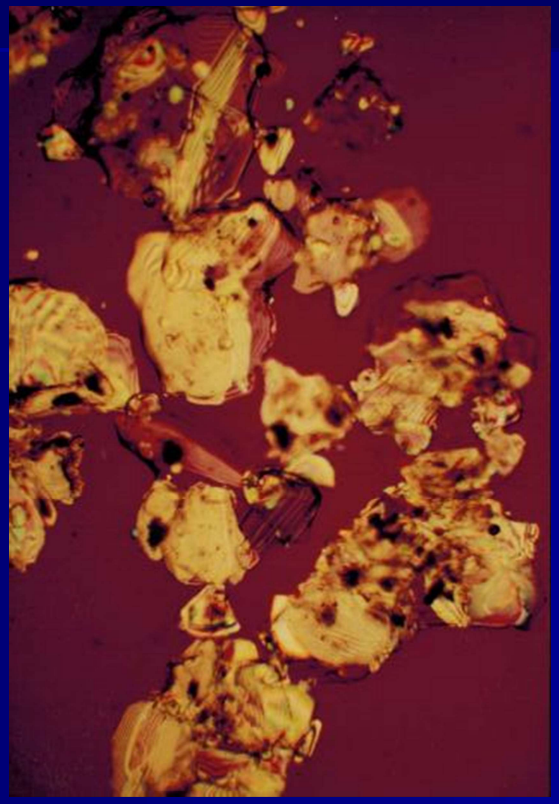
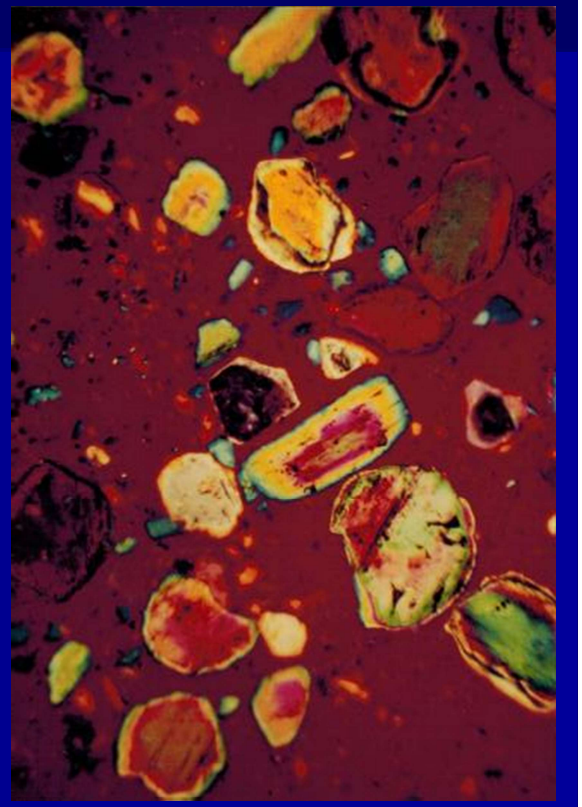
Identification of impurities by crystallisation

Gypsum
$CaSO_4 \cdot 2H_2O$



Astrakanite
$Na_2Mg(SO_4)_2 \cdot 4H_2O$



Bitter salt
$MgSO_4 \cdot 7H_2O$

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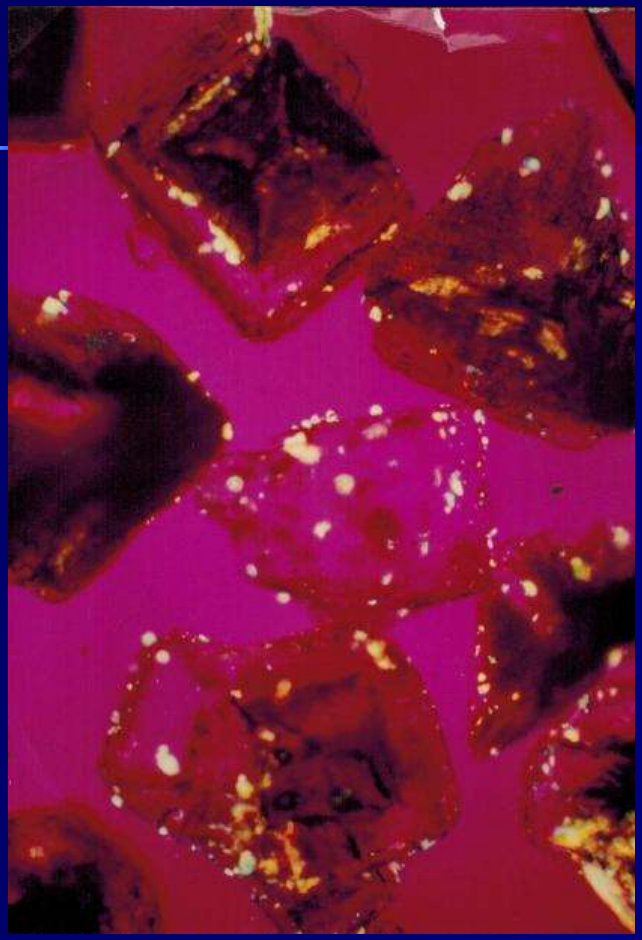
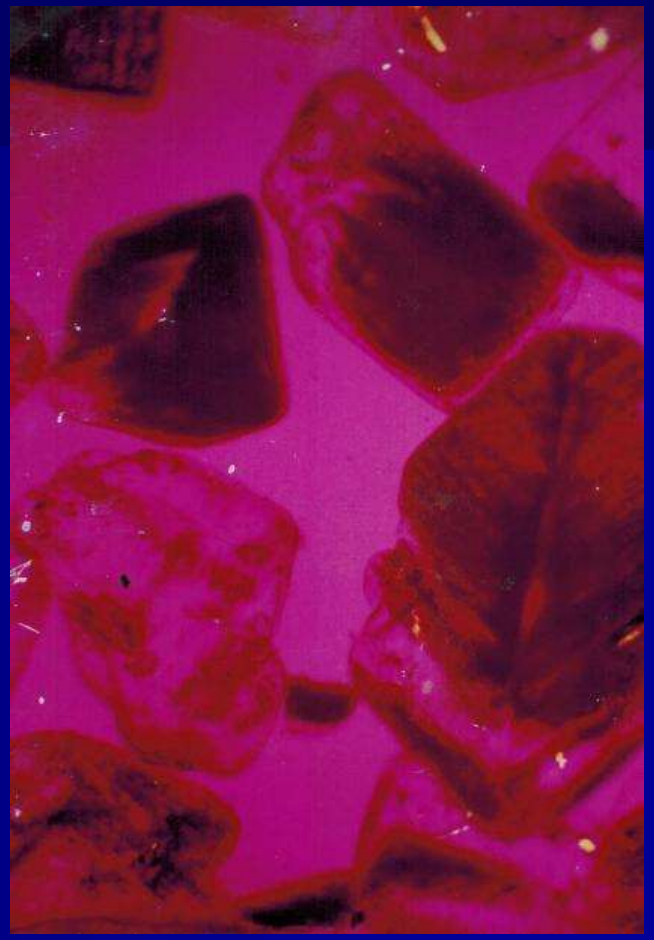
Raw salt and purified salt



Raw salt



Even repeatedly purified salt is not quite pure. This purity limit is the upgradeability.

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Development of upgradeability testing procedure

For what salt purification processes do we have to test the salt upgradeability?

- No crushing for pure coarse salt production
- Crushing for electrolytical brine preparation (3 and 1.5 mm)
- Milling for table salt production (0.8 and 0.4 mm)
- Flotation for rock salt purification (0.2 – 0.8 mm)
- etc.

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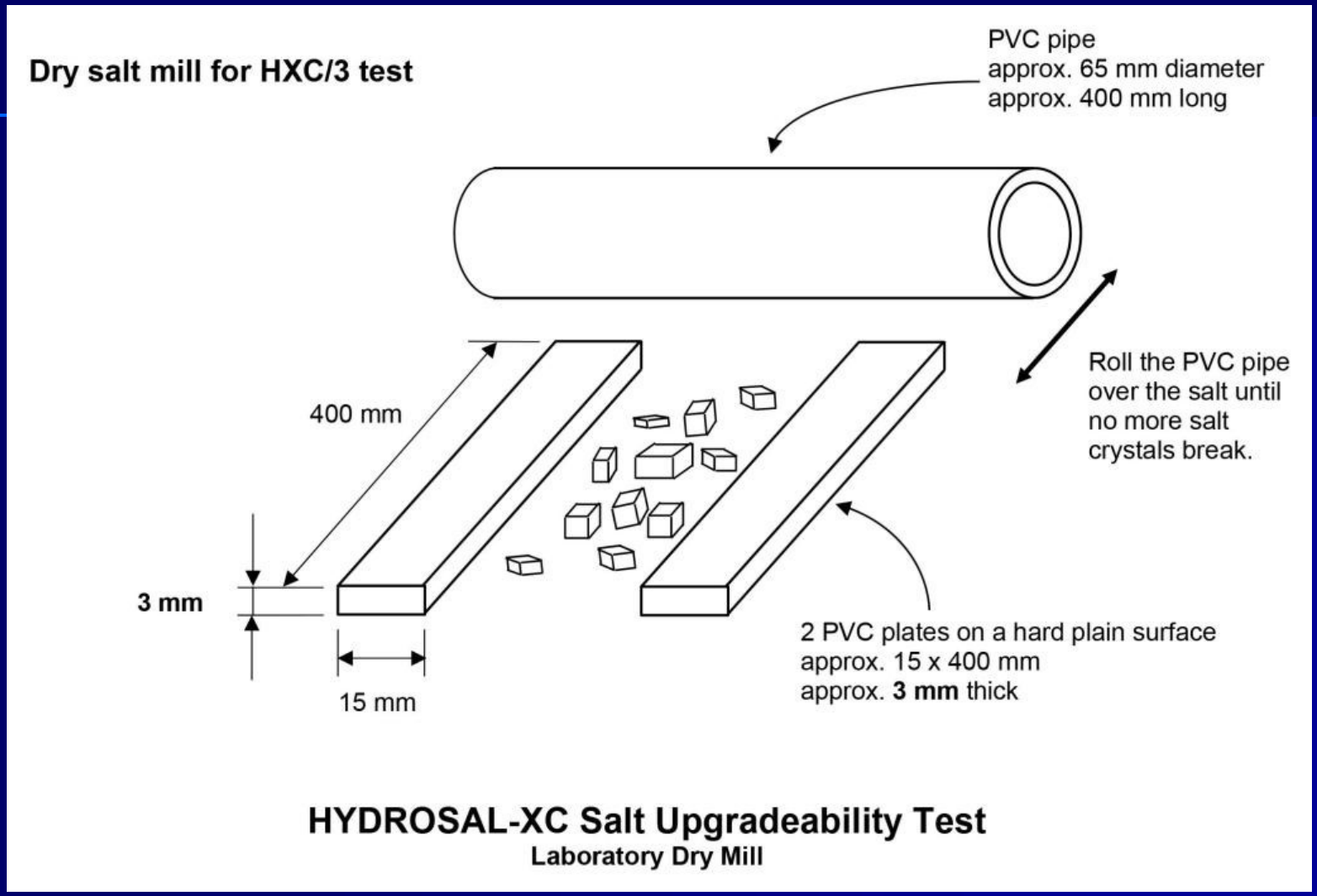
Dry salt crushing



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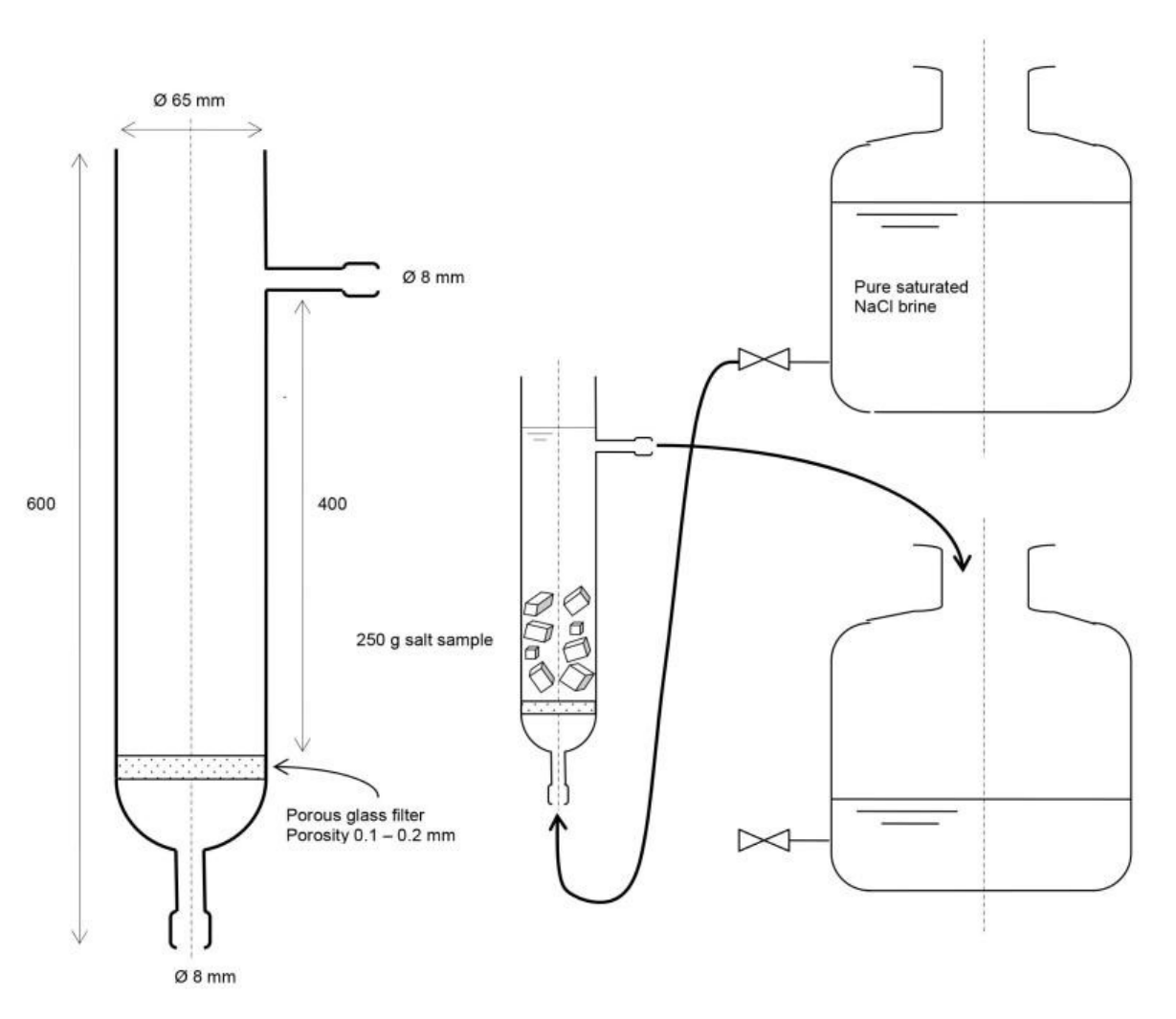
Hydroextraction



Modified from T. Masuzawa to facilitate a minimum 15 min. salt contact with pure saturated brine without recirculation

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Evaluation of upgradeability test results

- Raw salt and test purified salt are analysed
- Impurities are calculated as follows:
- Ca as CaSO4
- Balance SO4 as MgSO4
- Balance Mg as MgCl2
- Salts and insolubles are deducted from 100%
- The result is expressed as NaCl purity
- Results are shown as upgradeability curves
- Results serve selection of most economic process
- Results form bases for plant performance guarantees

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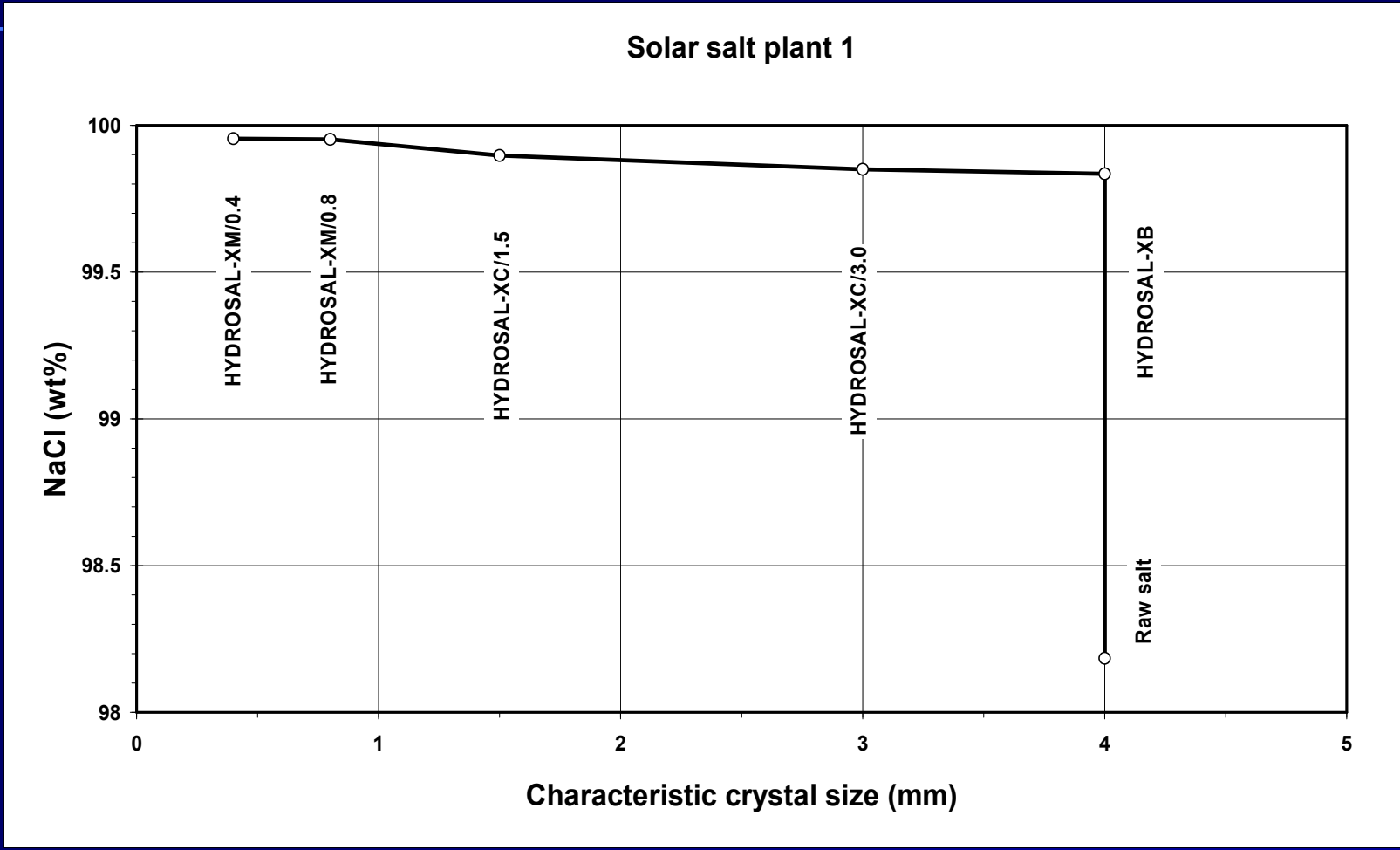
Salt upgradability test, NaCl content



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Evaluation of salt purification process performance

- Salt Partners guarantee 90% salt purification efficiency
- HYDROSAL process operates with 95 – 99% efficiency
- Raw salt, product salt and test purified salt are analysed
- Mass balance is calculated
- Purification efficiency is calculated
- Plant performance guarantees are verified
- Plant performance is optimised

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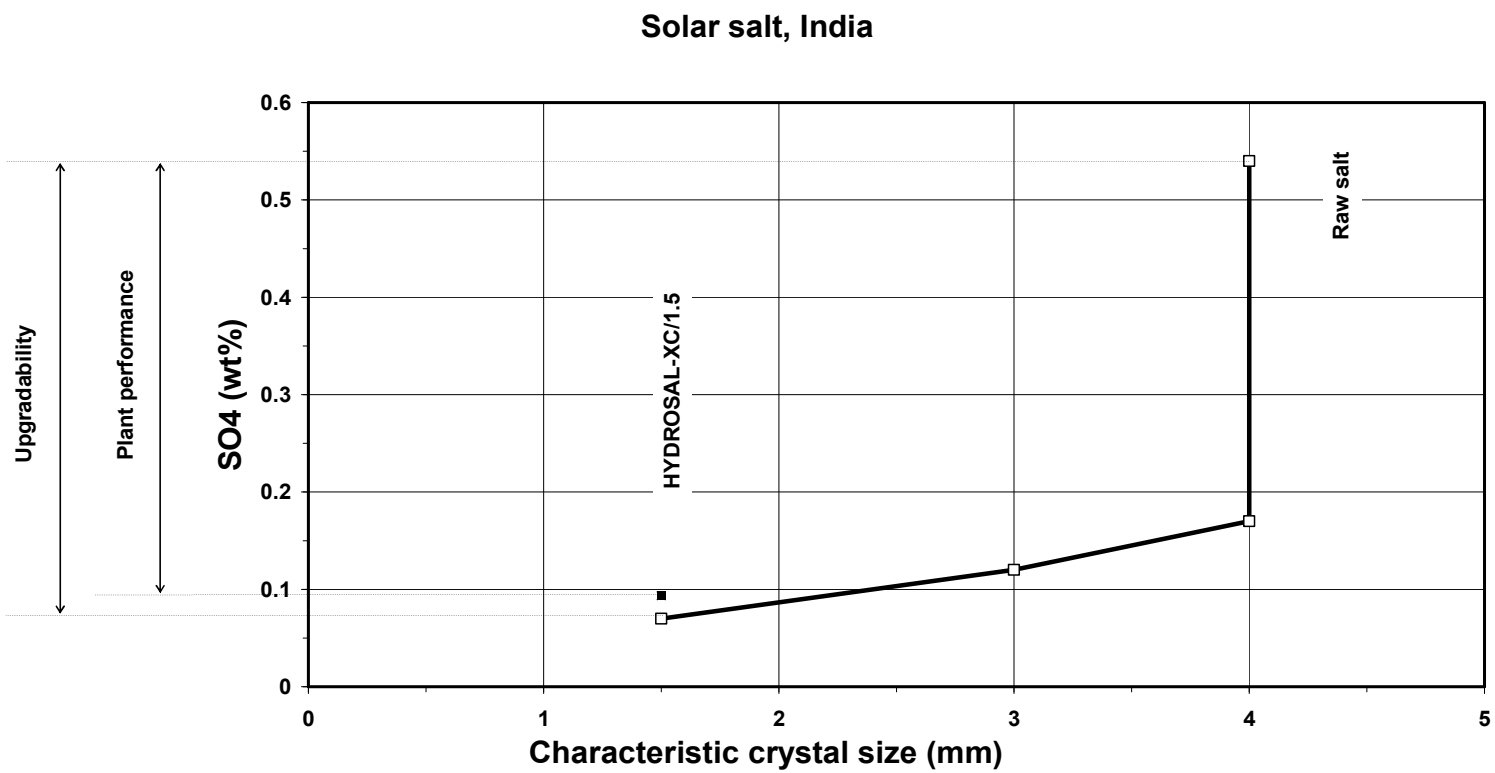
Plant efficiency calculation, sulphate



$$\text{Efficiency} = \frac{\text{Plant performance}}{\text{Upgradability}} = \frac{0.54 - 0.094}{0.54 - 0.070} = 95\ \%$$

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HYDROSAL refined solar salt vs. Swiss vacuum salt

		HYDROSAL refined salt	Swiss vacuum salt
CaSO4	ppm	136	17
MgSO4	ppm	55	5
MgCl2	ppm	74	
Na2SO4	ppm		420
Insolubles	ppm	20	20
NaCl	%	99.972%	99.954%

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Indian vacuum salts from concentrated sea water before and after HYDROSAL purification

	Tata salt from old vacuum plant	Sudh salt from new vacuum plant	Tata salt from new vacuum plant with HYDROSAL purification
Ca	< 0.05%	< 0.02%	< 0.02%
Mg	< 0.15%	< 0.1%	< 0.02%
SO4	< 0.35%	< 0.2%	< 0.07%
Insolubles	< 0.05%	< 0.02%	< 0.01%
NaCl	> 99.1%	> 99.5%	> 99.8%

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High quality European vacuum salt “A” before and after HYDROSAL purification

		Commercial vacuum salt product	HYDROSAL purified
Ca	ppm	< 1	< 1
Mg	ppm	0.12	0.07
SO4	ppm	118	29
K	ppm	87	72
Br	ppm	35	34
I	ppm	< 0.1	< 0.1
Ba	ppm	< 0.02	< 0.02
Sr	ppm	< 0.1	< 0.1
Al	ppm	< 0.05	< 0.05
SiO2	ppm	0.58	0.23

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High quality European vacuum salt “E” before and after HYDROSAL purification

		Commercial vacuum salt product	HYDROSAL purified
Ca	ppm	6.5	5.8
Mg	ppm	3.1	2.9
SO4	ppm	191	33
K	ppm	36	29
Br	ppm	29	28
I	ppm	< 0.1	< 0.1
Ba	ppm	< 0.02	< 0.02
Sr	ppm	0.1	< 0.1
Al	ppm	< 0.05	0.05
SiO2	ppm	0.81	0.47

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High quality European vacuum salt “N” before and after HYDROSAL purification

		Commercial vacuum salt product	HYDROSAL purified
Ca	ppm	211	66
Mg	ppm	6.8	1.2
SO4	ppm	820	229
K	ppm	225	185
Br	ppm	43	36
I	ppm	0.4	< 0.1
Ba	ppm	0.04	< 0.02
Sr	ppm	6.3	2.2
Al	ppm	1.0	0.1
SiO2	ppm	< 0.1	< 0.1

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Is salt upgradeability predictable?

Salt Partners built about 35 salt purification plants.

Since almost 40 years, we collected and tested about 2'000 salt samples.

More than 10'000 analytical results*) of raw salt against upgraded salt are shown on the following diagrams.

***) Underlying data tables are available for download from Salt Partners website.**

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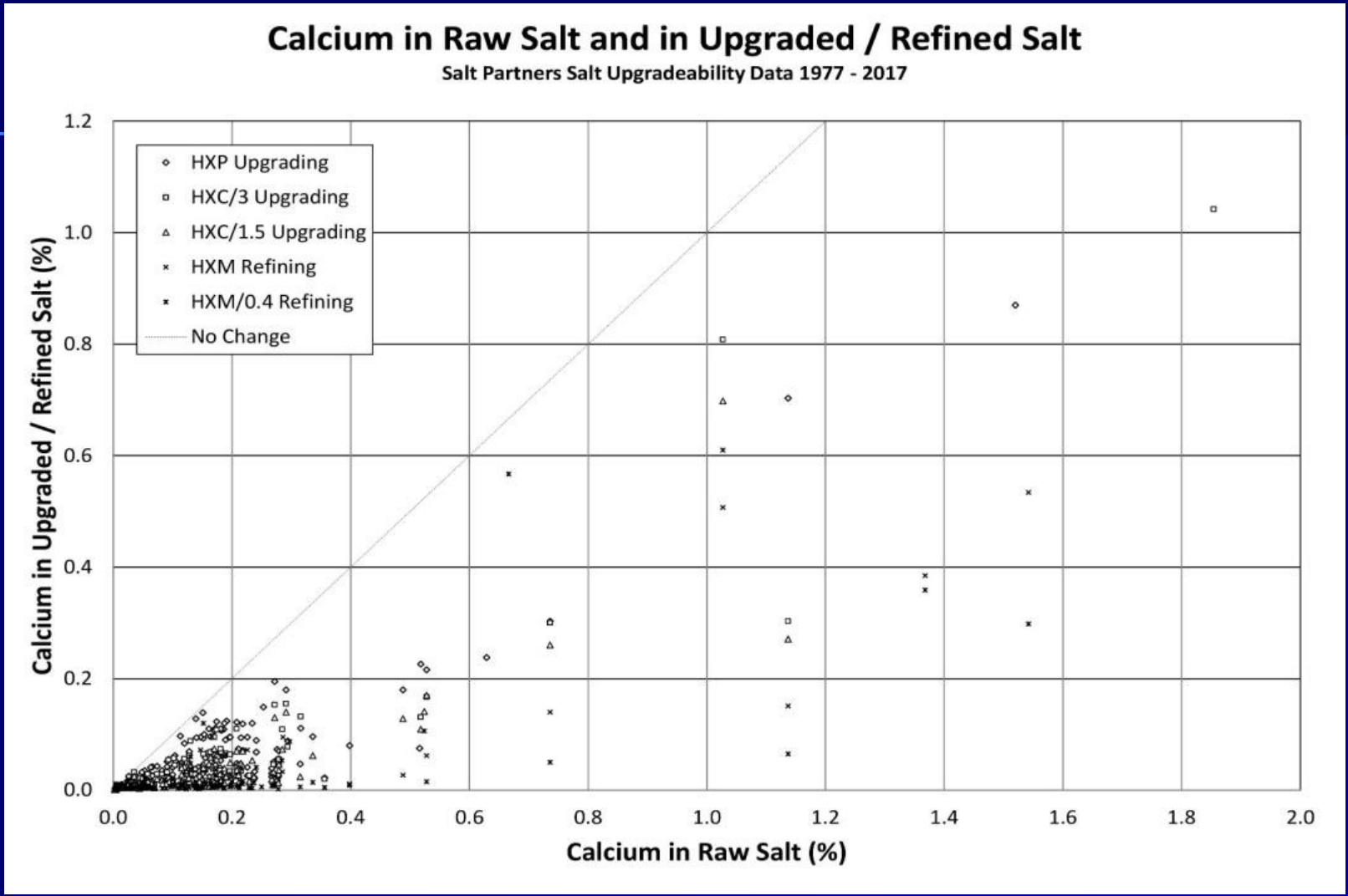
Calcium upgradeability



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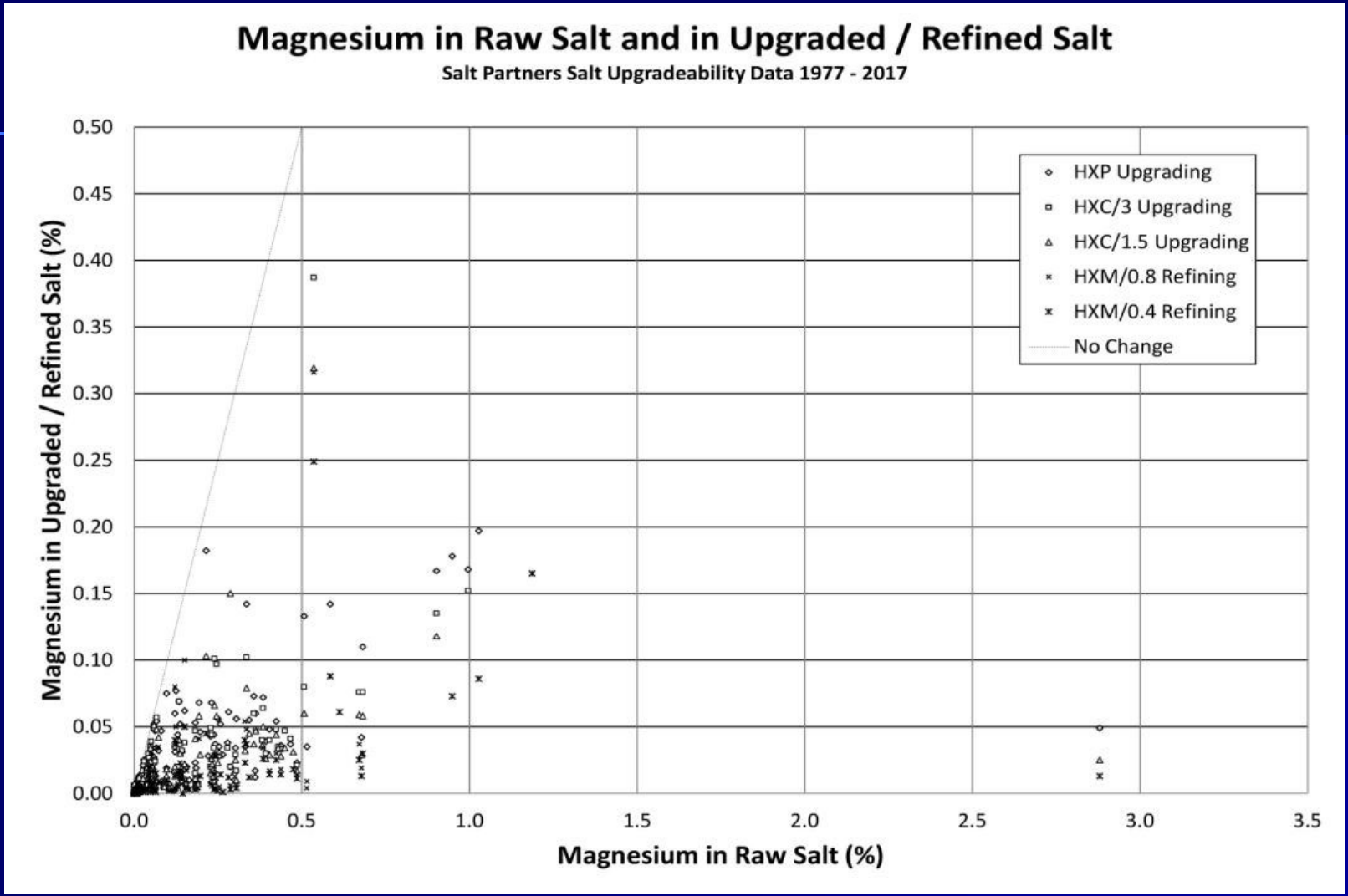
Magnesium upgradeability



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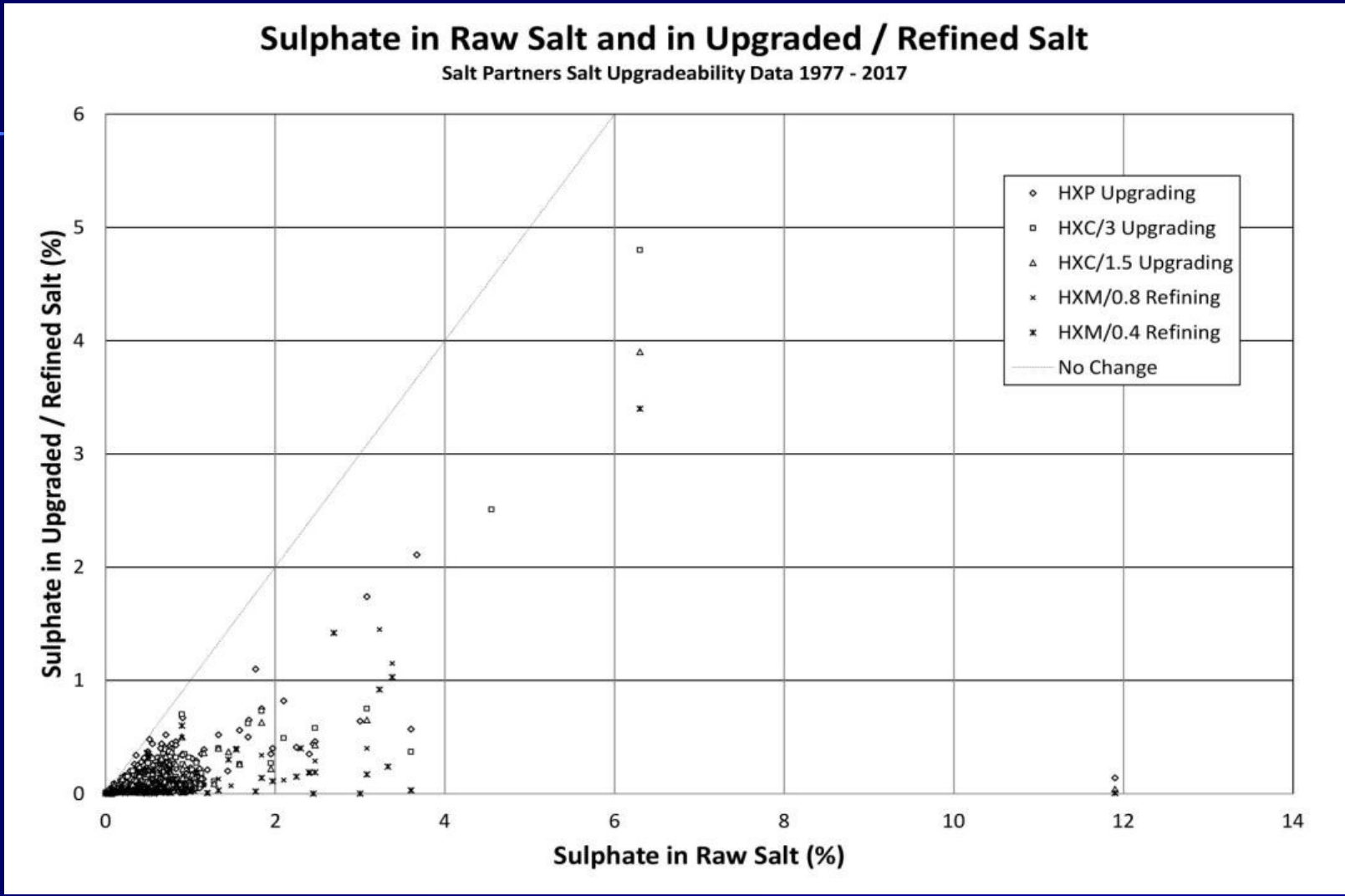
Sulphate upgradeability



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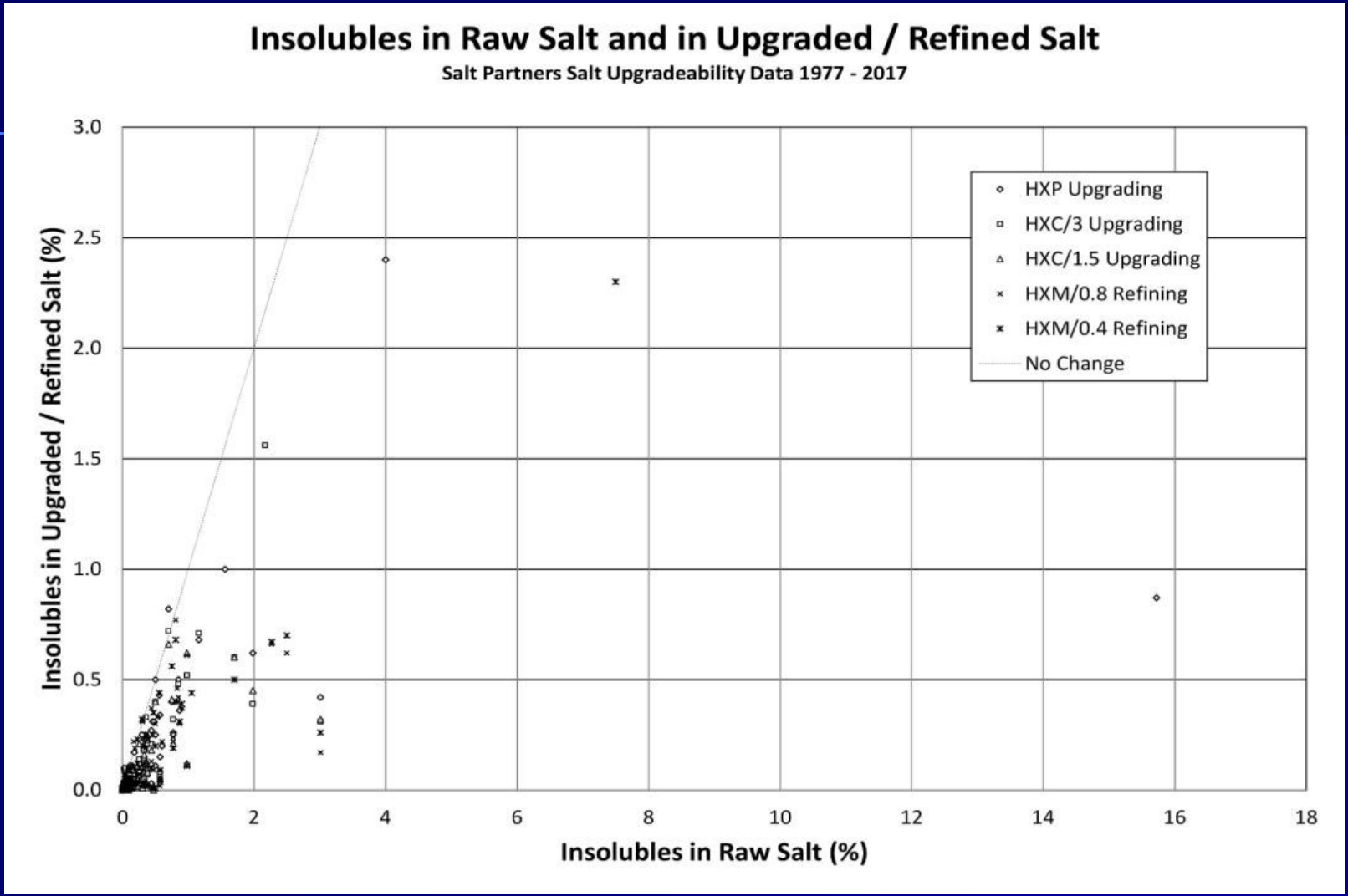
Insolubles upgradeability



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Conclusion

With about 35 plants built, about 2’000 salt samples tested and more than 10’000 analyses evaluated, we can confirm that salt upgradeability is not predictable from raw salt analysis alone.

Salt upgradeability is a physical property, which must be tested.

The only predictable parameter is the process purification efficiency.

Salt Partners guarantee 90% purification efficiency.

Our clients operate their plants between 95-99% purification efficiency.

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100 t/h industrial HYDROSAL-F rock salt upgrading plant in Spain

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40 t/h THERMOSAL recrystallised rock salt upgrading plant in Portugal producing purest industrial salt in Europe

		Performance test
Ca	ppm	0.6
Mg	ppm	0.2
SO4	ppm	53

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Why not turn your salt into gold?

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