

Massive-scale dissolution, conveyance and disposal of Dead Sea potash industries halite waste

Itay J. Reznik^{1} and Ittai Gavrieli¹*

¹Geological Survey of Israel, 32 Yeshayahu Leibowitz, Jerusalem, 9692100 Israel

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ASSOCIATED CONTENT

The associated content below contains 3 figures and 2 tables.

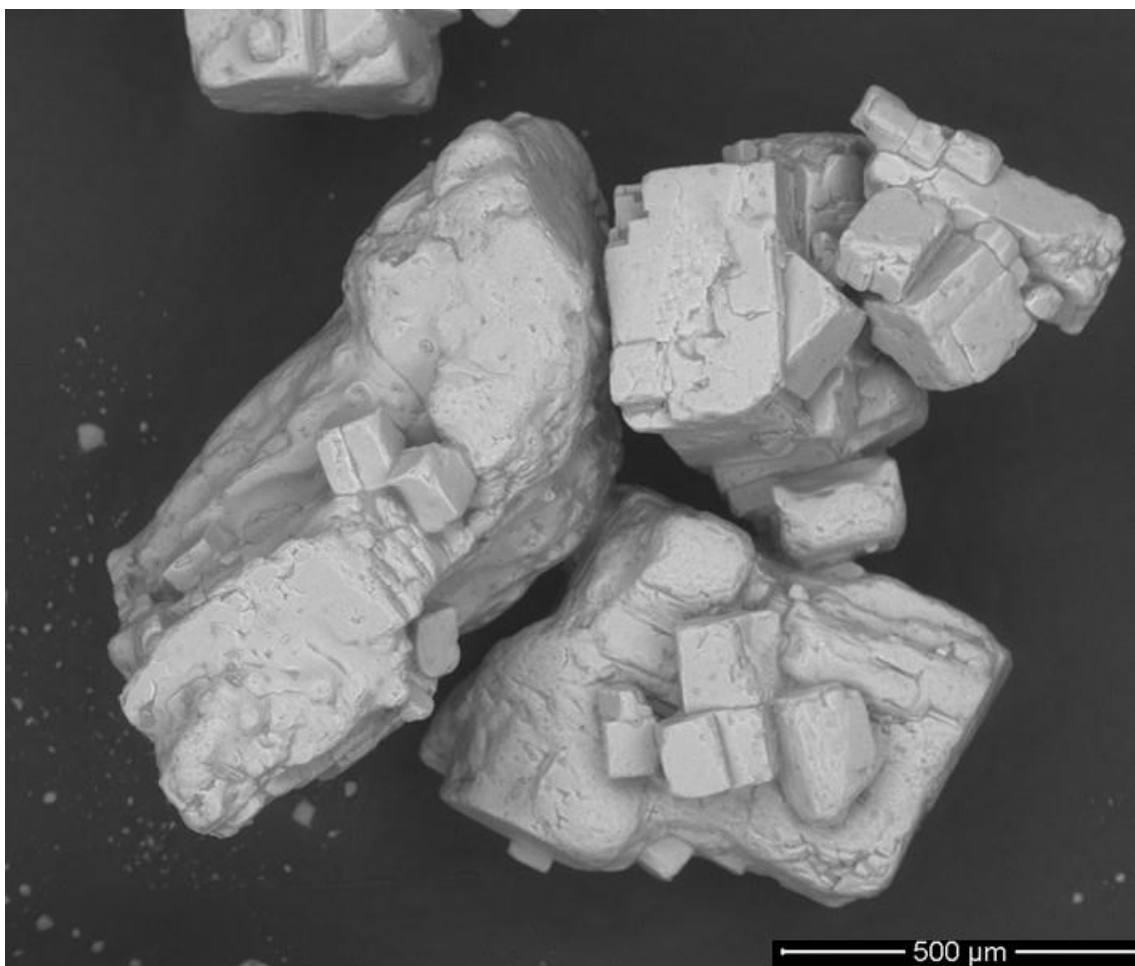


Figure S1. SEM images showing the cubic crystalline structure of the harvested salt.

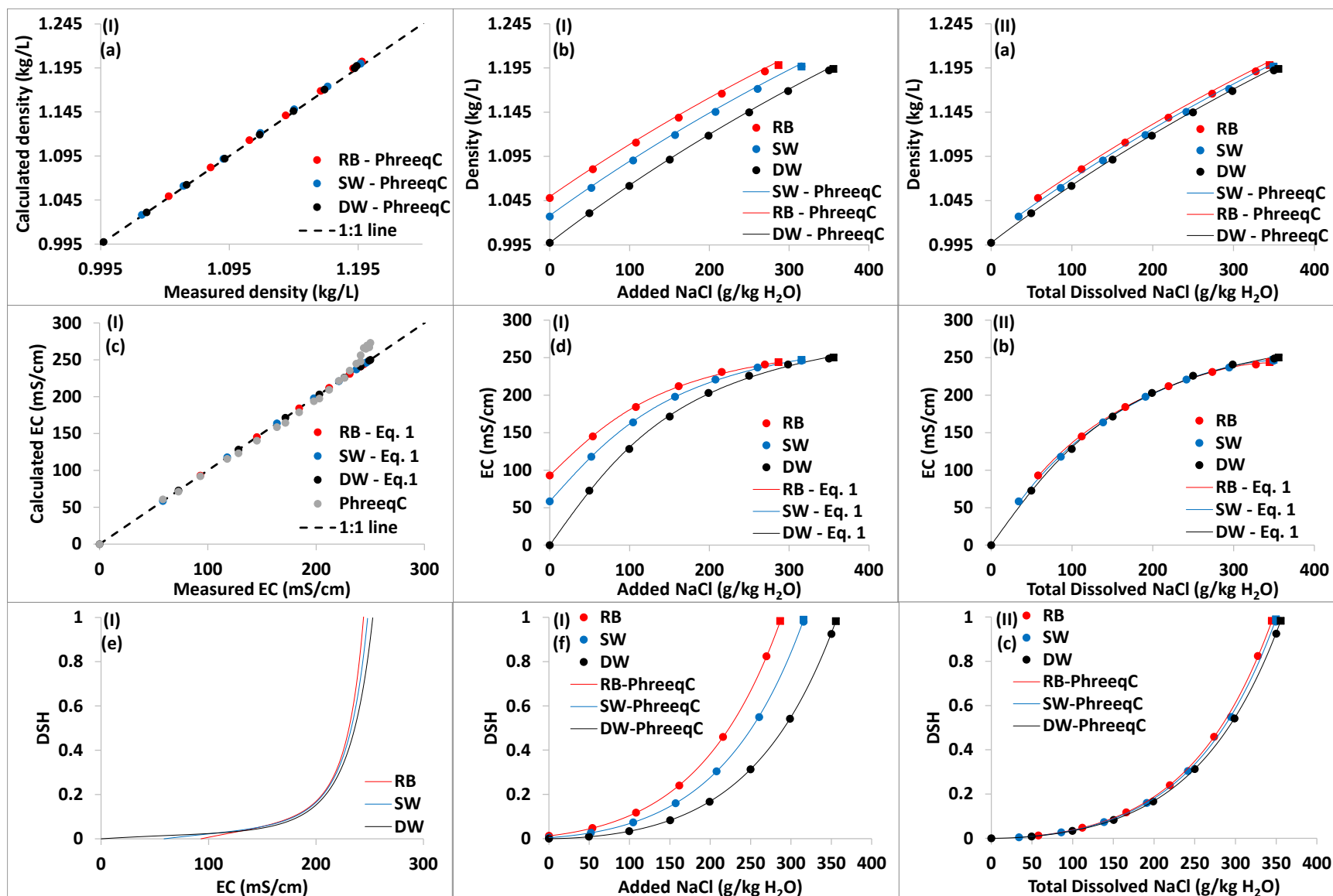


Figure S2. Results of the thermodynamic experiments: (I a) Solution densities - measured vs PhreeqC-calculated (kg L^{-1}). (I b) Solution densities as a function of added NaCl ($\text{g NaCl/kg H}_2\text{O}$). (I c) Electrical Conductivities (EC) - measured vs PhreeqC-calculated (mS/cm). Note the deviation between measured and calculated values at high ECs. To overcome this deviation, an empiric relationship was formulated (Eq. 1). (I d) Measured EC (mS/cm) as a function of added NaCl ($\text{g NaCl/(kg H}_2\text{O)}$). The solid lines were fitted according to Eq. 1. (I e) Degrees of saturation with respect to halite (DSH) as a function of EC (mS/cm). Due to ionic strength and compositional differences between the initial solutions, EC values at saturation, from low to high are $\text{RB} < \text{SW} < \text{DW}$, opposite to the EC order of the initial solutions ($\text{RB} > \text{SW} > \text{DW}$). (I f) DSH vs added NaCl ($\text{g NaCl/(kg H}_2\text{O)}$). Note the difference in the potential amounts of dissolved NaCl between solutions. Subplots (II a-c) Density, EC and DSH as a function of the total dissolved NaCl, respectively, defined as the initial NaCl + added NaCl.

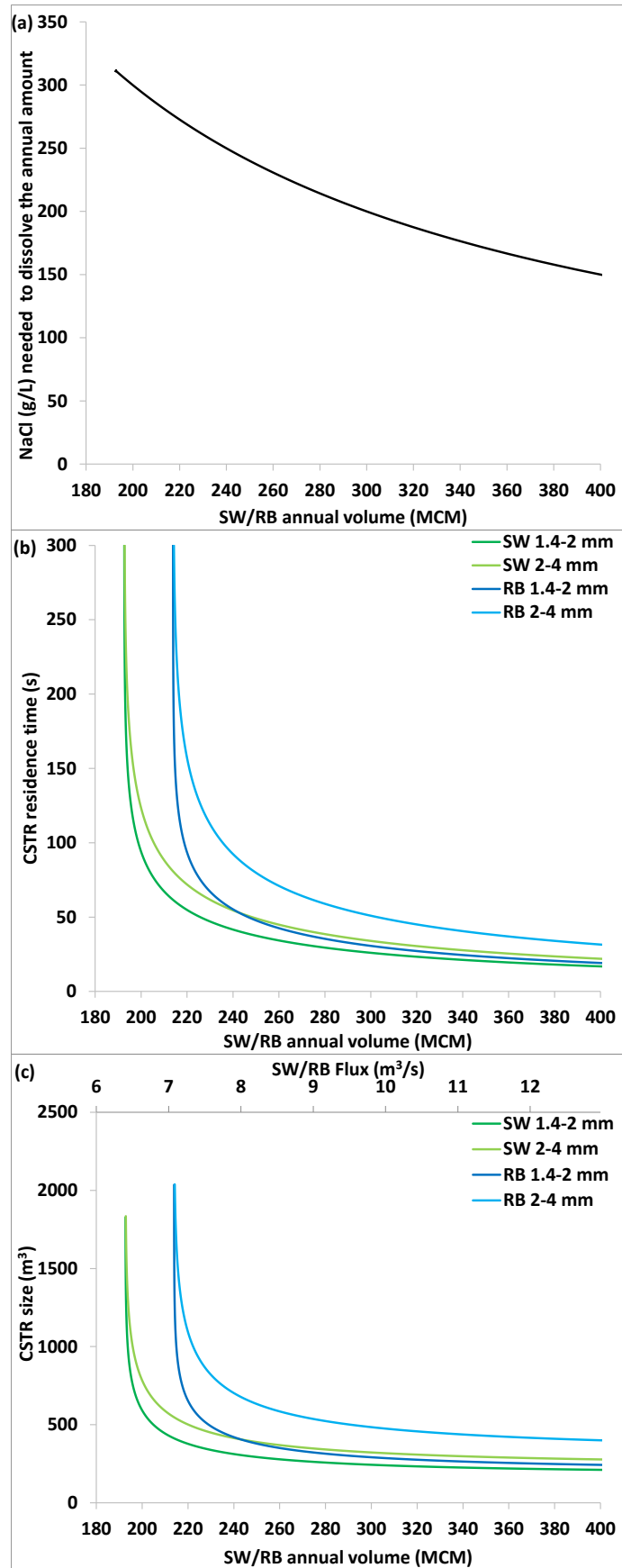


Figure S3. (a) Required salt concentration (g/L) to fully dissolve the annual amount of harvested halite as a function of annual volume of SW/RB (MCM). Boundary conditions were set according to the constraints of cases A and B. (b) CSTR average residence time (based on reaction kinetics) needed to dissolve a given salt concentration for a given solution type and volume. (c) Size of CSTR needed for full dissolution of the harvested salt based on residence time and SW/RB annual volumes (or flux, top x-axis) (Eq. 2).

Exp. #	Grain size (mm)	Water type	Salt [C] (g/Kg)	EC (mS/cm)	T (°C)	pH	Leftover crystals?	Density (g/cc)	T (°C)
TD-1	Unsorted	DW	0	0.0106	23	7.45	No	0.9973	23.9
TD-2	Unsorted	DW	50	72.9	22.6	8.668	No	1.0307	23.9
TD-3	Unsorted	DW	100	128.3	22.4	7.02	No	1.0617	23.9
TD-4	Unsorted	DW	150	171.6	22.7	6.388	No	1.0914	24
TD-5	Unsorted	DW	200	203	22.6	6.04	No	1.1185	24
TD-6	Unsorted	DW	250	226	22.8	5.511	No	1.1448	24.1
TD-7	Unsorted	DW	300	241	22.9	5.5	No	1.1689	24.1
TD-8	Unsorted	DW	350	249	24.1	7.02	No	1.1923	24.5
TD-9	Unsorted	DW	400	250	24.1	7.16	Yes	1.1989	24.3
TD-10	Unsorted	SW	0	58.5	23	8.439	No	1.027	23.8
TD-11	Unsorted	SW	50	117.9	23	8.416	No	1.0593	23.8
TD-12	Unsorted	SW	100	163.8	22.9	8.318	No	1.0903	23.8
TD-13	Unsorted	SW	150	197.9	23.1	8.288	No	1.1191	23.8
TD-14	Unsorted	SW	200	221	23	8.158	No	1.1453	23.9
TD-15	Unsorted	SW	250	237	23.3	8.038	No	1.1713	24
TD-16	Unsorted	SW	300	246	23.4	7.953	No	1.1968	24.2
TD-17	Unsorted	SW	350	247	24.1	7.88	Yes	1.2017	24.4
TD-18	Unsorted	RB	0	93	23.3	8.653	No	1.0479	23.8
TD-19	Unsorted	RB	50	145.2	22.8	8.539	No	1.0804	23.8
TD-20	Unsorted	RB	100	184.3	22.8	8.417	No	1.1106	23.8
TD-21	Unsorted	RB	150	212	22.8	8.32	No	1.1387	23.9
TD-22	Unsorted	RB	200	231	23.3	8.329	No	1.1659	24
TD-23	Unsorted	RB	250	241	23.4	8.146	No	1.1911	24.1
TD-24	Unsorted	RB	300	244	23.7	8.137	Yes	1.2035	24.2
K-1	1.4-2	DW	400	250	23.6	7.11	Yes	1.1983	24.4
K-2	1.4-2	SW	400	247	23.7	7.69	Yes	1.2018	24.4
K-3	1.4-2	RB	400	244	23.8	8.127	Yes	1.2034	24.7
K-4	2-4	DW	400	250	23.7	7.255	Yes	1.1987	24.5
K-5	2-4	SW	400	247	24.1	7.944	Yes	1.2011	24.9
K-6	2-4	RB	400	244	24.1	8.11	Yes	1.2031	25

Table S1. Thermodynamic and kinetic experimental conditions and results: salt used for the thermodynamic experiments was not sorted whereas the kinetic experiments were conducted on two sieved grain size ranges of 1.4-2 and 2-4 mm; solution type (DW, SW, RB);

mg/L	Na ⁺	K ⁺	Ca ²⁺	Mg ²⁺	Sr ²⁺	Cl ⁻	Br ⁻	SO ₄ ²⁻	TDS	kgw/kgs	DSH
TD-1	0	0	0	0	0.0	0	0	0	0	1.00	0.00
TD-2	20235	31	50	38	0.4	30321	30	119	50840	0.95	0.01
TD-3	37339	91	89	74	0.7	59071	44	159	96884	0.90	0.03
TD-4	57176	53	134	116	1.2	88395	54	191	146378	0.85	0.09
TD-5	75157	49	182	136	1.5	114636	67	315	190799	0.81	0.18
TD-6	91027	57	220	187	1.7	140712	80	331	232868	0.77	0.33
TD-7	106450	39	249	249	2.0	163286	94	403	271021	0.73	0.55
TD-8	120281	97	286	240	2.4	193452	76	450	315136	0.68	0.99
TD-9	122126	22	286	274	2.2	194748	101	479	318268	0.68	1.01
TD-10	12805	447	496	1562	8.2	24346	88	2865	42868	0.96	0.00
TD-11	32621	491	534	1574	8.4	55133	99	2953	93657	0.91	0.03
TD-12	51067	473	562	1585	9.1	82256	118	3329	139653	0.86	0.07
TD-13	71888	468	609	1592	9.2	112003	129	3381	190337	0.81	0.17
TD-14	87744	467	655	1633	9.4	136703	143	3287	230896	0.77	0.31
TD-15	99660	478	680	1547	9.4	162289	150	3250	268317	0.73	0.50
TD-16	117461	508	705	1642	9.8	188507	162	3348	312601	0.69	0.91
TD-17	120094	455	752	1694	10.2	194318	175	3517	321274	0.68	1.02
TD-18	21828	857	864	2800	15.0	40102	137	5615	72464	0.93	0.01
TD-19	42527	767	910	2733	15.2	71603	153	5743	124702	0.88	0.05
TD-20	60080	706	914	2682	14.9	98876	165	5620	169309	0.83	0.11
TD-21	81738	784	969	2760	15.5	128906	181	5772	221380	0.78	0.26
TD-22	100232	767	980	2665	15.3	154954	190	5635	265697	0.73	0.49
TD-23	111822	802	1027	2724	15.8	179824	198	5598	302270	0.70	0.78
TD-24	119563	783	1043	2714	15.6	194005	211	5654	324248	0.68	1.04
K-1	122150	19	296	284	2.3	196047	103	501	319656	0.68	1.04
K-2	120619	438	743	1669	9.9	194659	166	3570	322134	0.68	1.03
K-3	121133	810	1097	2854	16	191783	217	5929	323839	0.66	1.05
K-4	122103	26	276	265	2.1	193448	99	457	316880	0.68	1.00
K-5	124862	414	705	1575	10	190152	155	3308	321182	0.67	1.05
K-6	118665	813	1001	2618	15.3	192625	202	5552	321754	0.68	1.00

Table S2. Major chemical composition of the thermodynamic and kinetic experiment following the dissolution of halite. Water concentration in solution was included for unit conversion purposes ((kg H₂O)/(kg solution)). Charge balance error did not exceed ±2% in all experiments.