Supplementary Information for: Micro- and nanoplastics' transfer in freezing saltwater: Implications for their fate in polar waters

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Table 1: Concentration of stock solutions or stock dispersions

Stock solution or dispersion	Concentration
NaCl	100 g kg^{-1}
SA	≈ 1 g kg^{-1}
nPSL-200	100 mg kg^{-1}
nPSL-350	100 mg kg^{-1}
nPS-360	≈ 40 mg kg^{-1}
µPS	4.25 g kg^{-1}

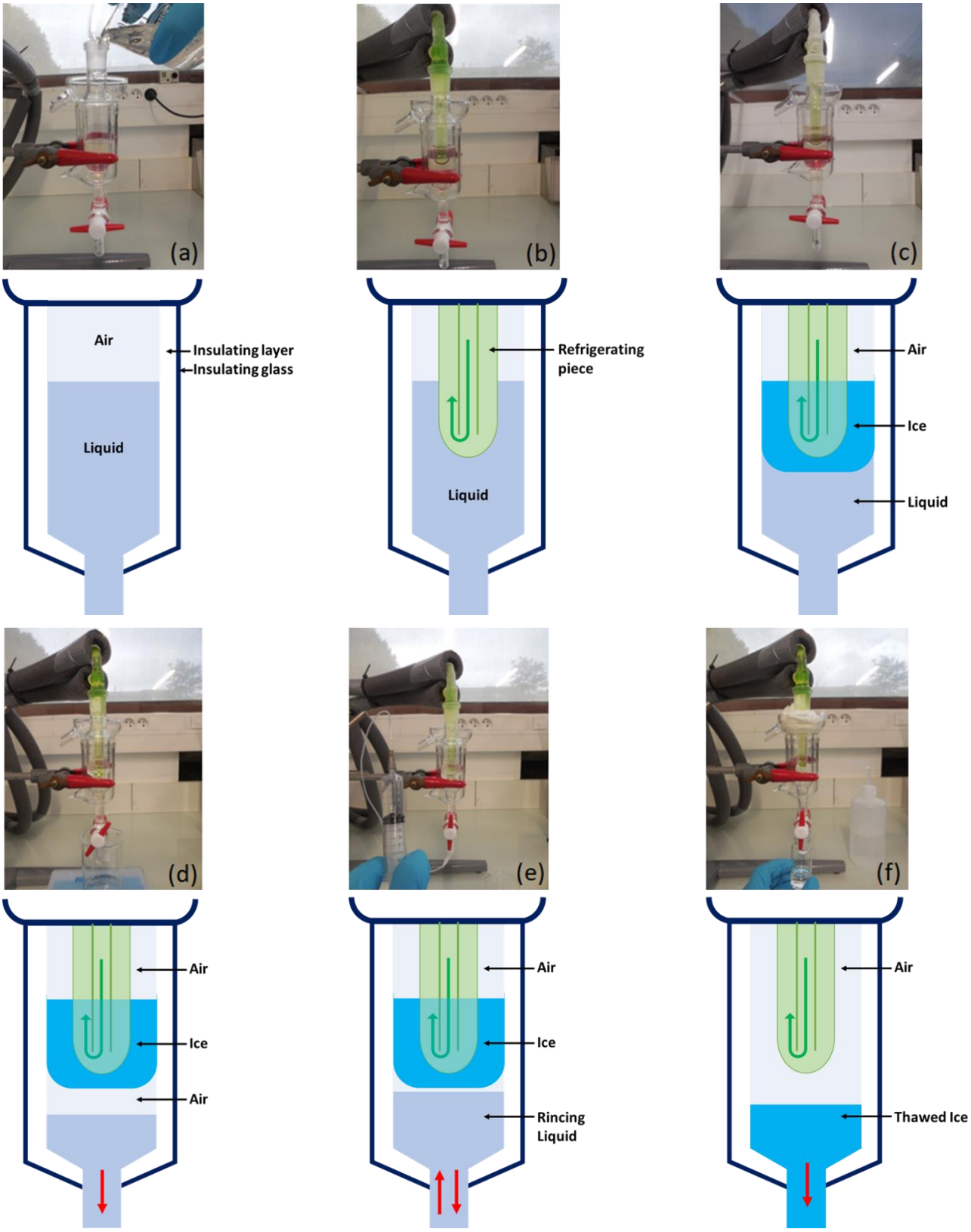

Figure S1: Steps of the progressive and partial freezing protocol in images (above) and corresponding diagrams (below): a) insertion of the solution in the freezing reactor, b) insertion of the cold finger, c) solidification of the liquid, d) recovery of the liquid phase, e) rinsing of the bottom of the vessel, f) recovery of thawed ice.

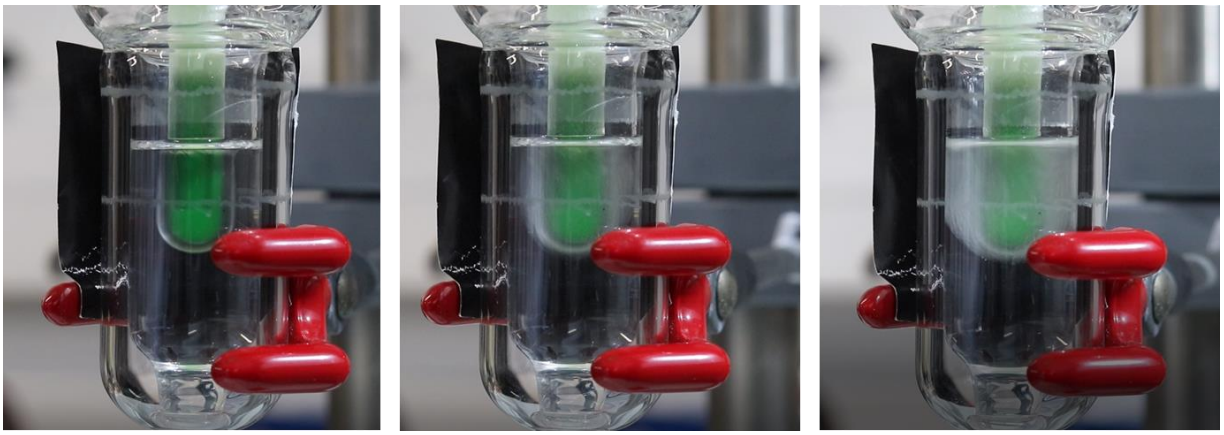

Figure S2: Examples of time-lapse photography, used to calculate speed and shape of freezing at 0 minutes, approximately 15 minutes and 40 minutes (35 g kg^{-1} NaCl)

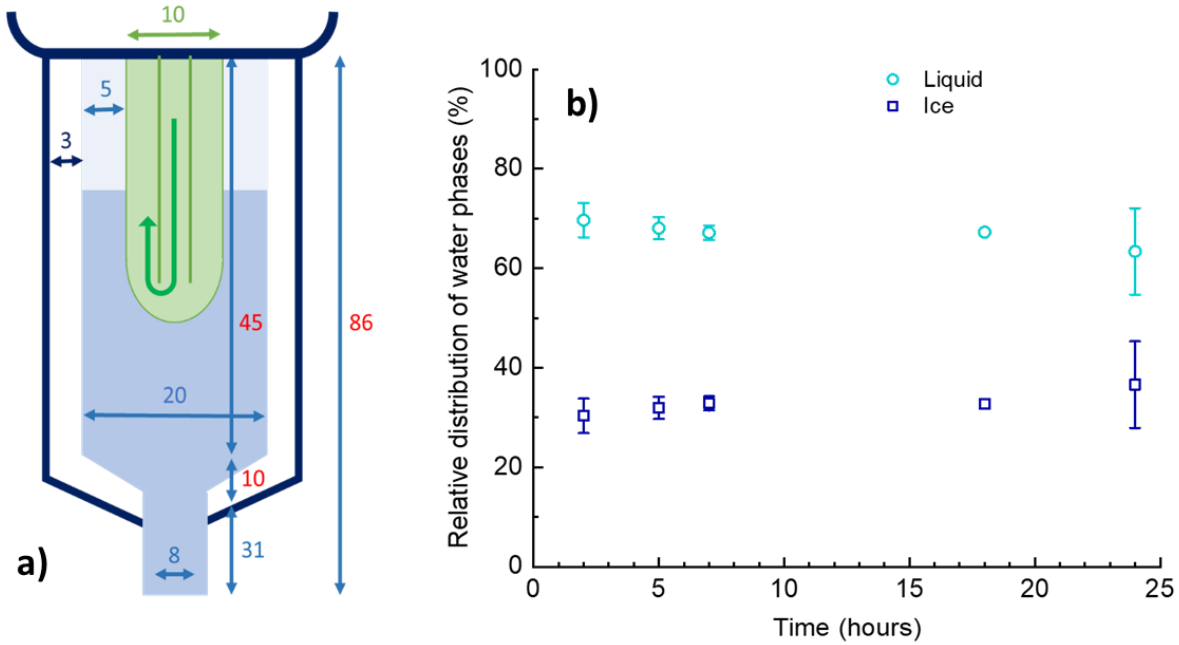

Figure S3: a) Dimensions of the system in mm (not to scale). From the exterior to the interior: the insulating layer of glass (dark blue), the inner vessel containing liquid (blue) and air (light blue), the refrigerating piece (green) with the direction of flow of the cooling liquid (bright green). Numbers in red represent dimensions that differed between the duplicate systems, with 86, 45 and 10 mm corresponding to 90, 52 and 7 mm, respectively. b) Evolution of the relative proportion of liquid and solid phases (m/m) for the 35 g kg^{-1} NaCl solution.

Table 2: Summary of mass of initial solution (M_{Init}), liquid (M_{Liq}) and ice (M_{Ice}) solutions recovered from the freezing reactor, losses of liquid or NaCl recovered, SA or particle concentrations measured in the initial solution (C_{Init}), and in the Liquid (C_{Liq}) and Ice (C_{Ice}) solutions recovered from the freezing reactor; and proportion of initial SA or particle masses recovered in liquid and in ice. Since SA is very stable when frozen in NaCl (mass balance of -1 ± 4%), for mixtures containing plastics and SA in NaCl, for simplicity we only showed the concentrations and mass balances of particles. For nPSL-200 and nPS-360 with NaCl and SA, concentrations in ice are the average of ice recovered in the two duplicate experiments.

	Freezing duration	Mass of solution (g)				NaCl Losses	Alginate Concentration (mg kg^{-1})			Distribution of Initial Alginate Mass between		
	(hours)	Initial	Liquid	Ice	Losses		Initial	Liquid	Ice	Liquid	Ice	Losses
SA	2	12.04	6.09	5.93	0%		21.49	31.57	11.20	74%	26%	0%
	2	12.01	5.50	6.75	-2%		21.49	30.45	9.13	65%	24%	11%
	5	12.01	5.75	6.08	1%		21.70	31.78	3.87	70%	9%	21%
	5	12.03	6.13	6.11	-2%		21.70	30.49	7.83	72%	18%	10%
	7	12.03	5.38	6.82	-1%		28.71	50.04	9.64	78%	19%	3%
	7	12.03	3.57	7.92	5%		28.71	48.99	12.69	51%	29%	20%
	24	12.02	4.82	6.63	5%		20.67	29.82	6.14	58%	16%	26%
	24	12.04	3.95	7.34	6%		20.67	49.26	6.56	78%	19%	2%
SA + NaCl	2	12.02	7.22	4.20	5%	8%	20.38	25.29	11.65	74%	27%	-1%
	2	12.00	8.00	3.65	3%	5%	20.38	24.52	11.84	80%	22%	-2%
	5	12.05	7.69	3.97	3%	9%	25.03	28.98	15.37	74%	27%	-1%
	5	12.01	7.59	4.09	3%	9%	25.03	31.36	16.19	79%	28%	-7%
	7	12.01	8.22	4.21	-3%	3%	25.54	26.57	12.42	71%	24%	5%
	7	12.00	7.83	3.94	2%	4%	25.54	31.48	15.96	80%	26%	-6%
	24	12.01	7.48	3.84	6%	9%	20.56	29.73	5.00	90%	9%	1%
	24	12.00	7.87	3.54	5%	10%	20.56	27.40	5.69	87%	9%	3%
	Freezing duration	Mass of solution (g)				NaCl Losses	Particle Concentration (mg kg^{-1})			Distribution of Initial Particle Mass between		
	(hours)	Initial	Liquid	Ice	Losses		Initial	Liquid	Ice	Liquid	Ice	Losses
nPSL-200	2	12.00	6.29	4.71	8%		10.18	13.93	1.46	72%	6%	23%
	2	12.00	4.23	5.13	22%		10.18	10.81	2.68	37%	32%	31%
	5	12.04	5.10	6.15	7%		10.90	14.43	1.74	56%	8%	36%
	5	12.03	4.46	7.00	5%		10.90	14.99	1.61	51%	9%	40%
	7	12.02	6.09	6.08	-1%		10.95	13.75	1.38	64%	6%	30%
	7	12.02	5.17	6.39	4%		10.95	14.70	1.35	58%	7%	36%
	24	12.02	6.29	6.01	-2%		14.08	18.33	2.44	68%	9%	23%
	24	12.03	6.12	5.51	3%		14.08	18.84	2.52	68%	8%	24%
nPSL-200 + NaCl	2	10.31	8.17	1.99	2%	4%	9.16	9.77	3.19	85%	7%	9%
	2	12.11	8.21	3.83	1%	4%	9.16	10.19	3.89	75%	13%	11%
	5	12.02	7.51	4.14	3%	6%	9.24	9.25	3.21	63%	12%	25%
	5	12.03	7.94	3.69	3%	12%	9.24	8.28	2.67	59%	9%	32%
	7	12.01	7.60	3.70	6%	8%	8.01	8.25	2.75	65%	11%	24%
	7	12.01	8.26	3.42	3%	6%	8.01	7.54	3.01	65%	11%	25%
	24	12.02	7.39	3.88	6%	12%	8.76	5.74	1.63	40%	6%	54%
	24	12.02	8.33	3.38	3%	9%	8.76	5.50	2.14	44%	7%	50%

Table 2: Continued

	Freezing duration	Mass of solution (g)				NaCl Losses	Particle Concentration (mg kg^{-1})			Distribution of Initial Particle Mass between		
	(hours)	Initial	Liquid	Ice	Losses		Initial	Liquid	Ice	Liquid	Ice	Losses
nPSL-200 + NaCl + SA	2	10.30	7.46	2.56	3%	11%	8.87	9.21	3.86	75%	11%	14%
	2	11.19	8.34	3.29	-4%	5%	8.87	9.83	3.86	83%	13%	5%
	5	11.13	7.79	3.30	0%	7%	8.95	9.83	4.78	77%	16%	7%
	5	11.63	8.36	3.27	0%	5%	8.95	10.06	4.78	81%	15%	4%
	7	10.88	7.56	3.28	0%	8%	8.96	9.87	3.32	77%	11%	12%
	7	12.01	8.67	5.48	-18%	3%	8.96	10.10	3.32	81%	17%	2%
	24	12.59	7.72	4.12	6%	15%	8.71	10.28	2.41	72%	9%	19%
	24	11.15	7.51	3.38	2%	6%	8.71	10.79	2.41	83%	8%	8%
nPS-360 + NaCl + SA	2	11.08	7.58	3.23	2%	11%	8.78	10.04	5.39	78%	18%	4%
	2	11.85	7.79	3.64	4%	10%	8.78	10.01	5.39	75%	19%	6%
	5	11.34	8.20	5.16	-18%	6%	10.25	10.81	3.79	76%	17%	7%
	5	10.80	8.66	2.66	-5%	6%	10.25	10.62	3.79	83%	9%	8%
	7	11.51	7.88	3.52	1%	8%	10.93	12.28	5.18	77%	14%	9%
	7	12.27	8.01	4.14	1%	8%	10.93	12.59	5.18	75%	16%	9%
	24	9.94	7.76	2.26	-1%	1%	10.68	12.62	1.00	92%	2%	6%
	24	10.76	7.65	2.56	5%	14%	10.68	12.78	1.00	85%	2%	13%
nPSL-350 + NaCl + SA	2	12.04	6.96	4.21	7%	11%	9.73	11.17	5.78	66%	21%	13%
	2	12.03	8.00	3.43	5%	7%	9.73	10.92	5.12	75%	15%	10%
	5	12.05	7.36	4.29	3%	6%	9.64	11.30	4.36	72%	16%	12%
	5	12.02	7.99	3.83	2%	4%	9.64	10.92	3.62	75%	12%	13%
	7	12.03	7.44	4.05	4%	9%	9.39	11.21	3.78	74%	14%	13%
	7	12.01	7.86	3.84	3%	6%	9.39	10.72	3.37	75%	11%	14%
	24	12.02	7.78	3.76	4%	10%	9.60	12.40	3.71	84%	12%	4%
	24	12.03	8.22	3.45	3%	9%	9.60	11.53	3.33	82%	10%	8%
µPS + NaCl + SA	2	12.00	7.93	3.77	3%	8%	4351	756	10396	11%	75%	14%
	2	12.00	8.28	3.38	3%	7%	4382	1063	9446	17%	61%	23%
	5	12.01	8.33	4.25	-5%	5%	4075	712	8016	12%	70%	18%
	5	12.01	8.83	3.67	-4%	-1%	4103	862	10948	15%	82%	3%
	7	12.02	8.09	3.40	4%	14%	4141	1065	9037	17%	62%	21%
	7	12.00	7.91	4.43	-3%	12%	4340	1545	8952	23%	76%	0%
	24	12.03	7.23	4.32	4%	NA	4451	427	9859	6%	80%	15%
	24	12.02	8.00	3.43	5%	6%	4443	707	11621	11%	75%	15%

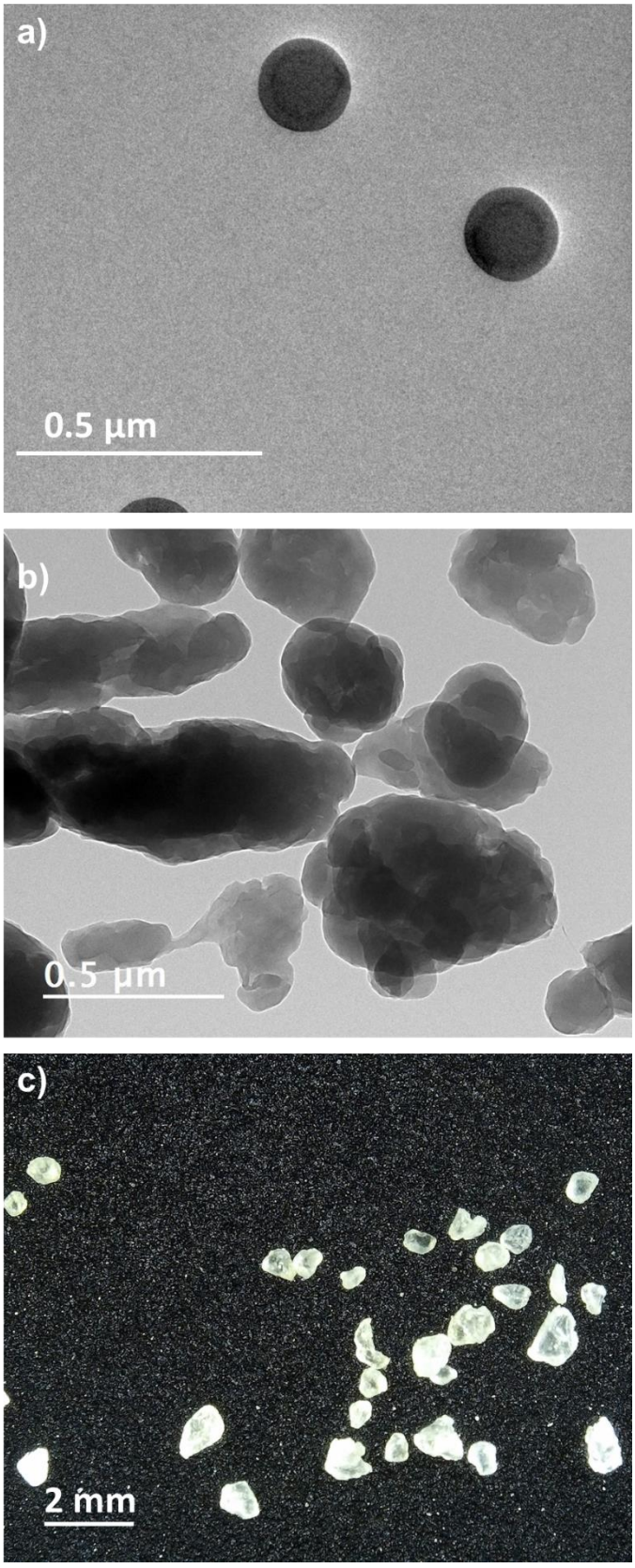

Figure S4: TEM images of a) nPSL-200 and b) nPS-360. c) Digital photography of µPS.

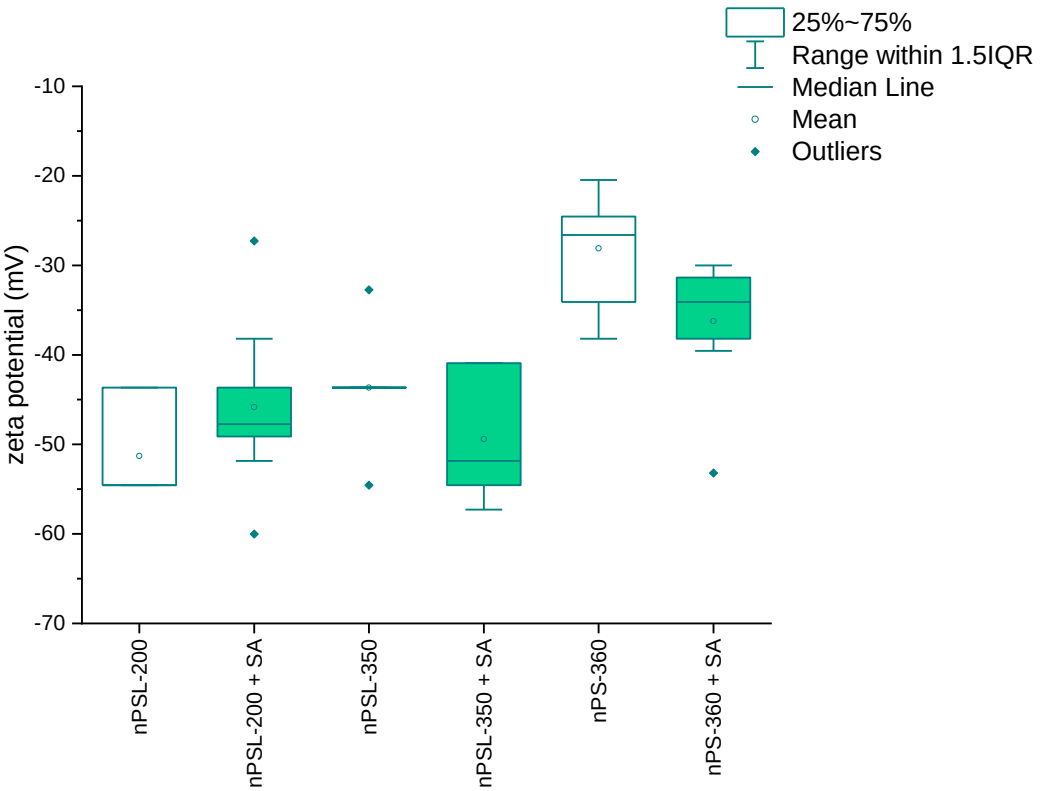

Figure S5: Zeta potential of 10 mg kg^{-1} of nanoplastic (nP) models in 0.23 g kg^{-1} NaCl, alone and with 50 mg kg^{-1} SA. Results are composed of 10 measurements in medium resolution mode.

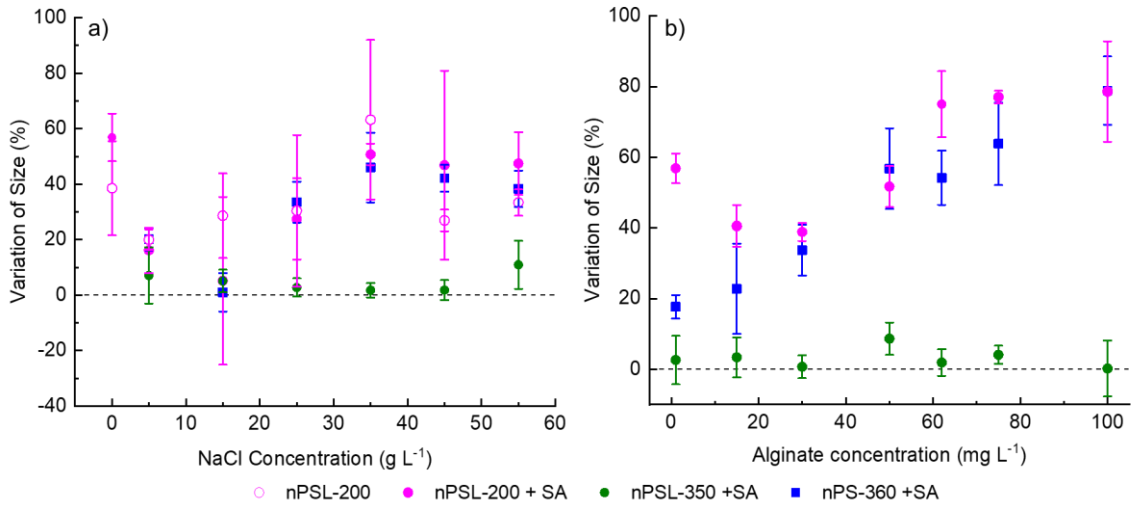

Figure S6: Variations of size of nanoplastics (nPs) after bulk freeze/thaw a) as a function of NaCl concentration (keeping SA at 50 mg kg^{-1}, if present) and b) as a function SA (keeping NaCl at 35 g kg^{-1} NaCl). Whether or not it has been purified, nPSL-350 does not form aggregates (≤10% dzH) (data not shown).

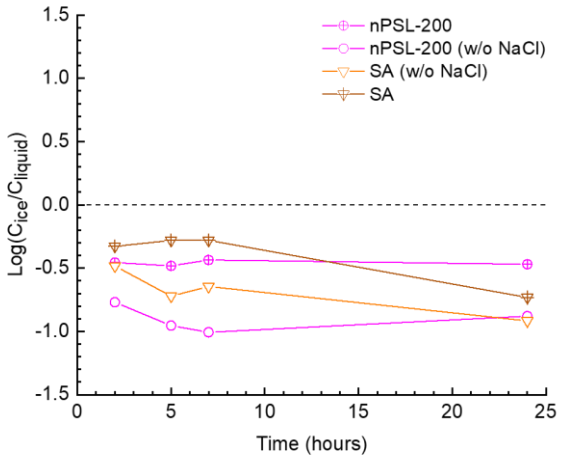

Figure S7: Logarithm of the partition coefficient between ice and liquid phase (C_{ice}/C_{liquid}) of nanoplastic nPSL-200 and SA, dispersed in deionized water at pH 8 or NaCl 35 g kg^{-1} pH 8, as a function of duration of the freezing experiment

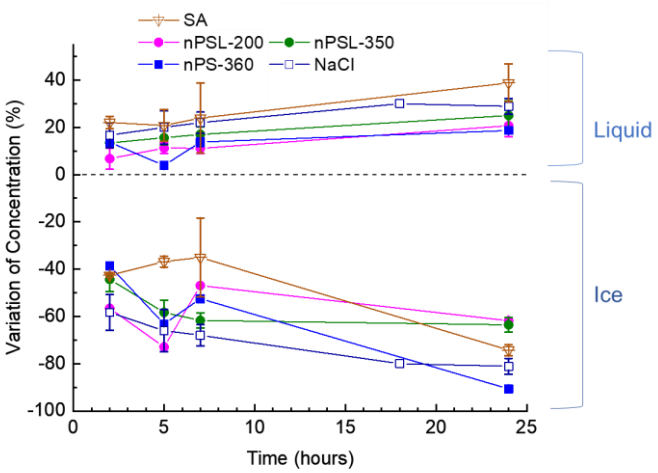

Figure S8: Variation of the concentrations of different species in liquid and ice, as a function of the duration of the freezing in the reactor. All experiments were conducted with 35 g kg^{-1} NaCl and 50 mg kg^{-1} SA at pH 8.

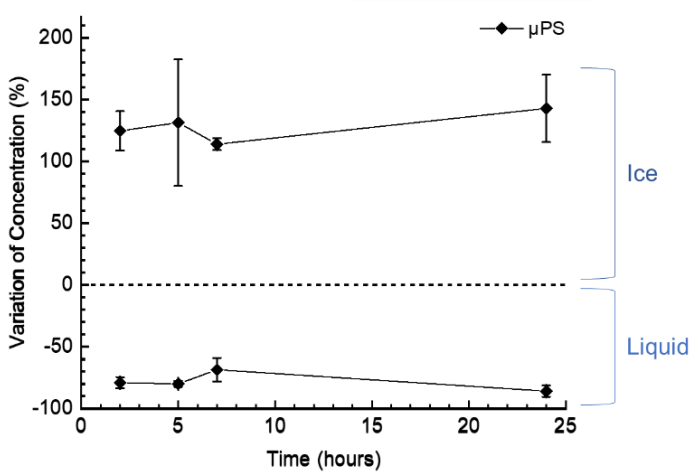

Figure S9: Variation of the concentration of polystyrene microplastics (µPS) dispersed in 35 g kg^{-1} NaCl at pH 8, and recovered in liquid and ice, as a function of the duration of freezing in the reactor