

A new approach to reclaim dialysate for wearable artificial kidneys

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Objectives

Extended research was conducted during the last decades to reclaim spent dialysate. No principle found so far is able to provide water autonomy to dialysis without expensive cartridges while concentrating all uremic toxins including urea in the little fluid amount a patient has to eliminate – like the healthy kidney

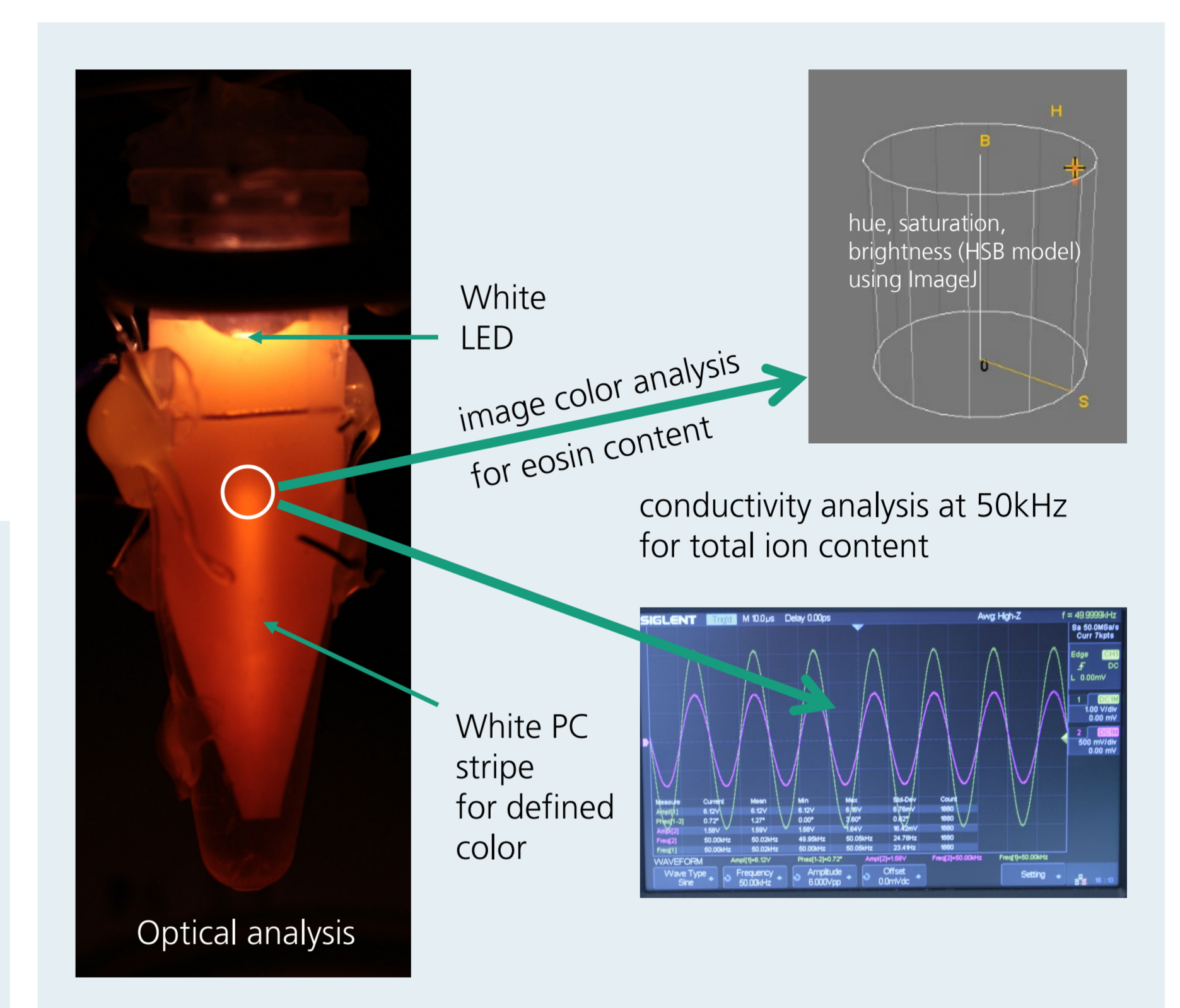
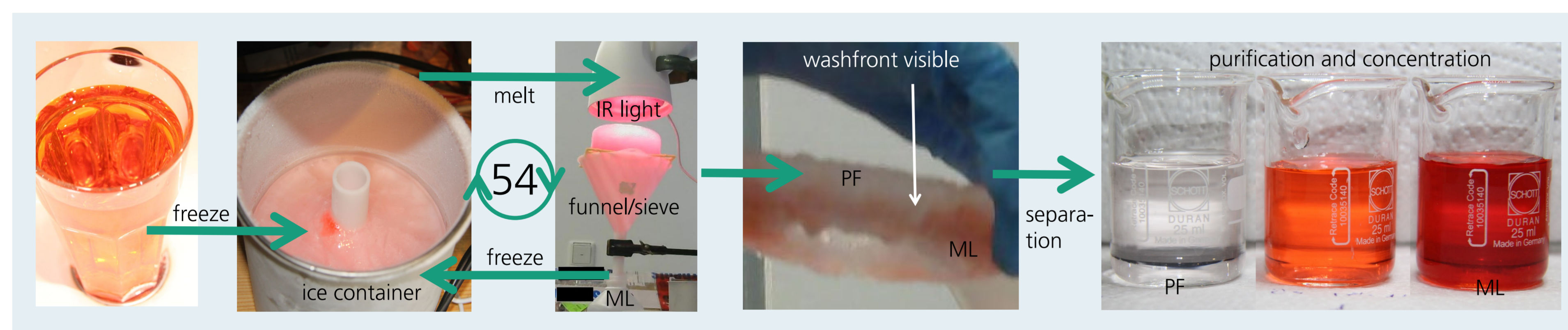
does. The reason is the similar molecular size of urea and water as well as retentate loss when filtering. If all toxins could be concentrated in the natural fluid loss of the patient a true water independence for any type of dialysis including wearable artificial kidney is achieved. A simple principle very common in pre reverse-osmosis times was neglected: **Cryopurification (CP)** – which utilizes the outstanding water ice capability to exclude impurities. Well known from beverage or chemical

industries it was transferred to in-vivo spent dialysate in this exploratory pre-study, the first time to our knowledge (pat. pending). Long term target is to **supply dialysis** of any kind **with pure water** in regions of water scarceness and to deliver dialysis water to home dialysis and wearable artificial kidneys allowing for mobile and longer dialysis sessions than 3x4h/week as well as to **reduce morbidity, dialysis costs and ecological footprint** in common.

Method

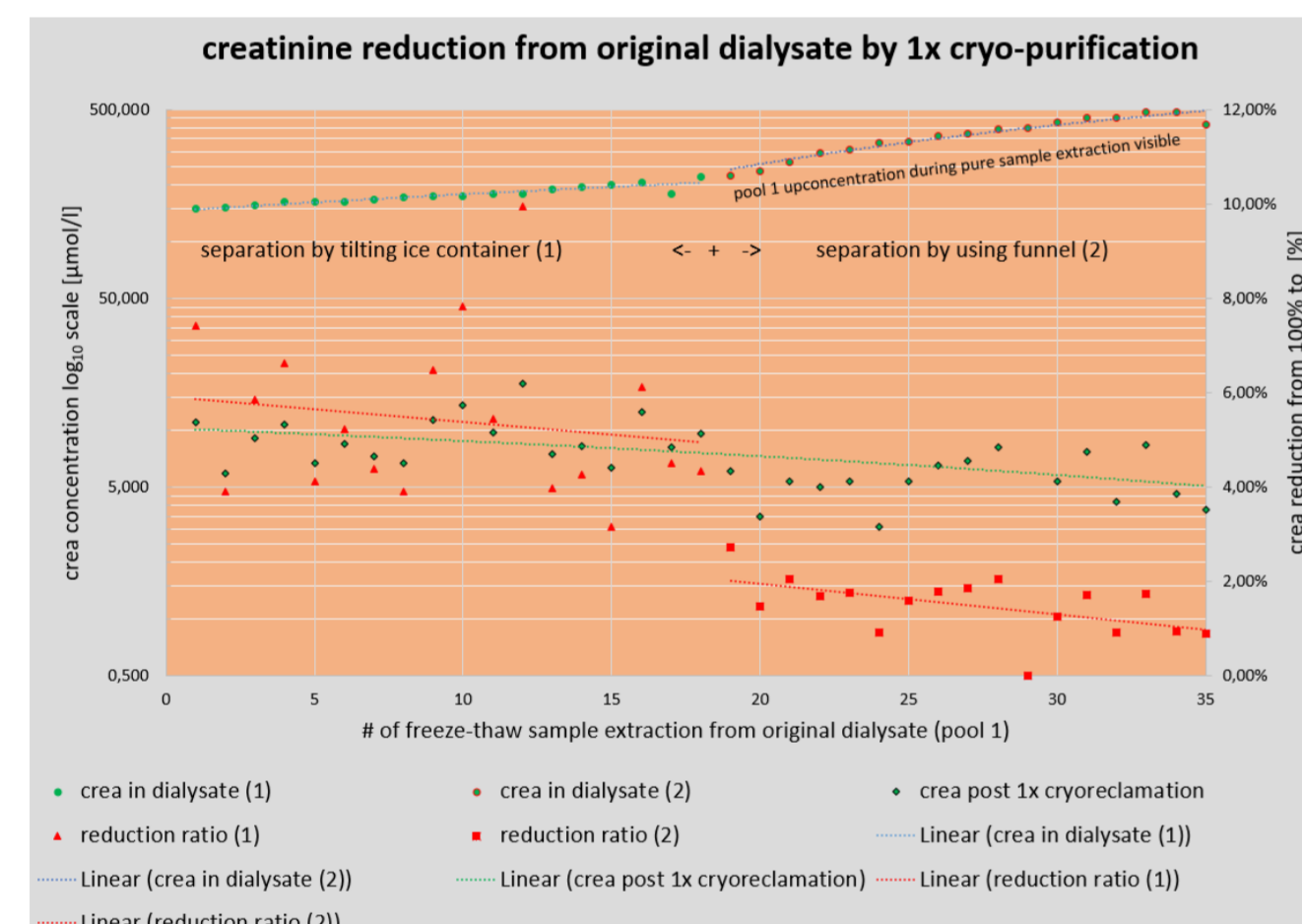
Spent dialysate from local dialysis was stained with 10 drops of red ink (eosin)/liter, then in 36 (pool1) + 18 (pool2) freeze-thaw cycles was crystallized, followed by a wash column like cleansing using infrared irradiation. A washfront is formed by irradiation and during melting the ice was separated into mother liquor (ML) and purified fraction (PF) along the washfront. Urea,

phosphate, creatinine, conductivity, optical density and dry mass were analyzed in ML and PF. Reduction ratio vs concentration as well as the reduction correlation coefficients of the 6 quantities were analyzed. Two fluid separation methods were used during melting: First 18 by simply tilting the ice container, all other as shown in the image using a funnel to avoid the ML passing the pure ice during tilting. Finally pure samples were pooled for another 18 cycles.

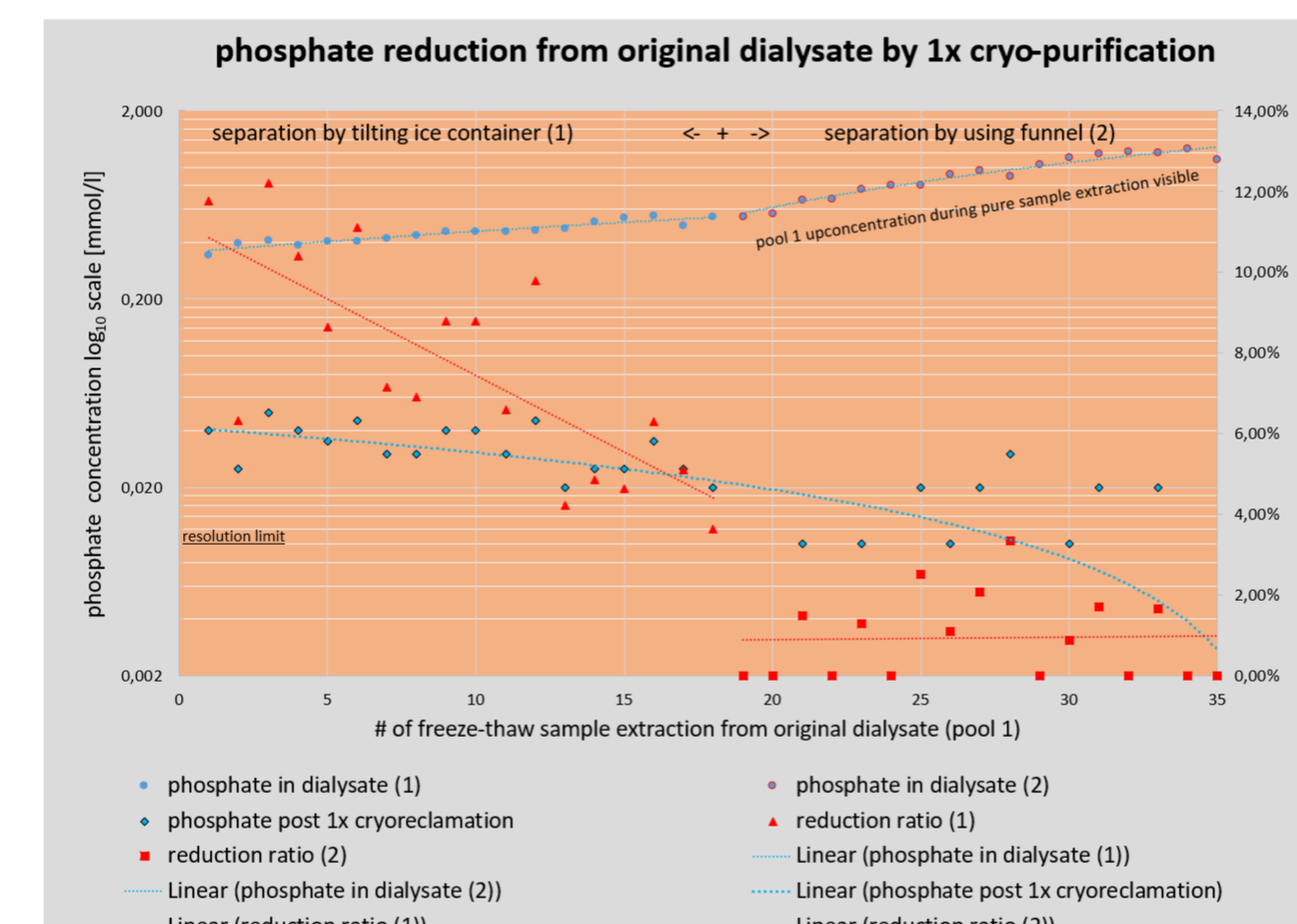


Results

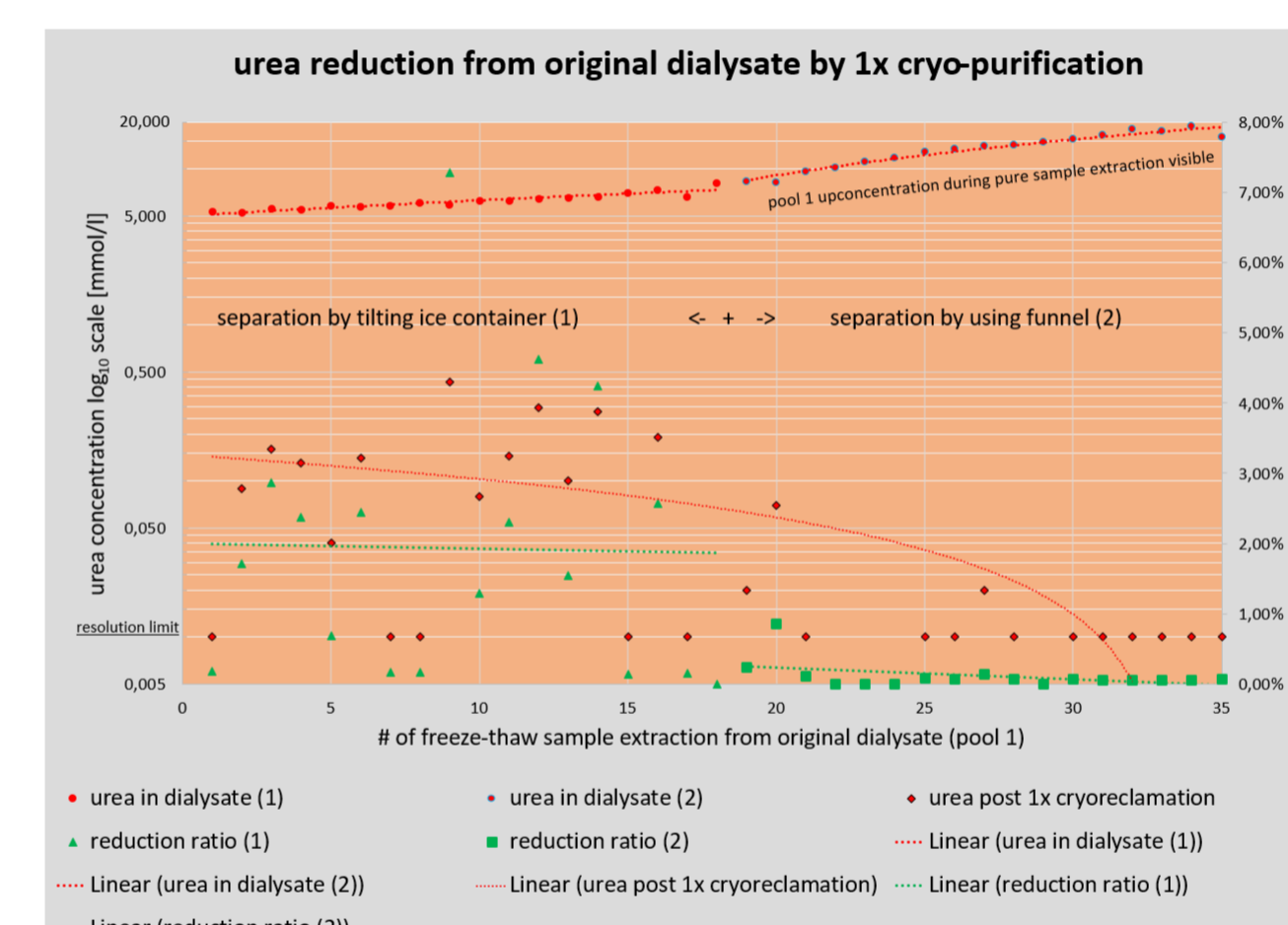
Purification < 700 Dalton



Creatinine was reduced from 100 to 1,6% after 1 cryo step using infrared funnel sieve.

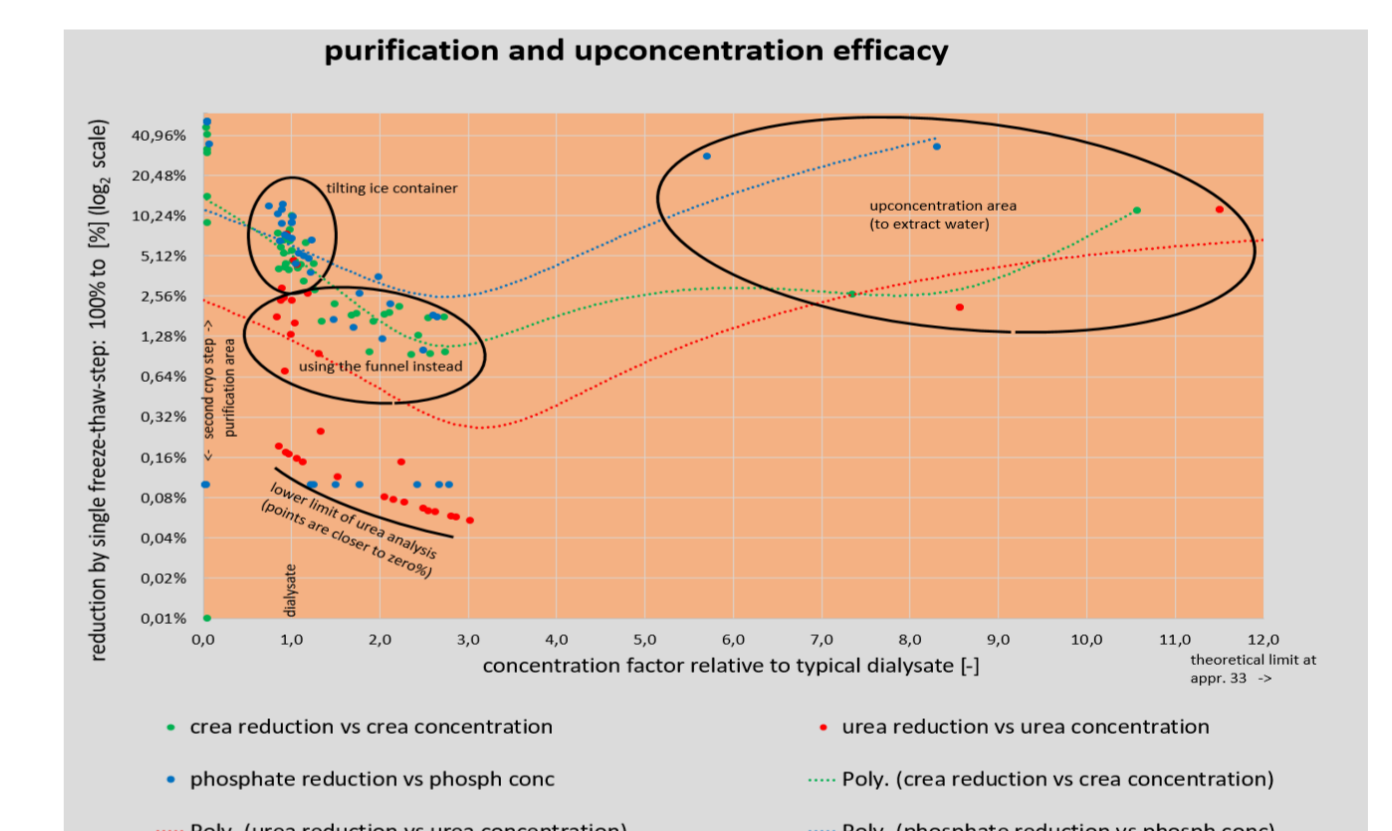


Phosphate was reduced from 100 to 1,0% after 1 cryo step using IR funnel sieve.

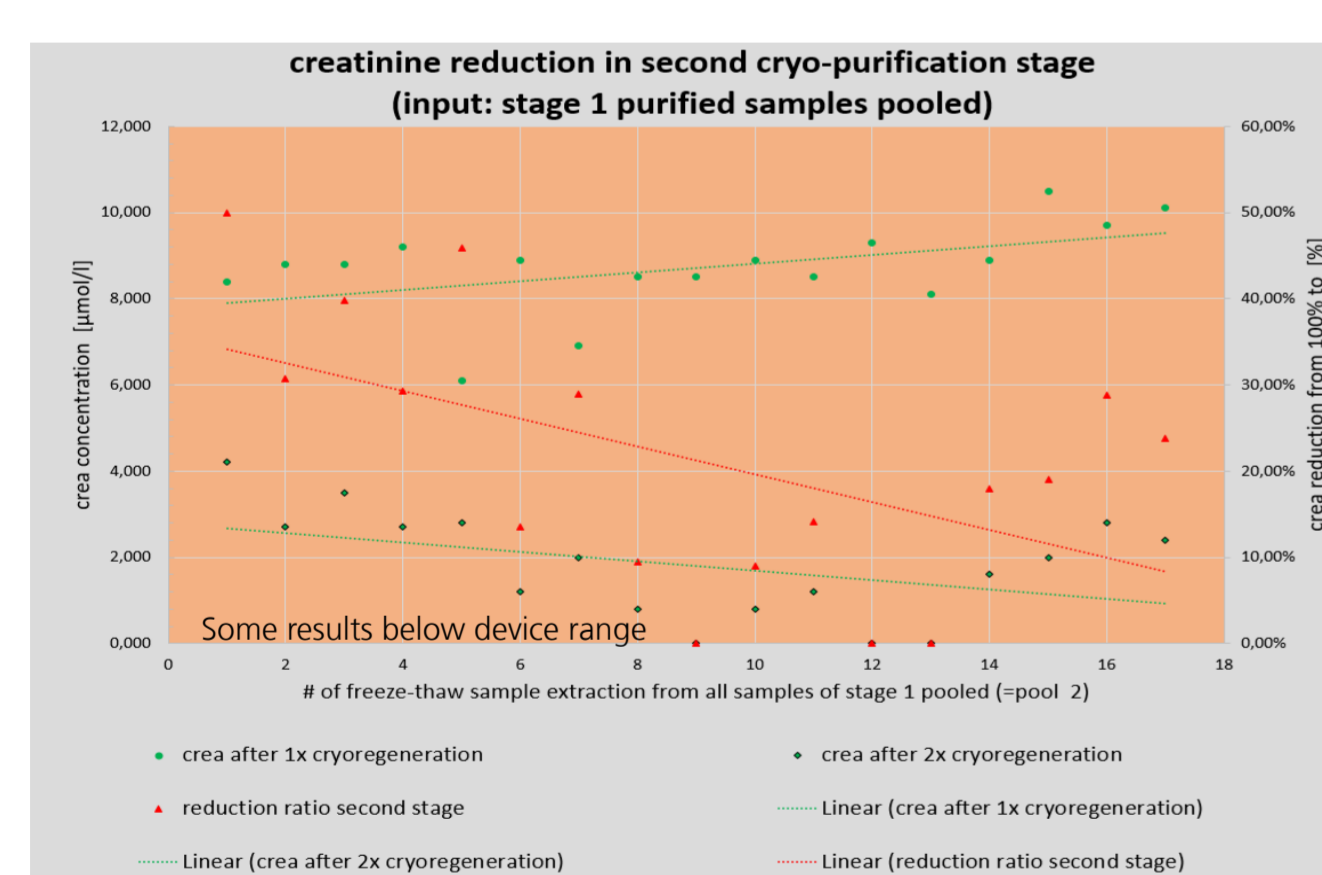


Urea was reduced from 100 to 0,11% with 1 cryo step. Second step was completely below device range.

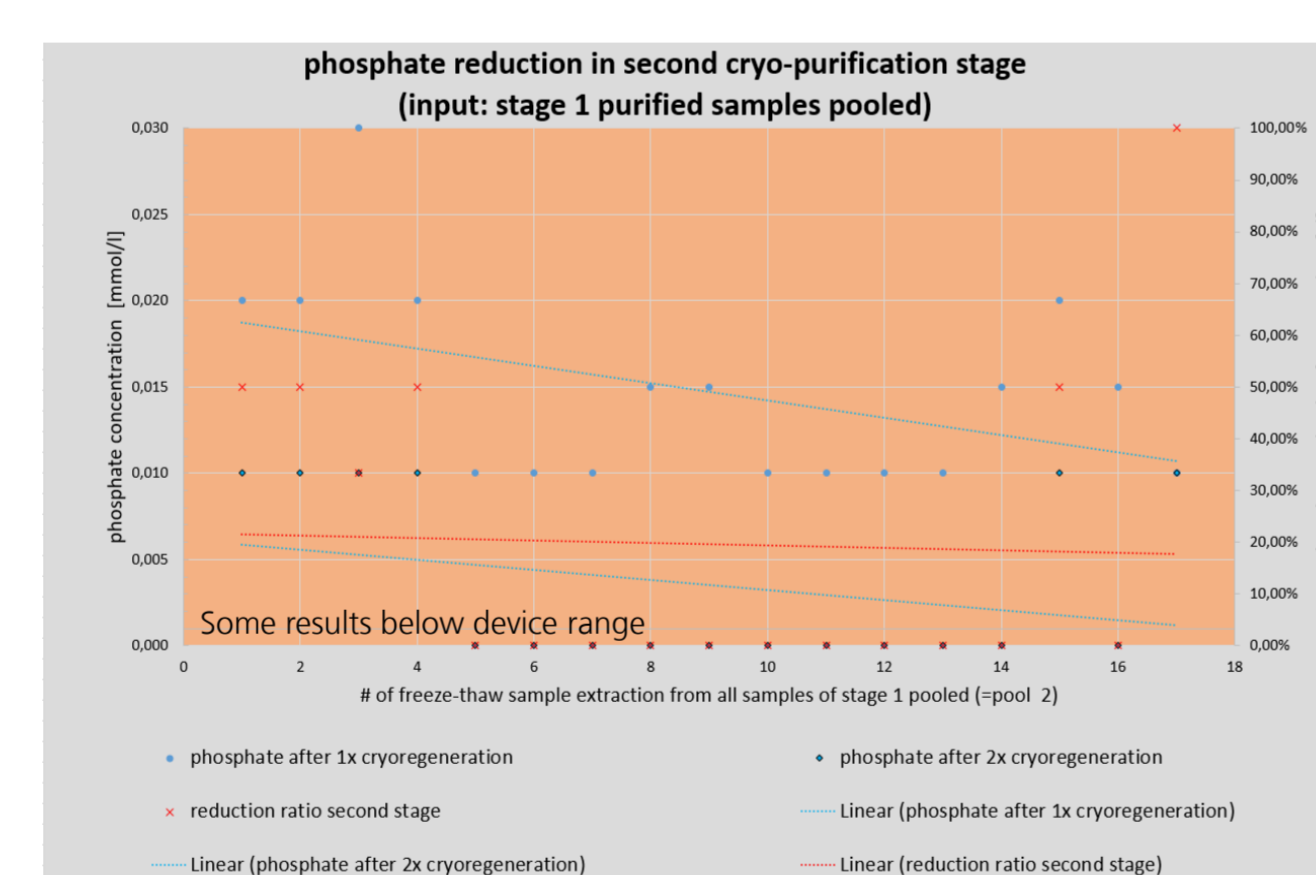
Purification operational range



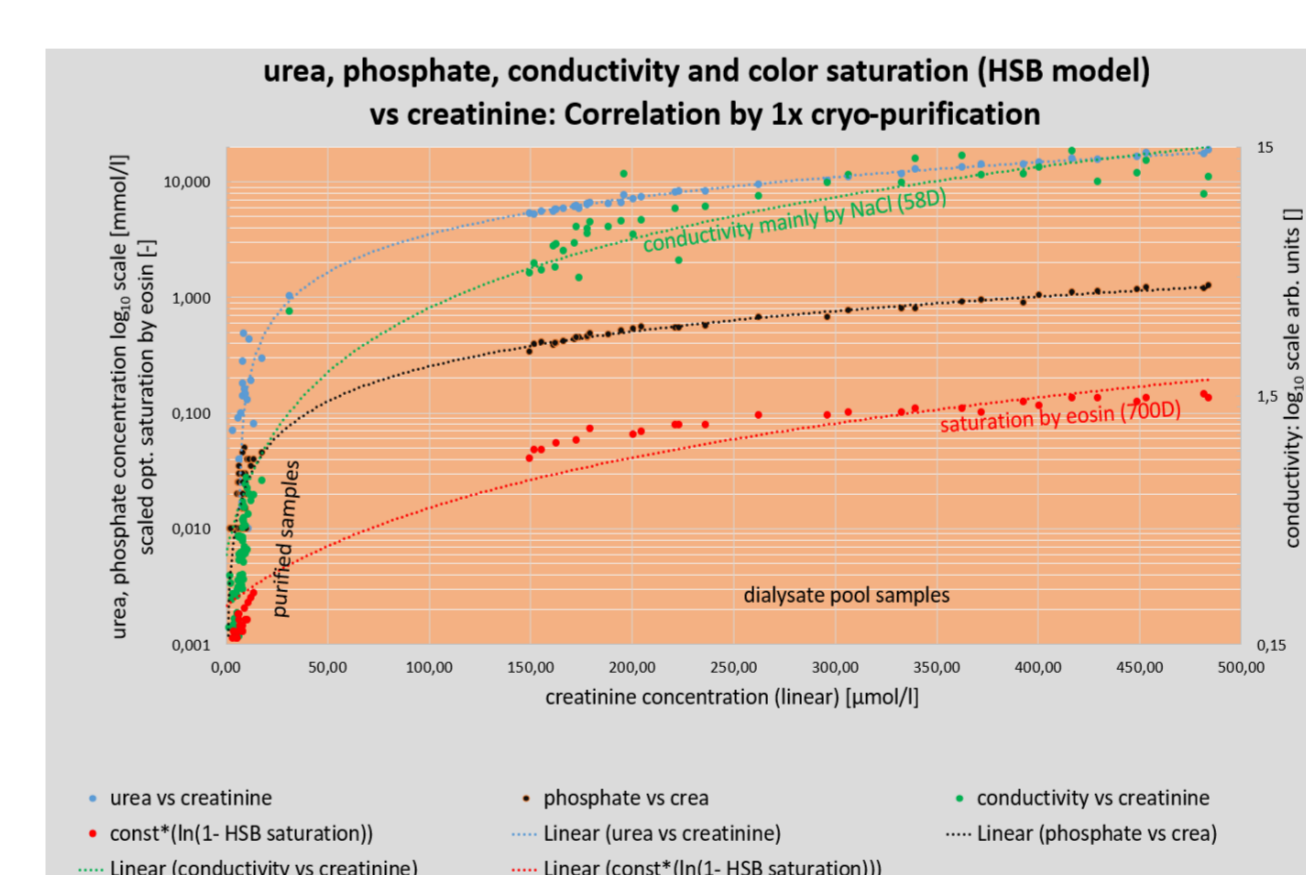
Solute extraction still possible at 1% of typical dialysate concentration. Water extraction still possible at >10-fold dialysate concentration. Cryo principle limits are not reached. Number of cryo steps is not limited at 2.



Creatinine was reduced to 0,34% after 2 cryo steps.

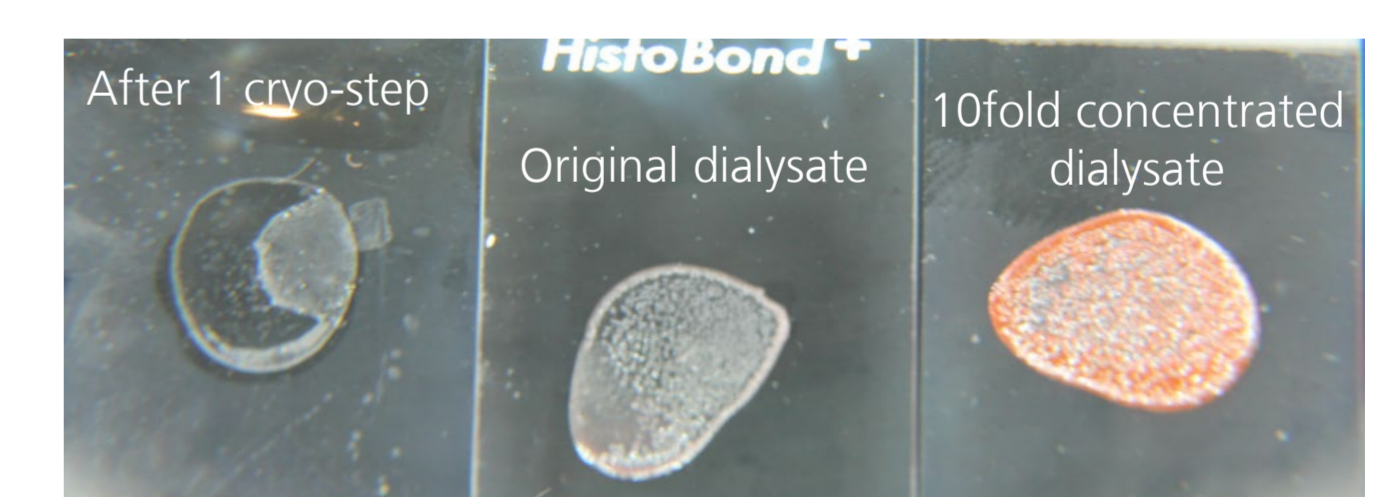


Phosphate was reduced to 0,2% after 2 cryo steps.



Chemical and derived measurements (conductivity, optical image analysis) both are highly linear (mind the log scale).

Purification >700 Dalton



Total dry material from 100µl fluid found after exsiccation (4h 41°C), reflected light ↑ and transmitted light ↓ exposure.



Absorption (lower right image) represents total dry mass of all non-volatile uremic toxins. It is fairly similar to small molecule reduction found in lab on that identical fluid samples using pixelwise integration and Lambert-Beer's law. This indicates heavy molecules to be removed either.

Reduction capability	Cryo mean of 2 stages (# not limited)	human kidney (laborlexikon.de) urine->blood/serum
	From 100% to [%]	From 100% to [%]
urea	0,120	1,80000
creatinine	0,337	1,07143
phosphate	0,197	4,12500

Comparison to healthy human kidney indicates that the dialysate by far is pure enough to be returned to the dialyzer and patient during dialysis.

CORRELATION	Cond.(all ions)	urea	crea	phosphate	hue	saturation	brightness	ln(1-sat)
Cond.(all ions)	1,000	0,964	0,966	0,970	0,305	0,952	-0,889	-0,973
urea		1,000	0,999	0,998	0,219	0,926	-0,884	-0,964
crea			1,000	0,998	0,228	0,932	-0,888	-0,968
phosphate				1,000	0,219	0,927	-0,883	-0,964
hue					1,000	0,409	-0,311	-0,358
saturation						1,000	-0,923	-0,992
brightness							1,000	0,924
ln(1-sat)								1,000

All agents, ionic (by cond.), urea, crea, phosphate and eosin (optical saturation) revealed reduction correlation >0,96; Hue (color tone) could not be used.

Conclusions

Cryopurification (CP) is shown to be a convenient standalone method for dialysate reclamation by simple hand experiments. Phosphate, creatinine and in particular urea have been reduced to levels compatible to fresh dialysate without any adsorbent or filtering. Also upconcentration ability collects nearly 100% of all uremic toxins in

significantly less than 10% of water – an amount the patients can supply by drinking. CP therefore is a simple physical principle acting on all uremic toxins (known and unknown) in similar effectivity. CP can supply many types of dialysis at any location – even in cars – with sufficient amount of water to operate in complete autonomy without patient dehydration. Solar panels are sufficient for CP operation. The simple technical setup (chiller

and wash column) can be produced in high numbers at low costs. Without further means the water must return to the very same patient, otherwise an endotoxin filter must be used. The existing number of experiments is still not sufficient and must be enlarged. A more automated setup is being built – “stay tuned”.