

## 1 Introduction

### Importance of Desalination

- With climate change & scarcity of fresh water, desalination is increasing in importance
- More than 16,000 desalination plants globally, with more coming on-line every year
- Provides fresh water for areas with limited fresh water resources
- Estimated to produce more than 95 million cubic meters of fresh water daily

### How Desalination Is Accomplished

- Primarily through Reverse Osmosis

### Byproducts of Desalination

- Brines which have salinities up to 2x higher those of the incoming sea water
- Most brines are returned to the ocean
- Over 142 million cubic meters per day

### Analysis of Desalination Discharge Brines

- Potential pollutants
  - Elements & permissible levels vary widely by country & region → no unified regulations
- "Mining" Elements with economic value
  - Wide variety of elements: B, Ca, Cs, Ga, In, Li, Mg, Mo, Rb, Sc, V, REEs, & more

### Goal

Measure Pollutants in & Elements which are "Mined" from Desalination Discharge Brines with ICP-OES

## 2 Analysis of Pollutants

### Regulated Elements & Levels in Various Locations

Element	Singapore <sup>1</sup> (mg/L)	Dubai (mg/L)	Huntington Beach <sup>2</sup> (mg/L)	Carlsbad <sup>2</sup> (mg/L)
Ag	0.1	0.005	0.11	0.156
Al	---	---	1.2	1.8
As	0.1	0.05	---	---
B	5	---	---	---
Ba	2	---	---	---
Cd	0.1	0.05	0.16	0.228
Cr	1	0.05	0.32	0.457
Cu	0.1	0.5	0.45	0.641
Fe	10	2	---	---
Hg	0.05	0.001	0.0064	0.00912
Mn	5	---	---	---
Ni	1	0.1	0.8	1.14
Pb	0.1	0.1	0.32	0.457
Se	0.5	0.02	---	3.42
Zn	1	0.1	3.1	4.39

<sup>1</sup> Discharge limits into watercourse

<sup>2</sup> NPDES discharge permits – Instantaneous Maximum Effluent Limitations

### Not much consistency among regions

- Different elements & concentrations
- Hg too low to be measured reliably by ICP-OES (aside from Singapore) → not considered here



### Avio 550 Max

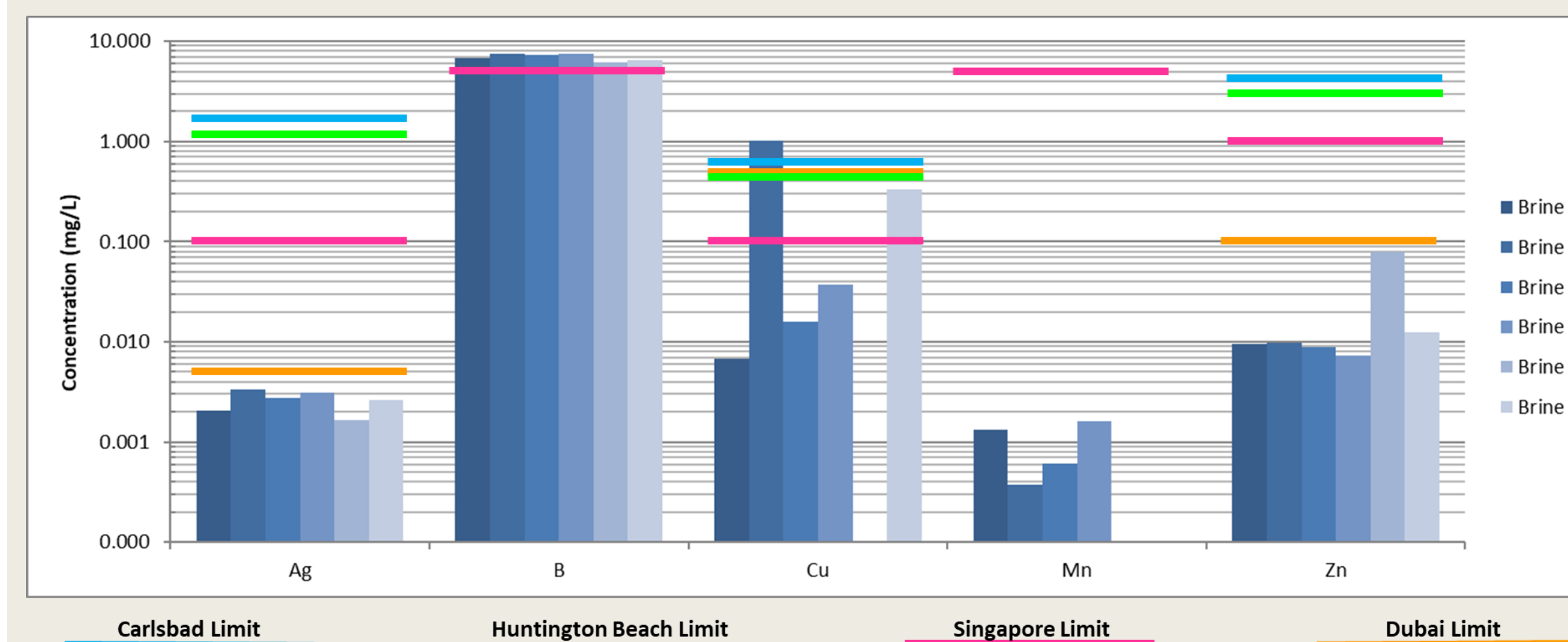
- Larger analyte list
- Higher throughput
- Simultaneous analysis
- Axial & Radial View
- Samples run undiluted
- ≈ 6% dissolved solids
- SeaSpray nebulizer with argon humidifier
- External calibrations in 6% NaCl

Element	Wavelength (nm)	Plasma View	Element	Wavelength (nm)	Plasma View
Ag	338.289	Axial	Cu	327.393	Axial
Al	396.153	Radial	Fe	259.939	Radial
As	188.979	Radial	Mn	257.610	Radial
B	249.772	Radial	Ni	232.003	Radial
Ba	233.527	Radial	Pb	220.353	Radial
Cd	228.802	Axial	Se	196.026	Axial
Cr	357.869	Axial	Zn	213.857	Axial

Internal Standards	Wavelength (nm)	Plasma View
Ga	417.206	Axial, Radial
Y	371.029	Axial, Radial

### Analysis of 6 Desalination Discharge Brines

- Measure all elements in table (aside from Hg) to cover 4 regions listed in table

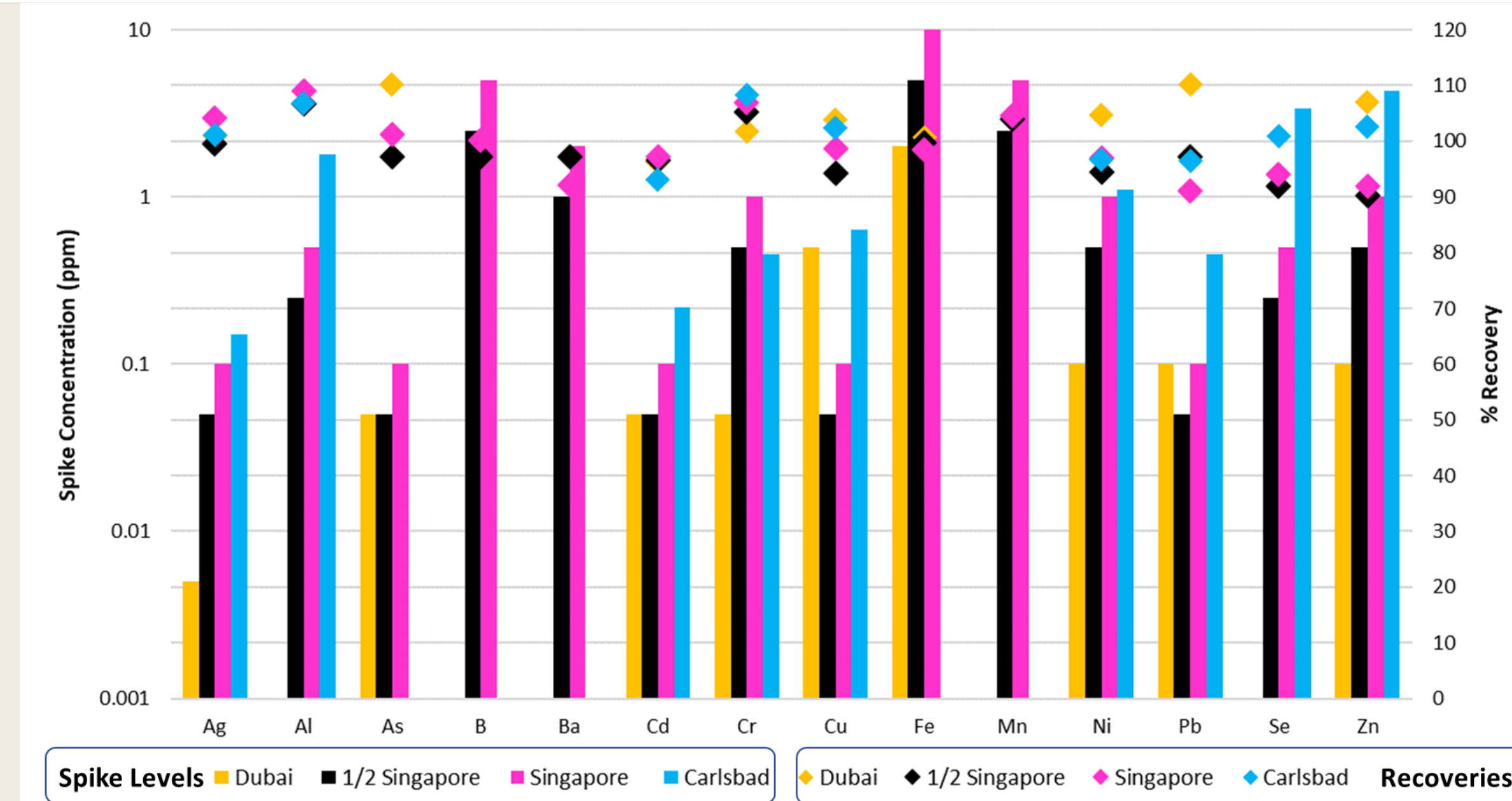


### Most Elements not Detected

- Only 5 elements detected
- Only B and Cu in Brine 2 are above regulated limits

### Accuracy

- Evaluate spike recoveries in a brine at low, medium, & high concentrations
  - Low: Spike at Dubai & half Singapore limits
  - Medium: Singapore (medium)
  - High: Carlsbad limits (high)
- Do not want false positives at the upper limits



**All recoveries within 10% → Accurate Measurements**  
Se not evaluated at Dubai limit (0.02 ppm) → too low for consistent, accurate analyses

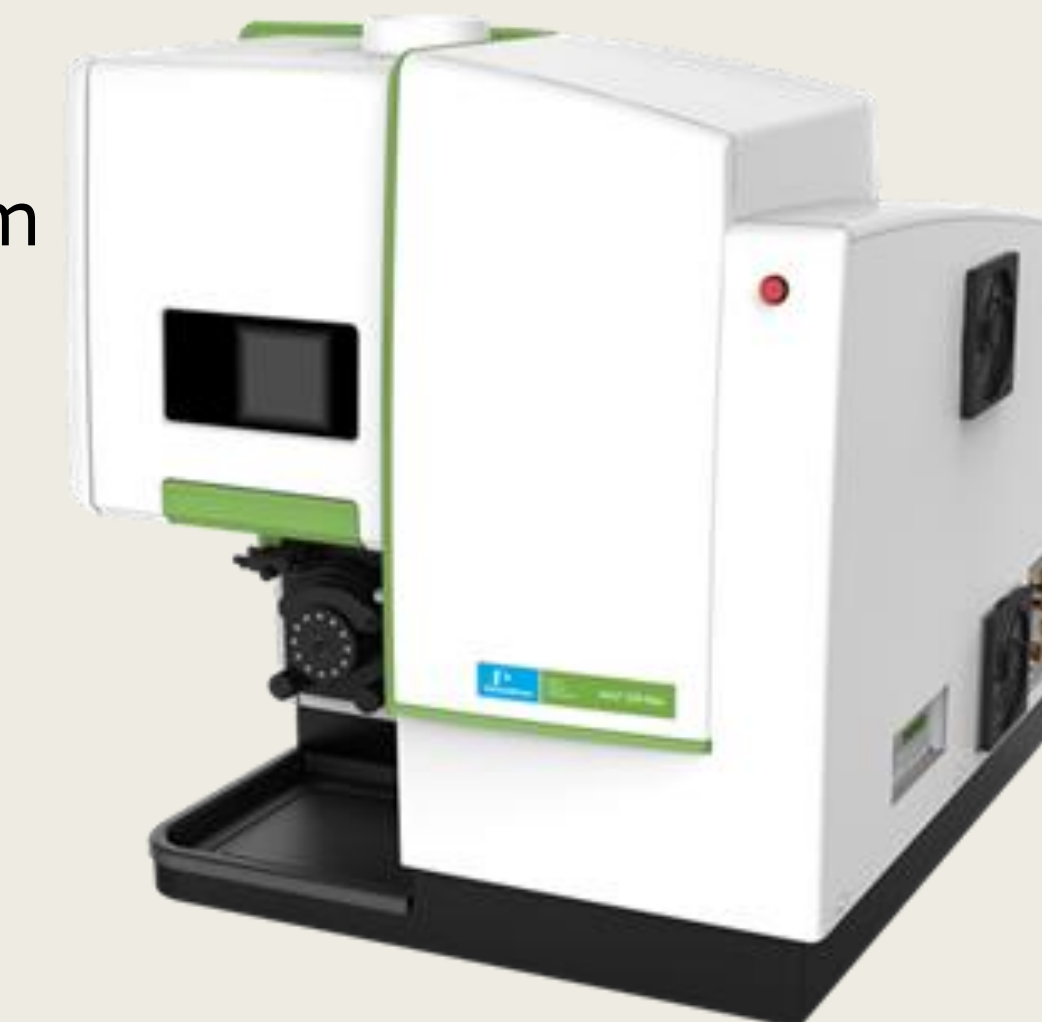
## 3 Analysis of Recovery Elements: Cs, Li, Rb

### Focus on Cs, Li, & Rb

- Atom lines with low ionization potentials → EIE effect
- Li is very sensitive with ICP-OES
- Cs & Rb generally have low sensitivity with ICP-OES

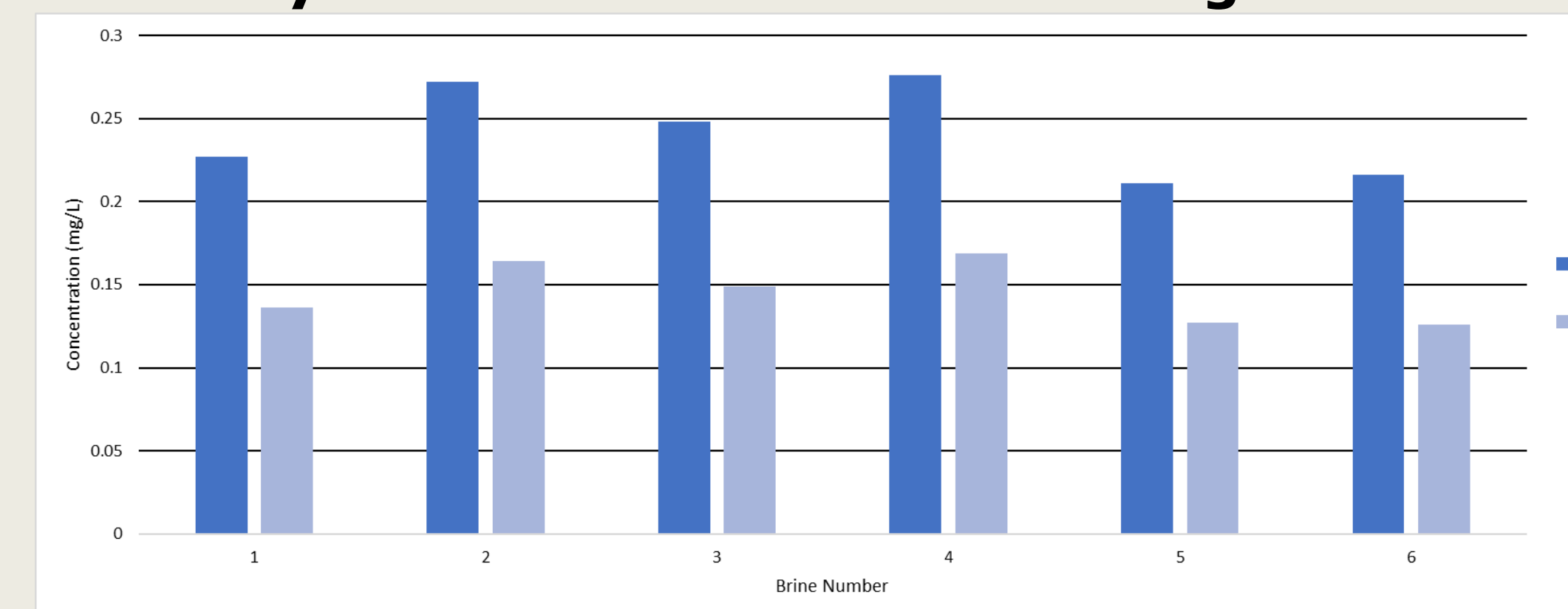
### Avio 220 Max

- High sensitivity
- Unlimited wavelength choice from 165 - 900 nm
- Hybrid Simultaneous analysis
- Axial & Radial View
- Samples run undiluted
- ≈ 6% dissolved solids
- SeaSpray nebulizer with argon humidifier
- External calibrations in 6% NaCl



Element	Wavelength (nm)	Plasma View
Cs	894.347	Axial
Li	670.784	Radial
Rb	780.023	Axial
In (IS)	325.609	Axial, Radial

### Analysis of 6 Desalination Discharge Brines

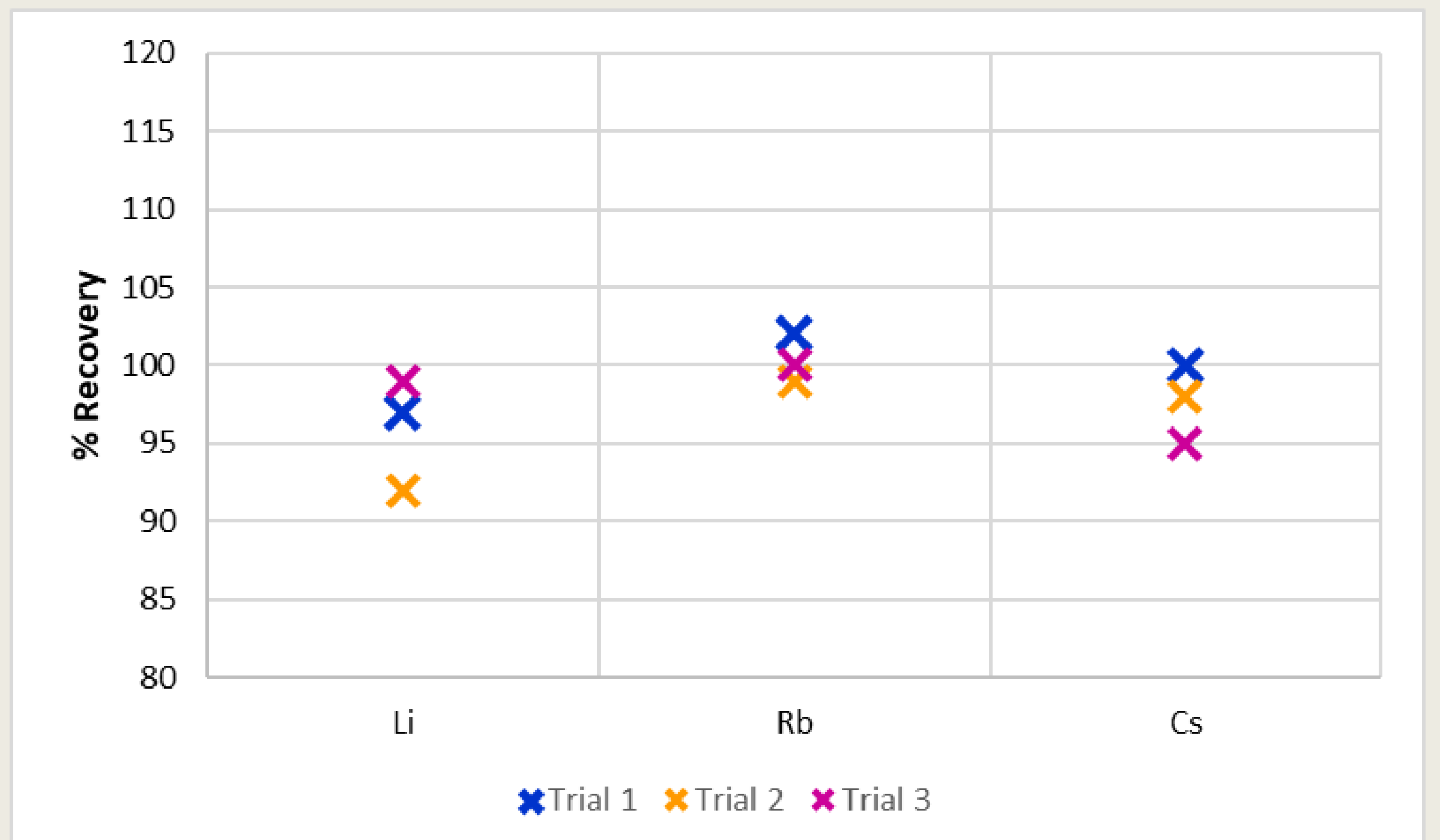


**Li & Rb present in all brines;  
Cs not detected in any of the brines**

### Accuracy

- Evaluate spike recoveries in one of the brines

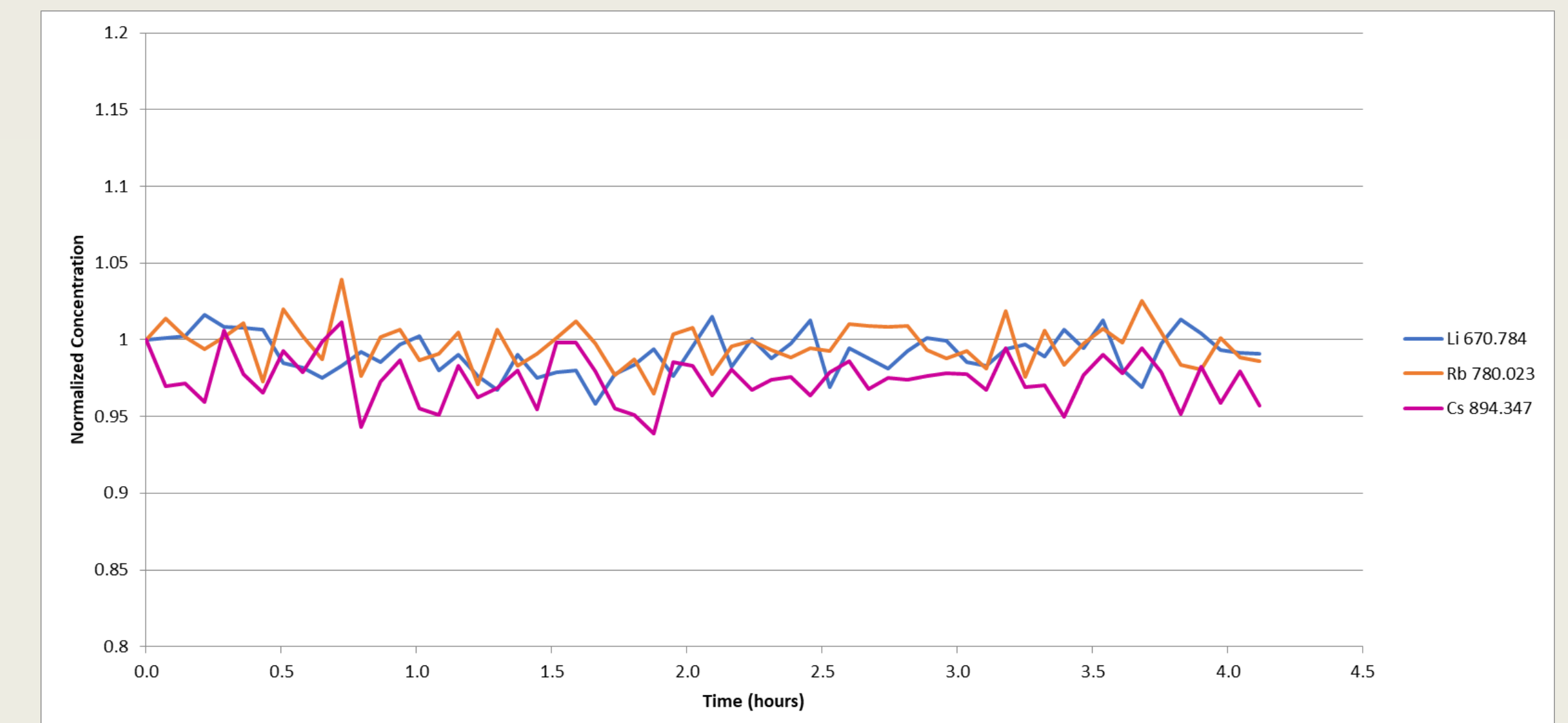
### Spike Recoveries: Cs = 0.04 ppm, Li, Rb = 0.2 ppm



**Recoveries within 10% - Accurate, Reproducible Results**

### Stability

**Repeated Measurements 0.1 ppm Spike in Brine Over 4 Hours**



**Signal variations of < 10% over 4 hours  
Robust, Stable Methodology**

## 4 Summary

The analysis of desalination discharge brines for elements of environmental and industrial importance can be accomplished ICP-OES. Because of its high matrix tolerance, brines can be analyzed undiluted by ICP-OES, minimizing sample preparation.

Environmentally important elements are measured to ensure that the oceans are not polluted through the desalination process, while industrially important elements must be measured to determine if concentrations are high enough for recovery to be economically feasible. Both these analyses are realized with the Avio family of ICP-OES instruments, which produce in accurate, robust results.