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Protocol for Creating Major Ion Solutions for Freshwater Systems

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ABSTRACT

Several experimental designs require serial dilutions of site water. To perform dilutions without the use of prefiltered water or without the addition of nutrients and trace metals in freshwater systems, major ion solutions (MIS) are required. MIS provides a nutrient and metal free dilution medium to minimize hypertonic and hypotonic effects on the organisms in the samples during dilutions by balancing major dissolved ions of Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, SO_4^{2-}, and Si^{4+} in freshwater systems. MIS are the equivalent of no nutrient artificial sea water for use in freshwater systems. Unlike artificial sea water, MIS formulation for use in freshwater systems changes from site to site. This protocol describes the process of creating a site specific major ion solution from results of elemental analysis data for use in the specified freshwater system.

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PROTOCOL CITATION

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KEYWORDS

Major Ion Solution, MIS, freshwater dilution media

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MATERIALS TEXT

$Na_2SiO_3x9H_2O$ (CAS 13517-24-3)
$CaCl_2x2H_2O$ (CAS 10035-04-8)
$MgSO_4x7H_2O$ (CAS 10034-99-8)
Na_2SO_4 (CAS 7757-82-6)
K_2SO_4 (CAS 7778-80-5)
Distilled Water
Carboy for the major ion solution
Graduated Cylinders

Find major ion composition of the freshwater body

1 Identify the elemental concentrations of Si^{4+}, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, and SO_4^{2-} in the freshwater system for which you wish to create a major ion solution.

Note: USGS reports are helpful for water bodies in the United States, but major ion compositions from elemental analysis are available for many systems from scholarly communication (peer reviewed manuscripts, theses/dissertations, government reports, preprints, etc.).

2 Convert the concentrations of the elements to mg/L from µM if the data is not already in this format.

Create the formulation of the major ion solution

3 Download Freshwater_Major_Ion_Solution_calculation.csv from Zenodo at http://www.doi.org/10.5281/zenodo.5019969.

Calculations and recipes to make major ion solution (MIS) for freshwater systems

USE FIRST TABLE FOR CORRECT CALCULATIONS — Note: substitute the final concentration of each ion (mg/L) in boxed area below

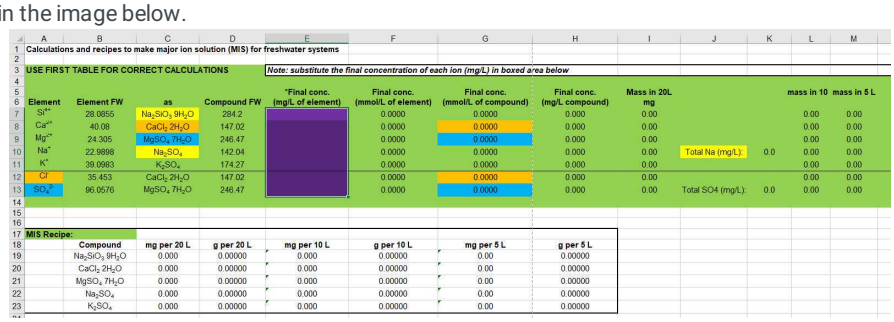
Element	Element FW	as	Compound FW	*Final conc. (mg/L of element)	Final conc. (mmol/L of element)	Final conc. (mmol/L of compound)	Final conc. (mg/L compound)	Mass in 20L mg			mass in 10	mass in 5 L
Si^{4+}	28.0855	$Na_2SiO_3\ 9H_2O$	284.2		0.0000	0.0000	0.000	0.00			0.00	0.00
Ca^{2+}	40.08	$CaCl_2\ 2H_2O$	147.02		0.0000	0.0000	0.000	0.00			0.00	0.00
Mg^{2+}	24.305	$MgSO_4\ 7H_2O$	246.47		0.0000	0.0000	0.000	0.00			0.00	0.00
Na^{+}	22.9898	Na_2SO_4	142.04		0.0000	0.0000	0.000	0.00	Total Na (mg/L):	0.0	0.00	0.00
K^{+}	39.0983	K_2SO_4	174.27		0.0000	0.0000	0.000	0.00			0.00	0.00
Cl^{-}	35.453	$CaCl_2\ 2H_2O$	147.02		0.0000	0.0000	0.000	0.00			0.00	0.00
SO_4^{2-}	96.0576	$MgSO_4\ 7H_2O$	246.47		0.0000	0.0000	0.000	0.00	Total SO4 (mg/L):	0.0	0.00	0.00

MIS Recipe:

Compound	mg per 20 L	g per 20 L	mg per 10 L	g per 10 L	mg per 5 L	g per 5 L
$Na_2SiO_3\ 9H_2O$	0.000	0.00000	0.000	0.00000	0.00	0.00000
$CaCl_2\ 2H_2O$	0.000	0.00000	0.000	0.00000	0.00	0.00000
$MgSO_4\ 7H_2O$	0.000	0.00000	0.000	0.00000	0.00	0.00000
Na_2SO_4	0.000	0.00000	0.000	0.00000	0.00	0.00000
K_2SO_4	0.000	0.00000	0.000	0.00000	0.00	0.00000

Screenshot of Freshwater_Major_Ion_Solution_calculation.csv

4 Fill in the mg/L box in the with the values calculated from Steps 1 and 2. The box to add this data is highlighted in purple in the image below.



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Mg^{2+}	24.305	$MgSO_4\ 7H_2O$	246.47		0.0000	0.0000	0.000	0.00			0.00	0.00
Na^{+}	22.9898	Na_2SO_4	142.04		0.0000	0.0000	0.000	0.00	Total Na (mg/L):	0.0	0.00	0.00
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Cl^{-}	35.453	$CaCl_2\ 2H_2O$	147.02		0.0000	0.0000	0.000	0.00			0.00	0.00
SO_4^{2-}	96.0576	$MgSO_4\ 7H_2O$	246.47		0.0000	0.0000	0.000	0.00	Total SO4 (mg/L):	0.0	0.00	0.00

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Compound	mg per 20 L	g per 20 L	mg per 10 L	g per 10 L	mg per 5 L	g per 5 L
$Na_2SiO_3\ 9H_2O$	0.000	0.00000	0.000	0.00000	0.00	0.00000
$CaCl_2\ 2H_2O$	0.000	0.00000	0.000	0.00000	0.00	0.00000
$MgSO_4\ 7H_2O$	0.000	0.00000	0.000	0.00000	0.00	0.00000
Na_2SO_4	0.000	0.00000	0.000	0.00000	0.00	0.00000
K_2SO_4	0.000	0.00000	0.000	0.00000	0.00	0.00000

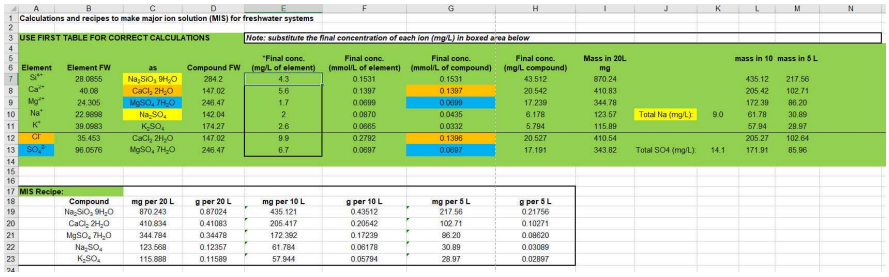
The box to add the concentrations to is highlighted in purple.

5 As multiple compounds contribute to the Na^{+} and SO_4^{2-} concentrations and Cl^{-} concentrations come from Ca^{2+} calculations, check to make sure that the concentrations are not magnitudes off compared to the reference. There is natural variability in the ionic composition of freshwater systems so some deviation is not an issue. The orange and blue highlights under final concentration column show the corresponding compounds between the cations and anions. If the values are several magnitudes off, use the values calculated using the anions. See the example below to see how this works.

The example used in the image below is for the upper Neuse River Estuary as reported in Paerl and Bowles (1987) from USGS data (Harned 1982).

Citation: Malcolm A Barnard (06/24/2021). Protocol for Creating Major Ion Solutions for Freshwater Systems . https://dx.doi.org/10.17504/protocols.io.bvyxn7xn

References:
Harned, D.A., 1982. *Water quality of the Neuse River, North Carolina-Variability, pollution loads, and long-term trends* (USGS Report No. 2185-D). USGPO,.
Paerl, H.W. and Bowles, N.D., 1987. Dilution bioassays: Their application to assessments of nutrient limitation in hypereutrophic waters. *Hydrobiologia*, *146*(3), pp.265-273. https://doi.org/10.1007/BF00016348



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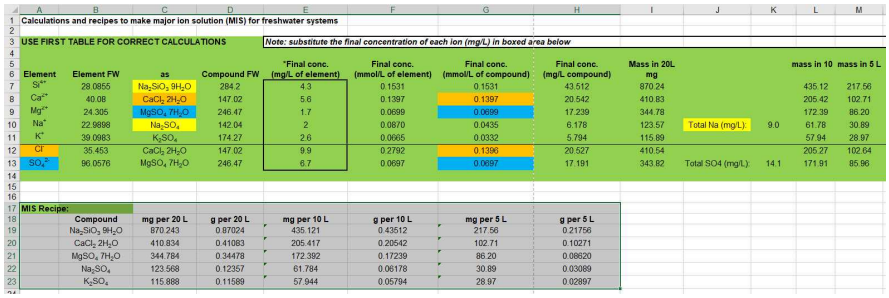
Si^{4+}	28.0855	$Na_2SiO_3\ 9H_2O$	284.2	4.3	0.1531	0.1531	43.512	870.24			435.12	217.56
Ca^{2+}	40.08	$CaCl_2\ 2H_2O$	147.02	5.6	0.1397	0.1397	20.542	410.83			205.42	102.71
Mg^{2+}	24.305	$MgSO_4\ 7H_2O$	246.47	1.7	0.0699	0.0699	17.239	344.78			172.39	86.20
Na^{+}	22.9898	Na_2SO_4	142.04	2	0.0870	0.0435	6.178	123.57	Total Na (mg/L):	9.0	61.78	30.89
K^{+}	39.0983	K_2SO_4	174.27	2.6	0.0665	0.0332	5.794	115.89			57.94	28.97
Cl^{-}	35.453	$CaCl_2\ 2H_2O$	147.02	9.9	0.2792	0.1396	20.527	410.54			205.27	102.64
SO_4^{2-}	96.0576	$MgSO_4\ 7H_2O$	246.47	6.7	0.0697	0.0697	17.191	343.82	Total SO4 (mg/L):	14.1	171.91	85.96

MIS Recipe:

Compound	mg per 20 L	g per 20 L	mg per 10 L	g per 10 L	mg per 5 L	g per 5 L
$Na_2SiO_3\ 9H_2O$	870.243	0.87024	435.121	0.43512	217.56	0.21756
$CaCl_2\ 2H_2O$	410.834	0.41083	205.417	0.20542	102.71	0.10271
$MgSO_4\ 7H_2O$	344.784	0.34478	172.392	0.17239	86.20	0.08620
Na_2SO_4	123.568	0.12357	61.784	0.06178	30.89	0.03089
K_2SO_4	115.888	0.11589	57.944	0.05794	28.97	0.02897

Example from the Neuse River Estuary of checking the relative concentrations in Major Ion Solution creation.

6 The concentrations to use when creating a major ion solution are in the MIS Recipe box at the bottom of the document. The recipes are highlighted below. Example is the same as in Step 5.



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Na_2SO_4	123.568	0.12357	61.784	0.06178	30.89	0.03089
K_2SO_4	115.888	0.11589	57.944	0.05794	28.97	0.02897

The MIS Recipe for use in creation of 5 L, 10 L, and 20 L of major ion solution.

Create the major ion solution

7 Add approximately 1/20 of your total desired volume of distilled water to your intended container for the major ion solution.

Example: use a 20 L carboy to create 20 L of major ion solution and use graduated cylinders for volumetric measurements.

8 Add in the $Na_2SiO_3x9H_2O$, $CaCl_2x2H_2O$, $MgSO_4x7H_2O$, Na_2SO_4, and K_2SO_4 in concentrations calculated in Step 6 to the distilled water in the major ion solution container.

9 Fill your container to your desired volume using distilled water. Mix the container until all of the salts dissolve.

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