

Dear Water Warriors,

Reduce, reuse n recycle 3R's in context of water motivated us to apply technology and resulted in disconnect from nature.

Actually, a single R, Respect is something that WATER always needed.

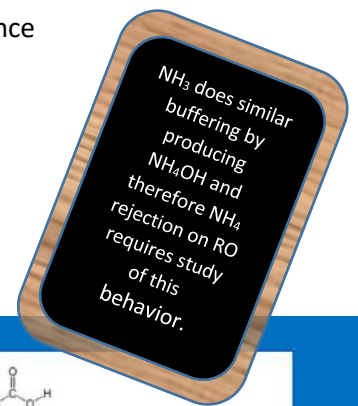


'Waughter' is an attempt to bring the dignity to the reborn water produced out of scientific efforts and adding to available WATER.

Urmi Patel

In this inaugural issue we focus on the "The Chemistry of Water" and try to make it useful to reader for the day-to-day work with water.

- 🌀 How much Acid or Alkali to dose to raise /reduce pH?
- 🌀 Why H<sub>2</sub>O with small molecular weight is passing but NaCl with 58 Molecular weight is rejected by RO membranes?
- 🌀 Buffering of CO<sub>2</sub> & NH<sub>3</sub>
- 🌀 Definitions & Ionic Balance
- 🌀 Significance of CaCO<sub>3</sub>



## Question 1:

A Typical waste water has pH of 6.7 and your task is to raise the pH to 7.5. That's it? Can you calculate quantity of NaOH needed to raise it to 7.5?

If you think you can, as you know  $\text{pH} = -\log [\text{H}^+]$ , don't get surprised to know you are wrong. The natural water contains CO<sub>2</sub> that can buffer H<sup>+</sup> (Refer Image 1.1). So, one should use a different equation of pH in this case as hereunder:

$$\text{pH} = 6.3 + \log \left( \frac{\text{HCO}_3^- \text{ as CaCO}_3}{\text{CO}_2 \text{ as CO}_2} \right) \quad (\text{Eq.1})$$

This brings additional problem to us. How much is HCO<sub>3</sub> in our water? To know that, please visit lab and test two parameters:

### Alkalinity

The alkalinity in water indicates the quantities of hydroxide, carbonate and bicarbonate in water. Water may contain either of the 2 never all 3.

The alkalinity of water is determined using two indicators. Phenolphthalein Indicator gives the P Alkalinity (End Point 8.3 pH) and Methyl Orange Indicator yields the M Alkalinity (End Point 4.2 pH).

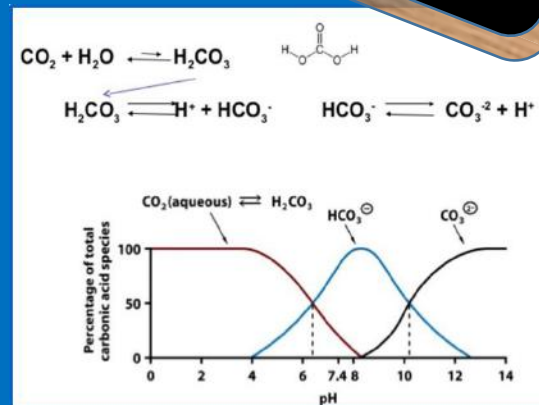


Image 1.1 : The pH and HCO<sub>3</sub>, CO<sub>3</sub> Relation

M alkalinity is also called Total alkalinity.

$$\text{M} = \text{HCO}_3^- + \text{CO}_3^{2-} + \text{OH}^-$$

$$\text{P} = \frac{1}{2} \text{CO}_3^{2-} + \text{OH}^-$$

If we apply modern maths on above we can understand below table:

Alkalinity Relationship			
Relation	Bicarbonate HCO <sub>3</sub> <sup>-</sup>	Carbonate CO <sub>3</sub> <sup>2-</sup>	Hydroxyl OH <sup>-</sup>
P = 0	M	0	0
M = P	0	0	M
M = 2P	0	M	0
M < 2P	0	2 (M-P)	2P-M
M > 2P	M - 2P	2P	0

The Lab technician tests water and reports M as 200 mg/l and P as 0. What it means is  $\text{HCO}_3^-$  is 200 mg/l.

Now if we put this value in [Eq.1](#) and solve it for  $\text{CO}_2$ , we will get:

$$\text{CO}_2 = 79.62 \text{ mg/l as CO}_2$$

In the event Acid or Alkali dosing to Reduce or Raise pH, we should understand what's happening to our equation. By Dosing  $X$  mg/l (ppm) Alkali.

Alkali :  $\uparrow \text{HCO}_3^-$  ,  $\downarrow \text{CO}_2$

Acid :  $\uparrow \text{CO}_2$  ,  $\downarrow \text{HCO}_3^-$

$$\text{pH} = 6.3 + \log \left\{ \frac{[(\text{HCO}_3^- + X) \text{ as CaCO}_3]}{[\text{CO}_2 - 0.88 * X] \text{ as CO}_2} \right\} \text{ (Eq. 1.1.)}$$

Sr No	Parameter	Unit	Value
1	pH Actual	-	6.7
2	pH Required	-	7.5
3	M Alkalinity	mg/l as $\text{CaCO}_3$	200
4	P Alkalinity	mg/l as $\text{CaCO}_3$	0
5	$\text{HCO}_3$	mg/l as $\text{CaCO}_3$	200
6	$\text{CO}_3$	mg/l as $\text{CaCO}_3$	0
7	OH	mg/l as $\text{CaCO}_3$	0
8	$\text{CO}_2$	mg/l as $\text{CO}_2$	79.62
11	Dose of NaOH/HCL	mg/l as $\text{CaCO}_3$	71.05
12	Dose as Such Alkali	mg/l as NaOH	56.84
13	Dose as Such Acid	mg/l as HCl	-53.28
	Available value		
	Desired		
	Fill after undersatnding M, P Relation		

A quick solution shall suggest that for our case we have to add 28.41 mg/l NaOH to raise pH to 7.5 from 6.7, if M Alkalinity is 200 mg/land P Alkalinity is 0 mg/l.



Now lets solve what was [0.88](#).

## Question 2:

**If you have \$5, ₹10 and €15, how much money you have?**

Well, you should know the conversion to bring them to a common unit as the answer shall be in \$, ₹ or €.

Similarly, in water chemistry the addition of impurities shall be done after converting it to a common unit of measurement.

Look at a Material  $\text{CaCO}_3$

$$\begin{aligned} \text{Molecular Weight} &= 40 + 12 + 3 * 16 \\ &= 100 \end{aligned}$$

$$\text{Valency} = 2$$

Therefore,

$$\begin{aligned} \text{Equivalent Weight} &= \text{Molecular Wt.} \div \text{Valency} \\ &= 100 \div 2 \\ &= 50 \end{aligned}$$

Thus, all the dissolved impurities are converted into equivalent  $\text{CaCO}_3$  before any further work.

So if  $\text{CO}_2$  has a molecular weight of  $12 + 2 * 16 = 44$ , since valency of gas is considered 1, the equivalent weight is 44.

Thus 0.88 is conversion of  $\text{CaCO}_3$  (50) into  $\text{CO}_2$  (44). CF to  $\text{CO}_2 = 44/50 = \text{0.88}$ .

On similar lines,

To Convert as such of Ion to equivalent  $\text{CaCO}_3$ , please multiply by:

Chloride	$\text{Cl}^-$	1.41 (50÷35.5)
Sulphate	$\text{SO}_4^{--}$	1.04 (50÷48)
Nitrate	$\text{NO}_3^-$	0.81 (50÷62)

Calcium	$\text{Ca}^{++}$	2.50 (50÷20)
Magnesium	$\text{Mg}^{++}$	4.20 (50÷12)

## Definitions & Ionic Balance

Let's have a look and image 1.2.

H, OH in centre as Cation & Anion is sign of Acidity or Basicity, if free. If bonded as in H-O-H it's Water.

Water contains some free space, not visible to naked eyes called Inter Molecular space (IMS). Impurities hidden in this space are termed dissolved, soluble.

Floating matter; Wood, plants, fibres, plastic, oil all remain on surface as their specific gravity is < 1.

Gases may be dissolved (in IMS), remember term DO it's the O<sub>2</sub> that is in IMS. Gases out of IMS are bubble and may stick to wall or come out in atmosphere.

Ions with +Ve charge are **Cation** and -Ve charge **Anion**.

## Hardness

Ca<sup>++</sup> & Mg<sup>++</sup> ion and others in same column in periodic table (Be<sup>++</sup>, Sr<sup>++</sup>, Ba<sup>++</sup>) have same characteristics. They tend to precipitate and stick to the surface causing scale.

As per rules of electroneutrality, ions though free entity must have a relation with counter ion to balance it's charge. One of the common most example of a relation is Na<sup>+</sup> & Cl<sup>-</sup>.

Hardness that has (M-Alkalinity as balancing ion is Temporary and the one with balancing ion as EMA is termed Permanent. Ca<sup>++</sup> & Mg<sup>++</sup> prefer M-Alkalinity and as long as M-alkalinity is available, all hardness would be temporary. Permanent hardness will appear only when Hardness > Alkalinity, here too alkalinity would love Ca<sup>++</sup> first and Mg<sup>++</sup> next.

## Equivalent Mineral Acidity (EMA)

Cl<sup>-</sup>, SO<sub>4</sub><sup>-</sup> & NO<sub>3</sub><sup>-</sup> are anions as they have -Ve Charge. Imagine their balancing ion is Na<sup>+</sup> and in that case they all appear like salt. NaCl Na<sub>2</sub>SO<sub>4</sub> and NaNO<sub>3</sub> respectively.

In case Na<sup>+</sup> is replaced by H<sup>+</sup> ion, they will look like HCl H<sub>2</sub>SO<sub>4</sub> and HNO<sub>3</sub>, the mineral acids. Thus, the anions that have potential to form mineral acids have a family name EMA.

**Total Anion**, therefore is sum of two differentiating anions **1. EMA & 2. M- Alkalinity**.

$$TA = M\text{-Alkalinity} + EMA$$

Rules of electroneutrality means Total Anion should be equal to Total Cation (in terms of same unit ppm as CaCO<sub>3</sub>), we say;

Total Cation = Total Anion ; And that means we need to now calculate the balance monovalent ions (Na<sup>+</sup>, K<sup>+</sup> etc) by subtraction:

$$Na^+ + K^+ = Total\ Cation - Total\ Hardness$$

Fe<sup>++</sup>, Cu<sup>++</sup> and other metallic ions are low in concentrations, and can be oxidized, precipitated and dealt like a suspended matter hence not calculated normally in ionic balance as a matter of simplicity.

Gases : CO <sub>2</sub> , O <sub>2</sub> , H <sub>2</sub> S	
Floating Matter : Wood Chips, Plants, Oil	
Clay, Silt, Organic Matter, Turbidity	
Colloids	
H <sup>+</sup>	OH <sup>-</sup>
Na <sup>+</sup> K <sup>+</sup>	HCO <sub>3</sub> <sup>-</sup> CO <sub>3</sub> <sup>-</sup>
Ca <sup>++</sup> Mg <sup>++</sup>	Cl <sup>-</sup> SO <sub>4</sub> <sup>-</sup> NO <sub>3</sub> <sup>-</sup>
Fe <sup>++</sup> Mn <sup>++</sup> → 3 Val.	PO <sub>4</sub> <sup>-</sup>
Silica, Sugar, Phenol	
Organics, COD,BOD,TOC etc.	Micro Organisms

Image 1.2 : Definition & Ionic Balance

So, a good engineer will walk 11 steps on the water analysis report before doing anything, to be sure he/she is working in right direction.

- Step 1 : Check Adequacy of Data
- Step 2 : Convert Impurities to CaCO<sub>3</sub>, if not reported as CaCO<sub>3</sub>
- Step 3 : Calculate EMA
- Step 4 : Calculate Total Anion ( = EMA + M-Alkalinity)
- Step 5 : Calculate Total Cation (TC = TA, H<sub>2</sub>O is Electro neutral)
- Step 6 : Find Na<sup>+</sup> + K<sup>+</sup> = TC – Total Hardness
- Step 6A : If you get – Ve Value, it indicates error in report
- Step 7 : Observe M and P Value
- Step 8 : Report HCO<sub>3</sub><sup>-</sup>, CO<sub>3</sub><sup>-</sup> and OH<sup>-</sup>
- Step 9 : Observe Total Hardness and M-Alkalinity
- Step 10 : Report Temporary and Permanent Hardness
- Step 11 : Report Sodium Alkalinity

## Reverse Osmosis & Chemistry:

This subject of salt behaviours needs explanation at fundamental levels.

Look at the table below:

Molecule	Molecular Weight	Size
H <sub>2</sub> O	18	~ 2.75 ANGSTROM
Na	23	Ionic Radius 154 pm
Na <sup>+</sup>	23	Ionic Radius 102 pm
F <sup>-</sup>	35.5	Ionic Radius 133 pm

pm IS peta meter  $1 \times 10^{-15}$

Wonder why the water is filtered across a composite polyamide membrane RO membrane with distributed pore size in the range of 3 – 10 Å, but Na<sup>+</sup> or F<sup>-</sup> which is at-least 1000 times smaller in size cannot?

The answer lies in understanding hydration.

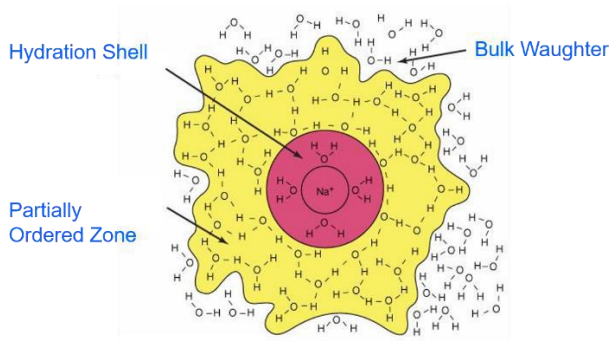


Image 1.3 : Hydration of Na<sup>+</sup> in H<sub>2</sub>O

The ions that are hydrated cannot move alone; they must take the hydration shell fully as well as little bit of partially ordered zone when they move.

Furthermore, a single Na<sup>+</sup> can not pass alone even if opportunity exists, as we cannot have Charge transferring across membrane. Counter charge e.g. Cl<sup>-</sup> shall also have the mood to go with Na<sup>+</sup>, this is very improbable and thus bulk of NaCl is rejected across RO membrane.

On different lines, find out why NH<sub>4</sub><sup>+</sup>, NO<sub>3</sub><sup>-</sup> is not rejected well on membranes but pass. **Waughter** is a wonder material and we consistently learn more.

## जल जीवन जननी !!

Vaishali Singh our summer intern, daughter of a farmer and an aspiring Chemical Engineer sow the seeds of this magazine; we wish her good luck !!



**Sanjeev Srivastava**

Lead Technology at Aktion Consultancy

3w · 🌐

'Waughter'

Jal jeevan and Janni.. the word 'waughter' heard many times as water never spelled to souls like daughter.

It's the name of our magazine, the first addition to be published on Jan 26, 2021. Thank you **Vaishali Singh**

You have created a new word WAUGHTER for entire water and waste water afterbirth.

#water #conservation  
#environment #climatechange #nature #trees  
#globalwarming #sustainability

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## Our world is Waughter

The technical knowledge share attempt of Aktion Consultancy and the contents in the magazine shall be qualified by Sanjeev Srivastava our Technology Lead.

Our next edition focuses on Organic Chemistry : **COD**

Please feel free to write or contact Ms Urmi Patel [info@aktionconsultancy.com](mailto:info@aktionconsultancy.com) 90991 55227

**Aktion Consultancy**  
C 1305, Rajyash Rise  
New Vasana,  
Nr Vishala Circle,  
NH-08,  
Ahmedabad - 380 051 India



Alka Srivastava - Founder