Chemicals in Water & Wastewater Treatment

Chemical Used for Precipitation

1. Aluminum sulfate – $Al_2 (SO_4)_3.18\ H_2O$
2. Aluminum chloride – $AlCl_3$
3. Calcium hydroxide – $Ca (OH)_2$
4. Lime
5. Ferric chloride – $FeCl_3$
6. Ferric sulfate – $Fe_2 (SO_4)_3$
7. Copperas – $FeSO_4.7H_2O$

Chemical Used for Neutralization

1. Calcium carbonate – $CaCo_3$
2. Calcium Oxide – CaO
3. Sodium bicarbonate – $NaHCO_3$
4. Sodium carbonate – Na_2CO_3
5. Sodium hydroxide – NaOH
6. Carbonic acid – H_2CO_3 – Gas (CO_2)
7. Hydrochloric acid – HCl
8. Sulfuric acid – H_2SO_4

Chemical Agents that have been used as Disinfectants

1. Chlorine and its compounds.
2. Bromine
3. Iodine
4. Ozone
5. Phenol & Phenolic compound
6. Alcohol
7. Heavy metals and related compounds
8. Dyes
9. Soap and synthetic detergents
10. Quaternary ammonium compound
11. Hydrogen peroxide
12. Per acetic acid
13. Various alkalies
14. Various acids of these most common disinfectants are the oxidizing chemicals and chlorine is the one used most universally.

Characteristics of Chlorine Compound

The principle chlorine compounds used at wastewater treatment plants are Cl_2, Sodium hypochlorite (NaOCl), Calcium hypochlorite [$Ca(OCl_2)$] and Chlorine dioxide (ClO_2). NaOCl is the safety concerns related to handling and storage of liquid chlorine.

Chlorine – Cl_2 can be present as a gas or a liquid. Cl_2 gas is greenish-yellow in color and about 2.48 times as heavy as air. Liquid chlorine is an amber color and about 1.44 times as heavy as water. Unconfined liquid chlorine vaporizes rapidly to a gas at standard temperature and pressure. With 1 liter of liquid yielding about 450 liters of gas. Chlorine is moderately soluble in water with max. The solubility of about 1% at 10 ^{0}C.

Chlorine Reaction in Water

When chlorine in the form of Cl_2 gas is added to water two reactions take place, Hydrolysis & ionization. Hydrolysis may be defined as the reaction in which chlorine gas combine with water to form hypochlorous acid (HOCl). $Cl_2 + H_2O$ @ $HOCl + H^+ + Cl$ó. The equilibrium constant K_H for this reaction is

$$K_H = \frac{[HOCl]\,[H+]\,[Cl]}{Cl_2} = 4.5 \times 10^{-4}\ (\text{mole/l})^2 \text{ at } 25\ ^0\text{C}.$$

Because of the magnitude of the equilibrium constant. Large quantities of Cl can be dissolved in water. Ionization of hypochlorous acid to hypochlorite ion (OCl^-) may be defined as

$$HOCl \leftrightarrow H+ + OCl^-$$

The ionization constant Ki for this reaction is

$$Ki = \frac{[H+]\,[OCl^-]}{[HOCl]} = 3\times10^{-8} \text{ mole/l at } 25\ ^0\text{C}.$$

The variation in the value of Ki with the temperature is reported in other references

The total quantity of HOCl and OCl^- present in water called the free available chlorine. The amount of nitrogen trichloride present in negligible up to chlorine to nitrogen ratio of 2.0. The chlorine is these compounds is called combined available chlorine. Residual, Combine or free.

Dechlorinating Compound

Compound	Formula	M.wt	Stoichiometric amount mg.	Range use
Sulfur dioxide	SO_2	64.09	0.903	1.0 - 1.2 mg/l
Sodium sulfite	Na_2SO_3	126.04	1.775	1.8 - 2 mg/l
Sodium bisulfite	$NaSO_3$	104.06	1.465	1.5 - 1.7 mg/l
Sodium metabisulfite	$Na_2S_2O_5$	190.1	1.338	1.4 - 1.6 mg/l
Sodium thiosufite	$Na_2S_2O_3$	112.02	0.556	0.6 - 0.9 mg/l

Typical dosage for various chlorination applications in wastewater collection and treatment

Application	Dosage range m/l
Collection	
Corrosion control (H_2S)	2 – 9 [a]
Odor control	2 – 9 [a]
Slime growth control	1 – 10
Treatment	
BOD reduction	0.5 – 2 [b]
Digester & Imhoff tank foaming control	2 – 15
Digester supernatant oxidation	20 - 140
Ferrous sulfate oxidation	-- c
Filter fly control	0.1 – 0.5
Filter ponding control	1 – 10
Grease removal	2 – 10
Sludge bulking control	1 – 10

Where,
a = per mg/l of H_2S,
b = per mg/l of $B.O.D._5$ destroyed
c= $6FeSO_4.7H_2O+3Cl_2$ @ $2Fe_2 (SO_4)3+42H_2O$

Test	Description
Total solid (TS)	The residue remaining after a wastewater sample has to be evaporated and dried at specified temperature ($103\ ^0C$ to $105\ ^0C$)
Total volatile solid (TVS)	Those solids that can be volatilized and burned off when the T.S. are ignited ($500\ ^0C \pm 50\ ^0C$)

TS = $\frac{\text{(Mass of evaporating dish + residue g.) – (Mass of evaporating dish)}}{\text{Sample taken}}$

TVS = $\frac{\text{(Mass of evaporating dish + residue) – (Mass of evaporating dish + residue after ignition)}}{\text{Sample taken}}$

TSS = $\frac{\text{(Residue on filter after drying) – (Tare mass of filter after drying)}}{\text{Sample taken}}$

VSS = (Residue on filter after drying) – (Residue on filter after ignition)
Sample taken

TDS = **TS - TSS**

Fresh wastewater is usually a light brownish grow color, however as the travel time in the collection system increased, and more anaerobic condition develop the color of the wastewater changes sequentially from gray to dark grow and ultimately to back when the color of wastewater is black, the waste water is often described as septic. In most cases, the gray, dark gray and black color of the wastewater is due to the formation of metallic sulfides, which form as the sulfide produces under as aerobic condition reacts with the metals in wastewater.

Temperature: Temperature of wastewater is higher than that of the local water supply because of the addition of warm water from household and industrial activities.

Constituent	Reason for important
Suspended solids	Suspended Solids can lead to the development of sludge deposits and anaerobic condition when untreated waste is discharged into the aquatic environment.
Biodegradable organics	Composed mainly of proteins, carbohydrates and fats biodegradable organics are measured most commonly is terms of BOD and COD. If discharged untreated wastewater to the environment their biological stabilization can lead to the depletion of natural oxygen resources and the development of the septic condition.
Pathogens	Communicable diseases can be transmitted by the pathogenic organism that may be present in wastewater.
Nutrients	Both nitrogen and phosphorous along with carbon are essential nutrients for growth when discharged to the aquatic environment these nutrients can lead to the growth of undesirable aquatic life when discharged in the excessive amount of land they can also result in pollution of groundwater.

Scaling Control

1. Acidifying to reduce pH and alkalinity
2. Reducing calcium concentration by ion exchange or lime softening.
3. Adding scale inhibitor chemical (antiscalant) to increase the apparent solubility of CaCo3 in the concentration stream.
4. Lowering the product recovery rate

Molecular formulas of some of the most common water treatment chemicals

Common Name	Chemical Name	Formula
	Aluminum hydroxide	$Al(OH)_3$
Filter alum	Aluminum sulfate	$Al_2(SO_4)_3 \cdot 14H_2O$
Ammonia gas, Ammonia	Ammonia	NH_3
Ammonia	Ammonium hydroxide	NH_4OH
	Calcium bicarbonate	$Ca(HCO_3)_2$
Limestone	Calcium carbonate	$CaCO_3$
Hydrated lime	Calcium hydroxide	$Ca(OH)_2$
HTH	Calcium hypochlorite	$Ca(OCl)$
Quick lime	Calcium oxide	CaO
Chloride of lime	Calcium oxychloride	$CaOCl_2$
Gypsum	Calcium sulfate	$CaSO_4$
Dry ice	Carbon dioxide	CO_2
	Carbonic acid	H_2CO_3
Liquid chlorine	Chlorine	Cl_2
	Chlorine dioxide	ClO_2
Blue vitriol	Cupric sulfate	$CuSO_4 \cdot 5H_2O$
	Dichloramine	$NHCl_2$
Ferrichlor, Chloride of Iron	Ferric chloride	$FeCl_3 \cdot 6H_2O$
Muriatic acid	Hydrochloric acid	HCl
	Hypochlorous acid	$HOCl$
	Methane	CH_4
	Monochloramine	NH_2Cl
	Nitrogen trichloride	NCl_3
Soda	Sodium bicarbonate	$NaHCO_3$
Soda ash	Sodium carbonate	Na_2CO_3
Salt	Sodium chloride	$NaCl$
Lye, Caustic soda	Sodium hydroxide	$NaOH$
	Sodium phosphate	$Na_3PO_4 \cdot 12H_2O$
Oil of vitriol, Vitriol	Sulfuric acid	H_2SO_4
Water	Water	H_2O

Some of the common polyatomic ions

Molecular Formula	Common Name
NH_4^+	Ammonium
H_3O^+	Hydronium
Hg_2^{2+}	Mercury (I)
OH^-	Hydroxide
CN^-	Cyanide
CO_3^{2-}	Carbonate
$CH_3CO_2^-$	Acetate
$C_2O_4^{2-}$	Oxalate
SO_4^{2-}	Sulfate
SO_3^{2-}	Sulfite
NO_3^-	Nitrate
NO_2^-	Nitrite
PO_4^{3-}	Phosphate
MnO_4^-	Permanganate
CrO_4^{2-}	Chromate
$Cr_2O_7^{2-}$	Dichromate
ClO_4^-	Perchlorate
ClO_3^-	Chlorate
ClO_2^-	Chlorite
ClO^-	Hypochlorite