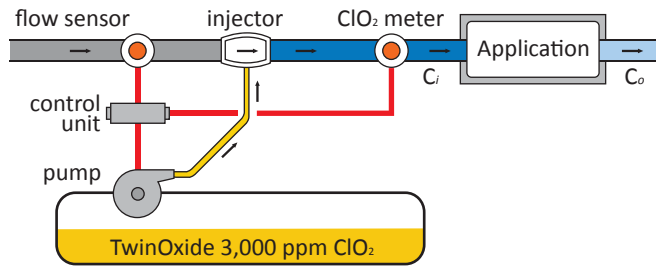


## COMPARISON BETWEEN TWINOXIDE® AND CLASSICAL CHLORINE DIOXIDE GENERATOR SYSTEM

### TWINOXIDE® SYSTEMS



TwinOxide® treatment does not produce any THM or hardly produce any other by products in water, so there is no need to use Carbon filter to remove THM or any other by products and UV light to remove residual chlorine dioxide from treated water that is why additional water treatment is not required to maintain microbiological stability and this is a huge cost savings. TwinOxide® does not have any taste and smell repercussions on beer quality, as well as it does not affect yeast mortality in fermentor and prevents any harmful bacterial growth which inhibits the process and spoils the product quality. So no need to through batches of bad quality due to spoilage this is also huge cost savings. The water goes everywhere and additional disinfection cost is not there.

Very negligible by-products see the table.

### CLASSICAL CHLORINEDIOXIDE SYSTEMS



In case of Classical Chlorine Dioxide application in breweries UV treatment on mains supply and In case of chlorine disinfectant use in breweries the requirement to carry out carbon filtration, typically for removal of THM (trihalomethanes) on mains supplies, removes the residual mains chlorine. In these circumstances additional water treatment is advised to maintain microbiological stability. That again increase costs and risks.

Very high toxic by-products level

By products levels in various chlorine dioxide systems

Product	ClO <sub>2</sub> (ppm)	ClO <sub>2</sub> (ppm)	ClO <sub>3</sub> (ppm)	pH
Dry reactants added to solutions	500	4326	241	1.0
Engelhard (BASF) Aseptrol Tablets	500	471	285	3.0
Rowpar® sodium chlorite solution	500	573000	34500	5.0
TwinOxide® Solution	3000	1.8	<2.5	3.0

TwinOxide® in Powder component form very stable which can be stored with 5 years guaranteed shelf life and in liquid finished product 0.3% chlorine dioxide solution ready for application 30-60 days stability.

### TwinOxide® stability in solution form

time after preparation	chlorine dioxide [g/l]	chlorite [mg/l]	chlorate [mg/l]
test method	analogue DIN 38408-T5	DIN EN ISO 10304-4	DIN EN ISO 10304-4
1 week	3,0	1,8	< 2,5
2 weeks	3,3	2,3	< 2,5
3 weeks	2,9	7,3	< 2,5
4 weeks	3,0	7,0	< 2,5
5 weeks	3,0	3,4	< 2,5
6 weeks	2,3	0,5	< 2,5
7 weeks	2,1	0,9	< 2,5
8 weeks	2,0	3,1	< 2,5
16 weeks	2,5	2,9	< 2,5

Classical gaseous chlorine dioxide in water is very unstable.

## TWINOXIDE<sup>®</sup> SYSTEMS

TwinOxide<sup>®</sup> is delivered as two components in powder form and based on actual need these two components are mixed in designated amount of water. After 1-3 hours, the produced 0.3% chlorine dioxide solution is ready to use and this solution has a chemical halftime of 30 - 60 days.

The TwinOxide<sup>®</sup> two-component system in the unmixed form has an imperishable shelf life. It has overcome all the problems of classical generation of chlorine dioxide mentioned in the same row and next column.

TwinOxide<sup>®</sup> in production process will reduce cost of addition of other disinfectants and antibacterial agent in the process and also will scale up the production level.

TwinOxide<sup>®</sup> does not Spoil RO membranes, ion exchange membranes and active carbon beds and can be used to remove biofouling in these places. It enhance the life of membranes and save a lot of money.

TwinOxide<sup>®</sup> has very very low demand in water with high organic organic matter.

Potential disposal problems is not there because of negligible by products.

Stainless steel or any other metals used in brewery process lines and tanks and equipments are not corroded by TwinOxide<sup>®</sup>.

Easy to produce, store, transport and apply.

Due to non toxic nature of TwinOxide<sup>®</sup> Brewery TwinOxide<sup>®</sup> practices does not need to be performed in under critical controlled conditions, in order to comply with the regulations and the maximal permissible exposure levels of TwinOxide<sup>®</sup> at the working place, that saves a huge amount of costs.

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## CLASSICAL CHLORINE DIOXIDE SYSTEMS

The problems forthcoming from the eight classical methods of generating chlorine dioxide have always been considered as very limiting and difficult and have restrained to an extent the large scale use of chlorine dioxide solution in (potable) water systems, although it is applied widely around the world:

- Material unfriendly (corrosive);
- Limited stability (gone within 6 hours);
- Risk to personnel (explosions may occur);
- On site generation, instantly applied;
- Not transportable and storable;
- Gaseous;
- Taste/odour problems;
- Substantial level of undesirable byproducts (e.g. THM's, HAA's) => environmental load;
- Dosing inaccuracy due to impurity of the solution.

Classical chlorine dioxide is risky to be allowed in process or dilution of beer and for other operations where TwinOxide<sup>®</sup> directly comes in contact with beer.

Classical chlorine dioxide spoil RO membranes, ion exchange membranes and active carbon beds and can not be used to remove biofouling in these places.

In comparision to TwinOxide<sup>®</sup> classical chlorine dioxide is poorer in terms of demand in water with high organic matter.

Potential disposal problems is high because of high by products.

There is more chance that Stainless steel or any other metals used in brewery process lines and tanks and equipments are corroded by classical chlorine dioxide generators.

Hazardous production process and no storage is possible, not transportable and very complicated to apply.

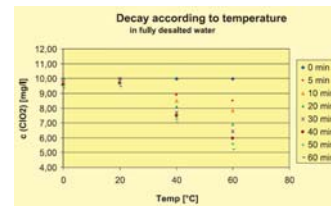
Due to toxic nature of chlorine dioxide gas production and controlled delivery by generator Brewery classical chlorine dioxide practices need to be performed in under critical controlled conditions, in order to comply with the regulations and the maximal permissible exposure levels of chlorine dioxide at the working place.

Control of production, control on production and dosing is complicated and not user friendly and risky



### TWINOXIDE<sup>®</sup> SYSTEMS

### CLASSICAL CHLORINE DIOXIDE SYSTEMS

Long shelf life of chemicals upto 25 years.	Very limited shelf life.
Easy to install and monitor easily and sensitively because of large residual availability.	Difficult to install and monitor.
No taste and smell repercussion in beer	Taste and smell repercussion chances may be there if by product production is not controlled.
Very effective and less CT values against bacteria and viruses.	Less stronger than TwinOxide <sup>®</sup> .
Funguses can be removed easily by TwinOxide <sup>®</sup> .	Less effective against fungus in comparison to TwinOxide <sup>®</sup> .
99% ClO <sub>2</sub> purity.	Even though by rule of EPA they have to generate 90% ClO <sub>2</sub> but they rarely do so.
<p>More thermal stability.</p> <p>With TwinOxide<sup>®</sup> 1 ppm residual of TwinOxide<sup>®</sup> solution in natural water will not decay or gas off even after 0, 5, 10, 15, 20, 30 minutes and 45 minutes but it may decay a very little amount after 60 minutes it may become 0.9 ppm, which may not be only because of heat. Even after 60°C the decay was not significant. That means TwinOxide<sup>®</sup> is more stable with heat at &gt;40°C.</p>	<p>The temperature influence on chlorine dioxide molecule in water solution is dominating in higher application concentrations only, compared with oxidizable water substances as already reported with classical chlorine dioxide. In higher concentration of about 10 ppm and temperature over 20°C plays a dominating role for the decay [see fig. 1]. Experiments are already done with classical chlorine dioxide solution prepared by hydrochloric acid and sodium chlorite method.</p> <div data-bbox="967 1128 1299 1332" data-label="Figure">  </div> <p>Fig. 1: Influence of temperature on the decay of a chlorine dioxide solution of 10 mg/l in fully desalted water.</p> <p>Particularly with temperatures above 40°C and an initial solution (desalted water) of 10 mg/l, a chlorine dioxide decay of up to 50 percent of the initial concentration could be observed within one hour. Within the scope of an optimized application, however, strongly degrading substances, predominantly iron, shall be removed in order to ultimately also avoid sedimentations on the surfaces. Different salt compositions of the water have no important influence on the decay of the chlorine dioxide.</p>
More selectivity in oxidation.	Less selectivity in oxidation.
More residual effect.	Less residual effect.
More effectiveness.	Less effectiveness.
Least by-product.	More by-product.
More transportability.	No transportability.
TwinOxide <sup>®</sup> can be transported in a small trolley and can be sprayed in various places.	Classical gaseous generators can not be transported in a small trolley and can be sprayed in various places.



## TWINOXIDE® SYSTEMS

More savings in man power requirement and maintenance.

Less cost and huge cost savings in many aspects.

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### Capital Costs - Chlorine Replacement

Equipment	Marshall St.	East Plant	Northeast Plant
Generators	\$80,000	\$80,000	\$80,000
Storage Tank(s)	\$50,000	\$30,000	\$50,000
Ferrous Feed System	\$10,000	\$6,000	\$10,000
Associated Piping	\$35,000	\$20,000	\$35,000
Building	\$150,000	\$100,000	\$150,000
Chlorine Contact Chamber Cover	\$88,000	\$40,000	\$165,000
Instrumentation	\$25,000	\$25,000	\$25,000
<b>Subtotal</b>	<b>\$438,000</b>	<b>\$301,000</b>	<b>\$515,000</b>
Pilot Test	\$125,000	-	-
<b>Total</b>	<b>\$563,000</b>	<b>\$301,000</b>	<b>\$515,000</b>

*This price assumes a prefabricated modular building to house the generating equipment and precursor chemicals. Generator size is based on plant capacities, and process water and electricity would have to be provided to the building to create a motive source for the ClO<sub>2</sub> generator output. All existing and proposed chlorine contact chambers are assumed sufficient for chlorine dioxide application, therefore, no new reactors are necessary.*

## CLASSICAL CHLORINE DIOXIDE SYSTEMS

Less savings in man power requirement and maintenance.

Cost of installation and operation is high and still chemical cost is also there.

### Operating Costs - Chlorine Replacement

Parameter	Marshall St.	East Plant	Northeast Plant
Average Flow (mgd)	7	2.5	6
Lbs/d ClO <sub>2</sub> (at 3 mg/l)	175	63	150
Annual ClO <sub>2</sub> Cost	\$150,000	\$53,500	\$128,200
Lbs/d FeCl <sub>2</sub> (at 4.8 mg/l)	550	250	475
Annual FeCl <sub>2</sub> Cost	\$24,000	\$11,000	\$21,000
<b>Total Annual Cost with FeCl<sub>2</sub></b>	<b>\$174,000</b>	<b>\$64,500</b>	<b>\$149,200</b>

*This table lists the operating costs for each Clearwater Wastewater Treatment Plant, based on the average flow rates and a chlorine dioxide dose estimated at 3 mg/l.*

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### The arguments that should be considered while calculating the price of TwinOxide®

- Cost of ownership of the installation that should be there for using chlorine dioxide generator or classical chlorine dioxide.
- Cost of certified personnel to use chlorine dioxide gas generators.
- Cost of hazard during generation of chlorine dioxide gas.
- Cost of liability insurance due to risk of using classical chlorine dioxide gas (explosion and implosion risk).
- Cost of pipeline corrosion due to use of gaseous chlorine dioxide generated by generator.
- No storage risk but disadvantage of transportability and loss for that due to choosing other additional options for disinfection.
- Negligible by products and free chlorine, chlorate, chloride & chlorite when we use TwinOxide®. So cost of not damaging environment and advantages due to that.

Criteria	TwinOxide®	Chlorine
Bio film eradication in the water circuit	TwinOxide® penetrates the bio film completely and eradicates very well.	In drinking water concentration only limited eradication due to lack of penetration of the bio film.
Deodorization	Deodorization characteristics and therefore smell and taste causers in water like Phenols, Amines and Algae are avoided or not produced.	Production of smell and taste influencers by reaction with Phenols, Amines and Algae.
pH-Value dependability during disinfection	Disinfection is pH-Value independent within a bandwidth of pH 4-10. Effective disinfection of concrete based pipeline circuits.	Disinfection only at pH-values < 7.5. Limited disinfection of concrete based pipeline circuits.
Building of cancer causing THM's and AOX	No THM building in drinking water. Only very limited AOX building.	Strong building due to reaction with organic material in water.
Building of mucous glands or mucous membranes irritating chloramines	No reaction with primary or secondary amines and therefore no chloramines are built. The typical swimming pool odor is disturbed by oxidation.	All amines are transformed to chloramines when reacting with chlorine.
Biocide and anti-virus working	Excellent biocide and anti-virus characteristics. When pH-values exceed >7.5 ca. 20-30 times stronger disinfectant working compared to chlorine.	Good biocides characteristics. Bad anti-virus characteristics. The biocide characteristics decrease strong when the pH-value exceeds 7.5.
Algicidal working	Excellent algicidal working by permanent disinfection (0.2-0.5 mg/L) dosage.	Only when using high concentrated dosages of chlorine.
Oxidizing working	Up to 2.6 times stronger oxidation compared to chlorine. Oxidation takes place by oxygen.	Strong oxidation that only oxidizes by AOX-building.
Net stability	TwinOxide® is still stabile in closed systems at temperatures 30-40 degrees Celsius. Reacts more selective than chlorine.	Temperatures >30 degrees Celsius disturb chlorine very fast. Less selective reaction then chlorine dioxide.
Level of corrosion	TwinOxide® contains hardly any chlorine and therefore the level of corrosion is very limited.	High corrosion level.
Rinsing capacity	Excellent rinsing capacities and therefore less rinsing water required for the desired effect.	Water containing chlorine has a strong adhesion characteristic and therefore a lot of rinsing water is required for the desired effect.

**1 liter of TwinOxide® 0.3% solution at 0.05 ppm disinfects 60,000 liters of water.**  
**1 liter of TwinOxide® 0.3% solution at 3 ppb disinfects up to 1,000,000 liters of water!**