

Downflow Gas Contactor: A Novel Technology For Effluent Treatment

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Abstract

Many industrial activities produce recalcitrant effluent that can't be easily treated and is detrimental to the environment. This necessitates physicochemical treatment to decompose industrial effluents to innocuous products and improve quality of treated effluent. Water is a key resource in the industry and with its limited availability and shortage in the last few years, the industry needs to work towards appropriate effluent treatment and recycle of treated water for suitable use. This article details a new Downflow Gas Contactor Reactor technology which is very effective in effluent treatment. This set-up is provided with a UV system. UV and H₂O₂ are used especially for recalcitrant chemicals like phenol, nitrogen-containing chemicals. The set-up has been used for trials of industrial effluent streams. The results obtained are interesting, some of which are presented in this article.

Downflow Gas Contactor

DGC technology with UV & TiO₂ catalyst can treat most of the industrial effluents to reduce COD/ BOD within regulation limits, whereby after tertiary treatment of the effluent, the water could be recycled for suitable use.

DGC is a downflow co-current device used for efficient mass transfer. It consists of a cylindrical section with a Specially Designed Inlet (SDI) at its entry (at the top), allowing both liquid and gas into the reactor (see Fig 1). SDI is the heart of this reactor technology. For a few specific applications, an additional inverted conical section may be provided after the cylindrical section, for improved performance. Gas is concurrently fed into the incoming liquid stream immediately prior to the column inlet through the SDI.

DGC dimensions and configuration depend on the application and operating conditions. As the continu-

ous phase expands into the column, part of the kinetic energy imparted to the fluid on its passage through the SDI is used in the formation of interfacial area. Intense turbulence and shear at the interface results in efficient gas-liquid mixing and allows mass transfer operations to approach equilibrium in very short contact times. Due to small gas bubbles and high mass transfer of gas into a liquid, the gas-liquid reaction proceeds fast.

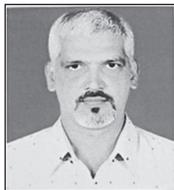
DGC can be operated at high pressures and temperatures, and in batch and continuous mode.

The inherent simple design and operation of DGC offer specific advantages over other conventional contactors/ reactors, as listed below:

- Lower power consumption.
- Smaller operating volume.
- 100% gas utilization and >95% approach to equilibrium in short contact time.

Since 2014, STEP is associated with WRK Design and Services Ltd., UK (<http://www.wrkdesign.co.uk>) for their novel Downflow Gas Contactor (DGC) reactor technology, which can be used for effluent treatment, chemical reactions and gas absorption. STEP has set up a DGC pilot unit in association with Snowtech Equipments Pvt. Ltd., Navi Mumbai for industrial effluent treatment to reduce COD/ BOD.

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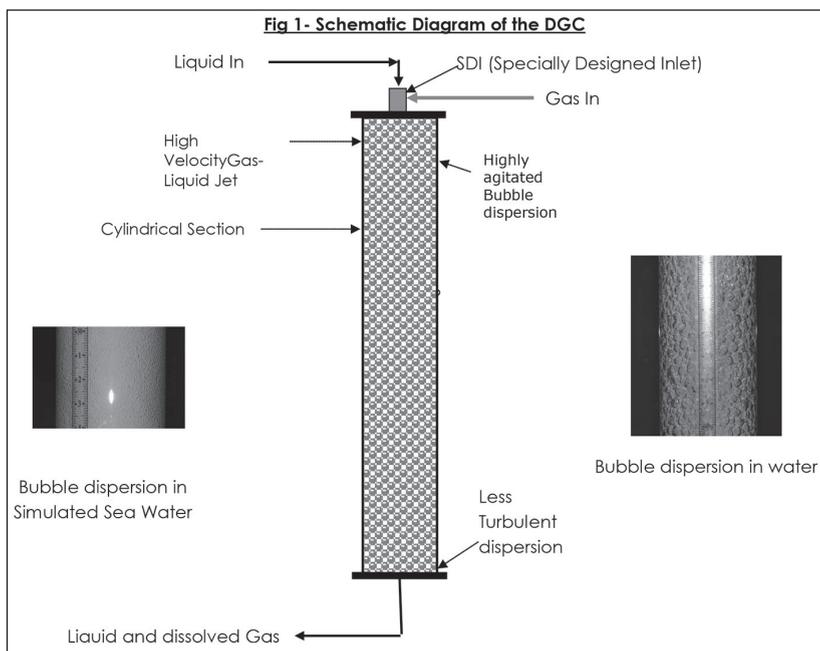


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- ❑ Photocatalytic degradation of chlorine & chloroamines in swimming pool water
- ❑ Treatment & breakdown of endocrine disruptors in sewage water

Trials on Industrial Effluents

STEP has conducted trials on more than 25 different industrial effluent streams on DGC using air/ oxygen or combination of air, H₂O₂ & UV for COD/ BOD reduction. These effluents were from different Indian companies including a Common Effluent Treatment Plant (CETP). Some of the streams were known to be difficult to degrade as they contained phenols and nitrogen containing chemicals. Results of some of these trials are given in table 1.

- High interfacial area (1000 –6000 m²/ m³), which improves reaction rates and reaction specificity.
- No internal moving parts like stirrer & hence lower operating costs.
- Higher gas hold-up (40-50%)
- Easy scale-up without loss in efficiency.

Effluent Treatment with DGC

DGC can be used efficiently in biological waste & effluent treatment; and in Advanced Oxidation Processes. It operates with air, oxygen, ozone, H₂O₂ and UV, individually or in combination. Photocatalytic oxidation using titanium dioxide along with UV, can breakdown “difficult” pollutants.

We have carried out trials on various industrial effluents in the UK (by WRK) and in India (by STEP). These effluent streams include:

- ❑ Industrial wastes containing chlorophenols, propylene glycol, methanol, cyclohexanedione, phenols, mixed alcohols, sugar condensate, sulfur chemicals, pharma & specialty chemicals, nitrogen containing chemicals.
- ❑ Landfill leachates
- ❑ Food industry waste viz. dairy, whey, orange, beverages

Table 1. Results of effluent treatment trials.

Sr. No	Stream	Oxidants	Operated Hours	Reduction In Parameters (%)	Initial Values (ppm)
1.	CETP	Air	6 to 8	COD-60 max, BOD-40 max, TDS-40 max	COD-2000, BOD-700, TDS-11000
2.	MEE condensate (pharma)	Air, H ₂ O ₂ & UV	5	COD- 49 max, TDS- 90 max, TAN-36 max	COD-12950, TDS- 2300, TAN- 2870
3.	Speciality chemicals, sulphur containing stream	Air, H ₂ O ₂ & UV	8	COD-68 max, BOD-70 max	COD- 6400, BOD- 3700, TDS-14000
4.	Phenols containing stream	Air, H ₂ O ₂ / UV	6	COD- 54, BOD- 56, phenols- 60	COD-24200, BOD- 9600, TDS-25000, phenols-520
5.	Alcohol containing stream	Air & H ₂ O ₂	4	COD- 35 max, BOD- 35 max, TAN- 95 max	COD-7900, BOD- 3100, TAN -93
6	Sulphate & Phosphate containing streams	Air & H ₂ O ₂ /UV	8	COD-20 & 28, TDS – 17 & Nil	COD-171000, TDS- 300000 & COD-32200, TDS- 137500
7	Speciality & nitrogen containing Chemicals	Air & H ₂ O ₂ /UV	9	COD-47, BOD- 45, TAN- 60	COD-110000, BOD- 45000, TDS- 258000, TAN-6800
8	Sugar condensate	Air	4	COD- 83	COD- 3500
9	Speciality Chemicals	Air	6	COD- 25, BOD- 27, TDS-11	COD-376300, BOD- 150000, TDS-390000
10	Speciality Chemicals containing phenol & nitrogen	Air + UV + H ₂ O ₂	10	COD- 36, Phenol- 33, TAN- 34	COD- 10000, phenols- 400, TAN- 196

Note: Trials 1, 2, 3, 5 & 10 were carried out under different process parameters. The reported results for these trials are the maximum reduction achieved.

Key results of the Trials:

- 1) Effluents were treated with a wide range of COD (2000 to 376300 ppm), BOD (700 to 150000 ppm) and TDS (2300 to 390000 ppm). COD reduction achieved was up to 83% in 4 to 10 hours.
- 2) For trial 6, 7 & 9 with high TDS (between 137500 to 390000 ppm), COD level reduced by 20 to 50% even when the initial COD level was very high (between 110000 & 376300 ppm). This is an important feature of DGC since conventional bio-aeration used in industry for effluent treatment, cannot function efficiently & effectively with high TDS.
- 3) For effluents with easy to degrade chemicals, only air could reduce COD by 25% (trial 9) and 80% (trial 8). Even for CETP (trial 1) with only air, we achieved around 60% COD reduction.
- 4) BOD generally reduced in-line with COD reduction levels.
- 5) In 4 trials (no. 2, 4, 7 & 10), TAN has reduced by 36 to 95%, with initial TAN levels between 93 to 6800 ppm.
- 6) TDS also has been reduced in few cases viz. trial nos. 1, 2, 6 & 9. We expect this TDS (which has reduced) to be from organic acid salt.
- 7) Phenols in effluent have been reduced by 60% from the initial level of 520 ppm (trial 4) in 6 hours, and 33% (trial 10) from an initial level of 400 ppm in 10 hours.

The above results and observations indicate that with appropriate operating conditions of DGC, and knowing the characteristics of the chemicals, in the stream, we can effectively reduce COD, BOD, TAN and phenols with combination of air, UV and H₂O₂.

Merits of DGC for effluent treatment:

- 1) DGC works well to degrade recalcitrant chemicals which are difficult to degrade. Thus, besides COD & BOD reduction, it has the ability to reduce ammoniacal nitrogen, phenols; and in certain cases, TDS.
- 2) It can reduce COD/ BOD even with high TDS levels (>100000 ppm), at which level biological reactor doesn't perform efficiently.
- 3) It can be used as a stand-alone operation or in combination with biological treatment in existing ETP/ CETP set-up.
- 4) DGC can be employed before or after biological treatment. Non-degradable or difficult to degrade chemicals can be converted to a simple biodegradable substrate which can be further treated in a biological reactor. Alternatively, DGC can be em-

ployed after biological treatment to eliminate the residual pollutants.

- 5) Contact time required to achieve a certain level of COD reduction is significantly lower than other processes, and the footprint of the plant is much smaller. Hence, DGC can be employed in smaller companies, which have 10 to 20 KLD effluent generation, and which have space constraint to set up conventional effluent treatment system with a bioreactor. In such cases, DGC could be used either to treat the effluent to the desired level before discharge or treat it upto certain level (say 1000-2000 ppm COD) and then send it for further treatment in a CETP.
- 6) Photocatalytic effluent treatment using air/ oxygen and UV with Titanium Dioxide can treat many of the industrial effluent streams, whereby the COD/ BOD levels can be brought down within the regulation limit.

Normally DGC set-up will need an air compressor to supply air for effluent treatment. However, for commercial plants, we can design a self-inducing SDI, which will suck in the requisite amount of air from the atmosphere. Thus, the capex for a compressor and opex for operating DGC set-up will be significantly reduced. The opex for DGC system will be mainly the electricity required for the pump + (0.5 to 1 KW) UV system. In case any H₂O₂ is used to facilitate oxidation, it will add to the cost. We estimate opex to be in the range of Rs 10 to 35/KL depending on the type of chemicals to be degraded and the size of the plant.

STEP is now discussing with a couple of companies to commercialise this technology in their existing ETP. Further, the company is also working with 3 environmental engineering companies who offer ETP packages to incorporate DGC based plants in existing set-ups or new ETPs.

Conclusion

DGC offers an innovative energy efficient and cost-effective technology for the treatment of industrial wastes. It can be efficiently and effectively used for effluent treatment to reduce COD/ BOD and degrade recalcitrant chemicals including phenols/ nitrogen containing chemicals. The ETP will have lower footprint, higher efficiency and lower opex than conventional treatment processes. Small companies producing 10 to 20 KLD effluent and who have space constraint to set up conventional bioreactor, could benefit from this technology.

