# DGC- An Emerging Technology for Waste Treatment

**Jyoti Palekar**
STEP Private Limited
C-1 Wing 1 Bindra Rose,
Mahakali Caves Road,
Andheri (East)
Mumbai 400093
(jyoti.palekar@stepsol.com)
Contact Number: 9820283540

**Abstract**

The DGC is a Downflow Gas Contactor Reactor. It is a co-current device and consists of a cylindrical upper section with an inverted conical lower section with a specially designed entry section (at the top), allowing both liquid and gas inputs into the reactor. Downflow Gas Contactor Reactor (DGC) technology is based on achieving efficient mass transfer through intense mixing in a gas liquid system. DGC technology is successfully used in pilot studies for process applications/ chemical reactions, wastewater treatment and gas capture. DGC reactor will have an advantage in reactions such as wet air oxidation, photolytic catalysis and other oxidation processes used for the treatment of wastewaters. The reactions can be conducted at lower temperature and pressures than normal process resulting in lower energy consumptions. Today when there is a trend towards using green and sustainable technologies for the treatment of wastewater, DGC technology can be considered one of those as it uses minimum resources, reduces the contact time & footprint and helps in saving the energy.

## 1.0 Introduction

Downflow Gas Contactor (DGC) Reactor is one of the most efficient gas liquid contacting devices evolved from a novel concept of contacting a continuous liquid phase with a dispersed gas phase through a specially designed entry section. The gas/liquid flow is co-current and dispersion is maintained at a desired level within the reactor by preventing gas bubbles flowing through the outlet of the reactor and thus ensuring 100% gas utilisation.

DGC reactor consists of cylindrical upper section and inverted conical lower section. Large quantities of reaction gas and slurry liquid are introduced via a proprietary reactor inlet to create a well dispersed gas/liquid dispersion, high gas hold-ups and very high gas/liquid mass transfer area- 1000 m2/m3 to 6000 m2/m3 depending on bubble sizes.

Gas-liquid bubble dispersion slowly expands down the fully flooded column and the level of dispersion, and thereby volume of the gas liquid dispersion, can be controlled by control of the operating conditions (liquid and gas flow rates). In the lower section of the column as the dispersion proceeds downwards, there is a degree of bubble coalescence since it is no longer within the region of direct inlet steam impingement. This coalescence produces larger bubbles, which rise up the column where they are broken up by the shear of the high velocity inlet liquid jet.

| DGC Reactor – A snapshot | |
|---|---|
| **Gas Utilisation** | 100% |
| **Gas/liquid mass transfer area** | 1000 – 6000 m2/m3 |
| **Volumetric Mass Transfer Coefficient** | 0.2 – 12 kLa |
| **Internal Moving parts** | Absent |
| **Scale-up (without loss in efficiency)** | Easy |
| **Engineering and Fabrication costs** | Low as the system can be fabricated in India. Only top nozzle of DGC will be imported |
| **Design** | Simple/ Compact /Flexibility |
| **Environmental Applications** | Gas absorption (Biogas enhancement, EO treatment, Air Stripping of VOCs/ Solvents etc)<br>Waste water treatment<br>DGC for Wet air oxidation process<br>Activated sludge treatment<br>Fermentation |
| **Operation Mode** | Batch/ semi/continuous mode |
| **Operating volume** | Smaller |
| **Tolerance to particulates** | high solid content |
| **Modifications** | Can be modified to incorporate UV, Ozone, $O_2$/ UV/ $TiO_2$ etc. can be modified to a Monolith |

The high gas/liquid ratio throughout the dispersion in the column results in excellent gas-liquid contacting and enables the maximum possible gas-liquid mixing. Many industries require gas/liquid contacting in a wide range of processes such as gas absorption, stripping, flotation, ozonation, micro bubble generation, oxidation, catalytic oxidation, hydrogenation, carbonation, fermentation, oxygenation, effluent treatment, mineral separation etc and DGC can be beneficial to all of them.

Pilot studies have been performed on gas absorption (CO2 capture from air and biogas) and DGC has been successfully used for process applications such as vegetable oil hydrogenation, catalytic hydrogenation of aldehydes, sugars & Itaconic acid and in transesterification reactions.

DGC reactor can be modified to incorporate UV & Ozone technology for treating 'difficult' liquid wastes. Modified DGC has been successfully used for the treatment of waste water containing phenols, chlorophenols, benzene derivatives, organic solvents such as methanol, ethanol, toluene etc., landfill leachates, pharmaceutical waste and organic food waste. DGC reactor has also been applied for treatment of farm effluent slurry by stripping Ammonia and the recovery of the Ammonia for use as liquid fertiliser.

DGC can be used Wet Air Oxidation process for Waste Water Treatment Technology for treating high COD streams.

The paper presents some of the case studies of DGC reactor and the potential application for treatment of waste.

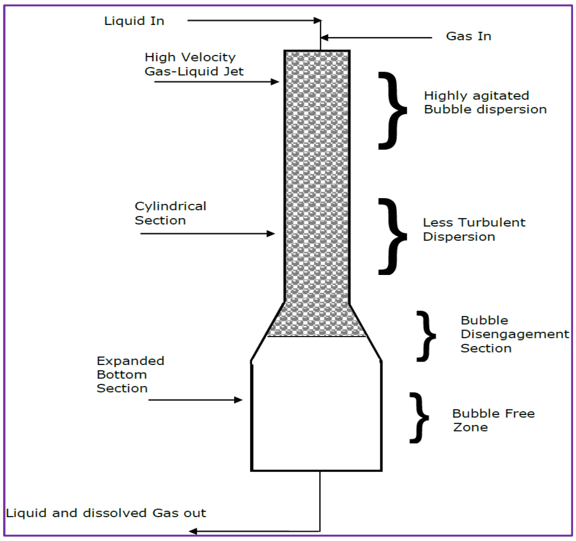


**Figure 1- DGC Reactor Concept**

**Figure -2 Stable bubble matrix formed, nearly uniformed sized bubbles results in a distinct gas-liquid interface**

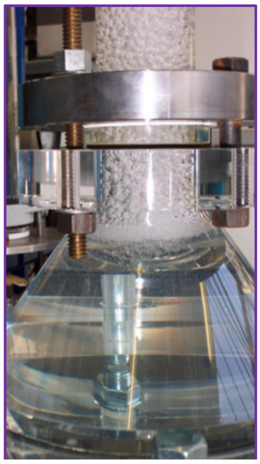

**Figure-3 Outlet – Cone**

## 2.0 DGC Case Studies

### 2.1 $CO_2$ Capture and Biogas Enhancement

A DGC Reactor of 50 mm dia and 1.5 M height were installed for the $CO_2$ absorption trials. Operating conditions, like liquid and gas flow rates, temperature, pressure and also absorbent liquid compositions were varied in order to study the effects of each operating condition. The most suitable absorbent liquid was alkaline seawater. All trials were undertaken on a batch mode. The pilot plant P&ID is presented in **Figure 4** and the summary of operating conditions are presented in **Table1**.

For the commercial applications it is estimated that a DGC reactor of 0.8-1.0 M diameter and 3.0 M height with liquid flow rates between 250 $M^3$/hr – 300 M3/hr would be required to treat 400 Nm3/hr of Biogas. Preliminary calculations show that a savings of approx. £32,000 per month can be made by enhancement of the methane content (60% CH4 to 97% CH4) of 400 NM3/hr of Biogas. An application for protection of the intellectual property is being made to the patent authority.

| | |
|---|---|
| Media Composition | 60% Biogas, 38% $CO_2$, 2% $H_2S$ |
| Media Used | Sea salt NaOH + Water<br>$Na_2Co_3$+ Water + Methyl Ethylamine<br>Sea water |
| Liquid Flow Rate | 10-15 L/min |
| Gas Flow Rate | 1-3 L/min |
| Pressure | 1-4.25 bar |
| Inlet $CO_2$ in Air | 38% |
| Outlet $CO_2$ in Air | 2-8 % |

**Table 1 $CO_2$ Capture from Biogas**

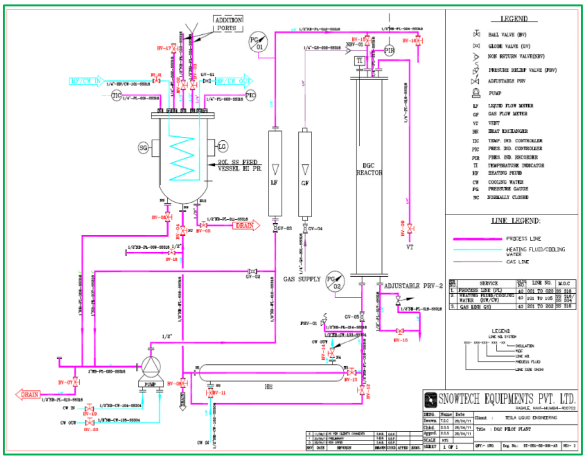

**Figure 4- DGC Pilot Plant P&ID**

## 2.2 Treatment of Wastewater from Pharmaceutical Industry

DGC system used for pilot studies consisted of a DGC Reactor, which incorporated a UV lamp and a receiver vessel. The DGC reactor comprised of two sections; a top section which consisted of a 50 mm diameter, 500 mm length glass column and a bottom section, which consisted of a 100 mm diameter, 1000 mm length glass column. The bottom section contained a UV lamp (2.0 kW) and the two columns were connected via a glass reducing adapter.

The effluent from the receiver vessel was pumped into the DGC unit top section through a flowmeter until the DGC was fully flooded. The effluent flowed through the top section into the bottom section, which contained the UV lamp. After passing through the UV section, and being subjected to UV irradiation, water flowed from the bottom of the DGC column back into the receiver vessel. Oxygen was introduced into the DGC system through a non return valve at a point into the liquid stream just before the inlet of the DGC system.

The UV system was switched on and oxygen was introduced into the reactor. Samples were taken every 1 – 2 hours and analysed for COD & TOC, after the liquid had been subjected to oxidation and UV irradiation. The set up is shown in **Figure 5**. The pilot plant operating parameters are presented in **Table 2** and the reduction in COD values is presented in **Figure 6**.

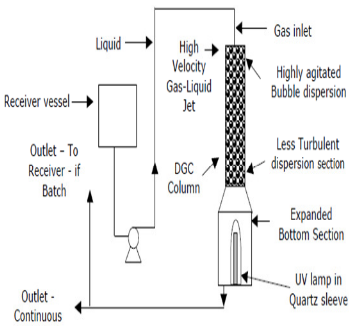


**Figure 5: DGC for Waste water Treatment Application**

| | |
|---|---|
| UV Lamp | 2.0kw |
| Flow Rate | 10 L/min |
| Gas Flow Rate ($O_2$ flow rate) | 0.05 L/min |
| Temperature | 19-33$^0$C |
| Pressure | 0-8 bar |
| Operating Mode | Batch |
| Volume Of DGC Reactor | 17 Liter |
| Batch Volume | 15 Liter |
| Residence time in DGC | 1.5 min |
| Contact time | $O_2$- 42 sec<br>UV- 36 sec |

**Table 2 Operating Parameters for DGC**

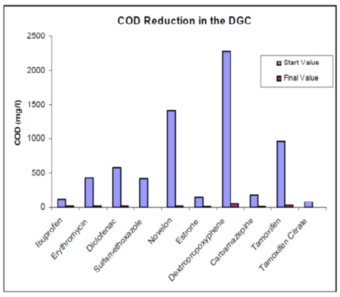


**Figure 6: COD reduction in DGC**

## 3.0 DGC and Emerging Technology

DGC technology can be potentially used for the treatment of wastewaters where biological treatment alone is not effective because of multiplicity of impurities and complexity of chemical structures of molecules present in the effluents. Often these complex molecules are not easily biodegradable and will either need separation prior to biological treatment eg. Separation of lignosulphite from pulp and paper industry, or will require physico- chemical treatment such as Wet air oxidation/ Fenton process eg. Treatment of spent caustic from refinery.

DGC technology can be used for wide application in waste treatment. Some of the applications will include:

1. Treatment of effluents from pulp and paper industry, Pharmaceutical effluents, spent caustic from refineries, pesticide effluents, dye industry and cyanide containing effluents eg. steel, electroplating industries.
2. Treatment of landfill leachates
3. DGC can be used for biological treatment process from achieving the effective transfer of oxygen.
4. For biogas enhancement – increasing the methane content of biogas
5. Reducing the carbon footprint by Carbon capture from flue gas- power plants, iron ore industry
6. Air Stripping of VOCs/ Solvents
7. Capture and degradation of gaseous pollutants such as ethylene oxide without scrubbing and generating liquid effluents.
8. Minimisation of sludge from wastewater treatment plant

DGC reactor will have an advantage in wet air oxidation, photolytic catalysis and other oxidation processes used for the treatment of wastewaters as due to the most efficient gas liquid mass transfer, the amount of gas/ chemical requirements will be minimum. Also these reactions can be conducted at lower temperature and pressures. Today when more and more industries are inclined towards using green and sustainable technologies for the treatment of wastewater, DGC technology can be a choice as it uses minimum resources, reduces the contact time & footprint and helps in saving the energy.