Effluent Treatment

All industrial processes manufacture products from raw materials with the help of various energy sources. The various stages in the manufacturing processes invariably produce unwanted by-products in the form of waste effluent streams of various concentrations and pollution potential. Solid wastes and gas wastes may also be produced.

The ideal process would have no waste. Process redesign to eliminate intermediate waste streams (in chemical processes) and pinch technologies for waste stream re-integrating into the industrial process are preferable processes for waste treatment. The uptake of such emerging technologies is small, but of increasing importance in the future.

In the meantime, the treatment of industrial effluent streams is a costly process involving the use of such equipment as blowers, pumps and transfer equipment.

Most industrial effluent is treated to decrease BOD (Biological Oxygen Demand) and COD (Chemical Oxygen Demand). These are the processes which involve intensive energy usage, mostly electricity.

The end product of a treatment process is normally water and sludge, which must be disposed of.

How to save energy in effluent treatment

Energy savings in effluent treatment systems can be considered under the following headings:

- Process Opportunities
- System Opportunity
- System Control and Optimisation.

Process opportunities

Here we focus on ways to avoid the production of effluent in the first place by examining alternative technologies that help to avoid effluent or reduce waste streams.

- **Retro-synthesis**

  It's true to say that waste prevention is more economical than treatment. In conventional designs of industrial processes, the synthesis route of a product is chosen first and the manufacturing system is designed to minimise waste or by-product formation.

  Such an approach limits the opportunities for waste prevention.

  Retro-synthesis is an approach which uses retro-synthetic algorithms and software tools, to work backwards from target raw materials to candidate starting materials in developing synthesis routes in order to minimise waste generation and hence waste treatment costs.

- **Mass Exchange Networks (MEN)**

  This process is analogous to 'pinch technology' used for energy integration networks using heat exchangers. Mass exchange networks are coming to the fore in pollution prevention. With MEN in the Chemical Industrial Processes (CIP), species are systematically tracked in and around a reactor and systems locate them to a process network.

  MEN can suggest steps that amount to simple in-process recycling, or point to the possibility of using absorption to collect materials before they become part of the waste effluent stream.

- **Pinch Technology**

  Waste streams are treated in a way analogous to thermal streams by matching one suitable stream against the other using mass transfer techniques. The result can minimise raw water demand and wastewater generation.

- Reverse Osmosis

  Reverse Osmosis is a process of using semi permeable membranes to extract solids for a stream such as waste effluent or solvents. Its low energy requirement makes it ideal for large volume applications.

- Electrochemical Processes

  Often electrochemical processes can be employed to produce chemicals and treat effluents containing valuable products such as silver.

System opportunities

There are several basic units in the treatment of industrial waste including:

- Balancing/Equalisation
- pH Correction
- Biological Treatment
- Clarification
- Sludge Disposal

In addition, where nutrient removal and sludge treatment is required, other processes may be included such as

- Chemical Precipitation
- Sludge Thickening and Conditioning
- Sludge Dewatering and Drying

Where waste water contains specific contaminates which are not removed or degraded in the normal physical, chemical or biological processes, advanced primary or secondary treatment processes may be required. These include:

- Filtration (Sand, Ultra-Filtration, Micro-screening, etc.)
- Reverse Osmosis
- UV Radiation
- Ozonation
- Chlorination
- Chemical Conditioning

Energy is used in all these processes but the Biological Treatment Process, particularly the Activated Sludge Process, can consume over 60% or more of the energy involved in effluent treatment and also represents the best energy saving opportunities.

Energy savings in activated sludge processes

The efficiency of the effluent system will depend on the type of system chosen. There are many types of effluent treatment systems, but most involve aeration as the main method of reducing BOD. Before a waste stream can be discharged from the industrial site, the BOD must be no higher then that specified by the Environmental Authorities.

The activated sludge plant is the most common plant for reducing BOD in industrial sites. Since the whole purpose of this type of plant is to get oxygen into the effluent, the mass transfer efficiency or the kWh per kg of oxygen transferred is very important.

Some plants are better at transferring oxygen than others, as the following table shows.

Aeration System (kg/kWh Electricity)	Oxygenation Efficiency
Diffused air	
Fine Bubble	1.5-3.6 (at depths 2.5-5 M)
Course Bubble	1.2-1.9
Mechanical Surface Aerators	
Rotating Vertically	1.5-2.2
Rotating Horizontally	1.2-2.4
Verturi Aerators	
Forced Draught	2.1-3.0 (depths of 4-7M)
Self Entrained	1.0
Jet Aeration	2.1-3.0 (depths 4-7M)

Having a high O_2 transfer efficiency is fine, but if you can't modulate that equipment when demand for aeration reduces, then energy will be wasted because too much oxygen will be put into the system. This also goes back to the initial process design. Experience has indicated that fine bubble, diffused air systems may be capable of high aeration efficiency in plants designed to produce fully nitrified effluents, but only if an anoxic zone for denitrification is included at the aeration tank inlet. Conversely, it has been found that surface aeration systems are potentially more efficient in systems designed to produce non-nitrified effluents.

- The design of aeration tanks to achieve high values of aeration efficiency and a good degree of control is based on successfully matching the air supply to the process oxygen demand requirements, so that excessive dissolved oxygen concentrations do not occur at time of low loading. To achieve this, the aeration tank should be designed as a plug flow system while minimising the aeration tank length to width ratio. An L/W ratio of 3:4 is required depending on the depth and the number of lanes. This results in a plug flow system and pronounced changes in oxygen demand from tank inlet to outlet.
- An anoxic zone should also be incorporated at the inlet end of the plug flow tank which will operate as a sector zone for flocculating bacteria and, in a nitrifying plant, will provide a certain degree of denitrification. Anoxic zones in effect liberate oxygen from the effluent that would otherwise be lost. This results in less oxygen required for the overall process and hence reduction in energy usage.
- The provision of multiple channels or tanks allow greater flexibility in matching loading rates to seasonal, present and future effluent flows depending on the seasonality of the industry in question. This would mean using only the correct number of tanks to ensure a high loading rate in the plant and hence increased aeration efficiency. The amount of oxygen required to satisfy unit mass of BOD is less in a highly loaded plant than in a low loaded plant.
- Sludge treatment using anaerobic processes can result in net energy outputs by way of methane gas which can be utilised in co-generation systems.

System Control and Optimisation

Matching air supply to process oxygen demand

The aeration system should be designed so that the demand for oxygen exerted by the microbial reactions is closely matched by the rate of supply of oxygen at all points in the aeration tank under varying conditions of organic loading.

Excessive high concentrations of dissolved oxygen result in a low net driving force for gas to liquid oxygen transfer and poor aeration efficiency. Low concentrations of dissolved oxygen result in poor reaction rate, limiting poor effluent qualities.

Variations in effluent flow rates and organic concentrations result in varying demands for oxygen. Energy savings can be achieved by using closed loop control systems which maintain dissolved oxygen concentrations within the target range.

Such flexibility of a control system will also allow greater throughputs of effluent to be treated without risk of damaging effluent quality.

Because many aeration systems are designed to meet peak demand, aeration turndown, and hence dissolved oxygen control, is the key to achieve energy efficiency.

The power consumption for maintaining dissolved oxygen (DO) at 4mg/l instead of 2mg/l would be 40% greater.

Control oxygen demand techniques could save between 10%-40% of the aeration costs.

Types of controls currently employed

- On/Off control of surface aerators where independent mixing is used. This is more suitable for energy savings rather then DO control, since a fixed DO profile is difficult to maintain with this system. It is least suitable for aeration tanks with 4 or less aerators in series, particularly where there is no tapered energy input. It is not suitable for adoption with aeration tanks with single aerators.
- Varying rotor immersion (using weir level control). This method is most suitable for completely mixed systems and for systems with tapered aeration.
- Variable compressor/rotor speed but ensure that agitation of the effluent is not affected. The variable speed control system utilising a frequency invertors unit to regulate the speed of the motor and hence the power absorbed by the aerator or blower. Variable speed control provides the closest DO control, particularly for aeration systems with long retention times and can give good energy savings compared to other options.
- Air flow balancing. Various combinations of the above such as variable speed with on/off switching. This method has proven to give good energy savings, particularly for large treatment plants where greater savings can be achieved.

Note:

- Good DO control can help avoid filamentous sludge bulking due to extended incidences of low DO.
- Some research has shown that redox potential may provide a tighter control of energy costs than DO control systems.

Hybrid Aeration Systems

Where the effluent environment may cause fouling of diffusers, a combination of surface aerators and diffused air system can be efficient.

Here a system with about 1/3 of the aeration volume equipped with surface aerators, followed by a plug flow diffused air plant incorporating tapered aeration, provides the most efficient system for the aeration of activated sludge. An overall efficiency of between 1.5-2.0kg/kWh is possible, together with an increase in diffuser life times compared with conventional fine bubble aeration system. This represents an increase in efficiency of over 20% compared to surface aeration and 10% compared to a fine bubble aeration systems.

Electric Ireland has considerable expertise in the efficient utilisation of Effluent Treatment Systems. If you require further information, please call us on 0800 056 9914 or 1800 200 513 or contact your Customer Relationship Manager.