Pretreatment of Industrial Wastewaters

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Introduction

Industrial wastewater is a global issue and covers a wide range of industries and (by their nature) contaminants. Ranging from the food and beverage industries (representing organic wastes) through to the petrochemical, pharmaceutical, mining and electroplating industries, a significant variety of contaminants exist, which in some areas are discharged ilegally to either sewer or environment, resulting in several significant issues (environmental damage, biodiversity deterioration, uptake into the food chain, etc.).

A key focus in many developed countries is the appropriate and sustainable treatment of industrial wastes to enable safe discharge to sewerage systems or the environment. As a general rule, the locality of industries dictates, to a large extent, the discharge of generated wastewaters. Many large industries are located in metropolitan or outer urban areas, and most of these will generally discharge to an available sewer, which transfers the waste to a municipal wastewater treatment plant. However, there are a large number of facilities that are located in regional and rural areas (dependent on resources used for the industry). These will include mine sites, but may also include wineries, abattoirs and similar facilities, which rely on food production. In these cases, it is more common that wastewater is treated on-site and discharged to the environment. There are also several centralised industrial treatment facilities that have a small sewer catchment dedicated to the industrial discharge (common in Southeast Asia) or rely on tanker transport (common in the Middle East).

Industrial wastewater is typically characterised by a wide range of contaminants which, if released inappropriately to the environment, will impact on water resources and amenities. In the past 30 years, evidence of industrial contamination has prompted for calls on tighter regulations of these systems, and wastewater has become a key target for control by regulatory authorities. Coupled with this, in some areas, where drought or water resources are scarce, the wastewater is regarded as resource, and treatment and reuse of the effluent is advocated. There is a significant amount of research associated with control of industrial wastewaters. Much has also been undertaken on anaerobic treatment of high organic wastewaters to biogas, and waste to energy. This represents a major driving force in development and take-up of pre-treatment of industrial wastes, where economic gain may be realised in treatment of wastewater, through resultant energy generation.

Some aspects of industrial wastewater pretreatment programmes (technical, administrative, fiscal) include the impact of industrial discharges on municipal treatment works and transfer systems; characterisation and categorisation of industrial wastewaters; end of pipe treatment technologies and in-plant water efficiency control, planning, development, management and troubleshooting of industrial wastewater treatment facilities; recycling, material recovery and waste minimisation; waste to energy and treatment and disposal of toxic sludge. Consequently, a robust approach in pretreatment of wastewater systems from an environmental and economic base, targets generation of useful by-products:

- energy generation;
- effluent re-use;
- residuals management.

Current issues

Industrial wastewater is typically characterised by a wide range of contaminants which, if released inappropriately to the environment, will impact on local and potentially regional resources (surface water, groundwater and land). This, in turn, can adversely affect natural amenities and human habitation (drinking water, crop growth, food chain, etc.). Consequently, the appropriate collection, treatment and disposal of contaminants of concern is paramount to ensure sustainable industrial operations and management.

Some of the contamination issues include the following:

- organic overloading of surface waters, leading to loss of amenity;
- loss of nutrients and eutrophication in surface water;
- emission of greenhouse gas as part of inadequate/storage and treatment of high strength organic wastes;
- impacting of beneficial re-use on municipal biosolids (through addition of toxic materials);
- mine acid drainage;
- arsenic groundwater contamination;
- land contamination.

Around the world, there are numerous cases of industrial-scale contamination and losses of environmental and social amenities from pollution (mine sites in South America, South Pacific, Africa, Eastern Europe, etc.; industrial pollution and contamination of potable drinking water supplies in Africa, the Americas, Asia).

Cost-effective treatment is also a major issue, with many industrial operators not interested in treating wastewater unless there is a rapid payback or unless the core business is impacted, with environmental concerns often last on the agenda. It is fair to say that most operators adopt economic principles which drive the process of wastewater management and implementation.
Legal, policy and management systems affecting industrial innovations

Two very important pieces of global legislation were approved by the United Nations in 2015 which have a tremendous implication on industrial, manufacturing and commercial activities especially in relation to environmental legislation. The United Nations approved the new set of Sustainable Development Goals (SDGs) for 2030, in New York in September 2015, with a wide range of issues and targets influencing global consumption and production patterns as well as the use of natural and mineral resources in parallel with specific socio-economic targets. Following the SDGs approval another major piece of legislation was delivered by the United Nations COP in Paris with the Climate Change agreement which aims to tackle also energy production and direct/indirect efficiencies in global industrial, manufacturing and commercial sectors.

Indeed as part of the future trends within IWA industrial specialists groups should be the projection for specific and general measures that industries should follow to make the necessary transition to the new models of energy and resource efficiencies as approved by the United Nations in 2015. Transition patterns to the new or innovative models of production should be monitored and reported within and from IWA’s Specialist Groups relevant to these sectors.

Revising policies and legislation nationally and globally will be making the movement of goods and services linked with the supply chains of various industrial sectors a bit more resilient and sustainable beyond the typical methods of the past decades that addressed linear production and growth models on strict financial measures and reviews.

As a typical research and development study in many environmental institutes and think tanks in the European Union, case studies analyse various industries for the following:

- potential innovations that would bring them into ‘smarter systems’ (often following big data and “the internet of things” for resource and energy needs);
- a wide range of improvements in industrial management systems primarily focusing on efficiencies with monitoring and control tools, i.e. clean-tech productions;
- and the use of applied CSR (Corporate Social Responsibility) reporting schemes which more often end up acting as a planning guide on what kind of technical and/or soft measures industries will need to improve efficiencies and minimise waste/wastewater streams over several years to achieve SDGs linked with their industrial sectors.

Risk analysis in industrial production has matured from a prevention scheme (legally binding) to a business evaluation model from the start of the investment, with alternatives for clean technology sought from an early design to avoid any possible contaminants and leaks that could be considered as detrimental to the business model and the brand projected by the owners of the facilities. This new way of thinking of industrial production also affects any supply chains linked with a specific product with an objective of improving whole-life assessments.

Additionally the use and establishment of eco-parks internationally that aim to attract greener investments and to enable improved regional and national production and manufacturing is also a subject of constant review; following conceptual developments on material flows versus cost accounting (MFCA, etc.), addressing areas of the evolving circular economy and investigating further case studies on industrial ecology themes.

In particular the opportunities on innovations with nanomaterials, the use of graphene as an evolutionary material with the potential to replace many aspects of controlling and capturing contaminants, and endless improvements in catalysts produced would provide a blueprint of how new and modernised industries will have to be pre-defined for their own environmental management risks to be tackled, but also to achieve potential improvements in the environmental management of current industries.

Existing knowledge and treatment of wastewater

As a general rule, the locality of the industry will dictate the discharge of the generated wastewater. The availability of the sewer typically results in preferential discharge to it, with subsequent dilution with domestic wastewater and treatment affected by the municipal WWTP. There are also industries located in regional and rural areas (dependent on resources used for the industry), which typically are licensed to treat on-site with local disposal (usually more stringent license criteria). Consequently,

<table>
<thead>
<tr>
<th>Industry</th>
<th>Typical contaminants</th>
<th>Typical treatment</th>
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<tbody>
<tr>
<td>Dairy</td>
<td>Organics, fats [BOD 3,000 mg/L]</td>
<td>DAF, biological (aerobic)</td>
</tr>
<tr>
<td>Meat/poultry</td>
<td>Organics, fats, blood, manure [BOD 2 - 5,000 mg/L]</td>
<td>DAF, biological (anaerobic/aerobic)</td>
</tr>
<tr>
<td>Vegetable/fruit</td>
<td>Dissolved organics, sugars [BOD (2,000 mg/L)]</td>
<td>neutralisation, biological (aerobic)</td>
</tr>
<tr>
<td>Bakery</td>
<td>Organics [BOD 3,200 mg/L]</td>
<td>Biological (aerobic)</td>
</tr>
<tr>
<td>Iron/steel</td>
<td>Phenols, SS, ammonia, cyanide [BOD 500 mg/L]</td>
<td>Coagulation (biological)</td>
</tr>
<tr>
<td>Galvanising industry</td>
<td>Heavy metals</td>
<td>Chemical precipitation, filtration</td>
</tr>
<tr>
<td>Petrochemicals</td>
<td>Phenols, oils [BOD 750 mg/L]</td>
<td>Separation, chemical oxidation, bio</td>
</tr>
<tr>
<td>Pulp/paper</td>
<td>SS, organics [BOD 4,000 mg/L]</td>
<td>Separation, biological</td>
</tr>
<tr>
<td>Textiles</td>
<td>SS, Organics, metals [BOD 6,000 mg/L]</td>
<td>Coagulation, biological, membrane, ozonation</td>
</tr>
<tr>
<td>Plastics/resins</td>
<td>Organics, phenol, oils [BOD 2,500 mg/L]</td>
<td>Separation, chem. oxidation, biological treatment</td>
</tr>
<tr>
<td>Beverage</td>
<td>Organics, sugars [BOD 2,000 mg/L]</td>
<td>Biological (high rate anaerobic, aerobic)</td>
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the treatment of industrial waste is very site specific and several treatment units are appropriate for these, which are dictated by the type of contaminants and the required water quality criteria.

Generally, there are numerous technologies for treatment: dissolved air flotation (DAF), anaerobic digestion, aerobic oxidation, chemical oxidation. Most of the processes have been developed from the wastewater and water treatment fields. However, specialised technologies have also been developed, particularly to deal with some of the more noxious contaminants of concern.

Some examples of treatment trains for varying industries in developed countries are as summarised in Table 1.

It can be seen that DAF, biological treatment and chemical coagulation are common processes. It should, however, be acknowledged, that contaminant take-up in the sludge of the treatment system will require specialist management, and the more noxious contaminants will require chemical fixing and disposal at a secure landfill.

General trends and challenges

As noted above, the key priority for pretreatment of industrial wastewaters is demonstration of control of contaminants and enabling sustainable facility operations and efficient management of resources, to achieve industrial and manufacturing objectives within a circular economy model.

In Europe there is considered to be a renewed environmental conscience creating a shift in industrial production, use of resources and energy (use of energy efficient technologies and the introduction of renewable energy resources including solar, biomass, wind and hydro-power). Legislation and economic incentives have been introduced to encourage adoption of ecologically friendly design such as extended producer responsibility (EPR) legislation. (Alexiou, 2014). Up to 1980, end of pipe pollution reduction was typically adopted, after which there was a strong focus on legislation. In 2000, cleaner technologies emerged, and since 2010 the advent of sustainable production has now largely been adopted in Europe (De Bernardino, 2014).

Anaerobic digestion, bioethanol production, membranes and tri-generation are some of the most promising technologies allowing the recovery of by products and simultaneous production of heat, cooling and power with technical, economic and environmental benefits (Alexiou, 2014). However, there are numerous other technologies currently being researched and implemented, including the following:

- low-energy DAF systems (smaller, more efficient, bubble size, without chemicals) (Menkveld, 2014) to enhance performance and operating costs;
- biochemical injection materials (including reactants, catalysts, adsorbents) and Nano-membranes for dealing with pesticides (Keller, 2014);
- chemical oxidation processes (which included Fenton, pyrite catalysed by hydrogen dioxide, sodium hypochlorite and ferrate oxidation) of pulp/paper industrial wastewater (Zhang, 2014);
- use of adsorption materials for removal of a wide range of contaminants (including colour from textiles, heavy metals, radioactive materials (Huang et al., 2014); alternative coagulants and aggregation in removal of particulates (Licsko, 2014).

There is also considered to be an increasing adoption of effluent reclamation from pretreatment of industrial wastewaters. Furthermore there are several installations in Australia and elsewhere that have adopted advanced treatment (at the end of the biological system) to enable reclamation for hosing down and washing (but separated from the production of foodstuffs).

Conclusions and research or development agenda

In summary, while industrial pretreatment covers a wide array of industries, the solutions are very site specific. General trends include research and development in the following areas:

- anaerobic digestion and generation of energy for high strength wastes;
- cost-effective aerobic treatment for wastewaters less than 2,000 mg/L BOD;
- membrane treatment for entrapment of contaminants;
- ion exchange and adsorption process for metal contaminants;
- water efficiency and advanced treatment methods to achieve water reclamation/re-use.

References


