

WASTEWATER TREATMENT— A PROCESS OVERVIEW AND THE ROLE OF CHEMICALS

Issue Date: December 2009

Abstract—Whether in reference to a refinery, a chemical process, or a utility plant, zero discharge or minimum discharge of effluent from the plant boundary is a present-day motto in safeguarding our environment. The enforcement of stringent environmental norms has spurred scientists and process owners to develop comprehensive wastewater treatment programmes to constantly improve effluent discharge quality, promote water savings through recycling, and eventually minimise plant life-cycle costs. This paper provides an overview of the major wastewater treatment processes and the roles different chemicals play in these processes.

Keywords—activated sludge, biochemical oxygen demand (BOD), chemical oxygen demand (COD), clarifier, coagulation, colloidal particle, dissolved air flotation, dissolved oxygen, emulsion, flocculation, neutralisation, oily wastewater, polyelectrolyte, precipitation, redox reaction, suspended solids (SS), turbidity, wastewater treatment

INTRODUCTION

Most industrial processes give rise to polluting effluents from the contact of water with gas, oils, liquids, and solids. The release of effluents to water bodies and soil renders them unsafe for drinking, fishing, agricultural use, and aquatic life.

The need for sustained development and industrial continuity calls for a systematic and comprehensive treatment of effluents to reduce all contaminants to acceptable limits, making the effluents environmentally safe before they are discharged outside the plant boundary. These standards are usually governed by legislative bodies and are modified from time to time. An example of typical discharge quality requirements for effluent water is provided in **Table 1**.

Based on the complexity of the process and the process industry, industrial wastewater requires specialised treatment to remove one or more of these pollutants:

- Suspended solids (SS) and/or turbidity
- Oil and grease
- Colour and odour
- Dissolved gases
- Soluble impurities and contaminants
- Heavy metals
- Germs and bacteria

Table 1. Typical Limits for Effluents Discharged into the Environment

Constituent	Desirable Limit, mg/L	Maximum Limit, mg/L
Ammoniac nitrogen	5	10
Arsenic (As)	0.1	0.5
Biochemical oxygen demand (BOD)	30	50
Cadmium (Cd)	0.1	0.2
Chlorine (residual)	1	2
Chromium, total (Cr)	0.1	0.2
Copper (Cu)	1.5	3.0
Chemical oxygen demand (COD)	150	200
Cyanide (CN)	0.1	0.2
Oil	15	25
Iron, total (Fe)	2	5
Lead (Pb)	0.1	0.3
Manganese (Mn)	2.0	3.0
Mercury (Hg)	0.001	0.05
Nickel (Ni)	0.2	1.0
Phenols	0.2	0.5
Phosphate, total (P)	30	40
Selenium (Se)	0.05	0.09
Silver (Ag)	0.05	0.1
Sulphide	0.2	0.5
Suspended solids	30	50
Turbidity	90	120
Zinc (Zn)	0.5	5
pH	6–9 Standard Units (SU)	

Note: Some countries provide limits on dissolved solids in treated effluent.

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In the coagulation process, the most difficult SS to remove are the colloids, which, due to their small size, easily escape both sedimentation and filtration.

ABBREVIATIONS, ACRONYMS, AND TERMS

API	American Petroleum Institute
BOD	biochemical oxygen demand
COD	chemical oxygen demand
CPI	corrugated plate interceptor
MSDS	material safety data sheet
NTU	nephelometric turbidity unit
redox	oxidation reduction
sp. gr.	specific gravity
SS	suspended solids
SU	standard units
WTP	wastewater treatment plant

Generally, industrial wastewater treatment programmes differ from industry to industry, except for sewage treatment. As a general philosophy, wastewater treatment is performed in three stages:

- **Primary treatment**, which consists of grit and floating oil removal, pH neutralisation, etc., takes care of most of the pollutants and toxic chemicals that can be easily removed from raw wastewater at this stage. Such pretreatment creates conditions suitable for secondary treatment.
- **Secondary treatment**, which removes major pollutants to achieve the disposal quality, is designed to substantially diminish the pollutant load. SS, emulsified oil, and dissolved organics are the major pollutants removed at this stage.
- **Tertiary treatment**, which is carried out for recycle or reuse of the treated effluent, polishes it to bring the biochemical oxygen demand (BOD) and SS levels down to a range of 10–20 milligrams per litre (mg/L).

AN OVERVIEW OF EFFLUENT TREATMENT PROCESSES

All effluent treatment involves a few fundamental chemical and physical processes for isolating the impurities/contaminants. A brief description of these processes helps in understanding the overall treatment philosophy.

Neutralisation (pH control)

The removal of excess acidity or alkalinity by treatment with a chemical of the opposite composition is termed neutralisation. In general, all treated wastewaters with excessively low or high pH require neutralisation before they can be disposed of in the environment. Dosing rates are decided based on treated effluent pH level. Primary acidic agents are hydrochloric or sulphuric acids. Primary base agents are caustic soda, sodium bicarbonates, and lime solutions.

Filtration

Filtration is a purely physical process for separating SS in which the effluent is passed through a set of filters with smaller pores than the contaminants, thus physically separating them out. The collected material is removed by backwashing for reuse of the filter element.

Coagulation

Coagulation destroys the emulsifying properties of the surface-active agent or neutralises the charged oil droplets. The free acid of alum breaks the emulsion by lowering pH. Zeta potential [1] is a convenient way to optimise the coagulation dosage in water and wastewater treatment. **Figure 1** illustrates the effect of alum dosing on zeta potential versus turbidity. The dosage at which turbidity is lowest determines the target zeta potential. The most difficult SS to remove are the colloids, which, due to their small size, easily escape both sedimentation and filtration. The key to effective colloid removal is to reduce the zeta potential with coagulants such as alum, ferric chloride,

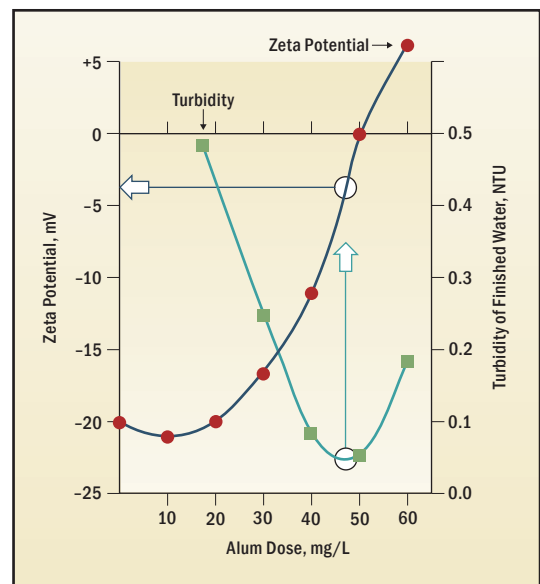


Figure 1. Example of the Effect of Alum Dosing on Zeta Potential Versus Turbidity

Zeta potential (Smoluchowski's formula) is dependent on the property of the SS and is calculated as:

$$\zeta = \frac{4\pi\eta}{\epsilon} \times U \times 300 \times 300 \times 1,000$$

ζ	=	zeta potential (mV)	(1)
η	=	viscosity of solution	
ϵ	=	dielectric constant	
U	=	$\frac{v}{V/L}$: electrophoretic mobility	
v	=	speed of particle	
V	=	voltage	
L	=	electrode distance	

and/or cationic polymers. Once the charge is reduced or eliminated, no repulsive forces exist and gentle agitation in a flocculation basin causes numerous successful colloid collisions. Microflocs form and grow into visible floc particles that settle rapidly and filter easily.

Flocculation

A flocculent gathers floc particles together in a net and helps bind individual particles into large agglomerates. Aluminium hydroxide [Al(OH)₃] produced after hydrolysis of alum [Al₂(SO₄)₃] forms a net in water to capture fine SS.

Oil/Water Separation

Oily wastewater is common in any industry because oil and grease are universally used as lubricants and solvents. Oil is required to be separated before the wastewater is discharged or recycled. In addition, in a refinery or petrochemical plant, recycling the recovered oil adds some value apart from pollution control. Oil remains present in wastewater in two forms, floating and emulsified. Floating oil is separated during primary treatment, and emulsified oil is removed during secondary treatment.

By virtue of oil being dismissible in water and having a density difference, the bulk of oil in wastewater remains in suspended form and can be separated through a settlement and skimming process. Oil is lighter and thus floats on top of the water surface, so it can be skimmed out through a mechanical separation process using mechanised skimmers in American Petroleum Institute (API) or corrugated plate interceptor (CPI) separators. More than one stage may be required to reach the discharge quality. For a stringent requirement, treated water may be passed through activated carbon filter adsorbers, which retain the oil particles within the carbon molecular space and provide for clear water to be discharged.

Emulsified oil needs the addition of cationic or anionic polymer, increased temperature, or

coalescing media. These can break the emulsion so that the oil particles can be subsequently removed by normal separation processes.

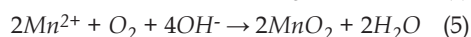
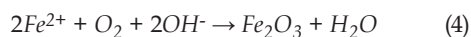
Metal Precipitation

Wastewater containing dissolved metals needs to be treated to reduce the metal concentration to below the toxicity threshold for organisms potentially exposed to the wastewater. Four main processes are available to accomplish this:

- The soluble metal ions can be converted to insoluble metal salts by chemical reaction to allow physical separation. Typical precipitation reactions are described by the following equations:



- The metal ions can be oxidised to produce insoluble metal oxides. For example, the reactions that occur during the oxidation of iron and manganese by oxygen are:



- The pH of the effluent can be conditioned. A few toxic and nontoxic metals, such as iron, copper, zinc, nickel, aluminium, mercury, lead, chromium, cadmium, titanium, and beryllium, can be precipitated within a certain pH range.
- Liquid polymerised aluminium can be used as a coagulant. This has been found to be extremely effective in heavy metal precipitation processes in industrial wastewater.

The insoluble compounds resulting from the application of any of the above processes are subsequently removed through the coagulation and clarification process by gravity settling, filtration, centrifugation, or a similar solid/liquid separation technique.

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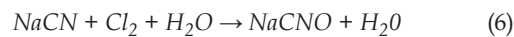
Zero discharge from an industrial unit is often a prerequisite in establishing a new plant.

Oxidation

Chemical/biological oxidation processes use (chemical) oxidants to reduce chemical oxygen demand (COD)/BOD levels and remove both organic and oxidisable inorganic components (metals). These processes can completely oxidise organic materials to carbon dioxide and water, although it is often not necessary to operate the processes to this level of treatment. Oxidation via aeration of the effluent significantly reduces the COD of the treated liquid. Aerobic digestion (in presence of activated sludge) is effected when the BOD in the effluent ranges from 100–1,000 mg/L.

Redox Reaction

An oxidation–reduction (redox) process is used to transform and destroy targeted water contaminants. Substances such as chlorine, cyanide, chromium, and nitrogen dioxide can be removed by redox reaction. As an example, sodium hypochlorite solution is used to treat dilute cyanide in wastewater:



Chemical Conditioning

Chemical conditioning improves sludge dewatering in sludge thickening devices. In this method, chemical coagulants/polymers are dosed to promote agglomeration of floc particles. The choice of chemical conditioners depends on the characteristics of the sludge and the type of dewatering device.

Disinfection

Wastewater before discharge or particularly for reuse needs to be disinfected. Chlorination is one of the most commonly used disinfecting methods; the newly developed processes employ ozone and ultraviolet rays. Ozone, a powerful oxidising agent mainly used to oxidise certain industrial wastewaters that cannot be treated effectively by conventional biological oxidation processes, can also simultaneously disinfect the effluent. Ultraviolet radiation, a kind of electromagnetic radiation, is also used to disinfect wastewaters to avoid any material addition.

Odour Control

Odour problems—mainly from gases such as hydrogen sulphide, ammonia, and methane present in a wastewater facility—are a concern for wastewater treatment personnel. The primary treatment for odour control is oxidation, which converts these gases to an odourless compound

and inhibits formation of anaerobic bacteria that produce gases. Specially treated activated carbon may be used as an odour control medium to absorb hydrogen sulphide.

ROLE OF CHEMICALS IN TREATMENT

Increasing concern about environmental damages from industrial pollutants poses new challenges daily to the discharge effluent quality requirement for industry. Zero/stringent quality of discharge from the industrial unit is often prerequisite to establishing a new plant, demanding more complex and controlled treatment of wastewater that cannot be achieved by standard treatment processes and chemicals. Researchers are engaged in upgrading the treatment processes and developing new chemicals to meet the stringent environmental norms while ensuring that the treatment cost remains reasonable.

As an outcome, there have been significant developments in manufacturing proprietary chemicals, inorganic and organic polymers, and blended chemicals with polymers, among others, for wastewater treatment. These chemicals are designed to work in the specific treatment processes described in the overview section and require significantly lower dosing rates, thereby producing very low amounts of sludge, which is convenient for disposal.

This section includes a general discussion of the types of chemicals and polymers and their applications, advantages, etc., in the treatment processes. It is not the intent of this paper to discuss the types and characteristics of all chemicals and polymers available from different manufacturers. Use of any specific brand or proprietary chemical in a project must be evaluated considering the inlet effluent characteristics, project environmental criteria, and recommendations from the chemical vendor.

Table 2 lists typical inorganic treatment chemicals and their feed rates.

Coagulants/Flocculants

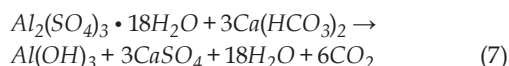
Adding coagulants to the wastewater creates a chemical reaction in which the repulsive electrical charges surrounding colloidal SS are neutralised, allowing the free particles to stick together and create lumps or flocs. The aggregation of these particles into larger flocs permits their separation from solution by sedimentation, filtration, or straining.

Table 2. Typical Inorganic Chemicals Used in Wastewater Treatment

Purpose/Chemicals	Dosing Level, mg/L
Disinfection	
Chlorine	
- Primary treatment effluent	5-10
- Activated sludge effluent	2-5
Chlorine dioxide	
- Primary treatment effluent	2-5
- Activated sludge effluent	1-3
Ammonia Removal	
Chlorine	10
Oxidation of Sulphides	
Chlorine	10-15
Hydrogen peroxide	1.0-1.5
Sodium nitrate	10-30
Coagulant Feed	
Aluminium sulphate (alum)	75-150
Ferric chloride	45-90
Lime	200-400
Ferrous sulphate	>1.5
Ferric sulphate	4-7
pH Control (to maintain alkalinity)	
CaCO ₃	100-500
Lime	200-500

Alum—Al₂(SO₄)₃•18H₂O

The role of aluminium sulphate—alum—in water treatment is known historically. It is an inorganic coagulant/flocculent (see Table 2). When alum and lime are added to the treatment process, the chemical reaction produces the following:



The dosing rate of alum depends on:

- Concentration (mg/L) of SS
- Nature of SS
- pH of effluent
- Type of flocculating equipment

Primary disadvantages of alum are:

- High dosing requirement, 70–250 ppm
- Excessive sludge formation (self-sludge) and its treatment, and loss of water with the sludge
- Lowering of the pH, needing lime dosing for pH control

Ferric Chloride

Ferric chloride is used as an inorganic emulsion breaker (described in the next section), especially to remove oil from water. The normal dosing rate works out to be 40–50 ppm.

Polyelectrolytes

Polyelectrolytes are one of the most widely used chemicals serving as coagulants/flocculents in modern water/wastewater treatment. Their primary advantages are their very low dosing requirement and their applicability over a wide range of pH compared with alum or other inorganic coagulants/flocculents.

Polyelectrolytes are categorised based on their product origin. Natural polyelectrolytes include polymers of biological origin derived from starch, cellulose, and alginates. Synthetic polyelectrolytes consist of single monomers polymerised into a high-molecular-weight substance.

The action of polyelectrolytes changes according to their type. Cationic polymers, in which the cations (positive charges) form the polymer, reduce or reverse the negative charges of the precipitate and therefore act as a primary coagulant.

Anionic polymers, based on carboxylate ions and polyampholytes, carry primarily negative charges and help in interparticle bridging along the length of the polymer, resulting in three-dimensional particle growth and thereby easy settlement.

A third type of polymer, developed from cationic polyelectrolytes of extremely high molecular weight, is capable of offering both coagulation and bridging.

Some of the widely used polyelectrolytes are described next.

Polyaluminium chloride is well-suited as a primary coagulant in a wide variety of industrial and domestic wastewater treatment plants (WTPs). Typical applications include removal of organic impurity, metals, domestic and oily waste, and phosphate. Efficient and effective in coagulating particles with a wide range of

Polyelectrolytes are one of the most widely used chemicals, serving as coagulants/flocculents in the modern wastewater treatment process, due to their very low dosing requirement and applicability over a wide range of pH.

Liquid polymerised aluminium coagulants are extremely effective in heavy metal precipitation processes and combined industrial wastewater treatment.

pH, the chemical offers very good turbidity removal and leaves no residual colour. Typical properties are:

- Available in 25%–40% concentrate
- pH (neat) = 2.3–2.9 SU
- Freezing point = $-5\text{ }^{\circ}\text{C}$ ($-23\text{ }^{\circ}\text{F}$)
- Odourless and colourless
- Specific gravity (sp. gr.) = 1.2

Liquid polymerised aluminium coagulants are extremely effective in heavy metal precipitation processes and combined industrial wastewater. These coagulants have a low impact on process water pH.

Aluminium hydroxide chloride/polymer is a technically advanced, high-performance coagulant based on aluminium hydroxide chloride blended with an organic polymer. The active component of the reagent is a highly cationic aluminium polymer present in high concentration, which is represented as $[\text{Al}_{13}\text{O}_4(\text{OH})_{24}(\text{H}_2\text{O})_{12}]^{7+}$. Typical properties are:

- Sp. gr. = 1.30
- pH = 1.0–2.0 SU
- Charge = +1950

High-molecular-weight cationic polymer (liquid) does not contain oil or surfactants and is designed for SS. It is specially recommended for use in non-potable raw water clarification, primary and secondary effluent clarification, and oil wastewater clarification. Dosing rate varies from 1–10 ppm for wastewater treatment. Typical properties are:

- Available in liquid form
- Sp. gr. = 1.21–1.23
- Viscosity = <700 centipoise
- pH = 3.0–4.2 SU
- Dosing concentration = 0.01%–0.1% aqueous solution

Cationic guanidine polymer, a cationic liquid organic polymer based on an aqueous solution of cyanoguanidine, is designed to coagulate colloidal solids and SS and is therefore recommended for use in non-potable raw water clarification, primary and secondary effluent clarification, oil wastewater clarification, and enhanced organics removal.

Organic polyamines are used as cationic emulsion breakers.

Apart from the above, there are commercially available proprietary anionic polyelectrolytes. The important ones are polystyrene sulphonic

acids and 2-acrylamido-2-methyl propane sulphonic acids.

Alkyl-substituted benzene sulphonic acids and **their salts** are used as anionic emulsion breakers.

Carbamate solution and **liquid thio-carbonate compound** are used to precipitate chelated metals.

Emulsion Breakers

In the coagulation process, chemicals help break the emulsion that keeps oil particles floating in water. The chemicals neutralise the stabilising agents that keep the oil particles floating, allowing them to settle and be removed as sludge. Alum, ferric chloride, sodium aluminates, and acids are common inorganic chemicals used as emulsion breakers. However, they have some disadvantages. The primary ones are:

- Their effectiveness is restricted to a narrow pH range; therefore, a higher dosing rate is normally required.
- A large quantity of watery sludge is produced, necessitating elaborate and expensive disposal.

Organic polyelectrolytes, mostly available as proprietary chemicals from different manufacturers, are highly efficient as emulsion breakers because of their cationic charges and effectiveness over a wide pH range. These chemicals help produce a lower quantity of sludge for easy and economical disposal and also add a lower level of chemicals in the treated effluent. As discussed in the polyelectrolytes section, a few popular polyelectrolytes are polyaluminium chloride, aluminium hydroxide chloride/polymer, high-molecular-weight cationic polymer (liquid), and cationic guanidine polymer.

Metal Precipitants

Some process wastewaters include complexing and chelating agents that bond to the metal ions, making precipitation difficult, if not impossible, for many precipitating reagents. Commercially available proprietary precipitants are capable of breaking many of these bonding agents, thereby precipitating the metal ions without adding other chemicals. In some instances, a combination of pH adjustment and varying reaction times may be required along with precipitants and flocculants for optimum result.

Liquid polymerised aluminium coagulants are extremely effective in heavy metal

precipitation processes and are popular in treatment of combined industrial wastewater. These coagulants have a low impact on process water pH.

Organosulphide compounds can be used to precipitate divalent metals in the form of insoluble metal sulphides.

Hydrogen peroxide (H₂O₂), ozone, and oxygen convert metals into oxides, which are insoluble in water and hence separated out through coagulation and the settlement process.

Oxidants

Typical oxidation chemicals are:

- **Hydrogen peroxide**, widely used as a safe, effective, powerful, and versatile oxidant. The main applications are oxidation to aid odour and corrosion control, organic oxidation, metal oxidation, and toxicity oxidation.
- **Ozone**, primarily used as a disinfectant but also aids removal of contaminants from water by means of oxidation. Ozone purifies water by breaking up organic contaminants and converting them to inorganic contaminants in insoluble form that can be filtered out. An ozone system can remove up to 25 contaminants, including iron, manganese, nitrite, cyanide, nitrogen oxides, and chlorinated hydrocarbons.
- **Oxygen**, which can be applied as an oxidant to realise the oxidation of iron and manganese (see Equations 4 and 5). The method is popular because of oxygen's abundant availability in the atmosphere.

Chemicals for pH Control and Odour Control

For pH control, lime solution, caustic soda, and sulphuric and hydrochloric acids are commonly used.

For odour control, hydrogen peroxide is widely used as a safe, effective, powerful, and versatile oxidant. Other chemicals used are ozone, hypochlorite, permanganate, and oxygen. Activated carbon filters are also used to absorb bad odours.

Disinfecting Agents

Chlorine gas or sodium hypochlorite is used as a primary disinfecting agent because of its easy availability and residual protection. However, because chlorine is reactive to some metals, ozone is also used as an alternative. Ultraviolet radiation is preferred in some cases because it does not add new chemicals to the process.

Other Chemicals

Antifoam is primarily used as a process aid. Antifoam blends contain oils combined with small amounts of silica and break down foam based on two of silicone's properties: incompatibility with aqueous systems and ease of spreading.

Lime, alum, ferric chloride, and polyelectrolytes are commonly used chemical conditioners for effective sludge thickening and dewatering.

Organic phosphorous/polysulphonate compounds are used as antiscalant dispersants and corrosion inhibitors. Typical compositions are phosphonates and organophosphorous carboxylic acids and their salts. Organophosphorous carboxylic acid compounds are water soluble; usual dosing rates vary from 15–25 mg/L.

DESIGN APPROACH

Designing a WTP for any project is always a unique and challenging process for WTP personnel because:

- Process flow data is inaccurate; normally, most source data is estimated, with a wide variation in minimum and maximum flows and flow durations.
- Input characteristics of the flow are guesswork.
- Effluent disposal criteria are specific to the project and guided by the local norms.

Plant designers should consider the following aspects in conceptualising a WTP:

- Optimally size the plant by integrating continuous and intermittent flows. Too small a plant does not provide the discharge quality, while too conservative a design requires high capital cost and leads to inaccurate treatment at lean flow conditions.
- Sequence and integrate the treatment processes for maximum effectiveness based on estimated effluent characteristics and their variations at different plant operating regimes.
- Conduct a jar test, described in more detail below, to optimise the selection and dosing rate of chemicals. Use vendor information to validate the design.
- Use a material safety data sheet (MSDS), described in more detail below, to build safety into process design, giving due consideration to safe handling, storage, and disposal.

Designing a good WTP for a project is always a unique and challenging task for WTP personnel.

Figure 2, a flow diagram for typical wastewater treatment in a refinery, highlights the processes and dosing chemicals.

Jar Test

Before a prototype plant is developed, it is customary to conduct a laboratory test to study the behaviour of an effluent, its response to the chemical treatment, and the chemical dosing rate. The jar test is a common laboratory procedure used to determine the optimum operating conditions, especially the dosing rate of chemicals for water or wastewater treatment. This method allows adjustments in pH, variations in coagulant or polymer dose, alternative mixing speeds, and testing of different coagulant or polymer types on a small scale to predict the functioning of a large-scale treatment operation. A jar test simulates the coagulation and flocculation processes that encourage the removal of suspended colloids and organic matter that can lead to turbidity, odour, and taste problems.

Material Safety Data Sheet

An MSDS provides relevant data regarding the properties of a particular substance/chemical. It is intended to provide designers, operators, and emergency personnel with procedures for

safely handling and working with a substance, and it includes information such as physical data (melting point, boiling point, flash point, etc.), toxicity, health effects, first aid, reactivity, storage, disposal, protective equipment, and spill-handling procedures. The format of an MSDS can vary from source to source and depends on the safety requirement of the country.

CONCLUSIONS

Wastewater treatment in any plant normally takes a back seat as designers focus primarily on the high-end plant equipment and systems to ensure higher plant efficiency, reliability, and availability. Supporting this conclusion is the fact that reliable design inputs are obtained from the vendor data only after major plant systems and equipment designs are in place and related data becomes available from equipment vendors.

This paper can be helpful at the initial project phase in conceptualising a WTP design in terms of the treatment processes and chemicals needed based on typical industry data and project environmental permits. The initial design can then be subsequently validated using actual equipment data and chemical vendors' recommendations. ■

The jar test simulates the coagulation and flocculation processes and is used to predict the functioning of a large-scale treatment operation.

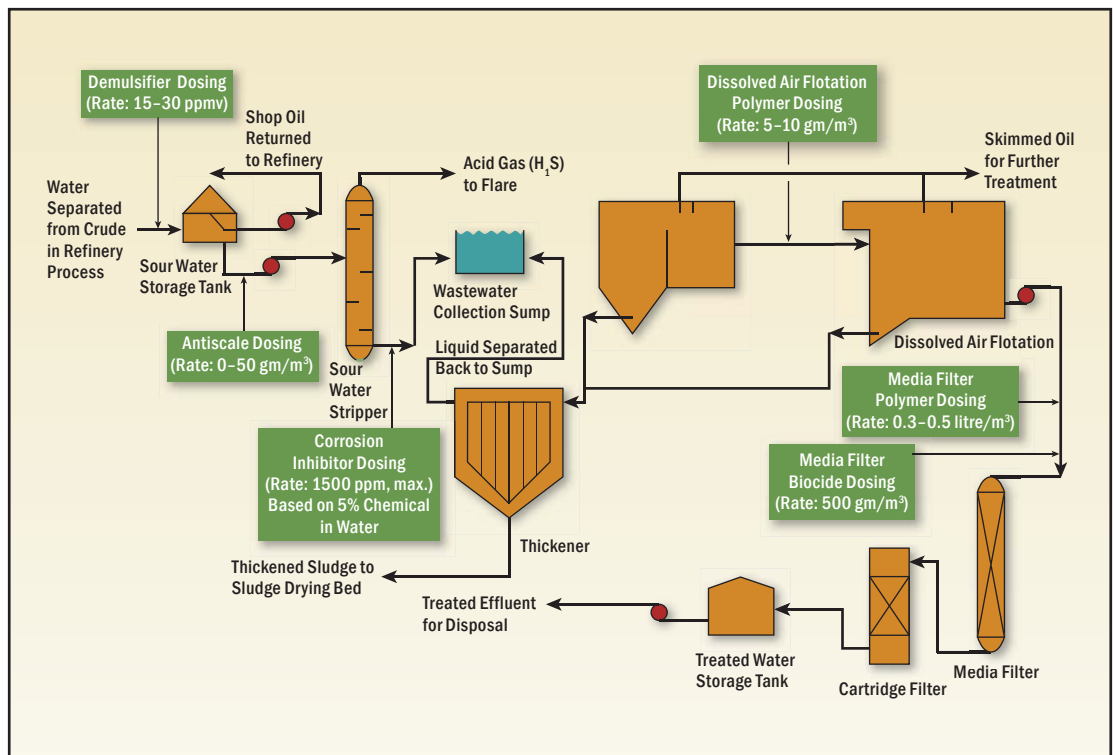


Figure 2. Dosing Scheme for a Typical Refinery Effluent Treatment Plant

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BIOGRAPHIES



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Kanchan has more than 23 years of experience in the industry. During this time, he has assumed responsibilities as manager and process engineer in various water treatment, process chemical, and fertilizer plants and has become familiar with their design, operation, and maintenance.

Kanchan is a Chemical Engineering graduate of Calcutta University, India.



Asim De is a mechanical engineering supervisor and has worked on both Power and OG&C projects in Bechtel's New Delhi Execution Unit. He is currently working on the Yajva power generation project. During his 4 years with Bechtel, he has also worked on the Jamnagar

Export Refinery captive power plant and Takreer FEED projects.

Asim has more than 31 years of experience in the industry and has worked in conceptual and detailed design for all power plant systems and equipment. In addition, he is familiar with commissioning power and desalination plants. He has assumed responsibilities as lead engineer, assistant chief engineer, and general manager in different organizations involved in the power generation business.

Asim is a Fellow of The Institute of Engineers (India). He is a Mechanical Engineering graduate of the Indian Institute of Technology, Kharagpur, a premier engineering institute; has an ME degree in Project Engineering from the Birla Institute of Technology, Pilani; and took a post-graduate executive course in Management at the Indian Institute of Management, Calcutta; all in India. He is a Six Sigma Yellow Belt.

