

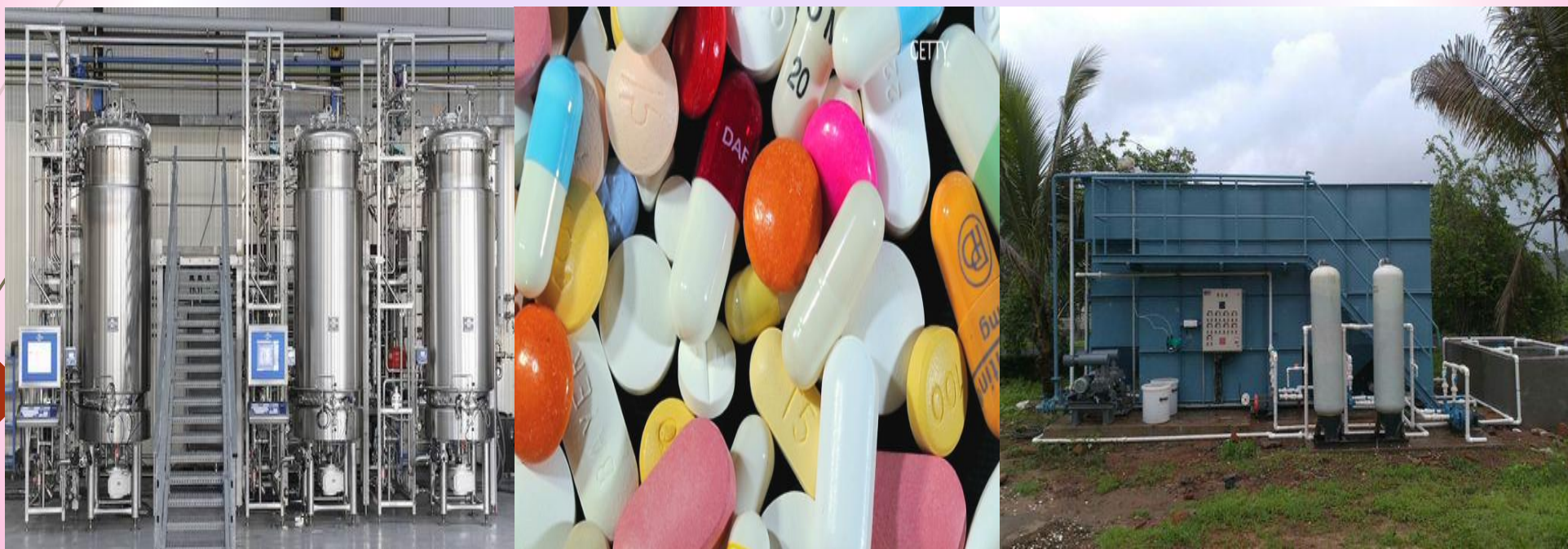
Treatment of Pharmaceutical Wastes



By/ Ahmed Mohamed Hasham

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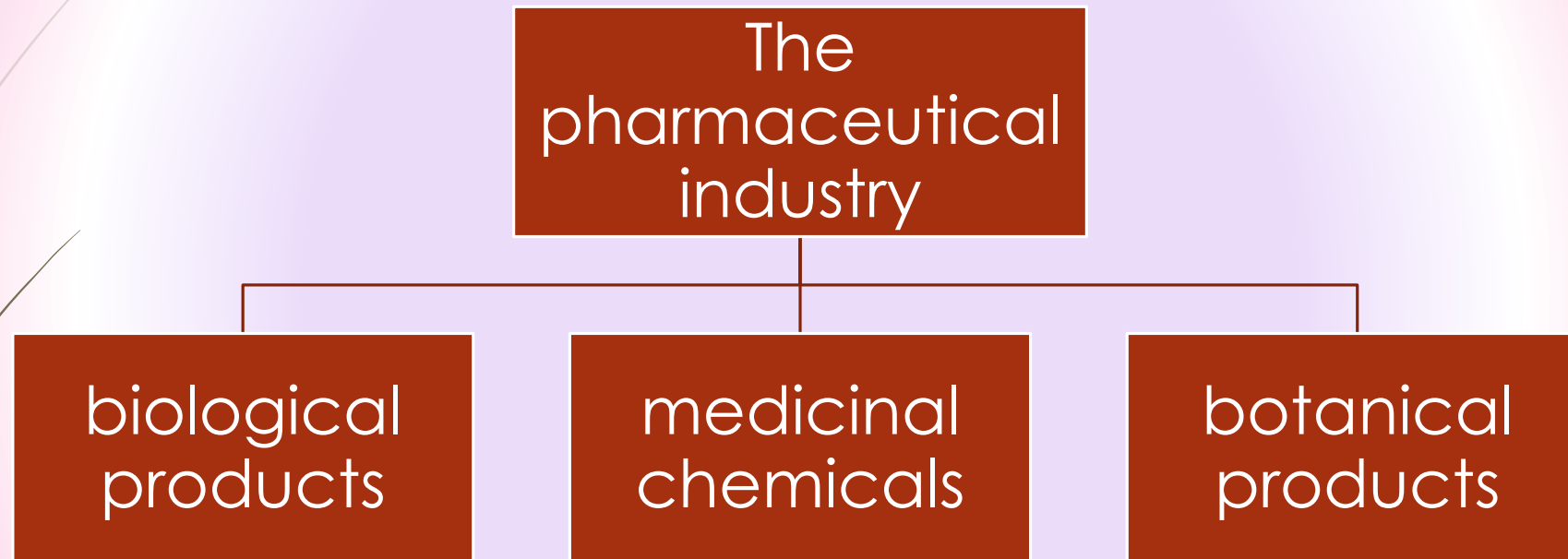
<https://eg.linkedin.com/in/ahmed-hasham-mmba-01024b27>

About the presenter



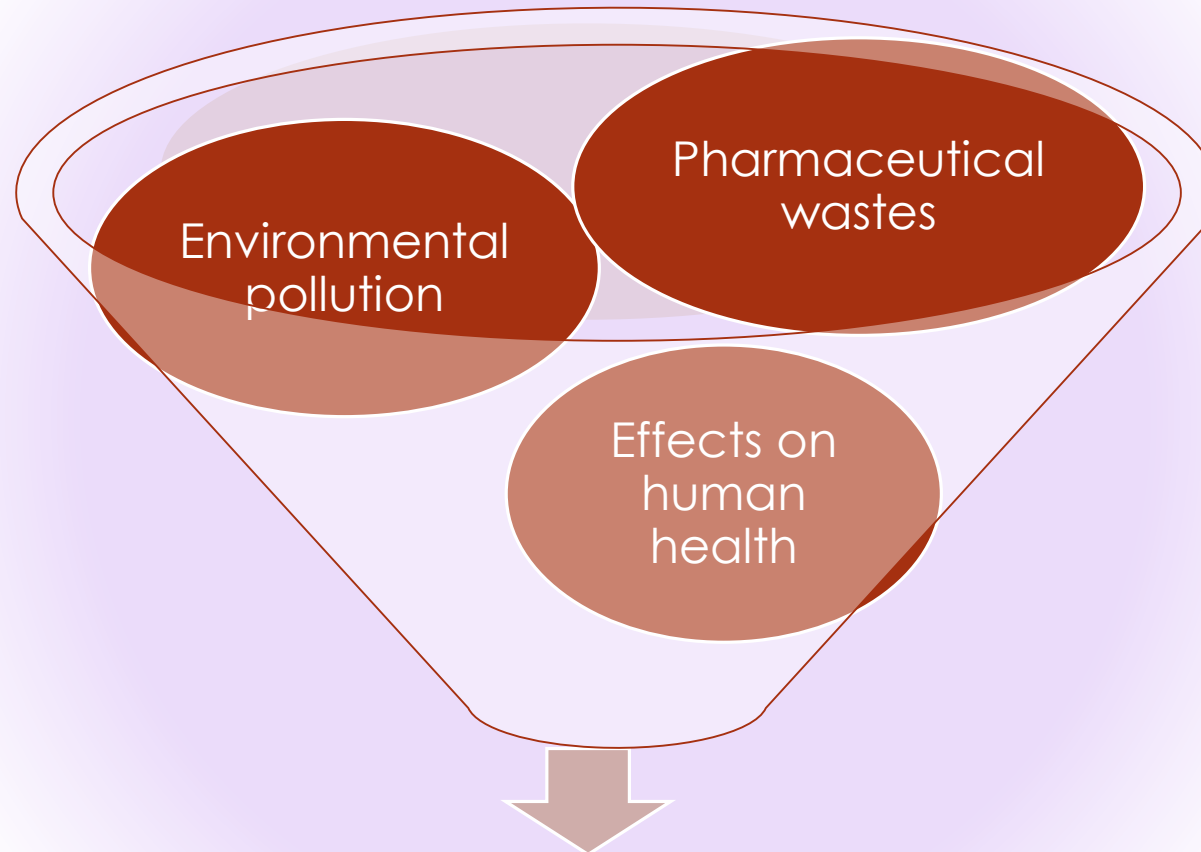
- **Member of the Board scientists Egypt.**
- **Member of Scientific Professions Syndicate.**
- **Member of the Arab Society for experts and Safety Professionals.**
- **Member of the International Association of Engineers.**
- **Expert in water and waste water treatment technologies.**
- **Certified trainer in water treatment field .**
- **Certified trainer in Quality Management Systems field.**

- <https://eg.linkedin.com/in/ahmed-hasham-mmba-01024b27>
- 0021 159465989
- ahmedhasham83@gmail.com



5

Problems:



Need to manage pharmaceutical waste and
minimize their effects

Sources of Pharmaceutical waste

6

Waste generated during the
manufacture

Passed recommended
shelf-life

**Waste
Sources**

Discarded due to
contaminated packaging

No longer required by the public

The industry is characterized by:

- a diversity of products.
- a diversity of Processes.
- plant sizes.
- wastewater quantity.
- wastewater quality.



The pharmaceutical industry represents a range of industries with operations and processes as diverse as its products

pharmaceutical effluent

- Hence, it is almost impossible to describe a “typical” pharmaceutical effluent because of such diversity. The growth of pharmaceutical plants was greatly accelerated during World War II by the enormous demands of the armed forces for life-saving products.
- Industrialization in the last few decades has given rise to the discharge of liquid, solid , and gaseous emissions into natural systems and consequent degradation of the environment



The Most detected compounds

- The most frequently detected compounds were basically of pharmaceutical origin, that is, coprostanol (fecal steroid), cholesterol (plant and animal steroids), *N,N*-diethyltoluamide (insect repellent), caffeine (stimulant), and triclosan (antimicrobial disinfectant), and so on.



Categorization of the pharmaceutical industry

Table 1 Classes of Pharmaceutical Products and Typical Examples [3]

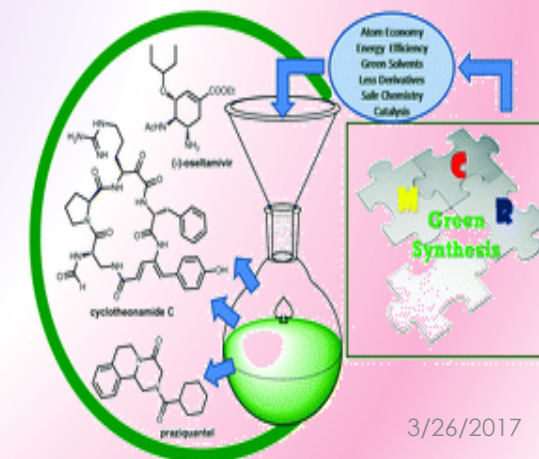
Classes	Subclasses with typical examples
Medicinal	Antibiotics (e.g., penicillins, tetracyclines) Vitamins (e.g., B, E, C, A) Anti-infective agents (e.g., sulphonamides) Central depressants and stimulants (e.g., analgesics, antipyretics, barbiturates) Gastro-intestinal agents and therapeutic nutrients Hormones and substitutes Autonomic drugs Antihistamines Dermatological agents-local anesthetics (e.g., salicylic acid) Expectorants and mucolytic agents Renal acting and endema reducing agents
Biologicals	Serums/vaccines/toxoids/antigens
Botanicals	Morphine/reserpine/quinine/curare Various alkaloids, codeine, caffeine, etc.

Subdivided of pharmaceutical industries:

- 1. Fermentation plants.
- 2. Synthesized organic chemicals plants.
- 3. Fermentation/synthesized organic chemicals plants (moderate to large plants) .
- 4. Biological production plants (production of vaccines-antitoxins).
- 5. Drug mixing, formulation, and preparation plants (tablets, capsules, solutions, etc.).

Most plants are actually combinations of :

- fermentation processes.
- organic synthesis processes.



Chemist/Ahmed Hasham

3/26/2017

Process description and waste characteristics

- Pharmaceutical waste is one of the major complex and toxic industrial wastes.
- various processes and a wide variety of raw materials to produce an array of final products.
- As a result, a number of waste streams with different characteristics and volume are generated
- According the seasonal use of many products, production within a given pharmaceutical plant often varies throughout the year, which **changes the characteristics of wastewater by season.**
- Hence, it is difficult to generalize the characteristics of the effluent discharged from these industries.

Fermentation Plants

Table 2 Characteristics of a Typical Spent Fermentation Broth [3]

<i>Composition</i>	
Total solids	1–5%
<i>The total solids comprise</i>	
Protein	15–40%
Fat	1–2%
Fibers	1–6%
Ash	5–35%
Carbohydrates	5–27%
Steroids, antibiotics	Present
Vitamin content of the solids	Thiamine, Riboflavin, Pyridoxin, HCl, Folic acid at 4–2,000 µg/g
Ammonia N	100–250 mg/L
BOD	5,000–20,000 mg/L
pH	3–7
BOD, biochemical oxygen demand.	

Various types of waste streams were generated from this plant depending upon the manufacturing process



Table 3 Characteristics of Untreated Synthetic Drug Waste [11]

Parameter	Concentration range (mg/L)
<i>p</i> -amino phenol, <i>p</i> -nitrophenolate, <i>p</i> -nitrochlorobenzene	150–200
Amino-nitrozo, amino-benzene, antipyrene sulfate	170–200
Chlorinated solvents	600–700
Various alcohols	2,500–3,000
Benzene, toluene	400–700
Sulfanilic acid	800–1,000
Sulfa drugs	400–700
Analogous substances	150–200
Calcium chloride	600–700
Sodium chloride	1,500–2,500
Ammonium sulfate	15,000–20,000
Calcium sulfate	800–21,000
Sodium sulfate	800–10,000

Table 4 Characteristics of Synthetic Organic Chemicals, Wastewater at Squibb, Inc., Humaco [12]

Waste	Flow, g/day		BOD (mg/L)	COD (mg/L)	BOD load (lb/day)		COD load (lb/day)	
	Avg.	Max.			Avg.	Max.	Avg.	Max.
Strong process	11,800	17,400	480,000	687,000	47,300	74,200	67,600	105,800
Dilute process	33,800	37,400	640	890	180	190	250	280
Service water	35,300	—	—	—	—	—	—	—
Composite	80,900	—	70,365	109,585	47,500	—	67,900	—

BOD, biochemical oxygen demand; COD, chemical oxygen demand.

The Ratio between BOD & COD

- The BOD to COD ratio of alkaline, condensate and combined wastewater was around 0.5–0.6, while for the acidic waste alone it was around 0.4, indicating that all these wastewaters are biologically treatable.
- The combined wastewater had average:
 - **TOC** **2109 mg/L**
 - **COD** **4377 mg/L**
 - **BOD** **2221 mg/L**
- Most of the solids present were in a dissolved form, with practically no suspended solids. The wastewater contained sufficient nitrogen, but was lacking in phosphorus, which is an essential nutrient for biological treatment.

Table 5 Characteristics of Alkaline Waste Stream of a Synthetic Drug Plant at Hyderabad [13,15]

Parameters	Ranges (max. to min.)	
	From Ref. [15]	From Ref. [13]
Flow (m ³ /day)	1,400–1,920 (1,710)	1,710
pH	4.1–7.5	2.3–11.2
Total alkalinity as CaCO ₃	1,279–2,140	624–5630
Total solids	1.29–2.55%	1 1825–23265 mg/L
Total volatile solids	13.1 –32.6% of TS	1,457–2,389 mg/L
Total nitrogen (mg/L)	284–1, 036 (TKN)	266–669
Total phosphorus (mg/L)	14–42	10–64.8
BOD ₅ at 20°C (mg/L)	2,874–4,300	2,980–3,780
COD (mg/L)	5,426–7,848	5,480–7,465
BOD:COD	—	0.506–0.587
BOD:N:P	—	100:(8.9–17.7):(0.265–1.82)
Suspended solids (mg/L)	—	11–126
Chlorides as Cl ⁻ (mg/L)	—	2,900–4,500

TS, total solids; TKN, total Kjeldhal nitrogen; BOD, biochemical oxygen demand; COD, chemical oxygen demand.

Fermentation/Synthetic Organic Chemical Plants

Table 7 Characteristics of an Acid Waste Stream of a Synthetic Drug Plant at Hyderabad [13]

Parameters	Ranges (max. to min.)
Flow (m^3/day)	435
pH	0.4–0.65
BOD ₅ at 20°C (mg/L)	2,920–3,260
COD (mg/L)	7,190–9,674
BOD/COD ratio	0.34–0.41
Total solids (mg/L)	18,650–23,880
Total volatile solids (mg/L)	15,767–20,891
Suspended solids	Traces
Total nitrogen (mg/L)	352
Total phosphorus (mg/L)	9.4
Total acidity as CaCO_3	29,850–48,050
Chlorides as Cl^- (mg/L)	6,500
Sulfate as SO_4^{2-} (mg/L)	15,000
BOD, biochemical oxygen demand; COD, chemical oxygen demand.	

Table 8 Characteristics of Combined Wastewater^a
of a Synthetic Drug Plant at Hyderabad [15]

Parameters	Range	Standard deviation
PH	2.9–7.6	—
BOD ₅ at 20°C (mg/L)	1,840–2,835	2,221±301
COD (mg/L)	4,000–5,194	4,377±338
BOD/COD ratio	0.46–0.54	—
Total organic carbon (C) (mg/L)	1,965–2,190	2,109±73
BOD exertion rate (<i>k</i>) constant ^b	0.24–0.36	0.28±0.02

^aAlkaline and condensate wastewater mixed in 1:1 ratio.

^bBOD, biochemical oxygen demand; COD, chemical oxygen demand.

Table 9 Characteristics of Pharmaceutical Industry
Wastewater Producing Allopathic Medicines [16]

Parameter	Range of concentration	Average concentration
pH	6.5–7.0	7
BOD (mg/L)	1,200–1,700	1,500
COD (mg/L)	2,000–3,000	2,700
BOD/COD ratio	0.57–0.6	0.55
Suspended solids (mg/L)	300–400	400
Volatile acids (mg/L)	50–80	60
Alkalinity as CaCO_3 (mg/L)	50–100	60
Phenols (mg/L)	65–72	65

Biological Production Plants

- These plants are mainly involved in the production of antitoxins, antisera, vaccines, serums, toxoids, and antigens. The production of antitoxins, antisera, and vaccines generates wastewaters containing animal manure, animal organs, baby fluid, blood, fats, egg fluid and egg shells, spent grains, biological culture, media, feathers, solvents, antiseptic agents, herbicidal components, sanitary loads, and equipment and floor washings.
- The various types of waste generated mainly include:
 - waste from test animals.
 - pathogenic-infectious waste from laboratory research on animal disease.
 - toxic chemical wastes from laboratory research on bacteriological, botanical, and zoological.
 - waste from antisera/antitoxins production.
 - sanitary wastes.

Table 10 Characteristics of Liquid Waste Arising in Liver and Beef Extract Production from a Biological Production Pharmaceutical Wastewater [18]

Constituents	Range	Mean
PH	5–6.3	5.8
Temperature (°C)	26.5–30	28
BOD ₅ (mg/L)	11,400–16,100	14,200
COD (mg/L)	17,100–24,200	21,200
BOD/COD ratio	0.66–0.67	0.67
Total solids (TS) (mg/L)	16,500–21,600	20,000
Volatile solids (VS) (mg/L)	15,900–19,600	19,200
TKN (mg/L)	2,160–2,340	2,200
Crude fat (mg/L)	3,800–4,350	4,200
Volatile fatty acids (VFA) (mg/L)	1,060–1,680	1,460

BOD, biochemical oxygen demand; COD, chemical oxygen demand; TKN, total Kjeldhal nitrogen.

Parameters of Significance for the Pharmaceutical Industry Wastewater

Table 12 Parameters of Significance for the Pharmaceutical Industry Wastewater [3]

pH	Fecal coliform
Temperature	Manganese
BOD ₅ , BOD _{ult}	Phenolics
COD	Chromium
Dissolved oxygen	Aluminum
TOC	Cyanides
Solids (suspended and dissolved)	Zinc
Oil and Grease	Lead
Nitrogen, (NH ₄ and organic-N)	Copper
Sulfides	Mercury
Toxicity	Iron

BOD, biochemical oxygen demand; COD, chemical oxygen demand; TOC, total organic carbon.

Waste recovery and control

- Production processes used in the pharmaceutical/fine chemical, cosmetic, textile, rubber , and other industries result in wastewaters containing significant levels of aliphatic solvents.
- organic solvents contribute 66% of the waste.
- aliphatic solvents contribute a significant proportion of the BOD/COD content of pharmaceutical effluents.
- Organic solvents are flammable, malodorous, and potentially toxic to aquatic organisms and thus require complete elimination by wastewater treatment systems.
- Recovery of various useful byproducts such as solvents, acids , sodium sulfate, etc. comprise a very important waste control strategy for pharmaceutical plants

- Solvents if not removed/recovered, will destroy the performance efficiency of biological treatment.
- The **mycelium**, which poses several operational problems during treatment, can be recovered for use as animal feed supplements. [Separate, filtration, drying, and recovery](#) of [mycelium](#) has been recommended as the best method for its use as animal feed or supplements.

Fungus Structure

The structure of a fungus is commonly in two parts:

- (1) Mycelium
- (2) Fruiting Body

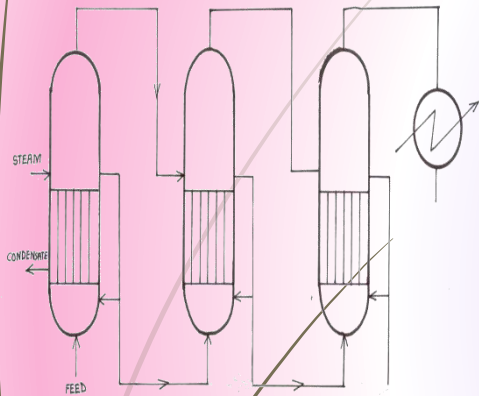


benefits of solvents recovery / removal

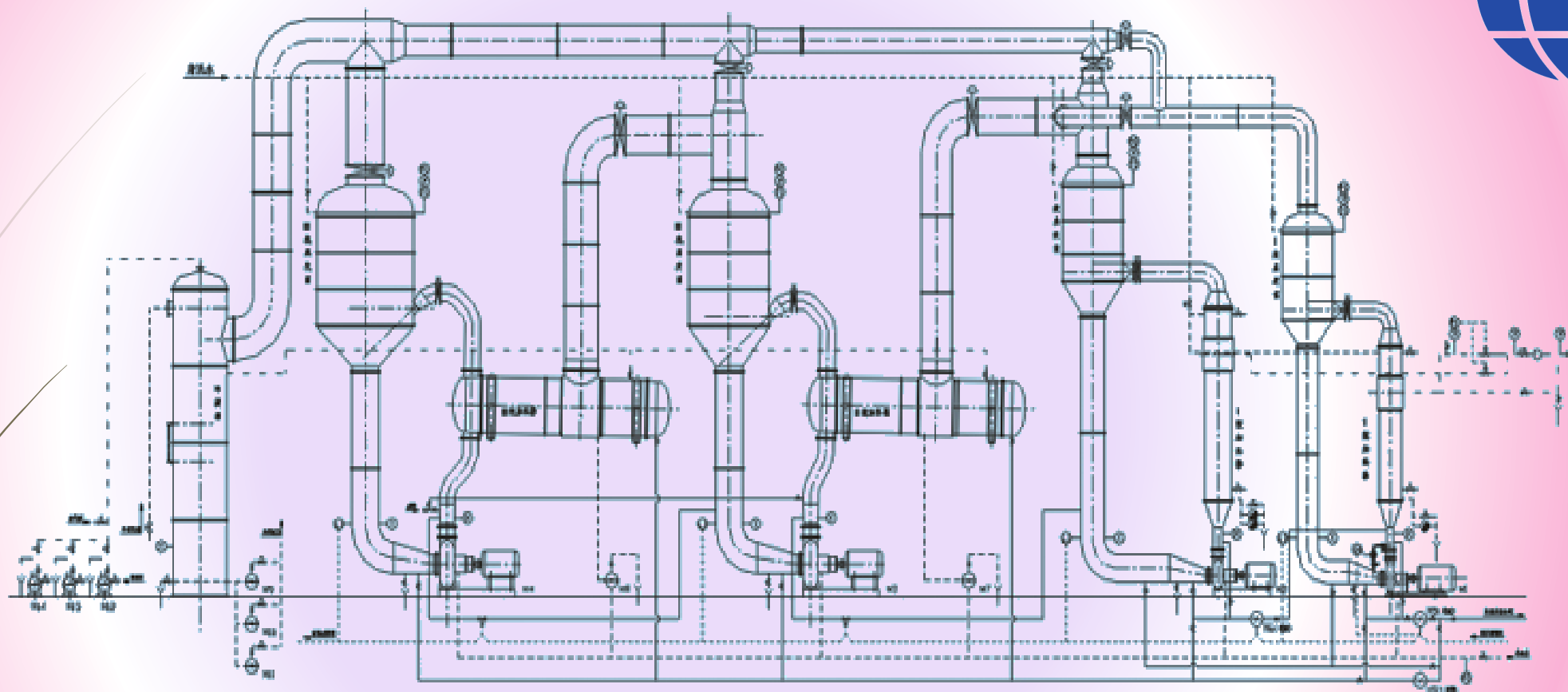
- Reduce the cost of biological treatment.
- gives economic returns in recovery of valuable byproducts.
- Increase performance efficiency of biological treatment.
- reduce flow into pharmaceutical effluents.



triple-effect evaporation system



- Large-scale recovery of antibiotic spent beers by triple-effect evaporators was carried out at Upjohn Co., Kalamazoo, Michigan, in the 1950s.
- Biochemical oxygen demand reduction with the triple-effect evaporation system was reported to be 96 to 98% for four different types of antibiotic spent beers.
- Five-day biological oxygen demand) load potential of 20,000 lb./day or greater. In the process, the spent beers were concentrated by multiple effect evaporators to 30% solids and the resulting syrup sold as a poultry feed additive. Any excess was incinerated in the main plant boilers. Abbott Labs reported that an average overall BOD reduction efficiency of the system up to 96% or more could be achieved. From 1972 to 1973, Abbott Labs in North Chicago, IL, recovered beers with a BOD₅



三效四段强制循环蒸发器流程示意图

Flow figure of triple-effect four-section forced circulating evaporator

Recovery of other valuable products

- Recovery of valuable products from penicillin, riboflavin, streptomycin, and vitamin B fermentation has been recommended as a viable waste control strategy when incorporated into animal feeds or supplements. Penicillin wastes, when recovered for animal feed, are reported to contain valuable growth factors, mycelium, and likewise evaporated spray-dried soluble matter .

Recovery of sodium sulfate

- The recovery and subsequent sale of sodium sulfate not only gave an economic return, but also reduced the influent sulfate concentration that may otherwise cause sulfide toxicity in anaerobic treatment of the pharmaceutical effluents.

ammonia recovery

- Scavenging and recovery of high-level ammonia waste streams is recommended as a viable option of ammonia recovery for waste streams containing high concentrations of ammonia nitrogen.

Recovery of alcohol

- The recovery of alcohol by distillation, concentration of organics, and use of waste activated sludge as a soil conditioner and fertilizer has also been reported .

Treatment processes

The treatment processes can be divided into the following three categories and subcategories:

- 1. physicochemical treatment process;
- 2. biological treatment process,
 - (i) aerobic treatment,
 - (ii) anaerobic treatment,
 - (iii) two-stage biological treatment,
 - (iv) combined treatment with other waste;
- 3. integrated treatment and disposal facility for a particular plant wastewater.

Physicochemical Treatment

Physicochemical treatment of pharmaceutical wastewater includes:

1. screening.
2. Equalization
3. neutralization/pH adjustment.
4. coagulation/flocculation.
5. sedimentation .
6. Adsorption.
7. ozone and hydrogen peroxide treatment.

screening.



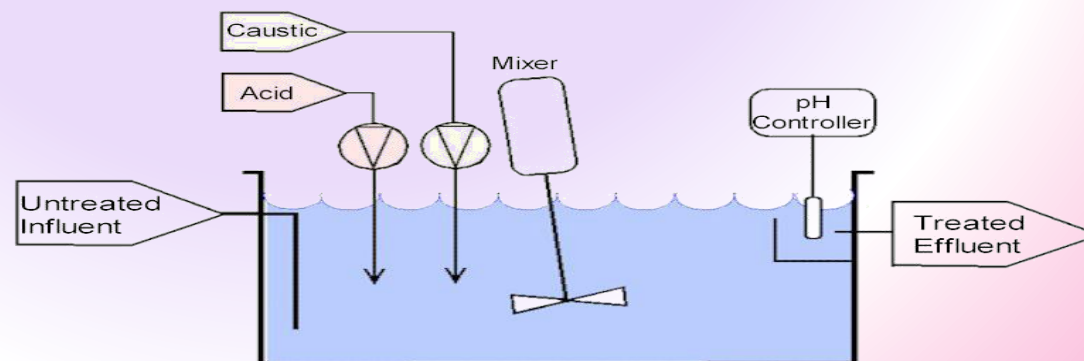
Extensive Holding and Equalization of Waste

- Use of an equalization basin has been reported effectively to control shock loading on further treatment units treating the pharmaceutical waste .
- The retention time and capacity of the holding tank in such cases is designed based on the degree of variability in composition and magnitude of the wastewater.



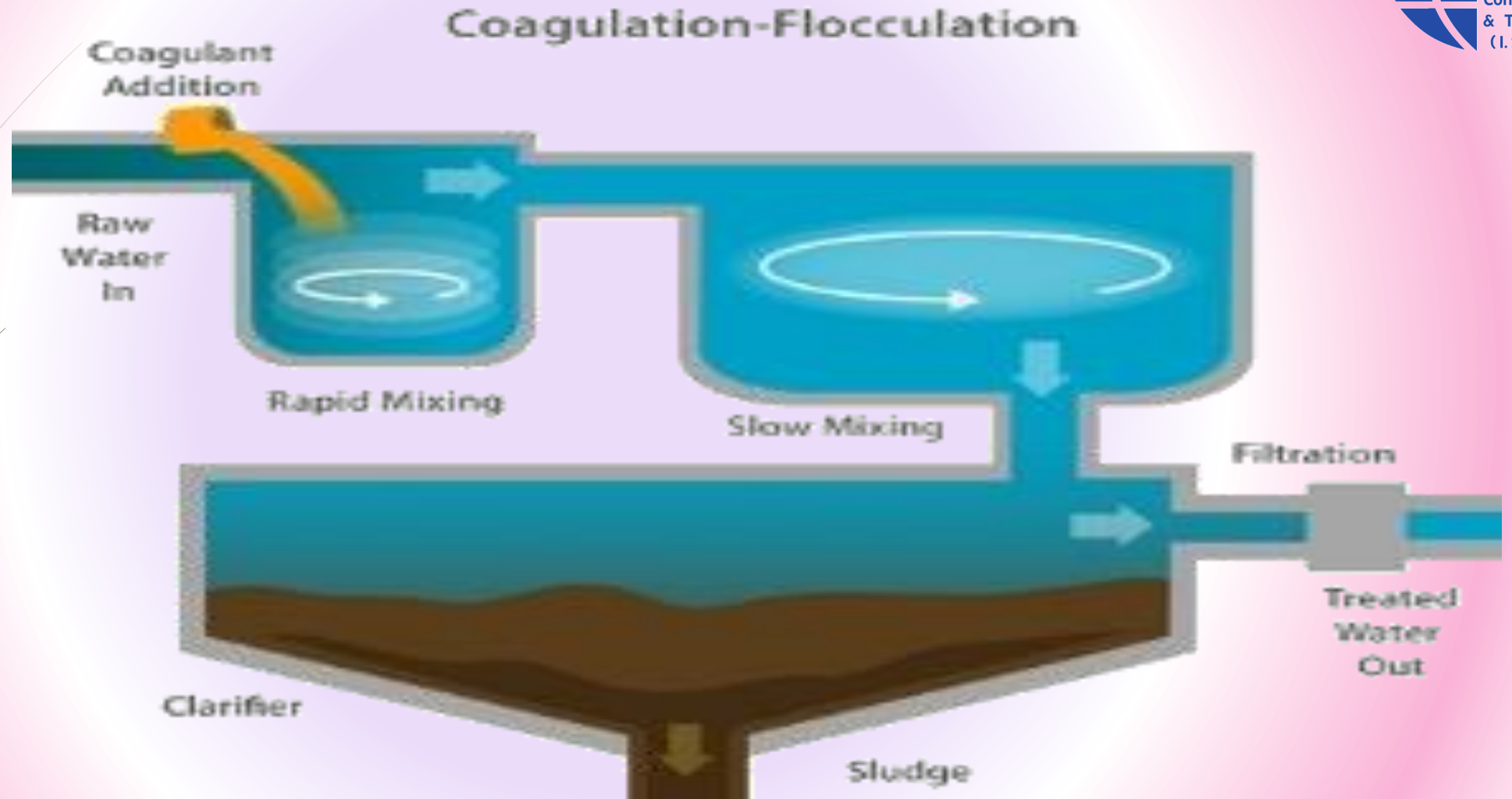
Neutralization/pH Adjustment

- Wastewater generated from the pharmaceutical industry varies greatly in pH, ranging from acidic to alkaline.
- Almost all types of w or acidic waste streams produced from the pharmaceutical industry are either alkaline or acidic, and require neutralization before biological treatment.
- Thus, neutralization/pH adjustment of the waste prior to the biological system is a very important treatment unit for the biological treatment of pharmaceutical wastewater.
- The pH of the wastewater in this unit is adjusted by adding alkali or acid depending upon the requirement of the raw wastewater.

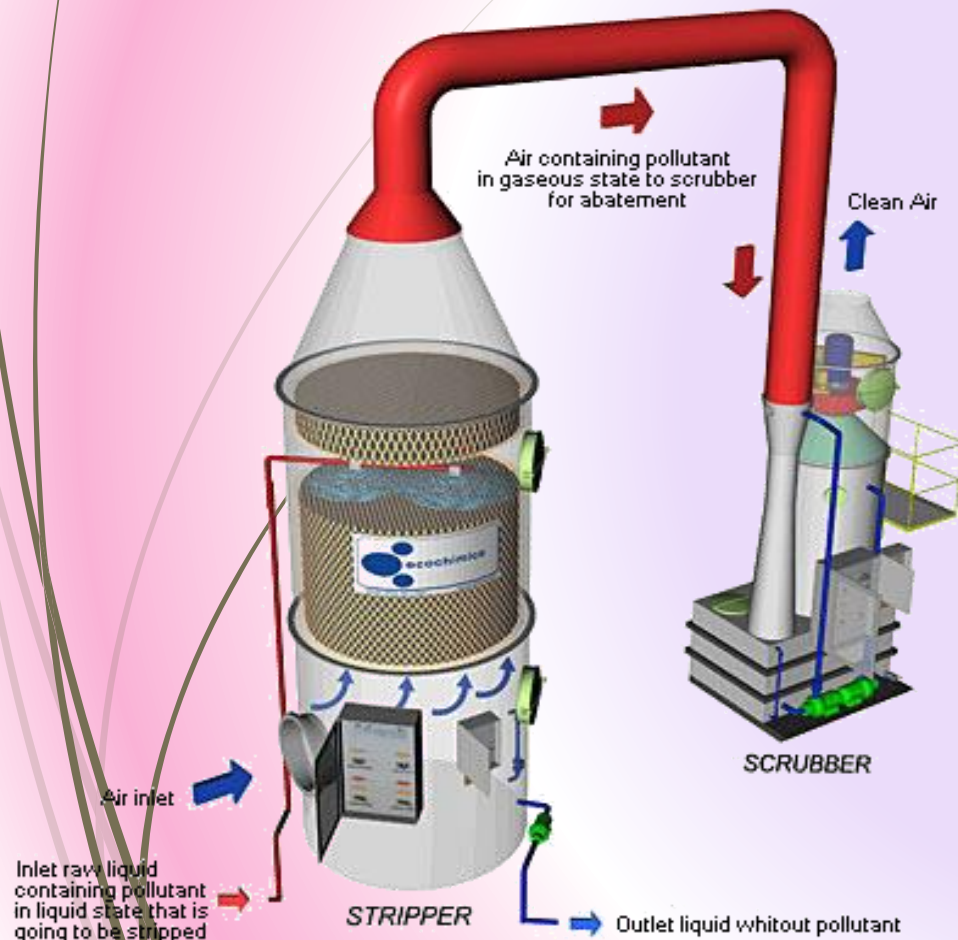


Coagulation and flocculation

- Coagulation and flocculation of the wastewater are carried out for the removal of suspended and colloidal impurities.
- The application of such treatment units greatly depends upon the suspended and colloidal impurities present in the raw wastewater. Coagulation and flocculation of pharmaceutical wastewater have been reported to be less effective at a pharmaceutical plant in Bombay that produces allopathic medicines .
- The effects of various coagulants such as FeSO_4 , FeCl_3 and alum on suspended solids and COD removal efficiency were evaluated , it was concluded that physicochemical treatment of effluent from this type of plant prior to biological treatment is neither effective nor economical.



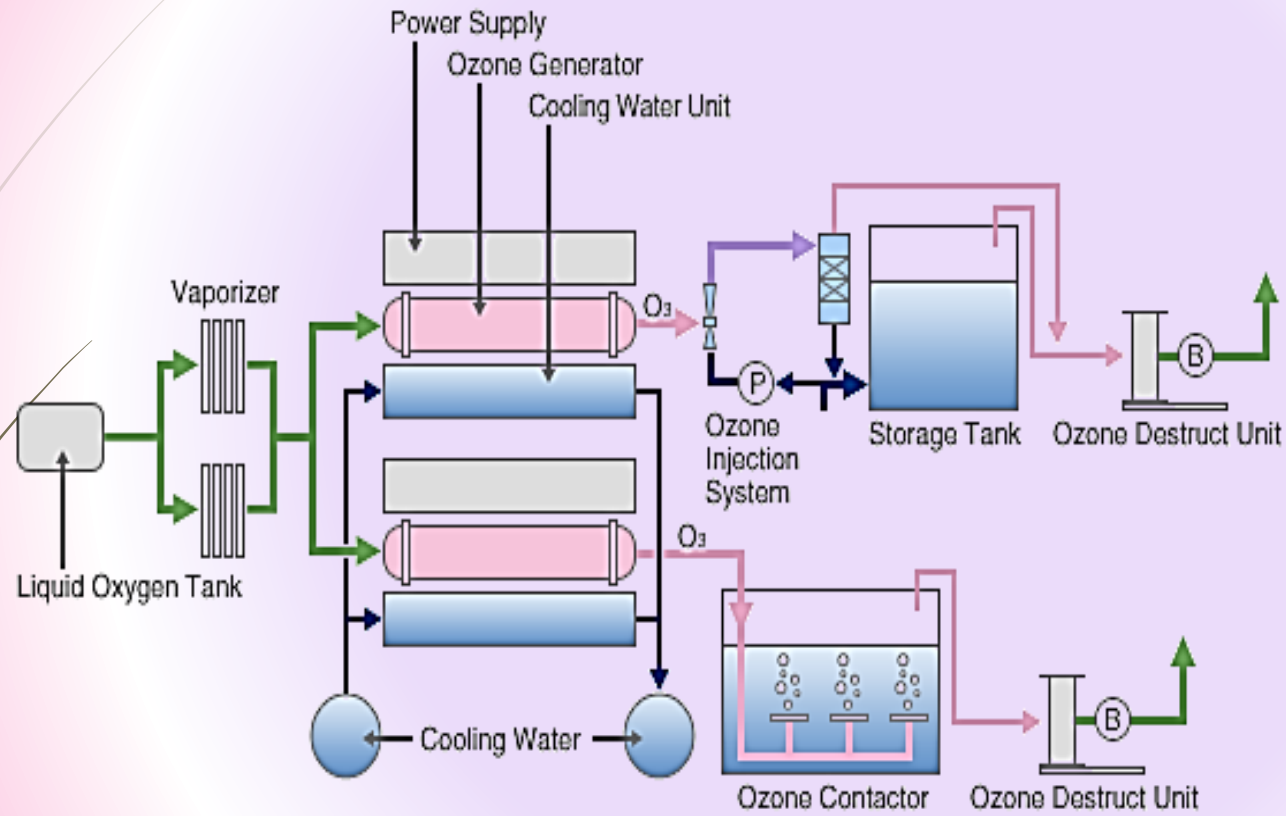
Air stripping



- Air stripping of pharmaceutical wastewater is a partial treatment used in particular for the removal of volatile organics from wastewater. M/S Hindustan Dorr Oliver, Bombay.
- COD removal efficiency up to 30–45% can be achieved by air stripping.
- It was found that adding caustic soda did not appreciably increase the air stripping efficiency.

Ozone/Hydrogen Peroxide Treatment

- Pharmaceutical wastewater contains various kinds of recalcitrant organics such as toluene, phenols, nitrophenols , nitroaniline , trichloromethyl propanol (TCMP), and other pollutants that exhibit resistance against biodegradation.
- Since these pollutants cannot be easily removed by biological treatment, biologically treated effluent exhibits a considerable oxygen demand, that is, BOD and COD, in the effluent.
- It has also been reported that activated carbon adsorption may not always be successful in removing such recalcitrant organics .
- ozone/hydrogen peroxide treatment may appear to be a proven technology for treating such pollutants from pharmaceutical wastewater.
- It has been concluded that biological pretreatment of pharmaceutical wastewater before ozonation/hydrogen peroxide treatment should be utilized in order to increase the level of treatment.



Biological Treatment

■ aerobic treatment systems :

1. activated sludge process.
2. extended aeration activated sludge process.
3. activated sludge process with granular activated carbon.
4. trickling filters and
5. rotating biological contactors.

■ anaerobic treatment systems :

1. membrane reactors.
2. continuously stirred tank reactors (anaerobic digestion).
3. Up flow filters (anaerobic filters).
4. fluidized bed reactors.
5. Upflow anaerobic sludge blanket reactors.
6. Anaerobic hybrid reactors.

Activated Sludge Process

- The activated sludge process has been found to be the most efficient treatment for various categories of pharmaceutical wastewater .
- It has also been reported that this process can be successfully employed for the removal of tert-butanol, a common solvent in pharmaceutical wastewater that cannot be degraded by anaerobic treatment.
- The American Cyanamid Company operated an activated sludge treatment plant to treat wastewater generated from the manufacture of a large variety of chemicals .
- The activated sludge process has also been successfully employed for the treatment of wastewater in the chemical and pharmaceutical industry and concluded that at an MLSS (mixed liquor suspended solids) concentration of 1800–2200 mg/L and aeration period of 24 hours, a COD removal efficiency of 50–83% can be achieved.

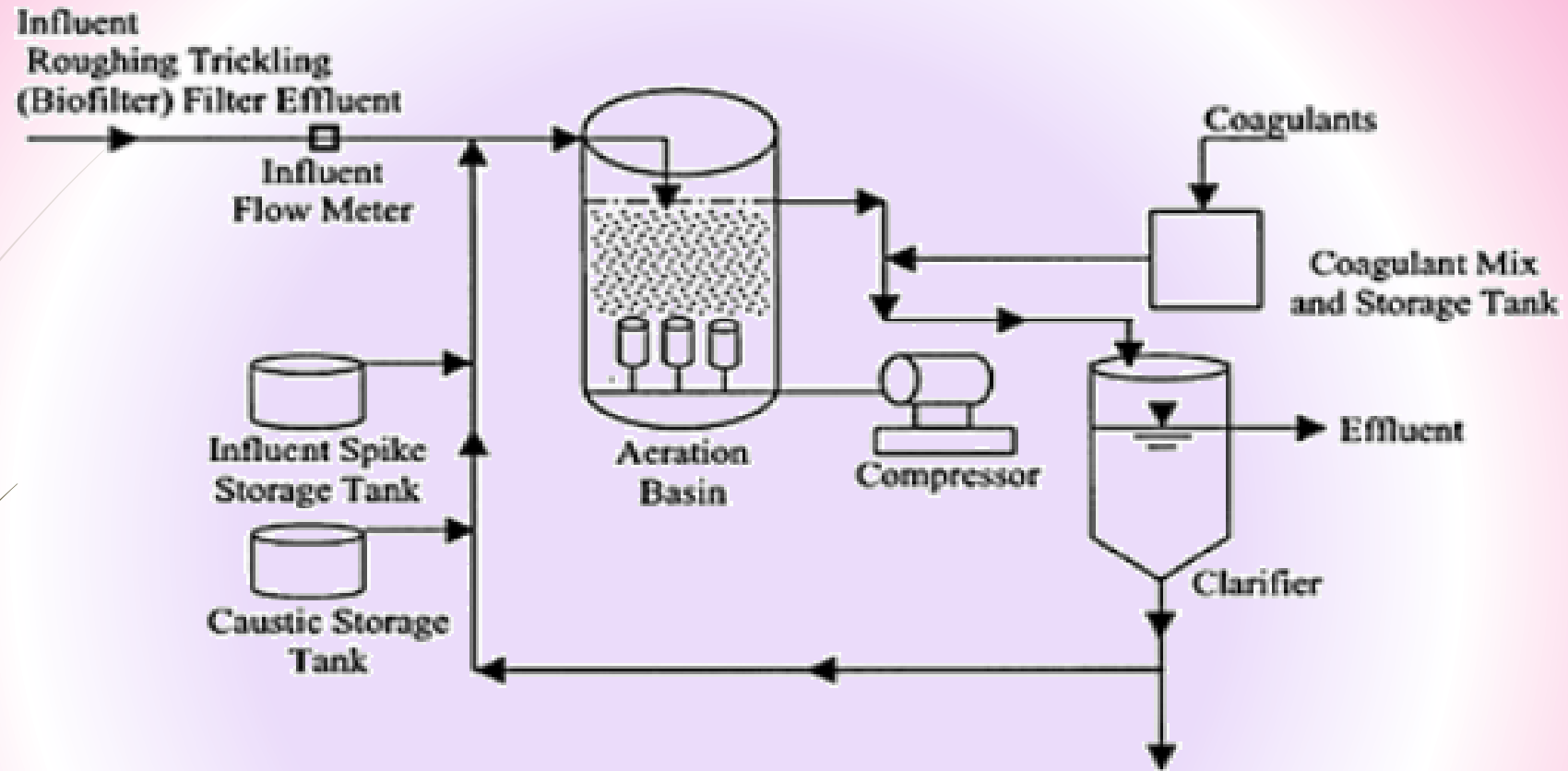
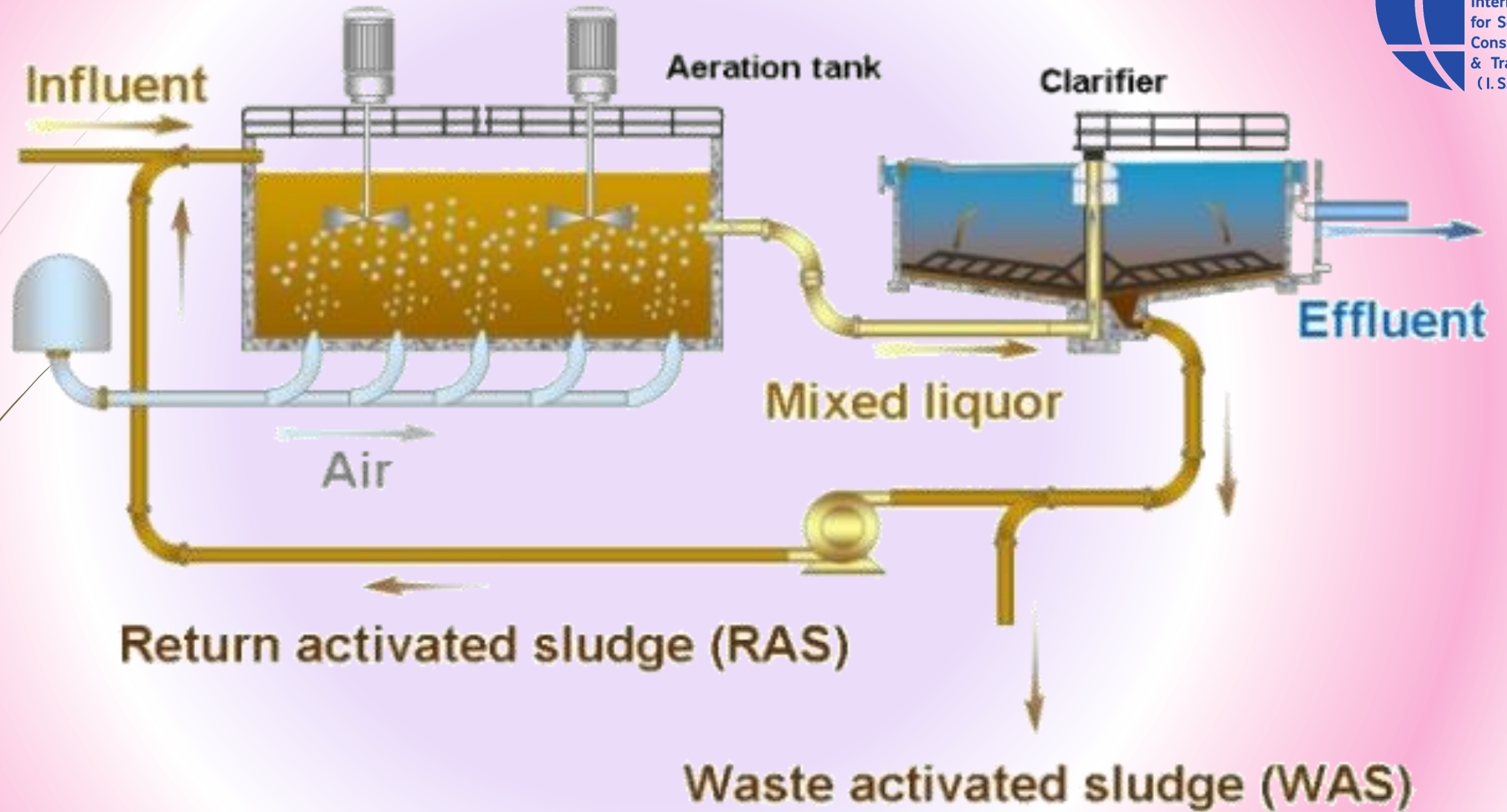


Figure 1 Schematic of the pilot plant at Merck and Co. Stonewall Plant in Elkton, VA.

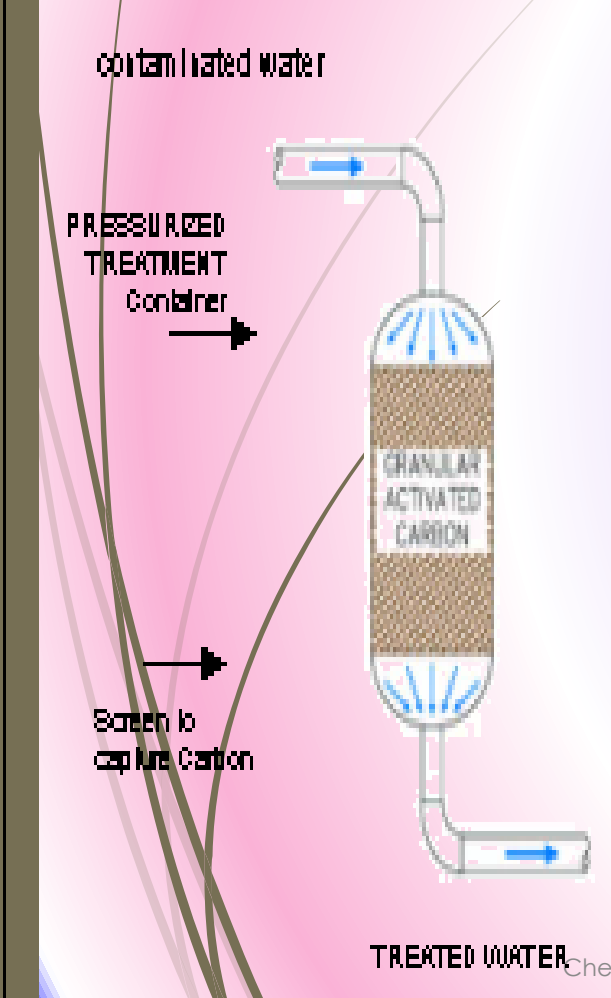


Alexandria Company for Pharmaceutical Case Study

- **The performance of the activated sludge process has been evaluated for the treatment of ACPCI (Alexandria Company for Pharmaceutical and Chemical Industry) effluent.**
- These drug formulation and preparation-type plants are mainly involved in the production of a wide variety of pharmaceuticals, including analgesics, anthelmintics, antibiotics, cardiacs, chemotherapeutics, urologics, and vitamins.
- **A study indicated that significant dispersed biosolids were found in the treated effluent when applying aeration for 6 hours. However, extending the aeration to 9–12 hours and maintaining the MLSS at levels higher than 2500 mg/L improved sludge settling and produced effluent with low SS.**
- **The study concluded that the activated sludge process is capable of producing effluent with BOD and SS values within the limits of the Egyptian standards. However, sand filtration was needed for polishing the treated effluent .**

Powdered Activated Carbon Activated Sludge Process

INSERT: GAC UNIT



- The treatment systems, ASP, PAC-ASP, and GAC, were all quite efficient in removing phenol.
- the performance of the PAC-fed ASP was found to be most efficient in terms of color removal, PAC, GAC, and the resin process were more efficient than ASP.
- whereas in terms of arsenic removal, GAC and resin column were found most efficient.
- Generally, it may be concluded that the addition of PAC in the ASP produced a better effluent than the ASP.
- Addition of PAC to the activated sludge process increases the soluble chemical oxygen demand (SCOD) removal from the pharmaceutical wastewater but no measurable effect in terms of soluble-carbonaceous biochemical oxygen demand (S-CBOD) was observed

Table 14 Characteristics of Wastewater from a Typical Pharmaceutical Industry [47]

Parameters	Average	Ranges (min.–max.)
Color	4,648	1,800–6,600
TSS (mg/L)	234	47–2,700
VSS (mg/L)	152	17–1,910
TOC (mg/L)	387	205–630
Arsenic (mg/L)	5.82	4–12
o-Nitraniline (ONA) µg/L)	12,427	3,200–30,500
Phenol (µg/L)	1,034	<10 to 3,700
2-NP (µg/L)	1,271	<10 to 2,900
4-NP (µg/L)	635	<10 to 2,300
TCE (µg/L)	4,080	620–6,550
DCE (µg/L)	291	<10 to 1,060

TSS, total suspended solids; VSS, volatile suspended solids; 4-NP, 4-nitrophenol; 2-NP, 2-nitrophenol; TCE, 1,1,2-trichloroethane; DCE, 1,1-dichloroethylene; TOC, total organic carbon.

Table 15 Performance Efficiency of Various Systems for the Treatment of Pharmaceutical Wastewater [47]

Parameter	Removal efficiency (%)			
	ASP	PAC-ASP	GAC	Resin column
Color	46.3	94.9	96.9	92
TOC	72.4	89.7	43.9	15
Phenol	95.8	>99	95.4	Nil
2-Nitrophenol	93.8	>99.2	99.1	72.3
4-Nitrophenol	89.4	96.5	96.5	65.8
o-Nitraniline	58.6	94.1	99.9	96.7
Arsenic	20.6	42.8	73.9	62.5
1,1,2-trichloroethane	94.2	96.4	99.4	99.8
1,1-dichloroethy lene	94.5	>96.6	95.5	96.6

ASP, activated sludge process; PAC-ASP, powdered activated carbon activated sludge process; GAC, granular activated carbon; TOC, total organic carbon.

Extended aeration

- The performance of the ASP has been found to be more efficient when operating on an extended aeration basis.
- The design parameters of the process were evaluated for the treatment of combined wastewater from a pharmaceutical and chemical company in North Cairo that produced drugs, diuretics, laboratory chemicals, and so on .
- The study revealed that at an extended aeration period of 20 hours, COD and BOD removal efficiency ranges of 89–95% and 88–98%, respectively, can be achieved. The COD and BOD values of the treated effluent were found to be 74 mg/L and 43 mg/L, respectively.



aerated lagoons

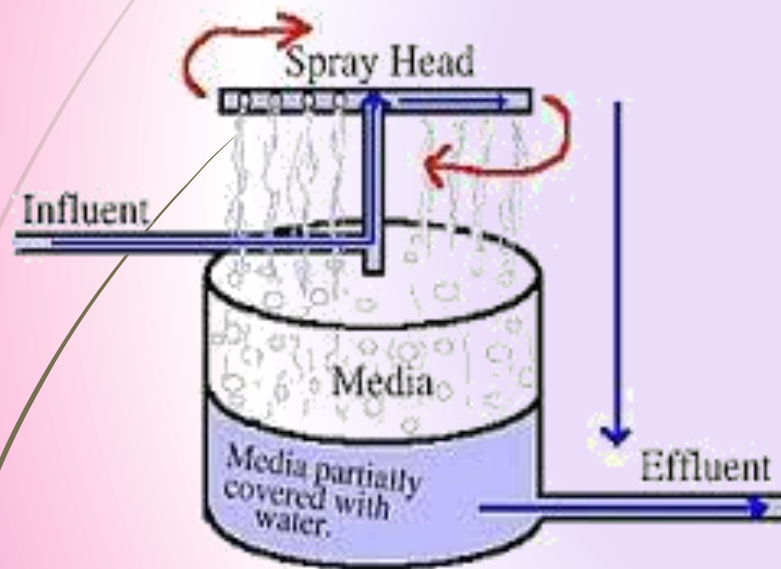
- The performance studies of aerated lagoons carried out by many researchers have demonstrated that lagoons are capable of successfully treating wastewater containing diversified fine chemicals and pharmaceutical intermediates.
- According studies The BOD removal rate K of the system was found to be 0.18/day and 0.155/day based on the soluble and total BOD respectively.



biological filter (trickling filter)

- The efficiency of the biological filter (trickling filter) for treatment of combined wastewater from a pharmaceutical and chemical company in North Cairo has been evaluated. The treatment system consisted of a biological filter followed by sedimentation.
- The degree of treatment was found quite variable. The COD and BOD removal efficiency of the trickling filter at an average OLR (organic loading rate) of 26.8 g BOD/m² day were found to be 43–88% and 58–87%, respectively.
- The study revealed that a biological filter alone was unable to produce effluents to a level complying with the national standards regulating wastewater disposal into the surface water

Trickling Filter:



The two-stage biological system

- The two-stage biological system generally provides a better quality of effluent than the single-stage biological system for the treatment of pharmaceutical wastewater.
- BOD and COD removal of 96% and 88%, respectively, may be achieved by employing a two-stage biological system .
- It has also been found that a two stage biological system generally provides a high degree of treatment. However, bulking sludge causes severe operational problems in the extended aeration system and sand filter.

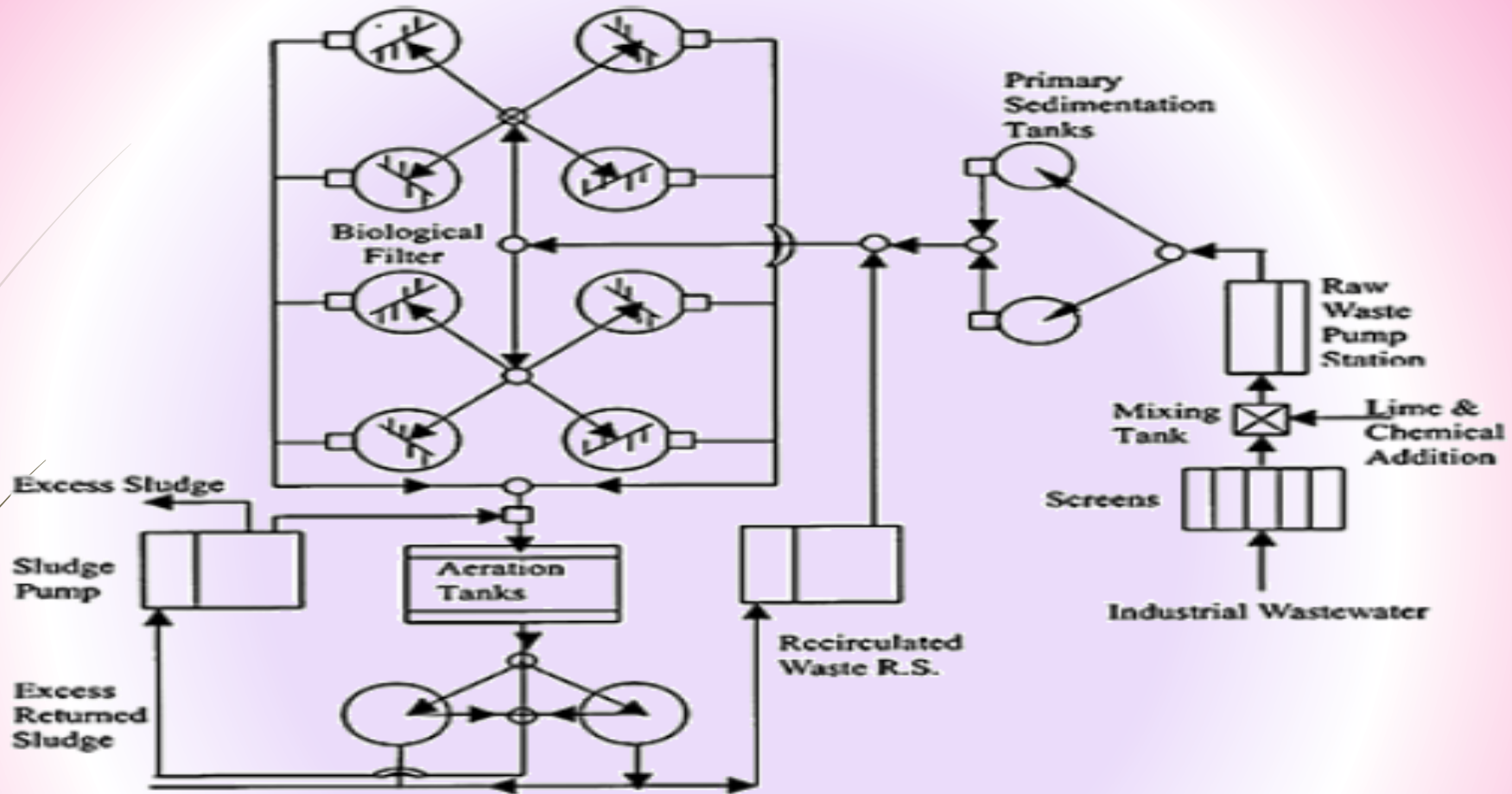
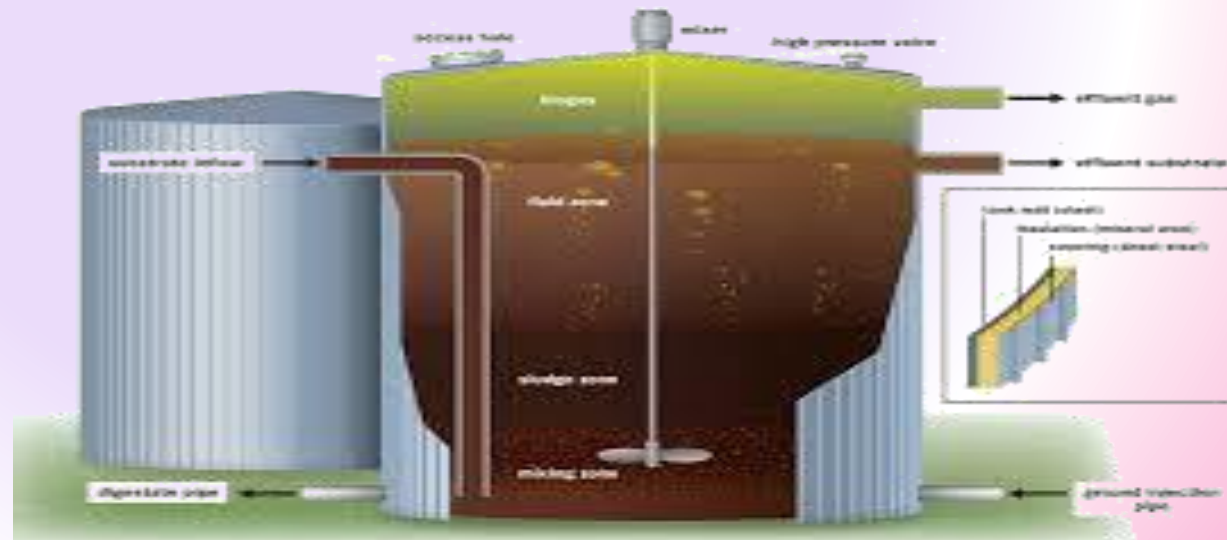


Figure 5 Flow diagram for treatment process using biological filters followed by activated sludge process.

- Anaerobic treatment of high-strength wastewater containing high sulfate poses several unique problems.
- The conversion of sulfate to sulfide inhibits methanogenesis in anaerobic treatment processes and thus reduces the overall performance efficiency of the system.
- Treatment of high sulfate pharmaceutical wastewater via an anaerobic baffled reactor coupled with biological sulfide oxidation is used in this case .



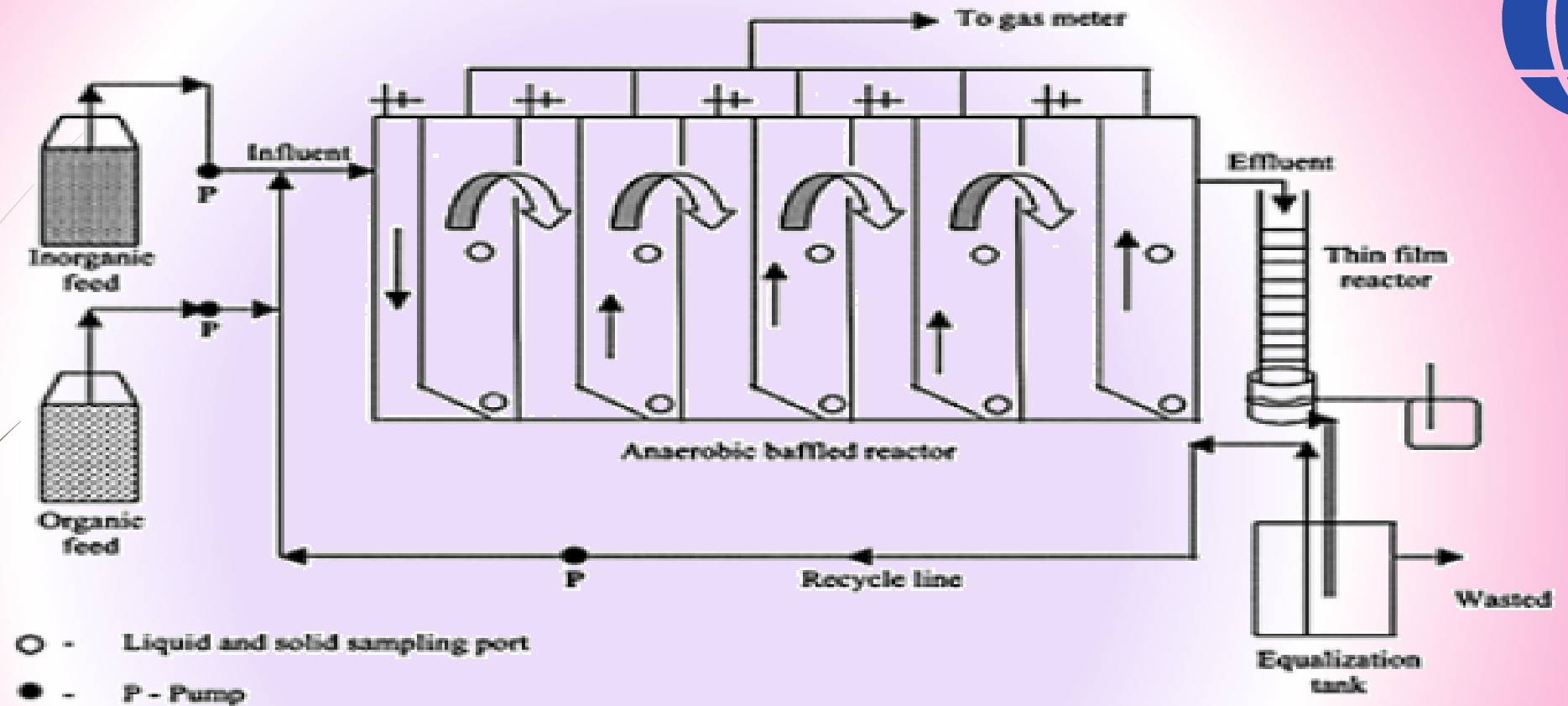


Figure 6 Schematic of anaerobic baffled reactor followed by thin film sulfide oxidizing reactor.

- ❖ A manufactures synthetic organic bulk pharmaceuticals, including :
 - ❖ dry vitamin powders, sulfa drugs, vitamin C, riboflavin, aromatics, and sodium sulfate salts.
- ❖ An integrated sodium sulfate recovery system was employed in this plant to recover sodium sulfate.
- ❖ The plant's waste control and treatment system includes:
 1. Screening.
 2. Preclarifier
 3. equalization with aeration (1 day d.t).
 4. pH adjustment/ neutralization.
 5. flocculator-clarifier.
 6. activated sludge process.
 7. secondary settler.
 8. two oxidation ponds in series.
 9. sludge thickening.
 10. aerobic sludge digestion.
 11. sludge drying beds
 12. final chlorination.

References

- ***Handbook of Industrial and Hazardous Wastes Treatment -Lawrence K.Wang ,et.al.***



- ahmedhasham83@gmail.com
- Isct.Egypt@gmail.com
- <https://www.facebook.com/isct.site/>

- 00201159465989
- 00201146139692

Thank you

Chemist/Ahmed Hasham

International for scientific consulting and training



I.S.C.T
Ahmed Mohamed Hasham
Water Treatment Technologies Consultant
Certified Trainer (Water Treatment & QMS)

Isct.egypt@gmail.com
Ahmedhasham83@gmail.com
<https://www.facebook.com/isct.scientific>

002-01159465989