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Industrial Waste Water Treatment

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INTRODUCTION

1.1. The Background

1. In many parts of the world, economic, social and political problems have arisen following rapid industrial development and urbanization, resulting in adverse effects on the quality of life. Urbanization in general initially places pressure and overstrains public amenities. However, long-term and wider issues would eventually also be encountered as industrialization and urbanization exert pressure on the larger resource base that supports the community. This larger resource base includes forestry, freshwater and marine resources, as well as space suitable for further development. The difficulties associated with environmental degradation often originate from industrial development. They are amplified by rapid urbanization that is responsible for the growth of many major cities. In Asia, urbanizations exacerbated by large rural–urban migrations. These migrations emerge in response to perceived opportunities for a better livelihood in industrialized, economically booming urban areas. Rapid industrialization and its concentration in or near urban centres have placed very high pressures on the carrying capacity of the environment at specific locations. At these locations waterbodies such as rivers, lakes, and coastal waters have typically been severely affected. Freshwater is a vital natural resource that will continue to be renewable as long as it is well managed. Preventing pollution from domestic, industrial, adagio-industrial activities is important to ensure the sustainability of the local development. Undoubtedly the water pollution control efforts which have been underway in many countries have already achieved some success. Nevertheless, the problems that are confronted grow in complexity and intensity. It is estimated that785 million people in Asian developing countries have no access to sustainable safe water (Sawhney, 2003). The pollution of freshwater bodies with the consequent deterioration in water quality can only worsen the situation. Such pollution has been brought about by the discharge of inadequately treated sewage and industrial wastewater. This book focuses on the latter. Perhaps not unexpectedly, as the demand for more water is met, the volumes of wastewater can also be expected to increase. Coastal waters are also under pressure as they receive effluents discharged directly into them or indirectly from rivers. While most communities in Asia do not use coastal waters as a source of potable water (via desalination), there is already a movement towards this direction, as in the case of Singapore. Even though coastal waters are not yet a major source of potable water, they are, nevertheless, very important since they support fisheries and tourism industries. The ecosystems in many of Asia's coastal waters are fragile; damage to these ecosystems because of pollution can adversely affect fishery industries. The latter, in many instances, depend on mangrove forests as spawning grounds for marine life which are subsequently harvested. Industrial wastewaters (including agro-industrial wastewaters) are effluents that result from human activities which are associated with raw-material processing and manufacturing. These wastewater streams arise from washing, cooking, cooling, heating, extraction, reaction by-products, separation, conveyance, and quality control resulting in product rejection. Water pollution occurs when

potential pollutants in these streams reach certain amounts causing undesired alterations to receiving waterbody. While industrial wastewaters from such processing or manufacturing sites may include some domestic sewage; the latter is not the major component. Domestic sewage may be present because of washrooms and hostels provided for workers at the processing or manufacturing facility. Examples of industrial wastewaters include those arising from chemical, pharmaceutical, electrochemical, electronics, petrochemical, and food processing industries. Examples of agro-industrial wastewaters include those arising from industrial-scale animal husbandry, slaughterhouses, fisheries, and seed oil processing. Agro-industrial wastewaters can be very strong in terms of pollutant concentrations and hence can contribute significantly to the overall pollution load imposed on the environment. It is perhaps ironic that the very resources which promoted industrial development and urbanization in the first place can subsequently come under threat from such development and urbanization because of over and inappropriate exploitation. Appropriate management of such development and resources is a matter of priority. The South Johore coast was such a case (ASEAN/US CRMP, 1991). This was then, economically, one of the fastest growing areas in Malaysia and potential damage to the environment of such development, if not properly managed, was recognized. The impact of industrial wastewater discharges on the environment and human population can be tragic at times. Some 50 years ago, the Minamata disease which spread among residents in the Yasuhiro Sea and the Agana River basin areas in Japan were attributed to methyl mercury in industrial wastewater (Matsuo,1999). However, tragedies as dramatic as the Minamata episode have not occurred frequently. Nevertheless, instances of pollution with potentially adverse impacts in the longer term have continued to occur. In the interim before the realization of these longer-term impacts, a decline in the quality of life arising from the deterioration in water quality which various populations must access may become increasingly discernible. Examples of these, their recognition, and the efforts made to remedy the situations in the 1980s include the protection of Malaysian coastal waters from refinery wastewater (Yassin, 1987), the Tamsui River in Taiwan where pesticides and heavy metals were discovered in the sludge (Liu & Kuo, 1988), the Nam Pong River in Thailand which was polluted by the pulp and paper industry(Pindarian, 1988), and the Buriganga River in Bangladesh which had been polluted by, among other industries, tanneries (Ahmed & Mohammed, 1988). Similar reports in the 1990s include the Kelani River in Sri Lanka (Bhuvendralingam*et al.*, 1998), the Laguna de Bay in the Philippines (Barril *et al.*, 1999), and the Koayu River which had occurrences of *Cryptosporidium* oocysts and *Giardia* cysts after receiving inadequately treated piggery wastewater (Hashimoto &Hirata, 1999). Such reports are still frequent in the 2000s and caused concerns in Vietnam (Nguyen, 2003) and Korea (Kim *et al.*, 2003). The fact that water pollution due to discharges of inadequately treated industrial wastewater has occurred over decades in Asia obviously means solutions have not been found for all such occurrences. Towards the end of 2004, the Huai River in China was reported to have been so seriously polluted by papermaking, tanning and chemical fertilizer factories, farmers in Sheniqua County had fallen very ill after using the river water (The Strait Times, 2004). There has, however, been progress and an example is the successful ten year river pollution clean-up program in Singapore (Chiang, 1988). Agro-industrial wastewaters, as a sub-class of industrial wastewaters, can have considerable impact on the environment because they can be very strong in terms of pollutant strength and often the scale of the industry generating the wastewater in a country is large. Citing ASEAN countries in Asia as examples, agro-industrial wastewaters had and, in some instances, still contribute very significantly to pollution loads. For example, in 1981 the Malaysian palm oi and rubber industries contributed63% (1460 td−1) and 7% (208 td−1) of the BOD (Biochemical Oxygen Demand) load generated per day respectively. This is compared with 715 td−1of BOD from domestic sewage (Ong *et al.*, 1987). In the Philippines, pulp and paper mills generated 90 td−1 of BOD load (Villavicencio, 1987). Agro-industrial sites are therefore often the largest easily identifiable point sources of pollutant loads. While there are exceptions, individual industrial wastewater sources associated with manufacturing in Asia are, in contrast, more often small to medium sized compared to the former. The classifications of a small and medium-sized manufacturing facility have been defined in terms of the numbers of employees employed at such sites — 10 ~ 49 persons and 50 ~ 199 persons respectively. Notwithstanding their small to medium sizes, the collective contribution from such enterprises to pollution is not necessarily negligible. It should also be noted that while industrial wastewater sources may be small to medium size, they are generally located in urban centres where building congestion is already a problem. To aggravate the situation, such factory operations may have no long-range project planning and are also unable to exploit advantages associated with economies of scale. A number of such operations may also try to maximize profits by reducing overheads and “unnecessary” expenditure associated with pollution control requirements— the result of an absence of an appropriate corporate culture and hence a weaker social conscience in terms of care for the environment. On a positive note, however, economic development over the last few decades have enabled necessary managerial, financial, and technological capabilities to address problems of pollution and environmental degradation over the broad spectrum of factory sizes. There is also a growing realization that the cost (in terms of the human and economic costs) of cleaning up after the act is frequently more than preventing the pollution in the first place.

1.2. What is Industrial Wastewater?

To begin the discussion on industrial wastewater, it may be useful to compare industrial wastewater with domestic sewage since designers of wastewater treatment facilities often begin their careers and almost certainly their education in environmental engineering by looking at sewage and sewage treatment plants. The latter can then provide a familiar framework which the reader can use to compare industrial wastewater and its treatment. Domestic sewage is wastewater discharged from sanitary conveniences in residential, office, commercial, factories and various institutional properties. It is a complex mixture containing primarily water (approximately 99%) together with organic and inorganic constituents. These constituents or contaminants comprise suspended, colloidal and dissolved materials. Domestic sewage, since it contains human wastes, also contains large numbers of micro-organisms and some of these can be pathogenic. Waterborne bacterial diseases that can be present in sewage include cholera, typhoid and tuberculosis. Viral diseases can include infectious hepatitis. Inorganic constituents include chlorides and sulphates, various forms of nitrogen and phosphorous, as well as carbonates and bicarbonates. Proteins and carbohydrates constitute about 90% of the organic matter in domestic sewage. These arise from the excreta, urine, food wastes, and wastewater from bathing, washing, and laundering, and because of the latter, soaps, detergents, and cleaning products can be found as well. Domestic sewage has a flow pattern which typically shows two peaks — in the morning before the start of working hours and in the evening after the population has returned from work. Typically, these hydraulic peaks would also become more distinct as the sewage flows considered come from smaller populations and consequently smaller sewer networks. Variations in sewage characteristics across a given community tend to be relatively small although variation across communities can be more readily detected. Notwithstanding these variations, the composition of domestic sewage is such that it lends itself well to biological treatment in terms of the availability of and balance between carbonaceous components and nutrients. The biodegradability of sewage can be estimated by considering its Chemical Oxygen Demand (COD)and the corresponding BOD5 (5-day BOD) and is indicated by its COD: BOD5and BOD5:N:P ratios. This would typically be about 1.5:1 and 25:4:1 respectively. The nitrogen, N, would typically be in the form of organic nitrogen and ammonia nitrogen (Am-N). Nitrates (NO3-N) would not be expected to be present as conditions in the sewers would be such that nitrate formation is unlikely while nitrate Degradation because of anoxic reactions is likely. The phosphorous (P) would bear combination of organic and phosphate (PO4*)* forms. The pH of sewage would be within the range of 6–9 and this is generally considered suitable for biological Processes. Examples of values of BOD5, TSS (Total Suspended Solids), and TKN (Total Kjeldahl Nitrogen) which have been used for purposes of plant designate 250, 300 and 40 mg L−1 respectively. As indicated earlier in this paragraph, sewage characteristics can vary across communities and a raw sewage BOD5 of500mg L−1 has been encountered. Industrial (including agro-industrial) wastewaters have very varied compositions depending on the type of industry and materials processed. Some of these wastewaters can be organically very strong, easily biodegradable, largely inorganic, or potentially inhibitory. This means TSS, BOD5 and COD values may be in the tens of thousands mg L−1.Because of these very high organic concentrations, industrial wastewaters may also be severely nutrient deficient. Unlike sewage, pH values well beyond the range of 6–9 is also frequently encountered. Such wastewater may also be associated with high concentrations of dissolved metal salts. The flow pattern of industrial wastewater streams can be very different from that of domestic sewage since the former would be influenced by the nature of the operations within a factory rather than the usual activities encountered in the domestic setting. A significant factor influencing the flow pattern would be the shift nature of work at factories. These shifts may be 8 h or 12 h shifts and there can be up to three shifts per day. These shifts may mean that there can be more than the two peaks in flow seen in sewage and there may be no flow for parts of the day. Factories may operate five to seven days per week. A consequence of this can be the possibility of zero flow on days when a factory is not operating. In contrast to the narrower band of variation in the characteristics of domestic sewage within a community, industrial wastewaters can have very different characteristics even for wastewaters from a single type of industry but from different locations. The cause of these differences has much to do with the operating procedures adopted at each site and the raw materials used therein. To further complicate matters, wastewater characteristics within a factory can also vary with time because it may practice campaign manufacturing, or it may practice slug discharges on top of its usual discharges. Apart from these events which occur on a regular basis, there would be spillages and dumping which may occur within the factory infrequently but can have very adverse impacts on the performance of the wastewater treatment plant. Consequently, it would be prudent to assess an industrial wastewater, as well as its pretreatment and treatment requirements very carefully and not immediately assume that its wastewater characteristics and treatment requirements are like a previously encountered example. It would also be prudent to acquire some understanding of the nature of the factory's operations. A more detailed discussion of the characteristics of industrial wastewater is made in Chapter 2. On some occasions industrial wastewater is discharged into a sewerage system serving commercial and residential premises. Such a combination of wastewater streams is known as municipal wastewater and the quality of such a mixture of wastewaters can vary depending on the proportion of industrial wastewaters in it and the type of industries contributing the industrial wastewater streams. Usually, the domestic and commercial components in municipal wastewater can be expected to provide some buffering in terms of the characteristics of the combined flow. This is then expected to enable the combined wastewater to be treated easily compared to the treatment of the industrial wastewater on its own. However, even where the option of discharging into a sewerage system is available, some degree of pretreatment is frequently required at the factory before such discharge is permitted. Such pretreatment may include pH adjustment to 6–9 and BOD5reduction to 400 mg L−1 as being currently practiced in Singapore (Pachigam *et al.*,1980). This is to protect the receiving sewers from corrosion and also protect the performance of the receiving treatment plant from organic substrate overload.

1.3. Why is it Necessary to Treat Industrial Wastewater?

All major terrestrial biota, ecosystems, and humans depend on freshwater (i.e. Water with less than 100mg L−1 salts) for their survival. The earth's water is primarily saline in nature (about 97%). Of the remaining (3%) water, 87% of it is locked in the polar caps and glaciers. This would mean only 0.4% of all water on earth is accessible freshwater. The latter is, however, a continually renewable resource although natural supplies are limited by the amounts that move through the natural water cycle. Unfortunately, precipitation patterns, and hence distribution of freshwater resources, around the globe is far from even. Where precipitation does fall heavily, there are often difficulties with storage because of space constraints. Furthermore, the available freshwater must be shared between natural biota and human demands. The latter, aside from direct human consumption, includes water for agricultural, urban, and industrial needs. Freshwater shortages increase the risk of conflict, public health problems, reduction in food production, inhibition of industrial production expansion, and these problems threaten the environment. Freshwater shortages are, however, not only due to uneven distribution of freshwater resources and demand for freshwater but also, increasingly, due to the declining water quality in freshwater sources already in use. This declining water quality is primarily due to pollution. It should not be forgotten that in the wider context of resources associated with water, the marine environment is also included in the picture. While the latter was, in the past, primarily associated with the fisheries resource, it can also include tourism and the feed for desalination in the current context. Untreated industrial wastewaters would add pollutants into waterbodies — freshwater and saline. These receiving waterbodies, freshwater and marine, can include ponds, lakes, rivers, coastal waters, and the sea. It would be useful to bear in mind that pollutants introduced into a river, or some other freshwater waterbodies do eventually end up in the sea, the ultimate receptacle for waterborne pollutants if these are permitted to find their way through the environment unimpeded. An example of riverine pollution are the rivers flowing through urban and industrial areas such as Hanoi and Ho Chi Minh City in Vietnam picking up pollutants such as heavy metals and organochlorine pesticides and herbicides. These pollutants reach the sea eventually and therein threaten the fisheries (Nguyen *et al.*, 1995). On Hainan Island (Southern China), for example, industries such as sugar refineries, paper mills, shipyards, and fertilizer plants accounted for about half the total wastewater generated and reaching the sea. This had resulted in incidences of the red tide in Hoashi Bay and an area northwest of the island (Du,1995). Obviously then, inadequately treated industrial wastewater discharged into rivers would not only affect the freshwater in these areas but also the receiving coastal and sea waters. Eventually coastal resources such as the mangrove and reef ecosystems, and thereafter fisheries would be affected. The discharge of inadequately treated industrial wastewaters can therefore have far-reaching consequences. In the last decade, the emergence of industrial pollution has been identified as a trend in the coastal areas of Southern China, Vietnam, Kampuchea, and Thailand. The effects pollutants have on the water environment can be summarized in the following broad categories:

(a) Physical effects — These include impact on clarity of the water and interference oxygen dissolution in it. Water clarity is affected by turbidity which may be caused by inorganic (Fixed Suspended Solids or FSS) and/organic particulates suspended in the water (Volatile Suspended Solids or VSS). The latter may undergo biodegradation and thereby also have oxidation effects. Turbidity reduces light penetration, and this reduces photosynthesis while the attendant loss in clarity, among other things, would adversely affect the food gathering capacity of aquatic animals because these may not be able to see their prey. Very fine particulates may also clog the gill surfaces of fishes and thereby affecting respiration and eventually killing them. Settleable particulates may accumulate on plant foliage and bed of the waterbody forming sludge layers which would eventually smother benthic organisms. As the sludge layers accumulate, they may eventually become sludge banks and if the material in these is organic then its decomposition would give rise to malodors. In contrast to the settleable material, particulates lighter than water eventually float to the surface and form a scum layer. The latter also interferes with the passage of light and oxygen dissolution. Because of the former, these scum layers affect photosynthesis. Discharge limits on wastewater or treated wastewater discharges typically have a value for TSS such as 30 mg L−1 or 50 mg L−1. Many industrial wastewaters contain oil and grease (O&G). While some of the latter may be organic in nature, there are many which are mineral oils. Notwithstanding their organic or mineral nature, both types of cause interference at the air-water interface and inhibit the transfer of oxygen. Apart from their interference to the transfer of oxygen from atmosphere to water, the O&G (particularly the mineral oils) may also be inhibitory. Unlike domestic sewage, industrial discharges can have temperatures substantially above ambient temperatures. These raise the temperatures of the receiving water and reduce the solubility of oxygen. Apart from this, rapid changes in temperature may result in thermal shock and this may be lethal to the more sensitive species. Heat, however, does not always have a negative impact on organisms as it may positively affect growth rates although there are limits here too since the condition may favor certain species within the population more than others and over time biodiversity may be negatively affected.

(b) Oxidation and residual dissolved oxygen — As suggested in the preceding paragraph, waterbodies have the capacity to oxygenate themselves through dissolution of oxygen from the atmosphere and photosynthetic activity by aquatic plants. Of the latter, algae often play an important role. However, there is a finite capacity to this re-oxygenation and if oxygen depletion, because of biological or chemical processes induced by the presence of organic or inorganic substances which exert an oxygen demand (i.e. as indicated by the BOD or COD), exceeded this capacity then the dissolved oxygen (DO)levels would decline. The latter may eventually decline to such an extent that septic conditions occur. A manifestation of such conditions would be the presence of malodors released by facultative and anaerobic organisms. An example of this is the reduction of substances with combined oxygen such as sulphates by facultative bacteria and resulting in the release of hydrogen sulfide. The depletion of free oxygen would affect the survival of aerobic organisms. DO levels do not, however, need to drop to zero before adverse impacts are felt. A decline to 3–4mg L−1, which still means the water contains substantial quantities of oxygen, may already adversely affect higher organisms like some species of fish. If inhibitory substances are also present, then the DO level at which adverse effects may be felt can be even higher than before. The case of elevated water temperatures due to warm discharge is somewhat different. The elevated temperatures can affect metabolic rates positively (possibly twofold for each 10◦C rise in temperature) but elevated temperatures also reduce the solubility of oxygen in water. This would mean increasing demand for oxygen while its availability declines. Because of the impact of DO levels on aquatic life, much importance has been placed on determining the BOD value of a discharge. Typical BOD5 limits set are values such as 20 and 50mg L−1;

(c) Inhibition or toxicity and persistence — These effects may be caused by organic or inorganic substances and can be acute or chronic. Examples of these include the pesticides and heavy metals mentioned in the preceding section. Many industrial wastewaters do contain such potentially inhibitory or toxic substances. The presence of such substances in an ecosystem may bias a population towards members of the community which are more tolerant to the substances while eliminating those which are less tolerant and resulting in a loss of biodiversity. For similar reasons, an awareness of the impact such substances have on biological systems is not only relevant in terms of protection of the environment but is of no less importance in terms of their impact on the biological systems used to treat industrial wastewaters. Even successful treatment of such a wastewater may not necessarily mean that the potability of water in a receiving waterbody would not be affected. For example, small quantities of residual phenol in water can react with chlorine during the potable water treatment process giving rise to chlorophenols which can cause objectionable tastes and odors in the treated water. Apart from the organic pollutants which are potentially inhibitory or toxic, there are those which are resistant to biological degradation. Such persistent compounds can be bioaccumulated in organisms resulting in concentrations in tissues being significantly higher than concentrations in the environment and thereby making these organisms unsuitable as prey/food for organisms (including Man) higher up the food chain. While some organic compounds may be persistent, metals are practically non-degradable in the environment.

With the above effects in view, industrial wastewater treatment would typically be required to address at least the following parameters:

(a) Suspended solids (SS).

(b) Temperature.

(c) Oil and grease (O&G).

(d) Organic content in terms of biochemical oxygen demand (BOD) or chemical oxygen demand (COD);

(e) pH.

(f) Specific metals and/or specific organic compounds.

(g) Nitrogen and/or phosphorus.

CHAPTER-2 Review of Literature

2.Industrial wastewater treatment using oxidative integrated approach

Authors
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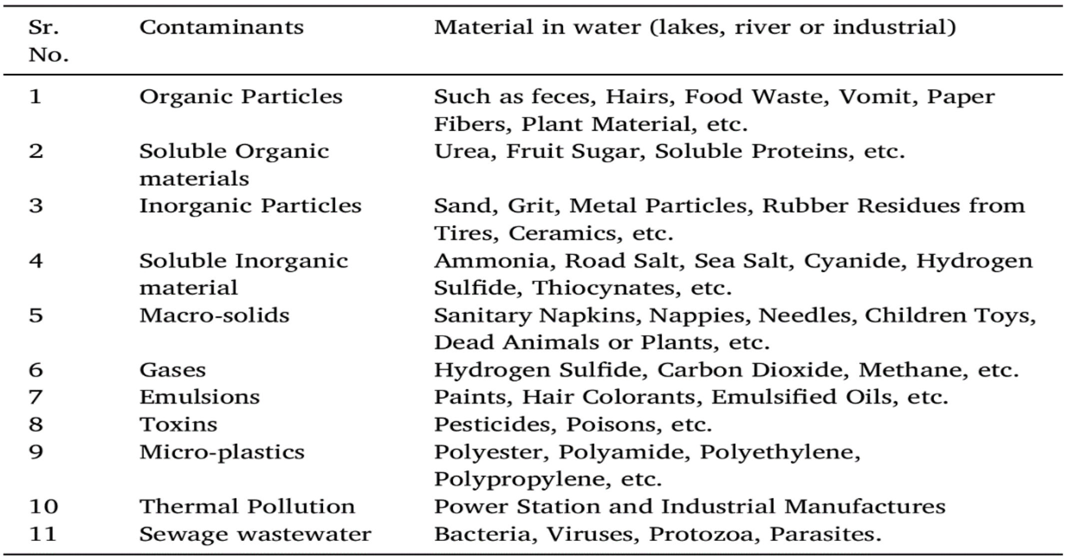
Objectives

The study aimed to investigate the effectiveness of using Ozone and H2O2 in combination for the treatment of industrial wastewater, specifically polymer and dye effluents,



Sr. No.	Contaminants	Material in water (lakes, river or industrial)
1	Organic Particles	Such as feces, Hairs, Food Waste, Vomit, Paper Fibers, Plant Material, etc.
2	Soluble Organic materials	Urea, Fruit Sugar, Soluble Proteins, etc.
3	Inorganic Particles	Sand, Grit, Metal Particles, Rubber Residues from Tires, Ceramics, etc.
4	Soluble Inorganic material	Ammonia, Road Salt, Sea Salt, Cyanide, Hydrogen Sulfide, Thiocynates, etc.
5	Macro-solids	Sanitary Napkins, Nappies, Needles, Children Toys, Dead Animals or Plants, etc.
6	Gases	Hydrogen Sulfide, Carbon Dioxide, Methane, etc.
7	Emulsions	Paints, Hair Colorants, Emulsified Oils, etc.
8	Toxins	Pesticides, Poisons, etc.
9	Micro-plastics	Polyester, Polyamide, Polyethylene, Polypropylene, etc.
10	Thermal Pollution	Power Station and Industrial Manufactures
11	Sewage wastewater	Bacteria, Viruses, Protozoa, Parasites.

Material and methods

2.1. Materials

COD reagents like H2SO4, K2Cr2O7, Fe2SO4, HgSO4, and Ag2SO4 were procured from the local vendor of Thomas Baker. A magnetic needle-based stirrer was used for continuous mixing. Ozonate (Make: Eltech, 5 g/hr) was used to add ozone to the effluent. H2O2(30%) was also procured from SD Fine. Sonication horn (Dakshin, 750 kW) was used for the treatment of effluent. COD digester (Hanna) was used to digest the water samples. Deionized (DI) (Make: Millipore Ultrapure Water System, Model Direct-Q5) water was used for dilution of the water samples during COD analysis. The DI water instrument was used from the Central analytical instrument laboratory, Department of Chemical Engineering, Institute of Chemical Technology, Mumbai, India. Whatman filter paper having a pore size of 42 μm was used for the filtration of the treated water sample.

2.2. Analytical methods

Standard COD procedure was used to estimate the COD of water samples (Jenkins, 1982).

2.3. Experimental setup and experimental procedure

A wastewater sample of volume about 250 ml was taken in a 500 ml glass beaker for the treatment. The approximate liquid height was 70 mm. A magnetic Stirrer was used at 240 Revolutions Per Minute (RPM) to continuous homogenize the wastewater (Fig. 1). Hydrogen Peroxide(H2O2) was directly added to the wastewater. Ozone(O3) was provided with a spherical sparger for uniform distribution of Ozone in the wastewater taken for treatment. Wastewater was treated using Sonication horn (22 kHz) at 40% power amplitude (i.e. 40% of 750 kW) for 1 hour and then filtered it using Whatman filter paper having a pore size of 42 μm. The formed suspended solids were removed using filtered paper. The COD of the filtered wastewater sample was analyzed using the standard COD procedure as mentioned in the analytical method section (Jenkins, 1982).

Methods

Laboratory-scale experiments were conducted using Ozone and Hydrogen Peroxide as oxidative agents to treat Polymer Wastewater and Ultrasonication with oxidative additives for Dye Wastewater. COD analysis was performed to measure the effectiveness of the treatments. Ozone and H2O2 were used in combination with ultrasonication and stirring for the treatment of dye wastewater. Hydrodynamic cavitation was integrated with Ozone and H2O2 for industrial effluent treatment. Energy and cost estimations were conducted for Ozone and Hydrodynamic Cavitation processes. The treatment of industrial effluents has limitations due to their hazardous nature and complex structure which resists biological treatment methods. The possible approach to the treatment of Polymer Wastewater and Dye Wastewater was studied by carrying out laboratory-scale experiments in the present study. These wastewater samples were collected from two different industries for the study. Ozone and Hydrogen Peroxide is used as oxidative agents for the treatment of these hazardous wastewater samples. The Polymer Wastewater was treated successfully using these oxidative chemicals and achieved a maximum COD reduction of up to 91%. The Dye wastewater was treated using Ultrasonication with oxidative additives and achieved a COD reduction of about 66%. Therefore, integrated approaches are a must to treat industrial complex wastewater effluents and optimization of possible combinations of individual units must be optimized.

The self-cleaning capacity of lake refers to the natural way in which the open water sources get rid of the pollutants discharged into it The industrial dye effluent was treated at a laboratory scale by integrated active oxidation processes like Ozonation, Hydrogen Peroxide followed by Urbanization Ozone and Hydrogen Peroxide was used as oxidative additives for the Treatment maximum reduction of COD in the polymer wastewater was obtained of about 91% in presence of additives over 60 min treatment with continuous stirring at 240 Revolutions Per Minute (RPM)The maximum reduction of COD was obtained about 66% for dye wastewater over 60 min of treatment significant reduction of COD of about 66% was observed with the same treatment approach after 60 min of treatment% Reduction – 20 66 techno-economic analysis has shown the commercial viability of the integrated process like Hydrodynamic Cavitation with oxidative additives Ozone and Hydrogen Peroxide. Ozone and H2O2 were used in combination to achieve synergetic oxidative effects for the treatment of industrial wastewater, resulting in significant reductions in COD levels. Ozone and Hydrogen Peroxide successfully treated Polymer Wastewater with a maximum COD reduction of 91%. Ultrasonication with oxidative additives achieved a COD reduction of 66% in Dye Wastewater. Ozone and H2O2 in combination produced hydroxyl radicals for effective degradation of organic pollutants in wastewater. The combination of Ozone, H2O2, ultrasonication, and stirring led to a 66% reduction in COD levels in dye wastewater. The integration of Hydrodynamic Cavitation with Ozone and H2O2 showed commercial viability for industrial effluent treatment.

Results

Polymer Wastewater achieved a COD reduction of up to 91% using Ozone and Hydrogen Peroxide. Dye Wastewater saw a COD reduction of about 66% with Ultrasonication and oxidative additives. The combination of Ozone and Hydrogen Peroxide showed higher COD reduction compared to using Ozone alone. The combination of Ozone and H2O2 led to a 66% reduction in COD levels in dye wastewater. The integration of Hydrodynamic Cavitation with Ozone and H2O2 showed a treatment cost of 10–20 INR/m3 for industrial effluent.

Conclusions

Integrated approaches involving oxidative treatments are essential for effectively treating hazardous and complex industrial wastewater effluents.

Optimizing combinations of treatment units is crucial for efficient wastewater treatment.

The study demonstrated the effectiveness of using Ozone and H2O2 in combination for the treatment of industrial wastewater, with the potential for commercial application when integrated with Hydrodynamic Cavitation.

2.2 Domestic and industrial wastewater treatment: status and challenges in India

Authors

Arya Vijayanandan; Absar Ahmad Kazmi; Ligy Philip

Planned water management is inevitable in India's path towards sustainable development. Rapid urbanization and population growth have resulted in significant amounts of wastewater being generated and severe water pollution-related issues in the country. Given the scarcity of freshwater resources and the extent of pollution, it is essential to implement and maximize safe wastewater reuse. The primary impediment to reaching this goal is the enormous disparity between treatment capacity and wastewater generation. Only effective water usage and wastewater reuse practices will help to meet future water demand. Enforcing zero liquid discharge and stringent regulations to ensure treated wastewater quality are necessary to optimally reuse industrial wastewater. The release of untreated industrial wastewater into municipal sewerage systems must be prevented. Selection of the appropriate treatment units, operation and maintenance, and real-time monitoring of wastewater quality are the key measures in ensuring the treated wastewater quality. Moreover, the current wastewater treatment methods need to be modified or upgraded to remove the toxic and emerging contaminants too. This chapter discusses the role of domestic and industrial effluents in water pollution, the challenges encountered, and regulations and policies related to water management. Examples of wastewater reuse and zero liquid discharge are also included in the chapter.

Water Management in India

Planned water management is crucial for sustainable development in India due to rapid urbanization and population growth leading to significant wastewater generation and water pollution issues.

The country faces a scarcity of freshwater resources and high pollution levels, necessitating safe wastewater reuse to meet future water demand.

Water Scarcity as a Global Issue

Water scarcity is a major global risk, with two-thirds of the world's population living in areas facing water scarcity for at least a month each year.

India and China account for 50% of this population.

Rapid urbanization and industrialization in India have increased water demand, but the existing infrastructure for wastewater treatment is inadequate, with only 37% of generated wastewater being treated.

Challenges And Solutions in Wastewater Management

India faces challenges in wastewater management, with diminishing freshwater resources and high-water demand from various sectors.

Wastewater reuse is essential to meet water demand and mitigate pollution issues.

Upgrading treatment methods to remove contaminants, enforcing regulations, and promoting zero liquid discharge are crucial steps.

Successful examples of wastewater reuse exist in India, requiring suitable technologies, policies, finance, awareness, and capacity building for large-scale implementation.

Support Tools for Sustainability

Support tools are being used to make decisions based on sustainability factors, land availability, and the end-use of treated wastewater.

Decision support systems are also helping with wastewater reuse, considering various factors like technology, economics, and the environment.

Water Footprint Estimation

Estimating the water footprint of products helps identify water over-usage and losses.

This approach is gaining popularity in industries to promote water conservation practices.

Two methodologies, one by the Water Footprint Network and the other recommended by ISO 14046, are used globally to estimate water footprints.

These tools help industries understand their water demand and consumption stages.

Circular Economy Approach

In the circular economy approach, wastewater is seen as a valuable resource for reuse.

Resource recovery from wastewater is a key aspect, focusing on extracting resources while minimizing costs and energy.

Strategies include preventing wastewater generation, resource recovery, and recycling.

The concept of the six R's - reduction, reclamation, reuse, recycling, recovery, and rethink - is essential in wastewater management.

Successful Case Studies in Wastewater Reuse

Several successful examples of wastewater reuse practices are seen in India, where treated wastewater is used for non-potable purposes like irrigation and industrial use.

Various treatment plants have been set up to treat wastewater and reuse it, reducing freshwater demand and generating revenue.

Strategies like zero liquid discharge and resource recovery are being implemented to promote sustainable wastewater management.

Importance Of Waste Treatment

Treatment of waste is valuable because it contains organic materials and nutrients.

It is important to prioritize turning waste into useful resources like fertilizer and biogas.

Local urban bodies (ULBs) should promote the production of these resources from sewage sludge.

Challenges In Waste Treatment

There is a need for stricter enforcement of policies and monitoring systems in waste treatment.

Proper record-keeping, regular monitoring, and strict discharge guidelines are necessary for the efficient operation of wastewater treatment plants (WWTPs) and common effluent treatment plants (CETPs).

Improving Waste Treatment Processes Uninterrupted power supply is crucial for WWTPs, and generating power from sludge digestion can help ensure this.

Capacity building for stakeholders in water management is essential.

Public awareness is needed for widespread wastewater recycling and reuse.

Training sessions can help address social stigma and health concerns related to wastewater treatment.

Public-private partnerships can help build infrastructure for waste treatment.

Financial models like design, build, operate (DBO) and design, build, operate, and transfer (DBOT) can be used for new projects.

Proper financial mechanisms are needed to increase treatment capacity and upgrade existing facilities.

Incentives for circular economy initiatives can encourage more ULBs and industries to adopt sustainable practices in waste treatment.

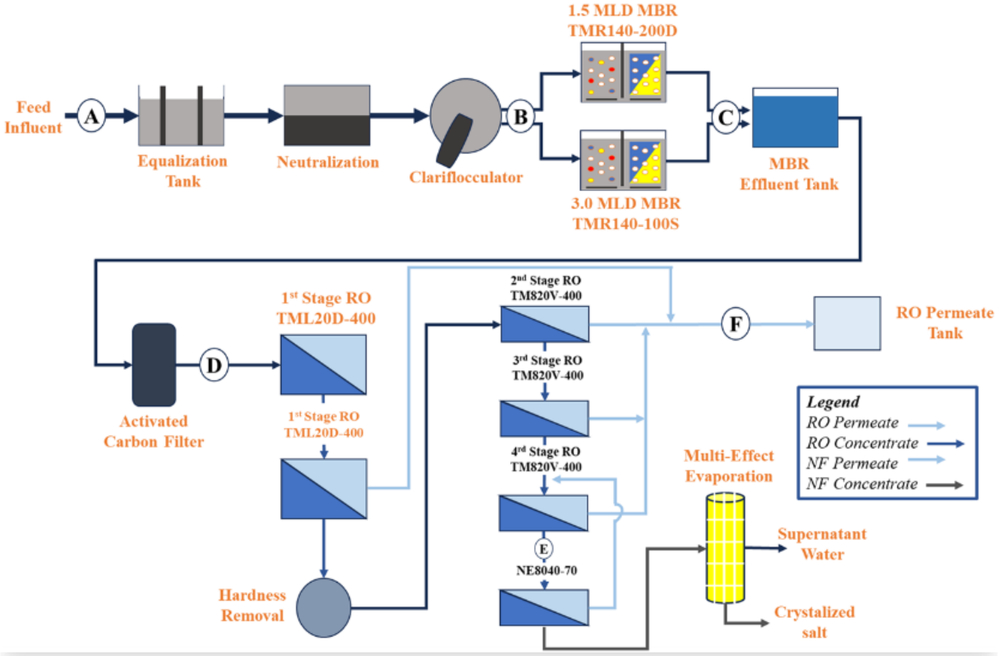


Figure 3.5: Schematic diagram representing unit processes involved in the wastewater treatment adopted by Chemplast group. (Modified from Aquatech, 2023)

2.2.1 DOMESTIC AND INDUSTRIAL WASTEWATER POLLUTANTS

The composition of wastewater mostly depends on its origin. It is estimated that around 80% of the water consumed is converted into wastewater. The major constituents of wastewater include organic matter, nutrients, dissolved ions, pathogens, heavy metals and emerging and toxic contaminants. The secondary treatment unit of WWTP is designed to remove organic matter. The average biological oxygen demand (BOD) and chemical oxygen demand (COD) concentrations in domestic wastewater range from 150 to 200 mg/L and 250 to 400 mg/L and may go as high as 300–400 and 600–800 mg/L, respectively, in water-scarce areas. Industrial wastewater may contain a high concentration of nonbiodegradable organic matter, and BOD/COD ratio is used to determine the biodegradability of industrial wastewater. Nutrient-rich wastewater discharge causes eutrophication in water bodies. The primary sources of phosphate in aquatic environments are industrial effluents from the fertilizer, detergent, and soap industries, agricultural run-off, and domestic wastewater containing detergents and cleaning agents. Nitrogen in wastewater is mainly present in the form of organic nitrogen and ammonia nitrogen. Complex organics, color and high content of dissolved ions are mostly associated with industrial wastewaters.

Conventional WWTPs focus on organic removal and pathogen reduction and little importance is given to the removal of excess nutrients. In recent years, biological nutrient removal (BNR) methods such as simultaneous nitrification–denitrification, Anammox, A2O and so on have been used to produce high-quality effluents for meeting water reuse criteria. Domestic and industrial wastewaters are the major contributors to heavy metal pollution in the environment. Total dissolved solids (TDS) in wastewater are mainly attributed to inorganic salts in wastewater and ionizable organics to a

certain extent. These substances escape the conventional filtration process and can cause taste, odor, and color to the water. The industrial activities which produce high-strength wastewater include steel production, pharmaceutical manufacture, mining operations, oil and gas exploration, agrochemicals, and food processing. High TDS can be reused only by adopting zero liquid discharge schemes employing reverse osmosis. TDS concentrations above 2200 mg/L in the treated wastewaters have shown toxic effects on the aquatic ecosystem. In addition, emerging contaminants (ECs) also pose a risk to the environment. ECs are the anthropogenic chemicals released into the environment at trace levels of concentration and they are found to exert harmful effects to aquatic life. ECs include pharmaceutically active compounds (PhACs), chemicals in personal care products, pesticides, and industrial chemicals. In recent years, microplastics (MPs) pollution has been of serious concern as these can also act as a carrier for other persistent pollutants such as hexachlorobenzene, triclosan, aldrin, tonalite chlordane, dioxin, among others (Mammo et al, 2020). Hence, the WWTPs need to be upgraded to remove these contaminants.

2.2.2 CURRENT STATUS OF WASTEWATER TREATMENT IN INDIA

Globally, it is estimated that over 80% of untreated wastewater is discharged into the water bodies (WWAP, 2017). The wastewater generation and the treatment capacity for different regions worldwide are presented in Figures 3.1 and 3.2. There is a significant disparity between the wastewater generated and treated in nations belonging to the Global South. According to the national inventory of sewage treatment plants (STPs) published by CPCB (2021), out of 1093 functional WWTPs in India, 570 WWTPs were found to comply with the prescribed discharge standards, which means that only 17% of the wastewater generated is getting the necessary treatment. Stringent rules and discharge standards are enforced for industrial effluents. According to the report submitted by CPCB to National Green Tribunal (NGT) in 2020, 64,484 industries require effluent treatment plants (ETPs) and 3% of them do not have ETPs. Out of eight CETPs located along the banks of River Ganga, only one was found complying with the discharge standards (CPCB, 2021).

There is a major shift towards the reuse of treated wastewater globally. In India, most states are reusing the wastewater for non-potable purposes such as horticulture, irrigation, washing activities, and non-contact impoundments. The state of Haryana is topmost in terms of the amount of wastewater reused, with approximately 80% of the treated wastewater used for various purposes. The National Capital Territory (NCT) of Delhi has set a target to increase wastewater reuse by 60% and the proposed reuse practices include irrigation, rejuvenation of water bodies, and indirect potable use.

Existing WWTPs have employed either conventional or advanced treatment technologies. The selection of treatment technology suitable for the wastewater characteristics is crucial to ensure

performance, along with proper operation and maintenance. Most common aerobic processes such as activated sludge process, sequencing batch reactor, membrane bioreactor, moving-bed biofilm reactor, trickling filter, oxidation ditch, and rotating biological contactors and anaerobic processes such as up flow anaerobic sludge blanket reactor, expanded granular sludge blanket reactor, and anaerobic filters are used as secondary biological treatment units. Sequencing batch reactor (SBR) is the most sought-after technology, followed by the activated sludge process (ASP). Anaerobic treatments are not preferred due to odor, corrosion, and low treatment efficiency issues. Most of the countries in the Global South rely on low-cost systems such as pond-based treatment.

2.2.3 REGULATIONS AND POLICIES ON WASTEWATER MANAGEMENT

There are laws and policies in place to prevent water pollution. In India, the Water Act, 1974 resulted in the establishment of central and state pollution control boards to curtail water pollution. The pollution control boards have actively enforced the regulations for treating and discharging municipal and industrial effluents. As part of the Environmental Act, 1986, regulations were introduced to specify the discharge standards for applications such as irrigation, domestic, industrial, recreation, and so on. There have been measures to curb pollution and rejuvenation of major rivers. The Ganga action plan (GAP) launched in 1985 created infrastructure for the collection and treatment of wastewater. The 'Namami Gange' program launched in 2014 with an approved budget of 20,000 crores aims at the conservation and rejuvenation of Ganga including infrastructure for wastewater treatment, river front development, cleaning of river surface, and the conservation of biodiversity. In addition, there are other flagship programs such as the Swachh Bharat Abhiyan (Clean India Mission), the Atal Mission for Rejuvenation and Urban Transformation (AMRUT) scheme, Jawaharlal Nehru National

Urban Renewal Mission (JNNURM) and the Smart City Initiative focusing on achieving SDG6 goals. The National Water Policy released in 2012 emphasizes the reusing and recycling of water and the provision of sanitation amongst other measures. The recent National Green Tribunal (NGT) order in 2019 highlights the need to reuse and recycle wastewater to meet the water demand. Thermal power plants within the 50 km radius of WWTPs are directed to use the treated wastewater as per the Tariff policy, 2016. There are initiatives to encourage sludge management. Solid waste management rules, 2016 mandate the urban local bodies (ULBs) to treat the sludge and promote reuse in agriculture. Waste to energy initiative is promoted by the Ministry of New and Renewable Energy.

There are no regulations focusing on wastewater management in most of the African countries. Many Arab countries have implemented guidelines for the reuse of treated wastewater. USEPA (National water reuse action plan), EU (Water framework directive), Australia (Guidelines for water recycling) and Singapore (Sewerage and drainage act) have stringent regulations and policies on wastewater management and reuse. These documents would be useful to other countries in policy making.

2.2.4 SUSTAINABLE WASTEWATER MANAGEMENT 3.5.1 Life cycle analysis the sustainability of WWTPs is often assessed by life cycle analysis (LCA). LCA helps to understand the environmental impacts of WWTPs during their life cycle. The environmental impacts of WWTPs are mainly attributed to energy consumption, chemical addition, greenhouse gas emissions, treated wastewater, and sludge containing nutrients and heavy metals (Kamble et al, 2019). Fossil fuel based power consumption is a significant contributor towards environmental impacts such as abiotic depletion potential, global warming potential, acidification potential, and photochemical ozone creation potential. Eutrophication potential (EP) is associated with nitrogen and phosphorus emissions in the treated wastewater. The implementation of nutrient removal technologies can bring down EP impact. Toxicity potential depends on the heavy metal content in the treated wastewater and sludge. The shift to greener electricity production can considerably reduce the global warming potential of WWTP. Decision support tools are primarily employed to select the most suitable wastewater treatment technology. There are several factors to be considered in technology selection. The latest decision support tools incorporate sustainability aspects, scenario-based decision making, land availability, and end-use of treated wastewater. Decision support systems are also being used for wastewater reuse. Several studies have included technological, regional, economic, social, and environmental factors in multicriteria decision analysis.

The water-intensive sectors can shift to innovative water management practices. Estimating the water footprint in manufacturing a product would reveal the over usage of water, water losses or any other unaccounted ways in which water is consumed. It is gaining popularity in the industrial sector to adopt water conservation practices. Two methodologies are used worldwide to estimate the water footprint, one developed by the water footprint network and the second recommended by ISO 14046. ISO water footprint tool incorporated the aspects of LCA in the estimation. The water footprint network helps industries to understand their water demand in production stages. Blue water footprint indicates freshwater consumption, grey water footprint shows wastewater generation, and green water footprint refers to the plant uptake of water.

There should be incentives for industries to follow sustainable water management practices. It can also attract investors. For example, the J&K industry is a leading paper manufacturer in India and has established one of the best production practices globally. One metric ton of pulp or paper is produced by consuming 50 m3 of water. The reclaimed wastewater is used as cooling water and is sent to the nearby village for irrigation.

Zero liquid discharge

Zero liquid discharge (ZLD) refers to the treatment and reuse of wastewater generated by industry within its premises. It was mandated by the CPCB in 2015 for textile and pulp and paper industries, distilleries, and tanneries. The textile industry in Tirupur is the first one to adopt a zero liquid discharge scheme in the country. With the adoption of reverse osmosis (RO), the industry could reuse the treated wastewater and recover the salts. The cost associated with RO and operational difficulties often limits the performance of ZLD scheme. The thermal treatment unit is also expensive, which increases the capital cost of ZLD. Successful case studies on zero liquid discharge are discussed below.

CASE STUDIES ON WASTEWATER REUSE

There are several successful examples of wastewater reuse practices in India and the CPHEEO (Central Public Health & Environmental Engineering Organization) has released a compendium on the STPs focusing on wastewater reuse. Selected case studies are presented here.

Tertiary treatment plants to meet industrial water demand in

India, Bangalore Water Supply and Sewerage Board (BWSSB) For water recycling and reuse, the BWSSB has set up two tertiary treatment plants (TTPs) in Bangalore: a 10 MLD plant in Yelahanka, and a 60 MLD plant in the Vrisha Bhavathi Valley in May 2003. In Figure 3.5 Schematic diagram representing unit processes involved in the wastewater treatment adopted by Champas group. (Modified from Aquatec, 2023).

10 MLD scheme, primary treatment (screening, grits removal, and grease removal), secondary treatment (primary settling and activated sludge process), and tertiary treatment (filtration using sand and gravel, and coagulation with aluminum sulphate for the removal of suspended particles) are included. The effluent from the secondary stage is used to meet the non-potable water demand by industries and commercial establishments. The TTP supplies chlorinated recycled water to ITC Ltd., Wheel and Axel Plant, and Bangalore International Devanahalli Airport. The treatment scheme at 60 MLD Vrishabhavathi Valley TTP comprises of trickling filter, DENSADEG high-rate clarifier (combined flash mixer, lamella separators, and counter current flow thickener), FLOPAC aerobic biological filtration unit, and chlorine-based disinfection. The chlorinated recycled water from TTP is sent to the nearby power plants (M/s Karnataka Power Corporation Ltd. in Bidadi and M/s Pulikeshi Power Corporation Ltd. in Kumbalgodu). This scheme generates revenue of about Rs. 18 lakhs per month.

Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB)

Two tertiary treatment RO plants having a capacity of 45 MLD each are set up at Kodangaiyor and Koyambedu by CMWSSB. The treatment units include pre-chlorination, rapid sand gravity filters, basket strainers, ultrafiltration, cartridge filters, RO, and ozonation. The treated water from Koyambedu is supplied at the rate of Rs. 65/KL to SIPCOT industries and other small-scale industries in the vicinity. It has led to a revenue generation of Rs. 19.67 crores. Kodangaiyoor plant supplies treated wastewater to industries located in Manali. The water is supplied at a rate of Rs. 80/KL and the revenue generated is Rs. 48.17 crores. The installation of the TTPs has reduced the freshwater demand by 40 MLD.

Surat Municipal Corporation (SMC) The SMC has constructed a 40 MLD TTP at

Pandesara industrial estate to treat the secondary treated wastewater from Bamroli WWTP. Treatment units include sand filtration, ultrafiltration, RO and activated carbon filtration and the treated water is supplied to the industries in Pandesara. This has resulted in a decrease in freshwater demand by 40 MLD. The treated wastewater is supplied at a rate of Rs. 23/KL and has generated a revenue of about 48 crores. SMC plans to establish more TTPs to Figure 3.6 Treatment process schematics of ZLD system with MBR and high-recovery RO/NF.

cater to the industrial water demand to save freshwater resources for potable water production and encourage wastewater reuse for more activities.

RESULT

Global water demand is expected to grow by 50% by 2030 and a 400% increase in global industrial water demand is predicted by 2050 (UNEP, 2016).

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CHAPTER-3

THE SEWAGE TREATMENT PLANT EXAMPLE

3.1. The STP Treatment Train Any wastewater treatment plant, with no exception of the sewage treatment plant, is a combination of separate unit processes arranged in a sequence such that each would support the performance of the downstream unit process or processes as wastewater with a particular range of characteristics progresses through the plant. This sequence of unit processes forms the treatment train. At the end of this treatment training, the resulting effluent is expected to meet a specified quality. The amount of treatment, and hence the complexity of the plant, is dependent on the treated effluent quality objectives and the nature of the raw wastewater. Notwithstanding the size and engineering complexity of some of these treatment plants, the unit processes in these plants can be classified into five groups:

(i) Preliminary treatment.

(ii) Primary treatment.

(iii) Secondary treatment.

(iv) Tertiary treatment and.

(v) Sludge treatment.

Readers who are familiar with sewage treatment plants (STPs) would have recognized the sequence of treatment stages described above. Sewage treatment plants typically include Stages 1, 2, 3, and 5 although increasing numbers of plants can now include Stage 4, tertiary treatment, as well. To provide a frame of reference for the reader as he/she progresses through the remaining chapters, this chapter provides a brief description and discussion of the unit processes in STPs. Subsequent chapters would then draw the reader’s attention to the possible differences one may encounter in industrial wastewater treatment plants (IWTPs), as compared to STPs, because of the differences in characteristics between industrial wastewaters and sewage. The treatment train of STP without tertiary treatment can comprise of the inlet pump sump with its racks or bar screens, grit removal, primary sedimentation, biological treatment process, secondary sedimentation and disinfection before discharge of the treated effluent. In some STPs nowadays, the primary clarifiers may be replaced by mechanically cleaned fine screens. Sludge from the primary clarifier and waste activated sludge from the secondary clarifier would be thickened, stabilized (typically aerobic means in small plants and anaerobically in large plants), conditioned, dewatered, and the resulting sludge cake disposed of.

3.2. Preliminary Treatment

The front boundary limit of a STP is typically the inlet pump station. The incoming sewer discharges the sewage into a pump sump and the inlet pumps therein would lift the sewage up to the level of the headworks in the plant. The incoming sewer draws its sewage from a sewer network designed to collect sewage from all the individual sources located within its catchment. The inlet pump sums of Steps can be deep with the deeper pump sums associated with the larger plants. This is because the larger plants serve larger communities, and this would have meant more extensive sewer networks and hence larger distances covered. The depth of the pump sump is determined by the necessity for an appropriate hydraulic gradient to ensure, where feasible, gravity flow of sewage in the sewer towards test. The reachable depth of the sloping sewer as it traveled from its catchment to the STP would be at its greatest just when it reaches the inlet pump station. Occasions when distances are large and the sewer would have been too deep if it were to run uninterrupted from catchment to STP, sewage pump stations may be inserted at intervals to lift the sewage and then to allow it to flow by gravity to the next pump station before being lifted again. Preliminary treatment takes place at the headworks. This stage can also include flow measurement but does not change the quality of the sewage substantially in terms of the typically monitored effluent quality parameters (e.g.

BOD5). It enhances the performance of downstream processes by removing materials which may interfere with mechanical, chemical, or biological processes. For example, the racks and coarse screens used are intended to remove relatively large sized suspended material and such devices typically have screen apertures of 25mm or larger. These devices may be manually cleaned as in basket screens or automatically cleaned as in mechanically raked bar screens. Material collected on sunscreens can include rags and plastic bags (Fig. 3.2.1) and these can damage downstream mechanical equipment such as pumps by binding the impellers. The material collected on these racks and screens would be removed regularly to avoid odorous conditions from developing and to prevent blinding of the screens when too much material has collected on it.

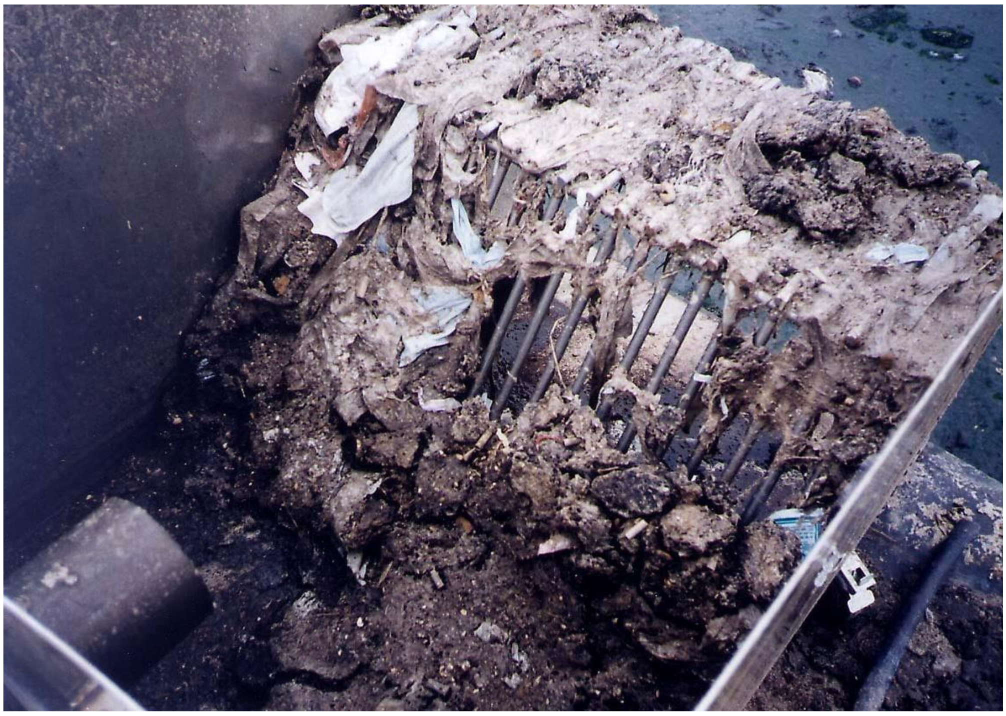


Fig. 3.2.1. Example of screenings collected on a manually cleaned rack. Note the gross material which includes pieces of paper and plastic wrapping. These can blind the screen unless regularly removed.

The mechanical equipment in contact with sewage may also suffer from excessive wear caused by the grit present in the latter. Grit is an inert inorganic material such as sand particles, eggshells, and metal fragments. Grit removal devices rely on differences in specific gravity between organic and inorganic solids to effect separation. It is important the device does not remove the organic solids but allows these to continue with the sewage flow to the next unit process. Grit removal devices may look like rectangular channel-like structures or more compact circular chambers. The channel-like devices are frequently aerated along one side of the channel to assist the separation by creating a rolling motion in the water as it flows through while the circular devices would rely on centrifugal forces as sewage is injected tangentially into the chamber. Aside from grit, sewage may also contain quantities of oil and grease (O&G). The bulk of this O&G is associated with cooking in the homes and is therefore organic in nature. The mineral oil content can be expected to be low. Excessive combined with particulates may blind downstream screens. The O&G may then continue into the aeration basins and interfere with oxygen transfer in the biological processes there. Excessive quantities of O&G entering these biological reactors may also result in “mud-balling” of the biomass where the latter agglomerate into small ball-like structures. Process performance may then deteriorate because of diminished contact between the microbial population and substrate. Where it is considered an issue, the O&G is removed with O&G traps. These are often baffled tanks with manual or mechanical skimmers for the removal of the free O&G which has floated to the surface of the water during the time the water spends in the trap and is then retained against the baffle. Like the screenings on the racks and screens, the trapped O&G has also to be regularly removed to avoid formation of odorous conditions.

3.3. Primary Treatment

Primary treatment follows the preliminary treatment stage. The purpose of primary treatment is to remove settleable suspended solids (SS) and typically about60% of these may be so removed with unaided gravity settling. While a small portion of the colloidal and dissolved material may be removed with the SS, this is incidental. Notwithstanding this, 30~40% of the BOD5 in the raw sewage may be removed with the SS. In gravity clarifiers, the relatively quiescent conditions therein would allow the settleable solids to settle to the bottom of the clarifier forming a sludge layer there. To achieve such settling conditions, the surface overflow rates chosen for design and operation of a clarifier usually range from0.3 to 0.7mms−1. In large clarifiers a scraper located near the base of the clarifier moves the sludge into a hopper from where it would be pumped to the sludge treatment stage. The settled sewage exits the clarifier by overflowing the outlet weirs. Typically, these weirs extend around the periphery of the clarifier. This is to accommodate the weir overflow rate deemed appropriate for a particular design. Where there is such a necessity, the weir length may be extended by supporting the launder on brackets some distance from the wall of the clarifier. Large Steps typically operate either circular or rectangular clarifiers while the smaller ones can use either circular or square clarifiers. Primary (and secondary) clarification in STPs is typically unaided in terms of coagulant use. Where coagulants have been used, SS and BOD5 removals up to90% and 70% respectively have been achieved. While the application of coagulants on a large scale in sewage treatment is relatively rare in Asia, it has appeared where there is a requirement to remove phosphorous. The coagulant may then be injected before primary clarification or into the biological aeration vessels. While primary treatment is usually achieved with gravity clarifiers, rotating and static fine screens have been used sometimes. Such screens typically have screen openings of about 0.8mm to 2.3mm. Since fine screens are operated at hydraulic loading rates an order of magnitude higher than those applied on clarifiers, they occupy much less space for equipment installation. If the sewage contains substantial quantities of O&G, then the screen would likely to be located after the O&G trap. This reduces the risk of the O&G combining with fine particulates and blinding the fine screen. Fine screens are not expected to remove as much of the SS and BOD5 as primary clarifiers would. Consequently, a STP which has fine screens in place of primary clarifiers would need to have its secondary treatment stage appropriately sized. Primary clarifiers and screens can be major sources of malodors. Avoiding over-designs especially in clarifiers (resulting in overly long hydraulic retention time and the consequent development of septic conditions) and good Housekeeping would help reduce the incidence of such odors. The development of septic conditions in screens are less likely to occur since the passage of sewage through the screen does provide a degree of aeration.

3.4. Secondary Treatment

The role of the secondary treatment is to remove the colloidal and dissolved material remaining after the preliminary and primary treatment stages. In sewage treatment, the secondary stage typically includes a biological process. The latter, often an aerobic suspended growth process where the microbial population used to treat the wastewater is suspended in the mixed liquor of the reactor, is housed in an aeration vessel or reactor which has been designed to be complete-mix, plug flow, or a condition between these two extremes — arbitrary flow (see Sec. 5.3for discussion on reactor configurations). These reactor variants best suit specific process variants. The latter includes the high rate activated sludge, conventional activated sludge, and extended aeration process. Among the differences between these process variants, two important ones are the hydraulic retention time (HRT)and the cell residence time (CRT). Typically, the high rate activated sludge process the shortest HRTs and CRTs and these parameters would increase in magnitude towards the extended aeration process. This means, for a given reactor volume, the high rate activated sludge system processes more sewage than the extended aeration system. The latter makes up for this “inefficiency” by usually being a more stable process and therefore easier to operate. Even within the three process variants identified above, there are further variants. For example, the oxidation ditch and aerated lagoons are two variants of the extended aeration process but housed in different reactor designs — plug-flow and arbitrary flow respectively. All these variants have reactors followed by secondary clarifiers. The latter serves to produce a treated effluent with 50 mg L−1 SS or lower and allow the return of biomass (or bio sludge) collected in the hoppers of such clarifiers to the reactors to maintain an adequate microbial population or mixed liquor suspended solids (MLSS) therein. While aerobic suspended growth systems are common, they are by no means the only types used for sewage treatment. Attached growth systems such as the trickling filter and rotating biological contactor may also be encountered in STPs. These systems have the micro-organisms forming a biofilm on a support medium which is typically a highly porous formed plastic shape with a large surface area to volume ratio. Such biofilms are not submerged in sewage (e.g. in the trickling filter) or only intermittently submerged (e.g. in the rotating biological contactor). Oxygen for the aerobic process is transferred from the atmosphere into the liquid film which forms on the biofilm. Figure 3.4.1 shows an activated sludge process variant which combined suspended growth with attached growth. Unlike the trickling filter and rotating biological contactor, the biofilms in such a system are continuously submerged in the reactor's mixed liquor. Since the biofilm support medium is submerged, its presence is not immediately obvious. Its presence is, however, suggested by the aeration pattern observable on the water surface. Because the diffusers have been concentrated beneath the support medium, the distribution of air bubbles on the water surface is not even as it would have been in an aeration vessel where the diffusers had been distributed evenly on the base of the vessel. In such processes, the biological reactor would also be followed by a secondary clarifier. This is to allow return of settled biomass to the reactor so as to maintain an adequate population of suspended microbes therein. The clarified effluent overflows the clarifier and can be discharged into a receiving waterbody if it does not require further treatment.

Fig. 3.4.1. Activated sludge plant for sewage treatment where the bioprocess is a combination of suspended and attached growth. The submerged biofilm support modules are located along a line running longitudinally and down the center of the tank.

3.5. Sludge Treatment

Biomass more than the quantity required for maintaining the MLSS concentration in the reactor is removed from the system via the excess sludge line. The waste sludge can be thickened in gravity thickeners and then aerobically or anaerobically digested to reduce solids content and to render the sludge safer in terms of pathogenic organisms (especially if the waste activated sludge had been mixed with primary sludge from the primary clarifiers. Typically, anaerobic digestion is used at large STPs while aerobic digestion would be used at those serving small communities. The anaerobic process in STPs is almost always used for treating the solids rather than the liquid stream. Anaerobic digesters at large STPs, aside from reducing the quantity of solids requiring final disposal, also offer the opportunity for recovering energy from the organic solids. The digested sludge is dewatered to reduce moisture and hence volume. Methods used include drying beds, filter presses, and centrifuges. Nowadays drying beds are rarely used at large Speciose of their large space requirements. The resulting sludge cake from the dewatering stage is disposed of as a soil conditioner, at landfills, or incinerated.

CHAPTER 4

THE INDUSTRIAL WASTEWATER TREATMENTPLANT — PRELIMINARY UNIT PROCESSES

4.1. The IWTP Treatment Train

In industrial wastewater treatment plants (IWTPs) there is a treatment train with unit processes arranged in a manner similar but not necessarily identical to that found in STPs. It is necessary to bear in mind that unit processes present in an STP can all be present in an IWTP treatment train, or many may not be present. Unit processes not typically found in STPs may also appear in an IWTP treatment train. Much depends on the industrial wastewater's characteristics and treatment objectives. This can result in significant differences between IWTPs and STPs. Theater, because of the greater similarities in sewage characteristics from location to location, tends to have a more recognizable arrangement of unit processes and plant configuration (as discussed in Chapter 3). Differences in the latter can often come about primarily because of plant size instead of the sewage's characteristics. Because of the differences in industrial wastewater characteristics, as discussed in Chapter 2, this is not so for IWTPs.

4.2. Wastewater Collection and Preliminary Treatment

IWTPs, like STPs, also begin with a sump where the inlet pumps are located. These sums serve to collect the wastewater from the factory before onward transmission to IWTP. These sums are, however, very rarely as large as those which may be found in STPs. This is because most IWTPs, but not all, serve a single wastewater source, which is the factory for which it has been constructed. Since the IWTP is often located close to the source of its wastewater, the inlet (or collection) sump is also rarely very deep (Fig. 4.2.1). This is because wastewater pipes leading from the factory to the IWTP rarely need to be placed in deep trenches at the IWTP end to ensure an adequate slope to facilitate wastewater flow. The incoming wastewater may, in fact, often arrive at the sump by way of surface drains instead of buried pipes. Where drains are used instead of pipes, care

Fig. 4.2.1. Shallow wastewater collection sump at a personal care products factory. Submersibles are located in this sump to lift the wastewater to the next unit process in the IWTP. The sheen on the water surface suggests the presence of O&G.

should be exercised to separate rainwater from the roof gutters and surface runoff from the wastewater flow. This is an important consideration at locations where seasonal rainfall can be heavy over relatively short periods of time. The resulting surge of high flows arising from rainwater can easily overwhelm an IWTP in terms of hydraulic capacity leading to, for example, washout of oil and grease from O&G traps and biomass from the bioreactors. Figure 4.2.2 shows a drain leading to an IWTP which has been covered to reduce entry of rainwater runoff. The drains leading to the collection sump may offer opportunities for the inclusion of preliminary treatment devices such as simple bar screens and O&G traps. Figure 4.2.2 which shows a wastewater drain leading to an IWTP's collection sump also shows a bar screen inserted into it. This has a function like the bar screens in STPs. Figure 4.2.3 shows a drain leading to another collection sump. In this instance a simple perforated baffle plate has been mounted in it. This served to remove some of the O&G present in the raw wastewater and is therefore a simple oil trap. The drain may eventually lead to a baffled tank O&G trap as showman Fig. 4.2.4. Application of such O&G traps early in the treatment train (e.g. in the drains leading to the IWTP) is useful for wastewaters such as palm oil refinery effluents where the suspended solids content is relatively low while the O&G content can be high. They can be important for enhancing the performance of downstream mechanical elements such as pumps and valves (reducing the risk of clogging), and unit processes such as the dissolved air flotation (DAF) (reducing the O&G load). DAFs may be required if there is a downstream requirement for relatively low residual O&G content — levels which cannot be met by the simple or baffled tank O&G traps. The simple upstream O&G traps do considerably reduce the O&G load on the DAF, and this would reduce the size of the DAF and quantities of air and coagulant required therein to achieve the desired performance. Even if such downstream processes are not present; the O&G traps would have helped make housekeeping at the equalization tank easier. The organic O&G recovered from such traps are frequently collected by manufacturers of coarse soaps. For example, if it is palm oil, it would be hydrolyzed with

Fig. 4.2.2. Covered drain leading to the collection sump of an IWTP. The (removed) cover had been placed over a coarse screen. The easily removable covers facilitate the removal of screenings from the screen. The drain is shallow because the distance between the factory and IWTP is small.

hydroxide ions in aqueous solution (i.e. saponified) and sodium palmitate ($CH_3(CH_2)_{14} \cdot COONa$), which is soap, is produced. The possible presence of O&G need not always be indicated by the nature of the industry — as in a palm oil refinery obviously generating wastewater with O&G. An example of a less obvious case would be the personal care products factory wastewater. The O&G in this instance was part of the formulation of the products resulting in “greasy” wastewater. The wastewater shown in Fig. 4.2.1obviously shows the presence of O&G by way of its surface sheen. Even less obvious than the personal care products factory is the case of the soft drinks bottling plant. Figure 4.2.5 shows the mineral oil collected by an O&G trap at such a bottling plant over a week. If this quantity of O&G had entered the downstream bioreactor, it would have affected the dissolution of oxygen into the reactor’s mixed liquor during aeration, caused the biomass to form small lumps resembling “Mud balls”, and compromised treated effluent quality. The reason for the occurrence of this O&G has been discussed.

Fig. 4.2.3. Baffle plate O&G trap inserted into a surface drain leading to the IWTP at a palm oil refinery. The effectiveness of such a simple device may be seen from the O&G accumulated behind the baffle plate. While not reducing the wastewater’s O&G content to the required levels, the trap significantly reduced the O&G load which would otherwise be imposed on the next unit process.

Fig. 4.2.4. The baffled tank O&G trap at a palm oil refinery provides for more quiescent conditions to allow for greater removal of O&G than what is possible with the simple trap shown in Fig. 4.2.3.In traps of this type, the O&G accumulated on the wastewater surface in each chamber is manually removed at intervals.

4.3. Wastewater Equilization

Unlike many STPs, IWTPs would frequently include equalization tanks in their treatment trains. These serve to produce flows, or compositions, or both which are closer to the average values used in the IWTP designs. In addition to this, and bearing in mind that factories are operated on the basis of shifts and if a particular factory is operating on fewer than three 8 h or two 12 h shifts per day, the equalization tank can also have the function of a holding tank so that wastewater can be stored and supplied continuously to a continuous flow IWTP even when

Fig. 4.2.5. Lubricating oil collected from the O&G trap at a soft drink bottling plant.

The lubricating oil came from excess oil applied to the bottle conveyor belt system. This dripped onto the floor and was eventually washed into the collecting drains leading to the IWTP. The factory has ceased operations and stopped discharging wastewater for the day. Where variable wastewater composition is an issue, the contents of the equalization tank would need to be mixed. Mixing is also important if the wastewater contains settleable material. In the absence of mixing, such material would settle and accumulate in the equalization tank. Mixing can be achieved with mechanical mixers or by aeration. Although the latter is typically performed through corsair aeration from coarse air diffusers or perforated pipes, some dissolution of oxygen would occur and this is useful if there is a concern that septic conditions may develop as biodegradable substances present in the wastewater degrade over the holding period. Figure 4.3.1 shows an aerated equalization tank which served lanolin extraction factory. The latter had a process which included washing wool prior to extraction of lanolin from the resulting wash water. The waste wash water contained significant quantities of O&G and very fine particulate material, giving the wastewater a thick brownish appearance. The equalization tank shown is vigorously aerated to reduce settling of the particulate material and had been designed with two chambers to facilitate cleaning in view of a wastewater which can easily fool the tank's fittings, walls, and base as shown.

Fig. 4.3.1. Two-chambered aerated equalization tank at a lanolin extraction IWTP.

The RHS chamber was being aerated while the LHS chamber was not at the time this picture was taken. The mixture of O&G and fine particulates makes fouling of the equalization tank a recurring and serious maintenance issue. The material on the walls and pipe (foreground of the picture) gives an indication of fouling. The latter had to be removed regularly to reduce the incidence of odors and slippery work surfaces. Where factories are not known to have shutdown periods and bypassing a unit process is undesirable, the latter, such as the equalization tank shown in Fig. 4.3.1, may be designed in pairs (for vessels this would more typically be two chambers) to facilitate partial shutdown of a stage in the treatment train so that maintenance can be performed. It is necessary to allow for some redundancies in IWTP. Without redundancy, plant maintenance can then only take place when the factory has a shutdown. Equalization tanks have also served to hold and so cool a warm wastewater stream prior to its treatment. Warm wastewater is a common occurrence in food processing and canning factories. In general, warm wastewaters occur more frequently than wastewaters with temperatures substantially below ambient. Factories often generate several wastewater streams with different temperature characteristics and the equalization tank then serves as a blending tank so that the IWTP may receive blended wastewater with more consistent thermal characteristics. These different wastewater streams may come from the different manufacturing lines within the factory. The importance of an adequately sized and properly operated equalization tank to overall IWTP performance cannot be overstated. Failing this, IWTP performance is unlikely to be stable and hence the treated effluent may not meet the discharge limits consistently.

4.4. Oil & Grease and Particulate Removal

Large quantities of fine particulates and O&G, which have been found in lanolin extraction wastewater, would impose high SS and organic loads on the bioreactors downstream. This would have led to higher oxygen demands. Sizing of such bioreactors, and possibly other types of downstream unit processes, can be reduced if some of the pollutants are removed upstream. As pointed out earlier (Sec. 4.2), DAFs may serve to remove pollutants such as O&G and fine particulates. Fig. 4.4.1 shows the lanolin extraction wastewater first shown in Fig. 4.3.1after DAF treatment. The improved clarity of the DAF treated wastewater is obvious indicating that the pollutant load had been much lowered, at least in terms of the fine particulates and O&G. To achieve such an improvement in wastewater quality by the DAF often requires the use of coagulants.

Among the coagulants used, aluminum (alum— $Al_2(SO_4)_3 \cdot 14H_2O$) and iron salts (ferrous sulphate— $FeSO_4 \cdot 7H_2O$; ferric chloride — $FeCl_3 \cdot 6H_2O$) are common. This is usually because of the relatively low cost and availability of these chemicals. In each case the coagulant reacts with the alkalinity in the wastewater and forms the metal hydroxide as in $Al(OH)_3$ or $Fe(OH)_3$. Since wastewater may not have sufficient alkalinity to react with the amount of coagulant added, alkalinity must be supplemented. Alum coagulation is generally effective over a pH range of 5.5to 8.0 whereas the iron salts can be effective over a wider pH range of 4.8 to11.0. pH control is an important consideration in coagulation as the solubility of the metal hydroxides increases outside of the optimum conditions determined for each wastewater. Precipitation of the amorphous metal hydroxide is a requirement for most coagulation and clarification processes to work effectively. The use of coagulants in wastewater treatment such as to assist air flotation is not without issue. The largely metal hydroxide sludge so generated requires disposal at landfills thereby increasing the overall cost of wastewater treatment. Large quantities can be generated when treating strong wastewater. The example provided in Fig. 4.4.2 is of a DAF which treated wastewater from a milk canning factory located in an urban area. Anaerobic treatment to reduce wastewater organic strength before aerobic treatment was not acceptable because of the potential odors from the former and consequent objections from neighbors. The coagulant assisted DAF was therefore used to remove O&G, and to reduce overall organic strength before the pretreated wastewater was discharged directly

Fig. 4.4.1. Coagulant assisted DAF pretreated lanolin extraction wastewater — Note the substantial improvement in clarity. Significant quantities of the O&G and fine particulates have been removed. Although the wastewater's clarity had improved so markedly, it still needed biological treatment to remove the dissolved organic components before the treated effluent met the discharge limits.

Fig. 4.4.2. Coagulant assisted DAF (top LHS) treating milk canning wastewater.

The pretreated wastewater is discharged directly into the bioreactor beneath the DAF for further treatment. The bags on the RHS contain dewatered sludge which was mainly made up of coagulation sludge from the DAF. into the activated sludge basin sited below the DAF unit. The bags beside the aeration basin show how much dewatered sludge can be accumulated over a month. DAFs do not lend themselves well to intermittent operation as time is required to stabilize the process following each start-up. As such it is desirable to operates continuously and this would require an appropriately sized equalization tank. Apart from the continuous and constant hydraulic load, the equalization tank would also have “averaged” the wastewater’s composition thereby allowing the possibility of lower chemicals consumption. Not over-sizing the equalization tanks, however, an important consideration for the same reason an anaerobic pretreatment stage was thought inappropriate for milk wastewater treatment. Other unit processes which may be used to remove particulates, especially the coarser and/or denser types, include the primary clarifier and fine screen. As with the DAF, primary clarifiers in industrial wastewater treatment are often preceded by coagulation and typically the latter is followed by flocculation with polymers. Figure 4.4.3 shows a labyrinthine type flocculator in a textile dyeing wastewater treatment plant. Such flocculators avoid the need for low-speed stirrers and may be favored if there is a desire to reduce the number of mechanical elements in the IWTP. The hydroxide precipitate formed from the coagulant’s reaction with

Fig. 4.4.3. Labyrinthine type flocculator (LHS) at a IWTP for a textile dyehouse. The dosing of the flocculant from a pipe just before the start of the first baffle of the flocculator can be seen on the LHS of the picture.

alkalinity agglomerated into larger more settleable particles in the flocculator, and liquid-solids separation would then take place in the clarifier (Fig. 4.4.4). The theater is rectangular in configuration as opposed to the circular configuration. The rectangular configuration usually lends itself better to a more space-saving arrangement of vessels at space constrained sites. The process of coagulation can also assist in removing the dyes dissolved in the textile wastewater. The use of coagulants to remove colors in industrial wastewater is a frequent occurrence. For such applications, iron salts may perform better than alum. As in the use of coagulants to assist the removal of O&G and fine particulates, coagulant assisted color removal also has the problem of disposing large quantities of sludge. It should, however, be noted that not all wastewaters are coagulated and flocculated before clarification. Pig farms generate very strong wastewater in terms of suspended material and dissolved components. Early removal of the suspended fraction serves to improve the performance of downstream biological unit processes. Such removal may be achieved with clarifiers. Notwithstanding this, and the case of piggery wastewater and other easily biodegradable wastewaters, the use of clarifiers has not always been successful. This is because septic conditions can easily develop if hydraulic retention times become too long resulting in the

Fig. 4.4.4. Rectangular clarifiers follow coagulation/flocculation at a textile dyehouse. Rectangular

vessels may be easier to arrange in a more space-saving manner compared to circular vessels. Release of gases generated. These then interfere with the settling process and possibly result in rising sludge. Such gases are often odorous, and this would certainly be so in the case of piggery wastewater. To avoid this, the primary clarifier can be replaced with the fine screen although the latter does not quite match the performance of a clarifier which is operating well. Figure 4.4.5 shows a mechanical fine screen which has been applied to piggery wastewater in place of primary clarifier. Screens can be an effective alternative to clarifiers where space at a site is constrained. Such fine screens may be mechanical as shown or nonmechanical versions like the curved self-cleaning screens. The non-mechanical versions which do require more attention from operators to avoid clogging, and hence overflowing, have been used successfully at locations where manpower is readily available and inexpensive. Apart from the obvious reduction in solids load on the bioprocess by clarifiers and fine screens, the latter could also aid the performance of downstream processes like pH adjustment. An example of this is pineapple canning wastewater. During preparation of the fruits prior to canning, trimming and washing result in bits of the fruit being carried away in the wastewater. Since the fruits are acidic, the bits of fruit making up the particulates are acidic and would have consumed large quantities of alkali if pH adjustment was attempted in their presence. These particulates can be easily removed with fine screens and their removal improves performance of the pH adjustment stage particularly in terms of alkali consumption.

4.5. pH Adjustment

Unlike domestic or municipal sewage where the pH range is typically 6.0~7.5, industrial wastewaters have pHs which vary over a much broader range — from very acidic to very alkaline. It should also be noted that a factory may generate several wastewater streams and among these can be those which are acidic while the rest may be alkaline. Consequently, it can be useful in terms of reducing chemical consumption for adjustment by providing sufficient equalization prior to pH correction so that the various wastewater streams may achieve a degree of pH adjustment through their own interaction. This becomes particularly important if the acidic and alkaline streams are not generated at the same time. Holding and blending becomes a necessary activity then. The difficulties with pH need not always occur because it is an inherent characteristic of wastewater. It should be noted that pH may be manipulated if chemical cracking of oily emulsions and coagulation had been necessary (as discussed in Sec. 4.4) and may subsequently need to be adjusted again prior to biological treatment. Automatic pH correction can be an unexpectedly difficult activity to perform satisfactorily. This is, in part, because of the difficulty associated with mixing a small quantity of reagent uniformly with a large volume of wastewater. This is made even more difficult if wastewater characteristics, such as its flowrate, changes rapidly. The value of adequate equalization or blending prior to pH adjustment cannot be overstated. Because of the relatively small size of many IWTPs, the preferred chemical for pH adjustment of acidic wastewaters is usually sodium hydroxide instead of lime. A solution of sodium hydroxide would be prepared prior to its injection into the pH correction tank. At IWTPs where the chemical consumption is sufficiently large to justify the additional handling facilities required, lime made up in the form of a slurry can be used. The handling of lime powder (its typical form when delivered to the IWTP) has safety requirements which operators at small It may not be equipped to cope with. Lime is usually chosen because it is cheaper than sodium hydroxide. When lime is used, it is necessary to appreciate that it is slower compared to sodium hydroxide. This means that the reaction tank must be increased in size to allow for the longer hydraulic retention times needed. Typically, a minimum of 20 min HRT is allowed for. The reaction tank's contents are mixed either with a mechanical stirrer or with air.

CHAPTER-5: CONCLUSION

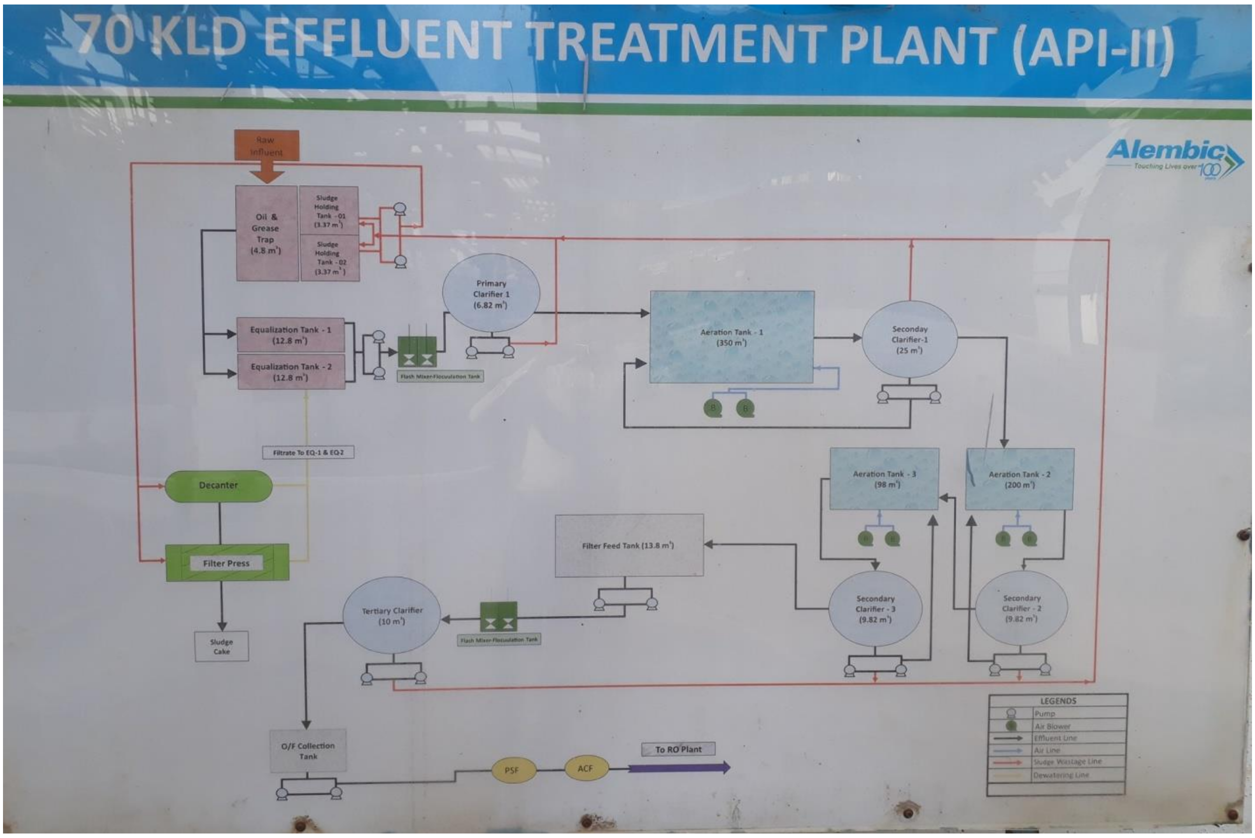


Fig: 70KLD ETP Plant

- 70 KLD Effluent Treatment Plant with primary, Secondary, And Tertiary Treatment

Advantages of ETP:

- Reduce off-site treatment cost.
- Unnecessary water usage during the processing is eliminated.
- Makes your industry self-sustainable.
- Helps reduce the contamination of natural water bodies and make the environment safe for others.
- This is the most cost-effective and environmental-friendly method.

Results and Discussion

Analysis of Industrial Waste Water Samples are collected from different plants before treatment and after treatment. As you can see in photos below, water sample photos are also attached in which we can clearly saw the effects of treatment. Results of Parameters such as pH, TSS, BOD and COD are meeting the Standard outlet parameters Source of SOP by Gujarat Pollution Control Board.

Sr.No.	Tests	Unit	Result Before Treatment	Result after Treatment
1.	pH	-	5-10	6.5-7.5
2.	TDS	mg/L	8000-10000	1000-2000
3.	COD	mg/L	10000-12000	500-1000

5.2: Testing of sample

In the study period, samples at different stages of treatment units of ETP were collected and analyzed for evaluation of ETP. The collected samples were analyzed for parameters viz., pH, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD) and Oil and Grease(O&G) .

5.3: pH the pH is determined by measurement of the electromotive force of a cell comprising an indicator electrode (an electrode response to hydrogen ions such as glass electrode) immersed in the test solution and a reference electrode contact between the test solution and the reference electrode is usually achieved by means of a liquid junction, which forms a part of the reference electrode. The emf of this cell is measured with pH meter. This is a high impedance electrometer calibrated in terms of pH. 100ml of the sample was taken in a beaker. The electrodes were dipped in it and the pH was recorded.

5.4: TDS

- 50ml of well-mixed sample was filtered through glass fibre filter.
- Then 10ml of distilled water was allowed to wash for complete drainage between washing and suction was continued for about 3 minutes after filtration is complete.
- Filtrate was transferred to an empty weighed (W1) crucible and evaporated on hot plate hot water bath.
- Crucible was transferred into hot air oven for dryness at 1050C ± 20C for at least one hour.
- Then the crucible was cooled in a desiccator and weighed. The process of drying and cooling and weighing was repeated until a constant weight (W2) was obtained

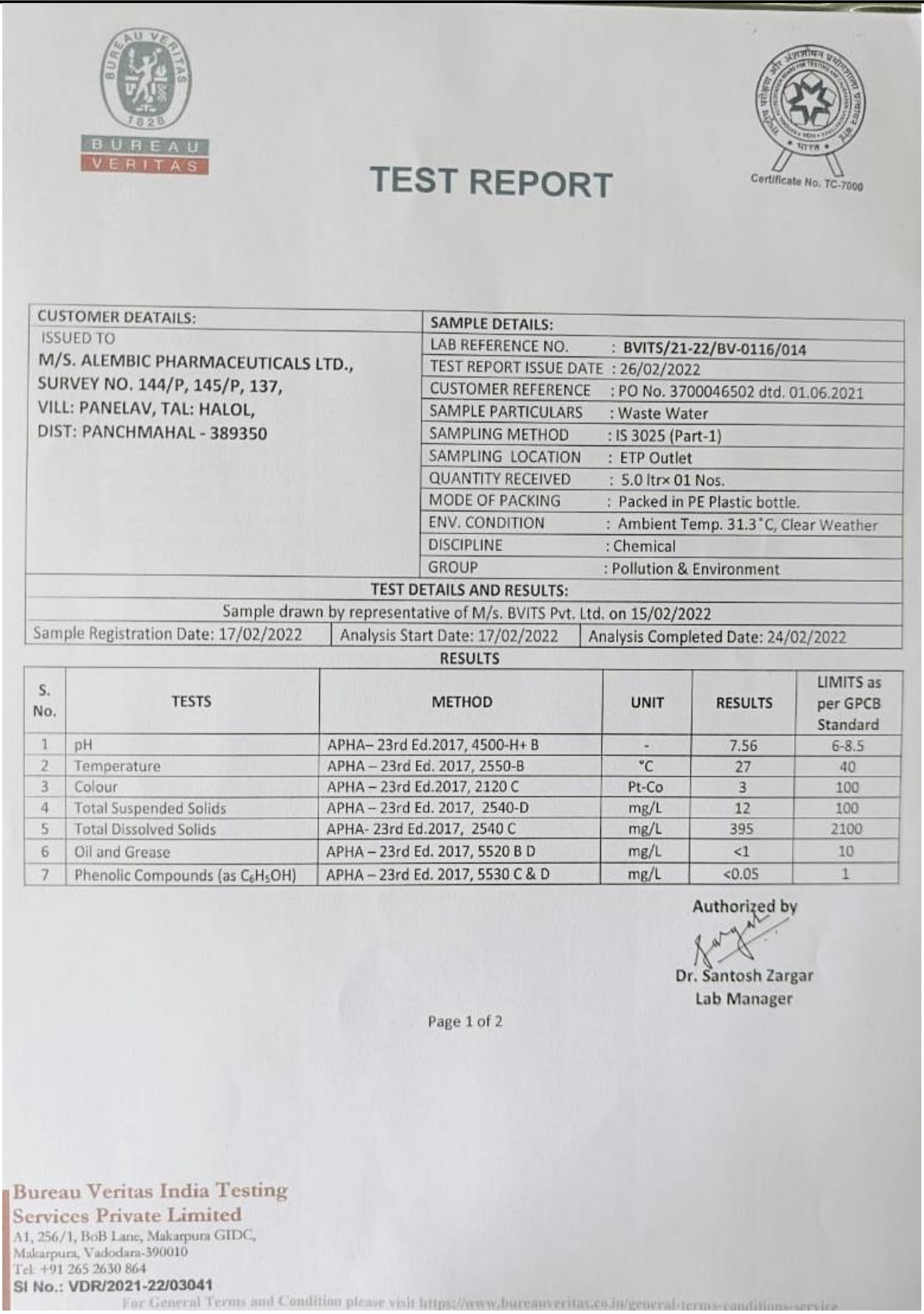
5.5 TSS

- The Filter paper disk was taken and dried at 105°C for an hour to remove (any water) moisture adhering to its surface.

- Then it was cooled in a desiccator and its weight was taken accurately on a precision balance [W1 (g)].
- Put the membrane filter on filter holder and wet it with water. 50ml of sample was filtered through it (to get a residue of 200mg) under vacuum.
- Filter membrane was filtered and dried at 103 - 105°C in an oven.
- Then the membrane filter was cooled in a desiccator and weighed. The process of drying, cooling and weighing was repeated until a constant weight (W2) was obtained.

Fig: ETP INLET & OUTLET SAMPLE


EQUALIZATION
TANK-02
CAPACITY: 12.8 KL



BUREAU VERITAS

Certificate No. TC-7000

TEST REPORT

CUSTOMER DEATAILS:	**SAMPLE DETAILS:**
ISSUED TO **M/S. ALEMBIC PHARMACEUTICALS LTD., SURVEY NO. 144/P, 145/P, 137, VILL: PANELAV, TAL: HALOL, DIST: PANCHMAHAL - 389350**	LAB REFERENCE NO. : **BVITS/21-22/BV-0116/014** TEST REPORT ISSUE DATE : 26/02/2022 CUSTOMER REFERENCE : PO No. 3700046502 dtd. 01.06.2021 SAMPLE PARTICULARS : Waste Water SAMPLING METHOD : IS 3025 (Part-1) SAMPLING LOCATION : ETP Outlet QUANTITY RECEIVED : 5.0 ltr× 01 Nos. MODE OF PACKING : Packed in PE Plastic bottle. ENV. CONDITION : Ambient Temp. 31.3˚C, Clear Weather DISCIPLINE : Chemical GROUP : Pollution & Environment

TEST DETAILS AND RESULTS:

Sample drawn by representative of M/s. BVITS Pvt. Ltd. on 15/02/2022

Sample Registration Date: 17/02/2022	Analysis Start Date: 17/02/2022	Analysis Completed Date: 24/02/2022

RESULTS

S. No.	TESTS	METHOD	UNIT	RESULTS	LIMITS as per GPCB Standard
1	pH	APHA– 23rd Ed.2017, 4500-H+ B	-	7.56	6-8.5
2	Temperature	APHA – 23rd Ed. 2017, 2550-B	°C	27	40
3	Colour	APHA – 23rd Ed.2017, 2120 C	Pt-Co	3	100
4	Total Suspended Solids	APHA – 23rd Ed. 2017, 2540-D	mg/L	12	100
5	Total Dissolved Solids	APHA- 23rd Ed.2017, 2540 C	mg/L	395	2100
6	Oil and Grease	APHA – 23rd Ed. 2017, 5520 B D	mg/L	<1	10
7	Phenolic Compounds (as C_6H_5OH)	APHA – 23rd Ed. 2017, 5530 C & D	mg/L	<0.05	1

Authorized by

Dr. Santosh Zargar
Lab Manager

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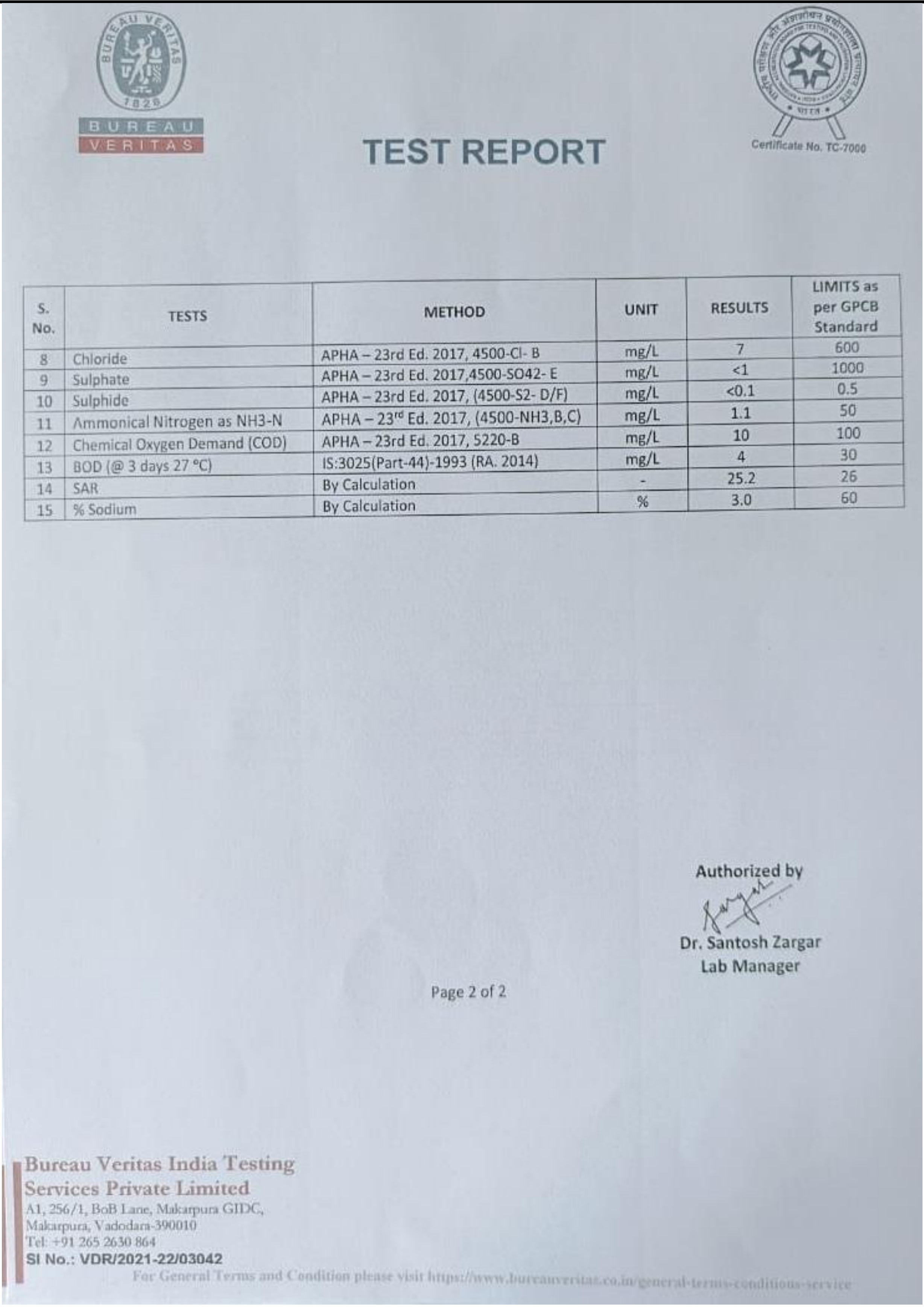

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TEST REPORT

S. No.	TESTS	METHOD	UNIT	RESULTS	LIMITS as per GPCB Standard
8	Chloride	APHA – 23rd Ed. 2017, 4500-Cl- B	mg/L	7	600
9	Sulphate	APHA – 23rd Ed. 2017,4500-SO42- E	mg/L	<1	1000
10	Sulphide	APHA – 23rd Ed. 2017, (4500-S2- D/F)	mg/L	<0.1	0.5
11	Ammonical Nitrogen as NH3-N	APHA – 23rd Ed. 2017, (4500-NH3,B,C)	mg/L	1.1	50
12	Chemical Oxygen Demand (COD)	APHA – 23rd Ed. 2017, 5220-B	mg/L	10	100
13	BOD (@ 3 days 27 °C)	IS:3025(Part-44)-1993 (RA. 2014)	mg/L	4	30
14	SAR	By Calculation	-	25.2	26
15	% Sodium	By Calculation	%	3.0	60

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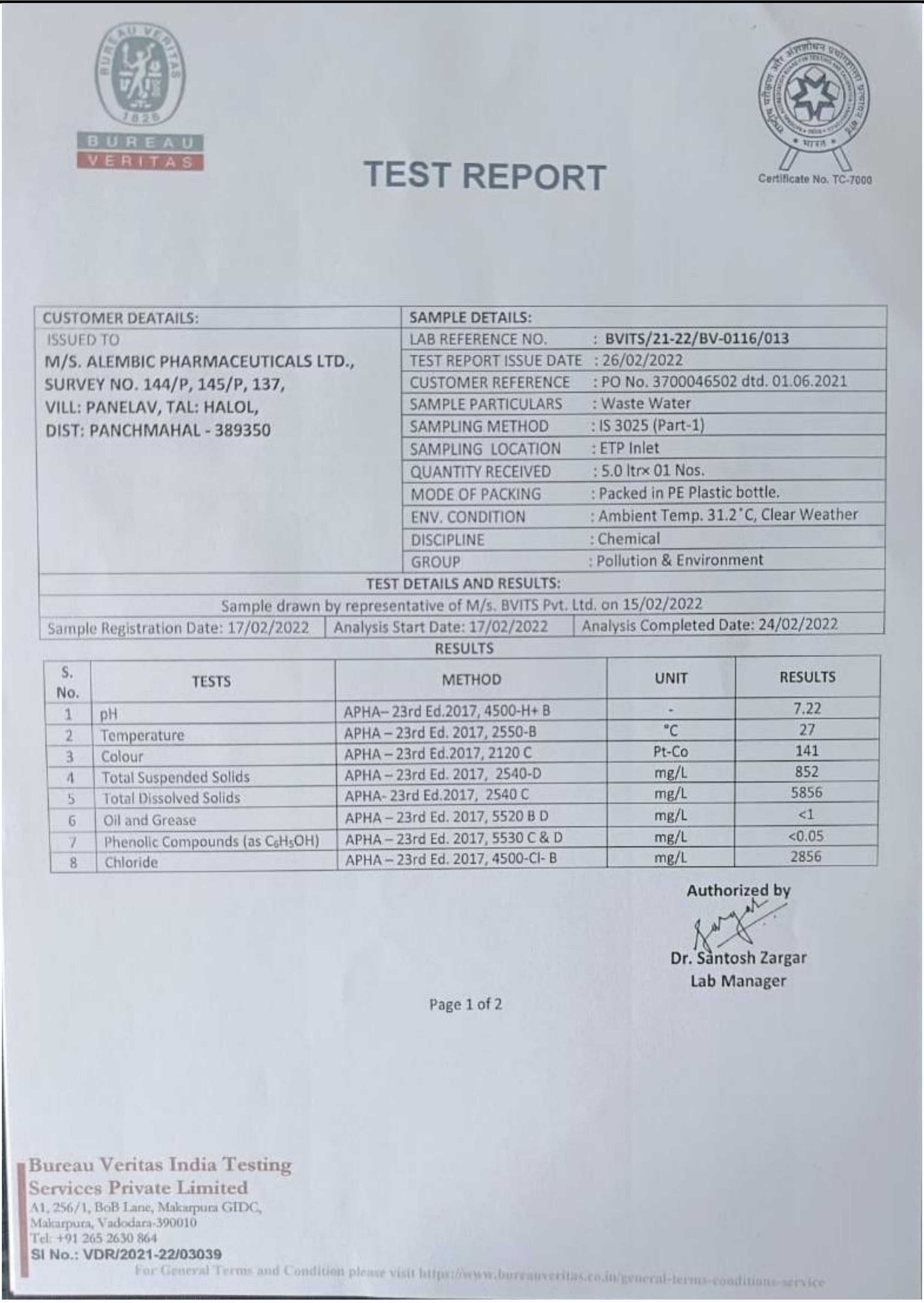

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TEST REPORT

Certificate No. TC-7000

CUSTOMER DEATAILS:	SAMPLE DETAILS:	
ISSUED TO **M/S. ALEMBIC PHARMACEUTICALS LTD., SURVEY NO. 144/P, 145/P, 137, VILL: PANELAV, TAL: HALOL, DIST: PANCHMAHAL - 389350**	LAB REFERENCE NO.	: **BVITS/21-22/BV-0116/013**
	TEST REPORT ISSUE DATE	: 26/02/2022
	CUSTOMER REFERENCE	: PO No. 3700046502 dtd. 01.06.2021
	SAMPLE PARTICULARS	: Waste Water
	SAMPLING METHOD	: IS 3025 (Part-1)
	SAMPLING LOCATION	: ETP Inlet
	QUANTITY RECEIVED	: 5.0 ltr× 01 Nos.
	MODE OF PACKING	: Packed in PE Plastic bottle.
	ENV. CONDITION	: Ambient Temp. 31.2˚C, Clear Weather
	DISCIPLINE	: Chemical
	GROUP	: Pollution & Environment

TEST DETAILS AND RESULTS:

Sample drawn by representative of M/s. BVITS Pvt. Ltd. on 15/02/2022

Sample Registration Date: 17/02/2022 | Analysis Start Date: 17/02/2022 | Analysis Completed Date: 24/02/2022

RESULTS

S. No.	TESTS	METHOD	UNIT	RESULTS
1	pH	APHA– 23rd Ed.2017, 4500-H+ B	-	7.22
2	Temperature	APHA – 23rd Ed. 2017, 2550-B	°C	27
3	Colour	APHA – 23rd Ed.2017, 2120 C	Pt-Co	141
4	Total Suspended Solids	APHA – 23rd Ed. 2017, 2540-D	mg/L	852
5	Total Dissolved Solids	APHA- 23rd Ed.2017, 2540 C	mg/L	5856
6	Oil and Grease	APHA – 23rd Ed. 2017, 5520 B D	mg/L	<1
7	Phenolic Compounds (as C_6H_5OH)	APHA – 23rd Ed. 2017, 5530 C & D	mg/L	<0.05
8	Chloride	APHA – 23rd Ed. 2017, 4500-Cl- B	mg/L	2856

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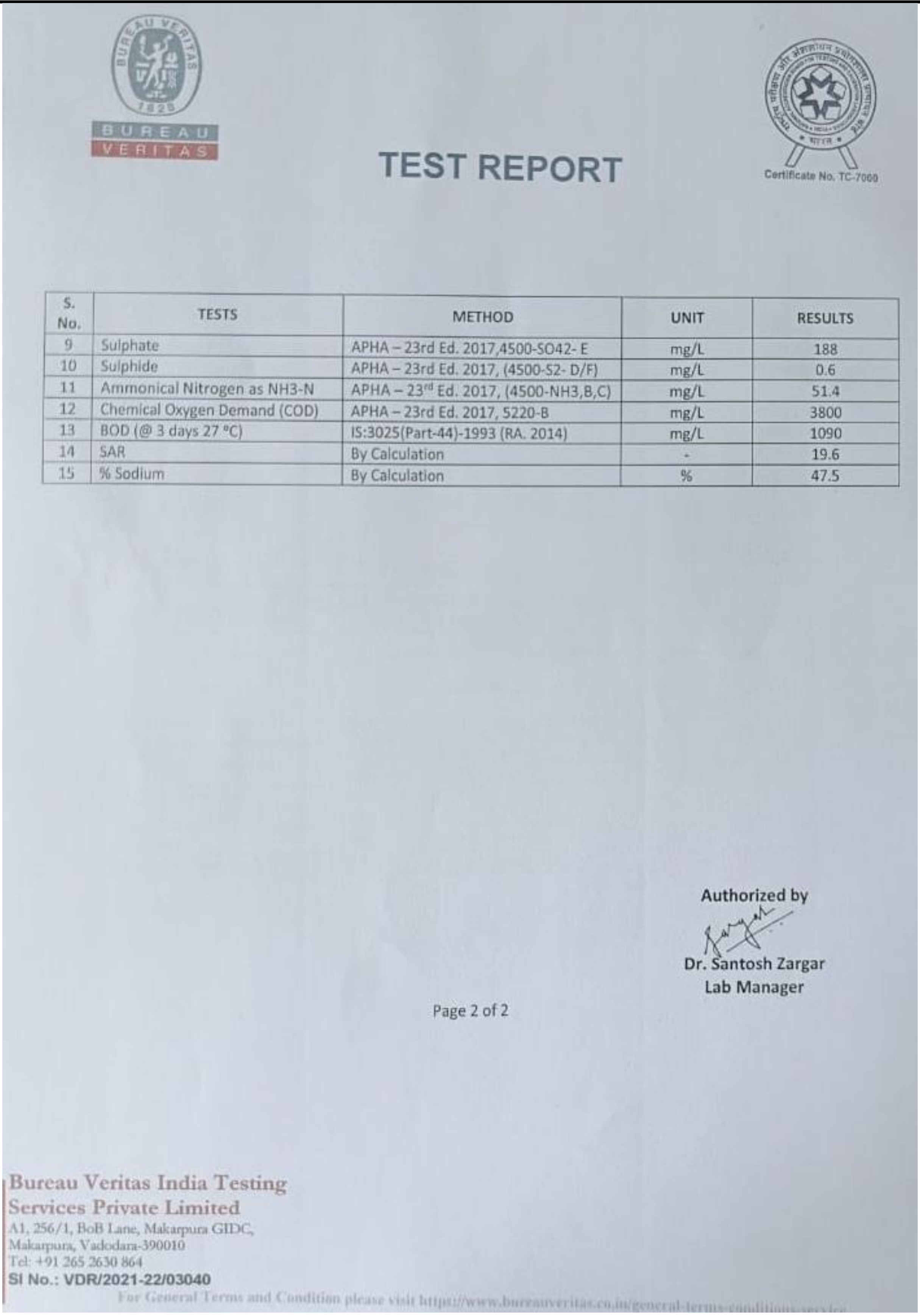

BUREAU VERITAS

TEST REPORT

Certificate No. TC-7000

S. No.	TESTS	METHOD	UNIT	RESULTS
9	Sulphate	APHA – 23rd Ed. 2017,4500-SO42- E	mg/L	188
10	Sulphide	APHA – 23rd Ed. 2017, (4500-S2- D/F)	mg/L	0.6
11	Ammonical Nitrogen as NH3-N	APHA – 23rd Ed. 2017, (4500-NH3,B,C)	mg/L	51.4
12	Chemical Oxygen Demand (COD)	APHA – 23rd Ed. 2017, 5220-B	mg/L	3800
13	BOD (@ 3 days 27 °C)	IS:3025(Part-44)-1993 (RA. 2014)	mg/L	1090
14	SAR	By Calculation	-	19.6
15	% Sodium	By Calculation	%	47.5

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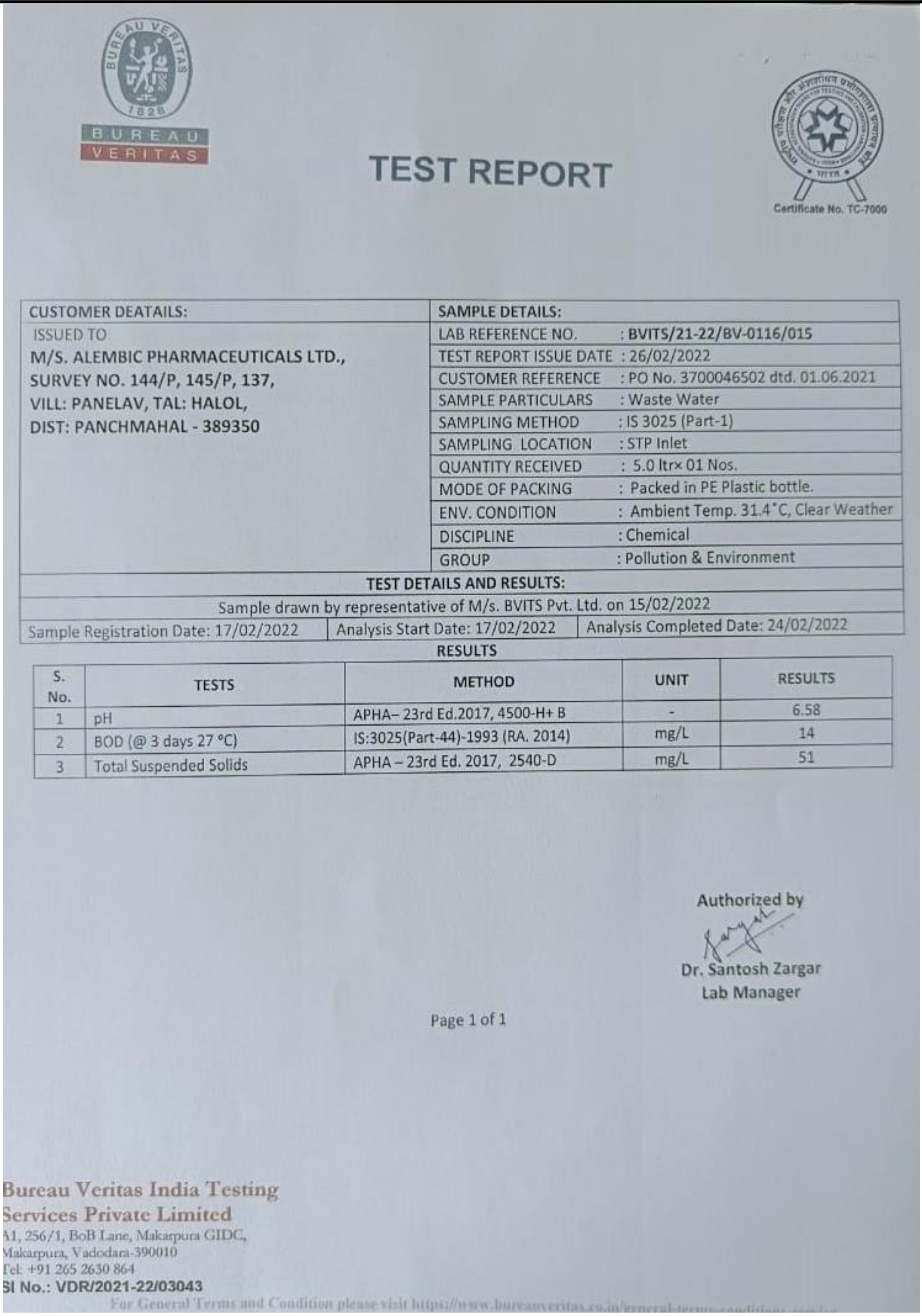

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VILL: PANELAV, TAL: HALOL,
DIST: PANCHMAHAL - 389350

SAMPLE DETAILS:

LAB REFERENCE NO. : **BVITS/21-22/BV-0116/015**
TEST REPORT ISSUE DATE : 26/02/2022
CUSTOMER REFERENCE : PO No. 3700046502 dtd. 01.06.2021
SAMPLE PARTICULARS : Waste Water
SAMPLING METHOD : IS 3025 (Part-1)
SAMPLING LOCATION : STP Inlet
QUANTITY RECEIVED : 5.0 ltr× 01 Nos.
MODE OF PACKING : Packed in PE Plastic bottle.
ENV. CONDITION : Ambient Temp. 31.4°C, Clear Weather
DISCIPLINE : Chemical
GROUP : Pollution & Environment

TEST DETAILS AND RESULTS:

Sample drawn by representative of M/s. BVITS Pvt. Ltd. on 15/02/2022

Sample Registration Date: 17/02/2022 | Analysis Start Date: 17/02/2022 | Analysis Completed Date: 24/02/2022

RESULTS

S. No.	TESTS	METHOD	UNIT	RESULTS
1	pH	APHA– 23rd Ed.2017, 4500-H+ B	-	6.58
2	BOD (@ 3 days 27 °C)	IS:3025(Part-44)-1993 (RA. 2014)	mg/L	14
3	Total Suspended Solids	APHA – 23rd Ed. 2017, 2540-D	mg/L	51

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CHAPTER-6

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