EPRA International Journal of Economic Growth and Environmental Issues- Peer Reviewed Journal
ISSN: 2321-6247
Volume: 9 | Issue: 1 | January 2021 | Journal DOI : 10.36713/epra0713 | SJIF Impact Factor (2020): 8.007

WASTEWATER TREATMENT TECHNOLOGY REVIEW

Soorya Narayan
Research Associate, International Centre for Technological Innovations

ABSTRACT

Clean water is a crucial natural resource on the planet, necessary for our lives. Wastewater, specifically used water, is a valuable resource, especially in many parts of the world, where repeated droughts and lack of water are involved. However, many toxic chemicals are found in wastewater, and cannot be released back into the environment until it is processed. Thus wastewater treatment has a double significance: restoring the availability of water and protecting the earth against toxins. In this paper emerging and innovative techniques of wastewater treatments are mentioned. Also, a comparison is made between the new techniques and existing techniques in the conclusion section.

1.0 INTRODUCTION

1.1 Water Scarcity in India

With a diverse population that is three times the size of the United States but one-third the physical size, India has the second-largest population in the world. Even though improvements have been made over the past decades to both the availability and quality of municipal drinking water systems, rural areas are still facing an acute water crisis. Many water sources are contaminated with both bio and chemical pollutants, and over 21% of the country's diseases are water-related.

The main reason for the water crisis in India is due to the lack of government planning, increased corporate privatization, industrial and human waste, and government corruption. The water scarcity in India is expected to get worsen by the year 2050 as its population will approximately be upstretched to 1.6 billion. These crises may often lead to national political conflict in the future. With this situation, wastewater management is the best option to control water scarcity to an extent. Today we have sophisticated methods to treat wastewater, these are physical, chemical, and biological methods. (Shannyn Snyder, 2016)

An image of people fighting each other for water in India

EPRA International Journal of Economic Growth and Environmental Issues- Peer Reviewed Journal
ISSN: 2321-6247
Volume: 9 | Issue: 1 | January 2021 | Journal DOI : 10.36713/epra0713 | SJIF Impact Factor (2020): 8.007

1.2 Existing Wastewater Treatment Methods

Physico-Chemical Treatment

In this technique, the appropriate method for treatment is decided based on the size of the pollutants. Larger particles are separated through gravity, flotation, or filtration techniques. However, smaller particles are much more difficult to separate. For removing these particles processes such as coagulation, flocculation, and sedimentation are used. These methods are generally used to treat industrial wastewater. It is ideal for the removal of suspended matter like heavy metals, inorganic substances, oil, and grease, as well as dissolved substances. (Ajay Kumar and Gautama Sunil Kumar, 2017)

Biological Treatment

Microorganism breaks down organic pollutants dissolved in the wastewater. These pollutants after breakdown stick together creating a flocculation effect. This allows the organic matter to settle out the solution which is then dewatered and disposed of as solid waste.

Biological wastewater treatment can be classified into three main categories:

1) Aerobic: In this process microorganism require oxygen to breakdown organic matter into carbon dioxide and microbial biomass

2) Anaerobic: In this process microorganism does not require oxygen to breakdown organic matter, the results are the production of methane, carbon dioxide, and excess biomass

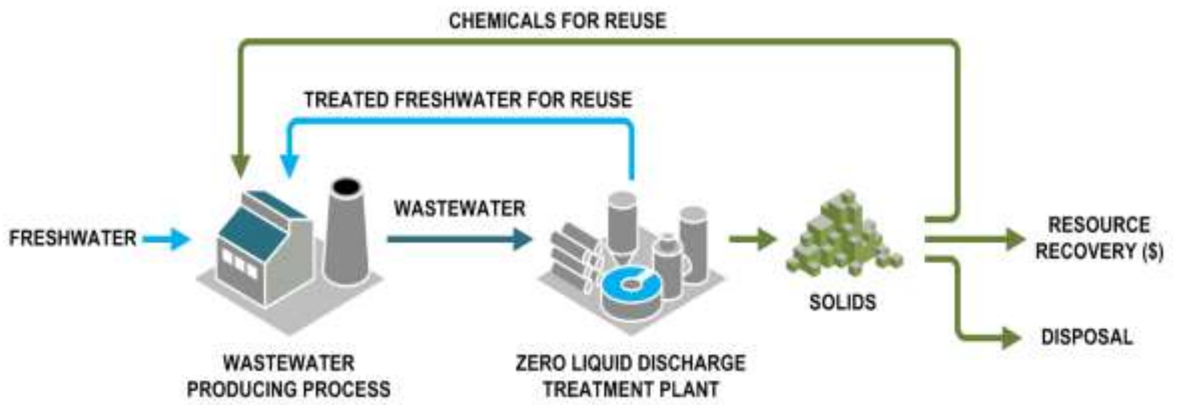
3) Anoxic: Microorganisms use other molecules than oxygen for growth, such as for the removal of sulfate, nitrate, nitrite, selenate, and selenite (Arun Mittal, 2011)

Recycle and Reuse

In this method, wastewater is recycled using a membrane-based system. These systems use ultrafiltration with a bioreactor to treat wastewater. This is a commonly used method in industrial and municipal wastewater management. Treated water is recycled for various purposes, such as irrigation.

Zero liquid discharge (ZLD)

Dissolved salts in the wastewater are removed using this technique, giving distilled water as the end product. Later on, methods like Reverse Osmosis (RO) are used to convert the treated water into drinkable water. ZLD plants are the most demanding target among other treatment plants because the cost and challenges of recovery increase as the wastewater gets more concentrated. (K. Amutha, 2017)



Zero liquid discharge (ZLD) Process

2.0 LITERATURE REVIEW

2.1 Innovative and Emerging Technologies in Waste Water Treatments

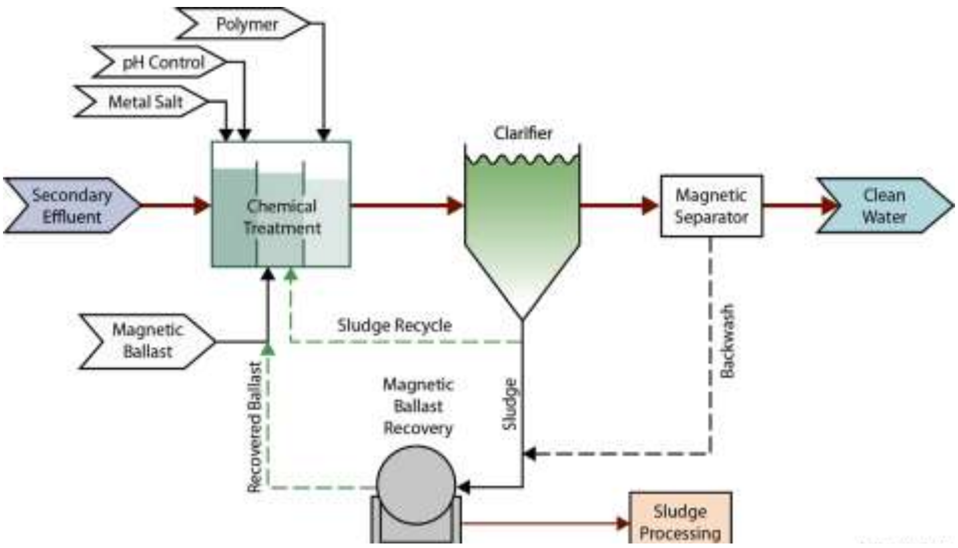
Blue PRO™ Reactive Media Filtration.

Blue PRO™ reactive filtration system is used to remove phosphorus from wastewater. Co-precipitation and adsorption are combined to a reactive filter media in an up-flow sand filter. The Blue PRO™ equipment includes continuous backwash moving-bed filtration technology preceded by chemical addition and a proprietary pre-reactor zone. Iron coagulant on the filter media is used to create reactive hydrous ferric oxide-coated sand media. Finally, phosphorus removal is achieved by adsorption and filtration. Due to a continuous regeneration process, there is no requirement for media change. After adsorption, the iron and phosphorus are abraded from the sand grains. The iron and phosphorus pass out in a waste stream while the sand is retained in the system. Because of the relatively small area of each filter unit, the Blue PRO™ system is most suitable for small to medium plants (less than 10 millions of gallons per day (MGD)). (Newcombe, R.L., et al, 2008)

Blue Water Blue Pro™ Phosphorus Removal System

Magnetite Ballasted Sedimentation

The process uses conventional chemical coagulation and flocculation along with the addition of finely ground magnetite as a ballasting agent. High-rate sedimentation is achieved due to the weight and ability to settle chemical flocs which are increased by dense magnetite. Approximately 85 percent of the settled sludge is recycled to provide nucleation sites for floc development. To recover the magnetite, Excess sludge is passed through a shear mill followed by a magnetic recovery drum before further processing. The recovered magnetite is returned to the process.



CoMag™ Process Flow Diagram

Multi-stage Filtration

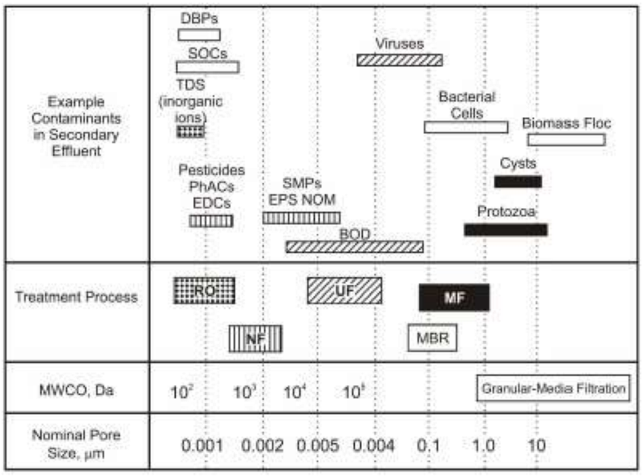
Usually, biomass solids are 8 to 10% nitrogen and 1 to 2% phosphorus by mass (Grady et al, In 2011). The phosphorus content of the biomass can be increased to 6 to 8 percent if increased biological phosphorus removal is carried out (Grady et al, 2011). The metal phosphate precipitate (some of it colloidal) would have a significant total phosphorus

EPRA International Journal of Economic Growth and Environmental Issues- Peer Reviewed Journal
ISSN: 2321-6247
Volume: 9 | Issue: 1 | January 2021 | Journal DOI : 10.36713/epra0713 | SJIF Impact Factor (2020): 8.007

portion if chemical phosphorus removal is achieved. Therefore, while 10, 20, or 30 mg/L total suspended solids could be permitted by the discharge permit, substantially lower total suspended solids could be required to meet the nutrient limits. Implementing filtration in series with a first-stage filter or first-stage clarifier and chemical addition between phases makes it possible to target the smaller colloidal particles escaping from the first step of solid separation. A system named Trident HS uses a tube clarifier first stage followed by an adsorption clarifier and mixed media or upflow moving-bed filter final stage. The Trident HS has been shown to achieve effluent total phosphorus of 0.02 mg/L (Liu, 2010). *Another system Blue PRO™ is a continuous-backwash, upflow-sand filter with adsorption media and can be used in series to achieve very low effluent solids levels. With two-stage, Blue PRO™ achieves total phosphorus between 0.009 and 0.018 mg/L (Leaf, 2007).*

Nanofiltration (NF) and Reverse Osmosis (RO)

NF and RO are processes of the membrane that could be used to remove compounds of recalcitrant that among other forms, organic biomass, phosphorus, and to minimize gross dissolved solids and to reduce phosphorus, delete viruses. RO acts through the membrane by high-pressure diffusion of solutes; both diffusion and sieving operations are used by NF. NF eliminates many of the same organic compounds that RO would target, but allows more to remain of the inorganic substance. For the removal of priority organic contaminants, recalcitrant organics, bacteria, and viruses, both methods are used. Recently, NF and RO have been regarded as a technology for achieving low total nitrogen levels. Nevertheless, recent research (Merlo et al. 2012) has found that even RO does not reliably reach total levels of nitrogen below 1.0 mg/L. Both are useful for the removal of toxins, hormones, pharmaceuticals, and other micro-constituents.



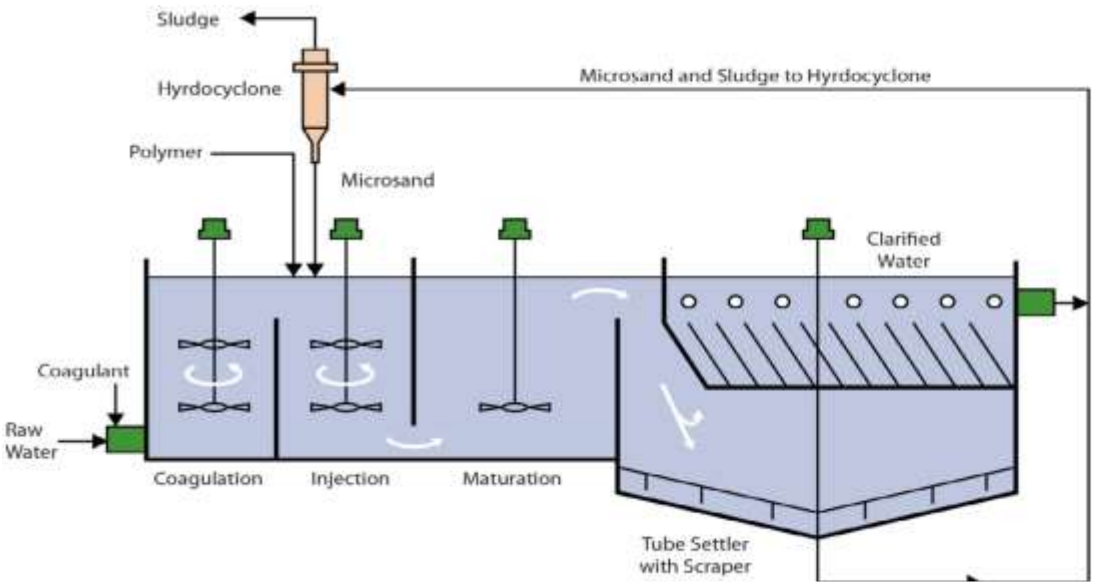
NF and RO Treatment Process Characteristics

Microwave Ultraviolet (UV) Disinfection

UV disinfection absorbs electromagnetic energy into wastewater from a mercury arc lamp. Electromagnetic radiation penetrates bacterial cells in the range of 100 to 400 nm (UV range), and functions as a bactericide. Typical mercury vapor UV lamps have electrodes that, by striking an electric arc, promote the generation of UV radiation. These electrodes are fragile and the primary cause of failure in UV disinfection systems is their degradation. By using microwave-powered, electrodeless, mercury UV lamps, microwave UV disinfection technology removes the need for electrodes. Microwave energy is produced by magnetrons in this technology and guided into quartz lamp sleeves containing argon gas via waveguides. As is the case with other mercury UV lamps, the guided microwave energy excites the argon atoms, which in turn excites the mercury atoms to create radiation as they return to lower energy states from excited states. Electrodeless lamps work at low pressure, reducing safety risks, and increasing the lifetime of lamps. Due to the absence of electrodes, microwave UV lamps allow greater versatility for variations in parameters such as lamp diameter, operating pressures, and filling materials. This allows for greater radiation optimization at particular regions of the wavelength. When the applied microwave power is raised, the intensity of the radiation rises. In modular, open-channel, and closed-vessel designs, microwave UV disinfection systems are available.

Actiflo® Process

The Actiflo® process is a high-rate process of chemical and physical clarification that involves the formation of suspended solids followed by lamellar settling onto a ballast particle (macros and). The method for the treatment of wet weather flows is considered a proven process but is also applied to primary and tertiary effluents. To destabilize suspended solids, the process begins with the addition of a coagulant. To allow the coagulant to take effect, the flow enters the coagulation tank for flash mixing, then overflows into the injection tank where micro sand is applied. The micro sand serves as a "seed" for floc formation, providing a large surface area for suspended solids to bond to and is the key to Actiflo®. It allows solids to settle out more quickly, thereby requiring a smaller footprint than conventional clarification. Polymers may either be applied to the injection tank, or the maturation tank at the next level. In the maturation tank, blending is slower, allowing the polymer to help bond the micro sand to the suspended solids that are destabilized. Eventually, with the aid of plate settlers, the settling tank efficiently eliminates the floc, allowing the tank size to be further reduced. Via overflowing weirs above the plate colonists, clarified water exits the process. With a traditional scraper system, the sludge mixture is collected at the bottom of the settling tank and pumped to a hydrocyclone situated above the injection tank. To distinguish higher density sand from lower density sludge, the hydrocyclone transforms the pumping energy in to centrifugal forces. The sludge is discharged from the top of the hydrocyclone while the sand for further use is recycled back into the Actiflo® process. For particles larger than 3 to 6 mm to not clog the hydro cyclone, screening is needed upstream of Actiflo®.



Actiflo® system diagram

For a full-scale Actiflo® system, multiple startup modes can be used. If a wet weather event is anticipated to occur within 7 days of the previous wet weather event, the units should be shut down but not placed on standby. Wastewater will stay in the tanks and at the time of the next rainy weather occurrence, a wet start-up would ensue. The intermittent flush standby mode should be used in the summer months when freezing is not necessary; and when freezing is possible, the continuous flush standby mode should be used. The effects of these standby modes should be a dry start-up in a successful wet operation.

Blue CAT™

The Blue CAT™ process is a combination of the Blue PRO™ adsorption filter process with an Advanced Oxidation Process (typically ferric with ozone) for tertiary removal of slowly biodegradable or nonbiodegradable micro-constituents that have passed through upstream treatment processes. The oxidation process also provides highly effective disinfection without chlorine by-products. The Blue PRO process provides adsorption of contaminants such as phosphorus in an up-flow sand filter with hydrous ferric oxide-coated media and a proprietary pre-reactor. Unpublished pilot trials of the Blue

CAT™ device have been performed at 10 GPM, according to the manufacturer. The results of these studies include an overall reduction of organic compounds from 4 to 1.5 mg/L, a high percentage reduction of estrogenic compounds and pharmaceutical surrogates tracked in the studies, disinfection of color removal to less than 2 CFU/100 mL, reduction of turbidity to 0.1 to 0.3 NTU, and total phosphorus removal by 95 percent. For additional contaminant removals and other secondary process changes, the residual Blue CAT™ waste stream can be recycled to the head of the facility. Two passes through Blue CAT™ can be combined in a sequence for improved contaminant-removal speeds, organic destruction, or disinfection.

Salsnes Filter

A removable fine mesh screen attached to an inclined moving wire cloth belt is used by the Salsnes filter to sieve solids from wastewater, filtering the water and dewatering the solids at the same time. For self-cleaning with compressed air, the belt rotates into an "air knife" to eject the solids into a sludge compartment. The Salsnes filter has proven to minimize powerful BOD and TSS by 40 percent and 65 percent, respectively, in one installation (McElroy, 2012). Performance depends on the distribution of influential solids and the size of the mesh chosen for the filter screen, which usually ranges from 100 to 500 microns (Sutton et al. 2008), although the Daphne Utilities WWTF installed a 1000 micron mesh screen. The hydraulic loading rate of the screen surface is an important factor affecting the performance of the screen. The pressure transmitter varies the speed of the belt to keep the liquid level close to the overflow elevation to ensure effective flow distribution. The belt is washed back to remove fat, oils, and grease. Filters are available in sizes with capacities of up to 2200 GPM for stand-alone units and 3500 GPM for units installed in a concrete channel. Multiple units can be installed in parallel to achieve the desired capacity. A dewatering screw press is available for transporting the solids and can produce up to 27 percent of the solids when used (Sutton 2008).

DensaDeg® Process

DensaDeg® is a high-quality chemical and physical clarification process that combines sludge ballast clarification and lamellar filtration, both of which have been established. The DensaDeg® process begins by adding a coagulant to destabilize suspended solids. The flow enters the flash mixing rapid-mix tank to allow the coagulant to take effect and then overflows into the reactor tank, where sludge and polymer are added. The draft tube and mixer in the reactor make it possible to mix the wastewater thoroughly with the recirculated sludge and the added chemicals. The sludge acts as a "seed" for the formation of floc providing a large surface area for suspended solids to bond to and is the key to DensaDeg®, allowing solids to settle more quickly, requiring a smaller footprint than conventional clarification.

Wastewater flows through a weir from the reactor tank through the transition zone before entering the clarifier. Clarifying effectively removes the flow with the help of seal tubes, allowing the size of the tank to be further reduced. Clarified water exits the process by overflowing the seal tubes. Sludge is collected at the bottom of the clarifier with a conventional scraper system and recycled back to the reactor tank. Periodically, a separate sludge pump energizes and discards a small portion of the sludge from the system. Scum is removed from the process at the top of the transition zone by a cylindrical collector that rotates periodically.

Several startup modes can be used for DensaDeg® full-scale applications. If a wet weather event is expected to occur within 6 hours of the previous wet weather event, the units should be shut down but not drained. Six hours later, the units may be drained, except for a depth of three feet in the clarifier. Both scenarios, which would include keeping the sludge collector running while the system is idle, would maintain a sludge inventory and a wet startup would follow at the time of the next wet weather event. After 12 hours, the tanks should be completely drained to prepare for a dry start. (Sigmund, Thomas, et al, 2006)

Details of the vendors providing each technologies.

Name	Capital Cost	Operational and Management Cost	Vendors name.
BluePRO™ ReactiveMedia Filtration	$178,300 (1 MSD)	$29,380 (1 MSD)	**Blue Water Technologies, Inc.** 10450 North Airport Dr. Hayden, ID 83835 Telephone: 888-710-2583 Fax: 208-209-0396 Website: http://www.blueH2O.net
Magnetite Ballasted Sedimentation	Not disclosed by the vendor.	Not disclosed by the vendor.	**CoMag**TM **– Siemens Industry, Inc. Water Technologies** Telephone: 866-926-8420 or 724-772-1402 Web: www.water.siemens.com
Multi-stage Filtration	Equipment cost varies with technology and performance requirements	Operating costs include pumping.	**Parkson – DynaSand** 1401 West Cypress Creek Rd Fort Lauderdale, FL 33309-1969 Telephone: 1-888-PARKSON Fax: 954-974-6182 Email: technology@parkson.com Web site: www.parkson.com
Nanofiltration (NF) and Reverse Osmosis (RO)	Not available	Not available	**Nitto Denko – Hydranautics** 401 Jones Rd Oceanside, CA 92058 Telephone: 760-901-2500 Fax: 760-901-2578 Email: info@hydranautics.com
Microwave Ultraviolet (UV) Disinfection	Not disclosed by the vendor.	Not disclosed by the vendor.	**Severn Trent Services – Microdynamics** 3000 Advance Ln Colmar, PA 18915 Telephone: 215-997-4000 Fax: 215-997-4062 Email: info@severntrentservices.com Website: www.severntrentservices.com
Actiflo® Process	Not disclosed by the vendor.	Not disclosed by the vendor.	**Kruger USA** 401 Harrison Oaks Blvd., Suite 100 Cary, NC 27513 Telephone: 919-677-8310 Fax: 919-677-0082 Email: krugerincmarketing@veoliawater.com Web site: http://www.krugerusa.com
Blue CAT™	Unavailable because no full-scale installation is in place	Unavailable because no full-scale installation is in place	**Blue Water Technologies, Inc.** 10450 North Airport Dr. Hayden, ID 83835 Telephone: 888-710-2583 Web site: www.blueh2o.net
Salsnes Filter	Capital cost is estimated at 30-50% less than for primary clarifiers	Not available	**Salsnes Filter AS, Verftsgt. 11** 7800 Namsos, Norway Telephone: +47 74 27 48 60 Web site: www.salsnes.com

EPRA International Journal of Economic Growth and Environmental Issues- Peer Reviewed Journal
ISSN: 2321-6247
Volume: 9 | Issue: 1 | January 2021 | Journal DOI : 10.36713/epra0713 | SJIF Impact Factor (2020): 8.007

DensaDeg® Process	Cost estimates are dependent upon local requirements and specific applications	Cost savings are linked to the relative ease of installation, operational flexibility, And low-energy consumption.	**Infilco Degremont Inc.** P.O. Box 71390 Richmond, VA 23255-1930 Telephone: 804-756-7600 Web site: http://www.infilcodegremont.com

4.0 CONCLUSION AND OBSERVATIONS

When compared with existing technologies The Blue PRO™ process appears to be similar to other advanced filtration processes preceded by iron addition but includes the reactive adsorption media and proprietary pre-reactor zone and regeneration process. Magnetite Ballasted Sedimentation uses typical chemical coagulation and flocculation along with the addition of thin ground magnetites as a ballast. Magnetite is denser than suspended solids and sand, and it generates heavy, dense floc that settles rapidly. This allows ordinary clarifiers to be loaded at higher than typical rates while maintaining high-quality effluent. When comparing with existing technologies, multi-stage filtration provides effluent solids quality better than single-stage sedimentation or filtration and approaching that provided by microfiltration membrane systems. Microfiltration and ultrafiltration membranes are used for membrane bioreactors where the membrane is in direct contact with the high solids mixed liquor. These membranes provide excellent removal of particulate and colloidal material but cannot remove dissolved constituents as an NF and RO. NF and RO remove total suspended solids, total dissolved solids, and other pathogens better than the ultrafiltration process. UV disinfection absorbs electromagnetic energy into wastewater from a mercury arc lamp. Electromagnetic radiation penetrates bacterial cells in the range of 100 to 400 nm (UV range), and functions as a bactericide. The Actiflo® process is a high-rate process of chemical and physical clarification that involves the formation of suspended solids followed by lamellar settling onto a ballast particle (macrosand). This process is very similar to conventional coagulation, flocculation, and sedimentation water treatment technology. The primary technical advance made in the Actiflo® process is the addition of microsand as a "seed and ballast for the formation of high-density flocs . When compared with existing technologies, Blue CAT™ requires less power than other advanced oxidation processes because of the system's catalytic configuration to maximize oxidative capability. No polymer is used in the process. A removable fine mesh screen attached to an inclined moving wire cloth belt is used by the Salsnes filter to sieve solids from wastewater to filter the water. The Salsnes filter's BOD and solids removal performance is better than traditional primary clarifiers. Solids removed with the Salnes filter and screw press are significantly drier than for a primary clarifier, typically 27% and 4% respectively. DensaDeg® is a high-quality chemical and physical clarification process that combines sludge ballast clarification and lamellar filtration. Fundamentally, this process is very similar to conventional coagulation, flocculation, and sedimentation treatment technology.

REFERENCES

1. *Shannyn Snyder, 2016, The water project https://thewaterproject.org/water-crisis/water-in-crisis-india*
2. *Ajay Kumar and Gautama Sunil Kumar, 2017, Preliminary study of Physico-chemical treatment options for hospital wastewater, Journal of Environmental Management Volume 83, Issue 3, May 2007, Pages 298-306.*
3. *Arun Mittal, 2011, Biological Wastewater Treatment,*
4. *K. Amutha, 2017, Sustainable chemical management, and zero discharges.*
5. *Newcombe, R.L., et al. "Phosphorus Removal from Municipal Wastewater by Hydrous Ferric Oxide Reactive Filtration and Coupled Chemically Enhanced Secondary Treatment: Part I – Performance," Water Environment Research, Vol. 80, No. 3, pp. 238-247, 2008.*
6. *Blue PRO™, "Hydrous Ferric Oxide (HFO) Coated Sand. Adsorptive Media Technical Summary," 2006.*
7. *Ellis, E.P, and A.H. Cathcart, "Selection, Installation, Startup, and Testing of the World's First Full-Scale CoMag Phosphorus Reduction Tertiary Treatment System," Proceedings WEFTEC 2008.*
8. *Booker, N.A., et al., "Novel High Rate Processes for Sewer Overflow Treatment," Water Science and Technology," Vol. 34, No. 3-4, pp. 103-109, 1996.*
9. *Grady, CPL Jr., et al., Biological Wastewater Treatment, IWA Publishing, and CRC Press, Taylor and Francis Group, Boca Raton FL, 2011.*
10. *Benisch, M., et al., "Can Tertiary Phosphorus Removal Reliably Produce 10 µg/L?," WEF Nutrient Removal Conference Proceedings, 2007.*
11. *Merlo, R., et al., "Analysis of Organic Nitrogen Removal in Municipal Wastewater by Reverse*

Osmosis," Water Environment Research, Vol. 84, No. 7, pp. 588–595, 2012

12. *Reardon, R.D., et al., "Membrane Treatment of Secondary Effluent for Subsequent Use," Water Environment Research Foundation Report No. 01-CTS-6, 2005*
13. *Meera, V., et al., "Microwave UV Comes to Texas," WEFTEC Proceedings, 2010*
14. *Gutierrez, R.L., et al., "Microwave UV – A New Wave of Tertiary Disinfection," WEFTEC Proceedings, 2006*
15. *Keller, John, et al., "Actiflo®: A Year's Worth of Operating Experience from the Largest SSO System in the U.S.," Water Environment Federation's Annual Technical Exhibition and Conference (WEFTEC), 2005.*
16. *Sigmund, Thomas, et al., "Operating Chemically Enhanced Clarification for Optimum Disinfection Performance," WEFTEC, 2006.*
17. *Blue PRO™, "Hydrous Ferric Oxide (HFO) Coated Sand, Adsorptive Media Technical Summary," 2006.*
18. *Newcombe, R.L., et al., "Arsenic Removal from Drinking Water by Moving Bed Active Filtration," Journal of Environmental Engineering, Vol. 132, No.1, pp. 5–12, 2006*
19. *McElroy, R. et al., "Restoring Lost WWTP Capacity through Innovative Technologies", WEFTEC 2012*
20. *Sutton, P. et al. "Rotating Belt Screens: An Attractive Alternative for Primary Treatment of Municipal Wastewater" WEFTEC 2008.*
21. *Sigmund, Thomas, et al., "Operating Chemically enhanced Clarification for Optimum Disinfection Performance," WEFTEC, 2006*