Research Article
Pharmaceutical Effluent Treatment Using Multi-effect Evaporator Process

R. Periyannan,1 J. Arun Prasad,1 S. Arulmozhi,1 M. Balaji,1 A. Gopalan,1 N. R. Banu Priya,2 P. Shanthi,3 G. Shanmugavadivel,4 B. Anukarthika,1 and Nyagong Santino David Ladu5

1Department of Civil Engineering, Erode Sengunthar Engineering College, Perundurai, Erode 638057, India
2Department of Civil Engineering, Dhanalakshmi Srinivasan Institute of Technology, Samayapuram 621112, India
3Department of Civil Engineering, Builders Engineering College, Kangeyam 638108, India
4Department of Electronics and Communication Engineering, M.Kumarasamy College of Engineering, Karur 639113, India
5Department of Mathematics and Physics, Rumbek University of Science and Technology, Rumbek, South Sudan

Correspondence should be addressed to S. Arulmozhi; arul3345@gmail.com and Nyagong Santino David Ladu; nyangongsantino19@gmail.com

Received 10 June 2022; Revised 11 July 2022; Accepted 13 July 2022; Published 21 August 2022

Academic Editor: Samson Jerold Samuel Chelladurai

Copyright © 2022 R. Periyannan et al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

The disposal practices of pharmaceutical-generated pollutants have become a serious threat to mankind’s health, safety, and environmental concerns. Pharmaceutically polluted effluents have been demonstrated as endocrine disruptors which mimic growth hormones when consumed at nG/L to mG/L concentrations. The production stages utilize both organic and inorganic compounds, which contribute to chemical oxygen demand (COD) and total dissolved solids (TDS) heavily. Conventional technologies have failed to accomplish zero liquid minimization. To achieve zero minimization, it is necessary to develop modernization techniques in effluent treatment streams. A novel technique to recover solids and organic matter removals as well as zero-liquid discharge (ZLD) flash mixer, stripping, and multi-effect evaporator (MEE) processes is employed. Flash mixing is a pre-treatment stage, and stripping enables solvent reclamation. The multi-effect evaporators involve heat transfer equipment mainly used for volume reduction and cutting down on waste handling costs. The multi-effect evaporator not only is able to eliminate pharmaceutical xenobiotics but also requires pre-treatments such as flash mixture and stripping column sections. Thus, this research emphasizes efficiently removing high total dissolved solids (HTDS) and high chemical oxygen demand (HCOD) from pharmaceutical effluent. The removal efficiency was found to be 85% for TDS and TSS, 93% for BOD, and 81% for COD, which is more than the conventional mode of treatment.

1. Introduction
In an arrangement to frame a salubrious and sound climate, water quality ought to be checked to such an extent that it exists in each of the separate principles. Among the various natural groups that India is confronting for 100 years, freshwater shortages are extremely high [1]. Water is a basic product for the life of every single living organic entity and an inestimable source on the Earth, yet this esteemed asset is progressively being compromised as human populations develop and injunctively approve more water for gardening purposes [2]. Wastewater is a fluid waste, released by business properties, house gardening, horticulture, and industry, which frequently contains a few foreign substances that result from the blending of wastewater from various sources [3]. In the event that appropriate plans for assortment, treatment, and removal of all the waste delivered by the city or town are not made, they will continue gathering and creating conditions that compromise the security of the designs, with the end goal that structures and streets will be harmed because of the collection of wastewater in the establishments. Furthermore, sickness-causing microbes will
rise in the stale water, and the soundness of the public will be in danger. Wastewater is any water that has been antagonistically impacted in quality by anthropogenic impact. It contains fluid waste released by house gardening, business properties, industry, and additionally, natural culture and can envelop a wide scope of expected pollutants and focus [4].

Most earthly usage alludes to municipal waste that contains an expansive range of toxins, coming about because of the blending of wastewater from various sources. According to estimates, anticipated wastewater from urban areas might reach 120,000 MLD by 2051, with rural India generating at least 50,000 MLD due to water supply designs for communal supplies in rural areas [5]. Most wastewater management plans, on the contrary, ignore the rising rate of wastewater generation. According to the Central Pollution Control Board (CPCB), India has 269 sewage treatment facilities (STPs); however, only 231 of them are operational. As a result, existing treatment capacity only covers 21% of current sewage generation. Untreated sewage is the primary source of pollution in rivers and lakes. The vast majority of STPs built under central funding schemes such as the National River Action Plan’s Ganga Action Plan and Yamuna Action Plan are not fully operational [6].

Heavy metals have been removed from wastewater using traditional procedures such as coagulation, electro-floatation, electrocoagulation, and electrodeposition [7]. However, they have a number of drawbacks, such as inadequate metal removal, sludge generation, and high energy requirements. Due to these drawbacks, a cost-effective, efficient, and environmentally friendly alternative approach known as “biosorption” can be used to remove heavy metals from wastewater. Microorganisms, plant-derived materials, agriculture or industrial waste, and biopolymers are all examples of biosorbents [8].

“Ordinary wastewater treatment processes do not wipe out drugs and chemicals, bringing about the arrival of low levels of these mixtures into the climate,” said Pedersen. The further developed processes do a very great job at eliminating compounds. Drug wastewater contains around 99.99% of water and 0.01% of different materials as disintegrated solids. For the most part, drug wastewater contains drug drugs (API and excipients) from creation, synthetic compounds and solvents from quality control, and oil and oil from utility and upkeep. In [9, 10], research was conducted on the phosphate minimizers through the screening process and clients to eliminate the phosphate from Pharma squander water utilizing a clump scale process. The three most effective phosphate minimizers were secluded and screened from the eutrophic lake water and wood soil tests. Among the singular strains, Pseudomonas sp was seen to be 68% evacuated at impartial pH. Contrasting with individual types of every microscopic organism, the blend of
Pseudomonas, bacillus, and enterobacter was seen to have a limit of 92.5% at a pH of 7 to 5. Along these lines, the microorganisms might use the pollutant’s supplements as energy sources or they might be used by co-digestion. Subsequently, this microorganism’s segregation may be utilized in the remediation of phosphate-polluted environments.

The phytoremediation strategy for the treatment of various sorts of wastewater has been utilized by a few scientists [11]. These procedures are considered to be financially savvy compared with different techniques. Different pollutants such as complete suspended solids, disintegrated solids, electrical conductivity, hardness, biochemical oxygen interest, synthetic oxygen interest, broken down oxygen, nitrogen, phosphorous, weighty metals, and different impurities have been decreased in various foreign substances which have been introduced into limited quantities utilizing the stripping section technique and conventional treatment strategy. The disposal of medical waste, particularly pharmaceutical waste, leads to water pollution. A number of pharmaceutical industry effluent disposals and their components create pollution in lakes and rivers [12]. The environment and health are directly or indirectly affected by pharmaceutical effluents, especially in the vicinity of pharma industrial zones [13]. The highly toxic refractory compounds released from pharmaceutical effluent are limited to their biodegradability, posing a potential threat to the natural ecosystem. Antibiotics produced by the pharmaceutical industry have a significant impact on the environment as they can disrupt effluent treatment processes and adversely affect the environment [14]. The hybrid process of peroxide and adsorption can be applied for the treatment of real industrial pharmaceutical wastewater containing complex organic compounds [15]. Numerous techniques have been developed to deal with such severely polluted effluents, including physicochemical [16] and biological strategies [17]. The development of water conservation strategies and cutting-edge wastewater treatment for water recycling is required due to the limited availability of good-grade water supplies. To eliminate colour from industrial effluents, improved treatment technologies must be developed [18]. Combined physico-chemical and biological treatment is an efficient method for the treatment of persistent compounds [19]. Electrocoagulation using iron sacrificial electrodes for the removal of Cd, Cu, and Ni from simulated wastewater reveals 99.97% removal of Ni at all initial concentrations [20].

Figure 4: Block diagram of novel treatment process.
2. Methodology

The flowchart showing the methodology is presented in Figure 1. The raw effluent was collected from a leading pharmaceutical company as per standard procedure and was brought to the laboratory where the samples were stored in a deep freezer at 4°C before analysing the samples. The methodology employed to analyze pH, TSS, TDS, BOD, and COD is as per the guidelines prescribed by the American Public Health Association [21].

3. Experimental Processes

3.1. Conventional Treatment. The presence of solids, organic materials, and other nutrients is removed from wastewater using a combination of physical, chemical, and biological processes and activities. It refers to a common wastewater treatment process that can lessen the noxious qualities of water-carrying waste, making it less dangerous and unattractive to humans. Figure 2 depicts an overview of conventional treatment stages and how they are linked to each other. The conventional treatment process poses problems during its operation, such as the presence of a high organic load in the clarifier, which produces the bad odour and black colour effluent. In an aeration tank, the COD of the effluent will not reduce more due to less microbial growth.

3.2. Novel Treatment Process. The methodology followed in the novel treatment is presented in Figure 3 and the schematic representation of the block diagram showing the novel treatment is presented in Figure 4. In the novel treatment mode, multiple effect evaporators were used, in which the effluent could not be introduced directly due to its high TDS, resulting in the formation of fouling, odour, and emissions in the evaporators. Hence, the TDS and COD must be reduced before introducing the effluent into the evaporators. The flash mixture tank and stripping column are used in order to reduce spent solvents and TDS in the effluents.

4. Results

4.1. Characteristics of Raw Pharma Effluent. The wastewater of every pharma interaction comprises contamination of different pH values. Likewise, an enormous variety exists in each boundary: TDS, TSS, BOD, COD, chloride, pH, and so forth. The characteristics of effluent analyzed for various pharmaceutical plants and their combined parameters are presented in Table 1 and Figure 5.

4.2. Comparison of Conventional and Multi-Effect Evaporator Method. The characteristics of effluent analyzed for pharmaceutical plants using conventional methods and multi-effect evaporators are presented in Table 2. The

---

**Table 1: Raw effluent characteristics from pharma industry.**

| S. no. | Parameters | Plant-1 effluent sample | Plant-2 effluent sample | Plant-3 effluent sample | Plant-4 effluent sample | Combined effluent |
|-------|------------|-------------------------|-------------------------|-------------------------|-------------------------|------------------|
| 1.    | pH         | 8                       | 7.5                     | 6.8                     | 6.8                     | 7.5              |
| 2.    | TSS, mg/l  | 2000                    | 1670                    | 2100                    | 1500                    | 2800             |
| 3.    | TDS, mg/l  | 14895                   | 13750                   | 14800                   | 12500                   | 15300            |
| 4.    | BOD, mg/l  | 9720                    | 10200                   | 6720                     | 7500                     | 8500             |
| 5.    | COD, mg/l  | 27000                   | 29230                   | 24480                   | 25200                   | 26500            |
| 6.    | TKN, mg/l  | 950                     | 785                     | 620                     | 550                     | 800              |

**Figure 5: Characteristics of raw pharmaceutical effluent.**
The authors declare that they have no conflicts of interest.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Data Availability

The data used to support the findings of this study are included within the article.

References

[1] S. Vigneswaran, H. H. Ngo, D. S. Chaudhary, and Y. T. Hung, *Physicochemical treatment processes for water reuse. Physicochemical treatment processes*, vol. 3, Humana Press, New Jersey, NJ, USA, 2004.

[2] S. Alhuja, M. C. Larsen, J. L. Eimers, C. L. Patterson, S. Sengupta, and J. J. Schnoor, *Comprehensive Water Quality and Purification*, vol. 1, pp. 44–45, Elsevier, Netherlands, Europe, 2014.

[3] G. Crini and E. Lichtfouse, “Advantages and disadvantages of techniques used for wastewater treatment,” *Environmental Chemistry Letters*, vol. 1, pp. 145–155, Springer-Verlag, Germany, 2019.

[4] L. A. Nageswara Rao, “Nanotechnological methodology for treatment of WW,” *International Journal of ChemTech Research*, vol. 6, no. No.4, pp. 2529–2533, 2014.

[5] M. A. Oturan and J. J. Aaron, “Advanced oxidation processes in water/wastewater treatment: principles and applications - a review,” *Critical Reviews in Environmental Science and Technology*, vol. 44, no. 23, pp. 2577–2641, 2014.

[6] A. Sonune and R. Ghate, "Developments in wastewater treatment methods," *Desalination*, vol. 167, pp. 55–63, 2004.

[7] S. Petrov and V. Nenov, "Removal and recovery of copper from wastewater by a complexation ultrafiltration process," *Desalination*, vol. 162, pp. 201–209, 2004.

[8] G. Gautami and S. Khanam, "Selection of optimum configuration for multiple effect evaporator system," *Desalination*, vol. 288, pp. 16–23, 2012.

[9] I. Oller, S. Malato, and J. Sánchez-Pérez, “Combination of Advanced Oxidation Processes and biological treatments for wastewater decontamination - a review,” *Science of the Total Environment*, vol. 409, no. 20, pp. 4141–4166, 2011.

[10] K. Usha, M. Muthukumar, and P. Lakshmanaperumalsamy, "Biological removal of phosphate from synthetic wastewater using bacterial consortium," *Iranian Journal of Biotechnology*, vol. 9, no. No. 1, pp. 37–49, 2011.

[11] P. Gupta, S. Roy, and A. B Mahindrakar, "Treatment of water using water hyacinth, water lettuce and vetiver grass - a review," *Resources and Environment*, vol. 2, no. 5, pp. 202–215, 2012.

[12] Greg Cima, "The dangers of improper drug disposal," *Journal of the American Veterinary Medical Association*, July 25, 2018.

[13] C. B. Patnedei and K. Prasadu, "Impact of pharmaceutical wastes on human life and environment," *Rasayan Journal of Chemistry*, vol. 8, no. 1, pp. 67–70, 2015.

[14] M. Kumar Purkait, P. Mondal, and C.-T. Chang, *Treatment of Pharmaceutical Industry Effluents, Treatment of Industrial Effluents*, p. 33, Imprint CRC Press, Florida, FL, USA, 2019.
[15] S. Patel, S. Mondal, S. K. Majumder, P. Das, and P. Ghosh, “Treatment of a pharmaceutical industrial effluent by a hybrid process of advanced oxidation and adsorption,” ACS Omega, vol. 5, no. 50, pp. 32305–32317, 2020.
[16] O. Sivriolu and T. Yonar, “Determination of the acute toxicities of physico-chemical pretreatment and advanced oxidation processes applied to dairy effluents on activated sludge,” Journal of Dairy Science, vol. 98, pp. 2337–2344, 2015.
[17] H. Zhang, M. Ihara, S. Hanamoto et al., “Quantification of pharmaceutical related biological activity in effluents from wastewater treatment plants in UK and Japan,” Environmental Science & Technology, vol. 52, no. 20, pp. 11848–11856, 2018.
[18] Y. Anjaneyulu, N. Sreedhara Chary, and D. Samuel Suman Raj, “Decolourization of industrial effluents: available methods and emerging technologies - a review,” Reviews in Environmental Science and Biotechnology, vol. 4, pp. 245–273, 2005.
[19] T. H. Le, C. Ng, N. H. Tran, H. Chen, K. Y. H. Gin, and K. Yew Hoong, “Removal of antibiotic residues, antibiotic resistant bacteria and antibiotic resistance genes in municipal wastewater by membrane bioreactor systems,” Water Research, vol. 145, pp. 498–508, 2018.
[20] U. T. Un and S. E. Ocal, “Removal of heavy metals (Cd, Cu, Ni) by electrocoagulation,” International Journal of Environmental and Sustainable Development, vol. 6, no. 6, pp. 425–429, 2015.
[21] Apha, Standard Methods for the Examination of Water and Wastewater, American Public Association, Washington, DC, USA, 2012.