Journal of Environmental Informatics Letters 8(1) 31-50 (2022)

Journal of Environmental Informatics Letters

www.iseis.org/jeil

Dairy Wastewater Treatment through Synergies of the Biological and Hybrid Membrane: A Systematic Review

G. Mekuria[1] *

[1] *Department of Industrial Engineering, College of Engineering, Debre Berhan University, Debre Berhan, Ethiopia*

Received 03 June 2022; revised 5 September 2022; accepted 19 September 2022; published online 07 October 2022

ABSTRACT. Wastewater treatment techniques have two categories: pre- and post-treatment. Physical, chemical, and biological pre-treatment techniques are commonly employed to treat dairy wastewater. Secondly, dairy wastewater post-treatment techniques include physico-chemical and membrane treatment approaches. This review article aims to critically examine and describe pre- and post-treatment techniques for dairy wastewater treatment. The benefits, drawbacks, performance comparisons, and features of each pre- and post-treatment have been extensively investigated. This article uses a systematic literature review method to review and examine other research findings. The results indicate that despite extensive studies on pre- and post-treatment techniques, both have limitations. In this context, aerobic pre-treatment, for example, has high lactose levels, low water capacity, and efficiency concerns. Furthermore, anaerobic pre-treatment has issues with lengthy starting times, a high fermentable lactose content, poor residual alkalinity, and fat consumption. In physico-chemical post-treatment, there are high amounts of sludge production and high quantities of chemicals required for pH corrections. Likewise, membrane post-treatment, for instance, has a short membrane lifespan, low selectivity and flux, linear up-scaling, and concentration polarization membrane fouling. Therefore, a synergy of physico-chemical and aerobic, for example, adsorption-aerobic, and synergy of pre-hydrolysis and anaerobic, such as enzymatic hydrolysis-anaerobic treatment, will help to overcome the drawbacks of both anaerobic and aerobic treatment techniques. In conclusion, the most promising techniques for dairy wastewater treatment are combinations of adsorption-aerobic and enzymatic hydrolysis-anaerobic with microfiltration, nanofiltration, reverse osmosis, and ultrafiltration.

Keywords: aerobic, anaerobic, dairy wastewater, physico-chemical treatment, pre-hydrolysis, pre- and post-treatment

1. Introduction

In the dairy industry, clean water is consumed in overall processes. Importantly, the industry's demand for water is colossal (Sarkar et al., 2006). As a result, the dairy industry is regarded as the biggest source of wastewater in many countries (Farizoglu and Uzuner, 2011; Shivayogimath and Naik, 2014). Further, this dairy wastewater comprises high organic materials, including proteins, carbohydrates, lipids, high BOD, COD, suspended solids, and oil grease (Farizoglu and Uzuner, 2011). For this reason, a major notice must be set to the dairy wastewater which is emancipated to the environment (Porwal et al., 2015). Of equal importance, appropriate treatments are required to prevent environmental pollution. Dairy wastewater treatment techniques are categorized into pre- and post-treatment techniques. Pre-treatment techniques are the prior phase in the dairy wastewater treatment process. Briefly, these techniques comprise physical, chemical, and biological treatment techniques (Loloei et al., 2014). Having that, in the physical treatment of dairy wastewater, the key process comprises removing the solid particles present in the dairy wastewater using a wire screen and a grit chamber (Janet Joshiba et al., 2019). Second, in chemical treatment, ferrous sulphate and lime are taken as a coagulant to control the pH of dairy wastewater (Slavov, 2017).

Then, the biological treatment technique is used as a pre-treatment for dairy wastewater treatment (Lateef et al., 2013). Besides, aerobic and anaerobic treatments are well-known elements of biological treatment techniques. Considering that aerobic treatment has various treatment processes, these include activated sludge, aerobic lagoons, trickling filters, rotating biological contractors, and sequencing batch reactors (Janet Joshiba et al., 2019). With this in mind, during the treatment process, organic nutrients are converted into carbon dioxide, water, and cellular materials by oxidizing constituents.

Similarly, anaerobic treatment has many dairy wastewater treatment processes, including complete stirred tank reactors, anaerobic filter reactors, up-flow anaerobic sludge blanket, anaerobic digestion, and membrane anaerobic reactors (Zhao et al., 2020). From the anaerobic process, methane (biogas) can be achieved as renewable energy (McAteer et al., 2020). The post-treatment techniques belong to the second phase in the dairy wastewater treatment process. These techniques embrace

* Corresponding author. Tel.: +251923388799.
E-mail address: getahunmekuria3@gmail.com (G. Mekuria)

ISSN: 2663-6859 print/2663-6867 online
 doi:10.3808/jeil.202200087

physico-chemical and membrane treatment. To begin with, the physico-chemical treatment process includes coagulation or flocculation, and adsorption (Kushwaha et al., 2011; Shete and Shinkar, 2013; Ahmad et al., 2019). Following this, the physico-chemical treatment is used to drop suspended, colloidal, and dissolved constituents. On the other hand, membrane treatment mainly comprises microfiltration, ultrafiltration, nanofiltration, electrodialysis, and reverse osmosis (Shete and Shinkar, 2013; Birwal et al., 2017). The rate of water usage and the necessity for environmental preservation have increased interest in wastewater reuse. In this context, membrane post-treatment in effluent treatment is described as one of the most promising techniques, allowing for water reuse. As a result, membrane treatment is utilized for high-quality by-product recovery that may be reused in industrial operations or for the discharge of high-quality effluent into the environment. However, despite extensive studies on pre- and post-treatment techniques, both have limitations. This article critically examines and describes pre- and post-treatment techniques for dairy wastewater treatment. The benefits and drawbacks, performance comparisons, and features of each pre- and post-treatment technique have been thoroughly explored. Furthermore, this article suggests areas where more study is needed.

2. Materials and Methods

A systematic literature review method is used in the material and method section to review and examine the findings of many independent researchers on similar concerns or subject areas. Meanwhile, before beginning the search for a relevant research paper, there must be specific inclusion and exclusion criteria. The inclusion and exclusion criteria are detailed in Table 1.

Table 1. Study Selection Criteria

No.	Description
1	Articles that focus on dairy wastewater treatment practices.
2	Articles that are published only in the English language.
3	Studies were published from 2010 to 2021.

The review synthesis will not include any research studies that do not meet the above inclusion criteria. Searching through numerous databases, including Emerald, Taylor and Francis, Elsevier Science Direct, Google Scholar, Springer Link, PubMed/Medline, JSTOR, CrossRef, Worldcat, PsycINFO, DOAJ, Scopus, ProQuest, Scielo, and Web of Science, is the next step after this. The notion of employing the keywords and phrases "pre-treatment techniques" and "post-treatment techniques" was relied upon for the article search in the interim. Pre-treatment techniques are used in the first part of the dairy wastewater treatment process, while post-treatment techniques are the second phase in the dairy wastewater treatment process. After scanning numerous databases, a total of 209 research publications were discovered. However, eight articles were omitted from the analysis owing to title and abstract eligibility restrictions, and eight more were excluded due to full-text eligibility constraints, leaving just 188 for analysis. A detailed process for choosing articles and carrying out a systematic literature review is shown in Figure 1.

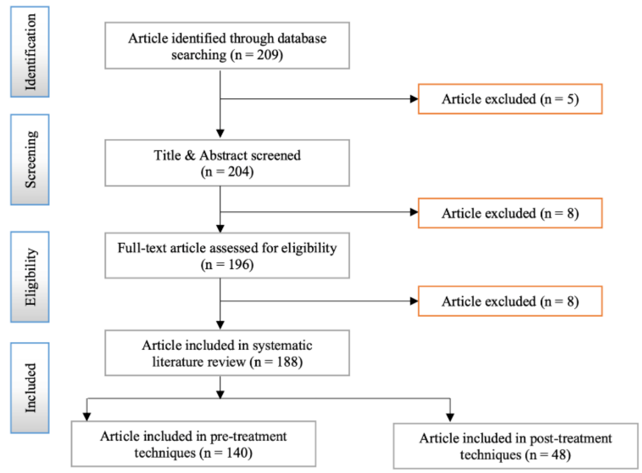

Figure 1. Flowchart of the systematic literature review.

3. Discussion of Diary Wastewater Treatment Techniques

3.1. Pre-Treatment Techniques

Table 2 summarizes the journal name and year of publication of the included reviews in pre-treatment techniques. The findings reveal more than 22.14% of the review articles from 2012/2013, 20% from 2010/2011, 17.86% from 2014/2015, 15.71% from 2018/2019, 12.86% from 2016/2017, and 11.43% from 2020/2021. As previously stated, in pre-treatment techniques, different methods are utilized to treat dairy wastewater, with biological treatment techniques taking precedence. Aerobic and anaerobic treatments are examples of these approaches. In the wastewater treatment system, both systems have various applications. Following that, both treatments are classed depending on the type of reactor and their benefits for treating dairy effluent. As a result, as seen by the listed research papers, numerous investigations on both biological treatment techniques have been conducted. The specifics of each research article are reviewed and summarized below.

Briefly, the included publications for the systematic review of aerobic treatment are as follows. Sequence batch reactors' principal benefit is that they create low-organic loading effluent that satisfies stringent effluent regulations. SBR treatment method can effectively remove the nutrients phosphate and nitrogen, as well as COD and BOD. The organic loading can be changed based on the hydraulic retention duration, generally 6 ~ 24 hrs. At 25 °C, volumetric organic loadings of 1.2 ~ 2.4 kg COD m^3/day resulted in COD elimination of 92 ~ 98%. At 5 °C, COD removal ranged from 75 ~ 85% for COD loadings ranging from 0.9 ~ 2.4 kg COD m^3/day, BOD removal efficiency 95%, NO_3-N removal by 90.3%, and TSS removal by 85.7%

Table 2. A Summary of the Names of the Journal and Year of Publication of the Included Reviews in Pre-Treatment Techniques

Journal name	2010 ~ 2011	2012 ~ 2013	2014 ~ 2015	2016 ~ 2017	2018 ~ 2019	2020 ~ 2021	Total
Middle-East Journal of Scientific Research	1	-	-	-	-	-	1
Journal of Chemical Technology and Biotechnology	3	1	-	-	-	-	4
Journal of Industrial Ecology	1	-	-	-	-	-	1
Applied Biochemistry and Biotechnology	1	-	-	-	-	-	1
Journal of Dairy Science	1	-	-	-	1	-	2
Journal of Bioscience and Bioengineering	2	-	1	-	-	-	3
Bioresource Technology	4	4	3	2	1	-	14
International Journal of Dairy Technology	-	2	1	-	-	-	3
Journal Cleaner Production	-	2	-	-	-	-	2
Bulgarian Journal of Agricultural Science	-	1	-	-	-	-	1
International Journal of Environmental Research	-	2	1	-	-	-	3
Journal of Environmental Chemical Engineering	-	1	-	-	-	1	2
International Journal of Advanced Science, Engineering and Technology	1	2	-	-	-	-	3
Engineering in Agriculture, Environment, and Food	1	-	-	-	-	-	1
Environmental Engineering and Management Journal	-	-	-	-	1	-	1
Water Science and Technology	-	1	1	2	-	-	4
International Journal of Computational Engineering Research	-	1	-	-	-	-	1
Desalination	2	-	1	-	-	-	3
International Journal of Hydrogen Energy	-	-	-	-	1	-	1
Journal of Environmental Management	2	-	-	-	-	2	4
Process Safety and Environmental Protection	-	-	-	-	1	-	1
Science of the Total Environment	-	-	-	-	1	1	2
Water Research	1	1	-	-	-	1	3
Water and Environment Journal	-	-	-	-	1	-	1
Civil and Environmental Research	-	1	-	-	-	-	1
International Journal of GEOMATE	-	-	-	1	-	-	1
Journal of Oleo Science	-	-	1	-	-	-	1
Chemistry International	-	-	-	1	-	-	1
Archives of Biological Science Belgrade	-	-	1	-	-	-	1
Food Technology and Biotechnology	1	-	-	1	-	-	2
A Journal of Science and Technology	-	-	-	-	-	1	1
Think India Journal	-	-	-	-	1	-	1
Water Environment Research	1	-	-	-	-	-	1
Environmental Technology	1	1	1	-	-	-	3
Journal of Environment and Earth Science	-	-	1	-	-	-	1
Advances in Environmental Technology	-	-	-	1	-	-	1
Chemosphere	-	-	-	-	-	1	1
Chemical Engineering and Processing: Process Intensification	-	-	-	-	1	-	1
Desalination and Water Treatment	-	1	4	-	1	-	6
Korean Journal of Chemical Engineering	-	-	-	-	1	-	1
International Journal of Natural Resource and Marine Science	1	-	-	-	-	-	1
Asia-Pacific Journal of Chemical Engineering	1	-	-	-	-	-	1
Scientific Bulletin. Series F. Biotechnology	-	-	1	-	-	-	1
International Conference on Science and Technology	-	-	-	-	1	-	1
Bioengineering	-	-	-	-	-	1	1
International Journal of Green Energy	-	-	-	1	-	-	1
Journal of Renewable Energy and Environment	-	-	-	-	1	-	1
Journal of Health Scope	-	-	-	1	-	-	1
International Journal of Environmental Science and Technology	-	1	-	1	-	-	2
Food Research International	-	-	1	-	-	-	1

Table 2 Continued

Journal name	2010 ~ 2011	2012 ~ 2013	2014 ~ 2015	2016 ~ 2017	2018 ~ 2019	2020 ~ 2021	Total
Brazilian Journal of Chemical Engineering	-	1	-	-	-	-	1
Science Asia	-	1	-	-	-	-	1
Aquademia	-	-	-	-	-	1	1
Energies	-	-	-	-	-	1	1
International Biodeterioration and Biodegradation	-	-	-	1	-	-	1
Ultrasonics Sonochemistry	-	-	1	-	-	-	1
Global NEST Journal	-	-	1	-	-	-	1
Water Resource and Industry	-	-	1	-	-	1	2
The International Journal of Biotechnology	-	1	-	-	-	-	1
Iranica Journal of Energy and Environment	-	-	-	-	1	-	1
International Journal of Environmental Research and Public Health	-	-	-	-	1	-	1
International Journal of Science Technology and Engineering	-	-	-	1	-	-	1
Journal of Environmental Engineering	-	-	-	-	1	-	1
International Research Journal of Engineering and Technology	-	-	-	-	2	-	2
Journal of Environmental Science and Health	-	1	-	-	1	-	2
International Journal of Applied Sciences and Engineering Research	-	-	-	1	-	-	1
Journal of Industrial Microbiology and Biotechnology	1	-	-	-	-	-	1
Jundishapur Journal of Health Science	-	-	1	-	-	-	1
Journal of the Taiwan Institute of Chemical Engineers	-	-	-	1	-	-	1
Process Biochemistry	-	-	1	-	-	-	1
Alexandria Engineering Journal	-	-	-	-	-	1	1
International Journal of Engineering Research and Applications	-	-	-	1	-	-	1
Biosystems Engineering	-	1	-	-	-	-	1
Water Practice and Technology	-	1	-	-	-	-	1
Sustainable Environment Research	-	-	-	1	-	-	1
Ecotoxicology and Environmental Safety	-	-	-	-	1	-	1
Advances in Environmental Biology	-	-	-	-	1	-	1
Separation Science and Technology	1	-	-	-	-	-	1
Journal of Environmental Biology	-	-	1	-	-	-	1
Renewable Energy	1	-	-	-	-	1	2
Water, Air, & Soil Pollution	-	-	-	1	-	-	1
International Journal of Sustainable Development and Planning	-	1	-	-	-	-	1
Sustainable Environment Research	-	-	1	-	-	-	1
Material Today: Proceedings	-	-	-	-	-	1	1
The International Conference on Emerging Trends in Engineering	-	-	-	-	-	1	1
Environmental Technology and Innovation	-	-	-	-	-	1	1
Journal of Ecological Engineering	-	-	-	-	1	-	1
Waste Management	-	1	-	-	-	-	1
Bioprocess and Biosystems Engineering	-	1	-	-	-	-	1
Total	28 (20%)	31 (22.143%)	25 (17.857%)	18 (12.857%)	22 (15.714%)	16 (11.429%)	140 (100%)

(Islam et al., 2011; Kayranli and Ugurlu, 2011; Rodríguez et al., 2011; Singh and Srivastava, 2011; Zina-tizadeh et al., 2011; Janczukowicz et al., 2012, 2013; Kulkarni, 2012; Matsumoto et al., 2012; Aygun et al., 2014; Nasr et al., 2014; Yahi et al., 2014; Ionescu et al., 2015; Pannirselvam et al., 2015; Soliman and Eldyasti, 2016; Jafarinejad, 2017; Ribeiro et al., 2017; Salari et al., 2017; Aziz et al., 2018; Leonard et al., 2018; Struk-Sokoowska et al., 2018; Azimi et al., 2019; Al-Dhabi et al., 2020; Vibhhute and Ingavale, 2020; Heidari et al., 2021; Anu et al., 2021).

To effectively treat wastewater, activated sludge processes entail a phase in which the wastewater must be in touch with bacterial biomass while being exposed to oxygen through an aeration system. The next step is a settling procedure. To keep the mixed liquor from being contaminated, some of the biomass separated in the clarifying tank flowed back to the aeration tank. To effectively treat wastewater, activated sludge processes entail a phase in which the wastewater must be in touch with bacterial biomass while being exposed to oxygen through an aeration system. The next step is a settling procedure. To keep the mixed liquor from being contaminated, some of the biomass separated in the clarifying tank flowed back to the aeration tank. Having that, the activated sludge processes removal effectiveness of COD was 97%, BOD was 97.5%, and TSS was 96% (Bosco and Chiampo, 2010; Emerald et al., 2012; Lateef et al., 2013; Shivsharan et al., 2013; Kowalska et al., 2014; Devi et al., 2014; Tricolici et al., 2014; Gayathri et al., 2015; Sharmila et al., 2015; Porwal et al., 2015). Sequencing batch flexible fibre biofilm reactor (SB-FFBR) is a modified sequencing batch reactor that allows microorganisms to grow on eight flexible fibre bundles. The operating volume of the bioreactor is 8 liters, and the cycle time is 24 hours. The bioreactor's performance is measured at 10, 3, and 10 distinct levels of influent chemical oxygen demand (COD_{in}; 610 ~ 8193 mg L^{-1}), retention time (RT; 1, 1.6, and 2 days), and organic loading rate (OLR; 0.38 ~ 8.19 g COD m^{-3} d^{-1}), respectively (Abdulgader et al., 2020).

Rotating biological contactors' principal benefits are implemented for wastewater treatment and have minimal land area, maintenance, energy, or start-up expenses, allowing for a more decentralized water treatment system. The BOD removal effectiveness was 96%, COD removal was 80%, and TSS removal was 79% at 8 rpm (Jeswani and Mukherji, 2012; Chethan et al., 2015; Hamasaki et al., 2017; Delgado et al., 2018; Ebrahimi et al., 2018a, 2018b; Kamath et al., 2018; Palakshappa et al., 2019; Samadi and Mirbagheri, 2019; del Álamo et al., 2020).

An essential treatment technique for removing pollutants from dairy effluent uses a treatment technique known as biological trickling filters. The biological trickling filter process involves flowing pollutants through a media bed containing microorganisms that break down organic nutrients. The biotrickling filter's performance indicated that butanol concentrations successfully ranged from 0.55 ~ 4.65 g/m^3, with a maximum withdrawal capacity of 100 g/m^3 (Mehrdadi et al., 2012; Shahriari and Shokouhi, 2015; Aziz and Ali, 2017, 2019; Zyłka et al., 2018).

Standard biological treatment methods combine with membrane filtration to achieve higher levels of organic load and suspended material removal. When correctly designed, these systems may also provide a high level of nutrient removal. For example, the effectiveness of MBR in removing pollutants is COD by 94.1%, BOD by 98.1%, ammonium by 99.6%, total nitrogen by 93.1%, and total phosphorous by 91% (Andrade et al., 2013; Fraga et al., 2016; Alimoradi et al., 2018).

The advantage of the membrane rotating biological contractor over the standard RBC is that the disk rotations serve as both an aeration source and an integrated mechanism to manage membrane fouling. In this context, the aeration system efficiency is excellent regardless of the type of membrane used. The permeability at the steady state of the MRBC membranes is, for the PVDF, 92.4% and PSF, 19.7%, higher than external filtration (Waqas et al., 2021).

It has proven possible to achieve high nitrogen, ammonium, phosphorus, and COD removal through a sequencing batch biofilm reactor (SBBR). High-performance pollutant removal is another use for it. The SBBR's operational strategy is crucial, meanwhile. The efficiency of SBBR in removing effluents from dairy wastewater is COD by 81.8% and ammonium by 85.1% (Ozturk et al., 2019).

In summary, the publications evaluated in the anaerobic treatment systematic review are as follows. For example, upflow anaerobic sludge blanket (UASB) reactors have been used effectively in full-scale wastewater treatment. Meanwhile, the UASB is the most effective treatment technology for soluble contaminants. A COD reduction of 77%, a BOD reduction of 87%, a TSS reduction of 47.1%, a TDS reduction of 57%, an oil and grease reduction of 92%, and a chloride reduction of 49.8% are the effluent removal rates for UASB from dairy wastewater (Kim and Shin, 2010; Gotmare et al., 2011; Passeggi et al., 2012; Thenmozhi and Uma, 2012, 2013; Chen et al., 2014; Couras et al., 2015; Elangovan and Sekar, 2015; Banu et al., 2015; Lavanya and Jodhi, 2016; Picos-Benítez et al., 2017; Batubara et al., 2018; Zhuang et al., 2018; Gundkal et al., 2019; Heydari et al., 2019; Jin et al., 2019; Yang et al., 2019; Lim et al., 2020; Mainardis et al., 2020).

In the dairy wastewater treatment process, stirred tanks are the most commonly employed form of the reactor. A stirred tank usually has one or more impellers installed on a shaft, baffles, and other internals such as spargers, coils, and draft tubes. Numerous parameters, such as tank and impeller shapes, tank aspect ratio, number, type, location, and size of impellers, degree of baffling, provide unrivaled flexibility and control over the performance of stirred reactors while also posing significant challenges to their design and scale-up (or scale-down) (Kumari et al., 2019).

For a decrease in BOD, COD, and VSS of dairy effluent, a biofilm support media consisting of fire bricks, gravels, PVC rings, bamboo rings, and foam cubes in batch 5 and repeated batch culture systems to immobilize biomass. The characteristics and type of the support material are related to the effectiveness of COD elimination. Anaerobic fixed film biotreatment has the efficiency of removing COD by 96%, BOD by 93%, and VSS by 90% (Qazi et al., 2011). The biohydrogen production in the CSTR and methane in the AFBR has shown an increasing trend despite the HRT extension. The CSTR had the greatest biohydrogen yield at 115.2 (± 5.3) L H_2/kg VS_{added}, while the AFBR had the highest methane output at 334.7 (± 18.6) L CH_4/kg COD_{added} (Yeshanew et al., 2016).

The best parameters for dairy wastewater treatment were COD: N: P ratio (1000 : 80 : 5), OLR (0.08 kg/m^3 hr.), aeration duration (40 min/hr.), MLSS (7500 mg/l), F : M ratio (0.0286 kg, COD/kg MLSS d), and HRT (6.33 hr.). Under these conditions, achieved values include: MLSS (3610 mg/l), MLVSS (2450 mg/l), SVI (110.8 ml/g), and turbidity (29.82 NTU). Accordingly, the UAASB reactor's integrated system provides an efficient and controlled procedure for extracting nutrients from industrial dairy effluent (Amini et al., 2013). The anaerobic digester performed well since COD reduction was over 90%, which was much better than the efficiency of pilot-scale anaerobic digesters handling this kind of dairy wastewater (Vlyssides et al., 2012; Uma Rani et al., 2013; Debowski et al., 2020; Tan et al., 2021). In the realm of anaerobic wastewater treatment, granule sludge-based anaerobic systems predominate (Karadag et al., 2015).

Sequential upflow anaerobic sludge bed reactors (UASBRs) can lower the amount of alkalinity needed to treat dairy wastewater by 0.05g OH/g COD_{added}, 71 ~ 100% for VFA, 50 ~ 92% for COD, and 63 ~ 89% for fatty matter removal (Erdirencelebi, 2011). The purpose of utilizing a microbial consortium in organic waste is to convert it into biogas in a granular sludge bioreactor known as an upflow anaerobic sludge-fixed film reactor (UASFF). With a 97.5% COD reduction and a 98% lactose conversion, UASFF effectively eliminates effluents

Table 3. Comparison of Pre-Treatment Techniques Performance on Dairy Wastewater

Reactor	Waste type	HRT	TSS	COD	BOD	TN	TP	TS	VSS	VFA	Methane	PH	References
			Reduction (%)	Reduction (%)	Reduction (%)	Reduction (%)	Reduction (%)	Reduction (%)	Reduction (%)	Reduction (%)	Average production (m^3/day)		
UASB	Dairy wastewater	-	56.54	87.06	94.50	-	-	-	-	0.28 ~ 0.43	179.35 ~ 125.55	6.9 ~ 7.1	(Gotmare et al., 2011)
SBR	Dairy wastewater	-	77.6	80.3	85.5	61.0	87.2	61.4	-	-	-	-	(Islam et al., 2011)
SB-FFBR	Dairy wastewater	1 d	77.3 ~ 99.3	86.8 ~ 97.5	-	-	-	-	-	-	-	-	(Abdulgader et al., 2020)
RBC	Dairy wastewater	4 d	-	50.48 ~ 80.11	-	-	-	-	-	-	45 ~ 58	-	(Samadi and Mirbagheri, 2019)
UASFF	Dairy wastewater	2 d	-	97.5	-	-	-	-	-	-	-	-	(Najafpour et al., 2008)
AFFB	Dairy wastewater	12 d	-	96	93	-	-	-	90	-	-	-	(Qazi et al., 2011)
SMBR	Dairy wastewater	-	-	98	-	86	86 ~ 89	-	-	-	-	-	(Andrade et al., 2014b)
SBBR	Dairy wastewater	8 d	-	81.8	-	-	-	-	-	-	-	-	(Ozturk et al., 2019)
Electro-Fenton-SBR	Dairy wastewater	10 hr	-	99	-	97	95	-	-	-	-	-	(Heidari et al., 2021)
Activated sludge	Dairy wastewater	-	-	80.0 ~ 88.4	-	-	-	-	-	-	-	-	(Emerald et al., 2012)
UASBR	Dairy wastewater	-	-	50 ~ 92	-	-	-	-	-	71 ~ 100	-	-	(Erdirencelebi, 2011)
ABR & UASB	Dairy wastewater	-	-	98	-	-	-	-	-	-	-	-	(Ji et al., 2020)
ASBR	Dairy wastewater	-	-	89.7	91	-	-	-	-	-	-	-	(Dehghani et al., 2014)
Anaerobic filter & biological aerated filter	Dairy wastewater	-	-	79.8 ~ 86.8	-	50.5 ~ 80.8	-	-	-	-	-	-	(Lim and Fox, 2011)
Biological trickling filter	Dairy wastewater	-	-	90.19	-	-	-	-	-	-	-	-	(Aziz and Ali, 2019)

(Sivaprakasam and Balaji, 2020).

The two most effective processes for treating dairy effluent are a combination of an anaerobic baffled reactor and an anaerobic sludge blanket that flows upstream. In the ABR treatment process, for instance, proteins were first denatured and coagulated into solids, which generated the ideal conditions for sludge retention in the sludge bed of the UASB. Fats were similarly adsorbed and degraded. The combined system successfully removed 98% of COD, significantly reduced extra sludge from 3 to 5 amounts of sludge (t)/day to 3 amounts of sludge (t)/month, and produced noticeable amounts of biogas. The remaining contaminants in the effluent also fulfilled applicable criteria (Ji et al., 2020).

Low-temperature ASBR may effectively treat household wastewater that has low strength. As temperature and HRT dropped, the COD elimination decreased. This impact was affected by the biomass concentration. Reduced biomass content in the reactor led to lower system performance. Higher HRTs are necessary for low-temperature and low-biomass environments. When the biomass concentration constant at 9.604 g VSS/L was employed, the ASBR performance was better under all applied temperatures and HRTs. At 10 g VSS/L, the system attained a high COD removal effectiveness of more than 93%. At 5 g VSS/L; however, the system's performance fell off by up to 33% (Wang et al., 2011; Dehghani et al., 2014).

Anaerobic filters are fixed-bed biological reactors having one or more series-connected filtering chambers. The filter material's active biomass, which is affixed to its surface and breaks down organic matter, traps particles when dairy effluent runs by it (Jo et al., 2016). Utilizing mixed culture PnSB, a membrane sequencing batch reactor was applied. This technique might be effective for digesting large organic matter molecules like oils and greases. Furthermore, PnSB thrives in anaerobic environments with ORPs ranging from 300 to 200 mV and pH ranging from 7.0 to 7.5 (Kaewsuk et al., 2010). Multiple vertical baffles with significant active microbiological mass are set in an anaerobic baffled reactor (ABR) to compel dairy wastewater to pass through the baffles, over them, or under them, covering the whole surface of the baffles and allowing contact between influent wastewater and biomass (Karadag et al., 2014).

3.1.1. Comparison of Pre-Treatment Techniques Performance on Diary Wastewater

Table 3 analyzes the effectiveness of several pre-treatment approaches in detail. SBR can reduce TSS by 77.6%, COD by 80.3%, BOD by 85.5%, TN by 61.0%, TP by 87.2%, and TS by 61.4% as a result. Meanwhile, BOD, COD, TSS, TN, and TP removal are effective. SBR is typically used for equalization and main clarity while having a minimal footprint. SB-FFBR has a one-day HRT and can lower TSS by 77.3 ~ 99.3% and COD by 86.8 ~ 97.5%. RBC has a 4-day HRT, a COD reduction capacity of 50.48 ~ 80.11%, and a medium methane generation capacity of 45 ~ 58 m^3/day.

Likewise, RBC has high contact time, good sludge setting properties, and low sludge production. Besides, SMBR can reduce COD by 98%, TN by 86%, and TP by 86 ~ 89 %. In line with this, SMBR has a high volumetric load possible, high effluent quality, lower sludge production, and a rapid rate of deterioration. SBBR can reduce COD by 81.8% and has eight days of HRT. Electro-Fenton-SBR has a high capacity of COD reduction by 99%, TN by 97%, TP by 95%, and can have a low HRT of 10 hrs. Similarly, activated sludge can reduce COD by 80 ~ 88.4%. ABR and UASB can reduce COD by 98%.

Additionally, UASB may reduce BOD by 94.50%, COD by 87.06%, VFA by 0.28 to 0.43%, TSS by 56.54%, and PH by 6.9 to 7.1 while producing 179.35 to 125.55 m^3 of methane per day. With a 48-hour HRT, UASFF can cut COD by 97.5%. AFFB can cut down, on 12 days of HRT, COD by 96%, BOD by 93%, and VSS by 90%. UASBR can reduce COD and VFA by 50 ~ 92% and 71 ~ 100%, respectively. ASBR can reduce COD and BOD by 89.7% and 91%, respectively. Anaerobic and biological aerated filters can reduce COD and TN with respective efficiency ranges of between 78.8 ~ 86.8% and 50.5 ~ 80.8%. Finally, a biological trickling filter may reduce COD in dairy effluent by 90.19%.

3.1.2. Advantages and Disadvantages of Pre-Treatment Techniques

This section presents the main advantages and disadvantages of each pre-treatment technique used in the dairy wastewater treatment process. For example, despite its benefits, the dairy industry uses aerobic biological treatment as a pre-treatment method. However, due to its high lactose content and low water buffer capacity, it is confined and has challenges with efficiency (Ahmad et al., 2019). Similarly, anaerobic biological treatment has so many advantages; for example, the anaerobic treatment uses less energy to function than aerobic treatment does. There is a six to eight-fold decrease in biomass production during the anaerobic phase compared to the aerobic period. The cost of treating and discarding sludge is thereby significantly reduced. Despite its advantages, anaerobic treatment has issues with extended start-up times, resulting from preliminary biomass adaptation, fat consumption, complicated substrate breakdown, a quick pH drop, and a high concentration of fermentable lactose. Moreover, a low subtract alkalinity and other factors (Slavov, 2017).

Contrarily, many scholars have recorded a range of treatment approaches to improve the efficiency, start-up time, effluent quality, and cost features of both aerobic and anaerobic biological treatment. Given this, it is possible to overcome the main drawbacks of aerobic pre-treatment procedures by using the physico-chemical treatment approach as a refining stage before the aerobic biological treatment process. For example, the adsorption treatment method excels in physico-chemical treatment because it effectively removes organic nutrients from dairy effluent while reducing energy consumption and improving efficiency (Kushwaha et al., 2011; Birwal et al., 2017; Jyothi and Bindu, 2017). Although, the pre-hydrolysis treatment techniques can be used as a prior phase before the anaerobic biological treatment process. To improve performance and reduce the start-up period. For example, enzymatic hydrolysis is a prominent pre-treatment method as a result of (90%) COD removal and high methane (biogas) production (4710 ml) (Mobarak-Qamsari et al., 2012). Table 4 lists the benefits and drawbacks of each pre-treatment method.

3.1.3. Major Features of Pre-Treatment Techniques

Table 5 summarizes the key components of each pre-treatment technique. The activated sludge process (ASP) consists of two tanks: an aeration tank and a sedimentation tank. Conventional trickling filters (CTF) consist of a dosing rate system, and the structure includes filter media, an underdrain system, and a settling system. A typical rotating biological contactor (RBC) includes circular discs, a horizontal shaft, and a sedimentation tank. Also, a sequencing batch reactor (SBR) is a single fill and draws system that comprises a tank, aeration, mix-

Table 4. Advantages and Disadvantages of Pre-Treatment Techniques

Categories	Reactor type	Advantage	Disadvantage
Aerobic	Activated sludge process (ASP)	Easy to operate. Easy to install. Odor free. Light footprint.	Low effluent quality. Higher sludge production. Higher energy consumption. Bulking. Foam production perception of iron and carbonates. Low efficiency during winter.
	Conventional trickling filters (CTF)	Low energy requirement. No especially skilled personnel required. Relatively low maintenance requirements. Reduce footprint and high efficiencies.	Low treatment efficiencies for BOD, COD, TSS, TN, and TP. Low pathogen removal. Process affected by climate conditions. Less flexibility in operating conditions.
	Membrane bioreactor (MBR)	High removal efficiency. High effluent quality. High volumetric load possible. High rate of degradation. Lower sludge production. More compact. Low energy consumption.	High cost of operation. Membrane pollution. Stress on sludge in external membrane bioreactor. Aeration limitation. Membrane fooling. Control of membrane fouling.
	Rotating biological contactor (RBC)	High removal efficiency. High contact time. Low space requirement. Low energy consumption. Less operator attention. Fewer maintenance requirements. Ability to withstand shock or toxic load. Good sludge setting properties. Low sludge production. Economical (low operating cost). Easy to operate.	Odor problems may occur. A highly skilled technical operator is required for both operation and maintenance. High protection is required from sunlight, wind, and rain (especially against freezing in a cold climate). Contact media not available at the local market. Continuous power supply required.
	Sequencing batch reactors (SBR)	High treatment efficiencies are possible for BOD, COD, TSS, TN, and TP. Equalizations, primary clarification. Small space requirement. Small footprint. Low flow application. Common wall construction for rectangular tanks. Easy expansion into modules. Operating flexibility and control. Controllable react time and perfect quiescent setting. Elimination of return sludge pumping. Potential capital cost saving by eliminating clarifiers and other equipment.	High energy consumption. A higher level of sophistication is required compared to conventional systems. Higher level of maintenance. Potential of discharging floating or settled sludge. Potential plugging of aeration device. Potential requirement for equalization. Installed aeration power based on percent oxic of the treatment time. Batch feeding from storage or bioselecting required to control bulking. Low efficiencies regarding the removal of toxic compound. Issues with shock load of toxic compound. Inhibition of the microorganisms.
Anaerobic	Anaerobic digestion (AD)	Low energy consumption. High removal efficiency. Less sludge production. Methane/biogas production. Less space requirement. Less N and P required. Lake of pathogenic organisms Cost-effective.	Long start-up time. The strict control of the operating condition. Highly sensitive to loads and organic shocks. Toxic compounds.

Table 4 Continued

Categories	Reactor type	Advantage	Disadvantage
	Stirred tank reactors (STR)	No biomass retention. High removal efficiency. Continuous operation. Reasonable temperature control. Simply adopts two-phase runs. Easy to operate. Easy to clean. Cost-effective.	Low conversion per unit. By-passing and channeling probably with weak agitation performance.
	Up-flow anaerobic filter reactors (UAFR)	High removal efficiency. Short HRT. Stable against organic and hydraulic shock loading. Less sludge production and sludge stabilized. No energy consumption.	Removal and cleaning of the clogged filter media are difficult. Risk of clogging. Effluent and sludge require further treatment. Low removal of pathogens and nutrients. Requires expert design and construction.
	Membrane anaerobic reactors (MAR)	Increase biomass retention. High removal efficiency.	High retention time.
	Up-flow anaerobic sludge blanket reactor (UASB)	Methane/biogas production. Low energy requirement. Small space requirement. Low sludge yield and well-stabilized sludge.	Insufficient treatment efficiency for BOD, COD, TSS, TN, and TP. Low pathogen removal. Skilled personnel required. High corrosion problem. Low flexibility in operating condition. Scum formation on the surface.
	Anaerobic sequencing batch reactors (ASBR)	High efficiency for COD and nutrients. High methane/biogas production. No primary and secondary settlers. Flexible control.	Low-performance efficiency if overload.
	Anaerobic baffled reactor (ABR)	Low energy requirement. Small space requirement. Low sludge yield and well-stabilized sludge. No especially skilled personnel required.	Insufficient treatment efficiency for BOD, COD, TSS, TN, and TP. Low pathogen removal. Heavy corrosion problem. Low flexibility in operating condition.

ing equipment, a decanter, and a control system. A membrane bioreactor (MBR) contains a membrane filtration tank and suspended growth bioreactors.

Moreover, AD has a sludge heater, gas collector cover, uptake tube, bottom draw-off pipe, and screw pump. STR usually has one or more impellers installed on a shaft, baffles, and other internals like spargers, coils, and draft tubes. Numerous parameters, such as tank and impeller shapes, tank aspect ratio, number, type, location, and size of impellers, and degree of baffling, provide unrivaled flexibility and control over the performance of stirred reactors while also posing significant challenges to their design and scale-up (or scale-down). AFR contains filter materials (ceramics, glass plastics, or wood). MAR contains membrane filtration tank, and anaerobic bioreactor. UASB contains sludge blanket, gas-solid separator, influent-distributor, and effluent withdrawal system. ASBR includes batch-fed, batch-decanted, and suspended growth system. Finally, the ABR number of the UASB reactor is connected in series.

3.2. Post-Treatment Techniques

Table 6 summarizes the journal name and year of publication of the included reviews in post-treatment approaches. 8.333%, 14.583%, 22.917%, 20.833%, 22.917%, and 10.417% of such reviews were published in 2010 ~ 2011, in 2012 ~ 2013, in 2014 ~ 2015, in 2016 ~ 2017, in 2018 ~ 2019, in 2020 ~ 2021, respectively. The most high-quality by-product, which can be reused in the system or public, is obtained from post-treatment techniques. Although a lot of researches have been performed on post-treatment techniques for dairy wastewater treatment, considering appropriate wastewater treatment techniques is still essential.

Adding substances like ferric chloride or polymer to wastewater to destabilize the colloidal components and encourage the tiny particles to aggregate into bigger settleable flocs is a common practice in the treatment of water and wastewater, known as coagulation-flocculation (Rivas et al., 2010; Ayeche, 2012; Wolf et al., 2015; Teh et al., 2016; Mateus et al., 2017; Formentini-Schmitt et al., 2018; Iwuozor, 2019). Changing the pH and using a few strong chemical coagulants are some of the options to treat dairy wastewater. These coagulants dissolve any emulsions formed by cleaning chemicals and sanitizers. Certain chemicals also precipitate solids and lipids (Benaissa et al., 2014; Loloei et al., 2014; Dela Justina et al., 2018; Suman et al., 2018; Kurup et al., 2019; Muniz et al., 2020, 2021).

Flocculation is a method that enhances particle connection, which expands aggregates and makes them simpler to be removed. The technique is frequently employed in dairy wastewater treatment facilities and may also be used to process samples for monitoring purposes (Shabna Banu and Meena John, 2017). Adsorption has an efficient performance for treating dairy wastewater with a high concentration of phosphorus. Be-

Table 5. Major Features of Pre-Treatment Techniques

Categories	Reactor type	Features
Aerobic	Activated sludge process (ASP)	Aeration tank.
		Sedimentation tank.
	Conventional trickling filters (CTF)	Dosing rate system.
		The structure contains filter media (20 ~ 100 mm diameter).
		An underdrain system.
		A settling system.
	Rotating biological contactor (RBC)	Circular discs.
		Horizontal shaft.
		Sedimentation tank.
	Membrane bioreactor (MBR)	Membrane filtration tank.
		Suspended growth bioreactors.
	Sequencing batch reactors (SBR)	Tank.
		Aeration.
		Mixing equipment.
		A decanter.
		Control system.
Anaerobic	Anaerobic digestion (AD)	Sludge heater.
		Gas collecting cover.
		Uptake tube.
		Bottom draw-off pipe.
		Screw pump.
	Stirred tank reactors (STR)	Impeller mounted on the shaft.
		Baffles.
		Spargers.
		Coils.
		Draft tubes.
	Anaerobic filter reactors (AFR)	Filter materials (ceramics, glass, plastic, or wood).
	Membrane anaerobic reactors (MAR)	Membrane filtration tank.
		Anaerobic bioreactor.
	Up-flow anaerobic sludge blanket reactor (UASB)	Sludge blanket.
		Gas – solid separator.
		Influent – distributer system.
		Effluent withdrawal system.
	Anaerobic sequencing batch reactors (ASBR)	Batch-fed.
		Batch-decanted.
		Suspended growth system.
	Anaerobic baffled reactor (ABR)	Number of UASB reactors connected in series.

cause of their superior removal effectiveness concerning their adsorption capabilities, agricultural-based adsorbents will be a competitive economic option for relatively expensive commercial carbon in dairy wastewater treatment. For example, an efficient way to reduce COD by 72.8% and BOD by 76.75% is to use a mixed bed stationary phase with CSAC and laterite in a 1:1 ratio (CSAC to laterite). Moreover, in a 2:1 proportion, it functions effectively to remove COD by 75.3% and BOD by 79.69%. Finally, in a 1:2 proportion, it is productive to remove COD by 80.65% and BOD by 81.09% (Moradi and Maleki, 2013; Karale and Suryavanshi, 2014; Afolabi et al., 2015; Al-Jabari, 2016; Kurzbaum and Bar Shalom, 2016; Al-Jabari et al., 2017; Falahati et al., 2018; Choi et al., 2019; Al-Ananzeh, 2021).

Similarly, the nanofiltration treatment technique, which requires less energy and has a higher rejection rate than RO and UF, is a promising technology for treating dairy wastewater. In the meantime, NF has the effectiveness of recovering high-quality dairy effluent that can be recycled (Luo et al., 2010; Luo and Ding, 2011; Luo et al., 2012; Riera et al., 2013; Andrade et al., 2014a, 2015; Chen et al., 2015; Mulyanti and Susanto, 2018; Chen et al., 2018; Marszałek and Puszczało, 2020). A filtration method is a microfiltration. During the treatment of dairy wastewater, macromolecular, colloidal, and suspended particles are concentrated, cleansed, and eliminated. A microporous membrane with an applied pressure range of 0.1 to 2 bar removes various suspended particles or colloidal components from an incoming fluid stream (Kumar et al., 2016; Nagappan et al., 2018).

Ultrafiltration is a process that operates at low pressure and removes colloidal and dissolved particles. There are two distinct kinds of ultrafiltration techniques: polymer-enhanced ultrafiltration and micellar-enhanced ultrafiltration (Bennani et al., 2014; Das et al., 2015; Zinadini et al., 2015; Li et al., 2018). This technique combines a two-stage UF/NF process. The ultracel PLGC ultrafiltration concentrated fat and protein during the first stage. Reusing the NF retentate for anaerobic digestion to create biogas is an option, while the second step aims to remove lactose from the retentate and reuse water from the permeate (Luo et al., 2011; Gong et al., 2012; Chen et al., 2016).

Such dairy factory effluent underwent reverse osmosis after a preliminary evaluation of its stability during storage.

Table 6. A Summary of the Names of the Journals and Year of Publication of the Included Reviews in Post-Treatment Techniques

Journal name	2010 ~ 2011	2012 ~ 2013	2014 ~ 2015	2016 ~ 2017	2018 ~ 2019	2020 ~ 2021	Total
Desalination	1	1	-	-	-	-	2
Separation and Purification Technology	-	1	1	-	-	-	2
Energy Procedia	-	1	-	-	-	-	1
Journal of Water Process Engineering	-	-	1	1	2	-	4
Advanced Journal of Chemistry-Section	-	-	-	-	1	-	1
Water Air Soil Pollut	-	-	-	1	-	-	1
Journal of Environmental Chemical Engineering	-	-	-	1	-	-	1
Chemical Engineering Transactions	-	-	1	-	-	-	1
International Journal of Advance Research in Science and Engineering	-	-	-	1	-	-	1
Applied Sciences	-	-	-	-	1	-	1
Desalination and Water Treatment	-	-	3	-	-	-	3
Bioresource Technology	1	-	-	-	-	-	1
Chemical Engineering Journal	1	-	-	2	-	-	3
Journal of Membrane Science	-	1	-	-	1	-	2
Journal of Food Science and Technology	-	-	-	-	-	1	1
Brazilian Journal of Chemical Engineering	-	-	1	-	-	-	1
Environmental Technology	-	-	-	-	1	-	1
Water Science & Technology	-	1	-	-	-	1	2
Industrial & Engineering Chemistry Research	-	1	-	1	-	-	2
International Journal of Environmental Health Engineering	-	-	1	-	-	-	1
IOP Conference Series: Earth and Environmental Science	-	-	-	-	2	-	2
Science of the Total Environment	-	-	-	-	-	1	1
Process Safety and Environmental Protection	-	-	1	-	-	-	1
Journal of Agricultural and Food Chemistry	1	-	-	-	-	-	1
Environment, Development and Sustainability	-	-	-	-	1	-	1
Ukrainian Food Journal	-	-	1	-	-	-	1
Water	-	-	-	-	-	2	2
Environmental Technology & Innovation	-	-	-	1	-	-	1
Fullerenes, Nanotubes, and Carbon Nanostructures	-	1	-	-	-	-	1
Pollution	-	-	-	-	1	-	1
Environmental Engineering Research	-	-	-	-	1	-	1
Applied Clay Science	-	-	-	1	-	-	1
International Journal of Civil, Structural, Environmental, and Infrastructure Engineering Research and Development	-	-	1	-	-	-	1
International Journal of Global Environmental Issues	-	-	-	1	-	-	1
Total	4 (8.333%)	7 (14.583%)	11 (22.917%)	10 (20.833%)	11 (22.917%)	5 (10.417%)	48 (100%)

Filtration performance was measured using permeate flux, water recovery, and water quality. A 540 m^2 RO unit is required to process 100 m^3/d of wastewater while recovering 95% of the water (Deshwal et al., 2021). This technique contains a sequential use of a combination of microfiltration and nanofiltration. Besides, microfiltration and reverse osmosis within different pressure levels for treating dairy wastewater (Bortoluzzi et al., 2017). Dairy wastewater is treated using a two-stage combination of nanofiltration and reverse osmosis. The first phase treats chemical-biological effluents using nanofiltration as a treatment technique. The original effluent is treated in the second step using reverse osmosis (Hepsen and Kaya, 2012; Kyrychuk et al., 2014).

3.2.1. Comparison of Post-Treatment Techniques Performance on Diary Wastewater

Table 7 compares the performance of post-treatment techniques in detail. As a result, a combination of coagulation/flocculation/sedimentation followed by microfiltration or nanofiltration (CFS-MF-NF) can remove COD by 96%, turbidity by 99%, color by 99%, and membrane fouling rate by 63%. Also, MF-NF can remove COD by 51%, TKN by 58%, turbidity by 100%, and color by 96%. Alike MF-OR can remove COD by 84%, TKN by 94%, turbidity by 100%, and color by 100%. On the other hand, MBR-NF can remove COD by 99.9% and TS by 93.1%. Inorganic coagulation (aluminum) can remove COD by 68% and turbidity by 95%. Inorganic coagulation (ferrous sulphate) can remove COD by 62% and turbidity by 95%. Coagulation and flocculation ($FeSO_4$) can remove COD by 50% and BOD by 60%. Coagulation (sludge) can remove COD by 65%, BOD by 67%, turbidity by 93%, TSS by 84%, and TDS by 85%. Novel natural coagulant (guazuma ulmifolia) can remove COD by 76.0%, BOD by 81.2%, and turbidity by 95.8%.

3.2.2. Advantages and Disadvantages of Post-Treatment Techniques

Physico-chemical treatment has various benefits, including efficiently removing suspended solids, colliding components, and dissolved constituents in dairy wastewater treatment. However, in physico-chemical post-treatment, there is high sludge production, and high quantities of chemicals required for pH corrections have a drawback. On the other hand, among post-treatment strategies, the membrane treatment technique has been identified as the most attractive method for dairy wastewater treatment and recycling. As a result, numerous researches focuse on enhancing the effluen's performance and quality by combining membrane treatment methods with other treatment philosophies (Kaewsuk et al., 2010; Andrade et al., 2013; Kumar et al., 2016; Bortoluzzi et al., 2017). In conclusion, the membrane treatment technique has many advantages for dairy industries, including less ecological footprint, reliable contaminant removal performance, low cost, and the possibility of renewable energy use (Sisay and László, 2021). However, membrane post-treatment, for instance, has a short membrane lifespan, low selectivity and flux, linear up-scaling, and concentration polarization membrane fouling. Table 8 lists the benefits and drawbacks of each post-treatment technique.

3.2.3. Major Features of Post-Treatment Techniques

Table 9 summarizes the key components of each post-treatment procedure. As a physico-chemical treatment technique, coagulation is made from different flash mixing materials such as hydraulic mixing using flow energy, mechanical mixing, diffusers and grid system, pumped blenders, and static mixer. Similarly, the flocculation system has two major components: horizontal paddle wheel type and vertical flocculation. Finally, absorption comprises three significant features:

Table 7. Comparison of Post-Treatment Techniques Performance on Dairy Wastewater

Reactor	Waste type	COD	BOD	TKN	Turbidity	Color	TOC	TSS	TDS	Membrane fouling rate (%)	TS	References
		Removal (%)	Removal (%)	Removal (%)	Removal (%)	Removal (%)	Removal (%)	Removal (%)	Removal (%)		Removal (%)	
CFS-MF-NF	Dairy wastewater	96	-	-	99	99	-	-	-	63	-	(Mateus et al., 2017)
MF + NF	Dairy wastewater	51	-	58	100	96	-	-	-	-	-	(Bortoluzzi et al., 2017)
MF + OR	Dairy wastewater	84	-	94	100	100	-	-	-	-	-	(Bortoluzzi et al., 2017)
MBR + NF	Dairy wastewater	99.9	-	-	-	-	-	-	-	-	93.1	(Andrade et al., 2014a)
Inorganic coagulation (Aluminum)	Dairy wastewater	68	-	-	95	-	-	-	-	-	-	(Loloei et al., 2014)
Inorganic coagulation (Ferrous sulphate)	Dairy wastewater	62	-	-	95	-	-	-	-	-	-	(Loloei et al., 2014)
Coagulation + Flocculation ($FeSO_4$)	Dairy wastewater	50	60	-	-	-	-	-	-	-	-	(Rivas et al., 2010)
Coagulation (Sludge)	Dairy wastewater	65	67	-	93	-	-	84	85	-	-	(Suman et al., 2018)
Novel natural coagulant (Guazuma ulmifolia)	Dairy wastewater	76.0	81.2	-	95.8	-	-	-	-	-	-	(Muniz et al., 2020)

Table 8. Advantages and Disadvantages of Post-Treatment Techniques

Categories	Type	Chemical	Advantages	Disadvantages
Physico-chemical treatment	Coagulation	$Al_2(SO_4)_3{\cdot}18H_2O$	Simple to apply and handle. Usually used. Less amount of sludge production than lime. Operative between pH 6.5 ~ 7.5.	Adds dissolved solids (salts) to water. Operative with a limited pH value range.
		$Na_2Al_2O_4$	Operative in hard water. A small amount is commonly required.	Often used with Al. High cost. Ineffective is soft water.
		$Al_{13}(OH)_{20}(SO)_4{\cdot}Cl_{15}$	In some applications, Floc, formed is a denser and fast setting than aluminum.	Not usually used. Little full-scale data compared to other aluminum derivatives.
		$Fe_2(SO_4)_3$	Operative within pH 4.6 and 8.8 ~ 9.2.	Adds dissolved solids (salts) to water. Commonly require adding alkalinity.
		$FeCl_3{\cdot}6H_2O$	Operative within pH 4 ~ 11.	Adds dissolved solids (salts) to water. Consumes twice as much alkalinity as aluminum.
		$FeSO_4{\cdot}7H_2O$	Not pH sensitive as lime.	Adds dissolved solids (salts) to water. Commonly requires adding alkalinity.
		$Ca(OH)_2$	Usually used. Very effective. May not add salts to effluent.	pH dependent. High sludge production. Overdose can result in poor effluent quality.
	Flocculation	-	Process simplicity. An expensive capital cost. Bacterial inactivation capability. Good sludge settling and dewatering.	High sludge production. Nondegradable nature.
	Adsorption	Activated carbon. Synthetic polymeric. Silica-based adsorbent.	High effluent quality. A highly effective process with fast kinetics. Wide range of commercial products. Wide variety of target contaminants. Technological simplicity and process simplicity.	High investment. Non-destructive processes. Non-selective methods. Requirements for several types of adsorbents.
Membrane treatment	Nanofiltration	-	Lower energy consumption. Higher rejection rate.	Membrane fouling. Insufficient separation. Treatment of concentrate. Membrane lifetime and chemical resistance. Insufficient rejection for the individual compound. The need for modeling and simulation tools.
	Reverse osmosis	-	Simple dewatering process. Low energy consumption. No requirement for a complicated setup. Low initial investment capital.	Membrane fouling. Membrane lifetime. A low range of operating parameters (flow rate, temperature, pH, and pressure). Efficiency decreases as feed concentration increases.
	Microfiltration	-	Low operating pressure is required. Low energy consumption. Low investment capital. Not require energy-intensive phase transitions.	Reduced innovation. Limited equipment option.
	Ultrafiltration	-	Low energy consumption. Simple structure. Less space requirement. Process simplicity. Commonly used.	Reduced innovation. Limited equipment option.

Table 9. Major Features of Post-Treatment Techniques

Categories	Reactor type	Features
Physico-chemical treatment	Coagulation	Flash mixing. Hydraulic mixing using flow energy. Mechanical mixing. Diffusers and grid system. Pumped blenders. Static mixer.
	Flocculation	Horizontal paddle wheel type. Vertical flocculation.
	Absorption	Activated carbon. Synthetic polymeric. Silica-based adsorbent.
Membrane treatment	Nanofiltration	Polyacrylamide.
	Reverse osmosis	Polyamide. Polyacrylamide.
	Microfiltration	Ceramics. Polypropylene.
	Ultrafiltration	Ceramics. Cellulose acetate. Polysulfone. Polyethersulfone. Polyvinylpyrrolidone. Polyacrylonitrile. Polyvinylidene fluoride.

activated carbon, synthetic polymeric, and silica-based adsorbent materials. The membrane treatment technique is the second post-treatment procedure. Meanwhile, these approaches include polyacrylamide-based nanofiltration (NF). In addition, reverse osmosis (RO) comprises two components: polyamide and polyacrylamide. Similarly, microfiltration (MF) contains polysulfone, polyethersulfone, polyvinylpyrrolidone, polyacrylonitrile, and polyvinylidene fluoride.

4. Conclusions

Wastewater treatment procedures have two categories: pre- and post-treatment. Physical, chemical, and biological pretreatment techniques are commonly employed to treat dairy effluent. Second, dairy wastewater post-treatment techniques include physico-chemical and membrane treatment approaches. The findings suggest that despite substantial research on pre- and post-treatment techniques, both have significant shortcomings. Importantly, to reduce energy consumption and to improve efficiency, the physico-chemical treatment, particularly, the adsorption treatment is used as a refinement before the aerobic biological treatment. As a pre-hydrolysis treatment technique, enzymatic hydrolysis is a prominent pre-treatment for the anaerobic biological treatment to reduce the start-up period. The high-quality effluent can be achieved from dairy wastewater treatment and the membrane treatment process. Finally, a combination of biological and physico-chemical treatment (e.g., adsorption-aerobic), a combination of pre-hydrolysis and biological treatment (e.g., enzymatic hydrolysis-anaerobic treatment), and an integration of hybrid membrane treatment with different combinations (e.g., RO, NF, MF, and UF) are future research areas.

Abbreviations

ABR	Anaerobic Baffled Reactor
AD	Anaerobic Digestion
AFBR	Anaerobic Fixed Bed Reactor
AFR	Anaerobic Filter Reactor
ASBR	Anaerobic Sequencing Batch Reactor
BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
CSAC	Coconut Shell Activated Carbon
CSTR	Continuous Stirred Tank Reactor
HRT	Hydraulic Retention Time
MAR	Membrane Anaerobic Reactor
MBR	Membrane Bioreactor
MLSS	Mixed Liquor Suspended Solids
MLVSS	Mixed Liquor Volatile Suspended Solid
MRBC	Membrane Rotating Biological Contactor
NF	Nanofiltration
NTU	Nephelometric Turbidity Unit
ORP	Oxidation Reduction Potentials
PnSB	Purple Non-Sulphur Bacteria

PSF	Polysulfone
PVC	Polyvinyl Chloride
PVDF	Polyvinylidene Fluoride
RBC	Rotating biological contactor
RO	Reverse Osmosis
SMBR	Submerged Membrane Bioreactor
SVI	Sludge Volume Index
TDS	Total Dissolved Solids
TKN	Total Kjeldahi Nitrogen
TN	Total Nitrogen
TOC	Total Organic Carbon
TP	Total Phosphorus
TS	Total Solids
TSS	Total Suspended Solids
UAASB	Up-Flow Anoxic-Aerobic Sludge Bioreactor
UASB	Up-Flow Anaerobic Sludge Blanket
UF	Ultrafiltration
VFA	Volatile Fatty Acids
VSS	Volatile Suspended Solids

Acknowledgments. I am grateful to the JEIL Editorial Office and reviewers for investing the time and effort necessary to evaluate the manuscript. My sincere gratitude goes out to everyone who offered wise comments and suggestions that helped me improve the quality of the manuscript.

References

Abdulgader, M., Yu, Q.J., Zinatizadeh, A.A., Williams, P. and Rahimi, Z. (2020). Performance and kinetics analysis of an aerobic sequencing batch flexible fibre biofilm reactor for milk processing wastewater treatment. *Journal of Environmental Management*. 255, 109793. https://doi.org/10.1016/j.jenvman.2019.109793

Afolabi, T.J., Alade, A.O., Jimoh, M.O. and Fashola, I.O. (2015). Heavy metal ions adsorption from dairy industrial wastewater using activated carbon from milk bush kernel shell. *Desalination and Water Treatment*. 57(31), 14565-14577. https://doi.org/10.1080/19443994.2015.1074619

Ahmad, T., Aadil, R.M., Ahmed, H., Rahman, U.U., Soares, B.C.V., Souza, S.L.Q., Pimentel, T.C., Scudino, H., Guimarães, J.T., Esmerino, E.A., Freitas, M.Q., Almada, R.B., Vendramel, S.M. R., Silva, M.C. and Cruz, A.G. (2019). Treatment and utilization of dairy industrial waste: a review. *Trends in Food Science and Technology*. 88, 361-372. https://doi.org/10.1016/j.tifs.2019.04.003

Al-Ananzeh, N.M. (2021). Treatment of wastewater from a dairy plant by adsorption using synthesized copper oxide nanoparticles: kinetics and isotherms modeling optimization. *Water Science and Technology*. 83(7), 1591-1604. https://doi.org/10.2166/wst.2021.089

Al-Dhabi, N.A., Esmail, G.A., Alzeer, A.F., and Arasu, M.V. (2020). Removal of nitrogen from wastewater of date processing industries using a Saudi Arabian mesophilic bacterium, Stenotrophomonas maltophilia Al-Dhabi-17 in sequencing batch reactor. *Chemosphere*. 268, 128636. https://doi.org/10.1016/j.chemosphere.2020.128636

Al-Jabari, M. (2016). Kinetic mass transfer adsorption model for treating dairy wastewater with stone cutting solid waste. *Environmental Technology and Innovation*. 7, 21-29. https://doi.org/10.1016/j.eti.2016.11.004

Al-Jabari, M., Iqefan, N., Zahdeh, N. and Dweik, H. (2017). Adsorption of organic pollutants from dairy wastewater on soil: Pollution problem and control. *International Journal of Global Environmental Issues*. 16(1-3), 149-161. https://doi.org/10.1504/IJGENVI.2017.083425

Alimoradi, S., Faraj, R. and Torabian, A. (2018). Effects of residual aluminum on hybrid membrane bioreactor (Coagulation-MBR) performance, treating dairy wastewater. *Chemical Engineering and Processing - Process Intensification*. 133, 320-324. https://doi.org/10.1016/j.cep.2018.09.023

Amini, M., Younesi, H., Zinatizadeh Lorestani, A.A. and Najafpour, G. (2013). Determination of optimum conditions for dairy wastewater treatment in UAASB reactor for removal of nutrients. *Bioresource Technology*. 145, 71-79. https://doi.org/10.1016/j.biortech.2013.01.111

Andrade, L.H., Mendes, F.D.S., Espindola, J.C. and Amaral, M.C.S. (2014a). Nanofiltration as tertiary treatment for the reuse of dairy wastewater treated by membrane bioreactor. *Separation and Purification Technology*. 126, 21-29. https://doi.org/10.1016/j.seppur.2014.01.056

Andrade, L.H., Mendes, F.D.S., Espindola, J.C. and Amaral, M.C.S. (2014b). Internal versus external submerged membrane bioreactor configurations for dairy wastewater treatment. *Desalination and Water Treatment*. 52, 2920-2932. https://doi.org/10.1080/19443994.2013.799048

Andrade, L.H., Mendes, F.D.S., Espindola, J.C. and Amaral, M.C.S. (2015). Reuse of dairy wastewater treated by membrane bioreactor and nanofiltration: Technical and economic feasibility. *Brazilian Journal of Chemical Engineering*. 32(3), 735-747. https://doi.org/10.1590/0104-6632.20150323s00003133

Andrade, L.H., Motta, G.E. and Amaral, M.C.S. (2013). Treatment of dairy wastewater with a membrane bioreactor. *Brazilian Journal of Chemical Engineering*. 30(4), 759-770. https://doi.org/10.1590/S0104-66322013000400008

Anu, N., Manikandan, P.M., Parvathy, K.K., Sandra, Nandhana, S.B.N. and Manikandan, K. (2021). Evaluation of dairy effluent treatment efficiency in aerated sequential batch reactor - a numerical approach. The International Conference on Emerging Trends in Engineering Yukthi-21, Government Engineering College Kozhikode, 24-26th September 2021 Evaluation. https://doi.org/10.2139/ssrn.4017869

Ayeche, R. (2012). Treatment by coagulation-flocculation of dairy wastewater with the residual lime of national algerian industrial gases company (NIGC-Annaba). *Energy Procedia*. 18, 147-156. https://doi.org/10.1016/j.egypro.2012.05.026

Aygun, A., Nas, B., Berktay, A. and Ates, H. (2014). Application of sequencing batch biofilm reactor for treatment of sewage wastewater treatment: effect of power failure. *Desalination and Water Treatment*. 52(37-39), 6956-6965. https://doi.org/10.1080/19443994.2013.823354

Azimi, S.C., Shirini, F. and Pendashteh, A. (2019). Evaluation of COD and turbidity removal from woodchips wastewater using biologically sequenced batch reactor. *Process Safety and Environmental Protection*. 128, 211-227. https://doi.org/10.1016/j.psep.2019.05.043

Aziz, H.A., Puat, N.N.A., Alazaiza, M.Y.D. and Hung, Y.T. (2018). Poultry slaughterhouse wastewater treatment using submerged fibers in an attached growth sequential batch reactor. *International Journal of Environmental Research and Public Health*. 15(8), 1734. https://doi.org/10.3390/ijerph15081734

Aziz, S.Q. and Ali, S.M. (2017). Characterization of municipal and dairy wastewaters with 30 quality parameters and potential wastewater treatment by biological trickling filters. *International Journal of Green Energy*. 14(13), 1156-1162. https://doi.org/10.1080/15435075.2017.1370594

Aziz, S.Q. and Ali, S.M. (2019). Treatment of synthetic dairy wastewater using disposed plastic materials as trickling filter media: optimization and statistical analysis by RSM. *Advances in Environmental Biology*. 13(10), 1-16. https://doi.org/10.22587/aeb.2019.13.10.1

Batubara, F., Ritonga, N.A. and Turmuzi, M. (2018). Start-up of upflow anaerobic sludge blanket (UASB) reactor treating slaughterhouse wastewater. *Journal of Physics: Conference Series.* 1116, 042008. https://doi.org/10.1088/1742-6596/1116/4/042008

Benaissa, F., Kermet-Said, H. and Moulai-Mostefa, N. (2014). Optimization and kinetic modeling of electrocoagulation treatment of dairy wastewater. *Desalination and Water Treatment*. 57(13), 5988-5994. https://doi.org/10.1080/19443994.2014.985722

Bennani, C.F., Ousji, B. and Ennigrou, D.J. (2014). Reclamation of dairy wastewater using ultrafiltration process. *Desalination and Water Treatment*. 55(2), 297-303. https://doi.org/10.1080/19443994.2014.913996

Birwal, P., Deshmukh, G., Priyanka., S.S. and Saurabh, S.P. (2017). Advanced Technologies for Dairy Effluent Treatment. *Journal of Food, Nutrition and Population Health*, 1(1), 1-5.

Bortoluzzi, A.C., Faitão, J.A., Di Luccio, M., Dallago, R.M., Steffens, J., Zabot, G.L. and Tres, M.V. (2017). Dairy wastewater treatment using integrated membrane systems. *Journal of Environmental Chemical Engineering*. 5(5), 4819-4827. https://doi.org/10.1016/j.jece.2017.09.018

Bosco, F. and Chiampo, F. (2010). Production of polyhydroxyalcanoates (PHAs) using milk whey and dairy wastewater activated sludge Production of bioplastics using dairy residues. *Journal of Bioscience and Bioengineering*. 109(4), 418-421. https://doi.org/10.1016/j.jbiosc.2009.10.012

Chen, Z.W., Luo, J.Q., Chen, X.R., Hang, X.F., Shen, F. and Wan, Y.H. (2015). Fully recycling dairy wastewater by an integrated isoelectric precipitation-nanofiltration-anaerobic fermentation process. *Chemical Engineering Journal*. 283, 476-485. https://doi.org/10.1016/j.cej.2015.07.086

Chen, Z.W., Luo, J.Q., Hang, X.F. and Wan, Y.H. (2018). Physicochemical characterization of tight nanofiltration membranes for dairy wastewater treatment. *Journal of Membrane Science*. 547, 51-63. https://doi.org/10.1016/j.memsci.2017.10.037

Chen, Z.W., Luo, J.Q., Wang, Y.J., Cao, W.F., Qi, B.K. and Wan, Y.H. (2016). A novel membrane-based integrated process for fractionation and reclamation of dairy wastewater. *Chemical Engineering Journal*. https://doi.org/10.1016/j.cej.2016.10.134

Chen, Z., Wang, Y.K., Li, K. and Zhou, H.B. (2014). Effects of increasing organic loading rate on performance and microbial community shift of an up-flow anaerobic sludge blanket reactor treating diluted pharmaceutical wastewater. *Journal of Bioscience and Bioengineering*. 118(3), 284-288. https://doi.org/10.1016/j.jbiosc.2014.02.027

Chethan, Deshpande, N.A., Chate, V.R. and, Pradeep, N.V. (2015). Treatment of Sewage by using Two-Stage Rotating Biological Contactor (RBC). *Journal of Environment and Earth Science*. 5(1), 116-122.

Choi, Y.K., Jang, H.M., Kan, E., Wallace, A.R. and Sun, W.J. (2019). Adsorption of phosphate in water on a novel calcium hydroxide-coated dairy manure-derived biochar. *Environmental Engineering Research*. 24(3), 434-442. https://doi.org/10.4491/EER.2018.296

Couras, C.S., Louros, V.L., Gameiro, T., Alves, N., Silva, A., Capela, M.I., Arroja, L.M. and Nadais, H. (2015). Anaerobic degradation of dairy wastewater in intermittent UASB reactors: Influence of effluent recirculation. *Environmental Technology*. 36(17), 2227-2238. https://doi.org/10.1080/09593330.2015.1025102

Das, B., Sarkar, S., Sarkar, A., Bhattacharjee, S. and Bhattacharjee, C. (2015). Recovery of whey proteins and lactose from dairy waste: A step towards green waste management. *Process Safety and Environmental Protection*. 101, 27-33. https://doi.org/10.1016/j.psep.2015.05.006

Debowski, M., Zielinski, M., Kisielewska, M. and Kazimierowicz, J. (2020). Evaluation of Anaerobic Digestion of Dairy Wastewater in an Innovative Multi-Section Horizontal Flow Reactor. *Energies*. 13(9), 2392. https://doi.org/doi:10.3390/en13092392

Dehghani, M., Rezaei, M., Shamsedini, N., Maleknia, H. and Javaheri, M.R. (2014). The Effects of Temperature on the Performance of Anaerobic Sequencing Batch Reactor in the Treatment of Synthetic Dairy Wastewater. *Jundishapur Journal of Health Sciences*. 6(4). https://doi.org/10.5812/jjhs.23455

del Álamo, A.C., Pariente, M.I., Martínez, F. and Molina, R. (2020). Trametes versicolor immobilized on rotating biological contactors as alternative biological treatment for the removal of emerging concern micropollutants. *Water Research*. 170, 115313. https://doi.org/10.1016/j.watres.2019.115313

Dela Justina, M., Rodrigues Bagnolin Muniz, B., Mattge Bröring, M., Costa, V.J. and Skoronski, E. (2018). Using vegetable tannin and polyaluminium chloride as coagulants for dairy wastewater treatment: a comparative study. *Journal of Water Process Engineering.* 25, 173-181. https://doi.org/10.1016/j.jwpe.2018.08.001

Delgado, N., Navarro, A., Marino, D., Peñuela, G.A. and Ronco, A. (2018). Removal of pharmaceuticals and personal care products from domestic wastewater using rotating biological contactors. *International Journal of Environmental Science and Technology*. 16, 1-10. https://doi.org/10.1007/s13762-018-1658-2

Deshwal, G.K., Kadyan, S., Sharma, H., Singh, A.K., Panjagari, N.R. and Meena, G.S. (2021). Applications of reverse osmosis in dairy processing: an Indian perspective. *Journal of Food Science and Technology*. 58, 3676-3688. https://doi.org/10.1007/s13197-020-04958-6

Devi, T.P., Ebenezer, A.V., Kumar, S.A., Kaliappan, S. and Banu, J.R. (2014). Effect of deflocculation on the efficiency of disperser induced dairy waste activated sludge disintegration and treatment cost. *Bioresource Technology*. 167, 151-158. https://doi.org/10.1016/j.biortech.2014.06.004

Ebrahimi, A., Najafpour, G.D., Anazadeh, M. and Ghavami, M. (2018a). Optimization of whey treatment in rotating biological contactor: application of taguchi method. *Iranian Journal of Energy and Environment*. 9(2), 146-152. https://doi.org/10.5829/ijee.2018.09.02.10

Ebrahimi, M., Kazemi, H., Mirbagheri, S.A. and Rockaway, T.D. (2018b). Integrated approach to treatment of high-strength organic wastewater by using anaerobic rotating biological contactor. *Journal of Environmental Engineering*. 144(2). https://doi.org/10.1061/(asce)ee.1943-7870.0001312

Elangovan, C. and Sekar, A.S.S. (2015). Performance evaluation of upflow anaerobic sludge blanket reactor process for dairy wastewater treatment. *Journal of Environmental Biology*. 36(6), 1305-1310.

Emerald, F.M.E., Prasad, D.S.A., Ravindra, M.R. and Pushpadass, H.A. (2012). Performance and biomass kinetics of activated sludge system treating dairy wastewater. *International Journal of Dairy Technology*. 65(4), 609-615. https://doi.org/10.1111/j.1471-0307.2012.00850.x

Erdirencelebi, D. (2011). Treatment of high-fat-containing dairy wastewater in a sequential UASBR system: Influence of recycle. *Journal of Chemical Technology and Biotechnology*. 86(4), 525-533. https://doi.org/10.1002/jctb.2546

Falahati, F., Baghdadi, M. and Aminzadeh, B. (2018). Treatment of dairy wastewater by graphene oxide nanoadsorbent and sludge separation, using In Situ Sludge Magnetic Impregnation (ISSMI). *Pollution*. 4(1), 29-41. https://doi.org/10.22059/poll.2017.233196.276

Farizoglu, B. and Uzuner, S. (2011). The investigation of dairy industry wastewater treatment in a biological high performance membrane system. *Biochemical Engineering Journal*. 57(1), 46-54. https://doi.org/10.1016/j.bej.2011.08.007

Formentini-Schmitt, D.M., Fagundes-Klen, M.R., Veit, M.T., Palácio, S.M., Trigueros, D.E.G., Bergamasco, R. and Mateus, G.A.P. (2018). Potential of the Moringa oleifera saline extract for the treatment of dairy wastewater: application of the response surface methodology. *Environmental Technology*. 40(17), 2290-2299. https://doi.org/10.1

080/09593330.2018.1440012
Fraga, F.A., García, H.A., Hooijmans, C.M., Míguez, D. and Brdjanovic, D. (2016). Evaluation of a membrane bioreactor on dairy wastewater treatment and reuse in Uruguay. *International Biodeterioration and Biodegradation*. 1-13. https://doi.org/10.1016/j.ibiod.2016.11.025
Gayathri, T., Kavitha, S., Adish Kumar, S., Kaliappan, S., Yeom, I.T. and Rajesh Banu, J. (2015). Effect of citric acid induced deflocculation on the ultrasonic pretreatment efficiency of dairy waste activated sludge. *Ultrasonics Sonochemistry*. 22, 333-340. https://doi.org/10.1016/j.ultsonch.2014.07.017
Gong, Y.W., Zhang, H.X. and Cheng, X.N. (2012). Treatment of dairy wastewater by two-stage membrane operation with ultrafiltration and nanofiltration. *Water Science and Technology*. 65(5), 915-919. https://doi.org/10.2166/wst.2012.937
Gotmare, M., Dhoble, R.M. and Pittule, A.P. (2011). Biomethanation of dairy waste water through UASB at mesophilic temperature range. *International Journal of Advanced Engineering Sciences and Technologies*. 8(1), 001-009.
Gundkal, P.S., Bagawan, S.A., Hogarti, M.J., Patil, O.V. and Bannur, R.R. (2019). Treatment of dairy industry wastewater by hybrid upflow anaerobic sludge blanket reactor. *International Research Journal of Engineering and Technology*. 06(09), 1257-1263.
Hamasaki, T., Hung, P.D. and Tsuno, H. (2017). Removal of organic matter in wastewaters of a milk factory and a hospital using a cubic lattice based rotating biological contactor in Vietnam. *International Journal of GEOMATE*. 12(32), 37-42. https://doi.org/10.21660/2017.32.6589
Heidari, M.R., Malakootian, M., Boczkaj, G., Sun, X., Tao, Y., Sonawane, S.H. and Mehdizadeh, H. (2021). Evaluation and start-up of an electro-Fenton-sequencing batch reactor for dairy wastewater treatment. *Water Resources and Industry*. 25, 100149. https://doi.org/10.1016/j.wri.2021.100149
Hepsen, R. and Kaya, Y. (2012). Optimization of membrane fouling using experimental design: an example from dairy wastewater treatment. *Industrial and Engineering Chemistry Research*. 51(49), 16074-16084. https://doi.org/10.1021/ie302450s
Heydari, B., Rafiee, S., Sharghi, E.A. and Mohtasebi, S.S. (2019). Considering an Up-Flow Anaerobic Sludge Blanket for the Treatment of Spearmint Essential Oil Wastewater and Biogas Production. *Journal of Renewable Energy and Environment*. 6(2), 1-7.
Ionescu, I.A., Bumbac, C. and Cornea, P. (2015). Formation of Aerobic Granules in Sequencing Batch Reactor SBR Treating Dairy Industry Wastewater. *Scientific Bulletin. Series F. Biotechnologies*. 19, 235-238.
Islam, M.N., Park, K.J. and Alam, M.J. (2011). Treatment of swine wastewater using sequencing batch reactor. *Engineering in Agriculture, Environment and Food*. 4(2), 47-53. https://doi.org/10.1016/S1881-8366(11)80020-0
Iwuozor, K.O. (2019). Prospects and Challenges of Using Coagulation-Flocculation method in the treatment of Effluents. *Advanced Journal of Chemistry-Section A*. 2(2), 105-127. https://doi.org/10.29088/sami/ajca.2019.2.105127
Jafarinejad, S. (2017). Recent developments in the application of sequencing batch reactor (SBR) technology for the petroleum industry wastewater treatment. *Chemistry International*. 3(3), 342-350.
Janczukowicz, W., Rodziewicz, J., Czaplicka, K., Kłodowska, I. and Mielcarek, A. (2013). The effect of volatile fatty acids (VFAs) on nutrient removal in SBR with biomass adapted to dairy wastewater. *Journal of Environmental Science and Health - Part A: Toxic/Hazardous Substances and Environmental Engineering*. 48(7), 809-816. https://doi.org/10.1080/10934529.2013.744658
Janczukowicz, W., Rodziewicz, J., Thornton, A. and Czaplicka, K. (2012). Effect of fermented wastewaters from butter production on phosphates removal in a sequencing batch reactor. *Bioresource Technology*. 120, 34-39. https://doi.org/10.1016/j.biortech.2012.06.020
Janet Joshiba, G., Senthil Kumar, P., Femina, C.C., Jayashree, E., Racchana, R. and Sivanesan, S. (2019). Critical review on biological treatment strategies of dairy wastewater. *Desalination and Water Treatment*. 160, 94-109. https://doi.org/10.5004/dwt.2019.24194
Jeswani, H. and Mukherji, S. (2012). Degradation of phenolics, nitrogen-heterocyclics and polynuclear aromatic hydrocarbons in a rotating biological contactor. *Bioresource Technology*. 111, 12-20. https://doi.org/10.1016/j.biortech.2012.01.157
Ji, S.P., Ma, W.Y., Wei, Q.W., Zhang, W.S., Jiang, F.Z. and Chen, J. (2020). Integrated ABR and UASB system for dairy wastewater treatment: Engineering design and practice. *Science of the Total Environment*. 749, 142267. https://doi.org/10.1016/j.scitotenv.2020.142267
Jin, Z., Zhao, Z.Q. and Zhang, Y.B. (2019). Potential of direct interspecies electron transfer in synergetic enhancement of methanogenesis and sulfate removal in an up-flow anaerobic sludge blanket reactor with magnetite. *Science of the Total Environment*. 677, 299-306. https://doi.org/10.1016/j.scitotenv.2019.04.372
Jo, Y., Kim, J. and Lee, C. (2016). Continuous treatment of dairy effluent in a downflow anaerobic filter packed with slag grains: Reactor performance and kinetics. *Journal of the Taiwan Institute of Chemical Engineers*. 68, 147-152. https://doi.org/10.1016/j.jtice.2016.08.021
Jyothi, C.S., and Bindu, A.G. (2017). Feasibility of anaerobic fluidized membrane bioreactor (AFMBR) in the treatment of dairy wastewater - a review. *International Journal of Innovative Research in Science and Engineering*. 03(01), 363-369.
Kaewsuk, J., Thorasampan, W., Thanuttamavong, M. and Seo, G.T. (2010). Kinetic development and evaluation of membrane sequencing batch reactor (MSBR) with mixed cultures photosynthetic bacteria for dairy wastewater treatment. *Journal of Environmental Management*. 91(5), 1161-1168. https://doi.org/10.1016/j.jenvman.2010.01.012
Kamath, A., Kharat, O., Mehta, R., Kalsekar, S. and Patil, D. (2018). Treatment of Dairy Effluent using Rotating Biological Contactors (RBC). *International Research Journal of Engineering and Technology.* 5(3), 2862-2866.
Karadag, D., Koroglu, O.E., Ozkaya, B., Cakmakci, M., Heaven, S., Banks, C. and Serna-Maza, A. (2015). Anaerobic granular reactors for the treatment of dairy wastewater: A review. *International Journal of Dairy Technology*. 68(4), 459-470. https://doi.org/10.1111/1471-0307.12252
Karadag, D., Köroılu, O.E., Ozkaya, B. and Cakmakci, M. (2014). A review on anaerobic biofilm reactors for the treatment of dairy industry wastewater. *Process Biochemistry*. 50(2), 262-271. https://doi.org/10.1016/j.procbio.2014.11.005
Karale, S.S. and Suryavanshi, M.M. (2014). Dairy wastewater treatment using coconut shell activated carbon & laterite as low cost adsorbents. *Civil, Structural, Environmental and Infrastructure Engineering*. 4(2), 9-14. http://www.tjprc.org/publishpapers/2-11-1394784122-2. Sheetal S Karale IJCSEIERD. full.pdf
Kayranli, B. and Ugurlu, A. (2011). Effects of temperature and biomass concentration on the performance of anaerobic sequencing batch reactor treating low strength wastewater. *Desalination*. 278(1-3), 77-83. https://doi.org/10.1016/j.desal.2011.05.011
Kim, S.H. and Shin, H.S. (2010). Enhanced Lipid Degradation in an Upflow Anaerobic Sludge Blanket Reactor by Integration with an Acidogenic Reactor. *Water Environment Research*. 82(3), 267-272. https://doi.org/10.2175/106143009x442899
Kowalska, E., Paturej, E. and Zielińska, M. (2014). Use of Lecane rotifers for limiting Thiothrix filamentous bacteria in bulking activated sludge in a dairy wastewater treatment plant. *Archives of Biological Sciences*. 66(4), 1371-1378. https://doi.org/10.2298/ABS1404371K
Kulkarni, P.M. (2012). Effect of shock and mixed loading on the performance of SND based sequencing batch reactors (SBR) degrading

nitrophenols. *Water Research*. 46(7), 2405-2414. https://doi.org/10.1016/j.watres.2012.02.008

Kumar, R.V., Goswami, L., Pakshirajan, K. and Pugazhenthi, G. (2016). Dairy wastewater treatment using a novel low cost tubular ceramic membrane and membrane fouling mechanism using pore blocking models. *Journal of Water Process Engineering*. 13, 168-175. https://doi.org/10.1016/j.jwpe.2016.08.012

Kumari, P., Prakash Kushwaha, J., Sangal, V.K. and Singh, N. (2019). Dairy wastewater treatment in continuous stirred tank electrochemical reactor (CSTER): Parametric optimization and kinetics. *Environmental Engineering and Management Journal*. 18(6), 1219-1230. https://doi.org/10.30638/eemj.2019.117

Kurup, G.G., Adhikari, B. and Zisu, B. (2019). Treatment performance and recovery of organic components from high pH dairy wastewater using low-cost inorganic ferric chloride precipitant. *Journal of Water Process Engineering*. 32, 100908. https://doi.org/10.1016/j.jwpe.2019.100908

Kurzbaum, E. and Bar Shalom, O. (2016). The potential of phosphate removal from dairy wastewater and municipal wastewater effluents using a lanthanum-modified bentonite. *Applied Clay Science*. 123, 182-186. https://doi.org/10.1016/j.clay.2016.01.038

Kushwaha, J.P., Srivastava, V.C. and Mall, I.D. (2011). An overview of various technologies for the treatment of dairy wastewater. *Critical Reviews in Food Science and Nutrition*. 51(5), 442-452. https://doi.org/10.1080/10408391003663879

Kyrychuk, I., Zmievskii, Y. and Myronchuk, V. (2014). Treatment of dairy effluent model nanofiltration and reverse osmosis solutions by nanofiltration and reverse osmosis. *Processes and Equipment of Food Productions*. 3(2), 280-287.

Lateef, A., Chaudhry, M.N. and Ilyas, S. (2013). Biological treatment of dairy wastewater using activated sludge. *ScienceAsia*. 39, 179-185. https://doi.org/10.2306/scienceasia1513-1874.2013.39.179

Lavanya, R. and Jodhi, C. (2016). Evaluation Studies on Hybrid up Flow Anaerobic Sludge Blanket Reactor for Treating Dairy Effluent under Different Season. *International of Journal of Engineering Research and Applications*. 6(3), 61-66.

Leonard, P., Tarpey, E., Finnegan, W. and Zhan, X.M. (2018). Efficient treatment of dairy processing wastewater in a laboratory scale Intermittently Aerated Sequencing Batch Reactor (IASBR). *Journal of Dairy Research*. 85(3), 379-383. https://doi.org/10.1017/S0022029918000584

Li, X.M., Jiang, L. and Li, H.X. (2018). Application of Ultrafiltration Technology in Water Treatment. IOP Conference Series: *Earth and Environmental Science*. 186(3), 012009. https://doi.org/10.1088/1755-1315/186/3/012009

Lim, B.C., Lim, J.W., Mohamed Kutty, S.R. and Ho, Y.C. (2020). A review on organic removal of manicipal and industrial wastewater using up-flow anaerobic sludge blanket (UASB) and its application in anammox process. *A Journal of Science & Technology*. 3(2), 2-13. https://myjms.mohe.gov.my/index.php/pjst/article/view/6147

Lim, S.J. and Fox, P. (2011). A kinetic analysis and experimental validation of an integrated system of anaerobic filter and biological aerated filter. *Bioresource Technology*. 102(22), 10371-10376. https://doi.org/10.1016/j.biortech.2011.09.005

Loloei, M., Nekonam, G., Alidadi, H. and Kor, Y. (2014). Study of the coagulation process in wastewater treatment of dairy industries. *International Journal of Environmental Health Engineering*. 3(12). https://doi.org/10.4103/2277-9183.132684

Luo, J.Q. and Ding, L.H. (2011). Influence of pH on treatment of dairy wastewater by nanofiltration using shear-enhanced filtration system. *Desalination*. 278(1-3), 150-156. https://doi.org/10.1016/j.desal.2011.05.025

Luo, J.Q., Ding, L.H., Qi, B.K., Jaffrin, M.Y. and Wan, Y.H. (2011). A two-stage ultrafiltration and nanofiltration process for recycling dairy wastewater. *Bioresource Technology*. 102(16), 7437-7442. https://doi.org/10.1016/j.biortech.2011.05.012

Luo, J.Q., Ding, L.H., Wan, Y.H. and Jaffrin, M.Y. (2012). Threshold flux for shear-enhanced nanofiltration: Experimental observation in dairy wastewater treatment. *Journal of Membrane Science*. 409-410, 276-284. https://doi.org/10.1016/j.memsci.2012.03.065

Luo, J.Q., Ding, L.H., Wan, Y.H., Paullier, P. and Jaffrin, M.Y. (2010). Application of NF-RDM (nanofiltration rotating disk membrane) module under extreme hydraulic conditions for the treatment of dairy wastewater. *Chemical Engineering Journal*. 163(3), 307-316. https://doi.org/10.1016/j.cej.2010.08.007

Luo, J.Q., Ding, L.H., Wan, Y.H., Paullier, P. and Jaffrin, M.Y. (2012). Fouling behavior of dairy wastewater treatment by nanofiltration under shear-enhanced extreme hydraulic conditions. *Separation and Purification Technology*. 88, 79-86. https://doi.org/10.1016/j.seppur.2011.12.008

Mainardis, M., Buttazzoni, M. and Goi, D. (2020). Up-flow anaerobic sludge blanket (UASB) technology for energy recovery: A review on state-of-the-art and recent technological advances. *Bioengineering*. 7(2). 43. https://doi.org/10.3390/bioengineering7020043

Marszałek, A. and Puszczało, E. (2020). Effect of Photooxidation on Nanofiltration Membrane Fouling During Wastewater Treatment from the Confectionery Industry. *Water*. 12(793). https://doi.org/doi:10.3390/w12030793

Mateus, G.A.P., Formentini-Schmitt, D.M., Nishi, L., Fagundes-Klen, M.R., Gomes, R.G. and Bergamasco, R. (2017). Coagulation/Flocculation with Moringa oleifera and Membrane Filtration for Dairy Wastewater Treatment. *Water, Air, and Soil Pollution*. 228(342). https://doi.org/10.1007/s11270-017-3509-z

Matsumoto, E.M., Osako, M.S., Pinho, S.C., Tommaso, G., Gomes, T.M. and Ribeiro, R. (2012). Treatment of wastewater from dairy plants using anaerobic sequencing batch reactor (ASBR) following by aerobic sequencing batch reactor (SBR) aiming the removal of organic matter and nitrification. *Water Practice and Technology*. 7(3). wpt2012048. https://doi.org/10.2166/wpt.2012.048

McAteer, P.G., Christine Trego, A., Thorn, C., Mahony, T., Abram, F. and O'Flaherty, V. (2020). Reactor configuration influences microbial community structure during high-rate, low-temperature anaerobic treatment of dairy wastewater. *Bioresource Technology*. 307, 123221. https://doi.org/10.1016/j.biortech.2020.123221

Mehrdadi, N., Bidhendi, G.R.N. and Shokouhi, M. (2012). Deter-mination of dairy wastewater treatability by bio-trickling filter packed with lava rocks - case study PEGAH dairy factory. *Water Science and Technology*. 65(8), 1441-1447. https://doi.org/10.2166/wst.2012.032

Mobarak-Qamsari, E., Kasra-Kermanshahi, R., Nosrati, M. and Amani, T. (2012). Enzymatic Pre-Hydrolysis of high fat Content Dairy Wastewater as a Pretreatment for Anaerobic Digestion. *International Journal of Environment Research*. 6(2), 475-480. https://doi.org/10.22059/ijer.2012.516

Moradi, O. and Maleki, M.S. (2013). Removal of COD from dairy wastewater by MWCNTs: adsorption isotherm modeling. *Fullerenes Nanotubes and Carbon Nanostructures*. 21(10), 836-848. https://doi.org/10.1080/1536383X.2011.613547

Mulyanti, R. and Susanto, H. (2018). Wastewater treatment by nanofiltration membranes. *IOP Conference Series: Earth and Environmental Science*. 142. https://doi.org/10.1088/1755-1315/142/1/012017

Muniz, G.L., Pereira, M.D.S. and Borges, A.C. (2021). Dairy wastewater treatment with organic coagulants: A comparison of factorial designs. *Water*. 13(2240). https://doi.org/10.3390/w13162240

Muniz, G.L., Silva, T.C.F.D. and Borges, A.C. (2020). Assessment and optimization of the use of a novel natural coagulant (Guazuma ulmifolia) for dairy wastewater treatment. *Science of the Total Environment*. 744, 140864. https://doi.org/10.1016/j.scitotenv.2020.140864

Nagappan, S., Phinney, D.M. and Heldman, D.R. (2018). Management of waste streams from dairy manufacturing operations using membrane filtration and Dissolved Air Flotation. *Applied Sciences*. 8(12), 2694. https://doi.org/10.3390/app8122694

Najafpour, G.D., Hashemiyeh, B.A., Asadi, M. and Ghasemi, M.B. (2008). Biological treatment of dairy wastewater in an upflow anaerobic sludge-fixed film bioreactor. *American-Eurasian Journal of Agricultural & Environmental Sciences*. 4(2), 251-257.

Nasr, M., Elreedy, A., Abdel-Kader, A., Elbarki, W. and Moustafa, M. (2014). Environmental consideration of dairy wastewater treatment using hybrid sequencing batch reactor. *Sustainable Environment Research*. 24(6), 449-456.

Ozturk, A., Aygun, A. and Nas, B. (2019). Application of sequencing batch biofilm reactor (SBBR) in dairy wastewater treatment. *Korean Journal of Chemical Engineering*. 36(2), 248-254. https://doi.org/10.1007/s11814-018-0198-2

Palakshappa, K., Sneha, M.K. and Chiranjeevi, M.R. (2019). Feasibility studies on the treatment of dairy wastewater using rotating biological contactor (RBC) under variable experimental conditions. *Think INDIA Journal*. 22(16), 3062-3066. https://doi.org/10.2139/ssrn.3511456

Pannirselvam, R., Ibrahim, Y. and Navaneetha Gopalakrishnan, A. (2015). Simultaneous carbon and nutrient removal from dairy wastewater in sequencing batch reactor (SBR). *Global Nest Journal*. 17(3), 628-636. https://doi.org/10.30955/gnj.001671

Passeggi, M., López, I. and Borzacconi, L. (2012). Modified UASB reactor for dairy industry wastewater: Performance indicators and comparison with the traditional approach. *Journal of Cleaner Production*. 26, 90-94. https://doi.org/10.1016/j.jclepro.2011.12.022

Picos-Benítez, A.R., López-Hincapié, J.D., Chávez-Ramírez, A.U. and Rodríguez-García, A. (2017). Artificial intelligence based model for optimization of COD removal efficiency of an up-flow anaerobic sludge blanket reactor in the saline wastewater treatment. *Water Science and Technology*. 75(6), 1351-1361. https://doi.org/10.2166/wst.2017.005

Porwal, H.J., Mane, A.V. and Velhal, S.G. (2015). Biodegradation of dairy effluent by using microbial isolates obtained from activated sludge. *Water Resources and Industry*. 9, 1-15. https://doi.org/10.1016/j.wri.2014.11.002

Qazi, J.I., Nadeem, M. and Baig, S.S. (2011). Anaerobic fixed film biotreatment of dairy wastewater. *Middle-East Journal of Scientific Research*. 8(3), 590-593.

Banu, J.R., Arulazhagan, P., Kumar, S.A., Kaliappan, S. and Lakshmi, A.M. (2015). Anaerobic co-digestion of chemical- and ozone-pretreated sludge in hybrid upflow anaerobic sludge blanket reactor. *Desalination and Water Treatment*. https://doi.org/10.1080/19443994.2014.912156

Ribeiro, R., von Atzingen, G.V., Lima, F., Okamoto, V.H.T., Arce, A.I.C., Tomamso, G. and da Costa, E.J.X. (2017). Real-time control system based on the values of derivative of the redox potential aiming nitrogen removal in a sequencing batch reactor applied in treating dairy wastewater. *Water, Air, and Soil Pollution*. 228(231), https://doi.org/10.1007/s11270-017-3401-x

Riera, F.A., Suárez, A. and Muro, C. (2013). Nanofiltration of UHT flash cooler condensates from a dairy factory: Characterisation and water reuse potential. *Desalination*. 309, 52-63. https://doi.org/10.1016/j.desal.2012.09.016

Rivas, J., Prazeres, A.R., Carvalho, F. and Beltrán, F. (2010). Treatment of cheese whey wastewater: combined coagulation – flocculation and aerobic biodegradation. *Journal of Agricultural and Food Chemistry*. 58, 7871-7877. https://doi.org/10.1021/jf100602j

Rodríguez, D.C., Ramírez, O. and Mesa, G.P. (2011). Behavior of nitrifying and denitrifying bacteria in a sequencing batch reactor for the removal of ammoniacal nitrogen and organic matter. *Desalination*. 273, 447-452. https://doi.org/10.1016/j.desal.2011.01.068

Salari, M., Ataei, S.A. and Bakhtiyari, F. (2017). Evaluation of sequencing batch reactor performance for petrochemical wastewater treatment. *Advances in Environmental Technology*. 3(3), 133-137. https://doi.org/10.22104/AET.2017.576

Samadi, F. and Mirbagheri, S.A. (2019). Biogas producibility and kinetic evaluation of anaerobic rotating biological contactors. *Water and Environment Journal*. 34(4), 575-583. https://doi.org/10.1111/wej.12486

Sarkar, B., Chakrabarti, P.P., Vijaykumar, A. and Kale, V. (2006). Wastewater treatment in dairy industries - possibility of reuse. *Desalination*. 195(1-3), 141-152. https://doi.org/10.1016/j.desal.2005.11.015

Shabna Banu, A.M. and Meena John, M. (2017). Pre-treatment of dairy waste water using biopolymeric flocculant extracted from orange peel. *International Journal of Advance Research in Science and Engineering*. 6(5), 360-371.

Shahriari, T. and Shokouhi, M. (2015). Assessment of bio-trickling filter startup fortreatment of industrial wastewater. *International Journal of Environmental Research*. 9(2), 769-776.

Sharmila, V.G., Kavitha, S., Rajashankar, K., Yeom, I.T. and Banu, J.R. (2015). Effects of titanium dioxide mediated dairy waste activated sludge deflocculation on the efficiency of bacterial disintegration and cost of sludge management. *Bioresource Tech- nology*. 197, 64-71. https://doi.org/10.1016/j.biortech.2015.08.038

Shete, B.S. and Shinkar, N.P. (2013). Comparative study of various treatments for dairy industry wastewater. *IOSR Journal of Engineering*. 03(08), 42-47. https://doi.org/10.9790/3021-03844247

Shivayogimath, C.B. and Naik, V.R. (2014). Treatment of dairy industry wastewater using an electrocoagulation technique. *International Journal of Engineering Research & Technology*. 3(7), 971-974.

Shivsharan, V.S., Wani, M.P., and Kulkarani, S.W. (2013). Isolation of microorganism from dairy effluent for activated sludge treatment. *International Journal of Computational Engineering Research*. 3(3), 161-167.

Singh, M. and Srivastava, R.K. (2011). Sequencing batch reactor technology for biological wastewater treatment: a review. *Asia-Pacific Journal of Chemical Engineering*. 6(3-13), https://doi.org/10.1002/apj.490

Sisay, E.J. and László, Z. (2021). Trend and novel possibilities of dairy wastewater treatment by membrane filtration. *Journal of Engineering Science and Technology Review*. 14(1), 46-55. https://doi.org/10.25103/jestr.141.04

Sivaprakasam, S. and Balaji, K. (2020). A review of upflow anaerobic sludge fixed film (UASFF) reactor for treatment of dairy wastewater. *Materials Today: Proceedings.* 43(2), 1879-1883. https://doi.org/10.1016/j.matpr.2020.10.822

Slavov, A.K. (2017). General characteristics and treatment possibilities of dairy wastewater - a review. *Food Technology and Biotechnology*. 55(1), 14-28. https://doi.org/10.17113/ftb.55.01.17.4520

Soliman, M. and Eldyasti, A. (2016). Development of partial nitrification as a first step of nitrite shunt process in a sequential batch reactor (SBR) using ammonium oxidizing bacteria (AOB) controlled by mixing regime. *Bioresource Technology*. 221, 85-95. https://doi.org/10.1016/j.biortech.2016.09.023

Struk-Sokoowska, J., Rodziewicz, J. and Mielcarek, A. (2018). Effect of dairy wastewater on changes in COD fractions in technical-scale SBR type reactors. *Water Science and Technology*. 2017(1), 156-169. https://doi.org/10.2166/wst.2018.099

Suman, A., Ahmad, T. and Ahmad, K. (2018). Dairy wastewater treatment using water treatment sludge as coagulant: a novel treatment approach. *Environment, Development and Sustainability*. 20, 1615-1625. https://doi.org/10.1007/s10668-017-9956-2

Tan, L.C., Peschard, R., Deng, Z., Ferreira, A.L.M., Lens, P.N.L. and Pacheco-Ruiz, S. (2021). Anaerobic digestion of dairy wastewater by side-stream membrane reactors: Comparison of feeding regime and its impact on sludge filterability. *Environmental Technology & Innovation*. 22, 101482. https://doi.org/10.1016/j.eti.2021.101482

Teh, C.Y., Budiman, P.M., Shak, K. P.Y. and Wu, T.Y. (2016). Recent advancement of coagulation-flocculation and its application in wastewater treatment. *Industrial and Engineering Chemistry Re-*

search. 55(16), 4363-4389. https://doi.org/10.1021/acs.iecr.5b04703

Thenmozhi, R. and Uma, R.N. (2012). Treatability studies of dairy wastewater by upflow anaerobic sludge blanket reactor. *Journal of Civil and Environmental Research*. 2(2), 43-49.

Thenmozhi, R. and Uma, R.N. (2013). Performance evaluation of hybrid upflow anaerobic sludge blanket reactor in the treatment of dairy waste water. *The International Journal of Biotechnology*. 2(5), 105-112.

Tricolici, O., Bumbac, C., Patroescu, V. and Postolache, C. (2014). Dairy wastewater treatment using an activated sludge-microalgae system at different light intensities. *Water Science and Technology*. 69(8), 1598-1605. https://doi.org/10.2166/wst.2013.752

Uma Rani, R., Adish Kumar, S., Kaliappan, S., Yeom, I.T. and Rajesh Banu, J. (2013). Impacts of microwave pretreatments on the semi-continuous anaerobic digestion of dairy waste activated sludge. *Waste Management*. 33, 1119-1127. https://doi.org/10.1016/j.wasman.2013.01.016

Vibhhute, H.V. and Ingavale, B. (2020). Effect of F/M ratio on the performance of sequencing batch reactor for dairy wastewater treatment. *Aquademia*. 4(2), ep20021. https://doi.org/https://doi.org/10.29333/aquademia/8422

Vlyssides, A.G., Tsimas, E.S., Barampouti, E.M.P. and Mai, S.T. (2012). Anaerobic digestion of cheese dairy wastewater following chemical oxidation. *Biosystems Engineering*. 113, 253-258. https://doi.org/10.1016/j.biosystemseng.2012.09.001

Wang, Z.W., Ma, J.W. and Chen, S.L. (2011). Bipolar effects of settling time on active biomass retention in anaerobic sequencing batch reactors digesting flushed dairy manure. *Bioresource Technology*. 102(2), 697-702. https://doi.org/10.1016/j.biortech.2010.08.045

Waqas, S., Bilad, M.R., Aqsha, A., Yub Harun, N., Ayoub, M., Wirzal, M.D.H., Jaafar, J., Mulyati, S. and Elma, M. (2021). Effect of membrane properties in a membrane rotating biological contactor for wastewater treatment. *Journal of Environmental Chemical Engineering*. 9, 104869. https://doi.org/10.1016/j.jece.2020.104869

Wolf, G., Schneider, R.M., Bongiovani, M.C., Morgan Uliana, E. and Garcia Do Amaral, A. (2015). Application of coagulation/flocculation process of dairy wastewater from conventional treatment using natural coagulant for reuse. *Chemical Engineering Transactions*. 43, 2041-2046. https://doi.org/10.3303/CET1543341

Yahi, H., Madi, N. and Midoune, K. (2014). Contribution to biological treatment of dairy effluent by sequencing batch reactor (SBR). *Desalination and Water Treatment*. 52(10-12), 2315-2321. https://doi.org/10.1080/19443994.2013.878254

Yang, G., Fang, H.Y., Wang, J., Jia, H. and Zhang, H.W., (2019). Enhanced anaerobic digestion of up-flow anaerobic sludge blanket (UASB) by blast furnace dust (BFD): feasibility and mechanism. International *Journal of Hydrogen Energy*. 44(53), 17709-17719. https://doi.org/10.1016/j.ijhydene.2019.05.154

Yeshanew, M.M., Frunzo, L., Pirozzi, F., Lens, P.N.L. and Esposito, G. (2016). Production of biohythane from food waste via an integrated system of continuously stirred tank and anaerobic fixed bed reactors. *Bioresource Technology*. 220, 312-322. https://doi.org/10.1016/j.biortech.2016.08.078

Zhao, K., Wu, Y.W., Young, S. and Chen, X.J. (2020). Biological Treatment of Dairy Wastewater: A Mini Review. *Journal of Environmental Informatics Letters*. 4(1), 22-31. https://doi.org/10.3808/jeil.202000036

Zhuang, H.F., Zhu, H., Shan, S.D., Zhang, L.T., Fang, C.R. and Shi, Y. (2018). Potential enhancement of direct interspecies electron transfer for anaerobic degradation of coal gasification wastewater using up-flow anaerobic sludge blanket (UASB) with nitrogen doped sewage sludge carbon assisted. *Bioresource Technology*. 270, 230-235. https://doi.org/10.1016/j.biortech.2018.09.012

Zinadini, S., Vatanpour, V., Zinatizadeh, A.A., Rahimi, M., Rahimi, Z. and Kian, M. (2015). Preparation and characterization of antifouling graphene oxide/polyethersulfone ultrafiltration membrane: application in MBR for dairy wastewater treatment. *Journal of Water Process Engineering*. 7, 280-294. https://doi.org/10.1016/j.jwpe.2015.07.005

Zinatizadeh, A.A., Akhbari, A., Farhadian, M., Mansouri, Y., Pirsaheb, M. and Amirsaie, R. (2011). Influence of process and operational factors on a sequencing batch reactor (SBR) performance treating stimulated dairy wastewater. *International Journal of Natural Resources and Marine Sciences*. 0(2), 111-124.

Zyłka, R.M., Dabrowski, W., Gogina, E. and Yancen, O. (2018). Trickling filter for high efficiency treatment of dairy sewage. *Journal of Ecological Engineering*. 19(4), 269-275. https://doi.org/10.12911/22998993/89657