Journal of Engineering and Sustainable Development
https://jeasd.uomustansiriyah.edu.iq/index.php/jeasd
https://doi.org/10.31272/jeasd.27.5.7

Vol. 27, No. 04, September 2023
ISSN 2520-0917

Original Research

THE ALUM WITH AUSTRALIAN PORCELANITE ROCKS EFFECT ON TREATING AND REMOVAL OF PHOSPHORUS FROM DAIRY WASTEWATER

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Received 26/03/2022 ***Accepted in revised form 28/06/2022*** ***Published 01/09/2023***

Abstract: The dairy industry is a vital food industry in the world. The dairy industry discharges large quantities of wastewater. In this article, it has been used jar test model JLT 6 Leaching test VELP Scientific, with all apparatuses and tools that can complete work. Alum, as well as Porcelanite Rocks from the North Territory area in Australia, were used as a treatment material for the removal of phosphorus. Results showed the effectiveness of phosphorous removal using alum improves when using these rocks because they contain different concentrations of positive ions in general and aluminium ions in particular. The optimum value of Al^{3+} is 0.5 mg/L. The percent of removal of phosphorus will reach 95.7%- 96% by 1.45 mg/L of the aluminium ion. The use of Porcelanite Rocks alone. cannot lead to clear removal of phosphorous or pollutants, rather it is used as an aid. The results also showed that Porcelanite rocks play a prominent role in preparing the therapeutic conditions for alum in terms of regulating the pH for better treatment, as they raise the pH at a time when the sulphates are reduced. With 20 mg/L of Porcelanite rocks, it has been completed the best removal of phosphorus at 20 ºC. Using alum with Porcelanite rocks as assistance in treatment will improve treatment by 30-40%. This process will drop residual aluminium concentration by about 10% from the total and then exclude health effects due to aluminium ions.

Keywords: *Dairy wastewater; gradient velocity; Porcelainite; phosphorus; Alum*

1. Introduction

In some countries, the dairy industry is the main source of state administration and may be equivalent to oil in others. Australia and many European countries depend on milk as an important source for the country's economy, in addition to being a major food item. [1-3]. Meanwhile, the treatment process of this type needs biological requirements, and the amount of energy will be required to provide these requirements. Poor handling of nutrients in anaerobic treatment is also a major obstacle in the application of biological treatments. The main point is either to resort to the use of large quantities of air or not to resort to anaerobic treatment and the subsequent side effects such as odors and other side problems [8-11]. Therefore, researchers research into physic-chemical methods like adsorption, electrical coagulation, and coagulation-flocculation for wastewater treatment of dairy products. Immense abolition of COD, BOD, TS, TN, and other organic compounds from dairy wastewater, was conquered in these studies [12-14]. Here, the

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alternative is not highly economical, as the use of chemicals will result in financial expenditures, as well as looking for sources to discharge the sludge and the resulting waste. For this came the need to find an economic technique that summarizes the need to use the addition of any substance of various kinds, whether chemical or biological [15-17]. Frequent approaches have been recognized and functionalized for cultivated water from wastewater. These procedures are commonly considered as Examples of these methods are Reverse Osmosis (Ebnesajjad and Landrock), Ultra-Filtration (UF), Nano Filtration (NF), and Micro-Filtration (MF) [18-20]. These technologies include what needs high energy to operate, and some that need raw materials that may cost high money and have other consequences. That is why it was necessary to search for a mechanism that needed to eliminate all these faults. For this reason, membrane distillation (MD), comes as a promising separation technology and gained attention in this space. This procedure is a non-isothermal procedure. It can be 100% rejection of inorganic materials. Subsequently, scientists endeavor to use this technique for regaining freshwater [21-24]. Although these technologies have a lot of advantages, specifically MD; but still use a local material more economical than loading the user's more costs due to new technologies and works.

The treatment system was based mainly on studying the properties of a substance available in the Australian flora. Australian nature is silicic rock, or what is stamped as Porcelanite rocks. The fear arising from the presence of residual aluminum in the treated water and on the other hand the financial income from reducing the amount of alum in the treatment procedures were the reasons for carrying out this research. The primary, point of this article is to diminish the large amount of alum that has been used in the act by the implementation of alternative methods and sources of treatment materials like aluminium and other ions recognized in Australian Rocks. It is a hard rock crust that arose within the variable clay rocks in the Darwin City area. Reference has been made to these rocks by several researchers, including [G. H. McNally, G. Clarke & B. W. Weber], noticed on the whole, the properties of these rocks can be extracted. Many laboratory experiments were performed and reference was made to many reference sources [24, 25]. On the other hand, the researcher [J. McNally], that his efforts and work have been focused on these rocks. He has devoted his work to this aspect. He has excelled in the details of these rocks' geology; the last researcher has beautified his work on these rocks. from the literature of work, as well as the analysis of samples in the Lab, assisted in preparing the characteristics of Porcelanite rocks as shown in Table 1. Laboratory tests and analyses have proven that the latter is free of substances and elements harmful to consumer health. This material has been used with and without alum to achieve the curing process for a range of synthetic models with different dissipation, ranging from low to high [26-30]. The results showed an improvement in the removal efficiency when using these rocks and alum together on alum alone. With an approximate rate of 35% for medium and high-stress models (60 and 120 units of turbidity per day), in addition, as an activity of the participation of positive ions in the removal process through various mechanisms, this is indicative of a loss of calcium ion at a rate of 50%. High pH values were also observed when using small proportions of Porcelanite rocks that led to displacement pH to the optimum limits for making aluminum hydroxide to the optimum limits, which are the values between 7 and 8 [31-35].

2. Dairy Wastewater Characteristics

The dairy industry has different types of salts, and the major types of these ions are calcium, potassium, sodium, and magnesium. On the other hand, there are ferrous oxides, alumina, silica, titanium, and phosphate. Therefore, the jar test technique will be applied to the samples to try to remove organic and inorganic materials [41, 42].

The focus was clear in this paper on removing phosphorous from these waters so it plays a major role in polluting the environment and destroying the water system in particular and the environment in general.

Alum has been used alone and with Australian rocks in another time to check the capability of removing pollutants, particularly phosphorus.

3. Materials and Methods

3.1 Materials

Models of silica rock were brought in and ground in mechanical engineering laboratories to be soft, soluble in water, and permeate between water molecules. Physiochemical analyses were performed on these rocks to determine the identity of the components and they were as shown in Table 1.

Tests of samples in this study aim to get rid of the particulate and colloidal. Devices which has been used to achieve this object, Jar test

Table 1. Illiterates the characteristics of Porcelanite rocks in different areas

Area of Samples % Content	Australia	Algeria	Kenia	Japan	Russia	American Lampas Desert
Silica	63.21	58.4	84.5	86.00	79.42	89.70
Alumina	1.11	1.66	3.06	5.80	6.58	3.72
Ferrous Oxide	0.65	1.55	1.86	1.60	3.56	1.11
Titanium	0.12	0.1	0.17	0.22	0.48	0.1
Phosphate	1.12	0.2	0.04	0.03	---	0.1
Calcium oxide	9.65	13.8	1.8	0.70	1.43	0.30
Magnesium oxide	9.98	4.57	0.39	0.29	0.98	0.55
Sodium Oxide	0.45	0.96	0.19	0.48	0.65	0.31
Potassium Oxide	0.12	0.50	0.91	0.53	0.72	0.41
Burning losses	9.88	17.48	6.08	4.40	4.91	3.70

3.2 Procedure of Work

A trim cylinder was used to categorize 1000 ml of the mechanized sample and to add it to the test jar flasks. As well as graduated pipettes were used to add the desired concentration of metal salt, increasing concentration from left to right. Then, been operated the stirrer to simulate the plant process. Finally, it has been determined the best dosage level by analysis of the supernatant.

3.3 Jar Test Technique

After adopting the criteria for sedimentation time between 90 and 150 minutes, the jar test was carried out based on the following working conditions:

1- Rapid mixing 150 rpm for 3 min.
2- Gentle mixing 30 rpm for 20 min.
3- Settling for 20 min.

Treatment tests were carried out at laboratory temperature (24±2 °C) using a Jar-test (Model FC4S, VELP - ITALY) with the following conditions: fast speed of 150 revs/min for 3 min, followed by the slow speed of 30 revs/min for 20 min, and finally decantation for 90 min.

3.4 Methods

The artificial maples revealed beyond has been used in this section as a fence to gather the objects. AUM is the main item in this work; however, to keep characteristics stable changing every week has been done.
Aluminium sulphate $Al_2(SO_4)_3.18\ H_2O$ has been used as a coagulant with a concentration of 1%. The preparation was achieved by adding 10 gm. to 1 liter of distilled water. Over this compound, different salts have been used to accomplish the work as detailed below:

Sucrose hydrate C12H22O11.H_2O
Sodium Phosphate Dodecahedra $Na_3PO_4.12H_2O$
Ammonium sulfate $NH_4.2SO_4$
The above work was done as per standards [43].

4. Results and Discussion

The results obtained as a result of the achievement of these examinations are shown in Fig. 1 below:
Alum 2.285 ml-- Al^{3+} =0.8 gm/l -- Al^{3+} =2.25 mg/L
Alum 2.857 ml -- Al^{3+} =1.00 gm/l ---- Al^{3+} =1.55 mg/L

Alum 3.428 ml ---- Al^{3+} = 1.2 gm/l ----- Al^{3+} =1.45 mg/L

Alum 4.285 ml ----- Al^{3+} = 1.5 gm/l ---- Al^{3+} =1.7 mg/L

These experiments Two-liter flasks were used to carry out the experiments with this device. In principle, the results should be divided by 2.

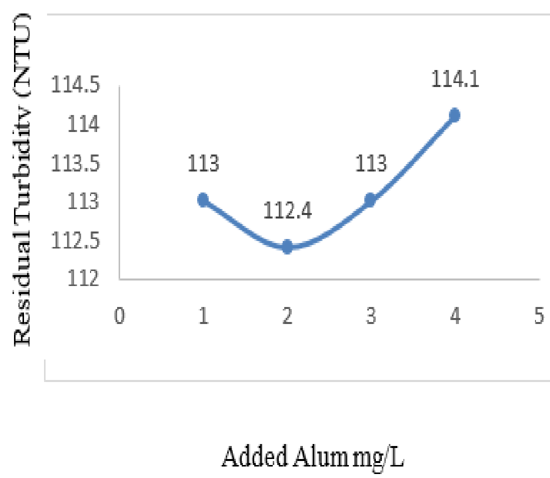

Figure 1. Relationship between added alum (mg/L) and residual turbidity (NTU)

Many factors have been accepted according to references [44-47].

- Time of flash mixing 3 min.
- Gradient velocity (G), for different temperatures (10, 30 degrees centigrade

will be 122.79 sec-1, and 205.7 sec, respectively.

- The results showed that the best slow mixing speed to achieve the best removal is (31.5 and 38.4 seconds -1 respectively), and the optimal sintering time is 30 minutes.

Many parameters play a big role in the mechanism of alum work. Temperature, pH, the rotational speed of paddles, viscosity of the liquid, velocity of flow (velocity of water molecules) as well as volume, and these parameters can be expressed as a gradient (G), which includes all these parameters.

The mixing process for this mixing takes place through several states, mechanically and hydraulically. In this paper, mechanical mixing was used by using the jar inspection mechanism. The mixing of the liquid has been measured through a scientific abbreviation called *(G)* [44-47]. The last component was developed by Camp and Stein (1943) [48-50]. G abbreviation has been defined by the Equation (1). The last equations were applied to this topic and the results are shown in Fig. 2.

$$G = \sqrt{W}/\mu \qquad (1)$$

Which W= Dissipation function,

μ = absolute viscosity Kg/m.sec.

This Equation can be represented in another term which is,

$$G = \frac{\sqrt{\text{CdA}\rho v^3}}{2\mu v} \qquad (2)$$

Where is v = Linear velocity of paddle brushes relative to fluid velocity and this can be calculated from this equation (3),

$$v = 2\pi rn/60 \qquad (3)$$

Where,
r = Rotational radius (m),
n = Number of rotations in minutes,
A = Area of blade (m^2),
ρ = Density of fluid,
V = Volume of liquid (m^3).

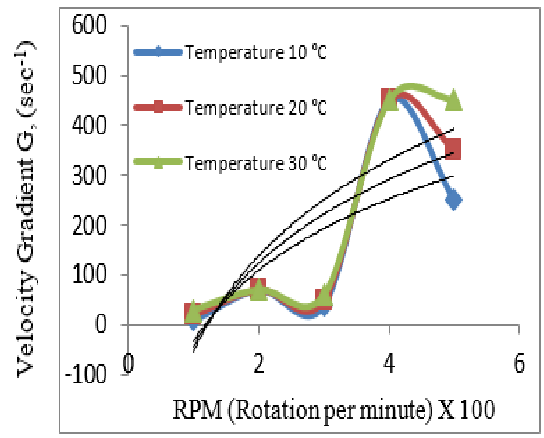

Figure 2. Relationship between the rotation of the paddle per minute and velocity gradient at different temperatures

The formation of aluminium hydroxide compounds when adding alum, as can be seen in Fig. 1, will lead to a decrease in the turbidity concentration present in the dairy wastewater. Here, a group of aluminium hydroxides will be formed according to Fig. 3. Based on these formulations, the group of aluminium hydroxides will trap phosphorous and even pollutants in wastewater. The phosphorus, being a negative root, also can combine with positive aluminium and form aluminium phosphate compounds that can be deposited. Note Equation No. 4. This latter also can act as a trapping network and therefore the phosphorus concentration will decrease in several directions, once upon its union with aluminium, and another when it is synthesized. From the grids, note Fig. 4, which illustrates the decrease in phosphorous concentration.

$$Al^{3+} + H_nPO_4^{3-n} = AlPO_4(S) + n\,H^+ \quad (4)$$

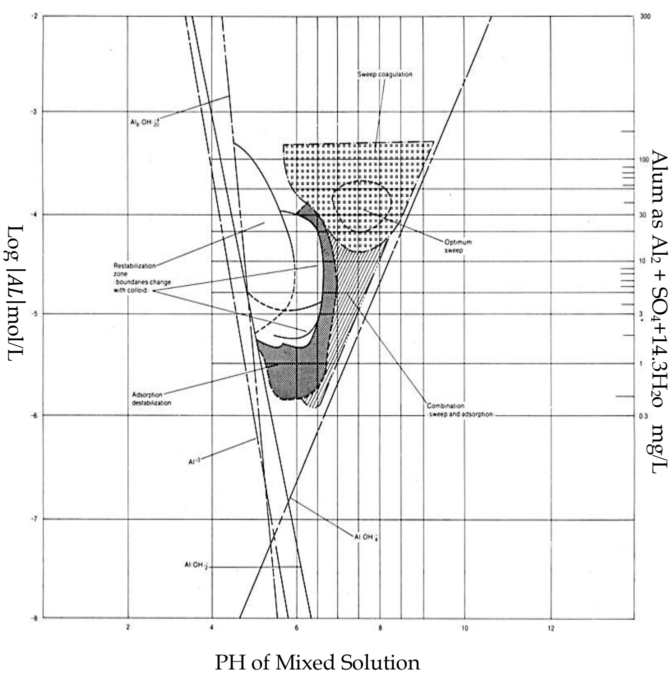

Figure 3. Design and Operation Diagram for alum Coagulation

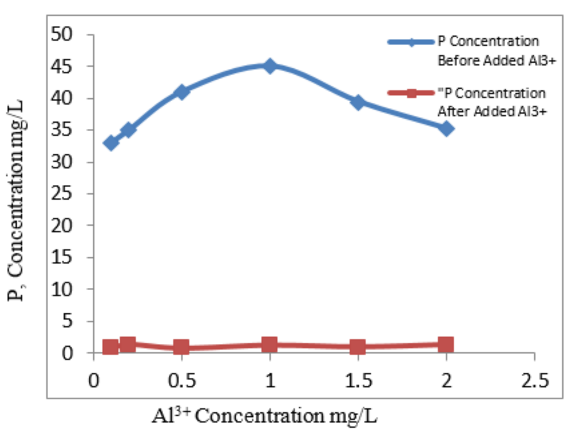

Figure 4. The relationship between concentrated aluminium and concentrated phosphorus

The optimum dosage of aluminium ion can be observed in Fig. 1. Alum with an aluminium concentration of 1.45 mg/L could enhance the removal of phosphorus by 95.7%~96%, as shown in Fig. 5.

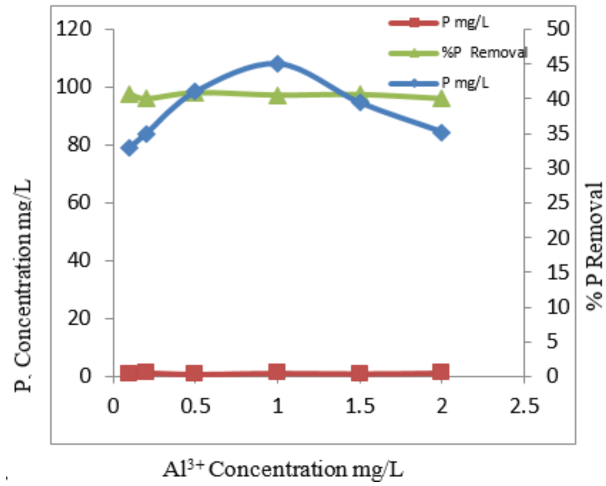

Figure 5. The relationship between concentrated aluminium and concentrated phosphorus

According to Fig. 6, It has been found the optimum amount of aluminum is about 0.5 mg/L with linger phosphorus about 0.68 mg/L, under gradient velocity equal to 1076.915 sec^{-1}.

It has been put Fig. 6 with equation Number 5, below to make a combined conclusion, and certainly reach the results which explaining the behaviors of treatment shown in Fig. 5.

All these parameters can be obtained from Equation (5) below.

$$y = 701.95x + 725.94 \quad (5)$$

The reduction of phosphorus concentration will be increased with the increase of phosphorus concentration in the bulk. The scaffolding mechanism will start once the increase of phosphors is saturated.

The application between parameters to achieve the best handling (speed of paddle rotation, temperature, physical and even chemical properties of the ocean, and other parameters) and the removal of phosphorous and pollutants, in general, using alum is illustrated in Fig. 6.

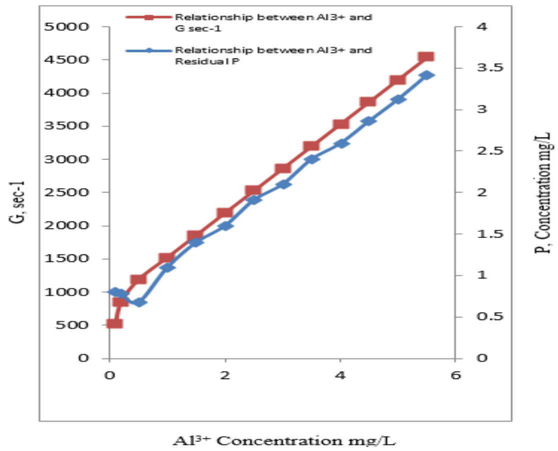

Figure 6. The relationship between concentrated aluminium and % phosphorus removal G

The context between agitation, aluminium ion, and phosphorus concentration has been described in Fig. 6 overhead [51]. Meanwhile, there are several tools and materials have been used to accomplish the work (NaOH, HCl) and individual molarities to control pH [54].

Porcelanite will now be added to synthetic samples under the aforesaid operating conditions. Porcelanite will now be added to synthetic samples under the abovementioned operating conditions. The treatment will be carried out under different concentrations of these rocks to know specifically the role of the latter in the treatment mechanism.

Porcelanite will now be added to synthetic samples under the aforementioned operating conditions. The treatment will be carried out under different concentrations of these rocks to know specifically the role of the latter in the treatment mechanism. It is noticed from Fig. 7 that the removal efficiency of phosphorous will increase. This is due to several reasons, including the presence of many positive ions in Porcelanite, especially aluminium and iron. These two ions can effectively form hydroxylation radicals with the ability to precipitate and precipitate.

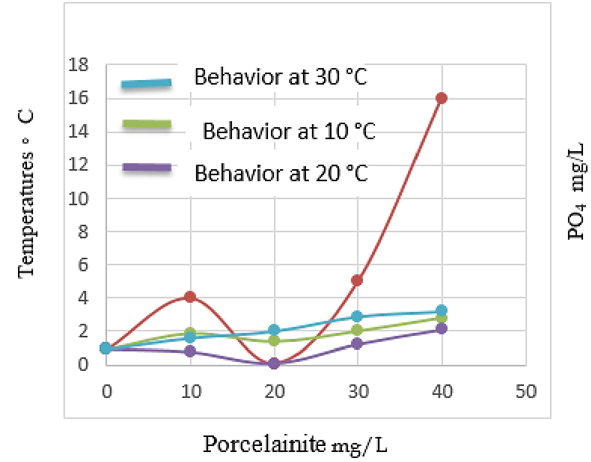

Figure 7. The relationship between added porcelainize and residual P at different temperatures

From Fig. 7, it is noticed that the phosphorus concentration will reach the lowest possible at a temperature of 20 degrees, due to the increase in the effectiveness of porcelaininite at this temperature. Removal with the addition of porcelanite and high tartar. Therefore, the optimum removal will be at 20°C, and then continuing to add Porcelanite will be ineffective only by an increase in dark and brown colour and pollutants.

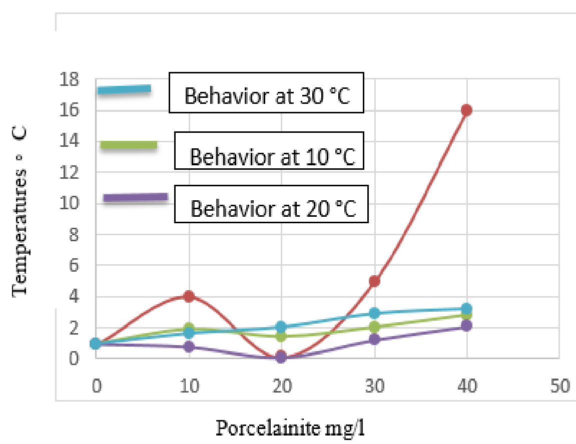

Figure 8. The relationship between added porcelanite residual P at 20°C

It is noticed from Fig. 8 that the behaviour of work at 20 °C is similar to that of removing phosphorous and contaminants with Porcelanite. It is noticed from Fig. 8 that the behaviour of work at 20 °C is similar to that of removing phosphorous and contaminants with Porcelanite. Here it can be said that the best removal and action of the laboratory model is at 20 °C. It is also noted that the phosphorus concentration is as low as possible.

4. Conclusions

- The residual turbidity has been 82.2%, under alum concentration 2 mg/L. The net of alum hydroxides will sweep phosphorus as well.
- The alum amount overhead means the concentration of aluminium ions is about 0.5 mg/L. The amount of 0.5 mg/L will reduce residual phosphorus to 0.68 mg/L
- The removal effectiveness of phosphorus is improved when using these rocks because they contain assorted concentrations of positive ions in broad and aluminium ions in particular.
- These ions are directed toward the hydroxyl radical to form hydroxide ion compounds that can often attract and catch pollutants with a negative charge, often.
- If you use these rocks alone, it cannot lead to a clear removal of phosphorous or pollutants but rather is used as an aid.
- These rocks play a prominent role in creating the treatment conditions for alum in terms of regulating the pH to gain better treatment, as they raise the number at a time when the sulphates reduce it.
- The best velocity gradient was attained at 20 C, and this value was gathered under liquid normal characteristics of dairy wastewater samples at room temperatures.
- Aluminum hydroxide forms could be built in a different pH number. The different forms of these compounds will support to subtraction of chromium ions in different ways.
- The removal of phosphorus will reach 95.7%~ 96% by 1.45 mg/L of the aluminium ion.
- With 20 mg/L of Porcelanite rocks, it has been completed best removal of phosphorus at 20ºC.
- Using alum with Porcelanite rocks as assistance in treatment will improve treatment by 30-40%. This process will drop residual aluminium concentration by about 10% from the total and then exclude health effects due to aluminium ions.

Acknowledgment

The authors present great thanks for Civil Engineering Department, Mustansiriyah University. Great thanks to RMIT University in Melbourne- Australia for help and support in achieving the production, as well as all working at the lab.

Conflict of interest

The authors state that there are no disagreements of interest considering the content of this manuscript.

References

1. Floros, J. D., et al. (2010). "Feeding the world today and tomorrow: the importance of food science and technology: an IFT scientific review." Comprehensive Reviews in Food Science and Food Safety **9**(5): 572-599.

https://doi.org/10.1111/j.1541-4337.2010.00127.x

2. Popkin, B. M., et al. (2012). "Global nutrition transition and the pandemic of obesity in developing countries." Nutrition reviews 70(1): 3-21. https://doi.org/10.1111/j.1753-4887.2011.00456.x
3. Douphrate, D. I., et al. (2013). "The dairy industry: a brief description of production practices, trends, and farm characteristics around the world." Journal of agromedicine 18(3): 187-197. https://doi.org/10.1080/1059924X.2013.796901
4. Britz, T. J., et al. (2006). "Treatment of dairy processing wastewaters." Waste treatment in the food processing industry: 1-28
5. Al Jawaheri, R. (2011). The use of constructed wetlands in the treatment of dairy processing wastewater.
6. Haimi, H., et al. (2013). "Data-derived soft-sensors for biological wastewater treatment plants: An overview." Environmental Modelling & Software 47: 88-107. https://doi.org/10.1016/j.envsoft.2013.05.009
7. Pal, P. and R. Kumar (2020). "Recent advances in biological treatment processes for wastewater and water treatment." Current Trends and Future Developments on (Bio-) Membranes: 41-66. https://doi.org/10.1002/jobm.202100225
8. Chernicharo, C. d. (2006). "Post-treatment options for the anaerobic treatment of domestic wastewater." Reviews in Environmental Science and Bio/Technology **5**(1): 73-92. https://doi.org/10.1007/S11157-005-5683-5
9. Chan, Y. J., et al. (2009). "A review on anaerobic–aerobic treatment of industrial and municipal wastewater." Chemical Engineering Journal 155(1-2): 1-18. https://doi.org/10.1016/j.cej.2009.06.041
10. Carrère, H., et al. (2010). "Pretreatment methods to improve sludge anaerobic degradability: a review." Journal of hazardous materials **183**(1-3): 1-15. https://doi.org/10.1016/j.jhazmat.2010.06.129.
11. Chowdhary, P., et al. (2017). Distillery wastewater: a major source of environmental pollution and its biological treatment for environmental safety. Green technologies and environmental sustainability, Springer**:** 409-435. https://doi.org/10.1007/978-981-15-1390-9
12. Pellegrin, M. L., et al. (2010). "Membrane processes." Water Environment Research **82**(10): 1159-1234.
13. Dadan-Garba, A. (2014). Investigation of Anthropogenic Water Contamination and the Design of a Multi-Stage Filtration System for Point of Use Application, University of Surrey, United Kingdom.
14. Akinwande, O. A. (2018). Color Removal from Combined Dye and Fruit Nectar Wastewater Using Adsorption and Microfiltration, Cleveland State University.
15. Williams, P. T. (2005). Waste treatment and disposal, John Wiley & Sons. https://doi.org/10.1002/0470012668
16. Ngoc, U. N. and H. Schnitzer (2009). "Sustainable solutions for solid waste management in Southeast Asian countries." Waste management 29(6): 1982-1995. https://doi.org/10.1016/j.wasman.2008.08.031

17. Mara, D. (2013). Domestic wastewater treatment in developing countries, Routledge.
18. Al-Juboori, R. A. and T. Yusaf (2012). "Biofouling in RO system: mechanisms, monitoring and controlling." Desalination 302: 1-23. https://doi.org/10.1016/j.desal.2012.06.016
19. Lahnsteiner, J., et al. (2018). "Direct potable reuse–a feasible water management option." Journal of Water Reuse and Desalination 8(1): 14-28. https://doi.org/10.2166/wrd.2017.172
20. Kavitha, J., et al. (2019). "Pretreatment processes for seawater reverse osmosis desalination systems-A review." Journal of Water Process Engineering 32: 100926. https://doi.org/10.1016/j.jwpe.2019.100926
21. Pellegrin, M. L., et al. (2010). "Membrane processes." Water Environment Research 82(10): 1159-1234. https://doi.org/10.1016/j.algal.2017.01.009
22. Saphira, M. R., et al. (2018). "Principles and Mechanism of Adsorption for the Effective Treatment of Palm Oil Mill Effluent for Water Reuse." Nanotechnology in Water and Wastewater Treatment: Theory and Applications: 1. https://doi.org/10.1155/2022/6603348
23. Cattaneo, M. (2019). "Livestock manure treatment for nutrients removal: consolidated techniques, emerging problems and new approaches.". http://dx.doi.org/10.2166/wqrj.2008.016.
24. G. H. McNally, G. C. B. W. W. (Nov. 2010). "Porcellanite and the urban geology of Darwin, Northern Territory." Australian Journal of Earth Sciences. https://doi.org/10.1046/j.1440-0952.2000.00764.x
25. McNally, G. H. (December 2001). "Geology and mining practice in relation to shallow subsidence in the Northern Coalfield, New South Wales." Australian Journal of Earth Sciences **47**(1): 14. https://doi.org/10.1046/j.1440-0952.2000.00761.x
26. Dadd, D. L. (2011). Toxic Free: How to Protect Your Health and Home from the Chemicals ThatAre Making You Sick, Penguin.
27. Lam, Y.-L., et al. (2012). "Developments in functional finishing of cotton fibres–wrinkle-resistant, flame-retardant and antimicrobial treatments." Textile Progress **44**(3-4): 175-249. https://doi.org/10.1016/j.carbpol.2013.04.004
28. Ebnesajjad, S. and A. H. Landrock (2014). Adhesives technology handbook, William Andrew.
29. McKeen, L. W. (2015). Fluorinated coatings and finishes handbook: The definitive user's guide, William Andrew. eBook ISBN: 9780323374675
30. Sun, Q., et al. (2020). "Assessment on thermal hazards of reactive chemicals in industry: state of the art and perspectives." Progress in Energy and Combustion Science 78: 100832. https://doi.org/10.1016/j.pecs.2020.100832
31. Edgar, K. J., et al. (2001). "Advances in cellulose ester performance and application." Progress in polymer science 26(9): 1605-1688. https://doi.org/10.1016/S0079-6700(01)00027-2
32. Moore, P. L. (2009). "Dynamics of ice flow and sediment transport at a polythermal

glacier terminus: Storglaciaren, Sweden.". Ann Arbor, MI 48106-1346

33. Govorushko, S. (2013). "Environmental problems of extraction, transportation, and use of fossil fuels." Fossil fuels: sources, environmental concerns and waste management practices: 1-84.
34. Govorushko, S. (2013). "Environmental problems of extraction, transportation, and use of fossil fuels." Fossil fuels: sources, environmental concerns and waste management practices: 1-84. SBN: 978-1-62808-412-2
35. Beiyuan, J. (2017). "Integrated remediation of metal-contaminated soils: biodegradable chelant-enhanced extraction and in-situ stabilization."
36. Crittenden, J. C., et al. (2012). MWH's water treatment: principles and design, John Wiley & Sons.
37. Kuokkanen, V. and T. Kuokkanen (2013). "Recent applications of electrocoagulation in treatment of water and wastewater—a review.". https://doi.org/10.4236/gsc.2013.32013
38. Sahu, O., et al. (2014). "Treatment of wastewater by electrocoagulation: a review." Environmental science and pollution research 21(4): 2397-2413. https://doi.org/10.1007/s11356-013-2208-6
39. Millar, G. J., et al. (2016). "Strategies for the management and treatment of coal seam gas associated water." Renewable and Sustainable Energy Reviews 57: 669-691. https://doi.org/10.1016/j.rser.2015.12.087
40. Bhateria, R. and D. Jain (2016). "Water quality assessment of lake water: a review." Sustainable Water Resources Management **2**(2): 161-173. https://doi.org/10.4236/jwarp.2010.29093
41. Piedrahita, R. H. (2003). "Reducing the potential environmental impact of tank aquaculture effluents through intensification and recirculation." Aquaculture 226(1-4): 35-44. https://doi.org/10.1016/S0044-8486(03)00465-4
42. Udaiyappan, A. F. M., et al. (2017). "A review of the potentials, challenges and current status of microalgae biomass applications in industrial wastewater treatment." Journal of Water Process Engineering **20**: 8-21. https://doi.org/10.1016/j.jwpe.2017.09.006
43. APHA, AWWA, WEF, "standard methods for the examination of water and wastewater", 16, 1985. https://doi.org/10.2105/SMWW.2882.002
44. Letterman, R. D., et. al., "Influence of Rapid Mix Parameters on Flocculation", Journal of AWWA, Vol. 65, 1973. https://doi.org/10.1002/j.1551-8833.1973.tb01933.x
45. Eckenfelder, W., and Wesley, Jr., "Industrial Water Pollution Control", McGraw-Hill, Inc., New York, 2000. ISBN**:** 9780071548663
46. Shames, N.K. (2005). “Coagulation and Flocculation," In: *Physicochemical Treatment Processes* (vol. 3). “Handbook of environmental engineering (Eds. L.K. Wang, Y.-T. Hung, N.K. Shames). *Humana Press*, Totowa, NJ, USA. https://doi.org/10.1385/159259820x
47. Amirtharajah, A. and K. M. Mills (1982). "Rapid-mix design for mechanisms of alum coagulation." Journal-American Water Works Association 74(4): 210-216. https://doi.org/10.1002/j.1551-8833.1982.tb04890.x

48. Tay, J.-H., et al. (2006). "Seafood processing wastewater treatment." Waste treatment in the food processing industry: 29-66. https://doi.org/10.12911/22998993/91879
49. Okioga, T. T. I. (2007). Water quality and business aspects of sachet-vended water in Tamale, Ghana, Massachusetts Institute of Technology.
50. AKERS, R. J. (2017). "Filtration pretreatment." Filtration: Principles and Practices, Revised and Expanded: 251.
51. Razzak, S. A., et al. (2013). "Integrated CO2 capture, wastewater treatment and biofuel production by microalgae culturing—a review." Renewable and sustainable energy reviews 27: 622-653. https://doi.org/10.1016/j.rser.2013.05.063
52. Luo, C. (1998). "Distribution of velocities and velocity gradients in mixing and flocculation vessels: Comparison between LDV data and CFD predictions." UMI Number: 9730390
53. Black, A., et al. (1957). "Review of the jar test." Journal (American Water Works Association) 49(11): 1414-1424.
54. Puckhaber, D., et al. (2020). "Impact of Particle and Equipment Properties on Residence Time Distribution of Pharmaceutical Excipients in Rotary Tablet Presses." Pharmaceutics 12(3): 283. https://www.jstor.org/stable/41254753