Present Scenario of Dairy Wastewater Treatment: A State of Art Review

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Abstract

Dairy industry is one of the leading consumer of water and producer of wastewater. Increased demand of dairy products results in rapid growth of dairy industry and hence wastewater production increases. Dairy effluent contains high concentrations of organic and inorganic substances that cause eutrophication in water bodies. This review study emphasizes on various treatment methods of DWW for period 2002 to 2021. Dairy wastewater imposes serious environmental concern because of the presence of wide range of fatty acids, proteins, nutrients, and other organics. These contaminants are difficult to treat in single step conventional treatment technique. In recent years much attention has been given for integrated system of dairy wastewater (DWW) treatment. The present review has deep insight for ongoing development in various treatment techniques of dairy wastewater. Moreover, this article intricate issue related with treatment followed by a brief discussion on the biological technique and special emphasis has been on the bio-filtration process. Extensive review study found that bio filtration method is environmentally sustainable and economically affordable technology as it requires minimal maintenance and low operating cost; filter media can be coarse gravel, stone, bio-carrier. Literature survey found that the bio-filtration process has the efficiency of removing BOD, COD, TP, TN (91.7–97.5, 74.1–99%, 98.3%, 88-91.5%). Fresh water crisis demands the reuse of DWW for non-potable purposes. Reuse of DWW in food, plastic, fuel, health and pharmaceutical industries helps to convert its zero value to a potential resource.

1.0 Introduction

India ranks first in milk production as per economic survey 2015-16 (Karadag, et al. 2015a). During the year 2017-18, milk production in India was 176.3 million tones, which represent 20% of world milk production(Basic Animal Husbandry Statistics, DAHD&F 2018). During 2017-18, India's per capita availability of milk was 375 g/day; while during 2019–2020 per capita availability of milk was 407g/day; and it is estimated to increase to 592 g/day by 2023-24. This indicates the huge production of dairy wastewater and focus on affordable treatment technique. Major portion of the dairy wastewater is produced from byproducts of cheese, whey, washing, quality control, and cleaning. Dairy wastewater mostly contains biodegradable organic content, but when directly disposed on environment, it causes hazardous impact on land and aquatic system (Lomte and Shinde 2018). The DWW contains oil, grease, and fat effluents which forms a film on water surface by eutrophication and obstructs the transfer of oxygen (Ahmad et al. 2019a).

Generally, dairy processing contains high concentration of organic components such as suspended solids (SS), nutrients,BOD, COD, oil and/or grease, and large variations in pH (Ozturk,et al. 2019), (Demirel, Yenigun, and Onay 2005a),(J. Luo and Ding 2011). The DWW is preferably treated either by biological or/and physico-chemical methods(Ahmad et al. 2019b), (Verma et al. 2012), (Lateef, et al. 2013). It also contains proteins, fats, lactose, and washing and cleaning of bottles contain acidic and alkaline chemical, tanks equipment(Carvalho, et al. 2013a). Study found that biological treatment is most suitable technology for reduction of organic mattersbyanaerobic filters, aerated lagoons, sequential batch reactor(Sirianuntapiboon, et al.2005),(Neczaj et al. 2008) trickling filter(Birwal 2017),(Aziz, et al.2016) activated sludge(Fang 1991),(Kolev Slavov 2017) UASB (Gavala et al. 1999),(Carvalho,et al. 2013a). The biological treatment method is of two types- aerobic and anaerobic method. The micro-organisms grow in presence of oxygen, decompose organic matter into water, carbon dioxide and cellular material ("Waste Treatment in the Food Processing Industry" 2005). Mostly used conventional anaerobic biological treatment processes are anaerobic filters(Omil et al. 2003), UASB reactors are mostly used for treating dairy waste water (Vlyssides et al. 2012), (Omil et al. 2003). Dairy industry on an average generates 1 to 2L of wastewater which can be also increased to 10L in processing 1L of milk (Lomte and Shinde 2018).

1.1 Background and Motivation

Wastewaters are produced by rinsing large tanks in receiving operation; rinsing of unconsumed products left in or on the surface of pump, pipelines, manufacturing equipment, and machines. Wastewater leakage/overflows; sludge that are released from clarifiers; rinsing of all manufacturing units; ash deposits on boilers, and failure of packaging operation are caused due to improper equipment operation (Mehrotra et al.2016). Wastewater characteristic depends on the amount of milk processed in the industry and types of product manufactured. It contains a good proportion of milk components like inorganic salts, casein, etc. It also consists of sanitizers and detergents which are used during washing purposes (Verma et al. 2012). These effluent compounds attract attention for need of extensive characterization and effective treatment.

1.2 Environmental Impact of DWW

The prime food processing industry in worldwide is dairy product industry (Jindal 2019). Large water consumption of this industry produces tremendous wastewater ("Technological Approaches for Novel Applications in Dairy Processing" 2018). Water is needed in each step of manufacturing process like disinfection, cleaning, heating, washing, and cooling. The DWW characteristics and amount depend on production capacity and operations(Slavov 2017). Basically effluents that come from dairy industry are slightly basic in nature and rapidly become acidic due to fermentation of milk sugar to lactic acid(Shete,et al. 2013),(Birwal 2017),(M. Patel, et al. 2018). Organic matter, suspended solids, lactose, proteins largely contribute towards its high BOD and COD (Shete,et al 2013). In the manufacturing process of cheese and casein units, major by-product of dairy factory is whey. Major components in whey are protein, lactose, lipids, vitamins, carbohydrates (De Jesus et al. 2015). Dairy sludge contains organic matter, fat, lactose, potassium, phosphorus. It also contain sanitizers and detergents that are used for cleaning and washing purposes along with that a large quantity of inorganic salts, oil and grease (Singh et al. 2013). Dairy effluents are whitish in color due to which

photosynthetic activity of aquatic life get reduced (Verma et al. 2012). Depending upon the product manufactured and the type of operation the less degradable lactose and fats can vary in different proportion. During production of ghee process it contains high lipids, while cheese process contains proteins, and carbohydrate (Birwal 2017).Most polluting by-product of dairy effluent is lactose because of its high BOD < 34,000 ppm and high COD < 61,000 ppm.

Researchers found that disposing of milk whey in water bodies causes water pollution due to the huge amount of high BOD, nitrogen, phosphorus, COD. The increase in COD in fresh water diminishes dissolved oxygen in the water bodies which leads to anaerobic condition in the water. All this enhance the process of eutrophication, which causes an excessive growth of aquatic plants and microorganisms. Figure 1 summarizes in general physico-chemical and bacteriological characteristics of dairy wastewater during DWW characterization.

(De Jesus et al. 2015). Some compounds are easily degradable like lactose but proteins and fats are not biodegradable (Omil et al. 2003). Every year approximately around 47% of whey produced world widely is discarded into water bodies, in wastewater treatment plant or loaded onto the land (Fraga et al. 2017). As whey wastewater contains a large amount of organic pollutant, a huge loss to resources if not recovered. Whey may create problem in the biological process of due to the presence of high BOD (Verma et al. 2017). The whey which are disposed of onto the land can deteriorate the physicochemical characteristics of soil, crop yields also reduces, and increases groundwater pollution (Cristiani-Urbina et al. 2000). Dairy waste water can be defined as complex type of substrate. It contains 97.7% of total COD in cheese processing WW by lactose, fats, protein, and lactate (Demirel, et al 2005a). The organic matter present in DWW enhances the decay rate, which creates an anaerobic condition in receiving water bodies by decreasing the DO level in water bodies(Andreottola et al. 2002). The dairy effluent contains hazardous waste which is disposed of in streams and water bodies. The effluent create an environment to multiply their growth of certain bacteria and algae, utilize the oxygen present in water bodies for their growth and it leads to death of aquatic plants, animals, fishes.

The aerosol that are emitted from dairy industry, settles down as dust causing corrosion (Jindal 2019). To overcome eutrophication before disposing wastewater it can be treated by through photosynthetic activities. Microalgae are able to prepare their own food with help of atmospheric carbon and sunlight. Microalgae generate organic biomass by fixing CO_2 at a higher rate by the help of photosynthesis process. Biomass is a source for generation of bio-based products like biofuels (Hemalatha et al. 2019a).

High concentration of organic matter in DWW can deteriorate municipal system (Slavov 2017), (Kolev Slavov 2017). Environmental issues arise in two approaches due to high organic load and salinity, which increases the wastewater treatment cost, and also increases the use in agricultural purposes as well as degradation of local land(G. Q. Chen et al. 2018). Methemoglobinemia can be caused by presence of ammonia, nitrate and nitrogen in raw milk and also can contaminate the groundwater when converted to nitrite (Kushwaha,et al 2011). Sewage fungus is an issue arise by DWW in the water bodies causing filamentous slimes (Wang et al.2019).

Rate of consumption of oxygen by microbes and reaeration rate from the atmosphere are the factors that changes DO rate. In both BOD and COD the organic material is transformed to carbon dioxide and water, but in case of 5th day BOD the organic matter are converted to new bacterial cells (Shete, et al. 2013).

Generalized characterization of dairy wastewater by various researchers is summarized in Table 1. Reason behind comparison of characterized values with standard give a clear view of the treatment required.

The dairy industry has great fluctuations in the quality and quantity of wastewater which are very problematic because milk products need different technological process to manufacture. The high heterogeneous milk production and discontinuous manufacturing process, it becomes difficult to generalize the characteristics of wastewater.

Table 1
Characterization of dairy wastewater by various researchers.

SN	Parameter	Min	Max	Mean	Discharge into public sewer (BIS 1981)	Usual range in irrigation water (FAO 1994)	Discharge into inland surface water (BIS 1981)	References
1	pH	4.9	11.3	7.52	5.5-9	6.5–8.4	5.5-9	(Mehrotra et al. 2016), (Schierano, et al. 2017), (Shete,et al. 2013), (Ozturk, et a l.2019), (Arumugam et al.2008), (Verma et al. 2012), (Sarkar et al. 2006a), (Al-wasify, et al.2017), (Lomte et al. 2018), (Suman, et al 2018),(Anju et al 2016)(Elangovan 2015),(Birwal 2017),(Samadi, et al. 2017),(Porwal, et al 2015),(Al-Malack et al. 2016), (Chatterjee and Priti 2013),(Fang 1991), (Hemalatha et al. 2019b),(Munavalli and Saler 2009) (Amini et al. 2013), (Gutiérrez, et al.1991),(Tawfik, et al.2008),(Demirel, et al.2005b), (Demirel, et al. 2005b)
2	TS (mg/l)	1690	70000	12357.14				(Mehrotra et al 2016),(Elangovan et al 2015),(Al-Malack et al 2016), (Verma et al. 2012), (Chatzipaschali et al 2012),(Ding et al. 2015),(Karadag, et al. 2015a)
3	TSS (mg/l)	310	6500	1395.36	600		100	(Mehrotra et al 2016),(Lomte et al 2018),(Suman, et al 2018),(Al-wasify, et al 2017), (Elangovan et al 2015),(Samadi, et al 2017),(Al-Malack et al 2016),(Aziz, et al 2016),(Verma et al 2012),(Telang et al 2015)
4	TDS (mg/l)	462	132000	19780.42	2100	2000	2100	(Suman, et al 2018),(Al-wasify, et al 2017), (Elangovan et al 2015),(Al-Malack et al 2016),(Chatterjee et al 2013), (Malakootian et al 2013),(Verma et al. 2012),(Telang et al 2015)

SN	Parameter	Min	Max	Mean	Discharge into public sewer (BIS 1981)	Usual range in irrigation water (FAO 1994)	Discharge into inland surface water (BIS 1981)	References
5	COD (mg/l)	940	12000	4027.57			250	(Mehrotra et al 2016),(Lomte et al 2018),(Suman, et al 2018),(Al-wasify, et al 2017), (Elangovan et al 2015),(Samadi, et al 2017),(Al-Malack et al 2016), (Chatterjee et al 2013),(Malakootian et al 2013),(Aziz, et al 2016),(Verma et al. 2012),(Telang et al 2015),(Ding et al. 2015),(Karadag, et al. 2015)
6	BOD (mg/l)	454	6280	2002.63	350		30	(Mehrotra et al 2016),(Lomte et al 2018),(Suman, et al 2018),(Al-wasify, et al 2017),(Samadi, et al 2017),(Al-Malack e al 2016), (Malakootian et al 2013),(Aziz, et al 2016),(Verma et al. 2012),(Telang et al 2015),(Karadag, et al. 2015a)
7	O&G (mg/l)	80	600	207.97	20		10	(Mehrotra and Trivedi 2016),(Al-wasify, Ali, and Hamed 2017), (Samadi, Mirbagheri, and Falsafi 2017), (Malakootian and Hatami 2013), (Verma et al. 2012), (Telang and Patel 2015)
8	Turbidity (mg/l)	372	1213	901.66				(Suman, Ahmad, and Ahmad 2018), (Al-wasify, Ali, and Hamed 2017),(Al-Malack and Aldana 2016)
9	Total N (mg/l)	84	2400	978.8			100	(Mehrotra et al 2016),(Elangovan et al 2015), (Samadi, et al 2017),(Aziz, et al 2016),(Ding et al. 2015),(Karadag, et al. 2015)
10	Phosphate (mg/l)	12	3000	524.94				(Mehrotra et al 2016), (Elangovan et al 2015), (Samadi, et al 2017),(Aziz, et al 2016), (Chatzipaschali et al 2012), (Ding et al. 2015)
11	Alkalinity (mg/l)	590	14000	7295				(Mehrotra et al 2016), (Chatterjee et al 2013)

SN	Parameter	Min	Max	Mean	Discharge into public sewer (BIS 1981)	Usual range in irrigation water (FAO 1994)	Discharge into inland surface water (BIS 1981)	References
12	Chlorides (mg/l)	112	1100	503	1000	1062	1000	(Mehrotra et al 2016),(Verma et al. 2012)
13	BOD:COD (mg/l)	1.1	1.65	1.37				(Mehrotra et al 2016), (Karadag, et al. 2015)
14	Temperature (mg/l)	26°c	33^{0}c	29.75	45		40	(Lomte et al 2018), (Elangovan et al 2015), (Chatterjee et al 2013),(Verma et al. 2012)
15	Sulfate (mg/l)	86	395	240.5	1000	960	1000	(Al-wasify, et al 2017),(Verma et al. 2012)
16	Volatile solid (mg/l)	1350	2100	1770				(Elangovan et al 2015),(Ding et al. 2015), (Karadag, et al. 2015)
17	Volatile suspended solid (mg/l)	1500	1900	1700				(Elangovan et al 2015), (Karadag, et al. 2015)
18	NH_3 N(mg/l)	< 1			50	0–5	50	(Al-Malack et al 2016)
19	Ca (mg/l)	227	1350	725.66		400		(Al-Malack et al 2016), (Chatzipaschali et al 2012), (Ding et al. 2015)
20	K (mg/l)	69.4	62000	31034.7		2		(Al-Malack et al 2016),(Ding et al. 2015)
21	Mg (mg/l)	62.9	625	343.95		60.75		(Al-Malack et al 2016),(Ding et al. 2015)
22	Na (mg/l)	453	600	521.33		920		(Al-Malack et al 2016),(Aziz, et al 2016),(Ding et al. 2015)
23	Fe (mg/l)	0.193	43	21.59		5		(Al-Malack et al 2016),(Ding et al. 2015)
24	Acidity (mg/l)	97500						(Chatterjee et al 2013)
25	EC	837µs/cm				3000		(Malakootian et al 2013)
26	Lactate(mg/l)	2000						(Chatzipaschali et al 2012)
27	Lactose(mg/l)	5200						(Chatzipaschali et al 2012)
28	Protein(mg/l)	1000						(Chatzipaschali et al 2012)

2.0 Bibliometric Analysis

In general bibliometric is categorized into two categories. Primary classification is based on the range of activities that provide detail data on research topics, pivotal journal and countries(Ramos-Rodrígue et al 2004). Secondary classification is used to trace links by applying social network analysis and relationship indicators, and interrelationship between various countries, institutes, and keywords. Ultimately these two categories provide detail study on what research, themes, and topics methods are peripheral or central to a study and how they vary with time(Zyoud et al. 2016). In bibliometric analysis the association of patent and literature outcomes have different advantages such as extent to better inform future theoretical, technological, innovation and direction for basic research, and identifying the technology development pace (Ardito, et al 2018). This review study initiates to involve bibliometric analysis related to dairy wastewater. Research gap in earlier studies identify using bibliometric analysis for both quantitative and qualitative evaluation of all publications of dairy wastewater treatment during 2001 to 2021 in present review paper.

2.1 Present Research Scenario of DWW

Results from study on web of science for “Dairy Wastewater Treatment”, latest performed on 2 November 2021, 1,222publications were obtained. Out of these, 1,135 were articles, 81 proceeding paper, 79 review articles, 13 early access, 7 meeting abstracts, and 1 correction. In the previous records dated from 2001 there is a little increase in 2015. But the most important increase was observed only after2018. All the publications were related to the study for period investigated (from April 2001 to June 2021) as observed in Fig. 2a. The four countries such as USA, India, Brazil, China together represent > 53% of all publications related to the topic i.e., dairy wastewater treatment in Fig. 2b. The main important part to note that developed country i.e., America and developing countries (India, Brazil, and Peoples Republic China) were found in enhancing a great interest in research on dairy wastewater treatment.

With extensive research, 31 authors have most prolific to publish studies on the research area as shown in Fig. 2c, Debowski M has 17 having highest publications, Zielinski M has 16 publications, Dabrowski W, Krzemieniewski M, Mohan SV with 10 publications, Borges AC, Ding LH, Fenton O, Freire DMG, Luo JQ, Madani A, Rodgers M, Tommaso G with 9 publications. These authors have published articles investigating either on dairy waste water treatment technology or combination of technology and reuse of dairy wastewater. Study found that elsevier publishes maximum with 455 articles. It was 50% of all publications. While, springer nature also published 134 papers as shown in Fig. 2d.

2.2 Bibliometric Mapping

In the bibliometric network view, the labels are represented by the help of extracted items, but in some of the cases it is not visible to avoid overlapping in circles, and every circle is explained by item’s occurrence. The color of the labels explains the cluster of items to which it belongs. The distance between two items shows the bond of relationship i.e. items which are close to each other are more strongly related and vice versa.

It was possible to verify that the most occurring items (largest circles) were removal, dairy wastewater, performance, nitrogen, phosphorus, constructed wetlands, microalgae, growth, biomass, nutrient removal, anaerobic digestion, efficiency, reuse, ultra-filtration, Nano filtration, oxidation, coagulation, recovery. In bibliometric mapping, the VOSviewer software classified and divided the terms into eight clusters. Figure 3 depicts the network view map generated in VOSviewer for dairy wastewater treatment. The largest group is red in color with highest number of items, comprising items more focused on nutrient and organic removal, treatment process. Such as biological nutrient removal, microorganisms, removal of phosphate, nutrient, organic pollutants, pathogens, sedimentation, contaminants, dissolved oxygen (DO), chemical oxygen demand (COD), biological oxygen demand (BOD), *eiseniafetida*, Escherichia-coli, bacteria, bio fertilizer, sludge treatment. The second cluster color is green which is more related to treatment units such as aerobic treatment, anaerobic treatment, anaerobic fermentation, biofilm reactor, methanogenesis, hydraulic retention time, microbial community, organic loading rate, sequential batch reactor, sludge blanket reactor, USAB, flocculants, granular sludge, fermentation.

This cluster contains 64items in total. The third cluster color is blue which mainly consist of 52 items, grouped terms concern in electrocoagulation, decolorization, disinfection, electro Fenton, electrolysis, kinetics, ozonation, photocatalysis, and response surface method. The fourth cluster is yellow and it consists of 49 items. This cluster mainly constitute terms such as constructed wetland, wetland, agricultural wastewater, design, denitrification, nitrification, flowrate, loading rate, flow constructed wetlands, horizontal subsurface flow, phytoremediation. The fifth cluster is pink in color, but cluster contains 43 items and is mainly related to reuse of dairy wastewater. The grouped items are biodiesel, biofuel, biogas, biomass, bioethanol, algal biomass, lipid accumulation, mixotrophic cultivation, swine manure. The sixth cluster is of 38 grouped items and black in color. But the items are reverse osmosis, micro filtration, Nano filtration, membrane fouling, ultrafiltration, membrane bioreactor, membrane fouling. The seventh cluster is orange in color but constitute 35 items. The grouped items are bio- augmentation, activated sludge, anaerobic bioreactor, batch reactor, biodegradation. The last cluster is brown in color and constitutes 28 items such as bioelectricity, microbial fuel cell, power generation, biofilm, electricity generation.

3.0 Dww Treatment Methods

Dairy wastewater in many countries directly disposed into water or onto the land which is not an acceptable method (Ahmad et al. 2019b). Figure 4 summarizes the available treatment methods on dairy wastewater. As it constitute harmful matter which can affect environment, aquatic life, animals, and human beings. It can be treated by different methods.

3.1 Wetland Treatment Processes

The wastewater treatment process use wetland method which is a natural process of treatment (Vymazal 2005a). It include microbial communities for wastewater processing(Slavov 2017).This process focuses on to improve the potential of wastewater treatment and also improve its quality before disposal. It is an artificial system in which aquatic and terrestrial plants are arranged. This treatment is considered as a sustainable wastewater treatment, as they perform same function as conventional treatment (efficient wastewater treatment) but in a more eco-friendly, economical, energy saver (Ahmad et al. 2019b). The root of these plants is in contact with water for a long period to remove contaminants from industrial wastewater (Schwantes et al. 2019). These plants are used for phytoremediation purposes which have been estimated to reduce environmental pollution by metals (Schwantes et al. 2019), as these types of plants have huge capacity to accumulate the harmful elements (Schwantes et al. 2019), (Ding et al. 2015). The removal of wetland treatment was highest for BOD, COD, suspended solids, nitrate, and coliforms. The moderate removal was for total nitrogen and phosphorus. The removal percentage of total nitrogen was 25% and ammonium reduces 16% in the wetland process (Ibekwe, Grieve, and Lyon 2003). In wetland system the DWW is treated under aerobic condition. In the aerobic pond the removal efficiency of BOD_5 was 85% at 20°c, in case of high load wastewater the treatment is done in facultative wetlands ("Books @ Www.Google.Co.In," n.d.). The removal efficiency in wetland process for BOD, and COD is high but for phosphorus and nitrogen the removal rates were lower. In most cases phosphorus removal is low and nitrogen removal is more than 50%(Verhoeven et al 1999). In the treatment process when the retention time of wastewater increased from 2 to 7 days the reduction for total nitrogen increases from 12 to 14% in the unplanted wetlands and 48 to 75% in the planted wetlands. The total phosphorus removal efficiency increases from 12 to 36% in the unplanted wetlands and 37 to 74% in planted wetlands (Tanner, et al 1995). In a study the *Typhadomingensis* was chosen because of its high productivity and nutrient removal efficiency (Schierano, et al 2017). In wetland process the nitrogen removal mainly dependent on microbial activities in root zones which is temperature sensitive, whereas the removal of phosphorus is not directly dependent upon the temperature, and also influence the redox levels by the effect of oxygen availability (Gottschall et al. 2007a). In aerobic wetland process the effluents are of high quality with removal efficiency more than 90% was obtained- COD, TSS, $BOD_{5,}$ organic N, and total coliforms (Slavov 2017).

Wetland treatment system use simple processes that include self-supported microbial communities, inexpensive treatment, initial investment, operation cost and maintenance cost is also low (Ibekwe, et al 2003). It also requires less energy as well as expert labors not required ("Vertical Flow Constructed Wetlands_ Eco-Engineering Systems for Wastewater ," n.d.). The drawbacks of this treatment system include the need for a large surface for installation, risk for ground water pollution and surface. In case of anaerobic wetland the NH_3 removal is limited and in aerobic process the phosphorus from PO_4^{3-} is limited (Slavov 2017) .

Wetlands process are effectively used in dairy industry for the treatment in Italy (Mantovi et al. 2003), Canada (Gottschall et al. 2007b), Ireland, Argentina (Schierano, et al 2017), (O'Neill, et al 2011). Generally wetlands are categorized into two types such as - horizontal and vertical flow constructed wetlands. In case of vertical flow constructed wetlands efficiently remove ammonia-N but denitrification process is limited in this process. Whereas in case of horizontal flow constructed wetlands provide a better environment for denitrification but the nitrification of ammonia is very limited because of its low oxygen transfer capacity (Vymazal 2007).

Plants like *typhasp, pistiasp, salviniasp, eichhorniasp* in constructed wetlands provide a source of substrate and carbon for microbes. Plants present in wetlands immediately oxygenate the substrate which is present close to the roots and increase the aerobic zone or else anaerobic zone. During the growing season plants remove the nutrients from wastewater. The removal percentage of total N, and total P was 16–75%, and 12–73% respectively by the nutrient uptake of plants (Cronk 1996).

Constructed wetlands can also be called as green treatment technology. This technology has been widely used in treating different types of wastewater like municipal, industrial, domestic, and agricultural wastewater. This process efficiently removes nutrient, organic matter, pathogens (Wu et al. 2015). The primary target of constructed wetland is to remove microbiological pollution. According to literatures many constructed wetlands (i.e. 60 in numbers) with macrophyte, the removal percentage of fecal and total coliforms was 95–99%, and removal efficiency of *fecal streptococci* was 80–90% (Vymazal 2005b).

Free water surface constructed wetlands are also called as surface flow wetlands. It consists of shallow basins and a structure that controls water depth. A 20-40cm of soil is needed to support the roots of macrophytes. They effectively remove suspended solids by filtration and sedimentation, and also nitrogen is effectively removed by nitrification and denitrification. Nitrifying bacteria in aerobic zones oxidized ammonium, and the denitrifying bacteria convert nitrate to free nitrogen or nitrous oxide in anoxic zones. The removal of phosphorus in this process is relatively slow because the contact between water column and the soil is limited. (Vymazal 2005a). Surface flow constructed wetland are most imitate natural environment which are more suitable for wetland species because of its permanent standing of water. In case of sub surface flow constructed wetland, water passes through the porous medium created by sand and gravel, therefore a limited number of wetland species are found (Miklas 2011). Macrophytes like yellow flag and canna lilies provide a large surface area for the attached growth of microorganisms. They stabilize the surface of wetland beds, also provide better condition for physical filtration, clogging is prevented by vertical flow system, during winter protect from ice (Brix 1994).

The wetland treatment process have various benefits such as requires less energy, low maintenance, and low operational requirements(Brix 1994). The denitrification process is limited in this process (Vymazal 2007). The disadvantages of this process are not suitable for steep sites, high land requirement, and requirement of base flow, limited depth range for flow attenuation, in non-growing season release nutrients.

3.2 Physico-Chemical Treatment

The physico-chemical treatment can reduce and deduct the protein colloids and milk fats present in dairy wastewater (Nadais et al. 2010). Coagulation and flocculation are the important steps in physico-chemical treatment which helps to treat the industrial wastewater (Ghernaout et al 2019).The principle of coagulation-flocculation is to accumulate particles present in waste water into settleable or filterable flocs prior to sedimentation or filtration. Agglomeration of particle is known as flocculation (Vigneswaran et al., n.d.). Coagulation-flocculation uses coagulant as Aluminum sulphate $Al_2(SO_4)_3$ to reduce hardness, and the concentration of phosphate (Hugar, n.d.). The coagulant can be natural (Moringaoleifera) or chemical (alum and ferrous sulphate) coagulant. The chemical coagulant is more effective in reducing the BOD, COD, and pH than natural coagulant (Hugar, n.d.). Chemical coagulant has ability to combine the dissolved organic matter, and insoluble particles present in DWW into large aggregates, hence they can be removed by sedimentation, floatation, filtration (Kushwaha, et al 2011). The DWW is treated by coagulation with coagulant as iron chloride ($FeCl_3$), aluminum sulfate ($Al_2(SO_4)_3$), calcium hydroxide ($Ca(OH)_2$ which removes 40% organic matter and nitrogen content. Calcium hydroxide removes 94% of suspended matter and 89% of total phosphorus (Hamdani, et al 2005). Also chitosan can also be used as adsorbent to remove COD from dairy wastewater. It is an eco-friendly substance, easily biodegradable, and nontoxic. The removal efficiency of COD is 79%, and by increasing the dosage of adsorbent the reduction increases (Geetha Devi, et al 2012). There are many physico chemical methods are available but adsorption is the best suited way to remove organic matters. In general activated carbon is used as a good adsorbent for the treatment of various industrial waste waters, so many investigators use low cost adsorbent like rice husk, coconut coir, and fly ash etc. The powdered activated carbon is also used to treat dairy waste water as adsorbent (Kushwaha, et al 2011).

The turbidity of wastewater is only caused due to the presence of suspended and colloidal solids, and which can be reduced by coagulation-flocculation. It also helps in removing organic substances which is responsible for COD, BOD contents. The addition of coagulant in wastewater results in disruption of particulate matter present in it, and followed by collision of particle. Ultimately results in sedimentation and flotation (Sarkar et al. 2006b).

The dairy wastewater can be alternatively treated with a process called electro coagulation or flotation. This method can successfully remove oil and grease, and suspended solids from different industrial effluents. This process is a combination of coagulation and flotation which can be induced by the passage of electric current (Şengil et al 2006). This process is more effective in treating wastewater containing particularly small and large suspended particles, oil and grease, phosphate, organic matter, and colloidal particles.(X. Chen, et al 2000)(Bektaş et al. 2004)(Brillas et al 2002). It is a most reliable and cost effective treatment process. The equipment used in this process is simple and easy to operate, operation time is also short, less amount of sludge, and amount of chemical needed is less (“Environmental Electrochemistry_ Fundamentals and Applications in Pollution ,” n.d.).

Membrane process is a method that removes or separates the particulate and colloidal substances from the wastewater which acts a selective barrier. Membrane processes such as ultra-filtration, microfiltration, reverse osmosis, Nano-filtration, and electro-dialysis are suitable method to remove all particulate and colloidal substances from wastewater (“Technological Approaches for Novel Applications in Dairy Processing” 2018). It is also known as pressure driven technology in which external pressure is applied so that molecules can then flow from areas of low concentration to high concentration. Nano-filtration falls in between ultra-filtration and reverse-osmosis. Its pore size is 0.4-2.0 nm and helps to retain the salts and organic compounds. It is mostly permeable in removing low molecular weight organic compounds and mono-valent salts (“Nanotechnology Applications in Dairy Science: Packaging, Processing, and ... - Google Books,” n.d.). The better water quality is obtained from reverse osmosis than Nano-filtration; because NF doesn’t give better permeate flux. The removal efficiency of TOC, TKN, and Lactose was 99.8%, 96.3%, 99.5% respectively by RO technology(Vourch et al. 2008).

Physico-chemical method is suitable process as it efficiently removes organic matter. The advantage of this process is operations are flexible, simple maintenance, simple process. It has low efficiency in removal of dissolved substances and produces a large amount of chemical sludge. Also it is not able to remove pathogens and other toxic substances. Therefore it is used for pre-treatment process (Z. Li et al 2018).

3.3 Biological Method

Biological treatment is the most efficient method to treat DWW (Lohani et al. 2016). It includes processes like activated sludge (Al-wasify, et al 2017), (Schwarzenbeck,et al 2005) trickling filter (Birwal 2017), aerated lagoons (Lateef, et al 2013), up flow anaerobic sludge blanket (Lomte et al 2018),(Samadi, et al 2017),(Tawfik, et al 2008)sequential batch reactor (Neczaj et al. 2008) etc. This process help in removing the organic materials present in wastewater (Carvalho, et al 2013a). This treatment method uses microbes to treat toxic chemicals, and high organic loading in wastewater. It is basically divided into two categories according to their oxygen requirement- aerobic, and anaerobic process. In presence of oxygen the microbes decompose organic compounds which is called as aerobic method (Janet Joshiba et al. 2019). The two factors that is responsible for the success of biological treatment such as the ability of microorganisms present in the treatment unit to decompose the organic matter present in the wastewater, and at the last phase of treatment the competence of solid-liquid detachment of the biomass (Schwarzenbeck, et al 2005). The

effluents of dairy industry contain fats, proteins, lactose, BOD, COD, and other compounds which can be reduced by biological treatment. It is a cost effective method (Abdulgader et al. 2009).

3.3.1 Aerobic treatment

The aerobic treatment of DWW is used to remove BOD and phosphorus and nitrogen are used for the reduction of organic supplements like P and N present in waste water (Janet Joshiba et al. 2019). In this process the water from industry in presence of oxygen is subjected to oxidation reaction which leads to reduce harmful microbes present in DWW (Janet Joshiba et al. 2019). This is a high challenging treatment which occurs only in presence of air and microorganisms use this oxygen to adapt organic contents, and which are then transformed to biomass, CO_2, H_2O (Janet Joshiba et al. 2019), (Shete,et al 2013). The two main processes of biological treatment is attached growth or biofilm process, suspended growth process. In theprocess of suspended growth the organic matter is degraded in the presence of oxygen by microorganisms(Wang, et al 2009). Normally all the compounds present in dairy waste water are easily degradable except the proteins and fats (Omil et al. 2003). Because of the presence of high organic content in the dairy waste water biological treatment is best suited treatment (Gutiérrez, et al 1991).

The treatment of wastewater with biofilm has various benefits as compared with suspended growth process, due to its operational flexibility, increases reaction rate, require less space (Andersson 2009). The growth and formation of biofilm to the surface of bio carrier is a complex process in bio-filtration. The attachment strength depends upon the properties of media surface, conditions of environment, characteristics of water, type of microbes. The growth of biomass will be continuous until the loss of biomass by sloughing and decay. In case of rich substrate condition the biofilm grows and accumulates in a faster rate than the detachment rate but in case of low substrate condition the biofilm growth rate is balanced by sloughing.("Waste Water Treatment Technologies - Volume I - Google Books," n.d.), (Holá, et al 2006). The moving bed system contains all biofilm processes, which has continuous moving media. This continuous moving media can be maintained by velocity of water, high air, and mechanical stirring (Rodgers et al 2003). The selection of bio-carrier media for the treatment is based on density, size, porosity, and erosion resistant (Christensson et al 2004), (Ødegaard, et al 2000).

Aerated lagoons are the best technologies practiced to treat dairy waste water and it work efficiently and easy to reduce organic and inorganic loading from dairy effluent (Renou et al. 2008). According to the type of wastewater the aerated lagoons can be worked both in aerobic and anaerobic process ("Books @ Www.Google.Co.In," n.d.). In many developing nations the aerated lagoons are suitable to treat wastewater from dairy industry due to its efficient activity and economically effective (Janet Joshiba et al. 2019). A number of bacteria involved in this process to convert the complicated organic and inorganic compounds to simple compounds (Moura et al. 2009). Aerated lagoons are designed and its functioning depends upon different parameters of microorganisms like their structure, nutrient uptake, morphology, type. Temperature is the most important factor to be considered due of its major impact on the metabolism of microorganisms (Renou et al. 2008). To enhance the treatment process many new advancement had been implemented in this process for efficient removal of toxic pollutant in the effluent. Water hyacinth and duckweed are some of the aquatic plants are used in the treatment process for reducing high amount of nutrients and organic contents (P. Luo et al. 2018). The major limitation is that hazardous disease like contaminated waterborne diseases caused in aerated lagoons, so as to avoid the disease from the lagoons precaution measures should be taken by the people who are working near the treatment plant and also it should be perfectly maintained (Alhamlan et al. 2013). The removal efficiency of nitrogen was 87.7% – 97.9% whereas TN content was found to be 85.4% – 96.1% (Alhamlan et al. 2013).

The growing interest for the high impact treatment of industrial waste water trickling filter is being used (Raj and Murthy 1999). In case of trickling filter the wastewater is applied on the bio carrier on which biofilm are developed and the organic matter present in the wastewater are decomposed by biofilm with the help of microbes which are residing inside biofilm. The trickling filter are not submerged into any medium, and through the sprayers the waste water are subjected in the medium as well as this method is used to degrade high nutrient and organic present in wastewater (Amal Raj and Murthy 1999). The media in the trickling filter are arranged with greater permeability, high void fraction, and greater surface area (Amal Raj et al 1999). Trickling filter efficiency depends upon the parameters like temperature, growth rate of microorganisms, pH, removal rate, volume of biomass, nutrient uptake. This type of treatment is also known as nitrogen sources and removal of nutrients (Shahriari et al 2015). The materials which are packed in this process are foam, plastics, rock etc. Trickling filter are used because of its cost effectiveness (Mehrdadi, et al 2012). The bio carrier used in the trickling filter depends on the following parameters like cost effective, high corrosive resistant, high strength, large surface area, elevated porosity, high shock resistance, less weight. The microorganisms present in the biofilm consume vital nutrients like H, C, P, K and also other nutrients. The nutrients and organic matter present in the wastewater are transferred to the biofilm (Shahriari et al 2015).

Activated sludge process is highly used to treat sewage and household wastewater. In case of dairy waste water, it is preferred for the reduction of nitrogen, ammonia, and carbon compounds (Renou et al. 2008). ASP is highly favorable method to treat dairy waste water due to its ability to treat and remove the nutrients present in the water (Umıejewska K 2017). The main ingredients of ASP are protozoa and microbes which help to degrade organic substances and nutrients present in waste water. These microorganisms are able to consume suspended organic substances present in dairy wastewater and then convert it into activated sludge which are on later stage recycled and removed (Tocchi et al. 2012). In this process, the waste water are allowed to pass through aerated tank and further the activated sludge which are formed is removed from the dairy wastewater with the help of clarifier (A. Patel et al. 2016). This method also able to remove complicated substances like lactose, oils, fats, and proteins(Tocchi et al. 2012). But the aerobic granular sludge process is more efficient than aerobic sludge process because of following reasons are elevated settle ability,

high biomass recovery, high resistance against shock, less toxicity (Vashi, et al 2018). The removal efficiency of COD and BOD were 96% within 5days (Lateef, et al 2013). The removal efficiency of COD was 90%, total nitrogen was 65% (Donkin et al 1997).

RBC primarily works on the principle of adsorption and normally used to treat industrial and household waste water (Jaison et al. 2017). This method is highly preferred to remove nitrogen compounds from waste water (Mehrdadi, et al 2012). RBC is an attached growth process and widely preferred method due to its less energy consumption and high removal efficiency (Jaison et al. 2017). To enhance the growth of microorganism aeration is provided (Jaison et al. 2017). The microorganisms present in biofilm consume nutrients and organic compound which leads to increase in biomass volume, and slowly biofilm layer get thickened and volume increases. The sludge which are thickened falls down from the carrier and get mixed with sludge digester and finally convert to water and gas (Kamath et al. 2018). To treat various types of waste water RBC is preferred due to its feature such as easy operation, large surface, easy construction, less energy consumption, less maintenance, cost effectiveness, less shock. It becomes the main treatment system in aerobic treatment of waste water (Ebrahimi et al 2009). The removal efficiency of COD was 85% in RBC process (Rusten, et al 1992). The removal efficiency of COD was 96% with HRT of 36hrs (Ebrahimi et al 2009).

Sequencing batch reactor is the most preferred technology for the treatment of dairy waste water. In this technology dairy wastewater is added in a single batch reactor, and treated for the reduction of organic compounds and then discharged (Kushwaha, et al 2011). In single batch reactor aeration, equalization and clarification all can be achieved (Samkutty, et al 1996). The SBR efficiency depends upon different parameters such as HRT, volume of dissolved oxygen, COD, composition of organic loading, denitrification, nutrient composition, nitrification. This treatment system is compatible for various industrial waste water because of its efficiency, and easy construction (X. Li et al 2002). The removal efficiency of SBR process are 90% COD, 80% TN, 67% total phosphorus, and BOD removal in the range of 97–98% (Schwarzenbeck, et al 2005).

3.3.1.1 Biofiltration

In the biofiltration process the microorganisms are fixed to a medium which are porous and helps in the process of breakdown of foreign pollutants present in wastewater. The microorganisms grow on the surface of the medium used, and are suspended on the liquid phase encompassing the medium particles by the formation of biofilm (Srivastava et al 2008).The medium present in filter bed constitutes materials which are relatively inert and provide large surface area for attachment of biomass along with nutrient supply. The efficiency of biofiltration depends on the two factors i.e. properties and characteristics of the medium, it includes ability to host the population of microbes, porosity, water retention capacities, compaction degree. As in case of normal filtration physical strainer is required for biodegradable pollutant to decompose, but in biofiltration biodegradable pollutant decomposed by biological degradation(Lewandowski et al 2011). With the advancement of biofiltration process, microbes (facultative, anaerobic, aerobic, fungi, protozoa, algae) are slowly developed on the surface of the media and form a slime layer or biological film called as biofilm. For the successful bio filtration operation main crucial factor that is to maintain and control a healthy biofilm around the medium. The efficiency of bio filtration method mainly depends on the activities of microorganisms, as a constant source of nutrients and organic substances are required for its effective and consistent operation, and also some chemoautotrophic microbes use inorganic chemical as their source of energy. The parameters that are responsible for the efficiency of bio filtration are pH, concentration of toxic pollutant initially, temperature, concentration of oxygen (Van Loosdrecht et al. 1990). For the better efficiency of bio filtration the filter media can be modified chemically and genetically modification of microbes. Table 2 summarizesbio filtration process using varying media to treat different types of wastewater.

Table 2
Treatment of wastewater by biofiltration process using different media.

SN	Biofilter media	Type of wastewater	Parameter Removal efficiency	References
1	Gravel, anthracites	Synthetic humic acid water	TOC 55%	(Lin et al 2011)
2	Large stone, saw dust, vermi compost with earthworm	Urban wastewater	TSS 88.6%, TDS 99.8%, COD90%, NO_3^-92.7%, PO_4^{3-}98.3%	(Tomar et al 2011)
3	Granular activated carbon, sand, gravel	Domestic wastewater	dissolved organic carbon 35–60%,pharmaceuticals and personal care products > 90%,baseline toxicity equivalent concentration 28–68%	(Reungoat et al. 2011)
4	Corbicula fluminea	Winery wastewater	COD 99%	(Cooper, et al
5	C. fluminea	Swine wastewater	sCOD 91%	(Domingues et al. 2021)
6	Corncob, woodchips, *Eiseniafoetida*	Domestic wastewater	COD 86%, $BOD_5$91%	(Karla et al. 2021)
7	Vermi filtration	Urban wastewater	$BOD_5$97.5%,tCOD74.3%, pCOD91.1%, TSS 98.2% and $NH4^+$ 88.1%	(Lourenço et al 2017)

3.3.2 Anaerobic treatment

As there are some disadvantages of aerobic treatment like high energy required through aeration, and efficiency is less due to growth of microorganisms (Sivakumar, et al 2012). Anaerobic treatment is an efficient method to degrade organic constitutes with the help of microbes in the absence of oxygen (Kalat et al 2017). In anaerobic digestion process involves two steps like stabilization and degradation with the help of microbes (Chatzipaschali et al 2012). The microbes with help in the anaerobic digestion are mixed culture of methanogenic and acidogenic(Krishnan et al. 2017). In comparison with aerobic treatment system generation of sludge is low and utilize a large content of organic waste for energy generation (Hamza, et al 2016). The factors responsible for the best efficiency in anaerobic process for the waste water treatment are sludge retention, and mass transfer (Lohani et al. 2016).

Anaerobic filter is a type of anaerobic treatment helps in treating low strength waste water and high strength waste water is limited because of high OLR (Karadag, et al. 2015b). The packing materials in the anaerobic filters are used to hold up the microorganisms in the voids. The packing material increases the surface area, and porosity. The sufficient surface area of the biocarrier improves biomass connection; large porosity lowers the reactor volume; and limits channel obstruction. The different materials used in anaerobic filter are seashell, plastic materials, sintered glass, charcoal, ceramic, rocks, limestone, clay (Karadag, et al. 2015b). The removal efficiency of COD was 80% (Loupasaki et al 2013).

In current days the up flow anaerobic sludge blanket has tremendously increased its popularity for waste water treatment containing organic materials. The settling characteristics of this type of reactor are better because the sludge of the reactor does not allow undergoing mechanical agitation. In UASB mixing occurs due to flow distribution; and that occurs with high velocity; and gas produces because of agitation (Kushwaha, et al 2011). This process is highly cost effective because it utilizes less pump energy for recirculation process and does not require any other expenses. It does not require any support materials for retaining a high density anaerobic sludge (Goli et al. 2019). The maximum removal efficiency of COD was 80%, and maximum BOD removal efficiency was 90% (Samadi, et al 2017).

Continuous stirred tank reactor is practiced widely in laboratory scale than in full scale treatment due to its HRT limitation. This process is applied in synthetic and diluted waste water treatment (Carvalho, et al 2013b). Recently researchers focused on the treatment of waste water by CSTR for degradation of organic matter, and methane yield (Morken, et al 2018).

Anaerobic fluidized bed reactor efficiency gets limited because during the operation of the reactor biomass loss occurs and also due to the presence of large quantity of solid in the wastewater (Kushwaha, et al 2011). An additional support has been created in the reactor which adhere the generated biomass and it causes low HRT and high loading capacities. But fluidized bed reactor has the capacity to treat high OLRs (Hamza,et al 2016). In case of AFBR the microbes get attached to the bio carrier media and effluent flows upward to the media. The bio carrier used in this process are sand particles, mud particles, plastic granules, charcoal pieces, glass beads (Chowdhury, et al 2017). The efficiency of FBR depends on different components like capacity to escape growth of biofilm thickness, and contact between fine particles carried out by microorganisms and liquid. The advantages of AFBR are high mass transfer rate, low clogging, capacity to handle high load, high biomass, low space requirement (Burghate et al 2013), (Shete,et al 2013). The maximum removal efficiency of COD was 84% (Janet Joshiba et al. 2019).

4.0 Conclusion And Future Scope

This study reviewed dairy wastewater literature during 2000 to 2020. Dairy industry produces huge volume of wastewater containing significant amount of nutrients like BOD, COD, nitrogen, phosphorus, oil and grease, protein, lactose, potassium, calcium, sodium, total solids, total suspended solids, total dissolved solids. The organic loadings of dairy effluent when mixed with fresh water causes eutrophication and deplete dissolved oxygen. Effluent constitute some complicated organic and chemical compounds which becomes difficult to degrade. In the preliminary treatment mostly oil, fats, solids, and grease can be degraded. Remaining organic loading can be degraded by biological treatment. During aerobic treatment, fats and other supplements can be degraded easily without much stretch, due to air circulation. Microorganisms with high removal capacity and high growth rate should be implemented to reduce time consumption in dairy wastewater treatment. In comparison with both the treatment process aerobic process is the outstanding process in the removal of fatty and organic compounds from effluent. The major drawback of aerobic system is high energy consumption and air circulation. In order to minimize the energy consumption, bio filtration like vermifilter, macrophyte can be added for oxygen supply. Review study found that anaerobic process is also well known in removing high organic load of the dairy wastewater using digesters and UASB.

Vermifiltration process is operated by the earthworms that becomes more vigorous and efficient with time as a large amount of worms grows. The treated effluent contains a large amount of nitrogen and phosphorus which can further help in horticulture. High organic loading of dairy effluents can only be treated by biological method. Also micro-organisms with high removal rate and high growth rate should be implemented in order to decrease time consumption and quick decomposition. Bio filtration with different bed materials and efficient microbes help to degrade the contaminants. Also other advanced technique need to be adopted by the treatment plant to reduce energy consumption which is a main drawback of the system. High energy consumption and circulation of air is a major drawback of the system. Hence much emphasis should be given to limitation of aerobic process and more research should be done on bio filtration bed materials.

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Authors Contributions

Pragyan Das contributed to conceptualization, formal analysis; investigation; methodology; software; roles/writing—original draft; and writing—review and editing.

Kakoli Karar Paul helped with supervision; validation; and writing—review and editing.

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Figures

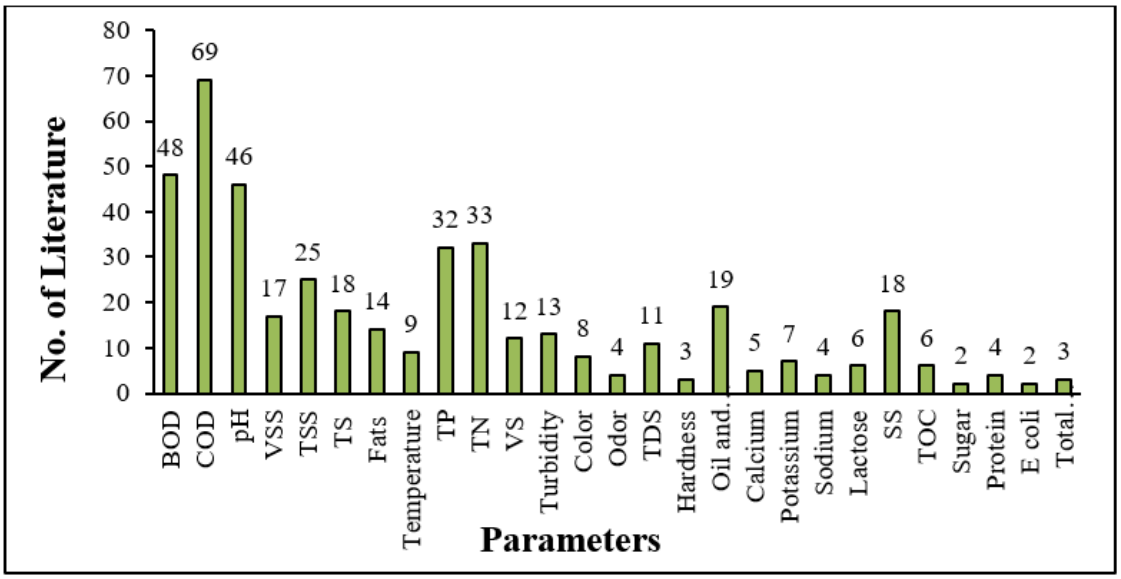

Figure 1

Literature review for physico-chemical and bacteriological characteristics of DWW

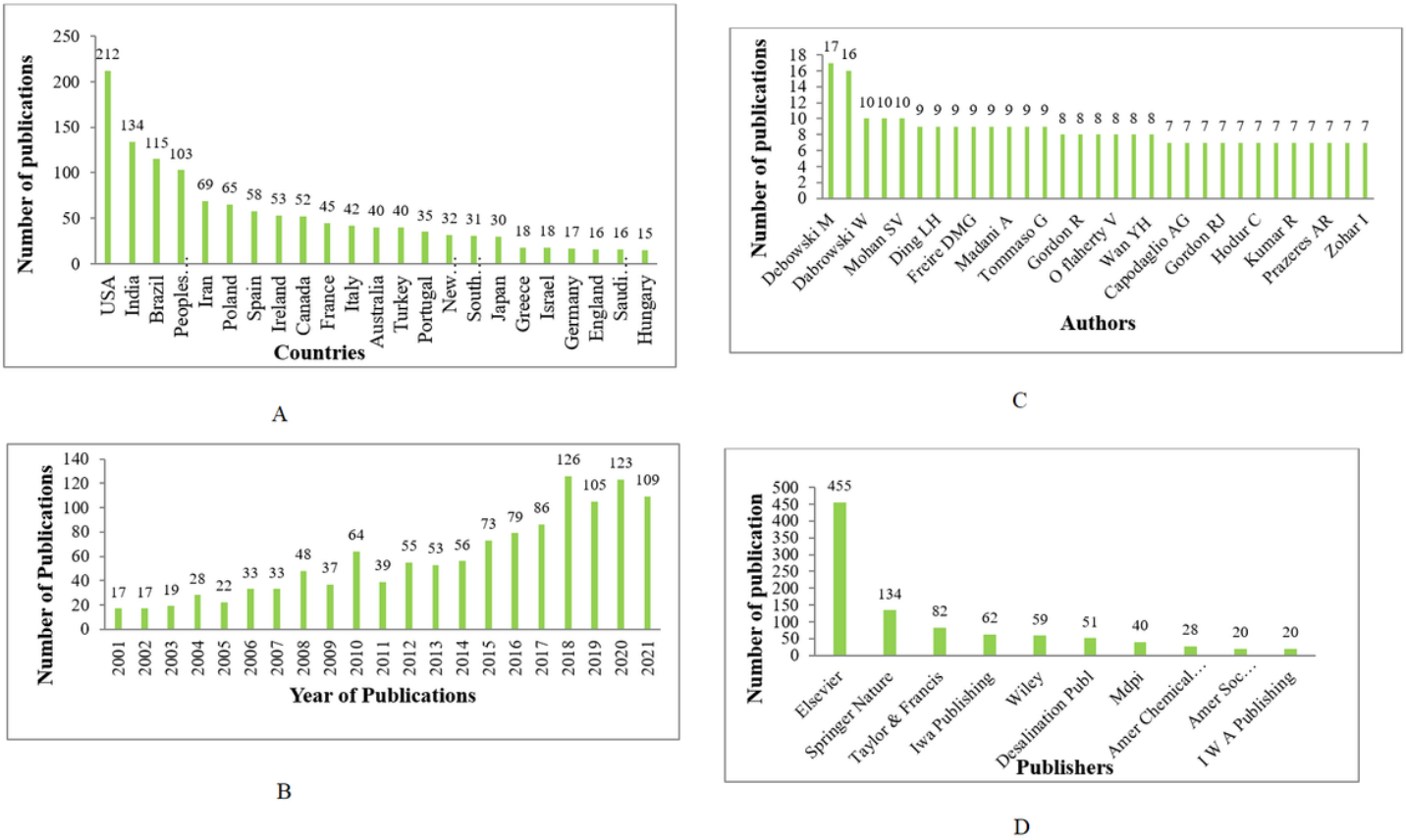

Figure 2

Publications related to the searched items dairy wastewater treatment from web of science database. (a) Number of publications per year (b) Countries that mostly published the studies (c) Researchers that most published studies (d) Publishers that mostly published the studies.

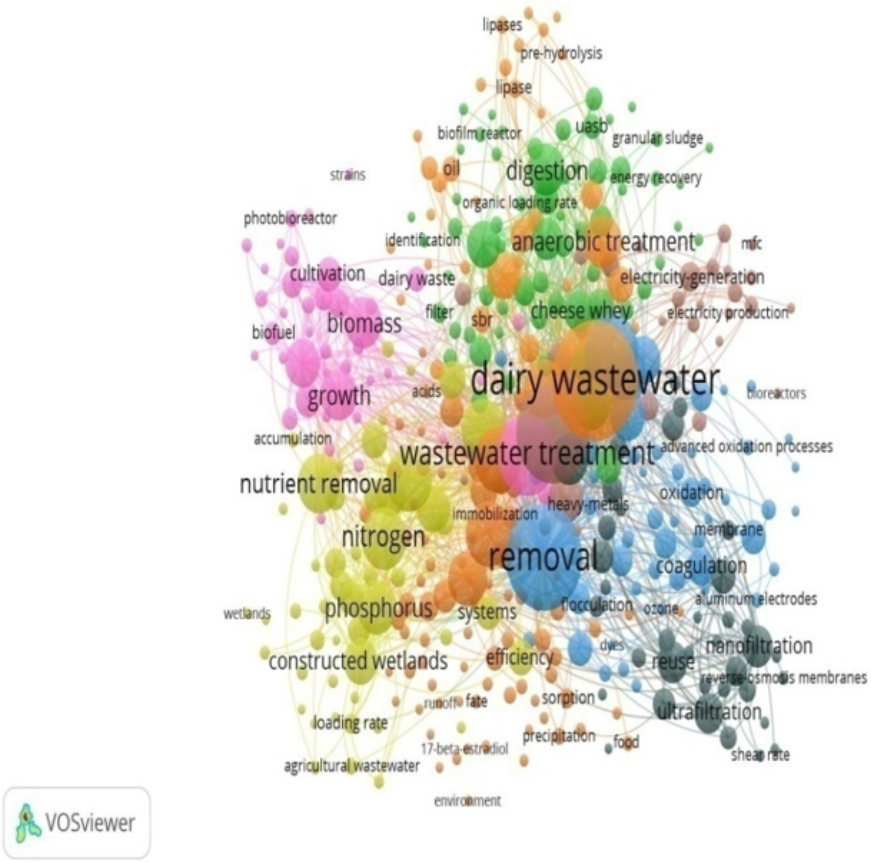

Figure 3

Network view map generated in VOSviewerfor dairy wastewater treatment. Color represents the clusters of extracted terms grouped by VOSviewer software according to the relations of items.

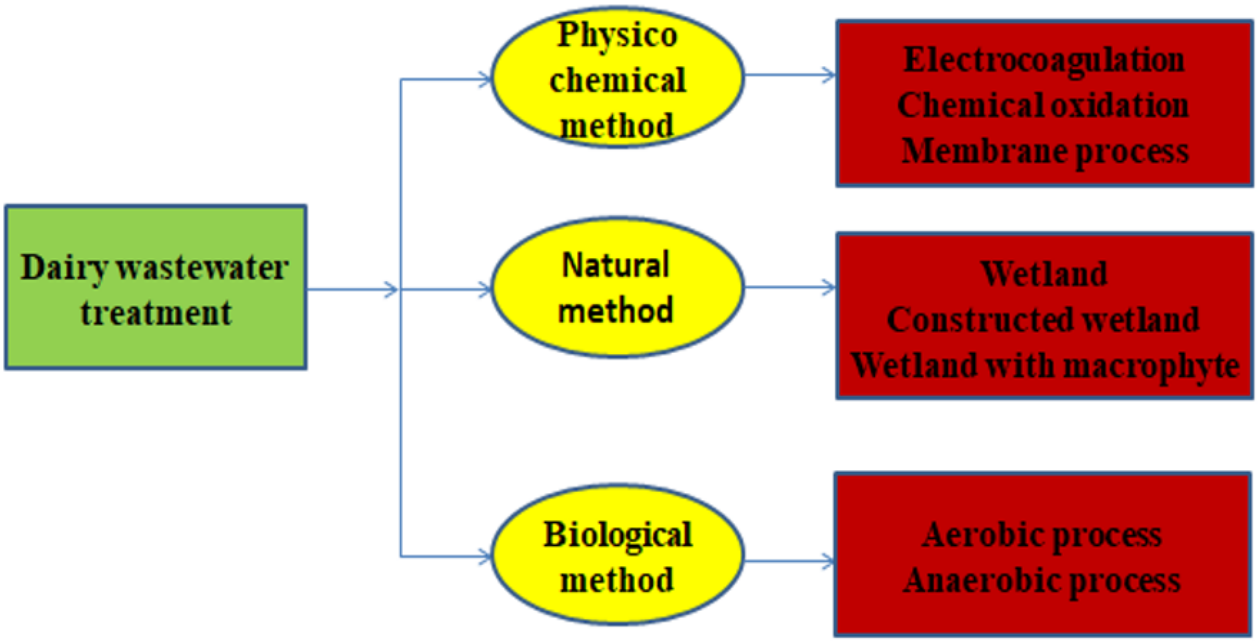

Figure 4