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Trickling Filters for The Removal of Residual Organic Matter in The Dairy Industry. A Review

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Abstract

Dairy industries have grown enormously in many regions of the world due to the demand for milk products. Dairy industries release large quantities of wastewater containing high chemical oxygen demand (COD), biological oxygen demand (BOD), organic and inorganic substances, which, if not properly treated, contaminate water resources. In the present work we consider analyzing the treatment of residual organic matter in the dairy industry, where trickling filters is a sanitation technology that uses microorganisms that adhere to a medium with a large surface area to remove mainly soluble organic matter such as BOD and COD as the wastewater passes through the medium. All trickling filters require primary treatment of suspended solids to prevent clogging of the filter media. Because trickling filters are designed to remove soluble organic matter, they are not expected to have high pathogen removal rates. This system, the removal efficiency achieved for BOD ranges from 69 - 78 % and for COD from 65 - 80 %, suspended solids removal from 38 to 56 %, for total dissolved solids from 20 to 36 % and other aggregates such as turbidity and color removal from 32 to 54 % and 25 to 42 % respectively. Membrane technology is an alternative to biotreatment used for BOD reduction in dairy wastewater replacing secondary clarifiers in membrane waste treatment plants (Kanwar et al., 2017). The trickling filter in this regard is potentially a viable option, as it is a simple and reliable biological treatment process and an appropriate option for small and medium-sized communities, requiring less space and time for BOD removal. This dairy wastewater treatment system presents an attractive alternative from a technical and economical point of view.

Keywords: *COD, BOD, trickling filter, wastewater, organic waste.*

Introduction

Agro-industries generate large amounts of wastewater that often remain untreated and are discharged into nearby water sources, contributing greatly to the global problem of environmental pollution (Ahmad et al., 2022). On the other hand, many of the small agro-industrial enterprises produce by-products and residues on a seasonal basis, generally do not have financial resources for the proper disposal of waste and in many cases do not respect the legislative norms on waste and wastewater (Akratoset al., 2020).It is one of the food industries that dumps three times as much waste as the volume of milk produced, between 3,739 and 11,217 million m3 per year and is the result of several processes such as cleaning, sanitation, manufacturing, heating, mixing, and refrigeration producing a large amount of organic load in the form of effluents (Joshiba et al., 2019).

Due to the high organic content of these types of wastes, in the water they form a film on the surface which hinders the transfer of oxygen and subsequently leads aquatic animals and plants to difficult survival conditions (Ahmad et al., 2019). Throughout Latin America, as in Ecuador, there are no efficient processes to treat waste, nor are environmental controls carried out on the subject. There are studies on the use of dairy waste where it can be reused as fertilizer in the agricultural sectors.

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(Alvarado, 2018)(Rodríguez & Martínez, 2020) Wastewater is the result of activity carried out by industrial sectors and biological procedures are used to treat them as it is economical and environmentally friendly. (Castillo, 2021)They are characterized by high levels of nitrates, nitrites and phosphates, nutrients responsible for the degradation of water resources by eutrophication (Chepngeno et al., 2022). The large volumes produced and seasonal variability make treating this wastewater an environmental challenge. (Love et al., 2019).

Trickling filters They are wastewater treatment systems that are responsible for putting the water in contact with the biomass adhered to a solid support to create a layer of biological oxidation, the use of trickling filters depends on the pretreated water being necessary a control and a repair of biomass (Ormarza & Ortiz, 2020). Trickling filters are a sanitation technology that uses microorganisms that adhere to a large-surface medium to remove soluble organic matter as wastewater passes through the medium. For all the above, the objective of this research is to study trickling filters for the removal of residual organic matter from the dairy industry. (Oakley & Sperling, 2017)

2. Dairy industries

The dairy industry is a food industry of high water consumption that due to its toxicity since it cannot be reused, since they release a large amount of COD, BOD, inorganic and organic particles, contaminates water effluents, greatly affects our ecosystem and biodiversity.(Kaur, 2021) During the dairy manufacturing process, large amounts of organic waste containing carbohydrates, proteins, fat or oil, water pH, phosphate and nitrate concentration are produced (Kushwaha et al., 2010).

2.1. Characteristics of wastewater from the dairy industry

They contain a high concentration of dissolved organic components, such as lactose, minerals, fats and whey protein, which vary mainly according to the type of products and operations (Ahmad et al., 2019). In addition, these residues contain a high level of organic matter, oil and fat, fatty acids and considerable nitrogenous compounds (Porwal et al., 2015).

On the other hand, Joshiba et al., (2019) mention that dairy wastewater is distinguished by its high organic content and is characterized by its high levels of COD and BOD, which generates serious problems for water sources where they are discharged.

Board 1. Characteristics of wastewater from the dairy industry

Types of waste	BOD	pH
Dairy effluent	1200–1800 mg $^{L-1}$	7.2–8.8
Milk & Dairy Products factory	4840.6 mg $^{L-1}$	8.34
Pressed cheesemilk	1,20,000–1,35,000 mg $^{L-1}$	6
Dairy washing water	—	6.4–7.1

Fountain: Modified table of Sinh et al., (2018)

Environmental impact of dairy effluents

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Dairy industries release wastewater containing high chemical oxygen demand (COD), biological oxygen demand (BOD), nutrients, in addition to organic and inorganic substances, if treated incorrectly, severely pollute water resources (Goli et al., 2019). The organic components present in dairy wastewater rot rapidly, decreasing the level of dissolved oxygen in the receiving water bodies, creating anaerobic conditions and a foul odor. (Rezwana et al., 2022). In addition, the receiving water becomes a breeding ground for mosquitoes and flies that can cause dangerous diseases such as malaria, chikungunya and dengue. (Qasim & Mane, 2013)

Milk effluent contains many components of milk such as inorganic salts, casein along with detergents and disinfectants used for washing, all these constituents are responsible for the increase in BOD and COD (Singh et al., 2014).

Wastewater from dairy industries results in the emission of toxic gases such as carbon dioxide, sulfur oxides and nitrogen oxide into the atmosphere, these compounds are greenhouse gases and can lead to global warming (Sinha et al., 2018). Dairy effluents result in the growth of algae and bacteria that provoke oxygen consumption in the water and cause suffocation in the river, this process causes the gradual death of fish (Al-Wasify et al., 2018)

Standards for effluent discharge to freshwater bodies

Wastewater discharged by industries may contain different types of toxic compounds that exert harmful effects on living organisms, specifically the microbial community (Akansha et al., 2020). For the determination of the quality limits for a given discharge, it is carried out by means of the following relationship: Ce = Cc + (Cc – Cr) R

Where: Ce: Average daily concentration of the pollutant, maximum permitted in the treated discharge or effluent; Cc: Average daily concentration of water quality criterion for assigned use; Cr: Concentration of the pollutant in the upstream section of the discharge, the value of which must be lower than the concentration of the quality criterion Cc; R: Qr/Qe = The flow ratio between the river and the discharge; Qr: Critical flow rate of receiving body; Qe: It is the flow rate of the discharge under future conditions.

Board 2. Discharge limits to a freshwater body

Parameters	Expressed as	Unit	Maximum permissible limit
Oils and Fats.	Sust. soluble in hexane	mg/l	30,0
Alkil mercury		mg/l	Not detectable
Aluminium	To the	mg/l	5,0
Total arsenic	As	mg/l	0,1
Barium	Three	mg/l	2,0
Boro Total	B	mg/l	2,0
Cadmino	Cd	mg/l	0,02
Total cyanide	CN^-	mg/l	0,1
Five	Zn	mg/l	5,0
Active Chlorine	Cl	mg/l	0,5
Chloroform	Ext. carbon chloroform	mg/l	0,1

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	ECC		
Chlorides	Cl^-	mg/l	1 000
Copper	With	mg/l	1,0
Cobalt	Co	mg/l	0,5
Fecal coliforms	NMP	NMP/100 ml	Removal > 99.9%
Color real	Color real	color units	* Negligible in dilution: 1/20
Phenolic compounds	Phenol	mg/l	0,2
Hexavalent chromium	Cr^{+6}	mg/l	0,5
Biochemical Demand for Oxygen (5 days)	DBO5	mg/l	50,0
Chemical Oxygen Demand	DQO	mg/l	100,0
Tin	Sn	mg/l	5,0
Fluorides	F	mg/l	5,0
Total Phosphorus	P	mg/l	10,0
Total iron	Fe	mg/l	10,0
Total Hydrocarbons Petroleum	TPH	mg/l	20,0
Total manganese	Mn	mg/l	2,0
Floating matter	Visible		Absence
Total mercury	Hg	mg/l	0,005
Nickel	Nor	mg/l	2,0
Ammoniacal nitrogen	N	mg/l	30,0
Total Nitrogen Kjedahl	N	mg/l	50,0
Organochlorine compounds	Total organochlorines	mg/l	0,05
Organophosphorus compounds	Total organophosphates	mg/l	0,1
Silver	At the	mg/l	0,1
Lead	Pb	mg/l	0,2
Hydrogen potential	pH		5-9
Selenium	Herself	mg/l	0,1
Total Suspended Solids	SST	mg/l	80,0
Total solids	ST	mg/l	1 600
Sulphates	SO_4^{-2}	mg/l	1000
Sulphides	S^{-2}	mg/l	0,5
Temperature	^oC		< 35
Surfactants	Active methylene blue	mg/l	0,5
Carbon tetrachloride	Carbon tetrachloride	mg/l	1,0

* Color appreciation is estimated over 10 cm of diluted sample

Fountain: According to the FAO (2015)

2.4. Types of dairy waste treatments

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Wet: They are considered a type of sustainable wastewater treatment, since they have the same function as conventional treatments, but in a more economical, environmentally friendly and energy-efficient way (Stefanakis et al., 2016). A wetland includes the use of microbial communities to improve wastewater, therefore this system uses natural processes (Eskicioglu et al., 2018).

However, this treatment also has some disadvantages, including the use of a large area, the potential risk to surface and groundwater, the presence of insects and the presence of hazardous volatile substances (Ahmad et al., 2019). Heavily laden dairy wastewater is treated in facultative wetlands, while an 85% reduction in BOD in aerobic ponds with dairy waste can be achieved in five days at 20°C (Schiriano et al., 2016).

Physico-chemical: The destruction and reduction of milk fat and protein colloids in dairy wastewater can be achieved by physicochemical treatments, one of the most important steps of physicochemical treatment is coagulation (Carvalho et al., 2013). This step reduces suspended and colloidal particles responsible for water turbidity and helps reduce organic substances responsible for COD and BOD contents (Ahmad et al., 2019). The addition of coagulant results in destabilization of wastewater particles, followed by collision of particle and floc formation, resulting in flotation or sedimentation (Ahmad et al., 2019).

Biological: Biological treatment is the most preferred method for dairy wastewater, which includes processes such as trickling filters, aerated lagoons, activated sludge, upflow anaerobic sludge mantle, anaerobic filters, sequential batch reactor (Yonar et al., 2018).

Biological treatment can be divided into two branches:

The aerobic method: It is used in most dairy wastewater treatment plants, but has reduced efficiency mainly due to rapid acidification and filamentous growth, as a result of the low buffering capacity of water and high level of lactose (Sinha et al., 2018). The anaerobic method- It depends on microorganisms, which grow in the presence of an oxygen-rich environment and oxidize organic compounds into carbon dioxide, water and cellular material.(Koleu, 2016)

Board 3. Advantages and disadvantages of aerobic and anaerobic treatment of dairy industry wastewater

Factors	Aerobic process	Anaerobic process
Reactors	Aerated lagoons, stabilized ponds, trickling filters, biological discs	Upflow packed bed reactor with anaerobic filter, downflow fixed film reactor.
Size	Large size	Smaller reactor size
Energy	A lot of energy is required	They produce energy in the form of methane.
Biomass produce	Produces 6 to 8 times more biomass than the anaerobic process	Less biomass is produced
Shock charging	Excellent performance in this regard.	Not very good response to shock load

Source: Sinha et al., (2018)

2.5. Trickling filters

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The basic operation of trickling filters is the biological removal of organic matter, studies showed to achieve high eliminations of COD that reached between 88 and 90%, low eliminations of electrical conductivity are also achieved.(Qarani & Mohammed, 2019)

2.6. Trickling filters for dairy waste treatment

In a trickling filter, wastewater is distributed on the upper surface and passes vertically down through a permeable medium such as rocks or plastics as the water flows down, soluble organic matter is removed by aerobic heterotrophic microorganisms that are contained in a biofilm attached to the medium. The biofilm grows gradually as it comes into contact with passing wastewater, aeration occurs through natural air convection through ventilation, ports connected to the lower drainage system at the base of the filter (Oakley & Sperling, 2017)(Du et al., 2019).

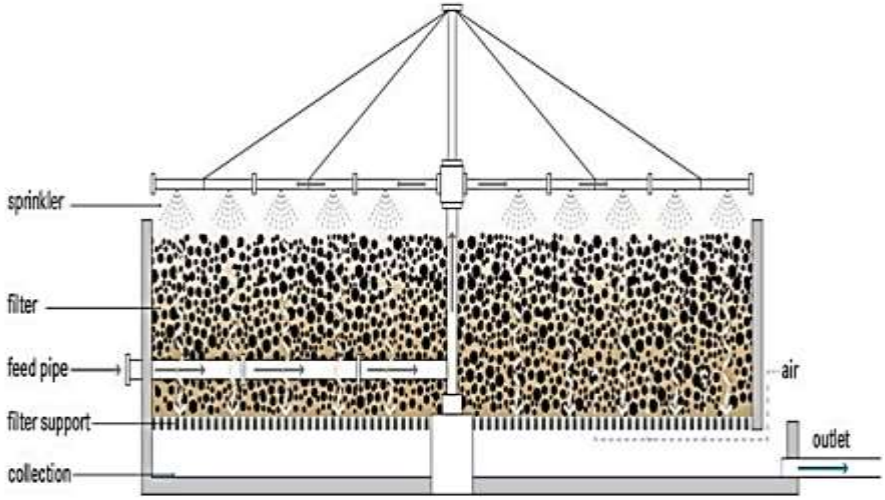

Figure 1. Schematic of a trickling filter

Fountain: Oakley & Sperling, (2017)

A trickling filter consists of a bed of stones or other natural or synthetic medium, on which wastewater is applied, the bed of the trickling filter consists of a permeable medium to which microorganisms adhere through which the liquid residue infiltrates. The biological filter is not a process designed to exert a true action of sieving or filtration of wastewater but to put wastewater in contact with biomass adhered to a fixed support medium, constituting a biological oxidation bed.(Bendesu & Martínez, 2017)(Rodriguez, 2019)

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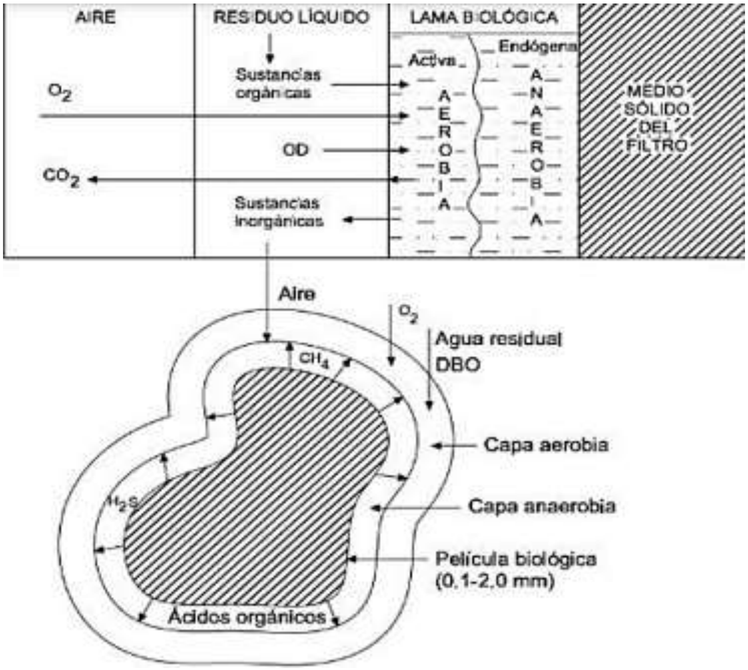

Figure 2. Schematic of the biological film of a trickling filter

Fountain: Jaramillo & Paredes, (2019)

2.7. Chemical oxygen demand COD

It is used to measure the oxygen equivalent of oxidizable organic substances with strong oxidizing chemicals in acidic environments and elevated temperatures (Bastug et al., 2022). For some antioxidant organic compounds, the use of a catalyst such as silver sulfate, COD is effective as an organic concentration parameter in industrial and domestic wastewater that is toxic to biological life (Dai et al., 2020).

2.8. BOD biological oxygen demand

It is a key indicator for understanding water quality to ensure environmental safety and human health (Nong et al., 2019). However, none of the current technologies are capable of online monitoring of water at the source, the sensors employ energy conversion to measure BOD, which is considered an international index for the detection of load of organic material present in wastewater (Sonawane et al., 2020).

2.9. Advantages of a trickling filter

Trickling filters is a cost-effective method for wastewater treatment, having contact with the biofilm generated on the surface of the filter media performs the degradation of organic matter by the action of microorganisms by oxidizing and reducing organic and inorganic pollutants. (Mendoza & Roca, 2021) The main advantages of using biological filtration are ease of operation and maintenance, flexibility for load changes, low construction costs, simple design, energy savings (Singer et al., 2017).

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2.10. Process of removal of residual organic matter by trickling filters

The process of removing residual organic matter consists of first going through the primary treatment before the effluents pass to the trickling filters, which is the secondary treatment. The primary treatment consists of separating coarse solids, suspended particles that can cause plugging, then the diagram of the process of removal of organic matter is shown.

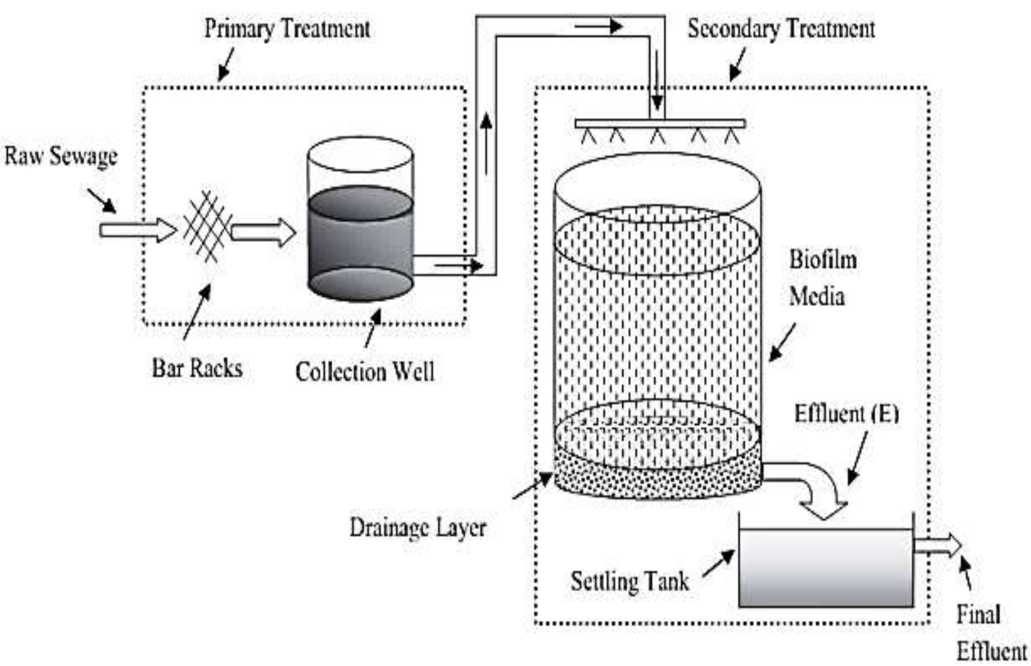

Figure 3. Diagram of the residual organic matter removal system with trickling filter

Source: (Ali et al., 2017)

In a trickling filter, organic pollutants such as biochemical oxygen demand (BOD), chemical oxygen demand (COD), ammonia and dissolved oxygen (DO) are dispersed on the surface and pass vertically downwards through a permeable medium where they will degrade organic matter with the help of microorganisms. . As the water flows downward, soluble organic matter is removed by aerobic heterotrophic microorganisms that are contained in a biofilm attached to the medium. The biofilm grows gradually as it comes into contact with passing sewage. (Oakley & Sperling, 2017)(Ali et al., 2017). Finally in the underground is the drains that carry the filtered effluent and allow air circulation.

In short, biological filters are bioreactors that by means of a layer of microorganisms adhered to a permeable medium allows the purification of wastewater. The permeable medium is called packaging which are usually rocks or plastics and microorganisms form a layer in the packaging which is called biofilm. Trickling filters typically achieve a BOD removal efficiency of 85-90% and a COD removal efficiency of 80-85% (Rodriguez, 2019)(Ali, et al., 2017).

3. RESULTS

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Biological methods are considered most effective for dairy wastewater treatment, where aerobic systems are easier to operate and control.High levels of COD demonstrate that dairy industry wastewater is highly polluted and fluctuating in nature (Goli et al., 2019).Akansha et al., , determined the maximum COD removal efficiency of 86.4% at neutral pH, this may be due to the different reactions taking place at different pH, on the other hand they observed, a lower COD removal efficiency at a lower pH due to the lower amount of insoluble ionic precipitates.(2020) In another study by Singh et al.,, using a biological wastewater treatment system for dairy products achieving a COD and BOD elimination of 77 % and 87 %, respectively. (2017) In the research conducted by Cuvi (2017), obtained the following efficiencies when using the different trickling filters on dairy residues as shown in the table below.

Board 1. Efficiency using different filters

Filter	Daily BOD of the tributary	Efficiency %
Low rate	100 - 300 (g DBO/m3)	80 - 85
Intermediate rate	240 - 480	50 - 70
High rate	0.5 - 1 (kg DBO/m3)	65 - 85
Super high rate	0.8 - 1.6 (kg DBO/m3)	65 - 80

Ahson *et al.,* (2017), demonstrated the concentration of BOD influent and effluent ranging between 156-278 mg / L 38-80 mg / L, while in the case of COD ranged between 139-342 mg / L 36-118 mg / l respectively, showed a maximum treatment efficiency of 72-77 % in terms of BOD and 73-79 % in terms of COD at a flow rate of 1.7 m3 / hour.

Another technology for the treatment of wastewater from dairy industries as mentioned by the authors Birwal & Priyanka, are the common membrane separation processes by microfiltration, nanofiltration, ultrafiltration, reverse osmosis and electrodialysis, with these methods a high recovery of the product is possible and the effluent produced is of high quality and can be used directly. (2017)

CONCLUSIONS

The dairy industry is an important food processing sector that uses a large amount of water and generates large amounts of dairy effluent. In general, it has high organic content of BOD, COD and temperature. If not treated properly and deposited directly on the ground, it can cause serious environmental problems and even affect humans, organisms that live in the water, such as fish and agriculture. Physico-chemical and biological treatment methods are used for the treatment of dairy waste. However, biological methods are preferred due to the better efficiency in removing soluble COD and reducing costs. The treatment with trickling filters is suggested for the direct use of the waste and its correct use does not generate odors. On the other hand, different alternative biotechnological ways are available to take advantage of the by-products of the dairy industry to obtain useful chemicals. The trickling filter in this regard is potentially a viable option, as it is a simple and reliable biological treatment process and an appropriate option for small and medium-sized communities, requiring less space and time for BOD removal. The trickling filter is suitable for the removal of residual organic

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matter from dairy industries, reaching an efficiency between 85%, 76%, 55% removal of COD and BOD. Membrane technology is an alternative to biotreatment used for BOD reduction in dairy wastewater replacing secondary clarifiers in membrane waste treatment plants (Kanwar *et al.,* 2017).

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