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Minimize environmental impact of dairy production through improve the life cycle. Part 1: Pollution load from Dairy wastewater in 6 of October Industrial City.

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Abstract:

In this study, characterizations of wastewaters produced from Dairy products facilities were investigated. 6th of October industrial zone has been selected as it is the biggest industrial city which includes 2000 registered companies distributed along eleven zones. Dairy industrial sector represents 12 % of total facilities (220 manufacturing facilities) .The main objective of this study is to estimate pollution load produced from dairy industry in different industrial area. Multiple Dairy products are represented such as milk, butter, cheese… etc. The analysis parameters , such as Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD_5) , Total Suspended Solids (TSS), alkalinity, turbidity, color and phosphorus. Final effluents were displaying higher values of organic matter than the allowed discharge limits according to the national standards. 90 % of the load from dairy industries is mainly of BOD and COD, which is caused by Lactose concentration. In addition, Cheese whey wastewaters have increased concentrations of BOD and organic matter. In case of discharge, this wastewater, without appropriate treatment, will contaminate water bodies, reducing the lifespan of sewage networks and the efficiency of wastewater treatment plant. Egyptian government has forced exceptionally strict rules Law 93 for the year 1962 and it's Ministerial Decree 44 for the year 2000 and the Egyptian Prime Minister's law 1012 for the year 2018 for the cost of industrial waste purification. Finally dairy wastewater is heavily polluted with organic load and should be treated before discharging.

Keywords: Dairy, Wastewater, sources, effluent, life cycle,

1. Introduction

Water is a vital origin of sustainability peculiarly in creating cities where more than one-third of the world's community lives in water-stressed, and by 2025 the number is anticipated to expand to two-thirds. [1,2] Egypt is among the most hyper arid countries where the annual share of water is 560 m^3 per person is very close to the international threshold absolute water scarcity and expected to drop below this threshold in the next five years . The whole world particularly the Middle East region and Egypt at the forefront are facing escalating water related challenges that include climate changes water scarcity environmental extreme events and increase in population[3].These circumstances have interrelated direct and indirect implications on the water availability and quality. United Nations (UN) sustainable development goals (SDG) giving high regards to the water sector and encourage to mitigate the climate change effect on cities which goes along with Egypt's vision 2030 [4].

This industrial zone consists of eleven industrial zones which nominated; first zone, the second zone, the third zone, the third extension zone, the fourth zone, the fifth zone, the sixth zone, the sixth extension zone, storage (1 and 2) zone, and developer zone [5]. Egyptian national industrial development strategy targets by the year 2025 that is Egypt becomes the leading industrialized nation in the Middle East and North Africa (MENA) region. This is required improvement the water quality and quantity and the new industrial cities are suitable in regard to the infrastructure and services [6, 7]. While, the rapid inflation in population which continues for decades it will be reached to 150 million by 2050. This high population growth rate the troubles revealed that fast deteriorating surface and groundwater quality [8,9].The 6th of October city is

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considered to be the oldest industrial zone was built with a total area of about 38 Km2 as shown in figure (1) The dairy industry includes the transformation of raw milk into pasteurized and sour milk, yoghurt, hard, soft and cottage cheese, cream and butter products, ice cream, milk and whey powders, lactose, condensed milk, as well as various types of desserts [10].

The dairy industries require large quantity of water for the purpose of washing of cans, machinery and floor, the liquid waste in a dairy originates from manufacturing process, utilities and service section. The clean water is used in various stages of dairy operations, such as, milk processing, cleaning, packaging and cleaning of the milk tankers and releases the wastewater which is known as dairy effluent [11]. Water is used for processing in the ratio of 1:10 (water: milk) per liter of milk. Dairy wastewater has high concentration of dissolved organic components like whey proteins, lactose, fat and minerals [12] and it is also malodorous because of the decomposition of some of the contaminants causing discomfort to the surrounding population. The dairy industry generates huge amount of wastewaters, approximately 0.2–10 L of waste per litre of processed milk [13]. Dairy wastes are largely neutral or slightly alkaline and have a tendency to become acidic quite rapidly, because of the fermentation of milk sugar to lactic acid. The lower pH may lead to the precipitation of casein. Dairy wastes are characterized by strong butyric acid odor and heavy black flocculated sludge masses [14]. Fats, oil and grease, also called FOG and can have negative impacts on wastewater treatment systems [15]. Oil and grease is composed primarily of a fatty matter from animal and vegetable sources, hydrocarbons of petroleum origin, the interferences include sulfur compounds and certain organic dyes [16]. Organic load is basically constituted by milk (raw material and dairy products), reflecting an effluent with high levels of chemical oxygen demand (COD), biochemical oxygen demand (BOD), oil and grease, nitrogen and phosphorus. Moreover, the automatic cleaning system CIP (cleaning in place) discards rinse waters with pH varying between 1.0 and 13.0, further complicating the question of treatment [17].

Wastes from milk product manufacture contain milk solids in a more or less dilute condition, but in varying concentration. These solids enter the waste from almost all of the operations. Wastewater generated by milk-based food industry [18]. Contaminants expected in the wastewater from Milk based food industry are shown in table (1). Dairy wastewater is one of the highly reached organic load wastewater and requires several separation techniques for each milk product to decrease the organic load into accepted limits [19]. The dairy wastewater characteristics and stream are the two most variables that influencing the quality of wastewater medicines. The dairy industry's wastewater is characterized by a variety of pH values and natural loads spoken to in Chemical Oxygen Request (COD), Organic Oxygen Request (BOD), Add up to Suspended Solids (TSS), Add up to Natural Carbon (TOC) and Lactose [20]. A few things about were conducted with dairy wastewater treatment utilizing distinctive procedures to control the dairy wastewater into acknowledged limits [21].

Figure(1) A Map of 6th of October industrial zone

Table. 1. Sources of pollution in dairy industry.

	Plant process	Waste generating process	Nature of Waste
1	Milk receiving	Tank truck washing	Milk solids + detergents
2	Clarifying and/ or standardizing	Sludge from centrifugal Milk solids high	Milk solids high inprotein & cells
3	Storage of rawmilk	Tank washing &sanitizing	Milk solids+ detergents +sanitizer
4	HTST Pasteurization, homogenization	HTST start-up & product change over cleaning	Milk solids + detergent +sanitizer

5	Standardizing,separating, cooling	Sludge from separator	Milk solids high in proteinsand cells
6	Vat processingcream	Cleaning and sanitizing	Milk solids+ detergent+ sanitizer
7	Storage of milk +cream	Cleaning and sanitizing	Milk solids+ detergent+ sanitizer
8	Filling and transferto cooler	Drips, broken packageconvey or lubrication cleaning	Milk solids + detergents + sanitizer+ lubricant
9	Cold storage &distributor	Broken packages conveyor lubricationreturns	Milk solids + detergents + sanitizer + lubricant

2- Material and Methods:

2.1. Selection of the studied area

The industrial zone consists of eleven industrial areas; first zone, the second zone, the third zone, the third extension zone, the fourth zone, the fifth zone, the sixth zone, the sixth extension zone, storage (1 and 2) zone, and developer zone (Table.2) [**22**].

Table (2) The total number of factories and dairy factories in the study area.

Industrial zone	Area	No of factories (all industries)	Dairy industry
6 October Industrial City	First	282	3
	Second	393	2
	Third	371	4
	Third Extension	241	3
	Fourth	95	3
	Fifth	72	1
	sixth	102	4
	Sixth Extension	197	3
	Developer Extension	135	2
	Storge 1(big)	232	1
	Storge 2 (300 m)	134	4

Figure (2) A map of 6th of October industrial zone showing the study area

2.2.Samples collection:

Treated dairy wastewaters samples were collected from the effluent of dairy factory located on 6th of October, city, Egypt. Eleven wastewater samples were collected weekly for the period from the 1st of January, 2021 to the 30th of June, 2021 to represent the effluent variation. The collected samples analyzed for the pollution indicators stated in

law 92/1962 and ministerial decree 44/2000 for discharge into public sewerage system. These analyzed parameters were total suspended solids (TSS), chemical oxygen demand (COD), biochemical oxygen demand (BOD), total kjeldahl nitrogen (TKN), total phosphorous (TP), oil and grease, phenol, cyanide; settle able solids, hydrogen sulfide. The analyses of all parameters were conducted according to the standard methods . Accuracy and precision of measurements were confirmed using external reference standards from Merck, and standard reference material and quality control sample from National Institute of Standards and Technology (NIST), were used to confirm the entire instrument reading **[23]**. All analyses were conducting in triplicate runs and all lab experiments were conducted by certified ISO17025 chemistry lab for examination of water and wastewater Housing and Building National Research Centre (HBRC) according to the standard method for water and wastewater examination 23rd edition, 2017.

3- Results and Discussions:

In recent years, great emphasis has been seen to reduce the environmental footprint of the activities in our daily lives. Food is essential for all life, and its production may have a significant environmental impact if it is not properly monitored. In this paper, the environmental impact associated with the production of dairy products, along with details of the leading method for estimating the impact, and life cycle assessment (LCA), are discussed. An overview of LCA studies assesses the environmental impact of dairy products**.**

3.1 Production rate and wastewater produced from dairy industry in each industrial zone

The present study shows that, the 6th of October industrial zone produces 333 Ton/day Whole milk, 89 Ton/day Whey, 130 Ton/day Curd, 57 Ton/day Butter, 96.25 Ton/day Cheese, 75 Ton/day Milk powder, 101 Ton/day Cream, and 71 Ton/day Yogurt with total product 952.25 Ton/day. About 33400 m^3/day contain high organic load are discharged directly into municipality as shown in Table (3).

	Unit	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6	Ext. 3	Ext. 4	Ext. 6	Store 1	Store 2
Flow	(m^3/day)	5000	15000	4000	2000	500	1000	2000	1000	2000	500	400
Production	**Production Rate** Ton/day											
Whole milk	(Ton/day)	50	60	70	40	5	8	50	20	30	0	0
Whey		20	10	10	15	1	0	2	2	4	10	15
Curd		25	30	12	10	0	0	3	0	20	20	10
Butter		12	20	5	10	0	0	1	0	2	2	5
Cheese		10	5	15	10	0.250	20	1	0	2	30	3
Milk powder		20	10	15	25	0	0	5	0	0	0	0
Cream		30	15	10	30	0	0	0	15	1	0	0
Yogurt		5	3	10	5	5	0	0	0	35	0	8

Table (3) Production rate and wastewater produced from dairy industry in each industrial zone

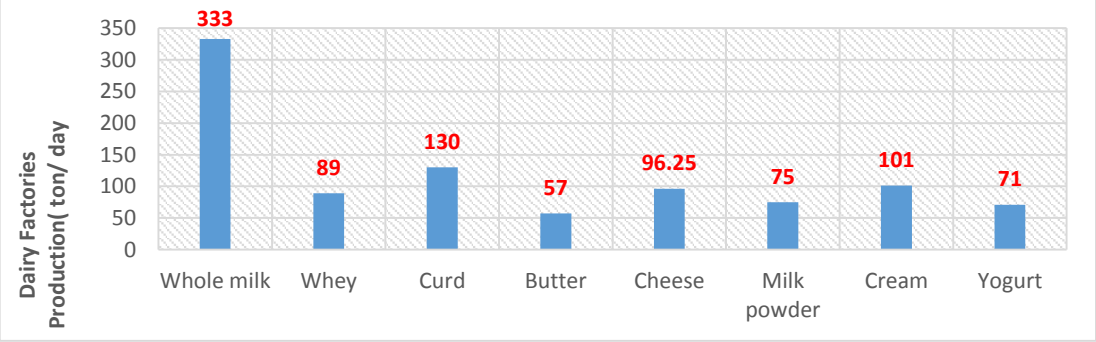

Fig 4. The Production rate of different dairy product in the different area Dairy

Dairy processing effluents are generated in an intermittent way and the flow rates of these effluents change significantly. The volume, concentration, and composition of the effluents arising in dairy industry are dependent on the type of product being processed, the production program, operating methods, design of

the processing plant, the degree of water management being applied, and subsequently the amount of water being conserved. These dairy industries generate different types of waste including: wastewater from the production line (cleaning of equipment and pipes) cooling water, domestic wastewater, the acid whey and sweet. Due to this the quality and quantity of the product content in the dairy wastewater at a given time changes with the application of another technological cycle in the processing line [**24**]. The sweet whey form the most polluting effluent by its biochemical composition rich in organic matter (lactose, protein, phosphorus, nitrates, nitrogen) and is from 60 to 80 times more polluting than domestic sewage. Dairy effluents decompose rapidly and deplete the dissolved oxygen level of the receiving streams immediately resulting in anaerobic conditions and release of strong foul odors due to inconvenience conditions. The casein precipitation from waste which decomposes further into a highly odorous black sludge at certain dilutions the dairy waste is found to be toxic [**25**]. Dairy effluent contains soluble organics, suspended solids, oil and grease.

3.2 Characterizations of Wastewater

Manufacturing processes make up a large portion of wastewater. Contaminated water, including sanitary activities, amounts for 50–80% of total water used in the dairy industry, with the remaining 20–50% being conditionally clean [**26, 27**]. In terms of volume, wastewater is expected to be around 2.5 times that of processed milk. The amount and qualities of wastewater are mostly determined by the factory's size, technology used, the effectiveness and complexity of clean-in-place (CIP) procedures, standard operating procedures (SOP) [**28,29**]. However, by implementing SOP, the global wastewaters mean volume can be reduced from 0.5-37 m^3 to 0.5–2 m^3 of effluent per m^3 of processed milk [**30,31**].

Dairy waste streams are warmer than municipal wastewater (10–20 °C), which results in faster biological degradation compared to sewage treatment plants [**32, 33**]. The average temperatures of industrial dairy effluents range from 17–18 °C in winter and 22–25 °C in summer [**34**]. Using the Arrhenius equation, the biodegradation rates and oxygen consumption can be predicted to be 1.5 times higher in summer than in winter [**35**]. The design winter temperature of 15 °C is adopted for this type of wastewater due to the utilization of hot water for washing and cleaning of equipment.

From the previous table, it is obvious that organic load is basically constituted by milk (raw material and dairy products), reflecting an effluent with high levels of chemical oxygen demand (COD), biochemical oxygen demand (BOD), oil and grease, nitrogen and phosphorus. Moreover, the automatic cleaning system CIP (cleaning in place) discards rinse waters with pH varying between 1.0 and 13.0, further complicating the question of treatment [**36,37**].

In figure (4), Chemical Oxygen Demand (COD) Concentration is ranged between 1633 mg/l and 19415 mg/l. Accordingly, the BOD concentration varied from 1120 mg/l to 13000 mg/l. However, maximum level of TSS is 3000 mg/l respectively (Figure, 5).

Table (4): The average characterization of dairy wastewater in different industrial zone in 6th of October industrial area

Waste produced from Industrial zone	pH	COD Mg/l	BOD Mg/l	TSS Mg/l	TOC Mg/l	Lactose g/l	Oil and Grease Mg/l
First Zone	**4.6**	**3550**	**2620**	**2000**	**1590**	**2.5**	**950**
Second Zone	**5.1**	**4600**	**3520**	**1410**	**1655**	**2.8**	**1004**
Third Zone	**5.4**	**1633**	**1120**	**910**	**830**	**2.2**	**600**
Fourth Zone	**6.2**	**2520**	**2210**	**1005**	**1155**	**2.6**	**800**
Fifth Zone	**5.2**	**8655**	**6412**	**2000**	**2177**	**3.2**	**1170**
sixth Zone	**5.6**	**5502**	**4366**	**1310**	**1070**	**3.1**	**850**
Third Extension Zone	**5.2**	**19000**	**13000**	**3000**	**5620**	**6.4**	**2400**
Developer Extension Zone	**5.8**	**4500**	**2300**	**1800**	**980**	**3.1**	**850**
Sixth Extension Zone	**5.4**	**10000**	**8200**	**2350**	**2190**	**4.3**	**1000**
Storge 1)big) Zone	**5.8**	**5600**	**4480**	**1200**	**2464**	**3.6**	**980**
Storge 2 (300 m) Zone	**5.8**	**19415**	**9705**	**2890**	**3654**	**5.1**	**2000**

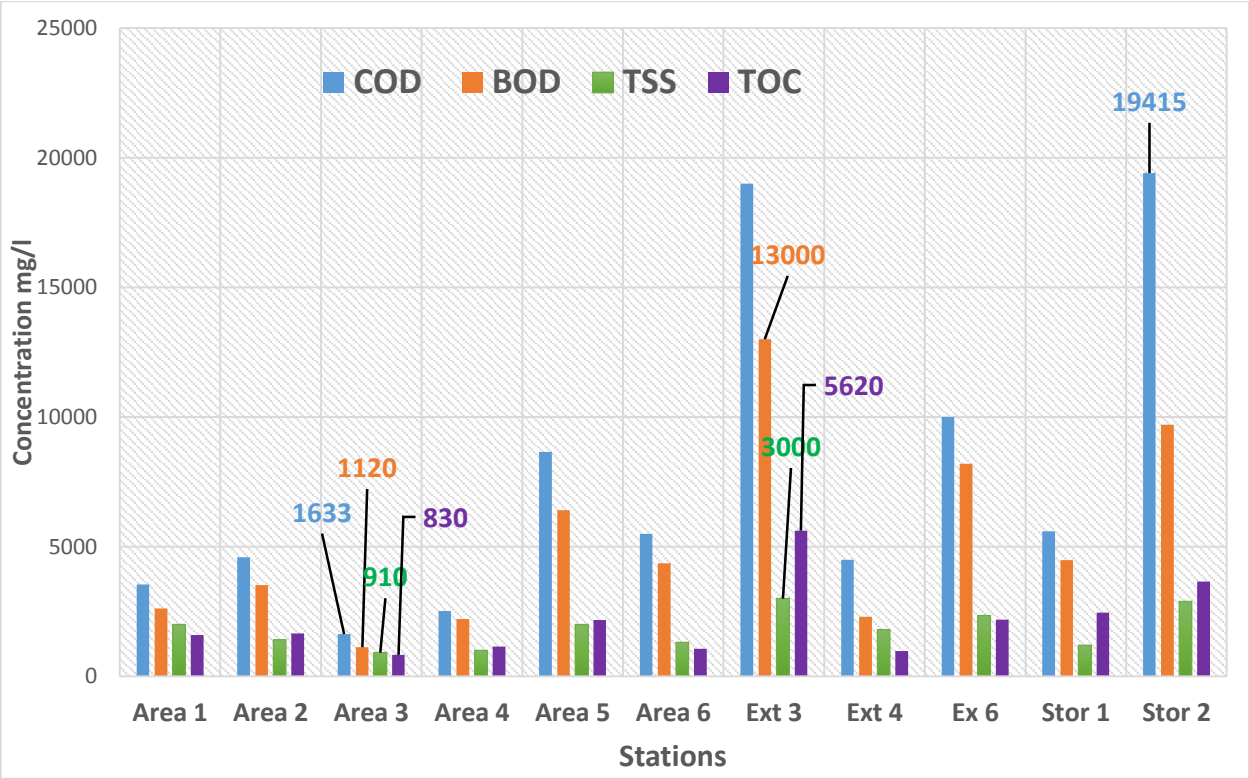

Figure (5) Variation of organic load in the different area.

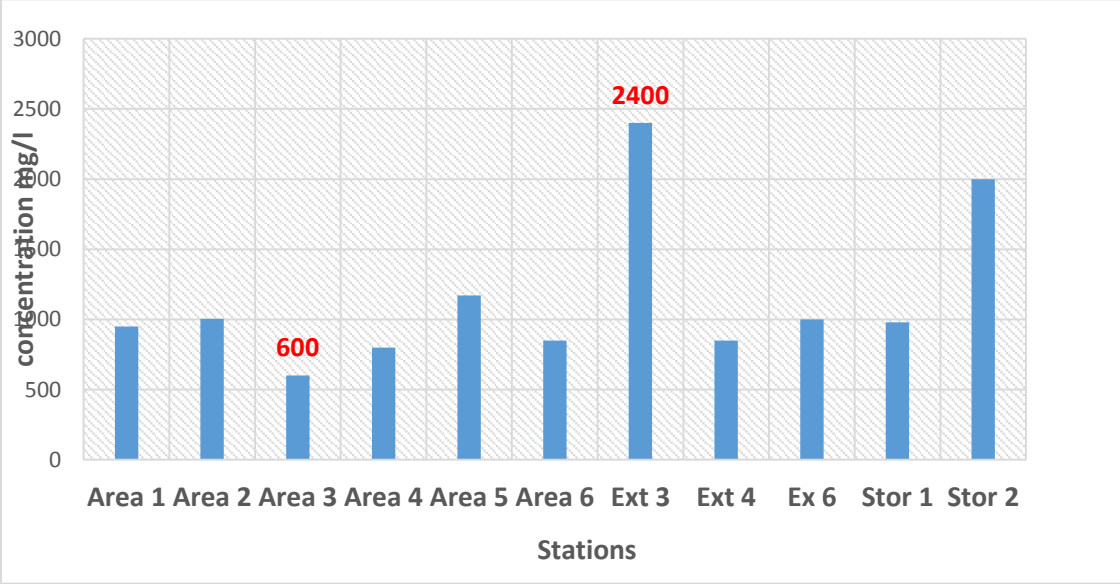

Fig.6. Variation of oil and grease concentration produced from dairy wastewater in different Industrial zone.

3.2.1 Effect of effluents on Environment

Wastewaters produced from dairy sector contain large quantities of milk constituents such as casein, lactose, inorganic salts oil and grease besides detergents. The production of pasteurized cream and butter generates effluents with high Oil and grease [**38**]. The dairy wastewater is basically composed of carbohydrates (lactose), proteins and fats. Thus, it is characterized by large amount of organic molecules, high fats, oils and grease (FOG) content along with milk solids, detergents, sanitizers, and residual milk wastes. Whey and butter are

playing a crucial role in generating effluent having high oil and grease load. [**39,40**].Oil & grease contamination is the most critical wastewater pollutants that may affect municipal wastewater pipes, The variation of Oil& grease is due to different types of dairy stuff used in the milk process for the various milk industries. These FOGs can cause serious issues of organic loading on local sewage drainage system [**41, 42**]. Wastewater produced is violating Environmental laws and Law regulates discharge wastewater to the municipality Law 93/1962 (Decree 44/2000). Results depicted in figure (6) illustrate the variation of oil and grease concentration from dairy wastewater in the different Industrial zone.

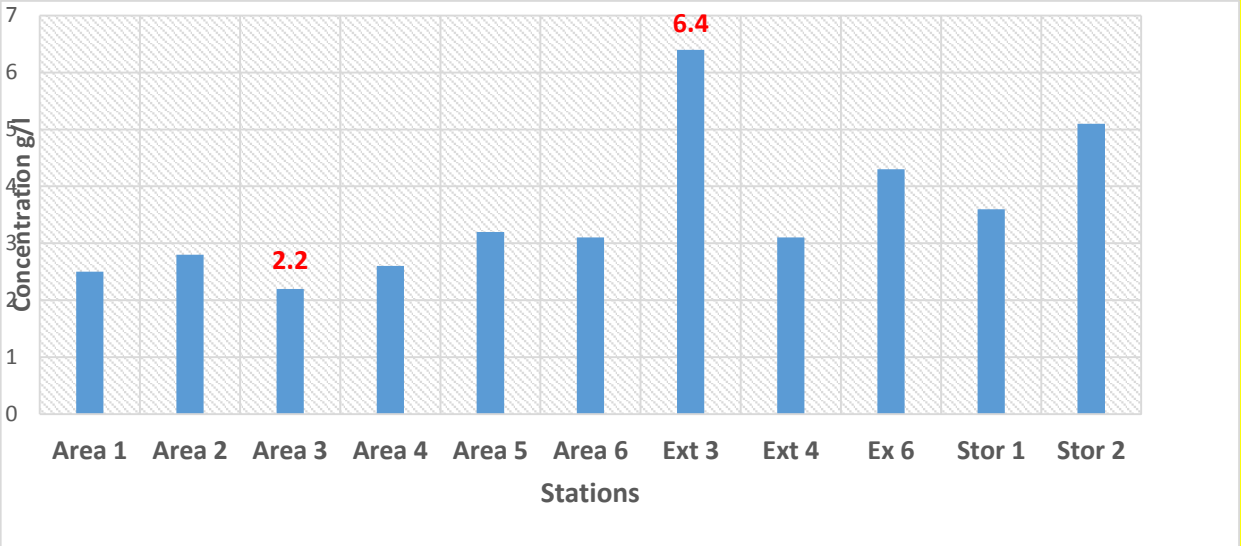

Fig.7. Concentration of dairy wastewater lactose contamination in the different stations at the study area.

From previous results we conclude that the main reason for the high organic load in the wastewater generated by the dairy industry is the presence of high concentrations of lactose in wastewater. The milk protein comprise two major classes, the casein and whey proteins. The caseins represent (80% of the total proteins) are of four major types [**43**].Typically, whey is contain of at least 98.0% lactose, 0.1% protein, 0.1–0.3% ash, 4.0–5.5% moisture and is free of fat. However, even in the absence of a major protein, this fraction remains very polluting to the environmental, considering the high (BOD) of lactose, the dominant compound. From figure (7) it obvious that, lactose concentration in the extended third zone reached to 6.4g/l, while lactose concentration in the second zone was 2.2 g/l. Lactose concentrations in industrial wastewater were found to have a negative impact on biological treatment process. Lactose despite being essential for various pharmaceutical products and preparations is discharged as a residue in the dairy sector. Extraction and separation of lactose from wastewater lowers treatment costs and allow it to be used as a by-product. To reduce the organic load in the sewage system, several experiments have been done to separate and recover lactose from dairy sector wastewater [**44**]

Conclusion:

The high pollution load of dairy wastewater is attributed to presence of large quantities of milk constituents, which contain mainly organic biodegradable materials, such as casein, lactose, and inorganic salts; in addition to detergents and sanitizers used for washing. The milk –processing industries discharging untreated /partially treated wastewater case serious environmental problems; it is very important to separate the lactose from water before draining it into the public sewage network to save the public municipal network and reduce the cost of treatment.

Conflict of Interests:

The author declares that there is no conflict of interest regarding the publication of this paper.

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