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WASTE WATER MANAGEMENT IN DAIRY INDUSTRY: POLLUTION ABATEMENT AND PREVENTIVE ATTITUDES

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Abstract: Increase in demand for milk and their products many dairies of different sizes have come up in different places. The dairy industry involves processing raw milk into products such as consumer milk, butter, cheese, yogurt, condensed milk, dried milk (milk powder), and ice cream, using processes such as chilling, pasteurization, and homogenization. The typical by-products of milk are buttermilk, whey, and their derivatives. The effluents are generated from milk processing through milk spillage, drippings, washing of cans, tankers bottles, utensil, and equipment's and floors. The dairy industry generate on an average 2.5-3.0 litres of wastewater per litre of milk processed. Generally this wastewater contains large quantities of fat, casein, lactose, and inorganic salts, besides detergents, sanitizers etc. used for washing. These all contribute largely towards their high biological oxygen demand (BOD), chemical oxygen demand (COD) and oil and grease much higher than the permissible limits. Among the biological treatments trickling filter and activated sludge process involve more economy high power requirement, more chemical consumption and large area requirement. Use of a dairy wastewater for irrigation after primary treatment in an aerated lagoon may also be good for the disposal of dairy wastes.

Keywords: Dairy industry, Wastewater, COD, BOD.

I. INTRODUCTION

The food industry have one of the highest consumptions of water and is one of the biggest producers of effluents per unit of production, in addition they generate a large volume of sludge during biological treatment. The dairy industry is one of those sector, in which the cleaning silos, tanks, homogenizers, pipe sand, heat exchangers other equipment, engenders a large amount of effluents with a high organic load. This organic load is basically constituted of milk (raw material and dairy products), reflecting an effluent with high levels of chemical oxygen demand (COD), biochemical oxygen demand (BOD), oils and grease, nitrogen and phosphorus. The automatic cleaning system – CIP (cleaning in place) – discard rinse waters with pH varying between 1.0 and 13.0, further complicating the question of treatment. BOD is directly related to milk wastes (90% to 94% of the effluent BOD), and in some cases losses can reach 2% of the volume processed by the industry [1].

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In order to reduce the effects of industrial sector pollutants, the end-of-pipe treatment techniques have been improved at the same time prevention measures are being implemented in order to minimize the production of residues. End-of-pipe control captures wastewater after its generation, enabling its discharge into environment. These are peripheral solutions that focus primarily on the chemical, biological and physical treatment of terminal streams. However, they address the symptoms and not the true causes of the environmental problems, and therefore they are not cost effective or sustainable. The essential feature of the pollution prevention program is the concept of reduction at sources, based on the idea that the generation of pollutant can be reduced or eliminated by increasing efficiency in the use of raw materials, energy, water and some other resources. Cleaner production intends to integrate the production aims in order to reduce the quantity and toxicity of residues and discharges. Pollution prevention or source generation reduction refers to any processor technology that seeks the reduction or elimination of the volume, concentration or toxicity of generating source residues [2]. The concept of cleaner production involves the reduction of negative environmental impacts throughout the products life cycle, from extraction of raw material to its final use.

The dairy is a multiproduct factory and its wastewater treatment process is based on five steps: (a) screening; (b) sand trap/oil and grease separation in a tank; (c) flow equalization in a tank; (d) an activated sludge process; (e) tertiary treatment in three facultative lagoons. However, the process is almost overloaded and requires a more complete diagnosis. On the other hand, minimization of the pollution index indicator must be evaluated, not only in terms of final treatment, but also as an opportunity to reduce production costs, by optimizing them and increasing process efficiency and profit [3], [4]. The purpose of this work was to identify operations or processes in which there were opportunities for reducing the impacts of load and volume in effluent treatment at a dairy factory.

II. SOURCES OF WASTE

The liquid waste from a large dairy originate from the following sections of plants- receiving station, bottling plant, cheese plant, butter plant , casein plant, condensed milk plant, dried milk plant, and ice cream plant. Waste also comes from water softening plant and from bottle and can washing plants. At the receiving station the milk is received from the farms and after inspection the same is emptied into large containers for transport to bottling or other processing’s. The empty cans are rinsed, washed sterilised and are returned to the farmers. At the bottling point, the raw milk delivered by the receiving station is stored. The processing includes cooling, clarification, filtration, pasteurization and bottling. In the above two sections, the liquid wastes originate out of rinse and washings of bottles, cans and equipment's, and thus contain milk drippings and chemicals used for cleaning containers and equipment's.

The skimmed milk may now be sent for bottling for human consumptions, or for further processing in the dairy for other products like non-fat milk powders. Milk powders are produced by evaporation followed by drying by either roller process or spray process. The dry milk plant wastes consist chiefly of wash waters used to clean containers and equipment's. The soured or spoiled milk and sometimes the skimmed milks are processed to produce caseins used for preparation of some plastics; the process involves the coagulation and precipitation of the caseins by the addition of some minerals acids. The waste from the section includes whey, washings and the chemicals used for precipitation. Very large dairies also produce condensed milk and ice creams. In addition to the wastes from all the above milk processing's units, some amount uncontaminated cooling water comes as wastes; these are very often recirculated [5], [6]. The dairy wastes are very often discharge intermittently; the nature and composition of waste also depends on the types of products produced and the size of the plants.

III. WASTE CHARACTERISTICS

Dairy effluents contain dissolved sugars proteins and fats and possibly residues of additives. The key parameters are biochemical oxygen demand (BOD), with an average ranging from 0.8 to 2.5 kilograms per metric ton (kg/t) of milk in the untreated effluent; chemical oxygen demand (COD), which is normally about 1.5 times the BOD level; total suspended solids, at 100–1,000 milligrams per litre (mg/l); total dissolved solids: phosphorus (10–100 mg/l), and nitrogen (about 6% of the BOD level). Cream, butter, cheese, and whey production are major sources of BOD in wastewater. The waste load equivalents of specific milk constituents are: 1 kg of milk fat = 3 kg COD; 1 kg of lactose = 1.13 kg COD; and 1 kg protein = 1.36 kg COD. The wastewater may contain pathogens from contaminated materials or production processes. A dairy often generates odours and, in some cases, dust, which need to be controlled. Most of the solid wastes can be processed into other products and by-products.

Effects of wastes on the receiving streams/sewers

As observed from Table 1 the waste is basically organic in nature.

Table 1: Composition of the waste water of typical dairy industries.

Item	**Value (influent)**
Ph	7.2
Alkalinity	600 mg/l as caco3
Total dissolved solids	1060 mg/l
Suspended solids	760 mg/l
BOD	1240 mg/l
COD	84 mg/l
Total nitrogen	84 mg/l
Phosphorus	11.7 mg/l
Oil and grease	290 mg/l
Chloride	105 mg/l

Source: M.N. Rao and A.K. Datta (2012), "*Waste water treatment*'', third edition. pp.254-258.

This is also slightly alkaline when fresh. Dairy effluents decompose rapidly and deplete the dissolved oxygen level of the receiving streams immediately resulting in anaerobic conditions and release of strong foul odour due to nuisance conditions. The casein precipitation from dairy waste decomposes further into a highly odorous black sludge. At certain dilutions the dairy waste is found to be toxic for fish and other aquatic living being and becomes breeding place for flies and mosquitoes. Dairy effluent contains soluble organics, and suspended solids, they degrade to promote release of gases, odour, imparts colour or turbidity, and promotes eutrophication [7].

IV. TREATMENT OF THE DAIRY WASTES

Dairy waste water have low COD and BOD ratio and it can be treated efficiently by biological processes. These wastes contain sufficient nutrients for bacterial growth and this can be prevented by:

(i) The prevention of spills, leakages and dropping of milks from cans.

(ii) The requirement of water can be minimised during washes.

(iii) By segregating the uncontaminated cooling water and recycling the same.

(iv) Utilization of butter milk and whey for the production of dairy by products.

Both high rates tricking filters and activated sludge plants can be operated very effectively for complete treatment of dairy waste. But these conventional methods involve much skilled persons and special type of equipment's. On the other hand the low cost treatment method like oxidation ditches is also used commonly. Use of dairy waste for irrigation after primary treatment in an aeration lagoon may also be good answer for disposal of dairy waste [8].

V. CHECKING OF DAIRY EFFLUENT

pH: - It is a term used to express the intensity of the acid or alkaline condition of a solution. It is a way of expressing the hydrogen-ion concentration or the hydrogen-ion activity. Pure water is said to be neutral, with a pH close to 7.0 at 25 °C (77 °F). Solutions with a pH less than 7 are said to be acidic and solutions with a pH greater than 7 are said to be basic or alkaline.

Chemical Oxygen Demand (COD):- The COD test is widely used as a means of measuring the organic strength of effluents. This test allows measurement of waste of a waste in terms of the total quantity of oxygen required for oxidation to CO_2 and H_2O. During the determination of COD, organic matter is converted to carbon dioxide and water regardless of the biological assimilability. The dichromate reflux method is preferred over procedures using other oxidants (e.g. potassium permanganate) because of its superior oxidizing ability, applicability to a wide variety of samples and ease of manipulation.

Biochemical Oxygen Demand (BOD):- It is defined as the amount of oxygen required by bacteria while stabilizing decomposable organic matter under aerobic conditions. The BOD test is widely used to determine the pollution strength of domestic and industrial wastes in terms of oxygen that they will require if discharged into natural water courses in which aerobic condition exist. It is not a precise quantitative test, although it is widely used as an indication of the organic quality of water. It is most commonly expressed in milligrams of oxygen consumed per litre of sample during 5 days of incubation at 20^0C. The BOD is used for measuring the oxygen consumed by living organisms (mainly bacteria) while utilizing the organic matter present in waste water.

Total Dissolved Solids (TDS):- It is a measure of the combined content of all organic and inorganic substances present in a liquid in molecular, ionized or micro-granular (colloidal sol) suspended form. Generally the operational definition is that the solids must be small enough to survive filtration through a sieve the size mm of two micrometer. The principal application of TDS is in the study of water quality for streams, rivers and lakes, although TDS is not generally considered a primary pollutant. It is used as an indication of aesthetic characteristics of drinking water and as an aggregate indicator of the presence of a broad array of chemical contaminants.

Suspended Solids (SS):- It refers to small solid particles which remain in suspension form in water as a colloid. It is used as one of the indicator of water quality. It is sometimes abbreviated SS, but is not to be confused with settleable solids, which contribute to the blocking of sewer pipes.

Oil and Grease:- Dissolved or emulsified oil and grease is extracted from water by intimate contact with an extracting solvent. Some extractable, especially unsaturated fats and fatty acids oxidize readily; hence special precautions regarding temperature and solvent vapour displacement are included to minimize this effect. Organic solvents shaken with some samples may form an emulsion that is very difficult to break. This method includes a means for handling such emulsions.

Sulfate:- In inorganic chemistry, a sulfate (IUPAC-recommended spelling; also sulphate in British English) is a salt of sulfuric acid. The sulfate ion is a polyatomic anion with the empirical formula SO^{2-4} and a molecular mass of 96.06 daltons (96.06g/mol); it consists of a central sulfur atom surrounded by four equivalent oxygen atoms in a tetrahedral arrangement. Many examples of ionic sulfates are known, and many of these are highly soluble in water. Exceptions include calcium sulfate, strontium sulfate, lead (II) sulfate, and barium sulfate, which are poorly soluble.

Chloride:- The chloride ion is formed when the element chlorine picks up one electron to form an anion (negatively-charged ion) Cl^-. The salts of hydrochloric acid HCl contain chloride ions and can also be called chlorides. The word chloride can also refer to a chemical compound in which one or more chlorine atoms are covalently bonded in the molecule. This means that chlorides can be either inorganic or organic compounds. The simplest example of an inorganic covalently-bonded chloride is hydrogen chloride, HCl. A simple example of an organic covalently-bonded (an organochloride) chloride is chloromethane (CH_3Cl), often called methyl chloride [9].

VI. PREVENTIVE ATTITUDES

Cleaning by means of the Clean in Place (CIP) system and the reuse and the recycling of water are examples of processes which reduce the volumetric coefficient. It minimized water consumption, in most of the processes; however, there were some exceptions, such as a few trucks that were not adapted with a “spray bowl” for washing by the CIP system. In addition, the spray dryer was operated manually rather than automatically, which consumed large amounts of water [10], [11]. The action proposed in two ways:

(1) A reduction in water consumption and

(2) Minimization of the organic load.

Water reuse and recycling was a reality in the dairy industry. Many processes, such as centrifugal separation with cooling water in a closed circuit recycled water. The filling machines (for milk packaging) were cooled with recovered water and the evaporated water (from the milk evaporator for the production of powdered milk) was used for cleaning trucks and outside floors. The retentate from the reverse osmosis system (used for desalination of boiler feed water) was mixed into the water supply reservoir. The effluent considered water consumption while the water evaporated in the boiler and cooling towers was not computed in the material balance. The sum of these preventive actions account for a 10% decrease in total effluents generated. The industry also took action to reduce of effluents loads, which is reflected by the low BOD, nitrogen, phosphorus and oil and grease coefficients. The actions taken were separation of discharged milk by automatic ejection of sludge in the centrifugal separators; segregation of whey from butter for use in animal feed; and recirculation of the first rinse water from the evaporators at the beginning of the process, reducing the organic load of fluids and dry products In spite of the great concern of the industry to minimize waste, there were still opportunities for the reduction of previous coefficients. The recovery of solids in the first rinse could be a pollution prevention action. There are examples of milk solids recovered by the use of membrane separation processes (reverse osmosis) used for production ice-cream and milk desserts [12], [13]. Three direct results were obtained: minimization of impact of the effluent generated; the production of casein and reuse of the permeated stream, which is of a high quality enough to be used for drinking water.

A central system for treatment of these rinse waters could be installed, recovering the milk solids, mainly from the reception and the fluid products sector. This is the direct result of the production of pasteurized butter and cream, which generates effluents with high values for this parameter. In this case, the simple separation of the first rinse water and its use for animal feed would be beneficial in the reduction of organic load. Once again, the membrane separation process was shown to be a promising alternative to the recovery of nutrients found in the effluents.

VII. RESULTS AND DISCUSSION

The industry should have comprehensive treatment system consisting of primary or secondary and/or tertiary treatment as is warranted with reference to influent quality and operate and maintained the same continuously so as to achieve the quality of the treated effluent to the standard Norms of Pollution Control Board for Milk Dairy Effluents as shown in Appendix-II. "Lucknow Producers Co-operative, Milk Union, 22, Jopling Road, Lucknow, (U.P)'' After visiting the "PARAG DAIRY" we know that the total raw milk coming per day is 2.0lacs litres as shown in appendix-II and after making different products like butter/ghee-10ton, milk powder-15ton,the effluent generated daily is 3.5 lakh litres per day.

Quality of raw milk: - The collected raw milk contains 100 bacteria every 2 Minutes 0/1200 bacteria per ml. It doubles for every 20 minutes after collecting the raw milk finally when it reaches to do it surprisingly contains much more number of bacteria i.e. 1cc=80 lakh bacteria's steroids, antibiotics. Bacteria spoil the milk, so milk can't be stored for long time. The quality of milk should be in such a way that the initial bacteria count must be less. Bacteria release enzymes which is harmful for human being. Acid forming bacteria consumes sugar in the milk and forms acid and gases. In short they decompose the milk within very few time, so total quality of milk depends upon the number of initial bacterial count.

Causes for maximum growth of bacteria in initial stage:

1. The causes of growth rate of bacteria are lack of awareness about the cleanliness.
2. At the time of collection of raw milk there are lacks of proper hygiene condition.
3. The pots used for collection of milk are not clean.
4. Milk collected from animals which are suffering from diseases like Tuberculosis, Ranikhet which containing more number of pathogenic bacteria. So, we have to be careful about it. We should try to remove the bacteria as maximum as possible.

Following are the remedies for the removal of bacteria-

1. Importance should be given for hygiene.
2. People collecting milk should use hand gloves.
3. Milk collecting pots must be properly washed and dried.
4. The collecting centres of milk must be clean and tidy.
5. Confirmation about animal health is necessary.

Method for counting bacterial growth: There are various chemical and electrical methods for counting initial bacterial growth.

 Chemical Method

1. Standard plate count Method
2. Litmus Paper Test
3. MBRT Test (Methyl Blue Reduction Time)

 Electrical Method

1. Milk Barometer
2. Online system

Waste characteristics: Dairy effluents contain dissolved sugar, protein, fats and the residue of additives. The key parameters are biochemical oxygen demand (BOD) with an average ranging from 0.8 to 2.5 kg per metric ton of milk in the untreated effluent; chemical oxygen demand (COD) which is normally about 1.5 times of BOD level; total suspended solids at 100-1000 mg/lit, total dissolved solids, Phosphorus and Nitrogen. Cream, butter, cheese and whey production are major sources of BOD in waste water. The waste load equivalents of specific milk constituents are; 1kg of milk fat=3kg COD; 1kg of lactose=1.13kg of COD; and 1kg protein=1.36Kg COD. The waste water may contain pathogens from contaminated material or production process. A dairy often generates odours and in some cases dust which need to be controlled. Most of the solid wastes can be processed in to other products and by-products [14].

Treatment technology: Pre-treatment of effluents consists of screening flow equalization, neutralization and air floatation. It is normally followed by biological treatment. If space is available, so we can also use land treatment or pond system are potential treatments. Other biological treatment systems are trickling filters, rotating Biological contactors, activated sludge treatment. Pre-treated dairy effluents can be discharged into the municipal sewage system, if capacity exists with the approval of relevant authority. Odour can be controlled by ventilation and scrubbing may be required where cheese is stored or melted. Fabric filters should be used to control dust from milk powder production to below 50 milligrams per normal cubic meter (mg/Nm3) [15].

Characteristics of dairy effluents- They are milky in colour, slightly alkaline in nature. The effluents become acidic quite rapidly due to fermentation of milk sugar to lactic acid.

***Raw effluent tank:* -** First of all raw materials comes in the raw effluent tank .Volumetric capacity of this tank is 100 CC.

Fat removal unit: - By pump action all fats can be removed.

***Equalizer:* -** Equalizer is a rotating device which separates clean water from the waste water. In this unit during running of equalizer the clear water goes down and it comes in pH tester and waste water comes above the equalizer.

Uproot anaerobic blanket: - Volumetric capacity of this tank is 500 CC. By pump action the waste water from equalizer tank comes in UASB (Upflow anaerobic Sludge Blanket) tank.

Aeration Tank: - In aeration tank there are two types of aeration takes place: (a) Mechanical aeration, and (b) Bubble aeration. In that tank water is continuously aerated. The colour of water must be Chocolate colour. It indicates that the bacteria are present in that tank. Volumetric capacity of this tank is 615 CC. In this tank aeration process takes place.

Clarifier: - In this tank sludge recirculation takes place.

Treated effluent tank: - All clean water comes in treated effluent tank. This clean water again reused for gardening and agriculture.

VIII. CONCLUSION

In conclusion it may be stated that effluent treatment need to be done chiefly due to this reason.

1. To avoid the ill effect of discharged untreated effluent into the environment.
2. To satisfy the statutory requirements of the state pollution control board and central pollution control board.
3. In realization of our commitment to the future generations to provide pollution free environment.

APPENDIX

Appendix I: Standards Norms of Uttar Pradesh Pollution Control Board for Milk Dairy Effluents.

Sr. No.	Details	Value
1.	pH	5.5-9.0
2.	Total Solids(mg/l)	Not to exceed 2200
3.	Total Dissolved Solids(mg/l)	Not to exceed 2100
4.	Suspended Solids(mg/l)	Not to exceed 100
5.	Total Chlorides(as Cl) (mg/l)	Not to exceed 600
6.	Sulfates(mg/l)	Not to exceed 1000
7.	Chemical Oxygen Demand (mg/l)	Not to exceed 250
8.	Biological Oxygen Demand(mg/l) (270c for 3 days)	Not to exceed 30
9.	Oil & Grease(mg/l)	Not to exceed 10

Appendix II: Analysis of Effluents of Lucknow Producer's Cooperative Milk Union.

Characteristics	Inlet (mg/l)	Outlet (mg/l)	Efficiency (%)	Norms (mg/l)
pH	6.93	8.92	28.72	5.5-9.0
TSS	1233.00	88.00	92.86	100.00
COD	2580.00	230.4	91.09	250.00
BOD	1139.00	25.00	97.80	30.00
O&G	1108.80	8.40	99.24	10.00

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