Performance Analysis of Constructed Wetland to Treat Wastewater from Dairy Industry

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Abstract - *Horizontal sub-surface flow constructed wetland have been used from 30 years. The classification of constructed wetland is based on the vegetation of constructed wetland is based on the vegetation type, hydrology & subsurface flow can be further classified according to the flow direction. It is estimated that about 2% of the total milk is wasted into drains Increase in demand for milk and their products many dairies of different sizes have come up in different places. The consumption of large volumes of water and the generation of organic compounds as liquid effluents are major environmental problems in milk processing industry. The removal efficiency through wetland is found to be high the removal efficiency of BOD 91-96% is and COD is 91-94%, Total dissolved solid is up to22 %.*

Key Words: *Dairy industry, constructed wetland, wastewater treatment.*

1. INTRODUCTION

The milk is one of the most significant product and it is required in daily life as an article of food. Then the milk is highly fresh, basic public strength and economic consideration are required that consumer should be provided with the product which remains good quality, pure, free from pathogenic bacteria. At all the steps of production quality control operation must be performed to keep a quality standard of milk which includes the maintenance of hygienic conditions at milking place, storage, transportation and handling the milk at reception docks, processing and packing etc. Till the milk is transported to the consumer is one of the biggest challenge for the dairy industry. The dairy industry is generally considered to be the largest source of food processing waste water.

In the processing of milk a large amount of water is used and this result in a generation of a high volume of effluent containing dissolved sugar, proteins, fats etc. the rise in demand for milk and their products numerous dairies of different size have come up in different places. The dairy industry involves processing raw milk into products such as consumer milk, condensed milk, cheese, butter, yogurt, dried milk (milk powder), and ice-cream, using processes such as chilling, pasteurization, and homogenization and residual milk (that is milk that remains in the pipeline, milking units, receiver, and bulk tank after emptying) and the wash water that cleans them, the various equipment, and the milk house floor. Almost all the dairy industries are facing problem of water treatment, disposal, and utilization of the waste water. Dairy wastewater are characterized by high chemical oxygen demand (COD) concentrations, biological-oxygen demand (BOD) and, this waste water commonly contains, chemicals (that is detergents, sanitizers, and acid rinses) water softener recharge water. Generally, contains fats, nutrients, lactose. These wastes are potential pollutants when they produce harmful effects on the environment and generally released in the form of solids, liquid waste and slurries contains a range of organic and inorganic chemicals. Beside like other industries that have serious waste disposal problem, the milk based food industry is faced with the view of having to erect many relatively small treatment plants. Oil and grease in wastewater generated from milk based food industry poses a major threat to the environment beside lactose, and have the waste generation and related environmental problems are also assumed increased importance. Poorly treated wastewater with high levels of pollutants caused by poor design, operation or treatment systems creates major environmental problem when discharge to surface water or land, it is estimated that about 2 % of the total milk processed is wasted into drains. 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 nuisance conditions disposal of wastewater into rivers, land, fields and other aquatic bodies, without or with partial treatment, in crude tanks, will soon offer a serious problem to health and hygiene. The problem is more serious, when it concerns waste water discharge before treatment from dairy or milk processing industry. The receiving water becomes breeding place for flies and mosquitoes carrying malaria and other dangerous diseases like dengue fever, yellow fever, chicken guniya.it are also reported that higher concentration of dairy waste is toxic to certain varieties of fish and algae.

1.1 Dairy Characteristics:

Dairy effluent contains dissolved sugars proteins and fats & probably residues of additives. The important parameters are BOD (biological oxygen demand), with an average ranging from 0.8 to 2.5 kilograms per metric ton (kg/t) of milk in the untreated effluent, COD (chemical oxygen demand) which is normally about 1.5 times the BOD level; Total suspended solids, at 100-1000 mg per liter, Total dissolved solids: phosphorus (10-100 mg/lit.), and nitrogen about 6% of the BOD level. Cream, butter, cheese and whey production are major source of BOD in wastewater. The waste load are equivalents of specific milk constituents, (1 kg of milk fat is equal to 3 kg of COD), 1 kg of lactose is equal to 1.13kg of cod. And 1 kg of protein s equal to 1.36 kg of COD. The wastewater may contain pathogen from contaminated materials or production process. A dairy often generated odor and in some cases dust, which need to be control.

Table no 1: Dairy Characteristics

Sr. No.	Details	Unit	Value
1.	p^H	-	-
2.	Total Solid	Mg/lit	2200
3.	Total Dissolved Solid	Mg/lit	2100
4.	Suspended solid	Mg/lit	100
5.	COD	Mg/lit	250
6.	BOD (27^0c for 5 days)	Mg/lit	Not To Exceed 100

2. Wetland

Land areas that are wet during part or all the year are stated as wetlands. These wetlands are either natural or artificial (constructed) from, have a substantial capacity for wastewater treatment. Constructed wetlands are manmade wetlands built to remove various types of pollutants that may be present in water that flows through them. They are constructed to recreate, to the extent possible, the structure and function of natural wetlands, which is to act as filters or natures kidney. Wetlands are ideally suited to this role, they possess the rich microbial community in the sediment to affect the biochemical transformation of pollutants, they are biologically productive, and most important they are self-sustaining. These factors make constructed wetland a very attractive option for water treatment compared to conventional systems, especially when lifetime operating costs are compared.

They consist of the transitional habits where the water table is at or near the surface of the land and includes areas that have shallow water over land, up to a depth of 1m.constructed wetlands are artificial wastewater treatment systems consisting of shallow ponds or channels which have been planted with aquatic plants and which depends on upon natural microbial, biological, physical and chemical; process to treat wastewater and are gaining acceptance in the recent years as a feasible option for the treatment of industrial effluents. The treatment system of constructed wetlands is based on ecological systems found in natural wetlands.

Constructed wetlands are different from natural wetlands in that they are designed, built and operated for human use and benefit. They are constructed in areas where a wetland did not exist before. Thus, over the designing and building, one can maintain significant control over the substrate, vegetation and hydraulic regime in the wetland. In controlling these parameters correctly, one can engineer the wetlands to effectively perform wastewater treatment task. Additional benefits of constructed wetlands may include providing habitat for wildlife; producing an aesthetically pleasing environment, as well as modifying the local hydrology. Constructed wetlands (CWS) are engineered systems that have been designed and constructed to utilize the natural process involving wetland vegetation, soil, and the associated microbial accumulations to assist in treating wastewaters. They are designed to take advantages of many of the same processes that occur in natural wetlands, but do so within a more controlled environment. The macrophytes have capacity to improve the water quality by absorbing nutrients with their effective root system. The constructed wetland treatment is the method by which the waste water is fed to the plant along its rootzone there by it degrades the wastes along its intake and then the water percolates through the soil layer towards the outlet by collecting the water.

Hence the importance of carrying out a treatment as a starting point to optimize a simple and economic method to treat the whole dairy effluent. Moreover, the Indian government has imposed very strict rules and regulations for effluent discharge to protect the environment. Some natural and affordable methods are also present like root zone. Constructed wetlands innovation is a built technique for refining wastewater as it goes through a characteristic procedure, which includes soil, sand, reduced scale life forms and vegetation. Constructed wetland also known as root-zone system or biofilter reed bed system or treatment wetland system or phytotechnology or phytoremediation system.

Besides the low construction and operation maintenance expenditure and ease of operation, wetlands have positive effects on the public with their aesthetic value. Once constructed wetlands enhance flora and fauna, it becomes favorable habitat for birds. Also. These wetlands have negligible effects on air quality since polluted water circulates underground, preventing odor appearance, so constructed wetland is natural and affordable method.

Constructed wetlands with horizontal sub-surface flow (HF CWs) have been used for wastewater treatment for more than 30 years. Most horizontal flow constructed wetland (HFCWs) have been designed to treat municipal or domestic wastewater. Nowadays, municipal HFCWs focus not only on common Pollutants but also on special parameters such as pharmaceuticals, endocrine disruptive chemicals or linear alkyl benzene sulfonates (LAS). At present, HF CWs are used to treat many other types of wastewater. Industrial applications include wastewaters from oil refineries, chemical factories, pulp and paper production, tannery and textile industries, abattoir, distillery and winery industries. The use of HF CWs is becoming very common for treatment of food-processing wastewaters (e.g., production and processing of milk, cheese, potatoes, sugar). HF constructed wetlands are also successfully used to treat wastewaters from agriculture (e.g., pig and dairy farms, fish farm effluents) and various runoff waters (agriculture, airports, highway, greenhouses, plant nurseries). HF CWs have also effectively been used to treat landfill leachate. Besides the use as a single unit, HF CWs are also used in combination with other types of constructed wetlands in hybrid systems.

2.1 Working of Constructed Wetland:

There are many physical, chemical and biological mechanisms that play part in the wastewater treatment within a constructed wetland system (hammer et al, 1989).

Biological process

In the performance of constructed wetland, there are six major biological reactions, including photosynthesis, respiration, fermentation, nitrification, denitrification and microbial phosphorus removal. **Photosynthesis** is performed by wetland plants and algae, with the process adding carbon and oxygen to the wetland. carbon and oxygen drive the nitrification process. Plants transfer oxygen towards their roots, where it passes through the root zones (rhizosphere). **Respiration** is the oxidation of organic carbon and is done by all leaving organisms, leading to the formation of carbon dioxide and water. The common microorganisms constructed wetlands are bacteria, fungi, algae, and protozoa. The maintenance of best conditions in the system is required for the proper functioning of wetland organisms.

Fermentation is the decomposition of organic carbon in the absence of oxygen, producing energy- rich compounds (e.g., methane, alcohol, volatile fatty acids.) this process is often undertaken by microbial activity. Nitrogen removal by nitrification/denitrification is the process mediated by microorganisms. The physical process of volatilization also is important in nitrogen removal. Plants take up the dissolved nutrients and other pollutants from the water, using them to produce additional plant biomass.

Wetland microorganisms, including bacteria and fungi, remove soluble organic matter, coagulate colloidal matter, stabilize organic matter, and convert organic matter into various gasses and new cell tissue. Many of the microorganisms are the same as those occurring in conventional wastewater treatment systems. Different types of microorganisms, however, have specific tolerances and requirements for dissolved oxygen, temperature ranges, and nutrients.

Chemical process: metals can precipitate from the water column as insoluble compounds. Exposure to light and atmospheric gasses can break down organic pesticides, or kill disease-producing organisms (EPA, 1995). The pH of water and soils in wetlands exerts a strong influence on the direction of many reactions and processes, including biological transformation, partitioning of ionized and un-ionized forms of acids and bases, cation exchange, solid and gasses solubility.

Physical process: sedimentation and filtration are the main physical process leading to the removal of wastewater pollutants. The effectiveness of all process (biological, chemical, physical) varies with the water residence time (that is, the length of time the water stays in the wetland). Longer retention time accelerate the removal of more contaminants, although too-long retention time can have detrimental effects.

3.2 Component of Constructed Wetland:

Constructed wetlands mainly consists of water, soil, and vegetation. The other components such as communities of microbes develop naturally.

Water: Wetlands are likely to form where landforms direct surface to shallow basin and where a relatively impermeable subsurface layer prevents the surface water from seeping into the ground. These conditions can be created to construct the wetland. A wetland can be built almost anywhere in the landscape by shaping the land surface to collect surface water and by sealing the basin to retain the water. Hydrology is the most important design factor in constructed wetlands because it links all of the functions in a wetland and because it is often the primary factor in the success or failure of constructed wetland. While the hydrology of constructed wetlands is not greatly different than that of other surface and near-surface waters, it does differ in several important respects: Small change in hydrology can have fairly significant effects on a wetland and its treatment effectiveness because of the large surface area of the water and its shallow depth, a wetland system interacts strongly with the atmosphere through rainfall and evapotranspiration (the combined loss of water by evaporation from the water surface and loss through transpiration by plants). The density of vegetation of a wetland strongly affects its hydrology, 1). by obstructing flow paths as the water finds its sinuous way through the network of stems, leaves, roots and rhizomes and, 2). by blocking exposure to wind and sun.

Substrates, sediments, and litter: Substrates used to construct wetlands include soil, sand, gravel, rock, and organic materials such as compost. Sediments And litter then accumulate in the wetland because of the low water velocities and high productivity typical of wetlands. The substrates, sediments, and litter are important for several reasons: they support many of living organisms in wetland substrate permeability affects the movement of water through the wetland. Many chemical and biological (especially microbial) transformation take place within the substrates.

Substrates provide storage for many contaminants. The accumulation of litter increased the amount of organic matter in the wetland. Organic matter provides sites for material exchange and microbial attachment, and is a source of a carbon, the energy source of drives some of the important biological reactions in wetlands. The physical and chemical characteristics of soils and other substrates are altered when they are flooded. In a saturated substrate, water replaces the atmospheric gases in the pore spaces and microbial metabolism consumes the available oxygen.

Vegetation: Both vascular plants (the higher plants) and the non-vascular plants (algae) are important in constructed wetlands. Photosynthesis by algae increases the dissolved oxygen content of water which in turn affects nutrients and metal. Vegetation in a wetland provides a substrate (roots, stems, and leaves) upon which micro-organisms can grow as they breakdown organic material. The community of micro-organisms is known as the periphyton. The periphyton and natural chemical process are responsible for approximately 90 percent of pollutant removal and waste breakdown. The plants remove about 7-10% of pollutants, and at as a carbon sources for the microbes when they decay. Different species of aquatic plants have different rates of heavy rates of heavy metal uptake, a consideration for plant selection in a constructed wetland used for water treatment.

During photosynthesis, plants consume carbon dioxide and release oxygen. Submerged aquatic plants growing within the water column raise the dissolved oxygen level in the wetland surface water and deplete the dissolved carbon dioxide, resulting in an increase pH. Rooted wetland microphytes also actively transport oxygen from the atmosphere to the sediments. Some oxygen leaks from root hairs in to the rhizosphere, supporting aerobic and facultative anaerobic micro-organisms in the otherwise anaerobic sediments and soil. Facultative anaerobic micro-organisms are those that are usually respire aerobically but can grow under anaerobic conditions. Macrophytic plants are critical to high pollutant removal rates in treatment of wetlands. Plants provide the necessary environment through oxygen and nutrient transfer to the sediments and soils through their fixation of reduced carbon to support diverse microbial population. Plants also release carbon compounds such as carbohydrates, which are products of photosynthesis that serve as a nutrient source for microbes that in turn may support other microbes. The result is a complex synergistic system between numerous micro-organisms for the degradation of a wide variety of contaminants. Thus, a complex web of interactions occurs between plants and the diverse community of micro-organisms. Plants control excess algal growth by intercepting sunlight. Algae are plants that release oxygen through photosynthesis. They are effective at removing nutrients from surface water. However, excess algal growth within a constructed wetland can result in the release of undesirable levels of suspended solids and increased Bio-chemical Oxygen Demand (BOD) levels to downstream reeving waters. A healthy stand of vegetation obstructs sunlight from reaching the water surface and reduce the growth of undesirable algae.

Microorganisms: A fundamental characteristic of wetlands is that their functions are largely regulated by micro-organisms and their metabolism. Micro-organisms includes bacteria, yeasts, fungi, protozoa, rind algae. The microbial biomass is a major sink for organic carbon and many nutrients. Microbial activity transforms a great number of organic and inorganic substances into innocuous or insoluble substances alters the reduction/oxidation (redox) conditions of the substrate and thus affects the processing capacity of the wetland is involved in the recycling of nutrients. Some microbial transformations are aerobic (that is they require free oxygen) while others are anaerobic (they take place in the absence of free oxygen). Many bacterial species are facultative anaerobes, that is, they are capable of functioning under both aerobic and anaerobic conditions in response to changing environmental conditions. Microbial populations adjust to changes in the water delivered to them. Population of microbes can expand quickly when presented with suitable energy-containing materials. When environmental conditions are no longer suitable, many microorganisms become dormant and can remain dormant for years.

The microbial community of a constructed wetlands can be affected by toxic substances, such as pesticides and heavy metals, and care must be taken to revent such chemicals from being introduced at damaging concentrations.

Liner: The liner keeps the wastewater in and groundwater out of the system. Although the liner can be made from a number of materials,30 mil polyvinyl chloride (PVC) is the most common and the most reliable. Clay liners are not recommended because they can crack if too thin, allowing untreated wastewater to move into the soil and contaminate groundwater.

3.3 Canna Indica

Fig. No.1 Canna Indica

canna Indica is commonly known as Indian shot, African arrowroot, edible canna, sierra Leone arrowroot, is a plant species in the family cannaceae. It is native to much of south America, central America, the west indies, Mexico, and the southeastern united states. It is also naturalized in much of Europe. canna Indica is a plant of tropical or subtropics origin in south America, distributed over a vast area, reaching southern region as province of Buenos Aires (PBA) in Argentina (350 south latitude).

Description of the species: Canna Indica, is a Mesophyte colonial terrestrial plant 0.5m and 2.5m height depending on the variety. Rhizomes are sympodial underground, with chestnut-brown cataphylls and abundant adaxial and abaxial roots. The aerial shoots are 1-3cm diameter, with 7-11 sheathing leaves, patent to reflexed the inferior, ascending the superiors, and sometimes convolutes. The phyllotaxic is distichous to spirally, and foliar sheaths are light green. Leaves are glabrous, green yellowish, adaxially fasciate, and abaxially grayish green and dull. The contour of leaves is narrow ovate with a length / width ratio of 2:1. The third leaf is 19-37 (55)cm in length x 10-18 (30)cm wide. The apices are acute, acuminate, twisted and mostly dry at tops, with cuneate decurrent asymmetric bases. Venation is eucamptodrome. Primary vein and foliar margins are colorless, with light green foliar sheaths and bracts. Inflorescences are politelicae, intermediate, of 40-41cm in length carrying 1-2 paracladia, each one bearing 1-4 nodes, each node carrying 2 flowers. The principal Florescence carries 6-8 nodes and the basal internode is of 16-17cm long. Flowers with 11-12 pieces are 7cm long, noncolors red or yellow or bicolours, bright red at the base and yellow in the third basal part. The floral tube is 3-4 cm long. The ovarium is inferior and green. Pollengrains are spherical or subspherical, 38-61-(63) µm, equinatae, spinules conical of 3x3 µm. capsule is spherical or subspherical, green of 2-3 x 2-4 cm. capsule have seeds, ovoid in shape, dark chestnut-brown or black in color, and of 0.5-0.7cm diameter.

4. Observation

4.1. pH: The pH of inlet and outlet sample from galvanized box planted with canna Indica was checked after starting continuous process operation.
During observations, the maximum pH value recorded of the inlet water is 7.76 and minimum pH value recorded is 7.20. The permissible pH range for the discharge of dairy industry waste water is 5.5-8.5. it was observed that the pH of the effluent discharge from the treatment system was found to be within the acceptable range.

4.2. Biochemical Oxygen Demand: The BOD of inlet and outlet sample from galvanized box planted with canna Indica was checked after starting continuous process operation.
The percent reduction in BOD is calculated based on five days at 20^{0}c cumulative average inlet wastewater BOD. The permissible BOD range for the discharge of dairy industry waste water is Not to Exceed 100. During observations, the BOD value of inlet water ranges from 360mg/lit to 5400 mg/lit. the result shows that the percentage reduction in BOD varies from 94.46% to 96.39%.

4.3 Chemical Oxygen Demand: The COD of inlet and outlet sample from galvanized box planted with canna Indica was checked after starting continuous process operation. The percent reduction in COD is calculated. The permissible COD range for the discharge of dairy industry waste water is 250 Mg/lit. During observations, the COD value of inlet water was observed minimum 550.2mg/lit and maximum 6980mg/lit. the result shows that the percentage reduction in COD varies from 91.1% to 94%.

4.4 Total Dissolved Solids: The TDS of inlet and outlet sample from galvanized box planted with canna Indica was checked after starting continuous process operation.
The percent reduction in TDS is calculated. The permissible TDS range for the discharge of dairy industry waste water is 2100 Mg/lit. During observations, the TDS value of inlet water was observed minimum 1038mg/lit and maximum 2760 mg/lit. The result shows that the percentage reduction in TDS varies from 3.58% to 18%.

4.5 Dissolved Oxygen: The DO of inlet and outlet sample from galvanized box planted with canna Indica was checked after starting continuous process operation. The inlet water shows the absence of DO throughout the testing period. The maximum outlet DO 5.0 mg/lit. and minimum do 1.9 mg/lit.

The DO is nil due to the presence of oil and grease in effluent from milk which prevent the entrance of atm.
The Nitrogen of inlet and outlet sample from galvanized box planted with canna Indica was checked after starting continuous process operation.

4.6 Nitrogen: The percent reduction in Nitrogen is calculated. During observations, the Nitrogen value of inlet water was observed minimum 56.9mg/lit and maximum137.7 mg /lit. The result shows that the percentage reduction in Nitrogen varies from 1.8 % to 46.675mg %.

The nitrogen is present in dairy waste as animal eat vegetation, in vegetation Nitrogen and phosphorus is present.

4.7 Phosphorus: The Phosphorus of inlet and outlet sample from galvanized box planted with canna Indica was checked after starting continuous process operation.
The percent reduction in Phosphorus is calculated. During observations, the Phosphorus value of inlet water was observed minimum 0.012 mg/lit and maximum 0.21 mg/lit. The result shows that the percentage reduction in Phosphorus varies from 16 % to 100 % The Phosphorus is present in dairy waste as animal eat vegetation, in vegetation Nitrogen and phosphorus is present.

5. CONCLUSIONS

Constructed wetland is economical compare to other conventional waste water system.so we can use this system to avoid ill effect of discharge untreated effluent on the environment.

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