**International Journal of Advanced Research and Development**
**ISSN: 2455-4030**
**Impact Factor: RJIF 5.24**
**www.advancedjournal.com**
**Volume 3; Issue 4; July 2018; Page No. 01-07**

# Process optimization of dairy wastewater cycle

**Aashika Patel[1], Vishakha Patel[2], Jyoti Singh[3], Mohit Ahir[4], Urvij B Dave[5]**
[1-4] BE Students, Department of Environmental Science & Technology, Shroff S.R. Rotary Institute of Chemical Technology, Vataria, Bharuch, Gujarat, India
[5] Guide & Assistant Professor, Department of Environmental Science & Technology, Shroff S.R. Rotary Institute of Chemical Technology, Vataria, Bharuch, Gujarat, India

**Abstract**
Dairy industry is one of the water consuming industry in India due to which there is more exploitation of natural resources. We have chosen Dairy Industry situated near our town for study purpose. The inlet raw milk is 1, 82, 000 l/day to process. For the processing of 1, 82, 000 l/day milk, water consumption is 3, 00, 000 l/day to 3,50,000 l/day. The ratio of water consumption rate is 1.64. The influent contains COD, BOD & pH etc. The influent COD ranges from 3200 mg/l - 3500 mg/l, which lead to waste generation in terms of SF and SNF. SF in the effluent is 367.33 kg SF and SNF in the effluent is 975.22 kg SNF. The ETP comprises of screen chamber, oil & grease tank & UASBR etc., which reduce COD load from 3800 mg/l to 25 mg/l. Stage wise efficiency has been identified and further UASBR efficiency is optimize. Process material balance & mass balance has been done for onsite treatment & waste reduction.

**Keywords:** optimization, COD, BOD, pH, SF, SNF

## 1. Introduction
India is one of the largest milk producers in the world. Indian milk industry more depends upon cooperative sectors where annual milk production is 155.5 million tones in year 2015-2016.In India 75,000 gallons per day dairy processing plant can use up to 110 million gallons of water a year. But if we are looking at world production then per cattle milk production is lowest in India. Indian milk's lifespan is very less in all over the world. Lots of milk is wasted due to lack of quality enhancement. The consumption of water per litre of milk production is also quite high in comparison to the other progressive countries. In New Zealand milk remains good in quality for six months of time due to addition of preservatives while in India it will be not more than 2 to 3 days. This is an attempt to highlight different techniques of milk processing with the perspective of Indian dairy industry and other dairies from all over the world. It also provides data of modifications required in Indian dairies. How to reduce wastewater cycle in milk processing and distribution. The scope of reuse and recycling of wastewater. Waste to energy possibility is also outlined with examples.

### 1.1 Background
Wastewater treatment technology is designed for elimination of contaminants to satisfy discharge standards. There are many methods for treating the dairy wastewater. Physico-chemical and biological treatment methods are usually used to treat the dairy effluent.
However, several studies had found that the process of removal of COD is very poor in Physico-chemical treatment the cost of the chemical reagents used is very high. Rather than Physico-chemical process, biological treatment has good organics removal and effluent quality. As a biological treatment, there is generally the activated sludge process and other anaerobic process is used.
The dairy industry needed very large amount of freshwater and generates huge amount of the wastewater from the cleaning transport lines and equipment between production cycles. This is particularly true for the dairy wastewater that it contains high concentration of the nutrients such as nitrate, sulphate, phosphate and high concentration of BOD, COD, suspended solids. This make the dairy effluent unsuitable to discharged to sewer system.
In recent years several process or treatments focused on the treatment of dairy effluent and it include the membrane technologies such as microfiltration, Nano filtration, reverse osmosis, ultra filtration. These membrane technologies become more energy efficient as compared to other methods.
In membrane processes, mostly Nano filtration or reverse osmosis is more usable treatment now a day.

### 1.2 Aim of Study
The aim of study is to optimize the wastewater cycle in dairy industry by providing the on-site treatment plant for recycling of the wastewater.

### 1.3 Objective of the Study
The objectives of the study is as follow
- To identify the sources of the wastewater in dairy
- To estimate the concentration of the pollution parameter in wastewater.
- To decide the type of treatment required by the wastewater.
- To provide the on-site treatment for the recycling of the wastewater.

## 2. Study on Dairy Processing Treatment

For project purpose, we choose one dairy near our town through which we can understand how the dairy processing units are works and the treatment of the dairy wastewater.

### 2.1 LCA of Milk Production in Dairy

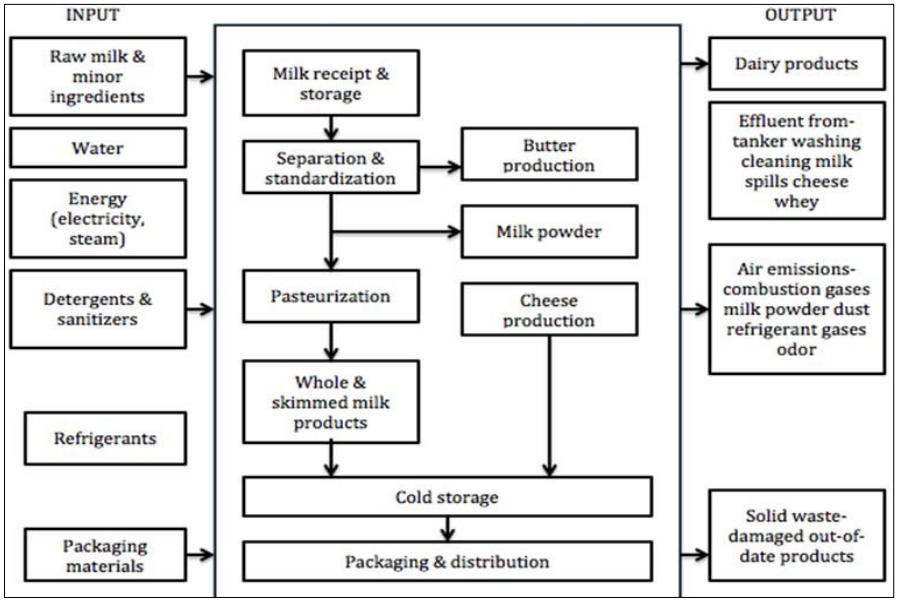


**Fig 1:** LCA of milk production in Dairy

The 5 major life cycle stages identified for the milk supply chain. These emissions from each of these stages are made up as follows:

- **Processing:** transport of milk to the processing plant; milk pasteurization and filling of bottles, including all material inputs to the plant (chemicals and coal or fuel oil for steam-raising); transport of materials to the plant.
- **Packaging:** manufacture of the primary packaging (plastic bottles and caps) and secondary packaging (crates), including the production of all raw materials; disposal of waste packaging products (transport to recycling process or disposal in a sanitary landfill).
- **Distribution:** transport from the dairy to the distribution center (DC), transport from the DC to retail stores; electricity, water, fuel and refrigerant use at the DC.
- **Retail:** electricity use at stores; refrigerant use and leakage.
- **Consumer:** transport of milk from store to home; domestic refrigeration of milk.

### 2.2 Sources of Wastewater in Dairy

**Table 1:** Sources of wastewater in Dairy

| Operation | Processes | Sources of Waste |
|---|---|---|
| Preparation Stages | Milk Receiving/Storage | ▪ Poor drainage of tankers<br>▪ Spills and leaks from the hoses and pipes<br>▪ Spills from the tanks<br>▪ Cleaning operation |
| | Pasteurization/Ultra Heat Treatment | ▪ Liquid losses<br>▪ Recovery of downgraded product cleaning operation<br>▪ Deposits on the surface of pasteurization and heating equipment |
| | Homogenization | ▪ Liquid losses/ leaks<br>▪ Cleaning operations |
| Product Processing Stages | Market Milk<br>Flavour Milk | ▪ Foaming<br>▪ Product washing<br>▪ Overfilling<br>▪ Sludge removal from Clarifier/ separator<br>▪ Damaged milk packages |
| | Ghee Making | ▪ Incomplete separation of kanjeri from ghee<br>▪ Spills and leaks<br>▪ Cleaning operations |

| | | |
|---|---|---|
| | Butter Making | ▪ Product washing<br>▪ Cleaning operation |
| | Powder Manufacture | ▪ Spills of powder handling<br>▪ Plant malfunction<br>▪ Cleaning of evaporators |

### 2.3 Process Plant Diagram

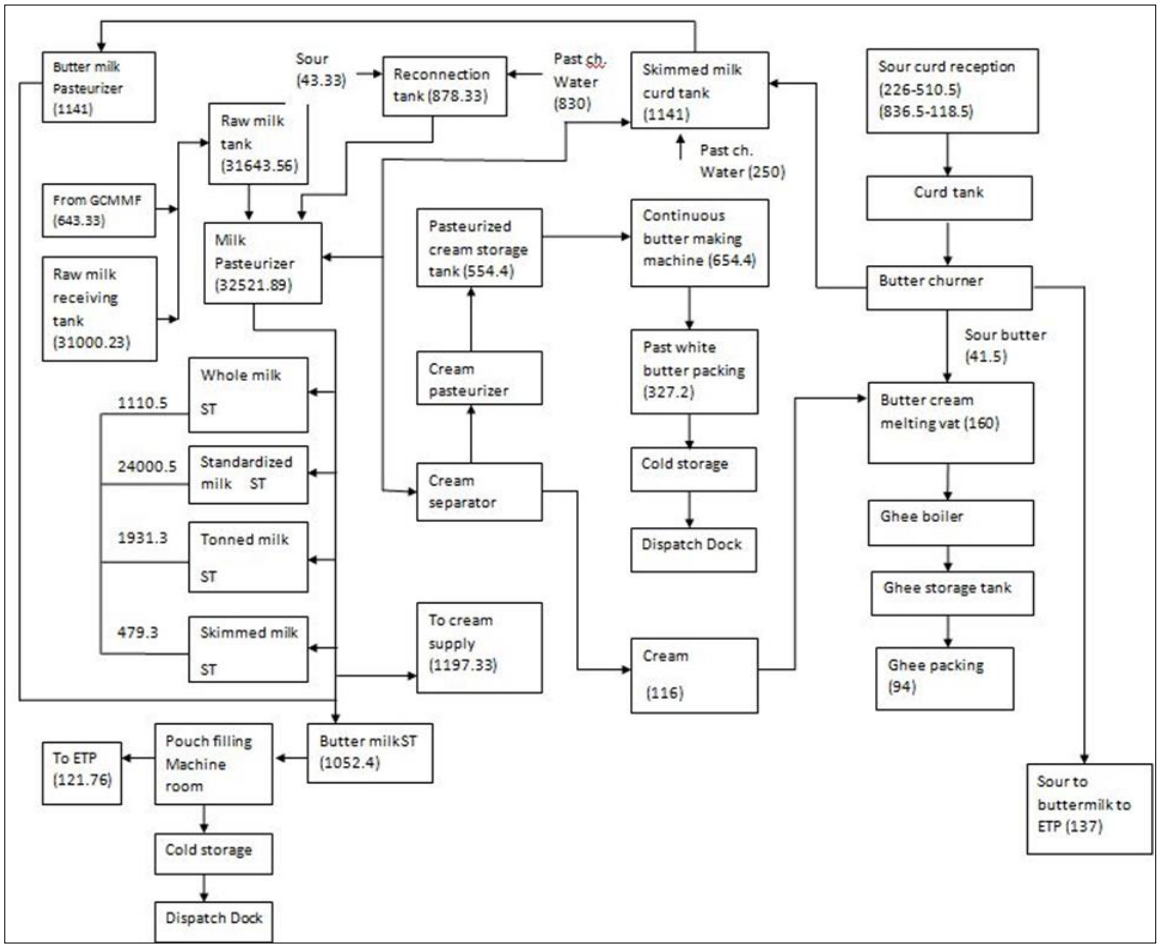


**Fig 2:** Process Plant Diagram

### 2.4 Characteristics of the Dairy Wastewater

Dairy wastewater is biodegradable in nature. The ratio of BOD to COD, indicate its biodegradability. The key parameters are BOD, pH, COD, total suspended solids (100-1000mg/lit), dissolve solids, Phosphorus (10-100mg/lit) and nitrogen (about 6% of the BOD level).

BOD: It is defined as the amount of oxygen required by bacteria while stabilizing decomposable organic matter under aerobic condition. It should be in the range of 0.8-2.5 kg/ton [6].

COD: The COD test is widely used as a means of measuring the organic strength of effluents. This test allows measurement of waste in terms of the total quantity of oxygen required for oxidation to $CO_2$ and $H_20$. It is normally 1.5 times the BOD level [6].

pH: It is a term used to express the intensity of the acid or alkaline condition of the solution. It should be near 7.

Suspended Solids: it refers to solid particles in small sizes which remain in suspension form in water as a colloid. It should be in the range of 100-1000 mg/lit [6].

Oil & Grease: Dissolved or emulsified oil and Grease is extracted from water by intimate contact with an extracting solvent.

### 2.5 Treatment of the Dairy Wastewater

Dairy wastewater has low COD and BOD ratio. Biological processes can treat it efficiently. These wastes contain sufficient nutrients for bacterial growth. This can be prevented by:

- The prevention of spills, leakages, and dropping off milk from cans.
- The requirement of water can be minimized during washes.
- By segregating the uncontaminated cooling water and recycling the same.
- Utilization of buttermilk and whey for the production of dairy by-products.

In the biological treatment, mostly high rates trickling filters

and activated sludge plants can be operated very effectively for the treatment of the dairy wastewater.

On the other hand, the low-cost treatment method like oxidation ditches also used commonly. After the primary treatment of the wastewater, dairy wastewater may also use for the irrigation purpose.

### 2.6 Water Balance

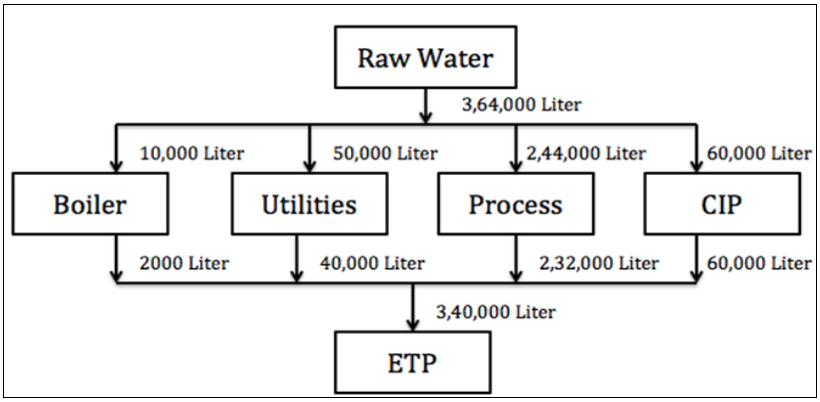


**Fig 3:** Water Balance in Dairy industry

## 3. Experimental Work

We have performed experiments on COD, BOD, pH Analysis at different time for input and output of the different point of ETP.

### 3.1 COD, BOD & pH Analysis

The results and analysis are given below:

**Table 2:** Analysis Result-1Of COD, BOD, pH

| Sr. No. | Sampling Point | COD (mg/l) | BOD (mg/l) | pH | % COD Removal |
|---|---|---|---|---|---|
| 1 | ETP inlet | 3800.21 | 6400 | 8.78 | - |
| 2 | Equalization tank | 2880.3 | 3400 | 7.96 | 24.21% |
| 3 | UASBR outlet | 1840 | 400 | 7.88 | 36.11% |
| 4 | Aeration outlet | 1020 | 288 | 7.03 | 51.08% |
| 5 | Clarifier | 560 | 150 | 6.90 | 37.7% |
| 6 | ETP Final outlet | 110 | 45 | 6.58 | 80.31% |

**Table 3:** Analysis Result-2 of COD, BOD, pH

| Sr. No. | Sampling Point | COD (mg/l) | BOD (mg/l) | pH | % COD Removal |
|---|---|---|---|---|---|
| 1 | ETP inlet | 3504.6 | 5600 | 4.75 | - |
| 2 | Equalization tank | 2630.5 | 3400 | 4.96 | 24.9% |
| 3 | UASBR outlet | 1905.6 | 200 | 4.63 | 27.55% |
| 4 | Aeration outlet | 960.8 | 82 | 5.11 | 49.58% |
| 5 | Clarifier | 440 | 60.50 | 5.34 | 54.2% |
| 6 | ETP Final outlet | 85.66 | 25 | 6.23 | 80.5% |

### 3.2 Calculation of Sn and SNF

- SNF calculation formula for Milk used in various states**:**

**Table 4:** SNF calculation formula for Milk used in various states

| SR. NO. | State | Formula | Remarks |
|---|---|---|---|
| 1 | Gujarat | CLR/4 + 0.21(Fat%) + 0.36 | Lactometer calibrated at 21 deg C |
| 2 | West Bengal | CLR/4 + 0.21(Fat%) + 0.36 | Lactometer calibrated at 15.5 deg C |
| 3 | Orissa | CLR/4 + 0.21(Fat%) + 0.36 | Lactometer calibrated at 15.5 deg C |
| 4 | WAMUL, Assam | CLR/4 + 0.20(Fat%) + 0.66 | Lactometer calibrated at 29 deg C |
| 5 | Maharashtra | CLR/4 + 0.21(Fat%) + 0.36 | Lactometer calibrated at 21 deg C |
| 6 | Goa | CLR/4 + 0.21(Fat%) + 0.36 | Lactometer calibrated at 21 deg C |
| 7 | MP | CLR/4 + 0.20(Fat%) + 0.70 | Lactometer calibrated at 29 deg C |
| 8 | UP | CLR/4 + 0.20(Fat%) + 0.29 | Lactometer calibrated at 15.5 deg C |
| 9 | Punjab | CLR/4 + 0.20(Fat%) + 0.29 | Lactometer calibrated at 15.5 deg C At DCS level it is CLR/4+0.20(Fat%) + 0.5 (Lactometer at 29 deg C) |
| 10 | Haryana | CLR/4 + 0.20(Fat%) + 0.29 | Lactometer calibrated at 15.5 deg C |

| | | | |
|---|---|---|---|
| 11 | BIS | CLR/4 + 0.25(Fat%) + 0.44 | Lactometer calibrated at 27 deg C |
| 12 | Tamil Nadu | CLR/4 + 0.20(Fat%) + 0.36 | Lactometer calibrated at 21 deg C |
| 13 | Karnataka | CLR/4 + 0.25(Fat%) + 0.35 | Lactometer calibrated at 27 deg C |
| 14 | A P | CLR/4+.21(Fat%)+.36 | Lactometer calibrated at 21 deg C |
| 15 | Kerala | CLR/4 + 0.20(Fat%) + 0.50 | Lactometer calibrated at 29 deg C |
| 16 | Pataliputra(Bih) | CLR/4 + 0.20(Fat%) + 0.14 | Lactometer calibrated at 15.5 deg C |
| 17 | Rest of Bihar | CLR/4 + 0.20(Fat%) + 0.66 | Lactometer calibrated at 29 deg C |

Other techniques to calculate the SF and SNF is based on the value of COD of the wastewater in which following formulas are used:

**1 kg SF=3 kg COD**
**1 kg SNF= 1.13 kg COD**

- Inlet COD = 3800.21 mg/l
  =0.0038 kg/l
- ETP Inlet water = 2,90,000 l/day
  kg COD generation = 2,90,000 *0.0038
  =1102 kg COD
- The milk content 85% Water, 9% SNF, 6% SF
  SF in the wastewater = 1102 / 3
  = 367.33 kg SF
  SNF in the wastewater = 1102 / 1.13
  = 975.22 kg SNF

### 3.3 Mass Balance of all Plants

### Milk Production Plant

**Table 5**

| Inlet Data | | Outlet Data | |
|---|---|---|---|
| From GCMMF | 643.33 | Whole Milk | 1110.5 |
| Raw Milk Receiving Tank | 31000.23 | Standardized Milk | 24000.5 |
| Raw Tank (From GCMMF + Raw Milk Receiving Tank) | 31643.56 | Toned Milk | 1931.3 |
| Recollection Tank | 878.33 | Skimmed Milk | 479.3 |
| | | Cream Milk Supply | 1197.33 |
| Total (Total Milk Pasteurizer) | 32521.89 | Total | 28718.63 |

Total Milk Production Inlet = 32521.89
Total Milk Supply = 28718.63
Waste Generated from the Milk Plant = Inlet – Outlet
=32521.89-28718.63
=3803.26Kg

### Ghee Production Plant

**Table 6**

| Inlet Data | | outlet Data | |
|---|---|---|---|
| Sour Butter | 41.5 | Ghee Packing (Output ) | 94 |
| Cream | 116 | | |
| Total | 157.5 | Total | 94 |

Total Ghee Production Inlet =157.5
Total Ghee Supply = 94
Waste generated from the Ghee plant = Inlet – Outlet
=157.5-94
=63.5Kg

### Buttermilk Production Plant

**Table 7**

| Inlet Data | | Outlet Data | |
|---|---|---|---|
| Water | 250 | Buttermilk Packing (Output ) | 1052.4 |
| Sour Butter Milk | 658 | | |
| Milk | 233 | | |
| Total (Skimmed Milk Curd Tank) | 1141 | Total | 1052.4 |

Total Buttermilk Production Inlet =1141
Total Buttermilk Supply =1052.4
Waste generated from the milk plant = Inlet – Outlet
=1141-1052.4
=88.6Kg

### Overall mass balance

**Table 8**

| | | |
|---|---|---|
| Total Input Data in All Plant | 643.33+31000.23+43.33+830 +800+250 | 33566.89 |
| Total Output Data in All Plant | 1052.4+479.3+1931.3+24000. 5+1110.5+327.2+94 | 28995.2 |
| Waste Generated | 33566.89-28995.2 | 4571.69 |
| Waste to ETP | 137+121.76 | 258.76 |
| Total Waste | 4571.69+258.76 | 4312.93 |

### Check of mass balance

**Table 9**

| | | |
|---|---|---|
| Total Input Data in All Plant | 32521.89 +157.5 +1141 | 33820.39 |
| Total Output Data in all Plant | 28718.63+94+1052.4 | 29865.03 |
| Waste Generated | 33820.39-29865.03 | 3955.36 |
| Waste to ETP | 137+121.76 | 258.76 |
| Total Waste | 3955.36+258.76 | 4214.12 |

Waste losses due to maintenance and manual work =98.81Kg

## 4. Result and Conclusion

At the end of the treatment we came to conclude that total waste generation from dairy is 367.33 kg of SF & 975.22 kg of SNF that is a higher side of waste for any dairy, need to be rectified by process optimization at manufacturing process at onsite treatment plant for recycling of wastewater. 3,40,000 litre of wastewater is treated dairy at effluent treatment plant daily.

### Experimental Procedure

Aastropure (P) Ltd located at Ahemdabad have batch scale process plant of UF Membrane which on approch has agrred

to conduct a run at 75% discount for find out product recovery analysis.

70 liter of waste water of Ghee plant has been taken for the experiment condusted at Aastropure (P) Ltd.

**Fig 4:** Setup of UF batch scale plant at Aastropure (P) Ltd

**Table 10:** Flow Rate and Time Interval

| Quantity of Waste water = 70 litre Pressure = 2.3 Bar | | | | |
|---|---|---|---|---|
| **Specification of UF Membrane** | **Sr. No** | **Flow Rate (ml)** | **Time (Sec)** | **Interval of Time Period (Minute)** |
| UF GD-UF 2000 P 1 GD technology, Chennai | 1 | 1300 | 60 | 0-10 |
| | 2 | 900 | 60 | 10-20 |
| | 3 | 920 | 60 | 20-30 |
| | 4 | 920 | 60 | 30-40 |
| | 5 | 910 | 60 | 40-50 |
| | 6 | 890 | 60 | 50-60 |

**Finding of UF Experimental Batch Scale Process**

1. Average flow rate is 0.973lit/min = 1liter/min.
2. In one hour we get recovery of 65 liter as permiate out of 70 liter of feed waste water.

**Stage wise cod removal of waste water from ghee plant**

**Table 11:** Feed, Retentate and Permeate of UF Filtration

| S. No | Name of COD of location | Quantum of COD (mg/l) |
|---|---|---|
| 1 | COD of ghee plant initially | 47124 |
| 2 | COD of feed (Inlet) of UF filtration | 28274 |
| 3 | COD of Retentate of UF filtration | 1348 |
| 4 | COD of Permeate of UF filtration | 200 |

This wastewater can be utilized for plant washout and other purposes. Total wastewater can be recycled is 10,000 liter per day. Such recycle produces saturated fat for commercial purpose like Soap manufacturing and cosmetics.

Rest water went to the ETP. The final discharge of ETP went to the irrigation purpose respect to the standards of irrigations need to be followed.

**Table 7:** Wastewater Standards for Irrigations

| Sr. No. | Parameter | Limit |
|---|---|---|
| 1 | Nitrogen | 5-30 mg/lit |
| 2 | Phosphorus | 10 mg/lit |
| 3 | Potassium | 30 mg/lit |
| 4 | pH | 6.5-8.4 |
| 5 | Boron | 0.7-3.0 mg/lit |
| 6 | Suspended solids | 50-100 |
| 7 | Dissolve solids | 500-2000 |
| 8 | Bacterial population | <10000 |
| 9 | Hydrogen Sulphide | 0.5-0.2 |
| 10 | BOD | <100 ppm |
| 11 | COD | <150 ppm |

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