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Assessment of Physico-Chemical Characteristics of Dairy Effluent and the Potential for its Reuse for Irrigation

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The quality of dairy effluent was assessed to ascertain its suitability for irrigation. The physico-chemical nature of dairy effluent (treated and untreated) was examined in comparison to standards used for irrigation water. The effluent contained inorganic matter in the form of cations and anions. Very high values of BOD and COD indicated high organic matter.

INTRODUCTION

Now-a-days a new trend has come up to utilize the effluents from dairies for irrigation of land and supply the fodder to the local market or farmers from whom the management is collecting milk. The dairy effluents have become a major source of pollution as they contain inorganic matter in the form of cations and anions and organic matter in the residual state. When this water is used for irrigation of land for growing fodder, the crops are infected and unhealthy, which cause many harmful effects on cattle milk production.

The milk production and cattle population in the city of Bikaner are the highest in Rajasthan. The dairy is situated at 5 km north of the main city of Bikaner and covers an approximate area of 10 acres. Its viable milk processing capacity is 1.6 lakh litres per day. Such a large processing of milk requires a surplus quantity of water which comes out in the form of dairy effluents. These effluents, when discharged, ultimately find their way into the soil, causing soil pollution.

Nature of the Effluent: The effluent consists of washing waters with their detergent residues and condensation from piped stream. These carry milk residues from milk cans, bottles and plant cleanings as well as leakage from valves and pipe lines and milk from broken or split bottles. The whey washings from the cheese plant, casein and lactose as milk residues from evaporators give effluents a very high BOD and COD, indicating high organic matter[1–4]. Thus, the effluent is alkaline when fresh but becomes acidic due to decomposition of lactose into lactic acid under anaerobic conditions, particularly after complete depletion of oxygen. Under aerobic conditions, the complex organic matter is hydrolysed as follows:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$$

Similarly, the intermediate products of protein hydrolysis are amino acids and are finally converted to ammonia, water, carbon dioxide and sulphates[5, 6]. The

released carbon dioxide dissolves in water making it acidic in nature while ammonia is converted to nitrates by nitrifying bacteria. Thus, there is conversion of complex organic matter to simpler inorganic forms by microbial activity[7].

$$C_{12}H_{22}O_{11} + H_2O \xrightarrow{\text{Lactose}} 2C_6H_{12}O_6 \text{ (glucose and galactose)}$$

$$2C_6H_{12}O_6 \xrightarrow{\text{Fermentation}} 4C_3H_6O_3 \text{ (lactic acid)}$$

$$\text{Amino acid} \xrightarrow[\text{oxidation}]{\text{Anaerobic}} \text{Fatty acid, ammonia, } CO_2, H_2S, CH_4, \text{ amines, mercaptans etc.}$$

Consequently, the nature of the effluent becomes acidic and the pH is lowered. The effluent has foul odour due to fermentation products. If used for irrigation, it may deteriorae the soil and, in turn, may inhibit plant growth.

EXPERIMENTAL

Selection of Water Sample Blocks: The entire passage of effluent flow, *i.e.*, from the point of its discharge from the dairy plant and its disposal to open land, was divided into four blocks.

Blocks I and II were untreated and Blocks III and IV were treated. Tap water was taken as control.

Block-I: Effluent from dairy is collected in a lagoon near pumping station. Being an ideal point to study the extent of pollution, the lagoon is marked as Block-I.

Block-II: The passage between the lagoon and the equalization tank is marked as Block-II.

Block-III: In' the equalization tank, the effluent is aerated to reduce the strength of wastes. It is marked as Block-III. Samples from here are supposed to be treated.

Block-IV: The treated water is collected in a high capacity covered tank. The tank is marked as Block-IV.

Three samples were collected from each block. Standard procedures were employed for physical and chemical analysis. Physical parameters include colour, odour, temperature, turbidity and conductivity. Chemical parameters are DO, BOD, pH, COD, total solids (TS), fats, alkalinity, anions (carbonates, bicarbonates, nitrates, fluorides, sulphates, chlorides) and cations (calcium, magnesium, sodium and potassium).

RESULTS AND DISCUSSION

Results of all parameters studies in tap water and effluents from various sampling blocks at different time intervals have been tabulated in Table-1.

pH: It has been observed that pH values for different samples lie between 6.40 to 8.11. Among treated and untreated samples, pH value is lowest for treated sample (6.40) and highest for untreated sample (8.11). The tap water used in milk processing in dairy has mean pH value 7.72.

TABLE-1
PHYSICO-CHEMICAL CHARACTERISTICS OF DAIRY EFFLUENT AND TAP WATER

S.No.	Block	pH	EC m-mhos/cm	Cations (meq.L)				Anions (meq/L)					TUR	DO mg/L	BOD mg/L	TS mg/L	Fat mg/L	SAR	PAR	RSC
				Na^+	K^+	Ca^{2+}	Mg^{2+}	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	F^-								
1.		8.02	3.21	15.07	0.40	5.90	5.28	7.90	21.00	1.90	8.20	1.60	15.20	2.10	2230	2830	24.00	6.39	0.17	17.72
2.	I	8.01	3.16	15.06	0.56	5.95	5.19	7.70	21.90	1.80	8.21	1.62	15.22	2.20	2240	2820	26.00	6.38	0.24	17.46
3.		8.05	3.20	15.70	0.75	5.98	5.10	7.92	21.80	1.85	8.26	1.67	15.60	2.22	2250	2526	26.00	6.68	0.32	17.74
4.		8.11	2.25	14.10	0.36	5.10	5.90	8.50	14.80	1.26	7.60	1.23	26.20	3.10	2020	2654	30.00	6.02	0.15	12.17
5.	II	8.09	2.22	13.70	0.38	4.98	5.95	8.70	15.80	1.24	7.50	1.24	16.22	3.12	2040	2660	32.00	5.88	0.16	13.60
6.		8.07	2.30	14.15	0.37	4.95	5.98	8.75	15.82	1.26	7.55	1.26	16.24	3.12	2040	2670	32.00	6.07	0.16	13.64
7.		7.06	1.75	09.70	0.26	7.62	2.30	5.10	12.80	2.43	3.10	1.12	08.10	1.14	240	1620	40.00	4.37	0.12	07.98
8.	III	7.10	1.90	09.80	0.25	7.70	2.33	5.22	12.75	2.40	3.25	1.16	08.12	1.12	245	1635	42.00	4.39	0.11	07.94
9.		7.08	1.80	09.82	0.24	7.60	2.34	5.20	12.60	2.42	3.30	1.14	08.26	1.17	250	1640	43.00	4.42	0.11	07.86
10.		6.54	2.05	10.20	0.28	6.20	3.10	3.70	11.06	2.80	4.40	1.22	08.25	1.95	290	1875	33.00	4.75	0.13	05.46
11.	IV	6.50	1.95	10.90	0.32	6.15	3.12	3.80	11.08	2.85	4.42	1.23	08.24	1.90	302	1890	35.00	4.90	0.14	05.61
12.		6.40	2.00	11.00	0.30	6.30	3.12	3.85	11.09	2.90	4.46	1.27	08.24	1.90	304	1880	36.00	4.70	0.14	05.52
Mean		7.42	2.31	12.43	0.37	6.20	4.14	6.36	15.20	2.09	5.85	1.31	11.99	2.08	1204.75	2250	33.25			
SD		0.71	0.30	02.35	0.14	0.98	1.54	6.60	04.18	0.66	2.18	0.19	03.97	0.78	977.02	527.10	06.26			
13.	Tap	7.70	1.70	08.05	0.16	6.75	2.50	5.90	03.40	1.74	5.27	1.45	00.90	6.10	3.10	240	0.04	3.75	0.07	1.05
14.	Water	7.72	1.75	08.00	0.14	6.40	2.70	5.82	03.41	1.76	5.20	1.50	01.00	6.20	2.10	250	0.05	3.69	0.06	1.13
15.		7.75	1.72	08.40	0.15	6.40	2.70	2.74	03.39	1.76	5.22	1.46	02.10	6.22	2.12	260	0.06	3.87	0.07	1.13
Mean		7.72	1.71	08.04	0.12	6.05	2.05	5.07	3.29	1.30	5.33	1.45	00.82	6.10	3.06	242.07	0.02			
SD		0.05	0.01	0.03	0.01	0.01	0.01	0.02	1.19	0.014	0.02	0.007	0.05	0.066	0.01	2.51	0.007			

Variation in pH is due to different concentration of cations and anions present in excess. Fresh effluent is slightly alkaline due to excess of carbonate and bicarbonate, which later on becomes acidic or neutral due to lactic acid formed by decomposition of lactose.

Tolerance limit is 6.5 to 8.5 for dairy effluent disposed on land[8]. pH has no direct adverse effect on health but it is an important characteristic to evaluate the suitability for irrigation, since it affects the availability of nutrients.

Electrical Conductivity (EC): The range of EC observed for different samples lies between 1.75 to 3.20 m-mhos/cm. Among treated and untreated samples, EC value is lowest 1.75 m-mhos/cm for treated and highest 3.20 m-mhos/cm for untreated sample.

Suitable limit for irrigation water is less than 2.250 m-mhos/cm. Water of higher EC values is used occasionally, but crop production, except in unusual situations, has not been satisfactory. Therefore, the use of water of moderate to high salt content may result in saline conditions.

Ideally, it could be inferred that EC of irigation water should be as low as possible but the water which is completely free from soluble salts is never the best for irrigation. Water having EC less than 0.2 m-mhos/cm has no fertility value and is well known to create permeability problem in soil[9].

Alkalinity: Alkalinity of irrigation water is determined either as RSC (residual sodium carbonate):

$$[(CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+})],$$

(all ions expressed in meq/L) or is determined as RSBC (residual sodium bicarbonate) in the absence of CO_3^{2-}.

In the effluent, the concentration of carbonate is found in the range of 3.70 to 8.75 meq/L. The concentration of bicarbonate varies from 11.06 to 21.90 meq/L. Due to high value of carbonates and bicarbonates, RSC values are higher for untreated than for treated samples.

RSC is the most important characteristic in determining the quality of water for irrigation purposes. The tolerance limit for RSC is 5 meq/L under favourable conditions (IS 1981, BIS 1888).

Carbonate ion has the potential to eliminate Ca^{2+}, hence is the most injurious of all ions. Carbonate and bicarbonate may have an indirect effect on the quality of water as they result in precipitation of calcium and magnesium, thereby increasing the sodium percentage. It has been reported that water with RSC more than 2.5 meq/L is not suitable for irrigation[10].

Chloride: Among treated and untreated samples, highest mean value is observed for treated (2.90 meq/L) and lowest for untreated (1.24 meq/L).

According to IS, tolerance limit for irrigation water is 600 mg/L (17 meq/L). Wheat, sorghum, cotton, barely are able to tolerate chloride in concentration from 62 to 80 meq/L, if irrigated through surface irrigation methods[10]. It is evident that crops can tolerate chloride much higher than the above limits.

Sulphate: Treated and untreated sample comparison shows lowest value for treated (3.10 meq/L) and highest value for untreated (8.26 meq/L).

Maximum acceptable concentration is 200 mg/L (4.16 meq/L). The BIS prescribed 400 mg/L (12.4 meq/L) as permissible limit of sulphate ion in the absence of alternative source. Presence of sulphate beyond limit is harmful as it directly affects the concentration of Ca^{2+}, Mg^{2+} and quality of water.

The concentration of sulphate ions observed in the present study are within the range prescibed by BIS; thereby indicating that this water is safe for irrigation as far as sulphate is concerned.

Fluoride: Highest value observed is 1.67 meq/L and lowest is 1.12 meq/L. The observed mean value for tap water is 1.45 meq/L.

Fluoride is an essential nutrient for plant growth, although excess of fluoride is toxic. Since there is no considerable change in fluoride concentration in the effluent, it can safely be used for irrigation.

Calcium: Concentration of calcium in effluent ranges from 4.95 to 7.70 meq/L. These values are within the allowable limits. The values for treated samples are higher than for untreated samples.

The effluent discharged on land should contain calcium 5.0 meq/L relaxable to 2.0 meq/L under favourable conditions. Moderate concentrations of calcium chloride are highly toxic to stone fruits and in sand cultures[11].

Magnesium: The range of concentration of magnesium varies from 2.30 to 5.98 meq/L. Among treated and untreated samples, the former has lower values.

According to BIS, maximum acceptable concentration and permissible concentration are 2.5 meq/L and 12.0 meq/L respectively for drinking water. The apparent specific effect of magnesium may be merely a deficiency of calcium induced by partial exclusion of calcium from plants in presence of excess magnesium[12]. Breaking down of chlorophyll molecule with blotches on leaves is caused due to magnesium deficiency.

Potassium: The concentration of potassium varies from 0.24 to 0.75 meq/L, which is within the permissible limits. Potassium is an essential element for plant growth. Its excess may induce iron chlorosis and magnesium deficiency[13].

Sodium: SAR (sodium absorption ratio) is used as a new basis for sodicity:

$$SAR = Na/\sqrt{Ca + Mg/2}$$

In the effluent, concentration of sodium varies from 9.70 to 15.70 meq/L. SAR calculated values for different samples lie between 4.37 to 6.68.

According to BIS, safest limit of SAR has been recognized as 10 but this is relaxable up to 30 in most favourable conditions of plant, soil, rainfall and management. The irrigation water having SAR 10, 20, 30 should not have EC less than 1, 2, 3, m-mhos/L respectively otherwise it will cause adverse effects on physical properties of soil due to lack of electrolyte concentration.

Turbidity: Variation range lies between 8.10 to 26.20. Treated samples have low turbidity which may be attributed to decomposition of organic matter. Mean value of turbidity in tap water is 0.82. The high value of turbidity in various samples is due to presence of high organic matter.

Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD): Among treated and untreated samples, the former have lower concentration of DO. BOD is the amount of oxygen utilized by micro-organisms in stabilizing

organic matter. Since untreated water has very high BOD, it will be highly toxic. Treated water, however, can be used for irrigation under suitable conditions.

Total Solids (TS): Concentration of total solids in various samples lies between 1620 to 2830 mg/L. Among untreated and treated samples, the values are higher for the former.

TS controls the availability of water to plants through osmotic pressure regulating mechanism[14], the tolerance limit for effluent to be discharged on land for irrigation is 2100 mg/L for dissolved solids. TS may be somewhat higher than this as these are nearly equal to sum of suspended and dissolved solids.

Fat: Effluent has fat concentration ranging from 24 to 60 mg/L. Tolerance limit to be discharged on land for irrigation is 10 mg/L, indicating that fat concentration in effluents (both treated and untreated) is somewhat higher than required to use water for irrigation purpose.

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