

Wastewater quality index (WWQI) as an indicator of secondary treated wastewater quality and sustainable water reuse

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Abstract

The purpose of the present study was the assessment of secondary treated wastewater of dairy industry effluent treatment plant as sustainable water resource in terms of wastewater quality index (WWQI). The results revealed that treatment process and discharged effluent is following the environment protection standards of Indian standards for discharge and irrigation. BOD values of 67% samples are higher than permissible limits of FAO and inland surface waters standards (30mg/l) (IS2490-Part I-1981). The other 15 measured physico-chemical parameters are within permissible values of Indian standards (IS2490-Part I-1981). The calculated WWQI values ranging from 43.77 to 68.97 are indicative of excellent to good quality of treated water in terms of physicochemical parameters. Still, the treatment process should be regularly monitored and improved to reach a better level of BOD and WWQI and hence better water quality.

Keywords: Secondary treated wastewater; Sewage treatment plant; Physico-chemical parameters; Waste water quality index

1. Introduction

Water is fundamental to life, but today, safe quality water is very difficult to get even in water suffice areas. Huge population, rapid urbanization, industrialization and modern civilization are a big challenge for water conservation and water quality management. Economic, industrial and social development are associated with environment changes and affect water quality adversely [1]. This precious and dynamic natural resource is often polluted in various ways [2], [3]. The food sector is one of the highest waters consuming and the biggest wastewater producing sector with dairy industry as example of this sector [4]. Water quality and quantity can be managed by suitable treatment of wastewater generated from such activities. With this purpose, effluent treatment plants are installed in various industries to treat generated effluent in the boundary itself and use treatment process as per quality of effluent generated. The primary goal of these treatment facilities is to produce effluent with minimum negative impact on human as well as environment health. The effluent quality is regularly monitored by sampling, testing and analysis. The water quality is described by a number of physical, chemical and biological parameters depending on the specific use. The study of these parameters is useful to know the nature of water environment of an area. This detailed analysis of these quality parameters produces a big data that is not useful for public or legislation judgement [5]. The wastewater quality index (WWQI) could be a more useful and scientific method to indicate the wastewater quality by combining a diverse set of wastewater quality data and generating a single numeric value. it helps in easy data interpretation and simple monitoring of various temporal and spatial variations in effluent quality. Water quality indexing of ground water samples and river waters have been done by many researchers [8], [9], [10], [11] in different regions of India as well in other countries. Similar approaches have been considered by many researchers which brought changes to the methodology depending on usage and parameters under consideration.

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2. Materials and methodology

- Study Area - Effluent treatment plants are installed in industries to meet regulating norms governed by pollution control boards. The ETP of SARAS dairy, Sri Ganganagar Zila Dugdh Utpadak Sehkari Sangh Ltd. Hanumangarh, (Raj), India having capacity to treat 500 m³ per day of effluent was selected for present study.
- Physicochemical Analysis - The secondary treated wastewater samples were collected from the ETP of SARAS dairy, Sri Ganganagar Zila Dugdh Utpadak Sehkari Sangh Ltd. Hanumangarh. The composite samples were collected fortnightly in cleaned, washed and rinsed glass bottles for a period of one year from February, 2020 to January, 2021. The collected samples were analyzed for various physico-chemical parameters-temperature, pH, electrical conductance (EC), Chemical Oxygen Demand (COD), biological oxygen demand (BOD), total alkalinity (TA), total hardness (TH), total dissolved solids (TDS), sodium (Na⁺), potassium (K⁺), calcium (Ca²⁺), magnesium (Mg²⁺), chloride (Cl⁻), sulphate (SO₄²⁻), nitrate (NO₃⁻) and fluoride (F⁻) as per standard methods. Temperature and pH were measured at the sampling site. DO fixation was performed at the location itself by adding manganese sulphate and alkaline KI solution and samples were stored at 4 °C for determining other parameters. For sampling and testing the procedure described in standard methods were adopted [12]. All the reagents used were AR grade and double distilled water was used for solution preparation [13].
- Computational Analysis - Waste Water Quality Index (WWQI) used for secondary treated water quality enables easy and rapid assessment of water reuse for agriculture or recreational purposes as well as comparison of various wastewater treatment processes [5], [14]. WWQI is computed from following expressions [15], [16].

$$WWQI = \sum q_i W_i / \sum W_i \dots\dots\dots (1)$$

where, q_i represents the quality rating for each of the water quality parameters used in the index and is given by

$$q_i = 100 (V_i - V_{10}) / (S_i - V_{10}) \dots\dots\dots (2)$$

V_i is measured value of the i th parameter in water sample, V_{10} is the ideal value of this parameter in pure water and S_i refers to acceptable limit as given in Indian standard [17]. W_i is unit weight for the i th parameter

$$W_i = k/S_i \dots\dots\dots (3),$$

where k is constant of proportionality and is assumed unity for the sake of simplicity.

Table 1 Physico-Chemical Parameters of ETP SARAS, Hanumangarh

Sample	Month	Temp.	pH	EC	COD	BOD	TH	TA	TDS	Na ⁺	K ⁺	Ca ⁺²	Mg ⁺²	NO ₃ ⁻	SO ₄ ⁻²	Cl ⁻	F ⁻	CO ₃ ⁻	HCO ₃ ⁻
EH1	February (1)	17.7	8.3	700	53.0	28.0	94	126	246	67	7.5	20.0	10.7	1.1	5.4	40	0.13	2	124
EH2	February (2)	18.2	8.4	726	57.0	32.0	90	128	218	72	7.1	19.2	10.2	1.2	5.5	42	0.11	2	126
EH3	March (1)	20.8	8.5	748	72.0	37.0	87	132	254	70	8.2	18.4	10.0	1.3	5.7	43	0.10	4	128
EH4	March (2)	22.0	8.6	760	77.0	40.0	102	144	286	74	6.0	21.6	11.7	1.4	6.2	47	0.14	6	138
EH5	May (2)	25.6	8.7	840	84.0	44.0	116	148	342	82	6.4	24.0	13.6	1.7	6.8	48	0.16	8	140
EH6	June (1)	27.8	8.8	800	70.4	36.0	110	140	316	78	7.5	23.2	12.6	1.4	6.3	47	0.15	4	136
EH7	June (2)	28.4	8.5	780	65.0	32.0	108	136	354	73	6.2	23.2	12.1	1.3	5.7	42	0.12	2	134
EH8	July (1)	27.5	8.3	746	55.8	27.0	96	132	328	65	6.2	21.6	10.2	1.6	6.5	43	0.14	2	130
EH9	July (2)	26.4	7.9	730	48.6	24.0	90	128	282	62	6.0	18.4	10.7	1.8	6.7	45	0.17	0	128
EH10	August (1)	25.0	8.0	710	56.6	28.0	88	122	268	58	6.4	16.8	11.2	1.7	6.4	41	0.16	2	120
EH11	August (2)	24.8	8.1	738	60.2	32.0	92	128	295	64	6.4	19.2	10.7	1.4	6.2	40	0.15	4	124
EH12	September (1)	24.2	8.2	724	48.8	26.0	94	123	272	62	6.7	19.6	10.9	1.2	6.0	37	0.17	0	123
EH13	September (2)	23.2	8.3	684	50.0	28.0	97	130	250	71	6.8	22.0	10.2	1.1	5.8	44	0.16	2	128
EH14	October (1)	22.5	8.3	670	46.7	25.0	104	126	234	67	6.9	22.4	11.7	1.3	6.0	49	0.17	0	126
EH15	October (2)	22.0	8.4	724	52.0	28.0	100	135	276	73	6.9	21.6	11.2	1.4	6.3	41	0.14	4	131
EH16	November (1)	20.3	8.2	734	48.0	24.0	96	121	294	75	7.2	20.8	10.7	1.6	6.7	44	0.16	0	121
EH17	November (2)	18.7	8.1	752	45.0	22.0	92	128	268	80	7.4	20.4	10.0	1.3	6.4	46	0.18	2	126
EH18	December (1)	17.0	8.3	778	47.0	25.0	88	131	282	85	7.5	18.4	10.2	1.1	6.0	41	0.16	4	127
EH19	December (2)	16.4	8.4	760	49.0	23.0	97	134	236	77	7.7	20.4	11.2	1.0	5.7	50	0.17	4	130
EH20	January (1)	14.4	8.3	740	52.0	27.0	90	126	218	74	7.6	19.2	10.2	1.0	5.3	45	0.15	0	126
EH21	January (2)	15.5	8.2	728	48.0	25.0	86	122	210	69	7.2	16.8	10.7	0.8	5.2	38	0.16	0	122

Table 2 Waste Water Quality Index (WWQI) of SARAS ETP, Hanumangarh

Para meter	IS- 229 6 (S _i)	Uni t Wt (W _i)	EH 1 (q _i W _i)	EH 2 (q _i W _i)	EH 3 (q _i W _i)	EH 4 (q _i W _i)	EH 5 (q _i W _i)	EH 6 (q _i W _i)	EH 7 (q _i W _i)	EH 8 (q _i W _i)	EH 9 (q _i W _i)	EH 10 (q _i W _i)	EH 11 (q _i W _i)	EH 12 (q _i W _i)	EH 13 (q _i W _i)	EH 14 (q _i W _i)	EH 15 (q _i W _i)	EH 16 (q _i W _i)	EH 17 (q _i W _i)	EH 18 (q _i W _i)	EH 19 (q _i W _i)	EH 20 (q _i W _i)	EH 21 (q _i W _i)
Temp.	25	0.0 400	2.8 3	2.9 12	3.3 28	3.5 20	4.0 96	4.4 48	4.5 44	4.4 00	4.2 24	4.0 00	3.9 68	3.8 72	3.7 12	3.6 00	3.5 20	3.2 48	2.9 92	2.7 20	2.6 24	2.3 04	2.4 80
pH	8.5	0.1 176	10. 20	10. 980	11. 765	12. 549	13. 333	14. 118	11. 765	10. 196	7.0 59	7.8 43	8.6 27	9.4 12	10. 196	10. 196	10. 980	9.4 12	8.6 27	10. 196	10. 980	10. 196	9.4 12
EC	225 0	0.0 004	0.0 1	0.0 14	0.0 15	0.0 15	0.0 17	0.0 16	0.0 15	0.0 15	0.0 14	0.0 14	0.0 15	0.0 14	0.0 14	0.0 13	0.0 14	0.0 14	0.0 15	0.0 15	0.0 15	0.0 15	0.0 15
COD	100	0.0 100	0.5 3	0.5 70	0.7 20	0.7 70	0.8 40	0.7 04	0.6 50	0.5 58	0.4 86	0.5 66	0.6 02	0.4 88	0.5 00	0.4 67	0.5 20	0.4 80	0.4 50	0.4 70	0.4 90	0.5 20	0.4 80
BOD	10	0.1 00	28. 00	32. 00	37. 00	40. 00	44. 00	36. 00	32. 00	27. 00	24. 00	28. 00	32. 00	26. 00	28. 00	25. 00	28. 00	24. 00	22. 00	25. 00	23. 00	27. 00	25. 00
TH	300	0.0 033	0.1 0	0.1 00	0.0 97	0.1 13	0.1 29	0.1 22	0.1 20	0.1 07	0.1 00	0.0 98	0.1 02	0.1 04	0.1 08	0.1 16	0.1 11	0.1 07	0.1 02	0.0 98	0.1 08	0.1 00	0.0 96
TA	200	0.0 050	0.3 2	0.3 20	0.3 30	0.3 60	0.3 70	0.3 50	0.3 40	0.3 30	0.3 20	0.3 05	0.3 20	0.3 08	0.3 25	0.3 15	0.3 38	0.3 03	0.3 20	0.3 28	0.3 35	0.3 15	0.3 05
TDS	500	0.0 020	0.1 0	0.0 87	0.1 02	0.1 14	0.1 37	0.1 26	0.1 42	0.1 31	0.1 13	0.1 07	0.1 18	0.1 09	0.1 00	0.0 94	0.1 10	0.1 18	0.1 07	0.1 13	0.0 94	0.0 87	0.0 84
Na ⁺	200	0.0 050	0.1 7	0.1 80	0.1 75	0.1 85	0.2 05	0.1 95	0.1 83	0.1 63	0.1 55	0.1 45	0.1 60	0.1 55	0.1 78	0.1 68	0.1 83	0.1 88	0.2 00	0.2 13	0.1 93	0.1 85	0.1 73
K ⁺	15	0.0 667	3.3 3	3.1 56	3.6 44	2.6 67	2.8 44	3.3 33	2.7 56	2.7 56	2.6 67	2.8 44	2.8 44	2.9 78	3.0 22	3.0 67	3.0 67	3.2 00	3.2 89	3.3 33	3.4 22	3.3 78	3.2 00
Ca ²⁺	75	0.0 133	0.3 6	0.3 41	0.3 27	0.3 84	0.4 27	0.4 12	0.4 12	0.3 84	0.3 27	0.2 99	0.3 41	0.3 48	0.3 91	0.3 98	0.3 84	0.3 70	0.3 63	0.3 27	0.3 63	0.3 41	0.2 99
Mg ²⁺	30	0.0 333	1.1 9	1.1 33	1.1 11	1.3 00	1.5 11	1.4 00	1.3 44	1.1 33	1.1 89	1.2 44	1.1 89	1.2 11	1.1 33	1.3 00	1.2 44	1.1 89	1.1 11	1.1 33	1.2 44	1.1 33	1.1 89
NO ₃ ⁻	50	0.0 200	0.0 4	0.0 48	0.0 52	0.0 56	0.0 68	0.0 56	0.0 52	0.0 64	0.0 72	0.0 68	0.0 56	0.0 48	0.0 44	0.0 52	0.0 56	0.0 64	0.0 52	0.0 44	0.0 40	0.0 40	0.0 32

SO ₄ ⁻²	400	0.0 025	0.0 0	0.0 03	0.0 04	0.0 04	0.0 04	0.0 04	0.0 04	0.0 04	0.0 04	0.0 04	0.0 04	0.0 04	0.0 04	0.0 04	0.0 04	0.0 04	0.0 04	0.0 04	0.0 03	0.0 03	
Cl ⁻	250	0.0 040	0.0 6	0.0 67	0.0 69	0.0 75	0.0 77	0.0 75	0.0 67	0.0 69	0.0 72	0.0 66	0.0 64	0.0 59	0.0 70	0.0 78	0.0 66	0.0 70	0.0 74	0.0 66	0.0 80	0.0 72	0.0 61
F ⁻	1.5	0.6 667	5.7 8	4.8 89	4.4 44	6.2 22	7.1 11	4.4 44	5.3 33	6.2 22	7.5 56	7.1 11	6.6 67	7.5 56	7.1 11	7.5 56	6.2 22	7.1 11	8.0 00	7.1 11	7.5 56	6.6 67	7.1 11
ΣW _i		1.0 899																					
Σq _i W _i			53. 02	56. 80	63. 18	68. 33	75. 17	65. 80	59. 73	53. 53	48. 36	52. 71	57. 08	52. 67	54. 91	52. 42	54. 82	49. 88	47. 71	51. 17	50. 55	52. 34	49. 92
WWQI = Σq _i W _i / ΣW _i			48. 65	52. 12	57. 97	62. 70	68. 97	60. 38	54. 80	49. 11	44. 37	48. 37	52. 37	48. 32	50. 38	48. 10	50. 30	45. 76	43. 77	46. 95	46. 38	48. 02	45. 80

3. Results and discussions

The measured physicochemical parameters are presented in table-1 and computed WWQI data values in Table-2. The data interpretation shows that treated effluent is of alkaline nature (pH range 7.9-8.8) and is within permissible limits of 6.5-8.5 [18] for most of the samples and within [19] public sewer limits of 6.0-9.0 for wastewater discharge into the environment. The soaps and detergents used for cleaning of dairy processing equipment and vessels raise the pH of the effluent. BOD values of 67% samples are higher than permissible limits of FAO and inland surface waters standards (30mg/l) [20]. The other physical as well as chemical parameters are within permissible values of Indian standards. WWQI summarizes large amounts of water quality data into simple terms (e.g., excellent, good, poor, etc.) (Table-3) for reporting to management and the public in a consistent manner. It enables rapid assessment of water reuse for agricultural or recreational purpose as well as for comparing different wastewater treatment sequences [5], [14].

Table 3 Waste Water Quality Index data

WWQI	Class	Water Quality
<50	I	Excellent
50-100	II	Good
100-200	III	Poor
200-300	IV	Very Poor
>300	V	Unsuitable

The WWQI values ranging from 43.77 to 68.97 (Table-2) are indicative of excellent to good quality of treated water in terms of physicochemical parameters (Table-3) [21]. WWQI was significantly higher during pre-monsoon sampling period as high atmospheric temperature of this area causes more evaporation resulting in concentration rise of WWQI determining parameters.

4. Conclusions

The present paper concludes that except BOD values of 67% samples and pH of 10% samples, all measured physicochemical parameters are within permissible standard limits. Cleaning process and hygiene of the dairy industry contribute a lot to these parameters and hence require proper cleaning and maintenance. The overall quality of secondary treated wastewater of SARAS ETP Hanumangarh, presented in a single numeric value WWQI, is of good quality. It is concluded that the functioning of effluent treatment plant is good, and it needs to be monitored at regular basis so that the pollution indicators like BOD, pH may be within the permissible limits as prescribed by Indian standards for this sector and an effluent generated after the treatment may be eco-friendly and could be used safe for recreational activities and field irrigation.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest

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