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Chronic Effect of Sugar Industry Effluent on Food Consumption and Growth of Freshwater Fish *Chanda nama*

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ABSTRACT

Industrial effluents represent a persistent source of contamination in freshwater ecosystems, where chronic exposure often poses greater ecological risks than short-term acute pollution events. Among these, effluents from sugar and distillery industries are of particular concern due to their high organic load, acidic nature, depletion of dissolved oxygen, and elevated biochemical and chemical oxygen demand. Such conditions can disrupt metabolic and physiological processes in aquatic organisms even at concentrations that do not induce immediate mortality. Feeding behavior and growth performance in fish are sensitive sublethal endpoints that provide early indications of physiological stress and potential long-term population-level impacts. Despite this, information on the chronic effects of sugar industry effluents on native freshwater fish species remains limited. The present study was therefore undertaken to evaluate the impact of prolonged exposure to low concentrations of sugar industry effluent on food consumption and growth in the freshwater fish *Chanda nama*, a species selected for its ecological relevance, sensitivity to water quality changes, and suitability as a biological indicator. Fish were exposed under laboratory conditions to two sublethal effluent concentrations, 2.8% (1/5 dilution) and 1.4% (1/10 dilution), based on the 96-h LC_{50} value, for a period of four weeks. Feeding rate, food utilization, survival, and growth in terms of body weight were monitored weekly and compared with a control group maintained in clean water. No mortality was observed in any treatment, confirming the sublethal nature of the exposure. However, effluent-exposed fish exhibited a progressive and concentration-dependent decline in food consumption and growth, whereas control fish showed steady improvement in both parameters. These findings demonstrate that chronic exposure to even low concentrations of sugar industry effluent can significantly impair metabolic functioning, feeding efficiency, and somatic growth in *Chanda nama*, underscoring the potential long-term ecological consequences for fish populations in contaminated freshwater habitats.

Keywords Sugar industry effluent, Food consumption, Growth, *Chanda nama*.

INTRODUCTION

Freshwater ecosystems are increasingly subjected to

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continuous inputs of industrial effluents, resulting in prolonged exposure of aquatic organisms to complex mixtures of pollutants (Mushtaq *et al*. 2020). Unlike acute toxicity, which primarily evaluates short-term lethality, chronic toxicity focuses on sub-lethal effects that develop gradually and often remain undetected until substantial ecological impairment occurs. Chronic exposure can disrupt essential physiological processes such as metabolism, energy allocation, growth and reproduction, ultimately leading to population decline and biodiversity loss (Rhind 2009, Costantini *et al.* 2025). Therefore, chronic toxicity assessments are considered indispensable for evaluating long-term ecological risks associated with environmental contaminants.

Among various industrial discharges, effluents from sugar and distillery industries represent a major source of organic pollution in freshwater ecosystems, particularly in developing countries such as India where sugar production is widespread (Kumar 2000, Chowdhary *et al*. 2017, Fito *et al.* 2019). Large volumes of wastewater generated during sugar processing and distillation are frequently released into nearby rivers, streams and reservoirs with inadequate treatment. These effluents are typically characterized by high organic load, suspended solids, dark coloration, acidic pH and extremely elevated biochemical oxygen demand (BOD) and chemical oxygen demand (COD) (Meneceur *et al.* 2023). When introduced into aquatic environments, such effluents rapidly deplete dissolved oxygen, alter physico-chemical properties of water, and impose severe physiological stress on aquatic biota (Menon *et al.* 2023).

Although acute fish mortality may occur under severe pollution events, aquatic organisms are more commonly exposed to diluted concentrations of effluents over extended periods (Hand 1994, Ngo *et al.* 2022). Under such conditions, fish may survive but experience chronic physiological stress that impairs normal biological functions. Consequently, assessment of chronic sub-lethal effects is ecologically more relevant than mortality-based acute toxicity tests for understanding the true environmental impact of industrial effluents (Iannacone *et al.* 2026). However, most studies on sugar industry effluents have primarily focused on physico-chemical characterization or short-term toxicity endpoints, while experimental evidence on long-term biological responses remains limited (Sipma *et al.* 2010, Guieysse and Norvill, 2014). Feeding behavior and growth performance are among the most sensitive and ecologically meaningful endpoints in chronic toxicity studies. These parameters reflect the integrated functioning of sensory perception, digestive efficiency, metabolic rate, and endocrine regulation (Rowan *et al.* 2024). Disruption of feeding activity reduces energy intake, while increased metabolic costs associated with detoxification further limit energy available for somatic growth and reproduction (Li *et al.* 2024). Persistent suppression of food consumption and growth can therefore compromise fish fitness, reduce reproductive potential, and negatively affect population sustainability. Several studies have reported reduced feeding and growth in fish exposed to industrial effluents, pesticides, and heavy metals, highlighting their value as early biomarkers of sub-lethal stress (James *et al.* 1995, Sarkar and Konar 1995). Fish are widely recognized as reliable bioindicators of aquatic pollution due to their ecological relevance, economic importance and high sensitivity to changes in water quality. Alterations in feeding behavior and growth often precede visible signs of toxicity and mortality, providing early warning signals of environmental degradation (López-López and Sedeño-Díaz 2015, Okwuosa *et al*. 2019). In this context, the freshwater fish *Chanda nama* was selected as the test organism for the present investigation. This species is widely distributed in Indian freshwater systems, including rivers, reservoirs, and wetlands that are frequently exposed to industrial effluents. Its small size, ease of maintenance under laboratory conditions, and rapid physiological response to environmental stress make it an ideal model for chronic toxicity studies. Moreover, *Chanda nama* occupies an important position in the freshwater food web, serving as prey for larger predatory fishes, thereby facilitating the transfer of pollutant-induced effects across trophic levels.

Despite its ecological significance, limited information is available on the response of *Chanda nama* to chronic exposure of industrial effluents, particularly those originating from sugar and distillery industries. The present study was therefore undertaken to evaluate the effects of sub-lethal concentrations of sugar industry effluent on food consumption and growth of *Chanda nama* under controlled laboratory conditions. By focusing on chronic sub-lethal endpoints rather than mortality, the study aims to provide ecologically relevant insights into how continuous low-level effluent contamination can impair fish health and threaten freshwater ecosystem stability. The findings are expected to contribute to environmental risk assessment frameworks and emphasize the need for improved effluent treatment and stricter regulatory control.

MATERIALS AND METHODS

Test organism and acclimatization

Healthy specimens of *Chanda nama* were collected from the Bhima River near Kangaon, Taluka Daund, District Pune, Maharashtra. Fish were transported to the laboratory and acclimatized for two weeks in aerated aquaria containing dechlorinated tap water. During acclimatization, fish were fed live earthworm pieces on alternate days. Only healthy individuals of uniform size (average length 6.5–7.0 cm; weight 4.0–5.0 g) were selected for experimentation.

Effluent collection and analysis

Sugar industry effluent was collected directly from the discharge outlet of a sugar mill. Physico-chemical characteristics of the effluent and control water were analyzed following standard procedures of (APHA 2000). Parameters such as temperature, pH, total hardness, dissolved oxygen (DO), BOD, COD, and total solids were recorded (Table 1).

Determination of sub-lethal concentrations

Based on preliminary acute toxicity tests, the 96 hr LC_{50} value of the effluent for *Chanda nama* was determined as 14%. two sublethal concentrations corresponding to 1/5 (2.8%) and 1/10 (1.4%) of the LC_{50} value were selected for chronic exposure. Test solutions were prepared using the dilution formula given by (FAO 1984).

Table 1. Showing physico-chemical parameters.

Sl. No.	Parameter	Tap water	Sugar industry effluent
1	Temperature	21°C	38°C
2	pH	7.7	5.7
3	Total Hardness	140	580
4	Dissolve Oxygen (DO)	6.8	Nil
5	Biological Oxygen Demond (BOD)	09	1830
6	Chemical Oxygen Demond (COD)	17	3541
7	Total Solid	290	725

Experimental design

Fish were divided into three groups: Control, 1.4% effluent, and 2.8% effluent. Each group consisted of ten fish maintained in separate aquaria for four weeks. Water was renewed weekly, and aquaria were kept free from mechanical disturbances. Survival, food consumption, and growth were recorded at weekly intervals.

Feeding and growth assessment

Fish were fed a known quantity of live earthworm pieces every alternate day between 09:00 and 10:00 hr. Uneaten food was siphoned out, blotted dry, and weighed. Food consumption was calculated as the difference between the initial and remaining food weights and expressed as mg g^{-1} body weight $week^{-1}$ (Webb and Brett 1972).

Growth was assessed weekly by recording changes in body weight. Individual fish were weighed using the displacement method, and percentage weight change was calculated relative to initial body weight.

Statistical analysis

Data on food consumption and growth were analyzed descriptively and compared between control and treated groups to evaluate concentration-dependent effects.

RESULTS

Survival

No mortality was observed in any experimental group

Table 2. Mortality and survival rate of fish, *Chanda nama* exposed chronically to two sub lethal concentration of the, sugar industry effluent.

Week	Control	Sugar industry effluent 2.8% (1/5)	1.4% (1/10)
Ist	0	0	0
IInd	0	0	0
IIIrd	0	0	0
IVth	0	0	0
% of mortality at the end of experiment	0%	0%	0%
% of survival at the end of experiment	100%	100%	100%

throughout the four-week exposure period. Fish exposed to both sub-lethal concentrations of sugar industry effluent (2.8% and 1.4%) exhibited 100% survival, comparable to the control group maintained in clean water (Table 2). The absence of mortality confirms that the selected effluent concentrations were sub-lethal and suitable for evaluating chronic physiological responses.

Food consumption

A clear divergence in feeding patterns was observed between control and effluent-exposed fish. Control fish showed a steady and progressive increase in food consumption throughout the experimental period, reflecting normal feeding behavior and metabolic activity. Total food intake increased from 81.5 mg week^{-1} in the first week to 220.5 mg week^{-1} by the fourth week, with standardized consumption rising from 19.05 to 50.00 mg·g^{-1}·week^{-1} (Table 3).

In contrast, fish exposed to sugar industry effluent exhibited a marked reduction in food consumption from the first week onward. Both effluent-treated groups showed negative values of total and standardized food consumption, indicating net biomass loss. The reduction was concentration-dependent, with the 2.8% effluent group displaying more pronounced declines than the 1.4% group. In the higher concentration, total weekly food consumption decreased progressively from −144.0 mg to −262.0 mg, while standardized consumption declined from

Table 3. Weekly food consumption of *Chanda nama* expressed as total intake (mg/week) and standardized consumption (mg·g^{-1}·week^{-1}) under control and effluent-exposed conditions.

Week	Treatment	Body weight (g)	Total consumption (mg/-week)	Standardized consumption (mg.g^{-1}·week^{-1})
I	Control	4.28	81.5	19.05
	2.8% (1/5)	4.25	−144.0	−34.09
	1.4% (1/10)	4.55	−49.5	−10.87
II	Control	4.33	134	30.95
	2.8% (1/5)	4.18	−209.0	−50.00
	1.4% (1/10)	4.52	−78.6	−17.39
III	Control	4.38	187.8	42.86
	2.8% (1/5)	4.15	−236.0	–56.82
	1.4% (1/10)	4.49	−107.5	23.91
IV	Control	4.41	220.5	50
	2.8% (1/5)	4.12	−262.0	−63.64
	1.4% (1/10)	4.46	−135.3	−30.43

Note. Negative values indicate net biomass loss, reflecting reduced food consumption.

−34.09 to −63.64 mg·g^{-1}·week^{-1} over the four-week period. Fish exposed to 1.4% effluent also showed reduced feeding, with total consumption ranging from −49.5 to −135.3 mg week^{-1} and standardized values from −10.87 to −30.43 mg·g^{-1}·week^{-1} (Table 3).

Growth performance

Growth patterns differed distinctly between control and effluent-exposed fish. Control fish exhibited a consistent and progressive increase in body weight throughout the experimental period. Mean body weight increased from an initial value of 4.2 g to 4.45 g by the end of the exposure period, corresponding to a cumulative weight gain of approximately 5.95% (Table 4).

Conversely, fish exposed to sugar industry effluent showed a gradual decline in body weight over time. Growth inhibition was evident in both effluent concentrations and followed a concentration-dependent trend. Fish exposed to 2.8% effluent exhibited the greatest reduction in body weight, with a cumulative decrease of 6.82% by the end of the experiment. The 1.4% effluent group showed a less pronounced but consistent decline, with body weight decreasing by 3.69% over the same period (Table 4). These results

Table 4. Growth in terms of weight, in grams/week of *Chanda nama* exposed chronically to two sub lethal concentrations of the sugar industry effluent.

Week	Control	Sugar industry effluent 2.8% (1/5)	1.4% (1/10)
Initial weight	4.2	4.4	4.6
I^st^	4.28 (1.90%)	4.25 (-3.40%)	4.55 (-1.09%)
II^nd^	4.33 (3.09%)	4.18 (-5.00%)	4.52 (-1.74%)
III^rd^	4.38 (4.28%)	4.15 (-5.68%)	4.49 (-2.39%)
IV^th^	4.41 (5.00%)	4.12 (-6.36%)	4.46 (-3.04%)
V	4.45 (5.95%)	4.10 (-6.82%)	4.43 (-3.69%)

indicate that chronic exposure to sugar industry effluent adversely affected somatic growth in *Chanda nama*, even in the absence of mortality.

In the present investigation, chronic toxicity studies were carried out on exposing the fish, *Chanda nama* to two sub lethal concentrations of sugar industry effluent. The concentrations were 1.1% and 2.2% to which the *Chanda nama* were exposed chronically. Effects of two sub-lethal concentration of effluent were studied considering aspects like survival, feeding, growth and histology of tissue.

DISCUSSION

The present study demonstrates that chronic exposure to sub-lethal concentrations of sugar industry effluent significantly alters feeding behavior and growth performance in *Chanda nama*, even in the absence of mortality. Such sub-lethal responses are ecologically important, as they reflect physiological stress that may compromise long-term survival, reproduction, and population stability. The observed reductions in food consumption and growth are consistent with earlier reports describing pollutant-induced metabolic and behavioral disturbances in freshwater fishes (Huang *et al.* 2025).

Alterations in feeding behavior under pollutant stress have been widely documented and are often attributed to impairment of sensory perception or disruption of neural and digestive processes (Hamidian and Feizi 2026). (Conti *et al.* 2025) reported that damage to taste receptors adversely affected feeding in fishes, while (Shanebeck 2023) demonstrated that sub-lethal detergent exposure interfered with feeding responses despite the presence of food. Such findings suggest that contaminants may disrupt chemosensory mechanisms essential for prey detection and ingestion. Similar behavioral impairment may explain the reduced food intake observed in effluent-exposed *Chanda nama* in the present study.

Growth in fish is closely linked to food intake; however, it is also influenced by environmental stressors that affect metabolic efficiency and energy allocation. In the present investigation, control fish exhibited progressive weight gain, reflecting normal physiological growth under optimal conditions. In contrast, effluent-exposed fish showed gradual weight loss, indicating that energy intake was insufficient to meet metabolic demands. Comparable growth suppression has been reported in fish exposed to a variety of toxicants, including pesticides, detergents, and heavy metals (Emenike *et al.* 2022, Chakraborty 2023, Ghafarifarsani *et al*. 2024). These studies suggest that chronic exposure to pollutants can reduce assimilation efficiency and divert energy toward detoxification and stress response mechanisms.

Neurophysiological impairment may also contribute to reduced feeding activity. Copper exposure has been shown to decrease acetylcholinesterase activity in fish, leading to disrupted synaptic transmission and altered feeding behavior (Nemcsók *et al.* 1984, Santos *et al.* 2022). Evidence of neural regeneration and partial recovery of feeding responses during prolonged exposure has been reported in some species; however, no such recovery was evident in *Chanda nama* during the four-week exposure period of the present study. This suggests sustained physiological stress under continuous effluent exposure.

The consistent decline in both food consumption and growth observed in *Chanda nama* underscores its sensitivity to changes in water quality and supports its suitability as a bioindicator species. Similar reductions in food utilization have been reported in *Catla catla* exposed to cadmium Vincent *et al.* (2002). The agreement between the present findings and previous studies (Mohanty *et al.* 2025, Jaiswal and Sharma 2025) strengthens the conclusion that chronic exposure to sub-lethal pollutant concentrations can severely impair fish health without causing immediate mortality.

Overall, the results of the present study clearly demonstrate that chronic exposure to low concentrations of sugar industry effluent disrupts normal metabolic functioning in *Chanda nama*, as evidenced by reduced feeding efficiency and inhibited growth. Such sub-lethal effects, if sustained in natural environments, may lead to reduced fitness, altered trophic interactions, and long-term population decline. These findings emphasize the ecological risks associated with continuous low-level industrial effluent discharge and highlight the need for improved effluent treatment, stricter regulatory enforcement, and routine biological monitoring of freshwater ecosystems.

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