Assessment Of Freshwater Carp Culture, Growth And Production In Domestic Sewage Oxidation Ponds In The Tropics: A Comparative Study

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Abstract
Domestic treated sewage in the tropics is a rich source of nutrients and hence can be used for intensive aquaculture as well as abating the eutrophication of water. The domestic sewage effluent contains excessive nutrients which may increase growth of aquatic plants and stimulate the production of natural food for fish cultured in it. We have evaluated the growth of carps in primary and secondary oxidation ponds. *Cyprinus carpio*, *Labeo rohita*, *Cirrhinus mrigala* and *Catla catla* were stocked in these oxidation ponds. The comparative survival, rate of growth and net fish production was studied for two years along with control fresh water-pond grown fishes of similar dimensions. Except for *C.catla,* all the fishes recorded high survival rate in the secondary oxidation ponds, whereas the fishes could not survive in the primary ponds which received untreated domestic sewage and had unfavourable physicochemical conditions. An annual net fish production of 8590 kg/ha/yr of *C.carpio*, 1706 kg/ha/yr of *L.rohita* and 1443 kg/ha/yr of *C.mrigala* respectively was obtained in the secondary oxidation ponds. All the fish species were also cultured in normal control fresh water pond, where the net fish production was found to be 2400 kg for *C.carpio*, 590 kg for *L.rohita* and 390 kg for *C.mrigala* per/ha/year. Excessive fish production was observed in secondary oxidation ponds in comparison to the fresh water control pond. These results have been found to be significant and important with reference to comparable growth and assessment of sewage carps cultured in different types of ponds. Growth and production of fish both, have been significantly higher in sewage ponds.

Keywords: Domestic sewage, Eutrophication, Fish production, Human consumption, Physico-chemical.

1. Background

Huge quantities of waste-water literally get wasted in the environment by multifarious human activities, especially the domestic water, which contains large quantities of kitchen waste, faeces, rotten vegetables and food items. From nutritional point of view, this natural entity, principally contains significantly high amounts of nitrogen, phosphorus and potassium. These excessive natural nutrients allow the growth of algal species, which if managed properly, can be reclaimed for animal or fish protein, (Allen, 1985; Saini and Sharma; 1999; Jamuna and Noorjahan, 2009; Ali et al., 2020; Wojciula et al., 2021).

The treatment of sewage, being a worldwide problem has received considerable scientific attention as the raw sewage contains high inorganic and organic compounds, and plenty of other products employed in our modern society. Biotic organisms like harmful bacteria, viruses, worms and protozoa remain in high density in sewage that affect natural water and its environment (Lahiri et al., 2018; Zaibel et al., 2019; Mandal et al., 2020; Liverpool-Tasie et al., 2021).

Though, fish farming using domestic sewage water has been experienced for hundreds of years by many countries across the world, (WHO, 1999; Nandeesha et al., 2002; Al-Ghais, 2013; Jana et al., 2018; Tomasetti and Gobler, 2020; Bhanot and Hundal, 2021), it still lacks the adoption on a large scale due to inhibitory attitude from hygienic point of view, as well as the fact that very few studies have been carried out to evaluate its true aquatic potential.

As there is a dire need to fill in these lacunae, a detailed assessment of the domestic sewage reuse for fish culture in the tropics, was carried out specially to evaluate several aspects of fishes cultured in domestic sewage oxidation ponds. In this study, we have comparatively analysed the culture, survival growth and net production aspects of four fishes: *C.carpio, L. rohita*, *C.mrigala* and *C.catla* in different tropical domestic sewage oxidation ponds along with a fresh-water control pond.

2. Methods

2.1. Experimental design: The experimental work was carried out in Shahpura sewage oxidation ponds, located at T.T. Nagar, 10 km south-east of Bhopal, India (25^0-17'), constructed in two series of primary and secondary ponds as per specifications of National Environmental Engineering Research Institute (NEERI), Nagpur India. Two ponds in series, one primary oxidation pond secondary oxidation ponds were selected for the study. Each pond had an area of 0.4 hectares. The ponds were typical sewage oxidation ponds, designated to treat biologically 3 million gallons of domestic sewage per day. Sewage from adjacent area was collected in a sump near Habibganj Railway Station, from where it was pumped to the oxidation ponds. The period of this study was 2 years. The raw sewage used to enter the primary ponds through 3 inlets and after the detention period of 7 to 10 days, the biologically treated effluent was released from secondary ponds through the outlet. The treated effluent from the secondary ponds was let out into a nala and into the fields for vegetable cultivation in an area extending more than 50 hectares. In the present study out of the 8 ponds, four were selected for fish culture. Two being primary, designated as IA & IB and two as secondary, called as IIIA & IIIB. Our data of the seasonal ranges of different physicochemical parameters of secondary oxidation ponds and control ponds has been published in Ecology, Environment and Conservation (Ali et al., 2023).

2.2. Fish Culture: Fish culture experiments were conducted in two oxidation ponds along with a fresh water control pond of same dimension. Main objective of the study was analysing aspects of fish culture and growth in domestic sewage oxidation ponds. Four different types of fishes such as *Cyprinus carpio*, *Labeo rohita* (Ham.), *Cirrhinus mrigala* (Ham.) and *Catla catla* (Ham.) with an average weight of 2 gms and 5 gms respectively were cultured in the experimental and fresh water control ponds. Fingerlings of all these fishes were purchased from M.P. Fisheries Corporation, Bhopal, Prior to stocking the record of their length and weight was made on the same day. The stocking density was calculated from the Standard Methods of fish culture (Jhingran, 1984). A density of 10,000 fingerlings per hectare in the following ratio of *C.Carpio, L.rohita, C. mrigala* and *C.catla* in 3:1:1:1 respectively was selected. Fishes were stocked using all standard precautions.

2.3. Experimental design: For monitoring the growth of the experimental fishes, 50 fishes were caught at random once every three months and their length and weight were recorded as per standard methods. The netting of fishes in oxidation and fresh water control pond was done at regular 3-4 monthly intervals with the help of local fishermen using standard nets. All these studies were conducted for two successive years.

2.4. Statistical analysis

The data were represented by mean ± standard error (SE) and analyzed using MS Excel 2013. The difference among different groups were compared using two- way ANOVA method with LSD test. $P<0.05$ was considered to be significant difference among different groups.

3. Results

Studies regarding fish growth of *C.carpio*, *L.rohita*, *C.mrigala* and *C.catla* were conducted in two types of oxidation ponds to evaluate the comparative growth and net fish production along with other physico-chemical parameters such as light penetration, temperature, pH. DO etc from human consumption point of view. The comparative physico-chemical parameter analysis is well supported by the data of fish culture experiments, whereas it has been observed that in the ponds IA & IB no fishes survived after 24 hours stocking of fingerlings of the selected species of fishes. On the other hand *C.carpio, L.rohita, C.mrigala* and *C.catla* did not show any post-stocking mortality in ponds, IIIA & IIIB (Table 2).

The reason for their not surviving could be due to extreme variations observed in the (IA & IB) oxidation ponds where physicochemical parameters were highly variable particularly dissolved oxygen, pH, and temperature in the all seasons. The lowest value of DO (1.00 mg/l and 1.50 mg/l) was found in IA and IB ponds (Table 1) in comparison to C (control) which may be due to the lack of adequate quantity of plankton in water along with severe of variations in these parameters. Due to very less amount of DO and light penetration, the algae was not formed and fishes could not survive in the initial oxidation ponds IA and IB which had untreated sewage, and also which became unhealthy for culture of fishes. There was severe oxygen depletion in the early hours of the days in these ponds and due to plenty of algal blooms throughout the year, especially during winter, the conditions were not suitable for fishes to survive in these ponds (IA&IB) which had received direct untreated sewage.

Table 1: Showing the average seasonal ranges of different physico- chemical parameters of different sewage oxidation and control ponds.

Seasons	Ponds	Light penetration (cm)	Temperature (°C)	pH	Dissolved oxygen (mg/l)
Winter	IA	17.60-20.40	17.70-22.10	7.20-9.50	2.05-7.72
	IIIA	16.40-25.80	18.30-23.80	9.10-10.00	5.30-13.30
	IB	18.70-21.80	18.60-21.90	7.80-8.70	3.60-9.60
	IIIB	15.60-26.30	18.10-23.90	9.40-10.20	5.10-10.40
	CP	35.60-41.30	18.50-24.10	7.80-8.40	5.40-7.20
Summer	IA	09.20-15.30	29.40-34.00	9.10-10.30	1.00-12.00
	IIIA	12.60-14.80	29.00-34.70	8.70-9.90	3.00-17.30
	IB	12.70-15.70	30.00-36.10	8.80-10.00	1.50-12.10
	IIIB	9.20-11.60	32.00-36.20	8.60-9.90	3.80-10.50
	CP	39.30-77.00	32.34-36.50	8.20-9.00	4.50-7.20
Rainy	IA	11.00-14.90	23.60-27.70	8.50-9.7	2.80-11.90
	IIIA	11.00-12.90	24.30-28.10	9.20-10.20	3.60-12.80
	IB	12.20-23.10	22.90-27.60	8.10-9.60	3.10-12.20
	IIIB	11.00-13.10	23.60-27.70	9.60-10.00	4.30-16.90
	CP	26.60-30.30	24.50-28.30	7.80-8.60	5.20-8.40

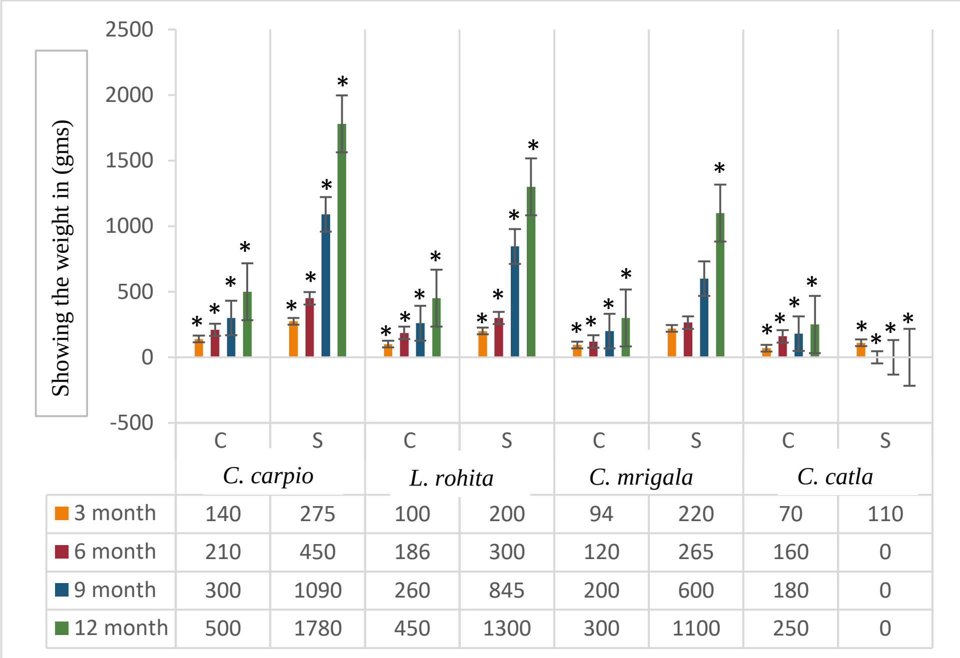
(IA, IB- Primary oxidation ponds, IIIA, IIIB - Secondary oxidation ponds: CP - Fresh Water control ponds)

Results have showed that the fishes did not survive in ponds (IA & IB), there being 100% mortality in these ponds. But there was no mortality of *C.carpio, L.rohita, C.mrigala* and *C.catla* in ponds (IIIA & IIIB). The growth of fishes was monitored for 9 to 12 months. After every 3 months about 50 fishes were caught at random from ponds (IIIA & IIIB) and the growth and other physico-chemical parameters such as light penetration, temperature, pH, DO were studied. It was observed that all the fishes grew well in these secondary oxidation ponds and gained higher weights as compared to fresh water control species. Out of the four species *C. carpio* was found to grow maximally whereas minimum growth was 0 *C. catla* (Figure 1).

It was observed that *C. carpio* weighing 2-3 gm at the time of stocking, gained a weight of 275 gm in oxidation ponds during a 3-month period. On the other hand, the same species from the fresh water control pond was gained only a weight of 140gm in the same period. After 6 months *C. carpio* in the oxidation pond had reached a weight of 450gm and its control counterpart had gained 210gm only (Fig 1).

Similarly, the other fishes *L.rohita* and *C. mrigala* gained weights of 200 and 220 gm within a period of 3 months in the oxidation ponds, whereas their growth in fresh water control pond was slow and the fishes reached 100 and 94 gms only during the same period. After 6 months *L. rohita* and *C. mrigala* recorded a weight of 300 and 265 gms in the oxidation ponds and its fresh water species gained a weight of 186 and 120 gms only in the same period of 6 months (Fig 1). It was observed that *C. catla* grew very slowly up to 4-5 months in the oxidation ponds. During the first summer after stocking *C. catla* in oxidation ponds did not survive. All other fishes were showed significantly faster growth in the secondary oxidation ponds and by the time of 9 months the fishes had grown significantly quite healthy. *C. carpio* had reached 1090 gm followed by *L.rohita* to 845 gm and *C. mrigala* to 600 gm in the IIIA & IIIB oxidation ponds. On the other hand the fishes *C. carpio, L.rohita* and *C.mrigala* in fresh water control pond had gained significantly low weights within the same period being 300, 260 and 200 gm respectively, despite supplementary feeding as per standard ratios (Jhingran, 1984).

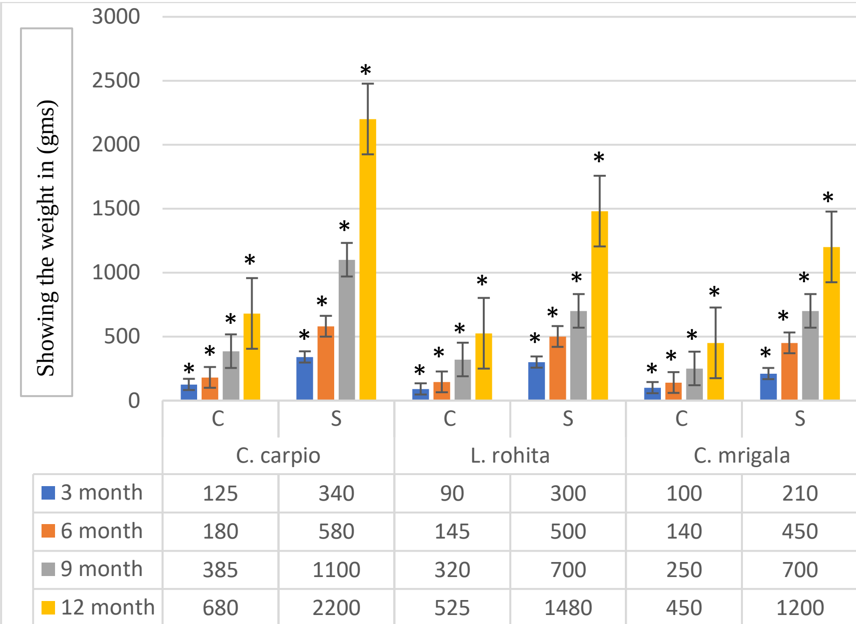
At the end of first year common carp gained a weight of 1780 gms in oxidation ponds and its control counterpart had reached only 500 gms. Similarly *L.rohita* and *C. mrigala* during one year in oxidation pond had gained weights of 1300 and 1100 gm whereas the same fresh water cultured fishes could reach only to 450 and 300 gm respectively (Fig 1).



	C. carpio C	C. carpio S	L. rohita C	L. rohita S	C. mrigala C	C. mrigala S	C. catla C	C. catla S
3 month	140	275	100	200	94	220	70	110
6 month	210	450	186	300	120	265	160	0
9 month	300	1090	260	845	200	600	180	0
12 month	500	1780	450	1300	300	1100	250	0

Fig: 1 showing the weight (gms) of control and sewage culture fishes in First year
C= Fresh water control pond S= Sewage oxidation pond, *Significant at $p<0.05$

In the second year the stocking of the fingerlings was not done in the initial ponds IA & IB due to their unfit ecological conditions for fish culture as observed during the first year. It was observed that fish growth in oxidation ponds in the second year followed a similar pattern to that of the first year and gained slightly more weights than the first year (Fig 2).



	C. carpio C	C. carpio S	L. rohita C	L. rohita S	C. mrigala C	C. mrigala S
3 month	125	340	90	300	100	210
6 month	180	580	145	500	140	450
9 month	385	1100	320	700	250	700
12 month	680	2200	525	1480	450	1200

Fig: 2 showing the weight (gms) of control and sewage culture fishes in second year
C= Fresh water control pond S= Sewage oxidation pond, *Significant at $p<0.05$

The annual fish production (net fish production (NFP)) was calculated for sewage oxidation ponds as well as the fresh water control pond and was found to be quite high for oxidation ponds. For *C.carpio* in the first year the NFP was 8590 kg/ha/yr followed by *L.rohita* 1706 and *C.mrigala* 1443.50 kg/ha/yr in oxidation ponds (Table 2). Comparatively low net fish production was obtained in the control pond which is in the following order *C. carpio* 2400 kg/ha/yr, *L.rohita* 590 kg/ha/yr and *C.mrigala* 393 kg/ha/yr. Average NFP for the three species i/e., *C.carpio*, *L. rohita* and *C.mrigala* was found to be 3913.17 kg/ha/yr in sewage ponds followed by 1128.20 kg/ha/yr in control pond. In the second year individual NFP species-wise found in the oxidation ponds was as follows: *C.carpio* = 8360 kg/ha/yr, *L rohita* = 2812 kg/ha/yr and *C.mrigala* = 2280 kg/ha/yr. The control pond NFP for *C.carpio* was only 2584 kg/ha/yr followed by *L.rohita* 997.50 kg/ha/hr *and C.mrigala* 850 kg/ha/yr. The average fish production for the three species i.e., *C. carpio*, *L. rohita* and *C. mrigala* in sewage and control pond in the second year was slightly higher than the first years NFP and it was 4484 and

1477.16 kg/ha/yr. Thus, it is evident from two years study that the fishes in the order *C. carpio*, *L. rohita* and *C. mrigala* grew almost 2-4 times faster than the control pond fishes (Table 2).

Table: 2 showing the net production (NPF) of fishes in control and sewage (IIIA & IIIB) Ponds

		First year			Second year		
Species		**Stocking density**	**Percent mortality**	**NPF (Kg/ha/yr.)**	**Stocking density**	**Percent mortality**	**NPF (Kg/ha/yr.)**
C. carpio	C	4000	10 - 15	2400.25	4000	5-10	2584
	S	5000	10 - 15	8590.31	4000	5-10	8360
L. rohita	C	1000	10 - 15	590.62	2000	5-10	997.5
	S	2000	10 - 15	1706.2	2000	5-10	2812
C. mrigala	C	1000	10 - 15	393.75	2000	5-10	850
	S	2000	10 - 15	1443.5	2000	5-10	2280
Average fish production	C			1128.2			1477.16
	S			3913.17			4484
stocking density of fingerlings per hectare per year = 10,000 c= control (fresh water) fishes; s= sewage culture fishes.							

4. Discussion

The massive amounts of nutrients in sewage function as perfect fertilizers for planktons and algae to flourish and enhance the productivity of the aquatic ecosystem, which is valuable food source for fish and other aquatic organisms (WHO, 1999; Al-Ghais, 2013; Lee et al., 2010). The data of the current study clearly indicated that fish species such as *Cyprinus carpio*., *Labeo rohita,* and *Cirrhinus mrigala* can be successfully grown and cultured in secondary waste-water oxidation ponds, if certain management practices such as conducive sustainability of ideal physico-chemical conditions: light penetration, temperature, pH and DO is followed. The data of present findings also indicate that pH values increased during afternoon and evening between (2-6 pm) when incidentally it was peak oxygen donation time due to high rate of algal photosynthesis. Thus, the high pH value due to increased algal biomass was responsible for precipitation of phosphate bringing about its reduction. The data of the resent study where high pH temperature and light intensity induced phosphate reduction due to coagulation and adsorption are in full collaboration with the earlier findings of (Rodgi et al., 1973). The survival rate of all three species except *C.catla* was 90-95% in IB & IIIB oxidation ponds, whereas the fishes could not survive in ponds IA & IB which received directly the untreated domestic sewage, and had a highly variable and unsustainable physicochemical status.

Common carp (*Cyprinus carpio* L.), is extensively circulated in Asia and Europe, and has a domestication history of over two thousand years (Bostock et al., 2010; Bhanot and Hundal, 202). In the present study fish growth results were quite interesting and significant throughout the study. It was found that *C.carpio* cultured for one year in oxidation ponds grew from 2 gm of initial weight to 1780 gm, whereas *L.rohita* grew from 5 to 1300 gm *and C.mrigala* from 2.5 to 1100 gm in the same time period. In the present study *C. catla* could not survive and grow in the oxidation ponds which may be due to its less adaptability to the sewage ponds environment. Thus, indicating the fact that, fish species have a variable adaptability and sensitivity towards their ecological surroundings.

Chatterjee et al., (2020) have used the oxidation ponds in Bhilai, India for fish culture in the same way as in the present study and reported good NFP results particularly with carps such as *C.catla* and *L.rohita*. The workers stated that *C.catla* and *L.rohita* grew up to an average weight of 900 and 1400 gm respectively. In the present study *C.catla* did not survive where as *C.carpio* grew considerably well and reached 1780 gm within one year which is quite more than what has been reported by (Chatterjee et al., 2020). *L. rohita* grew to a weight of 1300 gm within the same period, which is similar to that reported earlier. In the present study, the failure of *C.catla* to adopt the living conditions and grow in oxidation ponds may be due to such factors as competition for food and space, temperature, pH and other abiotic and biotic factors coinhabiting the pond. Treated sewage comprises less organic load than the raw untreated sewage, but has more nutrients than the secondary and tertiary effluents. However, certain obnoxious gases, un-ionized ammonia and other chemicals present in the domestic sewage make it anaerobic and to be unsuitable for direct culture and use by the fishes (Nwabueze, 2013; Waqar et al., 2013; Lahiri et al., 2018; Tomasetti and Gobler, 2020; Akdemir and Dalgic, 2021).

In the present study the most phenomenal growth, observed was that of *C.carpio,* which gained weight of 1780 and 2200 gm in the first and second years. These data suggest that *C.carpio* has better physiological adaptability than other fishes due to its detritus feeding habit, and the plenty of rich nutrient food available in the domestic oxidation ponds. The results of the present study also indicate that oxidation ponds particularly the secondary ponds gave high yields of fishes because of the manifold increase in natural food by the organic wastes which were introduced into it regularly via the domestic community influent which provided the main source of rich nutrients. Due to rapid bacterial decomposition, the primary nutrients like phosphorous nitrogen and ammonia were in plenty for the algae, which were in turn the basic food form for the fishes.

Ghoshal, (2016), Reported that the reaction of domestic sewage water on fishes expose to 70% dilution (70:30 sewage water: tap water) lost body balance within 5-6 hours for both the exposed fishes. The opercular movements of the fishes were reduced and later lethargic movement with frequent surfacing were noticed in both the cases. Waqar et al., (2013) reported that the bioremediation of sewage effluent for fish production, resulted in no fish survival in bioremediated water but 100% fish survival was recorded when this water was further treated with phyto remediating potential plants to reduce ammoniacal and nitrate concentration, which was lethal for fishes. However, these workers have used different forms of sewage and fed the fish ponds with sewage using dilution factor as main aspect for culture of fishes such as *Heteropterous fossilis, Clarias batrachus, Catla catla, Labeo rohita* and *Tilapia mossambicus,* where as we have used direct sewage in oxidation ponds.

5. Conclusion:

It is concluded that the domestic sewage fish culture has a good option of waste recycling as well as protein reclamation. In this study 8 to 8.5 tonnes of fish production per year have been achieved in the domestic sewage oxidation ponds. The results of the present study are highly encouraging as compared to earlier works. The biological treatment of domestic sewage oxidation ponds is one of the economical methods to produce fish and also can reduce the aquatic pollution. However more work has to be carried out in this aspect to remove myths & misbelieves of sewage pond aquaculture.

List of abbreviations

NEERI: National Environmental Engineering Research Institute
NFP: Net Fish Production
DO: Dissolve Oxygen

Declaration

Ethical approval and consent to participate: The Ethical Committee for Animal Experimentation and Research, Saifia College of Science, Bhopal, India certified the use of animals (approval number SSC/06-06-22/, dated October 26, 2006).
Consent for publication: Not applicable.
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Dr. Sharique A. Ali: Visualization, Conceptualization, Writing - Original Draft, Final Corrections, Supervision, Project administration, **Hanumanth H Raju**: Methodology, Formal analysis, **Gulafsha Kassab:** Writing – Statistical Analysis, Review & Editing and **Naima Parveen:** Writing - Review & Editing
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