

Changes in physicochemical, heavy metals and air quality in life episode of *Aplocheilus panchax* along Mahanadi industrial belt of India as a function of social lockdowns

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Abstract

The COVID-19 induced lockdowns have many positive effects on the environment. However, a preplanned experiment explaining the impacts of such lockdowns on environmental markers and appearance of fish species is lacking. We hypothesize that spotting the fish *Aplocheilichthys panchax* along the industrial belt of Mahanadi River near Cuttack in a never seen manner could be due to the regenerated environment. Heavy metals, water quality and air qualities along with spotting *A. panchax* in up, mid and down stations in Mahanadi River at Jagatpur industrial basins were analysed at pre-lockdown (end of March 2020) and after 60 days of lockdown (last week of May 2020). Here we show that an overall reduction of 45, 61, 79, 100, 97 and 90% of Fe, Cu, Ni, Cd, Pb and Zn, respectively, was recorded in the studied area after lockdowns. Similarly, dissolved oxygen and pH was elevated by 26 and 7%, respectively. Water temperature, conductivity and total dissolved solute levels were reduced by 7, 46 and 15%, respectively. Air NO₂, SO₂, NH₃, PM_{2.5}, PM₁₀ and CO levels were alleviated by 58.75, 80.33, 72.22, 76.28, 77.33 and 80.15%, respectively. Finally, for the first time we documented about 12 numbers of the *A. panchax* per 100 m shore line in the area. The observed lockdown induced environmental healing at the studied area could contribute to this and therefore a stringent environmental audit is suggested during post-COVID-19 periods to make the regenerated environmental status long lasting at several places of the planet.

Introduction

An intricate positive relation between Coronavirus (SARS-CoV-2) disease (COVID-19) outbreak induced lockdowns or shutdowns and environmental auto-regeneration is reportedly mapped by many environmentalists^{1,2,3,4,5,6,7,8}. Our previous studies indicate that the health of ecosystems and associated events in most of the urban and suburban areas were unexpectedly damaged due to high anthropogenic activities or climate change issues^{9,10,11,12,13}. It indicates that environmental audits were not stringent in India and in many other countries (**Supplementary Fig. S1**), perhaps for which, drastic diminish in fossil fuel burning by industry and vehicular operations under COVID-19 induced lockdowns was responsible for the reduction of water, air and noise pollution across many cities^{14,15,16,17,18,19,20,21,22}.

Industries are the only major sources of effluent discharges into the above river basin. The industries had already gone through environmental audit although monitoring was not done sufficiently for the same. It clearly indicates that environmental audit has not been transparent for industrial effluent discharges as a result its water was polluted and, this could be the fact in places where pollution is pre-dominant. It needs a local, national and global stringent environmental audit(s) to have everlasting regenerated nature that we have obtained due to COVID-19 induced lockdowns. Post-COVID-19 timings will be the best to employ such stringent environmental audit action because all the industries shall aggressively work after reopening. And it may lead to the pollution level back as observed in pre-COVID-19 timings. So, focusing on handling the current situation and planning for the post-COVID-19 timings seems to be the need of the hour. Therefore, to have ever lasting nurtured nature, amendment of such stringent action will give us a pollution free environment. To have first-hand information to provide a clue for the above discussion,

environmental data from field always provides a clue. Therefore, Mahanadi River, and its water and air quality (physicochemical and heavy metal distribution) and the presence of a fish species *Aplocheilichthys panchax* were studied in pre-and during COVID-19 induced lockdown periods. The data could be used as spotlight for future use in terms of post-COVID environmental policies in several places.

Data on pre-designed sampling for analyses of environmental health of any ecosystem just before implementation and after substantial period of full and stringent lockdowns, and its effects on the inhabitants are lacking because all studies are set after observing COVID-19 induced observed self-nurtured nature^{1, 5, 6, 7, 23}. While conducting such analyses at the highly polluted basin of Mahanadi river²⁴ near Jagatpur industrial basin of 1000 years old Cuttack city (20°30'14.5"N 85°54'29.2"E to 20°28'34.4"N 85°57'19.3"E), we found schooling of the fish species (*A. panchax*) which was absent while searched along the Mahanadi River for our earlier experiments in 2018-2019²⁵. Therefore, we hypothesize that the lockdown induced alleviation in pollution could be a reason for the appearance of the fish *A. panchax* in the study site. To answer the hypothesis, we have analysed the heavy metal contents, water quality, air quality and the fish *A. panchax* abundance in three stations (up, down and mid basin) at Mahanadi River near Cuttack Jagatpur industrial area of India. Correlation of the data on environmental toxicology in relation to environmental audit may not be ruled out.

Material And Methods

This experiment did not include sacrifice of fish, however, all experimental protocols including counting of fish is followed by Institutional ethical committee guidelines of Odisha University of Agriculture and Technology were followed to handle the fish with optimum care throughout the experiments.

Chemicals

All essential analytical grade chemicals for this study were purchased from Sigma-Aldrich Chemical Company, USA and from Himedia and SD Fine chemicals, Mumbai, India.

Sampling site and their status before and after lockdown

Mahanadi River system is the 3rd largest in the peninsula of India and has a long history of fisheries and agricultural irrigation to the state Chhattisgarh and Odisha. It is the largest river in the state of Odisha that serves as the source of domestic water supply to many cities including Sambalpur (population 0.2 million), Cuttack (population 0.5 million, 1000 years old city) and Paradeep (contains a major port of the country and population of 0.15 million) besides many officially undocumented number of rural and minor urban settlements. However, its basin near Choudwar-Jagatpur industrial belt (N: 20° 28' 34.43"; E: 85°48'15.13" and N:20°29'46.80"; E:85°53'32.76") which harbours mainly, steel, ferro alloys, chrome, textile, polythene, plastic and paper and pharmaceutical industries²⁴.

On one hand all these plants use a major portion of the river water, and on the other hand they flush the impurities and other effluents into its basin. It contains many toxic elements including heavy metals although such industries usually clear the environmental audits but found to discharge the toxic elements

into the nearby river or riverine systems^{33,34}. During the January to May, the river is always with the stagnant water and hence acts as a source of pollution accumulation. Noteworthy to mention that water in the above basin of the river is polluted and found to generate several bio-molecular stresses on the inhabitants including a wide range of fishes²⁴. Keeping in mind the above fact and possibility of reduction in pollution under the imposed lockdowns, the industrial belt of Mahanadi at Cuttack was fixed for the sampling site. The locations such as the mouth of canals and study sites before and after the lockdowns were photographed using a camera (Redmi note 5 pro 18 megapixel camera).

Water sampling

Clean opaque polyethylene bottles (500 mL) rinsed with water were used to collect the water samples from three different sites along the Cuttack Industrial belt of Mahanadi River near Jagatpur (approximately from 20°30'14.5"N 85°54'29.2"E to 20°28'34.4"N 85°57'19.3"E). Jagatpur is considered as the main hub for the industry and the basin water therefore remains polluted throughout the year due to industrial discharges²⁴. Anthropogenic discharges also contribute to the pollution in the basin. Therefore, three stations were chosen for the study i.e. near the Jagatpur industry (Mid-Basin, MB), down the Jagatpur site (Downstream, DS) and before the Jagatpur basin (Up-Stream, US). So the station sites were around the Jagatpur-Madhupatna-Choudwar (approximately from 20°30'14.5"N 85°54'29.2"E to 20°28'34.4"N 85°57'19.3"E) basin.

Physico-chemical quality analyses of water

Water samples were collected in the last week of March-2020 (pre-COVID-19 induced lockdown time periods) and in the last week of May 2020 (after 2 months of a stringent lockdown period) from MB, DS and US of Mahanadi River. About 500 mL water samples (below 30 cm deeper from the surface) after collected in opaque plastic bottles were immediately transported to the field laboratory. About 50 mL water was taken in opaque glass bottles in dark and pH, Dissolved Oxygen (DO), pH, Total Dissolved Solids (TDS) and conductivity in water samples were measured with the help of specific electrodes (mp Based Soil and Water Analysis kit, Model 1160, Esico International, New Delhi, India). The temperature of the river water was measured directly during sampling by using a mini Hg thermometer in °C scale. The electrodes were calibrated using appropriate standards just before measurements.

Heavy metal analyses of water

Elemental (Fe, Cu, Ni, Cd, Pb and Zn) analysis was done by using an inductively coupled plasma atomic emission spectrophotometer (Perkin Elmer, Waltham, Massachusetts, USA, Model no. AVIO 200) as described by Mohanty and Samanta²⁴, Das et al.²⁵ and Samanta and Paital³⁵. In brief, water samples (~ 50 mL) were preserved in opaque plastic bottled at -20 °C until analysis. Water samples were mixed with 1% v/v HNO₃ prior to elemental analysis. Above samples were filtered using membranes (0.45 mm filter) and were directly used to take atomic absorption spectra. The multi-element standard solutions were prepared at five points and the limits of detection of different samples were set at 0.850, 0.004, 0.035, and 0.001 and 0.0001 µg L⁻¹, respectively. Results were expressed as µg L⁻¹ in water the sample.

Air quality analyses and locating the fish *A. panchax*

Air quality data such as the levels of NO₂, SO₂, NH₃, PM_{2.5}, PM₁₀, CO and O₃ were correlated from the Central Pollution Control Board, Government of India (<https://cpcb.nic.in/>). The water sampling dates were correspondingly considered for the air data correlation. During sampling, presence of the fish *A. panchax* was noticed and subsequently was recorded (random sampling) by using a video camera and still photos were captured using a camera (Redmi note 5 pro 18 megapixel camera). Preliminary analyses of the results were correlated with the appearance of the fish in the river. The fish count was done in 100 m length along the shore line by random sampling method in the study area. About 3 m distance from the shore line was chosen to locate them as this fish prefers this area.

Statistics

Results were expressed as mean \pm standard deviation (n = 3). Means of different parameters were compared and analysed for differences using Two-way ANOVA (StatPages.org.) followed by Duncan's new multiple range test. T-test was employed to determine the changes in parameter between before and after lockdown. All numerical data were subjected to Discriminant Function Analyses using the methods described in ³⁵. Difference among the means was considered significant at P < 0.05 level.

Results And Discussion

Water and air quality

For the first time, modern humans lifted the weight of nurturing nature by doing nothing but only keeping themselves off the street and locked inside home to get rid of COVID-19 infection. Many cities had been experiencing heavy pollution during pre-COVID-19 timings and water bodies near industries and cities were found to be the main hub for pollution. It simply indicates that the industrial and anthropogenic pollutants were not treated before draining into water bodies. Instances of loose environmental audit and environmental clearances to industries also have been reported to contribute unprecedented damage to ecosystems ^{33,34}. As a result, pollution accumulates in rivers and riverine systems²⁶. Keeping in mind the intensity of pollution, sampling was done in the study site to indicate effects of industrial effluents in the study site (Fig. 1a).

The observed higher water pollution in the study site (Fig. 1b, c, d) could be a sensible factor, perhaps for which the river lacked the fish *A. panchax* when it was searched for experiments during 2018-2019²⁵. Although some of the studied parameters, especially the levels of heavy metals, were under control during the pre-COVID lockdown times, it probably was enough to disallow the above fish to grow in the study site. The pollution could also be the reason why large scale die-off events have been noticed along the rivers and riverine systems in India including Bay of Bengal and Mahanadi River during pre-COVID-19 timings²⁶. Two months of full and stringent lockdown in the study area was resulted in the clear water and associated ecological improvements in industrial canals discharging water into the river (Fig. 1b-k). Clear base of the canal (Fig. 1e), schooling of fish (**Fig. f and g**), shrinking of the canals discharging polluted water with growth wild plants (indicating increase in biodiversity, Fig. 1h, i **and j**), and clear water (Fig. 1k) in the mouth of the discharging canals are few of the outcomes of the lockdown. Probably, our

study is the first report with planned experimental analyses of environmental parameters at pre and post-COVID-19 time points indicating the appearance of a species in a niche under COVID-19 lockdowns (**video 1**).

We found that the dissolved oxygen level was increased during lockdowns by 15, 40 and 26% in US, DS and MB, respectively, than pre-lockdown times (Fig. 2a). Similarly, water temperature was also reduced by 4 (in US), 9 (in DS) and 8% in MB regions (Fig. 2b). pH of US and DS area was increased by 12 and 7%, respectively ($p < 0.003$, Fig. 2c). Water conductivity was drastically reduced by 47 (in both US and DS) and 44% in MB area (Fig. 2d). It could be due to loss of total dissolved solutes by 18 (in US), 15 (in AS) and 11% (in MB) regions during lockdown than pre-lockdown time (Fig. 2e). The changes are drastic and could be exemplary enough to accept that lockdowns had paramount effects on increasing the water of Mahanadi River and as observed in other rivers of India such as Yamuna River of New Delhi²⁷. This is possibly due to zero effluent discharge into the river as cleanness of its water was observed (Fig. 1b-j). Perhaps this is the reason why the fish *A. panchax* count during lockdowns was noticed being an average of 12, 8 and 16 numbers per $100 \times 2 \text{ m}^2$ area (Fig. 2f) after the lockdowns are implemented. Similar results without experimental analyses of the environmental quality were reported. For example, the suspended particulate matter in surface water was reduced by 15.9% in the Vembanad lake, the longest one in India²².

We found that air quality of the study area was also improved drastically (Fig. 2g). Data indicates that overall air quality parameters such as levels of NO_2 , SO_2 , NH_3 , $\text{PM}_{2.5}$ and CO were drastically reduced ($p \leq 0.001$). The levels of NO_2 , SO_2 , NH_3 , $\text{PM}_{2.5}$, PM_{10} and CO were reduced ($p < 0.001$) by 58.75, 80.33, 72.22, 76.28, 77.33 and 80.15%, respectively in post 2 months lockdowns than pre-COVID-19 study time whereas, O_3 level was increased ($p < 0.01$) in the air (Fig. 2g). Similar results have been noticed in many cities across the world^{1,5,7}. More particularly, reduction in 60% PM_{10} , 39% $\text{PM}_{2.5}$, 52.68% NO_2 , 30.35% CO and improvement $\geq 31\%$ air quality index in New Delhi, India, in March 2020 than April 2020 under COVID-19 induced lockdowns³. In China, overall environmental pollution level was found to be reduced by 30% in 2020 than 2019 due to 90% reduction in human mobility⁴. Air temperature was also found to be low ($r = 0.392$; $p < .01$) during the above timings at Jakarta, Indonesia that had induced positive effects on climate²¹. In some places in India, the temperature was also found to be reduced from 3 to 5 °C and noise pollution from 85dBA to $< 65\text{dBA}$ ²³. The most advanced countries such as the USA, Italy and Germany were also found to experience the historical reduction in NO_2 level by 25.5% under the lockdowns¹⁴. It is noteworthy to mention that $\text{PM}_{2.5}$ and NO_2 emissions have an intricate relation with COVID-19 in humans¹⁹.

As a result Few of such examples are elephant strolling through roads, deer on street of Japan, whales in Indonesia sea water, peacocks in human habitats at Delhi India, spotting coyotes (that normally timid of traffic) on the Golden Gate Bridge in San Francisco, USA, grazing deer few miles from the White House near Washington homes, wild boars in Barcelona and Bergamo, Italy, wild puma in Santiago, the capital of Chile, peacocks have strutted through Bangor and goats through Llandudno and sheep in Wales, and

the most convincingly, crabs and fish in Venice canal of Italy are noticed after lockdowns ^{17,28}. However, the invasion of species due to the reduction of environmental pollution or due to reduction of human dominancy is still not clear.

Heavy metal distribution

We have noticed that heavy metal (except Fe) concentration was reduced by $\geq 50\%$ in the water at all the stations (Table 1). Particularly, Cu content was reduced by 58, 59 and 65% at US, DS and MB areas, respectively. Similarly, Ni content was reduced by 91, 92 and 59% (US, DS and MB, respectively) in the studied area. The level of Cd was undetectable in lockdown time and similar data was found for Pd in US and DS area, but it was reduced to 93% in the MB area. Notably, Zn content in the water was also reduced by 98% (in US), 90% (in DS) and 86% (in MB) in the studied area (Table 1) in lockdown period than pre-lockdowns timings. The physico-chemical characteristics and concentrations of various heavy metals in the water samples collected from the three study sites were shown in Table 1. Data on effects of lockdowns on heavy metal content in water bodies are scanty. Although, the change in heavy metal contents in water bodies as a function of lockdowns are scanty, similar results of the reduction of Cr, Fe, Cu, Zn, Cd, Pb, As, and Se were noticed in coastal industrial city of Tuticorin, South India ²⁹.

Table 1
Heavy metal distribution before and after COVID-19 lockdowns in Mahanadi industrial river basin at Cuttack, India.

Metal	Time	Up-stream	Down stream	Mid-basin	WHO*	ICMR**	BSI#
Fe	BL	0.13 ± 0.001 ^c	0.15 ± 0.002 ^c	0.56 ± 0.005 ^a	1	1	1
	AL	0.073 ± 0.00 ^e	0.083 ± 0.000 ^d	0.30 ± 0.002 ^b	1	1	1
Cu	BL	0.76 ± 0.02 ^b	0.78 ± 0.061 ^b	0.89 ± 0.043 ^a	2	1.5	1.5
	AL	0.32 ± 0.01 ^c	0.31 ± 0.01 ^c	0.31 ± 0.01 ^c	2	1.5	1.5
Ni	BL	0.011 ± 0.000 ^b	0.013 ± 0.002 ^a	0.015 ± 0.001 ^a	0.02	BDL	BDL
	AL	0.001 ± 0.000 ^d	0.001 ± 0.002 ^d	0.008 ± 0.001 ^c	0.02	BDL	BDL
Cd	BL	0.0007 ± 0.000 ^b	0.0009 ± 0.000 ^a	0.0010 ± 0.000 ^a	0.003	0.001	0.01
	AL	BDL	BDL	BDL	0.003	0.001	0.01
Pb	BL	0.004 ± 0.000 ^c	0.009 ± 0.000 ^a	0.009 ± 0.001 ^a	0.01	0.1	0.05
	AL	BDL	BDL	0.0006 ± 0.000 ^b	0.01	0.1	0.05
Zn	BL	0.07 ± 0.001 ^b	0.07 ± 0.002 ^b	0.14 ± 0.020 ^a	5	15	15
	AL	0.001 ± 0.000 ^d	0.001 ± 0.000 ^d	0.02 ± 0.000 ^c	5	15	15

Data are represented for three consecutive day readings in up, down and mid-stream of the Mahanadi industrial belt at Cuttack. Before lockdown (BL, pre-COVID-19 time) and after lockdown (AL, during COVID-19 timing) sampling time difference was about 60 days. MANOVA was employed to know the significant difference among the mean values within a set (as on 23.05.2020) and before COVID-19 period. Mean values are considered as significantly different (assigned with different superscript) from each other at $p \leq 0.04$ level. *-limit of heavy metals set by the World Health Organisation, **-limit of heavy metals set by the Indian Council of Medical Research, New Delhi, India, #-limit of heavy metals set by the British Standards Institution.

Overall results and appearance of *A. panchax* in the study site.

DFA analyses have confirmed that all parameters taken together or in groups such as the studied environmental parameters or heavy metals have yielded all studied groups into six (before and after lockdown at three sites, Fig. 3). Therefore, all parameters were subjected to change as a function of COVID-19 induced lockdowns. Almost all parameters had a very high standardized coefficient for canonical variables via root 1 to root 4 (Table 2, **supplementary Table S1 and S2**). Therefore, since an overall improvement of the environmental parameters was noticed, the sub-verity fish *A. panchax* (grow

up to 2 cm) appeared in the river (Fig. 1g, 2f, Fig. 4, **video 1**). It is because; this fish prefers clear water in areas with dense growth of rooted or floating macrophytes³⁰.

Table 2

Standardized coefficient for canonical variables of environmental parameters and heavy metals as a function of COVID-19 timings and site of water stream in relation to the industrial belt in Mahanadi River.

Parameters	Root 1	Root 2	Root 3	Root 4	Root 5
DO	-0.2	0.442	0.889	-1.2205	1.89164
Temp	-0.4	0.318	-1.385	-0.3416	1.16639
pH	-4.0	0.717	-0.995	-0.2967	-0.63521
Conductivity	-0.9	2.049	0.915	-0.5242	-0.80021
TDS	-1.3	0.260	0.375	-0.2428	-0.51262
Fe	7.0	-0.592	-0.713	-0.6565	-0.46642
Cu	1.1	-0.851	-1.731	0.3770	2.78746
Ni	5.5	-0.288	0.309	0.6369	-2.22165
Cd	-3.7	0.479	0.071	0.4343	0.39227
Pb	1.4	-0.119	-0.893	-0.4383	0.68407
Zn	-0.8	-0.156	0.984	0.1687	-2.00592
EV	150933.3	8475.336	3034.573	172.6590	81.64398
CP	0.9	0.980	0.998	0.9995	1.00000
Environmental parameters and heavy metals as a function of COVID-19 timings (pre and during COVID-19 timings) and site (up, mid and downstream of Mahanadi River industrial belts near Jagatpur, Cuttack are included in the DFA analyses. The bold data indicate their significant contribution in segregating the groups distinctly as a function of the variable. DO-dissolved oxygen, Temp-temperature, TDS-total dissolved solid, EV-Eigen value, CP-cumulative proportion.					

The fish *A. panchax* can survive till the last few mL of water left in ditches for which it is employed to identify palaeo drainage basins for climatic and geological oscillations, biodiversity and evolutionary distribution of biota^{31,32}. This fish is susceptible to water pollution, as they were not available in the above basin on Mahanadi during pre-COVID-19 timings²⁵. It clearly indicates that the Mahanadi River at the studied basins remains polluted although some of the toxic heavy metals are found to be under standard level²⁴ (Table 1). The growth period of this fish to reach adulthood is around 2 months^{31,32}. Hence, healthy fish could be migrated to this area from the non-polluted sites and/or the fish could reproduce and fingerlings would have been grown to reach adulthood.

Environmentalists have been advocating that the self-regenerated nature will be degenerated quickly in post-COVID-19 timings because of the massive re-opening of the industries and vehicular exhaustion⁵. The industries will try to cover up the loss they did bear during the COVID-outbreak in post-COVID-19 time periods^{36,37,38,39}. Mahanadi River system is the 3rd largest in the peninsula of India and serves as the source of domestic water supply to many cities including Sambalpur (0.2 million population), Cuttack (0.5 million population) and Paradeep (a major port of the country and 0.15 million population) besides many officially undocumented number of rural and minor urban settlements. However, its basin near Choudwar-Jagatpur industrial belt harbours mainly steel, ferro alloys, charge chrome, textile, polythene, plastic and paper and pharmaceutical industries. Use of water from the river and flush their effluents containing many pollutants in turn are the main source of pollution in Mahanadi River²⁴. Therefore, stringent environmental audits need to be employed to maintain the revived nature in post-lockdown periods^{1,33,34}. In India, the environmental clearance from the governing body i.e. the Central Pollution Control Board states that the applications received and approval given for industrial activities are highly stringent and none of the industries violates them (**Supplementary Fig. S1**). If it is true in India, and in other countries, then the environment would not be polluted, remains as the unsolved question for a long time.

Stringent environmental audit to implement pollution clearance and “strict environmental safety and precautions” must be the need of the post-COVID-19 society to enjoy natural, sparkling water bodies, unpolluted water to drink and clear air to breathe. In India, the environmental clearance from the regulatory body i.e. the Central Pollution Control Board states that the applications received and approval given for industrial activities are highly stringent and none of the industries violates them. Then the pollution is from only vehicular operation must be debatable. But reduction in prevailing pollution from pre-lockdown to post lockdown strongly suggests that local, institutional, national and international bodies must join hands to implement strict audit system for industries. Probably in few counties such as India, implementation of such stringent rules has been started after the mishap occurred with a massive leak of styrene gas at an LG Polymer plant in Visakhapatnam early on Thursday (7th May 2020) which had killed 11 people and affected around 1,100 people along with many environmental crises. The Central Pollution Control Board of India, has directed all industries and state pollution control boards for a “good operable conditions” that include monitoring the deployment of pollution control equipments and effluent treatment plants, including safety equipment and machineries, and connectivity of sewers should be kept in before resuming operations at post-lockdown time. The board also issued a set of instructions to all pollution control boards and centres to ensure all units undertake a “proper safety and hazard audit” before they start operations after the lockdowns that is going to be ended on 31st May 2020⁴⁰. Similar steps by all nations need to be taken on urgent basis. Interference of international bodies in such environmental intervention programme must be highly solicited. Therefore, the world must put forth steps for the long terms maintenance of the self-regenerated environment in post COVID-19 timings before nature bounce back to experience the pre-COVID-19 time pollution¹.

Conclusion

For the first time the reappearance of the fish *A. panchax* in Mahanadi River industrial basins near Cuttack city is documented and it was solely due to the COVID-19 lockdown induced reduction in water pollution including heavy metals which was established via experimental data. Drastic diminish in effluent discharge from industries has contributed to the observed reduction in water pollution in many water bodies across the globe. It clearly indicates that environmental audit has been not transparent, so, very stringent implementation of environmental audit with follow up action is suggested during post-COVID-19 periods in order to have the long lasting regenerated nature (**Fig. 5**). Intervention of international agreements and involvement of intentional, national, institutional and local bodies are highly encouraged. Otherwise, the planet will miss the chance to recover and take control on such a regenerated environment and it would still wait for another COVID-19 outbreak for revival of nature.

Declarations

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Figures

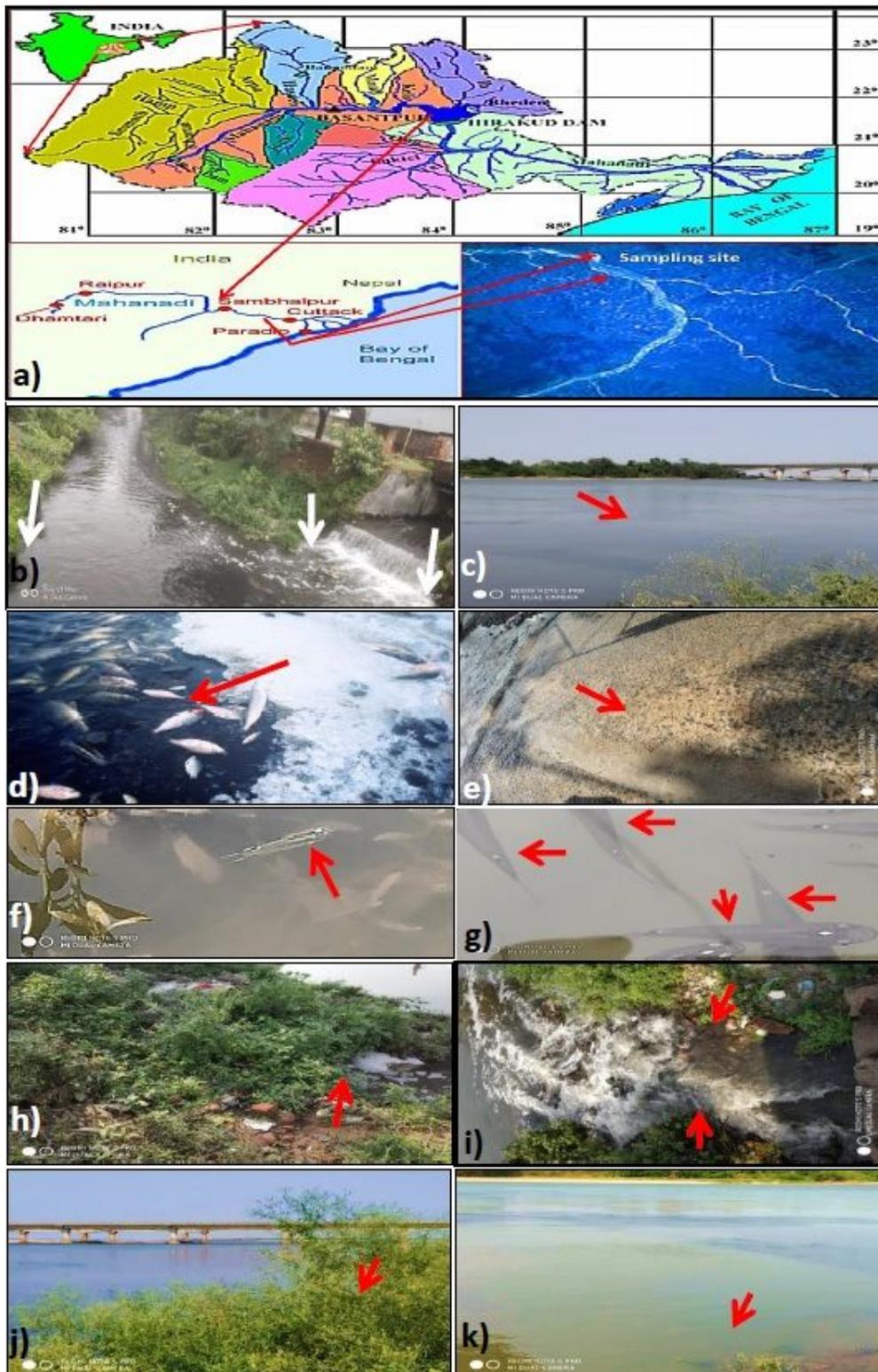


Figure 1

Visible ecological changes and spotting the fish *Aplocheilichthys panchax* in the Jagatpur industrial basin area of Mahanadi at Cuttack, India during COVID-19 induced lockdown. (a) The study area at its basin near Jagatpur which is approximately from 20°30'14.5"N 85°54'29.2"E to 20°28'34.4"N 85°57'19.3"E, (b) Pre-COVID-19 time period indicates industrial effluent discharge via canals to Mahanadi River especially to the study site, polluted water enters in the near industrial catchment area from industries (white

arrows) and also from city discharging canals making its water sometimes black (red arrow in Fig. c) colour. (d) As a result large scale fish die-off events (red arrow) due to pollution from industrial and anthropogenic activities in Mahanadi and its tributaries have been noticed at its lower basins due to heavy pollution load. (e) However, during-COVID-19 induced lockdown periods, it was observed that the base of most of the discharging canals (red arrow) were cleanly visible with clear water as a result decrease in pollution load. (f) Re-appearance of the fish *Aplocheilus panchax* (red arrow) in the studies area was clearly observed. (g) A close view of schooling of fish *A. panchax* is observed in the study area. (h) Also due to less polluted water load in lockdown periods, shrinking and drying (Fig. i) of the canals (red arrows) due to lack of discharging industrial effluents were observed followed by clear and visible water in the studied catchment area. (j, k) At some places where the canal mouths open to the river were also found to be grown with various wild plants and clean water indicating increase in biodiversity in the area.

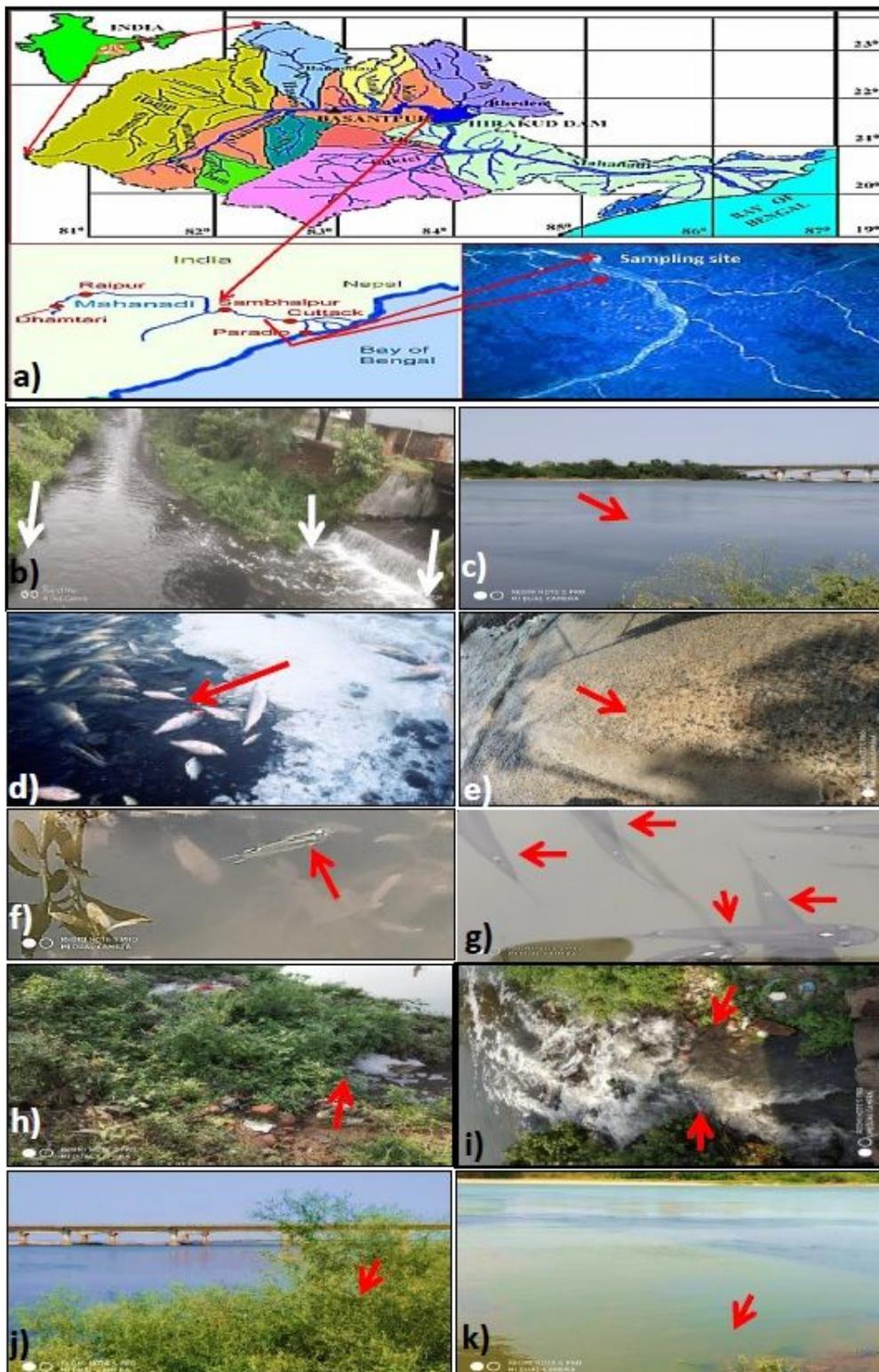


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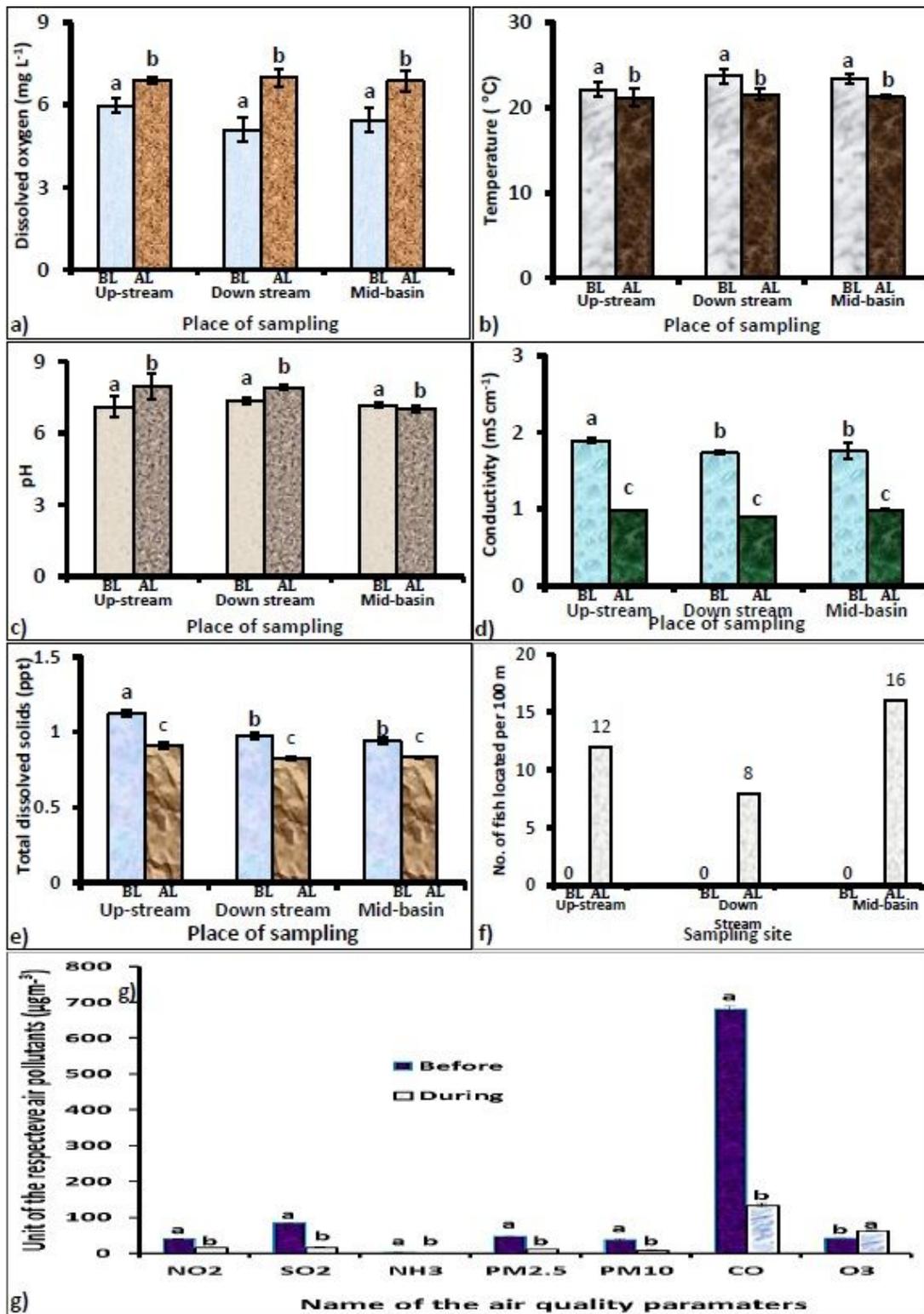


Figure 2

Increased water and air quality during COVID-19 and reappearance of the fish *Aplocheilichthys panchax* in the industrial basin of the river Mahanadi at Cuttack, India. Data are represented for three consecutive day readings in up, down and mid-stream of the Mahanadi industrial belt near Jagatpur at Cuttack. Students t-test was employed to know the significant different among the parameters between before COVID-19 period and during COVID-19 induced lockdown (as on 19.05.2020) and. All parameters were found to

significantly differ from the pre-COVID-19 period to the corresponding COVID-19 induced lockdown (2 months) at $p \leq 0.03$ ($n=3$) level and indicated with different superscripts. a) Dissolved oxygen content, b) temperature, c) pH, d) conductive, e) total dissolved solids and f) fish count, g) air quality data of three consecutive days from the site are presented ($p < 0.001$) with a clear increase in air quality due to lockdown. As a result of BL- before lockdown, DL-during lockdown of nearly two months.

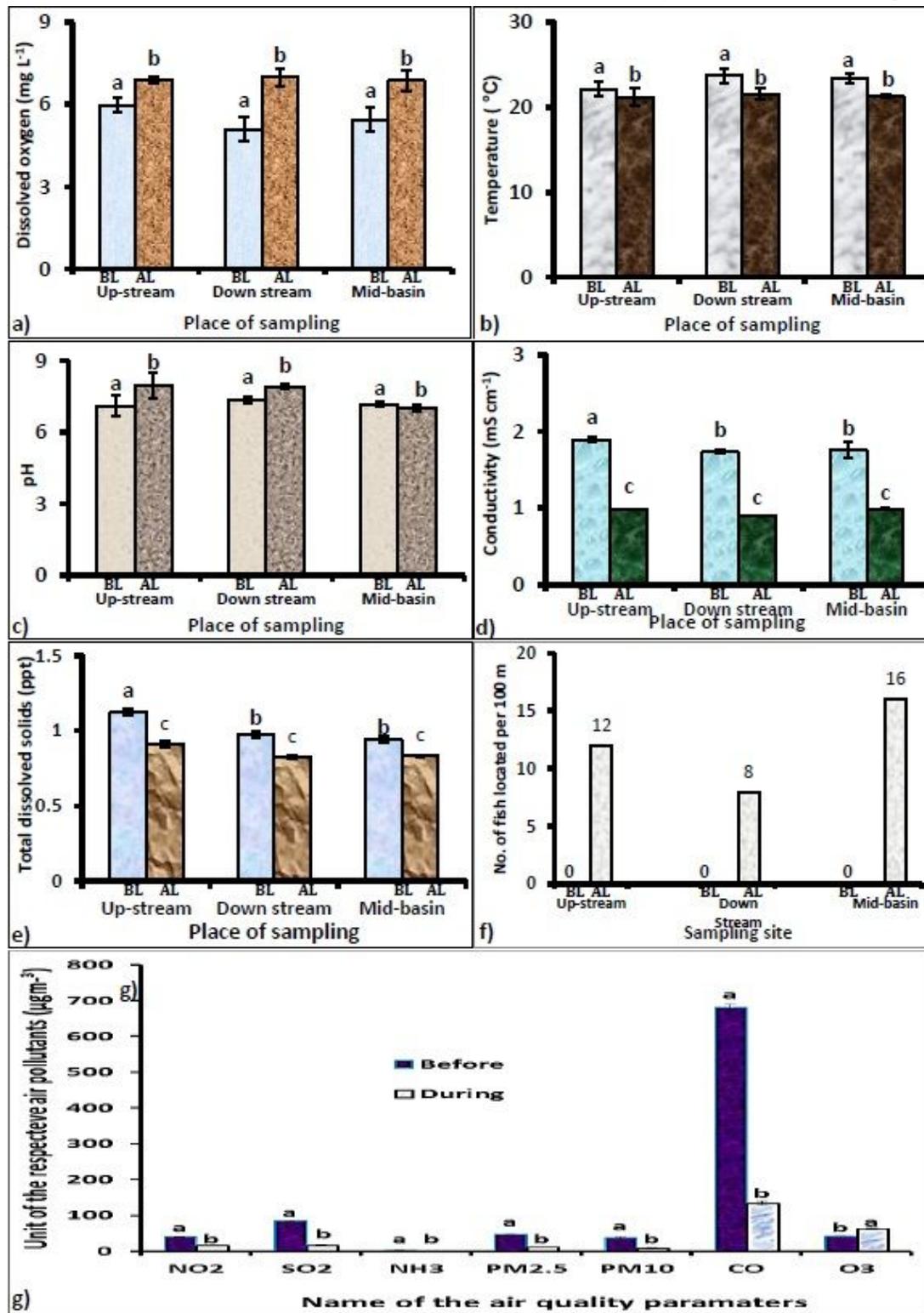


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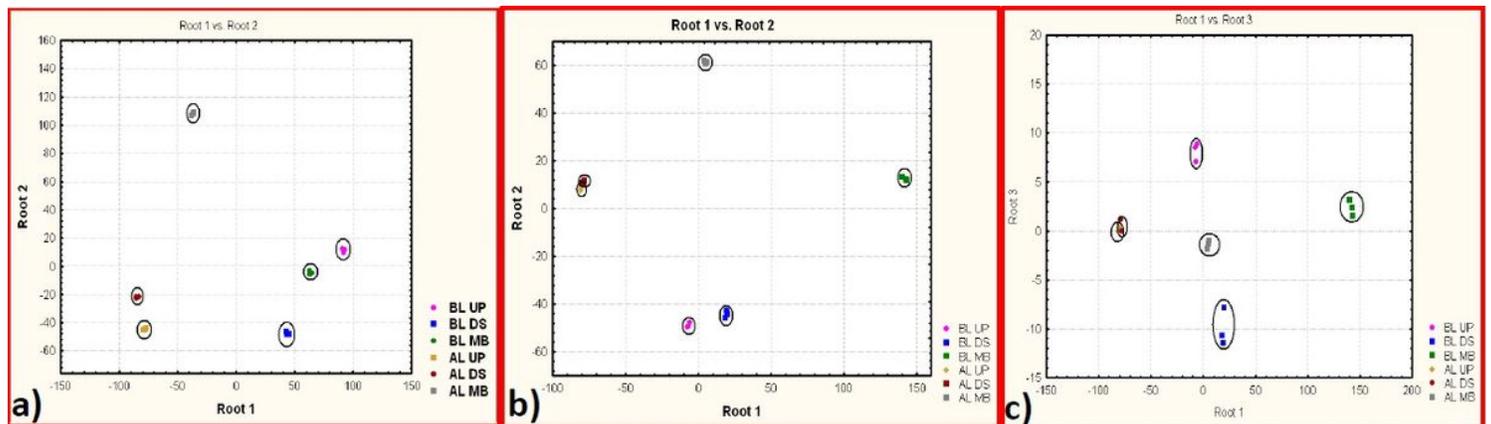


Figure 3

Discriminant function analysis of environmental parameters and heavy metals as a function of COVID-19 timings and site of water stream in relation to the industrial belt in Mahanadi River. Environmental parameters (taken alone in figure a) and heavy metal levels (taken alone in figure b) in Mahanadi River during pre-COVID-19 and during COVID-19 period (after about 2 months of lockdown) periods in the industrial belt in Mahanadi River, near Jagatpur industrial belt, Cuttack, India. Figure a clearly indicates that environmental factors noticeably and strongly contribute to separate the studied groups into six (before and after lockdowns in COVID-19 in three sampling sites i.e. in up, down and mid-basin of industrial belt of Mahanadi River), whereas, when heavy metals are taken alone (b) or together with environmental factors (c), up and down stream shows an unclear separation as compared to the distinct separation of the other groups as described above. Overall, all parameters have a strong contribution to separate the studies variance into clear six groups indicating their changes in relation to COVID-19 induced lockdowns. BL-before lockdown, AL-after lockdown, UP-upstream, DS-downstream, MS-mid basin.

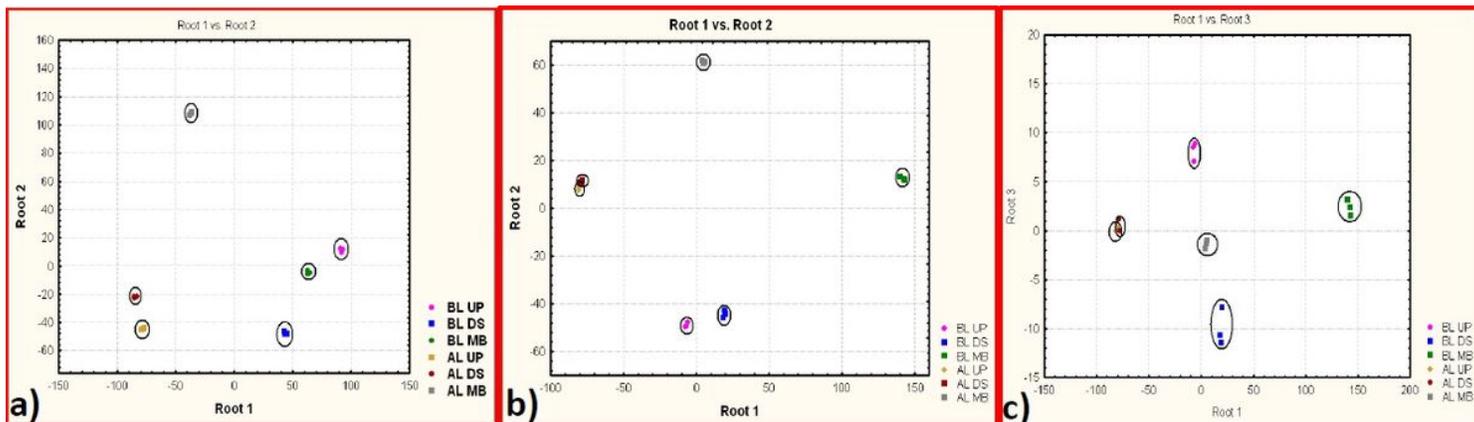


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Figure 4

Reappearance of the fish *Aplocheilichthys panchax*, in Mahanadi River polluted patch near Jagatpur industrial belt. Arrow indicates the fish schooling after 2 months of lockdown due to the reduction in pollution.



Figure 4

Reappearance of the fish *Aplocheilichthys panchax*, in Mahanadi River polluted patch near Jagatpur industrial belt. Arrow indicates the fish schooling after 2 months of lockdown due to the reduction in pollution.



Figure 5

A self-described figure suggesting a strict environmental audit following post COVID-time lines.

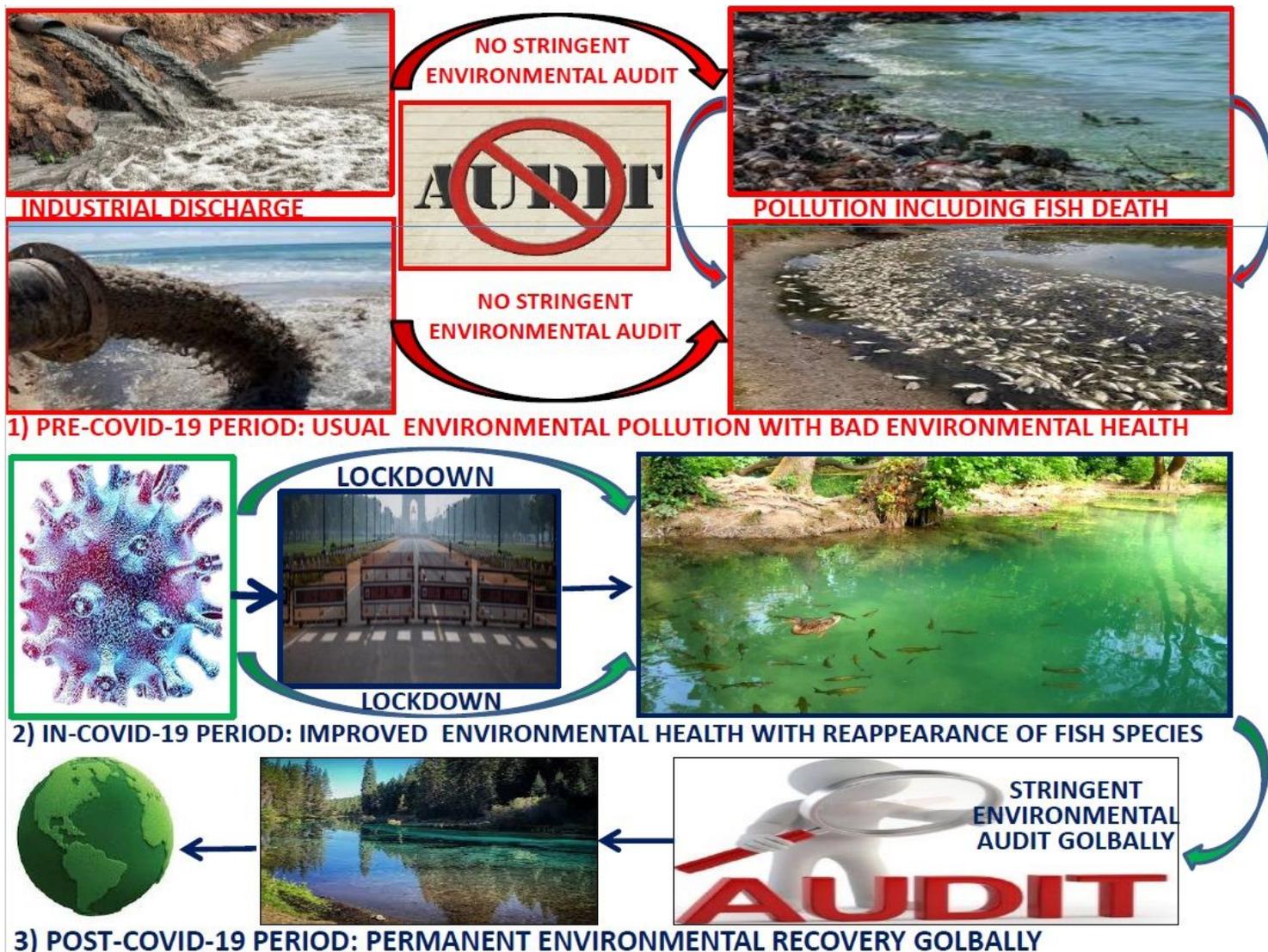


Figure 5

A self-described figure suggesting a strict environmental audit following post COVID-time lines.

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