15 -ാം കേരള നിയമസഭ

13 -ാം സമ്മേളനം

നക്ഷത്രചിഹ്നമിട്ട ചോദ്യം നം. 236 **10-03-2025 - ൽ മറുപടിയ്ക്ക്**

പെരിയാറിൽ ചത്തുപൊങ്ങിയ മത്സ്യങ്ങളെ സംബന്ധിച്ച പഠനറിപ്പോർട്ട്

ചോദ്യം		ഉത്തരം	
ശ്രീ. എ. കെ. എം. അഷ്റഫ്, പ്രൊഫ. ആബിദ് ഹുസൈൻ തങ്ങൾ , ഡോ. എം. കെ. മുനീർ , ശ്രീ. നജീബ് കാന്തപുരം		**ശ്രീ സജി ചെറിയാൻ (മത്സ്യബന്ധനം, സാംസ്കാരികം, യുവജനകാര്യ വകുപ്പ് മന്ത്രി)**	
(എ)	പെരിയാറിൽ ആലുവ പ്രദേശത്ത് മത്സ്യങ്ങൾ കൂട്ടത്തോടെ ചത്തു പൊങ്ങിയ വിഷയത്തിൽ കേരള യൂണിവേഴ്സിറ്റി ഓഫ് ഫിഷറീസ് ആന്റ് ഓഷ്യാനിക് സ്റ്റഡീസ് നടത്തിയ പഠനത്തിന്റെ റിപ്പോർട്ട് സർക്കാരിനോ, സർക്കാർ ഏജൻസികൾക്കോ ലഭിച്ചിട്ടുണ്ടോ;	(എ)	പെരിയാറിൽ മത്സ്യങ്ങൾ കൂട്ടത്തോടെ ചത്തു പൊങ്ങിയ വിഷയത്തിൽ കേരള യൂണിവേഴ്സിറ്റി ഓഫ് ഫിഷറീസ് ആന്റ് ഓഷ്യാനിക് സ്റ്റഡീസ് (KUFOS) നടത്തിയ പഠനത്തിന്റെ റിപ്പോർട്ട് സർക്കാരിന് ലഭിച്ചിട്ടുണ്ട്.
(ബി)	എങ്കിൽ അതിലെ കണ്ടെത്തലുകൾ വിശദമാക്കുമോ; റിപ്പോർട്ടിന്റെ പകർപ്പ് ലഭ്യമാക്കുമോ?	(ബി)	പെരിയാറിൽ മത്സ്യങ്ങൾ ചത്തു പൊങ്ങിയതിനെ തുടർന്ന് വകുപ്പിന്റെ നിർദ്ദേശ പ്രകാരം കേരള ഫിഷറീസ് സമുദ്ര പഠന സർവ്വകലാശാല (KUFOS) പനങ്ങാട് നിന്നുമുള്ള സർവ്വെയിലൻസ് ടീം സ്ഥലം സന്ദർശിച്ച് വെള്ളത്തിന്റെയും മത്സ്യങ്ങളുടെയും പുഴയിലെ ചെളിയുടെയും സാമ്പിളുകൾ ശേഖരിച്ച് പരിശോധന നടത്തിയിരുന്നു . ജലത്തിൽ ഹൈഡ്രജൻ സൾഫൈഡിന്റെയും അമോണിയയുടെയും അളവു കൂടിയതും ഓക്സിജന്റെ അളവ് കുറഞ്ഞതുമാണ് മത്സ്യങ്ങൾ ചത്തുപൊങ്ങിയതിന്റെ പ്രധാന കാരണമെന്നാണ് കുഫോസിൽ നിന്നും ലഭ്യമായ റിപ്പോർട്ടിൽ പറയുന്നത്. മത്സ്യങ്ങൾ ചത്തുപൊങ്ങുന്നതിലേയ്ക്ക് നയിച്ച ഈ ഘടകങ്ങൾക്ക് പുറമെ, ജലത്തിലും, അവശിഷ്ടത്തിലും, മത്സ്യങ്ങളിലും കനത്ത ലോഹങ്ങൾ, വിഷ രാസവസ്തുക്കൾ തുടങ്ങിയവയുടെ ഉൾപ്പെടെയുള്ള മൂലകങ്ങളുടെ ഉയർന്ന തോതിലുള്ള സാന്നിദ്ധ്യവും കണ്ടെത്തിയിട്ടുണ്ട്. അന്വേഷണ റിപ്പോർട്ടിന്റെ പകർപ്പ് ഇതോടൊപ്പം ഉള്ളടക്കം ചെയ്യുന്നു. റിപ്പോർട്ടിന്റെ അടിസ്ഥാനത്തിൽ സ്വീകരിക്കേണ്ട നടപടികൾ സംബന്ധിച്ച് പരിശോധിച്ച് വരുന്നു.

സെക്ഷൻ ഓഫീസർ

REPORT ON THE FISH KILL INCIDENT IN THE PERIYAR RIVER AND ADJOINING AQUAFARMS -DOWNSTREAM OF PATHALAM REGULATOR BRIDGE

By

Expert Committee constituted by

Kerala University of Fisheries & Ocean Studies

KUFOS Order No. GA8/3907/2024 dated 22.5.2024.

Contents

EXECUTIVE SUMMARY

Periyar River, a crucial waterway in Kerala, experienced devastating fish kill events from the 20th evening and culminated to a catastrophic proportion by the 21stof May 2024. A massive fish kill event occurred from downstream of Pathalam regulator – cum – bridge, which resulted in the death of hundreds of thousands of fish and aquatic fauna, impacting both the local ecosystem and the livelihoods of fishermen and fish farmers. This report on the fish kill incident spans across 15 comprehensive sections, providing an in-depth analysis of the event, its probable causes, implications and recommendations to avoid recurrence. The report covers the geographical and historical significance of Periyar River, the role of the Pathalam regulator cum bridge in water management and the impact of industrial discharges, domestic sewage, septage waste, agriculture runoff, and effluents from markets, hospitals, hotels, and other commercial establishments on water quality. It also examines the contribution of these factors in the recent fish kill event. Field visits and laboratory analyses provide empirical data on water quality and pollutant levels, while community reports and eyewitness accounts offer valuable insights into the local impact of the incident. The report also explores mitigation measures and concludes with actionable recommendations for policy reforms, sustainable practices and enhanced community involvement to prevent future incidents and restore the health of the River Periyar ecosystem. Comprehensive annexures include maps, diagrams, field visit observation and photographic documentation to support the findings and recommendations. At the same time, since the report is based on a short-term study and depicts the causes of this ecological disaster, it may fail to pin point to an absolute conclusion on the exact source of pollutants. So, it is believed that this report will throw light on the need of further continuing studies, in this regard. Localized fish kills in connection with the opening of the Pathalam regulator shutters are a regular phenomenon since many decades. Occasionally, minor fish mortalities were often reported from Purappallikkavu segment. The severity reached catastrophic proportions due to the increased contribution from industrial sources. Field visits, sample collection, and laboratory analysis revealed higher levels of hydrogen sulphide, as the prime culprit which was equally contributed by increased levels of ammonia. These together with lower dissolved oxygen levels created a death trap for most aquatic organisms including microbes to fishes. The severity of the event was evident by the extent of fish kill within a short time frame, which affected many kilometers (Pathalam to Mulavukad) and spread to tributaries till it merged with larger Vembanad Lake. Apart from these factors leading to fish kill, alarming levels of elements including heavy metals, toxic chemicals etc. were found in the water, sediment and fish. The disaster should be an eye-opener to implement stringent control on effluent treatment and release, increased surveillance on polluting industries and real-time monitoring of surface and bottom water and bottom sediments in the upstream and downstream of Pathalam regulator. Proper operational protocols and alert systems must be implemented for operating the regulator after checking the water quality from the upper and lower reaches. The report outlines recommendations for pollution control, operational guidelines for regulators, the need for assessment of biodiversity in Periyar River, the extent of pollutants in the system and suitability of the area for aquaculture and fisheries activities. Keeping this as the major objective, an Expert Committee was constituted vide University Order No. GA8/3907/2024 dated 22.05.2024 under the Chairmanship of Dr. Binu Varghese, Assistant Professor, Department of Aquaculture and the Convener-ship of Dr. Dinesh Kaippilly, Professor& Registrar (i/c). The Members of the Committee include Dr. Anu Gopinath, Head, Department of Aquatic Environment Management; Dr. M.K. Sajeevan, Head, Department of Fisheries Resource Management; Dr. Devika Pillai, Head, Department of Aquatic Animal Health Management & Director of Research; Dr. M. P. Prabhakaran, Assistant Professor, Department of Aquatic Environment Management and Shri. Saneer N.S., Fishing Technology Assistant. Dr. Rahul Krishnan, Assistant Professor, Department of Aquatic Animal Health Management contributed by analyzing the heavy metals, toxicants and histological studies. The inputs from various stakeholders were collected and compiled extensively.

1. Introduction

Periyar River, also known as the "Lifeline of Kerala," is the longest river in the State and plays a critical role in the ecological and economic well-being of the region. As the name indicates, it's the largest river of the State. The river supports diverse aquatic life, sustains traditional fishing practices and aquaculture activities and serves as a crucial source of potable water and irrigation. The river flows through the Periyar Tiger Reserve (PTR) which is the major hot spot of biodiversity in the State on which thousands of species depend on. There are millions of people who thrive on the mercy of this river for meeting their livelihoods through agriculture, industry, tourism, fishing and aquaculture.

The river has faced several environmental challenges over the decades from pollution to flooding. Pollution from industrial effluents, agricultural runoff, domestic sewage and effluents from markets, hotels, hospitals, and other commercial establishments significantly deteriorated the water quality in many stretches. Encroachments, sand mining and deforestation have led to habitat and species loss and the increased sedimentation, impacting the river's flow and overall ecological health. Climate change poses additional threats, with altered precipitation patterns and increased frequency of extreme weather events affecting the entire ecosystem associated with Periyar.

A massive fish kill event was reported downstream of Pathalam segment of the Periyar, from 20th evening and 21stof May 2024, causing significant ecological and economic damages. Kerala University of Fisheries and Ocean Studies (KUFOS) has already submitted a preliminary report (Annexure 1) in this regard and this report is the extension of the same, presenting the findings of the field study conducted to determine the causes of the fish kill and proposing the mitigation measures to prevent similar events in future.

2. Regulator cum Bridges in Periyar River

The lower reaches of the River Periyar has a few regulator-cum-bridges, out of which the three at Purappillikkav, Manjummal and Pathalam (Fig. 1) are the most important ones. These are located at different branches of Periyar to avoid incursion of saline water from the Arabian Sea / Vembanad Lake during the high tides and to regulate water levels for irrigation and drinking purposes. The Pathalam regulator-cum-bridge, connecting Eloor and Edayar is located amidst the Edayar industrial belt and is a crucial point in Periyar River (Fig. 2) as far its significant role played on the ecological, environmental, agricultural, fisheries and aquaculture activities are concerned. Since time immemorial the local inhabitants used to make temporary earthen barriers for protecting the agricultural crops from salinity intrusion which was later carried out by the Government, for the purpose. The temporary earthen barrier was replaced with a permanent concrete structure way back in 2016. As indicated earlier, it acts as a barrier against the incursion of saline water and also the chemical pollutants from entering the pumping stations of Kerala Water Authority at Elookkara

and Aluva situated about 4 km and 9 km away, respectively. The area offers the home ground to several industrial units, including many in the red category, raising concerns on potential pollution impacting water quality and aquatic life. In the upper region of Pathalam regulator, the water flow gets curtailed which induces thermal stratification in summer months and also act as a dumping yard of organic and inorganic materials. It is worth mentioning that regular flow in the upstreams and tidal influences in the downstream typically controls thermal stratification and creation of lentic environment and anoxic conditions. Obviously, the water quality parameters in the upper and lower layers are influenced by industrial and domestic effluents, local climatic conditions and flow management creating a complex and dynamic aquatic / terrestrial environment.

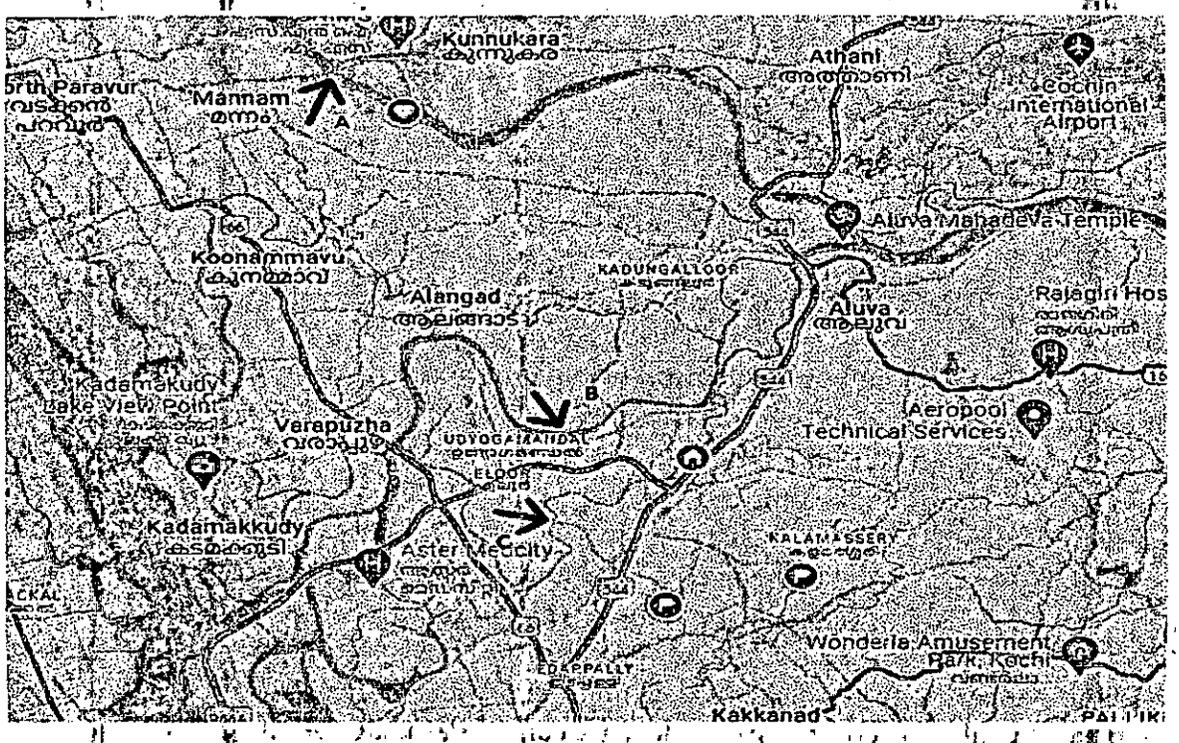

Fig. 1. The three major regulator bridges in the lower reaches of Periyar (A- Purappallikavu, B – Pathalam, C – Manjummal)

3. Fish and Fisheries of Periyár River

As already discussed, Periyar River flowing through the lush landscapes of Kerala, is not only a lifeline for the region but also a treasure trove of aquatic biodiversity. The river hosts the Periyar Tiger Reserve (PTR), one of India's 21 biodiversity hotspots. The reserve harbors a rich array of flora and fauna, including an impressive diversity of fish species. A recent aquatic faunal survey conducted in the PTR, in which KUFOS also participated, during 16-19 May 2024 recorded 56 species of food and ornamental fish. It includes 9 fish species showing micro-endemism within the PTR. Some of the notable endemics are *Gonoproktopterus micropogon periyarensis, Lepidopygopsis typus, Crossocheilus periyarensis, Garra periyarensis, Nemacheilus periyarensis* and *Nemacheilus menoni.*

Fig. 2. Pathalam regulator bridge and industries in the Edayar belt

Still it may be noted that comprehensive information and studies undertaken on the fish and fisheries of Periyar is scanty. Earlier surveys reported the occurrence of only 54 fish species from PTR (Radhakrishnan & Kurup, 2010) which got amended to 56 of late. The annual capture fisheries production was estimated to be a meagre of 2.3 tonnes from the Periyar Lake (Kurup et al, 2006) which is believed to be an under estimation by many fisheries scientists. The study indicates that gill nets and cast nets are the major fishing gears in operation. It was reported that the exotic species like *Cyprinus carpio* and *Oreochromis mossambicus* coexist with indigenous species listed above. Fishing with stake nets, Chinese dip nets, gill nets and trammel nets are the major livelihood activities in the downstream of Pathalam regulator and adjoining islands. Thousands of people are engaged in the ancillary jobs related to fisheries for their daily bread and butter.

To understand the impact of the fish kill, a comprehensive survey was conducted to identify the fish species and other aquatic organisms found dead in the Pathalam - Cheranelloor - Moollampilly - Kothad - Pizhala - Kadamakkudy-Mulavukadu segments (Annexure 2). This information is crucial for assessing the ecological damage created by the mishap and drawing guidelines for the future restoration efforts.

4. Aquaculture activities

Downstream of Pathalam segment supports a vibrant fisheries sector as far as the number of stakeholders engaged and associated socio economic significance are concerned. Major fisheries and aquaculture activities in the area are Chinese dip nets, stake nets, traditional trapping cum holding system (*Chemmeen kettu*), brackish water

fish farming, cage-farming apart from fishing using the gill nets and cast nets by local fishers. There are about 150 cage fish farms, apart from many traditional *Chemmen kettu* and fish farms in the region.

The major fishes farmed in the cages are the high value species like Asian sea bass, pearl spot, red snapper, giant trevally etc. All these fishes are highly susceptible to water pollutants and low dissolved oxygen (DO) as they are farmed at higher densities of 25 - 30 kg/cubic meter, in confined cages.

5. Description of the Fish Kill

The fish mortality was reported from the late evening hours of 20th May 2024 and it culminated into a fish kill on the next day. Mass fish mortality was also reported from different regions in the following days. The fish kill event extended upto the area where the river merges with the larger Vembanad Lake. Dead fishes were found floating on the water surface throughout the affected area and got accumulated along the banks and bottom of the river. Field visits confirmed the severity of the devastating occurrence with hues and cries from everywhere from all realms of life. Bunches of putrified fishes were seen to be heaped along the banks of the river with irritating off odour. The farmers were literally weeping with a turbulent state of mind cursing the officials. They begged for the compensation of their crop loss. The shrimp and crabs were also found dead in huge numbers in the premises. Initial estimates suggest that hundreds of thousands of fish were affected, including several species that are critical to the aquatic ecosystem (**Fig. 3**), impacting both the ecosystem health and the livelihoods of fishermen and fish farmers. Mass mortality was observed in a large number of *Chemmen kettu* which had opened sluice gates on that eventful day as they were unaware of the consequences of the shutter opening.

Fig. 3. Dead fishes from the study area

The fish kill was triggered by the opening of three shutters of Pathalam regulator cum bridge - one at 3.30 pm and the other two at 6.00 pm on 20.05.2024 and the resultant outflow of polluted water. The Irrigation Department informed that they opened the same as there was increase in water level owing to the opening of Boothathankettu barrage and the prevailing heavy rains on the day. The released water had undesirable substances and reduced oxygen levels which led to massive fish kill in the downstreams. The stagnation of water in the upstream of the regulator and the accumulation of organic and inorganic wastes and pollutants created anoxic conditions in the benthic region. The accumulation of organic materials like domestic wastes, discharges from public drains, decaying plant and animal materials, effluents from markets, hotels, etc., leads to the production of noxious gases like hydrogen sulphide, methane, ammonia etc. This is the primary reason for fish mortality coupled with changes in water quality parameters like decreased dissolved oxygen, sharp variations in important parameters like temperature, pH, salinity, etc. All these factors alone or in combination with others are capable of causing only localized fish death as the ill effects will be diluted and nullified soon. It will be confined only to the initial reaches of the downstream as fishes will move away from the polluted region in search of clean waters with desirable quality standards. Such incidents are common with the opening of even other regulator shutters in Periyar, especially much larger Purapallikkavu, wherein cage fish farmers are forced to move further downstream due to complete or gradual loss of stocked fish after the establishment of the permanent regulator in place of the temporary earthen bund. Unlike the fishes naturally inhabited in the river, the ones inside the cage can't escape from the incoming polluted water. They become stressed and died resulting in huge economic loss.

6. Industries around

Edayar Industrial area located on the banks of Periyar, includes various industries concerned with chemicals, tanneries, fertilizers, metals, meal processing, rubber, food processing etc. These industries are concentrated in the industrial zones such as Edayar, Eloor and Udyogamandal. Effluent management practices vary across industries, with some adopting advanced treatment technologies while others lag behind (**Fig. 4**).

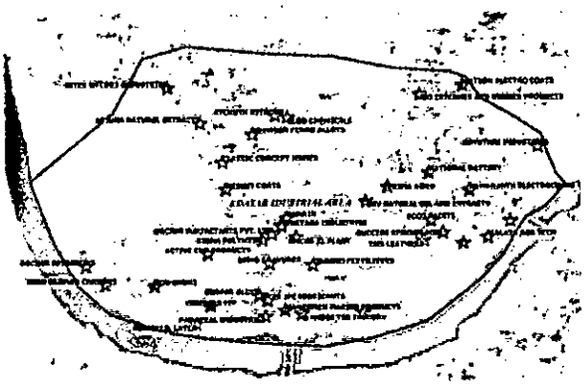

Fig. 4. Companies in Edayar Industrial area

7. Water Pollution

a) Sources of Pollution

Historical data and case studies highlight the significant impact of industrial discharges on the water quality of Periyar River. Analyses of specific pollutants such as heavy metals, organic compounds and other toxic substances, demonstrate the extent of contamination. Comparative studies of water quality of upstream and downstream of industrial zones offer insights on the industrial impact to the scenario. Identifying and elaborating on the sources of pollution in Periyar River is crucial for understanding the fish kill incident. Major sources of pollutants include:

- **Industrial Effluents**: Discharges from chemical, mineral, wastes and meal processing, tanneries and other manufacturing industries contain hazardous pollutants. Many industries fall in the red category due to their specific and hazardous raw materials or products. Very few companies have legal permission to discharge treated effluents leading to the river. The monitoring and surveillance of effluent treatment and discharge need to be more stringent
- **Agricultural Runoff**: The banks of Periyar are highly fertile and a lot of agricultural activities happen there since time immemorial. The hilly region from where the river originates has extensive plantations like tea, cardamom etc., which are known to use excessive pesticides and chemicals during different stages of cultivation. Pesticides, fertilizers and sediments from agricultural fields enter the river through runoff, especially after heavy rains. This in turn leads to eutrophication and excessive growth of aquatic weeds like water hyacinth etc. The death and decay of these vegetation leads to poor water quality.
- **Domestic and Urban Sewage**: Untreated or partially settled sewage from residential areas, hotels, hospitals, shops and slaughterhouses contributes to organic waste and pathogens. This is one of the major sources of pollution in Periyar. There is hardly any sewage treatment plants exist along the course of the river. All the sewage from Panchayaths, Municipalities and Corporations unfortunately ends up in Periyar. Moreover, many Local Self Governments are ignorant about the septic tank waste, kitchen wastes etc. getting channelized through illegal pipes which are connected to the drainage system. Apart from these, many residential and commercial buildings are directly releasing sewage of all types to the river.

b) Types of Pollutants

- **Heavy Metals**: Alarmingly, all the tested heavy metals had the presence in the river, sediment and in fish. The relative presence varies with location and there is no defined maximum residue level for some parameters in BIS or FSSAI.
- **Pesticides**: Residues from industries and agricultural runoff. Though major pesticide producers are closed down a few years back, there are toxic elements still in water and sediments. This shows the earlier accumulation as well as excessive use in agriculture.

- **Nutrients**: Excessive nutrients are the major cause of aquatic weed proliferation and associated eutrophication in the river especially in smaller tributaries. Mainly, nitrogen and phosphorus from fertilizers and sewage cause eutrophication.
- **Organic substances** both from the river system and external sources.
- **Toxic chemicals** from the industrial effluents, hospitals, industrial areas especially plywood industry and companies in the upstream.

8. Pollution Monitoring and Control

Current pollution monitoring and control measures include government regulations, monitoring programs and enforcement actions. Kerala Pollution Control Board (KPCB) and Central Pollution Control Board (CPCB) are involved in monitoring and controlling of pollution in the river. National Green Tribunal has constituted a committee for surveillance and monitoring.

9. Field Visits and Sample Collection

As per the directions of the Hon'ble Vice Chancellor of KUFOS and Department of Fisheries, samples were collected on 21st and 23rd May 2024 (**Fig. 5**). Samples of water, sediment and fish were collected for the analysis to assess the water quality and reasons for fish kill by the experts at KUFOS. Observations were made on water quality parameters, mortality of aquatic life and fish behavior during the event of pollution. The team also interacted with local people, fishermen, fish farmers, environmentalists and government officials.

10. Sampling Methods

Standard protocols were followed for sample collection and analysis to ensure accuracy and reliability of the investigation.

10.1. Sampling Locations

Sampling locations were identified from the upstream and downstream areas of the Pathalam Bridge. A total of 11 sites were selected which include one site near the bridge in the stagnant navigation canal, one on the lotic upstream side and nine sites from the downstream (TCC outlet, center of the river after the industrial area, FACT outlet, Alliance Marine outlet, Sud Chemie in the Edayar region, cage fish farms at Cheranallore, Varappuzha, Kothad and Moolampally). Locations were selected based on probable pollution sources, areas of reported fish mortality and the premises of regulator bridge.

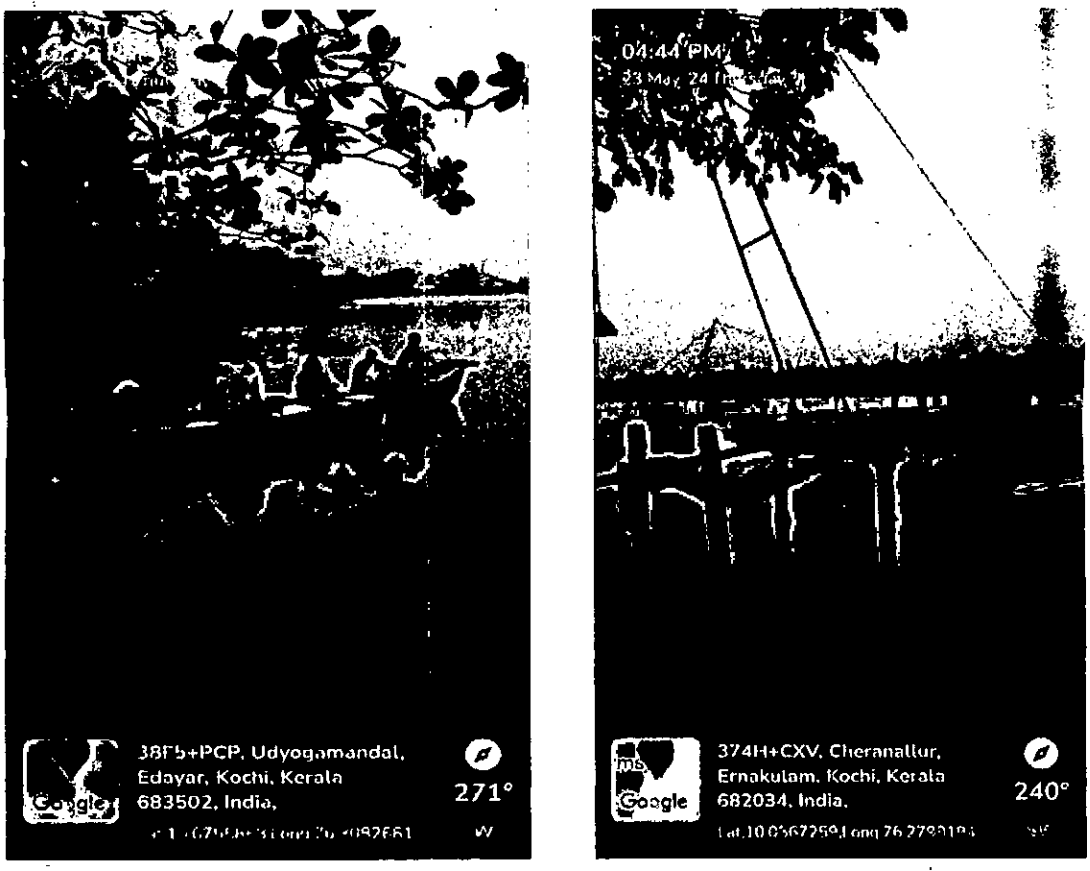

Fig. 5. Sample collection from the affected areas

10.2. Laboratory Analysis

Standard methods were followed for the collection and analysis of the water, sediment and fish samples.

- **Water Quality parameters**: Tests were performed to find out the water quality parameters such as pH, temperature, dissolved oxygen, salinity, ammonia, hydrogen sulphide, silicate, iron, calcium, heavy metals and other metals such as Cadmium, Lead, Arsenic, Chromium, Nickel, Copper, Zinc, Cobalt, Manganese, Uranium, Selenium, Rubidium and Cesium.
- **Sediment Analysis**: Examination of sediment samples was carried out for pollutants and heavy metals (Cadmium, Lead, Arsenic, Chromium, Nickel, Copper, Zinc, Cobalt, Manganese and Uranium). Other metals include selenium, Rubidium and Cesium)
- **Toxicant Analysis:** Analysis was done for DDT, BHC, PAH, Benzenes, Tetrachloro-Methane, Chlorodiphenyl-Methane, Alkylated Benzenes, Examination of water, sediment and tissue of fishes from Kothad. Water samples from upstream and downstream of Pathalam regulator were also analyzed.

11. Causes of fish kill

Detailed examination of the water, sediment and fish was done carried out meticulously using the standard operating procedures to find out the actual cause of fish kill. The results were presented among the committee members for further deliberations. This report is the culmination of the above activities.

11.1. Water Quality Parameters on the day of fish kill

Data on key water quality indicators on the day of the incident is given in **Table 1**. It was noticed that the pH ranged from 6.6 (Moolampilly site) to 7.2 (Varappuzha site). The temperature was normal which ranged from 29.8 to 30.2 without much variation. The turbidity levels were 6.25 to 6.95 NTU which is higher than the normal. The other parameters like silicates, calcium were also higher. These factors might not have contributed to the fish kill though minor deviations from the normalcy existed.

Table 1. Water parameters of cage farms affected by fish kill (21.05.2024)

Site/ Parameter	Temp (C)	D.O (mg/l)	pH	H2S (mg/l)	Ammonia (mg/l)	Turbidity (NTU)	Silicate (µmol/l)	Ca (mg/l)
Kothad farm	30.2	1.14	6.7	2.53	1.97	6.25	144.79	500
Moolampilly farm	29.8	0.3	6.6	2.53	1.39	6.84	72.56	1250
Varapuzha farm	29.9	3.08	7.2	3.79	1.56	6.94	122.75	850

Dissolved Oxygen levels were as low as 0.3ppm at the Moolampilly, 1.14 ppm at Kothad and 3.08 ppm at Varappuzha cage farm sites wherein complete mortality was observed. The dead and decayed organisms including fishes in the river with increased biological oxygen demand may be the reason for the extremely low DO obtained at Moolampilly. These low DO levels alone can cause complete mortality in the cage farms wherein sea bass and pearl spot are mostly stocked. However, fishes in the river escaped from these low oxygen conditions by moving further downstream. It was observed that air breathing fishes like catfishes were also found dead. This indicates that reduction in DO alone cannot be attributed to the present fish kill.

The levels of **Hydrogen Sulphide**, a lethal toxic gas to aquatic life, were found at an extremely higher range. It was 2.53 ppm in Kothad and Moolampilly and reached to 3.79 ppm at Varappuzha. This toxicant is fatal to the most aquatic fauna even at the lower detection levels. This could be the primary cause of fish mortality as we interpret it through the specific fish behavior, histological studies and the narration by local people. This is a known irritant which creates itching and off odour even at a

lower concentration of 0.5 ppm. The behavior of fishes prior to mortality conforms to this observation as they tried to jump out of water in cages. The analysis of CCTV footage from a few cage farm sites in Cheranelloor area showed very specific and most uncommon behavioural changes among the fishes both inside and outside the cages by midnight of 20.5.24. The fishes stocked in the cages were strugglingly jumping out of water with high rate of unrest. Even the air breathing fishes which are hardier than the normal fishes showed this kind of stress leading to mortality. The fishes further showed sideways and erratic movements losing the balance in cages. Normally, the fishes gulp on the surface layers, if there exists anoxic conditions. Those in river also showed rapid surfacing, rushed to smaller canals and even jumped on to the river banks. The chemical might have created severe irritation to fish while it got exposed to the skin and gills. The farmers and local people who happened to get in contact with contaminated water suffered from severe itching and irritating off odour beyond the extent of tolerance.

The **Ammonia** levels also shooted up drastically to lethal levels. The unionized ammonia is toxic even at very low concentrations to the tune of 0.05 ppm to most fishes and crustaceans. Here it ranged from 1.39 ppm at Moolampilly to 1.97 ppm at Kothad site. The fishes showed extreme stress and absolute unrest leading to damaged gills and internal organs. So, the ammonia toxicity could have also caused severe fish kill.

The **heavy metals (Table 2), pesticides and other chemicals (Table 3)** tested in selected sites also had shown very high values in water, sediment and fish. The detected levels are alarming and need to be addressed at the earliest. Though these factors might not have directly contributed to the present fish kill event, they must have adversely affected the health of fish. Many parameters are much beyond the drinking water and consumption limits prescribed by different organizations.

11.2. Water Quality Parameters after the fish kill

The sample collections done after one day of fish kill (23rd of May 2024) is given in **Table 4**. The expert team visited various sites and collected samples from the upper and lower reaches of Pathalam regulator and from the cage fish farm, which was one of the first cage farms which got exposed to contaminated water at Cheranalloor.

The basic water quality parameters such as temperature, pH and salinity were found to be stable in the river, except the sharp variations observed at the outlet points of industries. This normalcy might have been due to the opening of shutters and heavy rainfall during these days. However, the fluctuations in these parameters at outlet points of factories are evident from the **Table 4**.

Table 2. Heavy metals and others observed in the water, sediment and fish on the day of fish kill (21.05.2024) with available standards

Place/ Parameter	Heavy metals										Other metals			
	Cadmium	Lead	Arsenic	Chromium	Nickel	Copper	Zinc	Cobalt	Manganese	Uranium	Iron	Selenium	Rubidium	Cesium
Water (mg/l)														
Kothad	0.001	< 0.000	**0.054**	0.018	**0.193**	**0.165**	4.931	0.017	**9.834**	0.016	**89.37**	**0.052**	2.339	0.019
Moolampilly	0.003	< 0.000	**0.105**	0.034	**0.084**	0.037	0.414	0.009	**0.605**	0.036	**8.088**	**0.061**	4.549	0.036
Varapuzha	**0.006**	< 0.000	**0.074**	0.039	**0.253**	**0.096**	2.614	0.042	**30.402**	0.017	**7.885**	**0.054**	3.668	0.016
STD(IS 10500:2012)	0.003	0.010	0.010	0.050	0.020	0.050	5.000	NL	0.100	NL	0.300	0.010	NL	NL
Fish (mg/kg)														
Kothad	0.035	0.055	0.483	0.755	0.438	1.128	56.013	0.066	15.731	0.022	3.987	0.380	0.394	0.005
Moolampilly	0.012	0.005	0.799	0.538	0.355	0.721	16.293	0.009	1.901	0.002	0.878	0.659	1.745	0.007
Varapuzha	0.010	< 0.000	0.320	0.562	0.375	0.570	6.988	0.010	0.211	0.001	3.296	0.297	1.911	0.019
STD (FSSAI)	0.300	0.300	*	*	*	*	*	*	*	*	*	*	*	*
Sediment (mg/kg)														
Kothad	1.836	4.224	1.095	28.081	7.822	9.378	218.822	3.120	62.271	0.674	10449.5	0.779	6.739	0.155
Moolampilly	0.773	5.472	1.729	29.636	7.917	8.011	88.906	2.558	28.028	0.801	11215.9	0.755	8.033	0.204
Varapuzha	1.660	4.585	0.834	25.392	7.345	8.889	206.605	2.806	52.343	1.188	10254.9	0.734	7.790	0.150

Table 3. Presence of Insecticides/Toxicants in the water, fish and sediments					
Pesticide/Toxicants	**Fish (Kothad) 21.05.24**	**Water (Kothad) 21.05.24**	**Sediment (Kothad) 21.05.24**	**Water (Upstream) 23.05.24**	**Water (Downstream) 23.05.24**
DDT (sum of O,P-DDE, P,PDDE O.P-DDD, PP-DDD. O.P.DDT & P P-DDT expressed as DDT)	75.8 mg/kg	251 mg/l (0.001)	220 mg/kg	82.3 mg/l (0.001)	148.3 mg/l (0.001)
BHC (sum of alpha-HCH, beta HCH, gamma HCH & delta HCH expressed as BHC)	30.2 mg/kg	120.5 mg/l (0.002)	133 mg/kg	12.4 mg/L (0.002)	117.1 mg/l (0.002)
PAH (sum of fluoranthene, BbF, BkF, BaP, BgP and InD expressed as PAH)	4.79 ng/g	28.96 ng/ml (<0.0001)	26.2 ng/g	24.12 ng/ml (<0.0001)	10.6 ng/ml (<0.0001)
Benzenes, tetrachloro-Methane, chlorodiphenyl-Methane, Alkylated benzenes	Detected	Detected	Detected	Detected	Detected
Kothad – Mortality of cage fish; Upstream – Above Pathalam Regulator Bridge; Downstream – Below Pathalam Regulator Bridge. *Values in brackets – BIS Standard for potable water*					

Table 4. Water parameters of Periyar River in the up and downstream of Pathalam regulator 23rd May 2024								
Sampling site/ Parameter	**Temp (°C)**	**DO (mg/l)**	**Salinity (ppt)**	**pH**	**H2S (mg/l)**	**Ammonia (mg/l)**	**Silicate (µmol/l)**	**Ca (mg/l)**
Upstream Channel	28.7	4.66	0.4	7.2	1.26	1.26	82.75	525
Upstream open	28.7	4.98	0.05	6.7	2.53	0.28	89.55	75
TCC outlet	29.1	5.68	0.1	7.1	1.26	0.14	174.12	25
Central Portion	28.9	5.68	0.04	6.9	2.53	0.12	57.03	25
FACT outlet	29	5.85	0.05	5.6	2.53	0.51	176.6	25
Alliance outlet	28.9	5.71	0.05	6.8	2.53	0.13	51.08	25
Sud chemie	28.9	5.68	0.04	7	1.26	0.2	150.66	25
Cheranelloor farm	29.8	3.64	0.06	6.8	2.53	0.66	120.58	25

The level of dissolved oxygen was noticed to be reaching back to normal levels and this can be due to the opening of shutters, mixing of water from the Boothathankettu and heavy precipitation. The DO levels varied from 4.98 ppm in the upstream to 5.68 ppm in the downstream. However, the DO levels in the Cheranalloor farm was yet to be recovered and was found to be falling at 3.64 ppm. This may be due to higher oxygen demand as many dead and decayed fishes were still floating in the cages and river bottom. The comparatively lower DO levels to the tune of 4.98 ppm recorded might be due to the lack of proper mixing of water in the upstream areas. It was alarming as there were increased levels of ammonia and hydrogen sulphide even after opening the three shutters of the regulator. Undesirable levels of both these chemicals were observed in the upper and lower reaches of the Pathalam segment. This indicates the increased accumulation of these toxic elements in water and sediments. The undesirable levels were also observed at Cheranalloor farm, which clearly shows the ecological damage caused by the fish kill in areas which are many kilometers away from the epicenter. These increased levels may also be due to the consistent death and decay of organic matter along with the effluents from the regulator. It is also reported that at certain outlet points the committee observed some yellow coloured powder like substances suspecting the presence of direct release of sulphur into the water body.

The ammonia levels were 0.12 ppm at the downstream of Pathalam regulator to as high as 0.66 ppm at the Cheranalloor farm. It may also be noted that the ammonia levels were at 1.26 ppm at the navigation channel (which was closed). The ammonia level at the upper reaches also showed double the value than the lower stream. This indicates the higher accumulation of ammonia in the upper part of Pathalam regulator.The sulphide levels were still at very dangerous levels both at the upper and lower reaches. It varied from 1.26 ppm at TCC outlet where much dilution is happening to 2.53 ppm at the upper and lower streams of the river. Similar higher levels were also observed at Cheranalloor farm. This indicates that the water body above the Pathalam regulator is functioning as a reservoir of hydrogen sulphide. This could be due to the increased accumulation and slow dissolution as only 3 of the 13 shutters were opened.

While the concentrations of pollutants (**Table 3**) like heavy metals (**Table 5**) and other elements were compared with permissible limits, majority of these parameters were above permissible limits prescribed for the potable water. The maximum residue levels (MRL) for many elements are yet to be fixed for sediments and fishes in our country. The accumulation of heavy metals in the samples collected from faraway places such as Moolampally is alarming.

Pesticides and other toxicants were far beyond the permissible limits. The accumulation of these toxic chemicals in the water, sediment and fish meat is alarming. This area needs urgent attention and the sources need to be identified. As major companies producing these chemicals were shut down a few years back, the status of stock disposal, use of banned chemicals in plantations, agriculture and industries needs to be thoroughly assessed.

Table 5. Heavy metals and others observed in the water a day after fish kill (23.05.2024) with available standards												
Place/ Parameter	Heavy metals									Other metals		
	Cadmium	Lead	Arsenic	Chromium	Nickel	Copper	Zinc	Cobalt	Manganese	Iron	Selenium	Cesium
Water (mg/l)												
Upstream Channel	0.001	0.040	0.019	0.514	0.516	0.537	3.012	0.024	5.065	2.376	0.000	0.004
Upstream	0.018	0.031	0.013	0.534	0.546	0.620	1.775	0.021	4.491	3.967	0.012	0.002
TCC out	0.025	0.023	0.012	0.543	0.677	0.586	3.355	0.051	2.788	2.351	0.006	0.002
Central Region	0.005	0.047	0.009	0.531	0.451	0.507	0.700	0.018	1.083	2.453	0.009	0.001
FACT out	0.014	0.027	0.010	0.522	0.534	0.573	1.900	0.047	3.669	6.681	0.003	0.002
Alliance out	0.004	0.028	0.089	0.440	0.334	0.363	0.633	0.034	9.191	11.782	0.011	0.004
Sud Chemie	0.009	0.028	0.013	0.565	0.449	0.576	2.474	0.016	1.912	8.272	0.002	0.008
Cheranelloor farm	0.009	0.029	0.013	0.548	0.490	0.616	1.058	0.010	1.072	3.300	0.009	0.002
STD(IS 10500:2012)	0.003	0.010	0.010	0.050	0.020	0.050	5.000	NL	0.100	0.300	0.010	NL

Biological Health: Health indicators in fish samples, such as the presence of lesions and pollutant bioaccumulation were investigated by the team. Mainly the samples of pearl spot were used for the laboratory examinations.

11.3 Necropsy examination

Samples of fishes received at ARL-KUFOS were subjected to postmortem examination. Findings include severe congestion and hemorrhages in gills with epithelial sloughing. Examination of affected fishes were suggestive of a toxicant associated fish kill corroborated with the onsite observation of fishes showing aquatic surface respiration (ASR) and aerial emergence behavior. Hematological analysis indicated immature red blood cells in the fish blood indicative of toxic pollution in the water body concurrent with the gill lesions indicated previously (Fig. 6a to 6e).

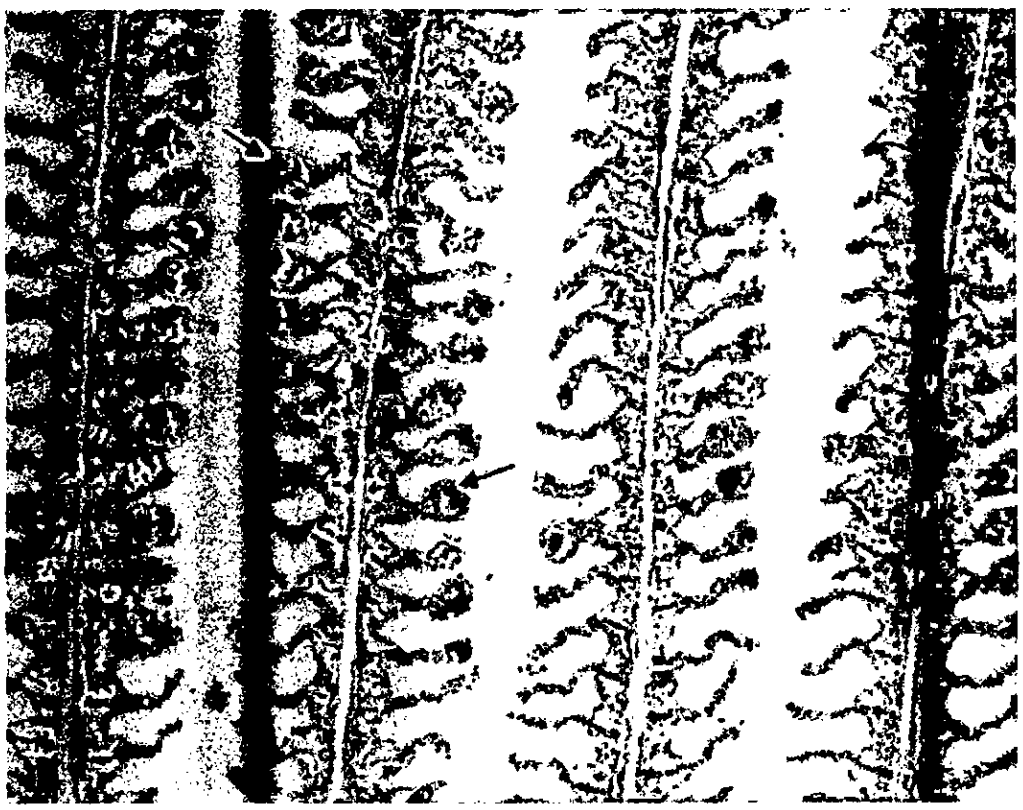

Fig. 6a. Severe telangiectasis and/or lamellar thrombosis in the gill

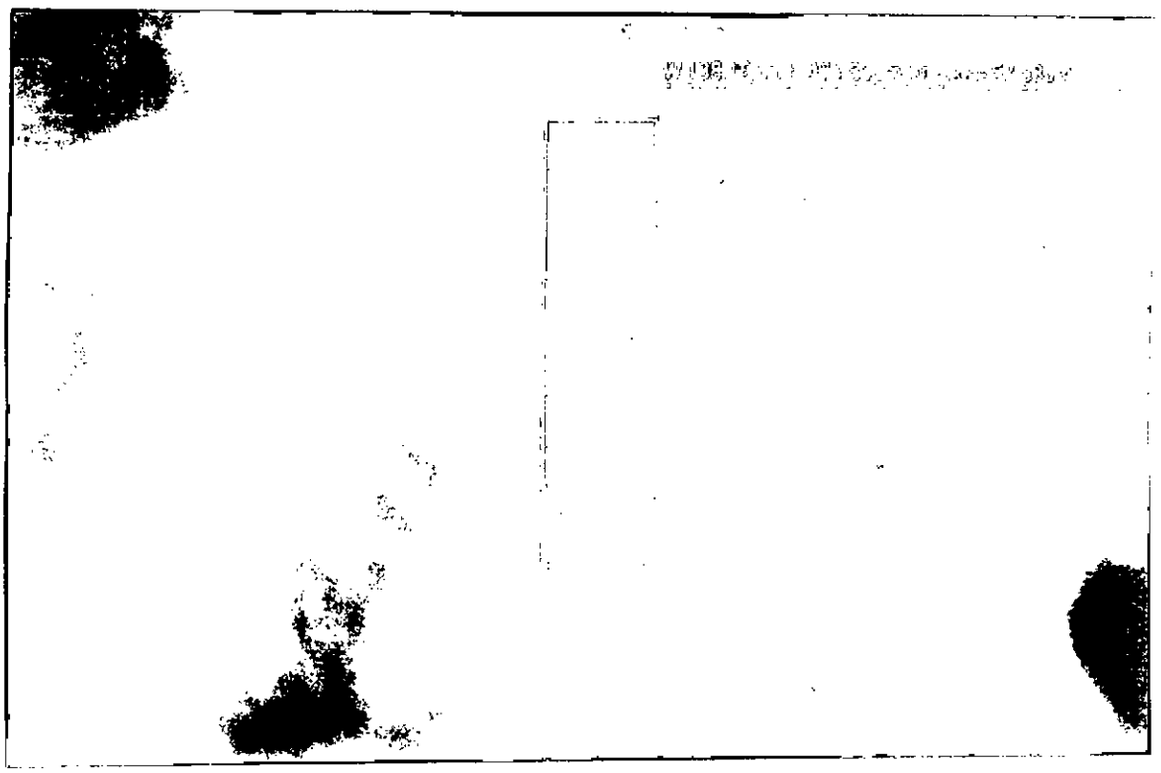

Fig. 6b. Hemorrhages and epithelial lifting in gills

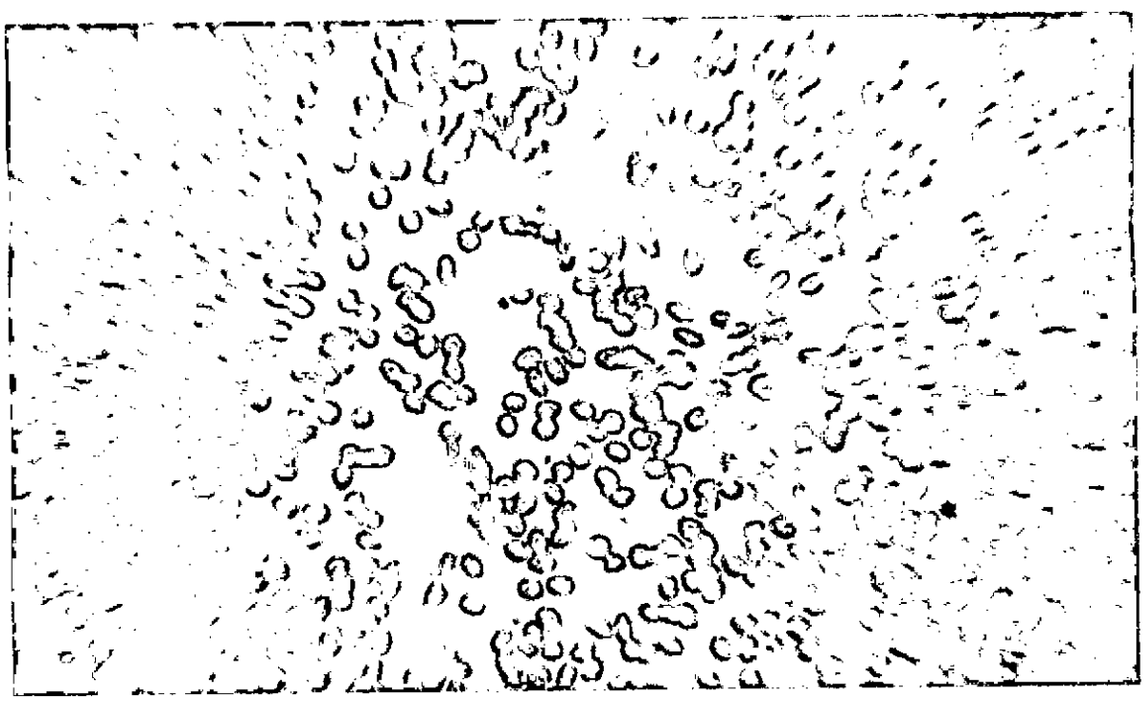

Fig. 6c. Numerous immature RBCs in the peripheral blood

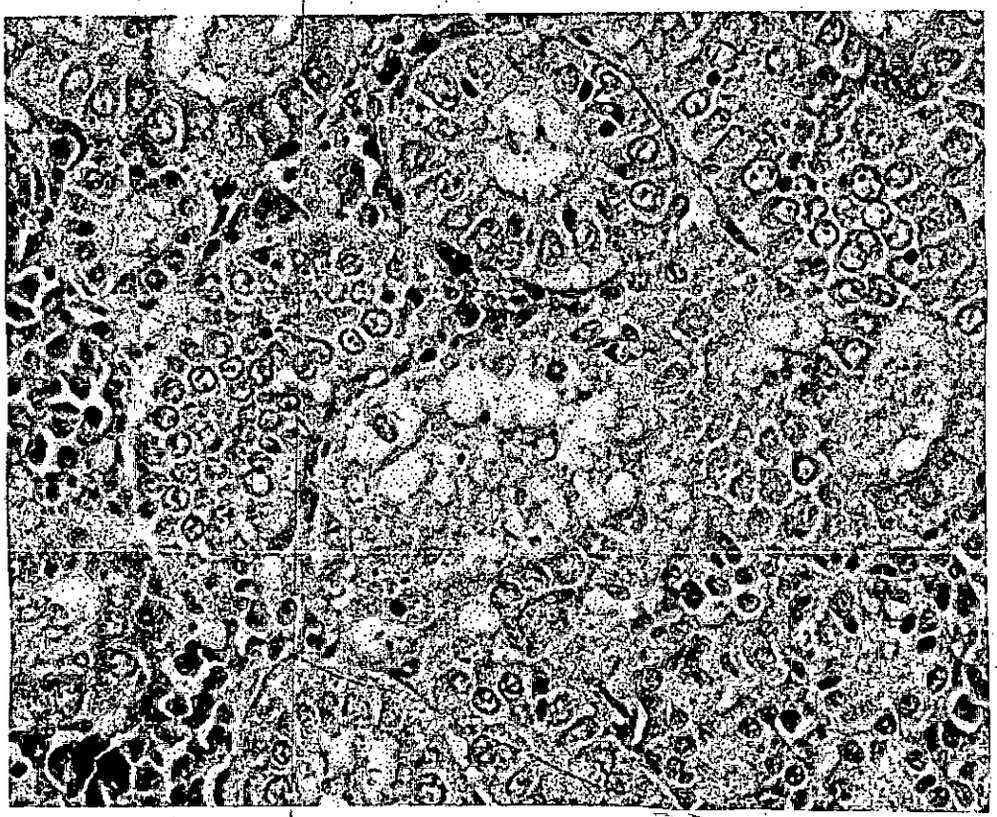

Fig. 6d. Extensive necrosis and hydropic degeneration of tubular epithelium

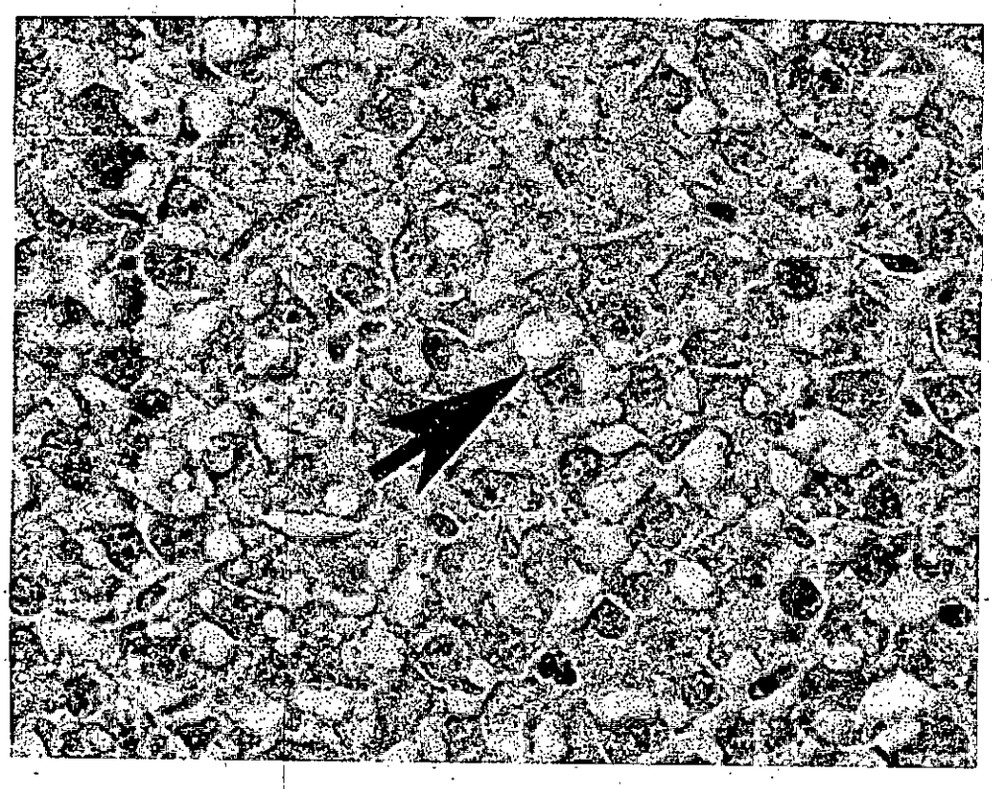

Fig. 6e. Vacuolar degeneration in the liver

12. Data Interpretation

The relationship between hydrogen sulphide (H_2S), ammonia (NH_3) and low dissolved oxygen (DO) in fish mortality is complex, involving interactions that significantly affect aquatic environments.

Hydrogen sulphide is a toxic gas produced by the anaerobic decomposition of organic matter. It is also produced by industrial effluents such as sulphate, Sulphur etc. There are industries which have hydrogen sulphide as a product and byproduct. In water, it is particularly harmful to fish due to the following reasons:

Toxicity: H_2S is highly toxic to fish. It interferes with cellular respiration by binding to hemoglobin which reduces the oxygen-carrying capacity of blood.

Low Concentration Effects: Even at low concentrations, H_2S can cause significant stress, leading to gill damage and reduced oxygen uptake.

Synergistic Toxicity

Ammonia and hydrogen sulphide both interfere with respiratory enzymes and gill function. Low DO exacerbates the situation by limiting the oxygen available for respiration and increasing the fish's susceptibility to toxins.

Stress and Mortality

Fish exposed to low DO, high ammonia and hydrogen sulphide simultaneously experience multiple stressors that overwhelm their physiological systems. The combined effects lead to increased mortality rates due to respiratory failure, cellular damage, and inability to detoxify harmful substances.

13. Summary

The interplay between hydrogen sulphide, ammonia and low dissolved oxygen created a highly stressful and lethal environment for fish and other aquatic fauna. Accumulation of excessive organic matter and nutrient input lead to eutrophication, causing low DO levels. Anaerobic conditions enhanced the production of hydrogen sulphide and ammonia, both of which are highly toxic to fish. The combination of these factors resulted in increased fish mortality due to compromised respiration and systemic toxicity. This natural situation might have worsened by the discharge of sulphur and sulphates in to the system, which ultimately ended up in hydrogen sulphide production. Apart from all these, there are industries known to discharge hydrogen sulphide directly into the water bodies.

14. Recommendations

- Implement effluent treatment and release regulations as per the norms of the National Green Tribunal. Emphasizes the essentiality of a dyke wall with a walk way along the Eloor -Edayar stretch.

- Real-time monitoring system for water quality parameters may be installed in the immediate upper and lower stretches of the Pathalam Regulator bridge and the shutter operations shall be aligned in tune with the data obtained.

- A Co-ordination Committee including members from various Departments and LSGD to be formed to regulate the operation of regulator cum bridge

- An AI assisted system for display and alert may be devised for issuing early warning signals to the stake holders in the downstream before opening the shutters.

- Biodiversity assessment and continuous monitoring of the upper and lower streams of Pathalam bridge may be initiated.

- Suitability of sites including water and sediments quality may be ascertained before licensing aquaculture activities.

- KUFOS may be entrusted to undertake an in depth study on fish and fisheries including aquaculture activities in the River Periyar.

- A special drive may be undertaken to clean Periyar and create mass awareness on water pollution with the participation of government and non-government agencies, public and the industries by using CSR Fund.

- Distribution of proper compensation to fishermen, allied workers and fish farmers in the River Periyar and other places wherein similar incidents were reported.

- Proper control and regulations may be followed in the use of pesticides and fertilizers in the agriculture sector.

- Proper domestic and commercial sewage treatment mechanism and control measures may be ensured.

- Unregulated discharges from the domestic and commercial establishments may be penalized.
- Engage local communities in monitoring efforts through citizen science initiatives.

15. References

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16. Acknowledgements

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Annexure 2. List of dead fishes observed		
Sl No	**Common name**	**Scientific name**
1	Pearlspot	*Etroplus suratensis*
2	Seabass	*Lates calcarifer*
3	Sole / flatfish	Pleuronectiformes
4	Needle Anchovy	*Ehirava fluviatilis*
5	Orange chromide	*Pseudetroplus maculatus*
6	Mossambique tilapia	*Oreochromis mossambicus*
7	Nile tilapia	*Oreochromis niloticus*
8	Mud crab	*Scylla spp*
9	Shrimp	Penaeids
10	Catfish	*Mystus armatus*
11	Scats	*Scatophagus argus*
12	Mangrove snapper	*Lutjanus argentimaculatus*
13	Filament barb	*Dawkinsia filamentosa*
14	Gobies	*Glossogobius giuris*
15	Lady fish	*Sillago sihama*
16	Glass fish	*Parambassis spp*
17	Giant travelly	*Caranx ignobilis*
There were many unidentifiable fishes seen in the video grabs of various visual media.		

Annexure I

KERALA UNIVERSITY OF FISHERIES AND OCEAN STUDIES
കേരള ഫിഷറീസ്-സമുദ്രപഠന സർവ്വകലാശാല
PANANGAD P.O., KOCHI 682 506, KERALA, INDIA

☎0484- 2703782, Fax: 91-484-2700337; *e-mail*: utypanangad@kufos.ac.in , registrar@kufos.ac.in *website*: www.kufos.ac.in

Preliminary Report on the Mass mortality of fishes in Periyar River on 21.05.2024

As per the letter No. JDFEKM/136/2024/B1 dated 22.05.2024, the Joint Director, Fisheries (Central Zone), Directorate of Fisheries, Govt. of Kerala has requested the University to conduct a detailed study on the mortality of fish in Periyar river occurred on 21.05.2024. The University as per order No. GA8/3907/2024 dated 22.05.2024 has constituted an Expert Committee with the following members to conduct detailed investigation on the matter and directed to submit a preliminary report on or before 24.05.2024.

Dr. Binu Varghese, Asst. Prof., Dept. of Aquaculture - Chairman
Dr. Anu Gopinath, Prof. & Head, Dept. of Aquatic Environment Management – Member
Dr. M.K. Sajeevan, Head, Dept. of Fisheries Resource Management - Member
Dr. Devika Pillai, Head, Aquatic Animal Health Management - Member
Dr. M..P. Prabhakaran, Asst. Prof., Dept. of Aquatic Environment Management – Member
Shri. Saneer N.S., Fishing Technology Assistant - Member
Dr. Dinesh Kaippilly Professor & Registrar i/c. - Convener

The Committee members visited the sites on 23.05.2024 and collected water and fishes. As per direction of Hon'ble Vice Chancellor, the University had already collected samples on 21.05.2024 for conducting detailed study on the matter.

After detailed study, the Committee found that the recent fish kills are linked to the events after the opening three shutters of Pathalam regulator in the afternoon hours of 20.5.2024. However, local environmentalists intimated minor fish kills in the upstream area of the regulator on the previous day. The mass mortality was seen in the downstream stretches from early morning on 21.05.2024 onwards and it extended about 10 km.

Initial mortality due to poor water quality parameters led to mass mortality of aquatic fauna for many kilometres from the source on 20.05.2024. The water quality got further deteriorated due to this mass mortality and the system is yet to recover. The inhabitant fishes and those stocked in more than 100 cages in the river got killed in the event.

The sources of pollutants may be of organic / inorganic origin or both and the analysis on these aspects is progressing at KUFOS labs. Certain critical tests will take at least a fortnight for getting the accurate results.

Basic water quality parameters like temperature, salinity, pH, dissolved oxygen and ammonia were analysed on the day of mass mortality and on the day after. These need to be compared with prior data of Pollution Control Board (PCB). PCB has promised that the data can be made available on 26.05.2024 and the comparative analysis will be incorporated in the final report. During the analysis, in general, lower dissolved oxygen level as low as 1.14 ppm, abnormally high values of ammonia i.e., 3.296 ppm & silicates to the level of 176.9 micro mole per litre, Sulphide to the level of 3.7859 ppm, Calcium to the level of 1250 ppm in some selected areas and low pH levels to the tune of 6.6 (which are undesirable traits as far as the water quality parameters for a healthy aquatic ecosystem are concerned) were observed. These can individually or collectively cause reduced health, stress and even mortality in aquatic organisms.

Analysis of hydrogen sulphide which is yet another critical undesirable water quality parameter which has the potential of killing fishes is also in progress in KUFOS labs. This will indicate the presence of organic load from certain specific origins. Likewise, ICPMS (Inductively Coupled Plasma Mass Spectrometry) analysis is also in progress at KIUFOS labs for finding out the presence of heavy metals, if any.

The analysis of CCTV footage from a few cage farm sites in Cheranelloor area showed very specific and most uncommon behavioural changes among the fishes both inside and outside the cages by midnight of 20.5.24. The fishes stocked in the cages were strugglingly jumping out of water with high rate of unrest. Even the air breathing fishes which are hardier than the normal fishes showed this kind of stress leading to mortality. Other aquatic organisms including shrimps, crabs and other invertebrates were also found dead in large number. This clearly indicates that the water must have contained some very undesirable compounds of organic or inorganic origin with the potential of making the fish highly stressed leading to sudden mortality. The fishes further showed sideways and erratic movements losing the balance in cages. Normally, the fishes gulp on the surface layers, if there exists anoxic conditions.

The people in the surrounding localities reported that they have observed erratic movements of fishes into the smaller canals or even to the embankments in order to escape from polluted waters. The mass mortality of fishes within a span of 2-3 hours indicates the presence of some pollutants in the water and our current studies will be able to throw light on these agents to a great extent.

Analysis of gills and gill filaments of the affected fishes showed necropsy and stained blood smears indicating the presence of certain toxic substances.

In this context, it is noteworthy to mention that during the meeting convened by Shri. P. Rajeeve, Hon'ble Minister for Industries on 23.05.2024, there was a pressing demand from the public for a comprehensive report on the biodiversity in the river with a comparative analysis of the old data. So, the need of the hour is to take precautionary measures to avoid such undesirable incidents in future.

It is further reported that there has been an allegation by local people on the duration / timing of shutter operations done during these days. Sudden mixing of upstream water and down stream water must have resulted in certain dynamic changes in the water quality. So, they are agitatedly demanding that strict monitoring and regulation by a competent authority with the support of scientific organisations is to be implemented to scientifically manage the opening and closing of shutters of the regulator bridge. Obviously, the operations of shutters need to be regulated by considering the water quality aspects of the upstream and downstream regions of the river using the data generated by KUFOS.

It is reported that there are at least half a dozen poultry meal factories in the region generating foul and irritating off odour resulting serious social concerns. The process of the plant operations, protocols and the associated inputs involved along with the products and bye products outflow are to be seriously investigated to find out the probable pollutants, if any.

It is also reported that at certain outlet points the committee observed some yellow coloured powder like substances suspecting the presence of direct release of sulphur into the water body.

It may be noted that fishes are reared at the density of 20 to 30 kg/m^3 in cages and even a slight change in water quality / health of the animal / environmental parameters / host pathogen dynamisms will contribute to the sudden death of fishes.

To conclude, KUFOS recommends a real time monitoring and regular sampling system in Periyar river throughout the year to avoid this kind of incidences in future. We can install water quality checking probes in different parts of river permanently which will enable continuous monitoring of water quality parameters. The University has successfully demonstrated its capacity in Vembanad lake monitoring studies which were compiled scientifically and handed over the same to the Hon'ble Chief Minister and Fisheries Minister of Kerala.

Hence, the committee unanimously recommends to allocate a special fund for Periyar River monitoring in terms of pollution, biodiversity index, carrying capacity and absolute ecosystem health.

Sd/-

Registrar i/c.