Journal of ENVIRONMENTAL Treatment Techniques

J. Environ. Treat. Tech.
ISSN: 2309-1185

Journal web link: https://dormaj.org/index.php/jett
https://doi.org/10.47277/JETT/10(4)302

Photodegradation and Toxicity Assessment of Lambda-Cyhalothrin Demonstrated by Histopathological and Biochemical Indices in Grass Carp

Mehwish Niaz, Mehwish Khalid, Nazish Iftikhar, Imran Hashmi*

Institute of Environmental Sciences and Engineering, School of Civil and Environmental Engineering, National University of Sciences and Technology, Sector H-12, Islamabad, 44000, Pakistan

Abstract

The unsustainable use of agrochemicals has impacted non-target environments mainly the aquatic ecosystem. Lambda-cyhalothrin (LCT), a common toxic insecticide has found its way to freshwater resources through runoff, leaching, and percolation. This has not only compromised the chemical integrity of the water reserve but also challenged the survival of aquatic life forms. In this study, grass carp (widely consumed fish in Pakistan) were exposed to environmentally relevant concentrations (0.75, 1, and 1.25µg/l) of LCT and consequent impacts were observed. Moreover, UV light was employed to assess the photodegradation of LCT within experimental tank waters. After 96hr co-exposure experiments, fish presented severe histopathological lesions in its vital organs such as muscles, gills brain, and liver. Furthermore, biochemical indices of fish serum like glucose, total protein, triglycerides, and amylase levels were also compromised resulting in hypoglycemia and fluctuating serum composition. UV light photo degraded LCT (at all concentrations) and three different UV exposure timings (10, 20, and 30 min) when observed through gas chromatography. Gas chromatography results showed that as the initial concentration of LCT increased percent removal or photodegradation decreased. Maximum removal of LCT (62%) was observed at the lowest exposure dose of 0.75µg/l and it decreased with the increasing initial concentration of LCT.

Keywords: Lambda-cyhalothrin, Histopathology, Serum biochemistry, Photodegradation

1 Introduction

Conventional agricultural practices and indiscriminate use of pesticides around the world are one of the leading causes of freshwater contamination. The residues of agricultural chemicals and pesticides drift toward surrounding water bodies through runoff causing water pollution. Agro and chemical waste from agricultural land is not only a serious threat to freshwater resources but also has severely degraded the water quality of Rawal Lake (1). Lambda-cyhalothrin (LCT) is an effective insecticide and is actively used for both pests (2) and vector control (3). It belongs to the pesticide class "pyrethroid" and is fat soluble (4). Widespread use of this insecticide for cotton and other crops has led to its escape to surrounding waters challenging the survival of aquatic life forms (5). Literature reports the detection of lambda-cyhalothrin in various water bodies across the world such as 0.00132-0.060µg/L in rivers of Brazil, 0.346µg/L in rivers of Greece, 0.797µg/L in various agricultural zones of the US and 0.983µg/L in various ecosystems of Costa Rica (6). Pyrethroids pose detrimental effects on aquatic life, affecting the marine population significantly (7). Within the aquatic systems, fish are the fundamental components and top consumers. Being in direct contact with water, they are entirely dependent on water for their existence. Therefore, they may be used as bioindicators for the evaluation of any contaminant within aquatic systems (8). The lipophilic nature of LCT (pyrethroids) enables quick access to several tissues, putting the central nervous system at huge risk (9). It was reported earlier (10) that pesticides not only circulate and accumulate within many living organisms but also migrate through the entire food chain. The residues of such toxins within fish tissues have been reported to be transmitted to the human food chain too, posing an indirect threat to the human population (11). Owing to the toxic potential of lambda-cyhalothrin, it is extremely vital to remove it from all facets of our environment, especially freshwaters. Most of the removal techniques are still challenged as they are not sustainable (12). Of all proposed techniques, photochemical degradation is by far considered the most efficient, fast, and environmentally sustainable process (13).

Grass carp (*Ctenopharyngodon idella*) was introduced to Pakistan for the first time, back in 1964 through China (14) and now it's one of the most consumed fish proteins in Pakistan (15). One of the most reliable techniques for toxicity assessment among fish is histopathological examination (16). It has also been reported that exposure to LCT causes extreme stress to fish and also alters its biochemical parameters (17). The biochemical analysis of fish serum may offer great insight (18) for ascertaining toxic impacts. The mode of action of organochlorine pesticides is by blocking the enzyme acetylcholinesterase which results in severe physiological malfunctioning (19). This study is aimed at assessing the toxic impacts of exposure to lambda-cyhalothrin on histopathological and biochemical parameters of fish serum. Moreover, a UV lamp was used to assess the possibility and

***Corresponding author:** Imran Hashmi, Institute of Environmental Sciences and Engineering, School of Civil and Environmental Engineering, National University of Sciences and Technology, Sector H-12, Islamabad, 44000, Pakistan, E-mail: imranhashmi@iese.nust.edu.pk

extent of photodegradation along with its photolytic by-products. The purpose of using UV light in this study is to propose a green technique for the removal of toxins from water resources to protect aquatic life from pyrethroids toxicity, which has not been done before.

2 Materials and Method

2.1 Chemicals

A commercial formulation of lambda-cyhalothrin from Orange Protection, available locally was procured for exposure experiments. It contains 25% lambda-cyhalothrin as the active ingredient. For biochemical indices, standard reagent kits were procured from Advanced Medical Products (AMP) diagnostics Austria and stored at 4°C. Pure standard of LCT was purchased from Sigma Aldrich (31058) with a purity of ≤95% and stored at -20°C. HPLC/GC grade n-hexane from MERCK was procured and used as a solvent for gas chromatography analysis.

2.2 Investigational fish specimen

Grass carp (*Ctenopharyngodon idella*) was selected as the test fish for this study. Its bulk purchase was done from Punjab Fish Hatchery, Rawal Town, Islamabad. They were transported within aerated polyethylene bags and immediately transferred to glass experimental tanks (dimension 3x2ft, capacity 80L) once within the laboratory. The average length of the fish was 6.08 ± 0.4cm and its weight was around 18 ± 0.3g. The tanks were filled with 30 liters of tap water and supplied with air pumps to regulate the supply of oxygen. The stock (100-150) fish were then acclimatized to the laboratory conditions for a week before the exposure investigation. During the acclimatization period, they were regularly fed with pellets of commercial fish feed. Tank water was also changed on alternate days with the help of suction pumps. Both, the stock as well as experimental fish were placed within the same laboratory environment during the study period. The handling and experimentation on fish were done by the recommendations prescribed in OECD test guidelines no. 203 fish acute toxicity testing (20).

2.3 Instrumentation

A chemistry analyzer, AMP PICCOS II was used for determining the biochemical parameters of fish. For UV irradiation, a mercury lamp with 11W and 245nm was purchased locally. Gas Chromatogram (GC 2010) was employed to analyze photodegradation samples. GC was equipped with column Teknokroma TR-520232 TRB-5MS (0.30m, 0.25mm, and 0.25µm) and an electron capture detector (ECD). The temperature of the oven was set from an initial temperature of 80^0C for 1 min and then increased gradually at the rate of 30^0C per min up to 160^0C and held for 2 min. Later, the temperature was raised to 260^0C at the rate of 3^0C per min and maintained. The temperatures of the injector and detector were programmed at 300 and 320^0C respectively.

2.4 In vivo exposure experiment

Environmentally relevant concentrations i.e. 0.75, 1, and 1.25µg/l of commercial grade lambda-cyhalothrin were prepared in distilled water and introduced within experimental tanks (1.5 x 2ft) with 30 liters of water. LCT was then degraded using UV lamps (aquarium UV sterilizer) for the specified time of 10, 20 and 30 mins (21). Lamps were placed inside experimental tank water containing an identified concentration of LCT and photodegradation was initiated. After stipulated times, the UV lamp was removed and a total of 12 randomly selected fish were introduced into the tank. The tanks were then covered with wooden boxes to reduce light interference and the experiment was continued for 96hrs. All of the experiments were conducted in triplicates along with control to obtain reproducible results.

2.5 Sample Collection

After 96hrs exposure, randomly selected fish was sacrificed, and four organs (gills, muscle, brain, and liver) were carefully extracted for histopathology. Each organ was placed in Bouin's fluid for 24hrs and then dehydrated using graded series of ethanol. Tissues were then cleared in xylene and infiltrated in paraffin. 4-6µm thick sections of paraffin blocks were prepared with the help of a rotary microtome and then stained with hematoxylin-eosin stain. These prepared tissues were then viewed under the optical microscope (ZEISS Primo Star, observed at 40x). The analysis of histopathological alterations was done with the help of a semi-quantitative method, where tissue damage due to any exposure is graded with the help of a score ranging from 0 (no damage) to 3 5, or 10, depending on the extent of damage (22). Biochemical indices were evaluated by sedating fish with the help of clove oil. After 10mins, fish blood was sampled through caudal puncture using a syringe and stored in yellow caped ETDA tubes containing gel, to activate serum separation. It was then homogenized at 4000rpm at 25^0C for 20mins. When the serum was separated, it was mixed with standard reagents according to the instructions in the manual and analyzed through a chemistry analyzer (23). For photodegradation investigation, immediately after UV exposure i.e. at 0 and 96hrs, 50ml of water was sampled for photodegradation analysis through gas chromatography. It was stored in 50ml centrifuge tubes covered with foil and stored at 4°C.

2.6 Standard stock solutions and chromatographic conditions

Standard stock solutions of lambda-cyhalothrin were prepared in n-hexane and analyzed through GC while fresh. The working solutions were prepared from stock solution, making a series of dilutions with concentrations from 0.5 to 1.5 µg/l and a linear calibration curve was obtained. Calibration of lambda-cyhalothrin was conducted using gas chromatography equipped with column HP 5 (30mm x 0.32mm ID coated with 0.25 um film and an electron capture detector. The temperature for the injector was 300°C while the detector was set at 320°C.

3 Results and Discussion

3.1 Histopathology

Each organ presented significant damage due to varying exposure dosages of UV-degraded lambda-cyhalothrin. The histopathology of control fish organs showed normal histology and was noted as a reference to estimate the extent of damage in exposed organs. Table 1 provides the detailed semi-quantitative count of two organs along the control organs.

3.1.1 Gills

Control group gills showed normal and symmetrically arranged lamellae without fusion or degeneration (Table 1). No cytoplasmic vacuolization or hyperplasia was observed in control gills. Control gills had healthy cells without an architectural loss (Fig 1).

Table 1: Semi-quantitative count of fish organs: (-) No damage; (+) Mild damage; (++)

Lesions	Control	0.75 (µg/l)	1.0 (µg/l)	1.25 (µg/l)
Gills				
Necrosis (N)	-	++	++	++
Lamellar fusion (LF)	-	++	+++	+++
Cytoplasmic Vacuolation (CV)	-	++	++	+
Lamellar degeneration LD	-	+++	+++	+++
Architectural loss (AL)	-	+++	++	+++
Hyperplasia (H)	-	++	+	+++
Muscles				
Degeneration	-	++	++	++
Necrosis	-	++	++	++
Splitting of muscle fiber (S)	-	+++	++	++
Degeneration	-	++	++	++
Brain				
Structural damage (SD)	-	+	++	++
Hemorrhage (H)	-	+	+	+++
Necrosis (N)	-	++	++	+++
Vacuoles (V)	-	++	++	+++
Liver				
Pycnotic nuclei (PN)	-	++	++	++
Vacuolization (V)	-	++	++	++
Necrosis (N)	-	++	++	+++
Bile stagnation (BS)	-	++	++	++

Moderate damage; (+++) Severe damage

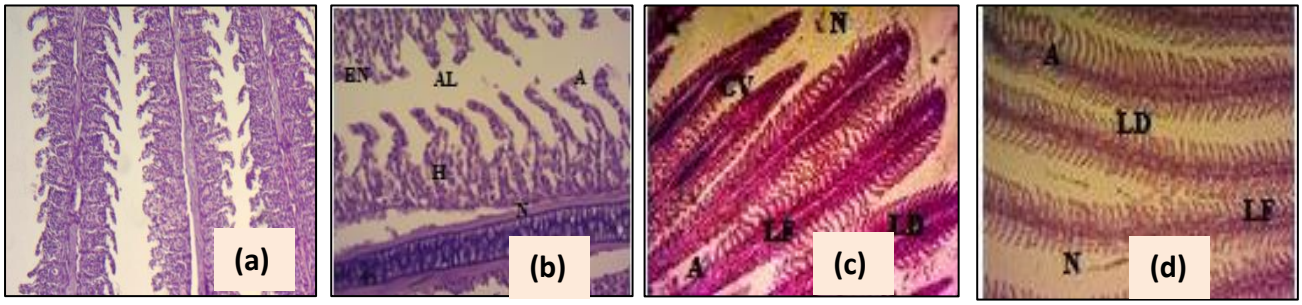
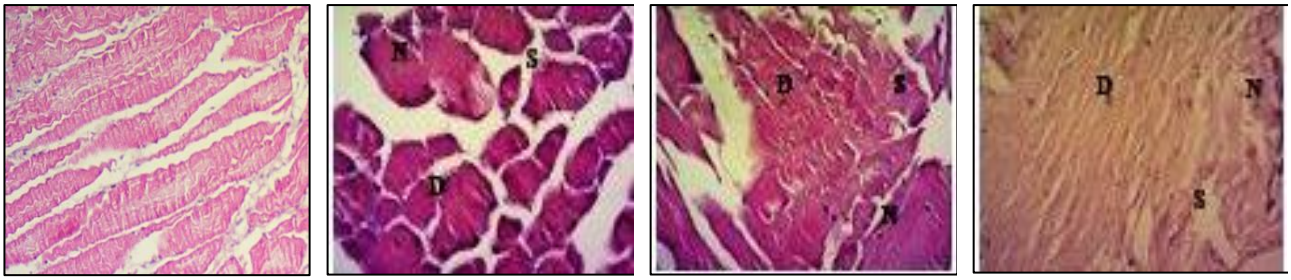


Figure 1: Histopathological alterations within fish gills after exposure. (a) Control showing normal healthy gills. (b) Gills exposed to 0.75 µg/l of LCT presented necrosis (N) and Lamellar fusion (LF). (c) Gills exposed to 1 µg/l of LCT presenting necrosis (N), lamellar fusion (LF), lamellar degeneration (LD), cytoplasmic vacuolization (CV), and architectural loss (A). (d) Gills exposed to 1.25 µg/l of LCT with maximum architectural loss (A), lamellar fusion (LF), lamellar diffusion (LD), and necrosis (N).

Treated group gills, which were treated with UV-degraded lambda-cyhalothrin showed significant damage with all three exposure concentrations (0.75, 1, and 1.25 µg/l) of lambda-cyhalothrin (Fig 1). Lamellar degeneration, fusion, and architectural loss were the most pronounced lesion (+++) caused by all three concentrations of lambda-cyhalothrin. Cytoplasmic vacuolization was more evident in 0.75 and 1 as compared to 1.25µg/l. Hyperplasia was the least frequent lesion (+) and was most extensive at the highest exposure dosage i.e. 1.25µg/l. Cytoplasmic vacuolization was more prevalent in lower exposure dosages (0.75 and 1µg/l) as compared to higher dosages (1.25µg/l). Furthermore, Gills are the characteristic organs of fish that are actively involved in respiration, acid-base balance, excretion, and osmoregulation. Therefore, With large surfaces directly exposed to water, gills are more prone to contaminants (24). With exposure to toxins, a defense mechanism activates resulting in hyperplasia and architectural loss (25). All these lesions have been reported in several other studies too, supporting the results of the current study (26, 27). The stressed fish eventually died when exposed to higher concentrations. The induced stress impairs the respiratory system which was the consequence of the result of LCT on the gills in agreement with the results of previous study (28).

3.1.2 Muscles

Control group muscles presented normal and healthy muscle fibers without any sign of necrosis or degeneration. Muscle fibers in healthy unexposed fish were packed tightly together and arranged in a homogenous manner (Fig 2). Treated group muscle histology was significantly damaged. Multiple lesions such as necrosis, degeneration, and splitting of muscle fibers were observed within exposed fish muscles (Fig. 2). The most pronounced effect (+++) observed in exposed fish muscles was splitting and degeneration of muscle fibers. At 0.75, fibers were damaged the most in comparison to other two concentrations. Necrosis and degeneration progressed with time and was amplified at 96 hrs.



(a) (b) (c) (d)

Figure 2: Histopathological alterations within fish muscles after exposure. (a) Control showing normal healthy muscles. (b) Gills exposed to 0.75 µg/l of LCT showed a lesser degree of splitting of muscle fibers (S), necrosis (N), and degeneration (D). (c) Gills exposed to 1 µg/l of LCT. (d) Gills exposed to 1.25 µg/l of LCT presented maximum degeneration (D) followed by necrosis (N) and splitting of muscle fibers (S).

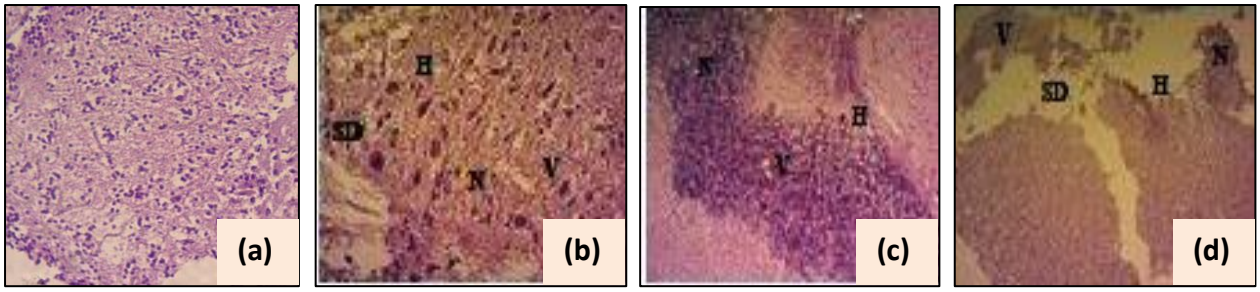


Figure 3: Histopathological alterations within fish brain cells after exposure. (a) Control showing normal healthy brain cells. (b) Gills exposed to 0.75 µg/l of LCT with necrosis (N), vacuolization (V), hemorrhage (H), and structural degeneration (SD). (c) Gills exposed to 1 µg/l of LCT. (d) Gills exposed to 1.25 µg/l of LCT.

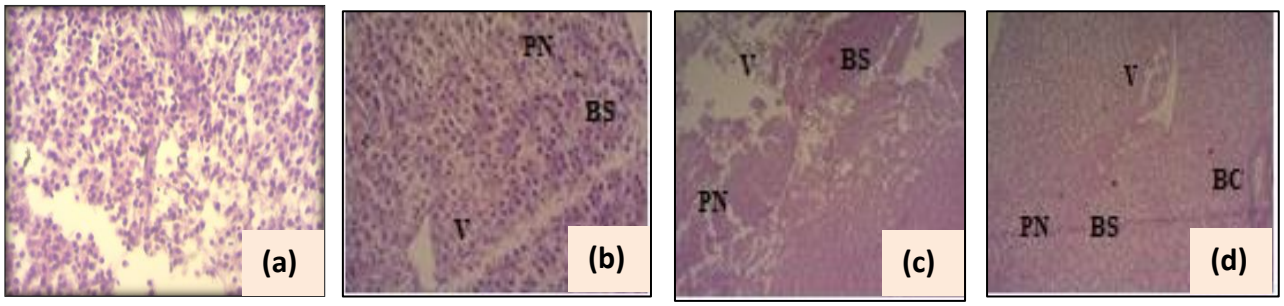


Figure 4: Histopathological alterations within the fish liver after exposure. (a) Control showing normal healthy hepatocytes. (b) Gills exposed to 0.75 µg/l of LCT with vacuolization (V), pycnotic nuclei (PN), and bile stagnation (BS). (c) Gills exposed to 1 µg/l of LCT. (d) Gills exposed to 1.25 µg/l of LCT.

With time, muscle fibers started degenerating and losing the densely packed formation. Necrosis was also observed within fibers, depicting the destructive impacts of the exposed toxin. Fish is an efficient source of protein where fish muscles being the direct and rich source. To assess the vulnerability of humans to pesticide contamination, it is important to evaluate the extent and nature of damage caused to fish muscle as a result of being exposed to pesticides. Bioaccumulation of pesticides is found maximum in muscles as reported in literature (29) and he has also mentioned the degeneration of muscles affected by the toxicants. Similar alterations were observed in another study with co-exposure to pesticides and heavy metals (26).

3.1.3 Brain

Control group fish brain cells displayed normal healthy cells. There were no recognizable signs of damage (Fig. 3). Treated group brain cells presented serious degenerative changes owing to the neurotoxic nature of lambda-cyhalothrin. Lesions observed in the treated group included necrosis, structural damage, and vacuolization within the cells (Fig.3). Severe necrosis and vacuolization (+++) of brain cells were observed in the fish that was administered the highest dose exposure i.e. 1.25µg/l. The structural damage was not a very persistent lesion (+) as it only appeared mildly in all three exposure dosages. Hemorrhage was the most persistent lesion caused by the neurotoxin with maximum damage at the highest exposure dosage. Brain is the controlling center of vertebrates. Fish when living in contaminated waters, the pollutants reach deep into organs such as the brain through blood circulation (30). Synthetic pyrethroids such as lambda-cyhalothrin usually obstruct normal neuronal physiology by disturbing the ion exchange channels (31). Structural damage and vacuolization of brain cells is one of many histological responses toward exposure to toxins (32).

3.1.4 Liver

Control group liver histology appeared normal without any pathological changes. The hepatocytes appeared healthy and positioned amid blood capillaries also known as sinusoids (Fig. 4). Treated group hepatocytes displayed serious histological alterations due to toxins. Common lesions among all three concentrations were the appearance of pycnotic nuclei and vacuolization within the cytoplasm (Fig. 4). Necrosis and bile stagnation was most pronounced (+++) at the highest exposure dosage i.e. 1.25. At the lowest dosage, the most recurrent anomaly was pycnotic nuclei. In some photomicrographs, blood congestion was observed depicting severe damage to the

hepatocytes. Histopathological examination of the liver is considered to be an accurate method for toxicological studies (16). The liver is the organ largely affected by contaminants and its physiology gets compromised while carrying out detoxification (25). The liver tends to accumulate toxins, making it more prone to atrophy as compared to other organs (33). Vacuolization and necrosis were some of the distinct anomalies found in treated group livers, which are similar to the results reported earlier (34). Likewise, congestion in central veins, aggregation of melanomacrphages, and observation of multiple and moderate-size vacuoles were seen in the liver tissue of treated fish reported in previous study (35).

3.2 Biochemical analysis

To ascertain toxicity in fish organs and physiology, a biochemical analysis may offer great insight (18). Lambda-cyhalothrin, being a neurotoxin may cause significant disturbances within the fish body.

3.2.1 Glucose

Glucose levels tend to be the most sensitive entity of any organism under stress, where greater stress exhibits higher glucose levels (36). Within the initial 24hrs, there was a significant decrease in glucose levels as compared to the control. Glucose level then increased from 24 to 48hrs, indicating that the fish is under stress. Hyperglycemia or an increase in glucose level may be considered a physiological stress response of fish to cope with the increase in energy demand (37). After 48hrs, the glucose levels decreased slightly and again till 72hrs, with minor changes up to 96hrs. A similar trend was depicted at all three concentrations of lambda-cyhalothrin (Figure 5) and corroborated by results reported in previous study (38).

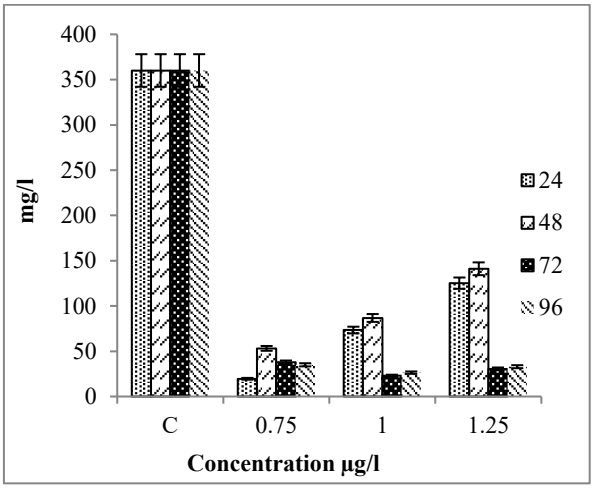


Figure 5: Temporal variation of glucose within fish serum (0-96hr)

3.2.3 Total Protein

Serum protein is of clinical importance for physiological evaluation. Since the majority of serum protein is produced within the liver, its level can be taken as an indicator of any probable liver impairment. There was a decrease in total protein levels within the first 24hrs which is a standard response to toxicity. Previous study reported that a decrease in total protein due to pesticide exposition could be attributed to protein metabolism and synthesis within the liver (36). A similar decreasing trend was reported in previous study (39). From 24-96hrs, there was an intermittent increase and decrease response of total protein levels (Figure 6).

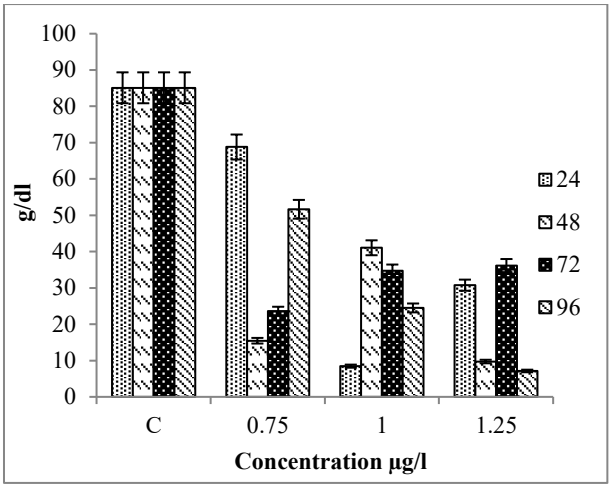


Figure 6: Temporal variation of total protein within fish serum (0-96hr)

All three concentrations depicted very less variations during the entire experiment, however, at 1 (µg/l), a sudden increase in protein level was observed at 48hrs. exposure to toxic chemicals impairs the albumin and globulin ability to regulate total protein levels which may explain this unusual spike (40). This anomaly may also be attributed to changes in environmental factors such as temperatures and dissolved oxygen levels. Similar results were reported in previous study (41). Moreover, When fish are stressed, they may experience oxygen deficiency, which might impair their protein level (23).

3.2.4 Triglycerides

Triglyceride refers to the fat content within the fish serum. After a considerable initial decrease in triglycerides, compared to control, a general increase was observed mostly till 72hrs and then a decrease in the last 24 hrs. An increase of triglycerides or hyper triglyceramic conditions of fish under stress could be attributed to the damage to vital organs, as reported in previous study (10). Another study reported that liver cells help release specific enzymes in the blood that are responsible for converting triglycerides into fatty acids and glycerol. Once they are damaged due to toxic exposures, triglyceride remains non-metabolized hence causing hyper triglycemia (42). The decrease of triglycerides observed in the last 24 hrs of the experiment can be due to lethal damage to the kidney of fish caused by LCT (or pyrethroids) also reported in previous study (43). It was also reported that irregularity within the serum enzyme activity of the liver may also cause hypo triglycemia (44).

3.2.5 Amylase

Amylase is an enzyme that helps in breaking down carbohydrates and complex sugar molecules (45). Initially, there was a significant drop in amylase levels within 24hrs after which an inconsistent pattern was observed till 96 hrs. Asadi et al., 2006 reported that amylase levels are primarily determined by the variations in energy levels in fish bodies. As fish face stress conditions due to toxic exposure, the energy demand for the body increases, causing a decline in amylase levels and vice versa. This explains the irregular levels of amylase throughout 96 hr experiments (46). The figure presents the trend.

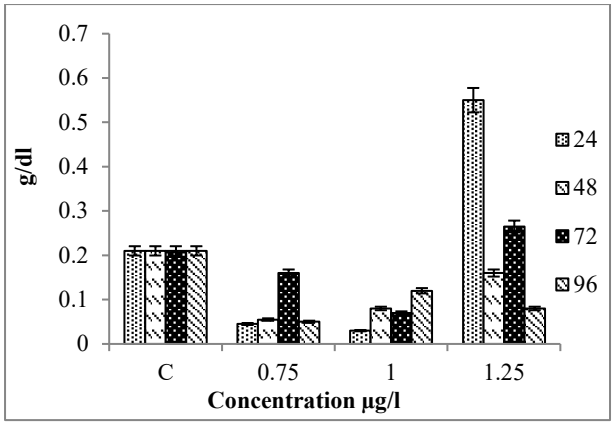


Figure 7: Temporal variation of triglycerides within fish serum (0-96hr)

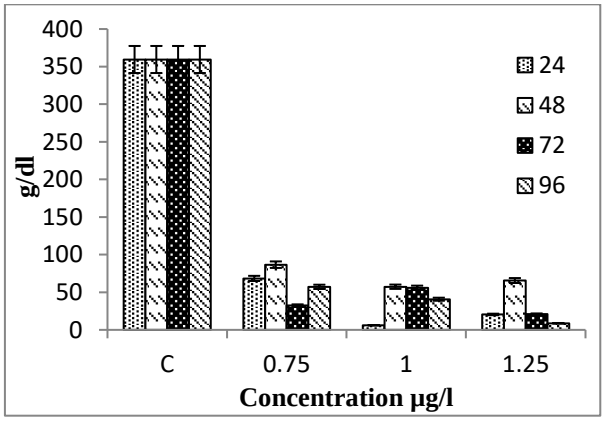


Figure 8: Temporal variation of amylase within fish serum (0-96hr)

3.3 Analysis of photodegradation of Lambda-cyhalothrin

Pure standards of six successive concentrations of lambda-cyhalothrin (0.5-1.5 µg/l) were prepared in pure GC/HPLC grade n-hexane to determine its retention time. The resulting chromatogram (Fig 9) presented a sharp peak at 6.0903 ± 0.079507 minutes showing the elusion of pure lambda-cyhalothrin. This time was then considered as its retention time.

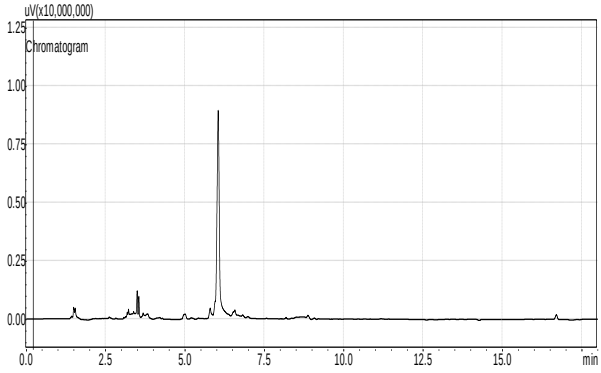


Figure 9: Chromatogram of lambda cyhalothrin standard

With the help of standard lambda-cyhalothrin, 4 serial dilutions were prepared and passed through a gas chromatogram. Using the peak area of pure standard (Fig 10), a standard calibration curve was plotted with the R^2 value of 0.9884.

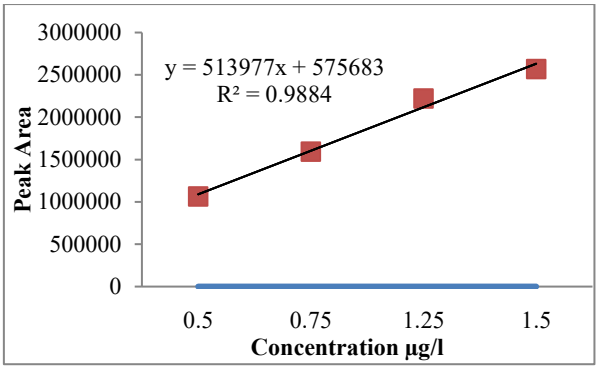


Figure 10: The standard curve between peak area and concentrations of LCT

To ascertain photodegradation all collected samples were run through a gas chromatogram and the peak area was compared. For determining the amount of analyte, the response factor of every concentration of LCT was calculated using the following formula (47):

Response Factor = Peak Area of Standard / Amount of standards

Based on this calculation, the average response factor was calculated, which was then further used to calculate the amount of analyte using the following formula:

Amount of Analyte = Peak Area of sample / Response Factor

Table 2 details the amount of analyte calculated with different concentrations of LCT as well as varying UV exposure times.

Table 2: Amount of analyte

Time (min)	Concentration µg/l		
	0.75	**1**	**1.25**
10	0.28	0.47	0.6
20	0.336	0.48	0.99
30	0.48	0.65	1.05

After determining the amount of analyte, the following formula (48) was used for calculating the amount of LCT that was degraded as a result of UV lamp exposure.

$R\ (\%) = C_0 - C_t / C_0 * 100\%$

where R presents pesticide residue (%), C_0 is the initial concentration and C_t is the final concentration of the analyte.
A uniform and inverse trend of photodegradation were observed at three different concentrations of lambda-cyhalothrin. Table 2 shows a decreasing trend of percent removal concerning time. However, as the initial concentration of LCT increased, the degradation amount decreased. More exposure to UV resulted in lesser degradation of lambda-cyhalothrin and vice versa. Varying the voltage and type of UV lamp used for photodegradation may result in the complete removal of LCT. The photodegradation trend is expressed in the figure. A similar photodegradation trend was presented in another study in which photodegradation was found to be dependent on the UV exposure time (49).

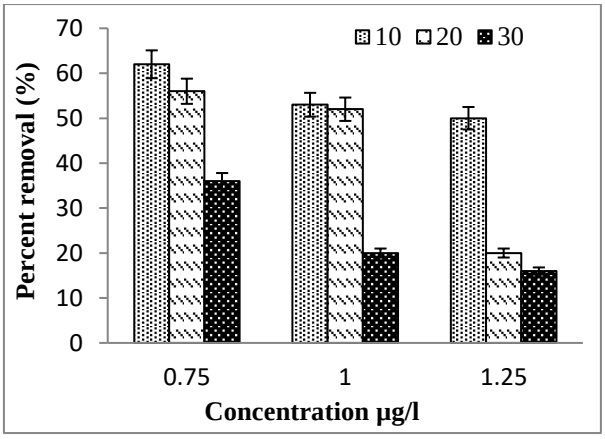


Figure 11: Photodegradation of Lambda cyhalothrin

4 Conclusion

In this study, pesticides affect fishes directly through accumulation in their bodies that causes quite severe disabilities or impairment in metabolic, physiologic, and structural changes in various organs. Chronic exposure to environmentally relevant concentrations of this toxic compound revealed serious histopathological lesions. Gill lesions included necrosis, curling of secondary gill lamellae, hyperplasia, and architectural loss, while muscles were degenerated presenting necrosis and split muscle fibers. However, the semi-quantitative scoring did not present any trend due to which a dose-response relationship was not developed. The biochemical parameters like glucose and total protein levels presented significant fluctuations, hypoglycemia or reduced glucose levels are strong indicators of fish under stress. Total protein levels depicted an inconsistent trend which may be considered as a stress response from fish to adjust to the toxic environment. UV light photo degrades lambda-cyhalothrin in an aqueous medium. The samples analyzed through gas chromatography exhibited a considerable decrease in the amount of analyte, evidencing photodegradation. The maximum removal efficiency was observed at the lowest exposure dosage of 0.75µg/l and UV time of 10min. Hence, the photodegradation of toxic compounds through UV light may be employed as the least intrusive technology to get rid of toxic composites from our water reserves to preserve the sanctity of aquatic ecosystems.

Acknowledgments

This study was carried out under the Master's research funds at the National University of Sciences and Technology and the National Research Program for Universities (NRPU) (5995/Federal/NRPU/R&D/HEC/206). The authors are extremely thankful to the Environmental Microbiology and Toxicology Research and Teaching Laboratories at the Institute of Environmental Sciences and Engineering, School of Civil and Environmental Engineering, National University of Sciences and Technology, Islamabad, Pakistan.

Ethical issue

Authors are aware of and comply with, best practices in publication ethics specifically about authorship (avoidance of guest authorship), dual submission, manipulation of figures, competing interests, and compliance with policies on research ethics. Authors adhere to publication requirements that the submitted work is original and has not been published elsewhere in any language. Also, all procedures performed in studies involving human participants were following the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. All procedures performed in this study involving animals were following the ethical standards of the institution or practice at which the studies were conducted.

Competing interests

The authors declare that no conflict of interest would prejudice the impartiality of this scientific work.

Authors' contribution

All authors of this study have a complete contribution to data collection, data analyses, and manuscript writing.

References

1. Ghumman AR. Assessment of water quality of Rawal Lake by long-time monitoring. Environmental Monitoring and Assessment. 2011;180(1):115-26.
2. Xie J, Wang P, Liu J, Lv X, Jiang D, Sun C. Photodegradation of lambda-cyhalothrin and cypermethrin in aqueous solution as affected by humic acid and/or copper: intermediates and degradation pathways. Environ Toxicol Chem. 2011;30(11):2440-8.
3. Arslan A, Rathor HR, Mukhtar MU, Mushtaq S, Bhatti A, Asif M, et al. Spatial distribution and insecticide susceptibility status of Aedes aegypti and Aedes albopictus in dengue affected urban areas of Rawalpindi, Pakistan. J Vector Borne Dis. 2016;53(2):136-43.
4. Guedegba NL, Imorou Toko I, Agbohessi PT, Zoumenou B, Douny C, Mandiki SNM, et al. Comparative acute toxicity of two phytosanitary molecules, lambda-cyhalothrin and acetamiprid, on Nile Tilapia (Oreochromis Niloticus) juveniles. J Environ Sci Health B. 2019;54(7):580-9.
5. Xia H, editor Removal of Lambda-Cyhalothrin by Water Hyacinth (Eichornia Crassipes). 2008 2nd International Conference on Bioinformatics and Biomedical Engineering; 2008 16-18 May 2008.
6. Vieira CED, dos Reis Martinez CB. The pyrethroid λ-cyhalothrin induces biochemical, genotoxic, and physiological alterations in the teleost Prochilodus lineatus. Chemosphere. 2018;210:958-67.
7. Galadima M, Singh S, Pawar A, Khasnabis S, Dhanjal DS, Anil AG, et al. Toxicity, microbial degradation and analytical detection of pyrethroids: A review. Environmental Advances. 2021;5:100105.
8. Bin Dohaish AJ. Impact of some heavy metals present in the coastal area of Jeddah, Saudi Arabia on the gills, intestine and liver tissues of Lutjanus monostigma. Journal of Environmental Biology. 2018;39:253-60.
9. Kumar A, Sharma B, Pandey RS. Alterations in nitrogen metabolism in freshwater fishes, Channa punctatus and Clarias batrachus, exposed to a commercial-grade λ-cyhalothrin, REEVA-5. Int J Exp Pathol. 2012;93(1):34-45.
10. Lushchak VI, Matviishyn TM, Husak VV, Storey JM, Storey KB. Pesticide toxicity: a mechanistic approach. Excli j. 2018;17:1101-36.
11. Hasan Z, Ghayyur D, Hassan Z, Rafique S. Histomorphometric and Hematological Profile of Grass Carp (Ctenopharyngodon idella) during Acute Endosulfan Toxicity. Pakistan Veterinary Journal. 2015;35.
12. Colombo R, Ferreira TCR, Alves SA, Carneiro RL, Lanza MRV. Application of the response surface and desirability design to the Lambda-cyhalothrin degradation using photo-Fenton reaction. Journal of Environmental Management. 2013;118:32-9.
13. Liu PY, Li B, Liu HD, Tian L. Photochemical behavior of fenpropathrin and λ-cyhalothrin in solution. Environ Sci Pollut Res Int. 2014;21(3):1993-2001.
14. Naeem M, Zuberi A, Salam A, Ashraf M, Elahi N, Ali M, et al. Induced spawning, fecundity, fertilization rate and hatching rate of Grass carp (Ctenopharyngodon idella) by using a single intramuscular injection of ovaprim–C at a fish hatchery Faisalabad, Pakistan. AFRICAN JOURNAL OF BIOTECHNOLOGY. 2011;10(53):11048-53.

15. Khalid M, Naeem M. Proximate Analysis of Grass Carp (Ctenopharyngodon idella) from Southern Punjab, Pakistan. Sarhad Journal of Agriculture. 2018;34.
16. Hadi A, Alwan SF. Histopathological changes in gills, liver and kidney of fresh water fish, Tilapia zillii, exposed to aluminum. International Journal of Pharmacy & Life Sciences. 2012;3(11).
17. Bacchetta C, Rossi A, Ale A, Campana M, Parma MJ, Cazenave J. Combined toxicological effects of pesticides: A fish multi-biomarker approach. Ecological Indicators. 2014;36:532-8.
18. Agrahari S, Pandey KC, Gopal K. Biochemical alteration induced by monocrotophos in the blood plasma of fish, Channa punctatus (Bloch). Pesticide Biochemistry and Physiology. 2007;88(3):268-72.
19. Mahdi B. Physiological Dysfunction in Fish After Insecticides Exposure. In: Stanislav T, editor. Insecticides. Rijeka: IntechOpen; 2013. p. Ch. 4.
20. OECD. Test No. 203: Fish, Acute Toxicity Test2019.
21. Djouaka R, Soglo MF, Kusimo MO, Adéoti R, Talom A, Zeukeng F, et al. The Rapid Degradation of Lambda-Cyhalothrin Makes Treated Vegetables Relatively Safe for Consumption. Int J Environ Res Public Health. 2018;15(7).
22. Raskovic B, Poleksic V. Fish histopathology as biomarker in ecotoxicology. 2017. p. 155-81.
23. Iftikhar N, Hashmi I. Assessment of immunohematological, hematological and biochemical responses in cultivable fish Cyprinus carpio exposed to an antibiotic sulfamethoxazole (SMX). Journal of Water and Health. 2020;19(1):108-19.
24. Peebua P, Kruatrachue M, Pokethitiyook P, Kosiyachinda P. Histological Effects of Contaminated Sediments in Mae Klong River Tributaries, Thailand, on Nile tilapia, Oreochromis niloticus. ScienceAsia. 2006;32.
25. Camargo M, Martinez C. Histopathology of gills, kidney and liver of a Neotropical fish caged in an urban stream. Neotropical Ichthyology - NEOTROP ICHTHYOL. 2007;5.
26. Arulraj JS, Pandurengan P, Arasan S, Gopalrajan S, Paulraj J. Acute Toxicity of Lamda-Cyhalothrin and the Histopathological Changes of Gill and Liver Tissues of Tilapia (Oreochromis niloticus). Journal of Coastal Research. 2019;86(sp1):235-8, 4.
27. Fernandes CE, da Silveira AW, do Nascimento Silva AL, de Souza AI, Povh JA, Dos Santos Jaques JA, et al. Osmoregulatory profiles and gill histological changes in Nile tilapia (Oreochromis niloticus) exposed to lambda-cyhalothrin. Aquat Toxicol. 2020;227:105612.
28. Alalibo K, Patricia UA, Ransome DE. Effects of Lambda Cyhalothrin on the behaviour and histology of gills of Sarotherodon melanotheron in brackish water. Scientific African. 2019;6:e00178.
29. Kumar Maurya P, Malik DS, Kumar Yadav K, Gupta N, Kumar S. Haematological and histological changes in fish Heteropneustes fossilis exposed to pesticides from industrial waste water. Human and Ecological Risk Assessment: An International Journal. 2019;25(5):1251-78.
30. Lakshmaiah G. A Study on the effect of organophosphorus insecticide phorate on brain histopathology of the common carp Cyprinus carpio. 2016.
31. Sabra F, Mehana E-S. Pesticides Toxicity in Fish with Particular Reference to Insecticides. Asian Journal of Agriculture and Food Sciences. 2015;3:40-60.
32. Lakshmaiah G. Brain histopathology of the fish Cyprinus carpio exposed to lethal concentrations of an organophosphate insecticide phorate. 2017.
33. Kaoud H, El-Dahshan A. Bioaccumulation and histopathological alterations of the heavy metals in Orechromis niloticus fish. Nat Sci. 2010;8.
34. Bhuvaneshwari R, Padmanaban K, Babu Rajendran R. Histopathological Alterations in Muscle, Liver and Gill Tissues of Zebra Fish Danio Rerio due to Environmentally Relevant Concentrations of Organochlorine Pesticides (OCPs) and Heavy Metals. International Journal of Environmental Research. 2015;9(4):1365-72.
35. Singh U, Pandey RS. Fertilizer industry effluent induced hematological, histopathological and biochemical alterations in a stinging catfish, Heteropneustes fossilis (Bloch, 1794). Environmental and Sustainability Indicators. 2021;10:100110.
36. Fırat O, Cogun HY, Yüzereroğlu TA, Gök G, Fırat O, Kargin F, et al. A comparative study on the effects of a pesticide (cypermethrin) and two metals (copper, lead) to serum biochemistry of Nile tilapia, Oreochromis niloticus. Fish Physiol Biochem. 2011;37(3):657-66.
37. Jyothi B, Narayan G. Certain pesticide-induced carbohydrate metabolic disorders in the serum of freshwater fish Clarias batrachus (Linn.). Food Chem Toxicol. 1999;37(4):417-21.
38. Perveen S, Hashmi I, Khan R. Evaluation of genotoxicity and hematological effects in common carp (Cyprinus carpio) induced by disinfection by-products. J Water Health. 2019;17(5):762-76.
39. Khan A, Shah N, Muhammad M, Khan MS, Ahmad MS, Farooq M, et al. Quantitative Determination of Lethal Concentration Lc₅₀ of Atrazine on Biochemical Parameters; Total Protein and Serum Albumin of Freshwater Fish Grass Carp (Ctenopharyngodon idella). Pol J Environ Stud. 2016;25(4):1555-61.
40. Abdel-Daim MM, Dawood MAO, Elbadawy M, Aleya L, Alkahtani S. Spirulina platensis Reduced Oxidative Damage Induced by Chlorpyrifos Toxicity in Nile Tilapia (Oreochromis niloticus). Animals (Basel). 2020;10(3).
41. Gopal V, Parvathy S, Balasubramanian PR. Effect of Heavy Metals on the Blood Protein Biochemistry of the Fish CYPRINUS CARPIO AND ITS USE AS A BIO-INDICATOR OF POLLUTION STRESS. Environmental Monitoring and Assessment. 1997;48(2):117-24.
42. Verma A, Prakash S. EFFECT OF ARSENIC ON SERUM BIOCHEMICAL PARAMETERS OF A FRESH WATER CAT FISH, MYSTUS VITTATUS2020.
43. Borges A, Scotti LV, Siqueira DR, Zanini R, Amaral F, Jurinitz DF, et al. Changes in hematological and serum biochemical values in jundiá Rhamdia quelen due to sub-lethal toxicity of cypermethrin. Chemosphere. 2007;69(6):920-6.
44. Atli G, Ariyurek SY, Kanak EG, Canli M. Alterations in the serum biomarkers belonging to different metabolic systems of fish (Oreochromis niloticus) after Cd and Pb exposures. Environmental Toxicology and Pharmacology. 2015;40(2):508-15.
45. Bhilave M, Nalawade V, Kulkarni J. Amylase activity of fingerlings of freshwater fish Labeo rohita fed on formulated feed. International Journal of Fisheries and Aquatic Studies. 2014;2(1):53-6.
46. Asadi F, Halajian A, Pourkabir M, Asadian P, Jadidizadeh F. Serum biochemical parameters of Huso huso. Comparative Clinical Pathology. 2006;15(4):245-8.
47. Zafar R, Bashir S, Nabi D, Arshad M. Occurrence and quantification of prevalent antibiotics in wastewater samples from Rawalpindi and Islamabad, Pakistan. Sci Total Environ. 2021;764:142596.
48. Weng X, Cai W, Lan R, Sun Q, Chen Z. Simultaneous removal of amoxicillin, ampicillin and penicillin by clay supported Fe/Ni bimetallic nanoparticles. Environ Pollut. 2018;236:562-9.
49. Mbugua J, Mbui D, Gn K. Investigation of Rate of Photo Degradation of Chlorothalonil, Lambda Cyhalothrin, Pentachlorophenol and Chlropysis on Tomato and Spinach. Modern Chemistry & Applications. 2017;05.