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Bisphenol A Used in Plastic Industry Negatively Affects Wild Vimba Bream (*Vimba vimba*)

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Abstract

Used as a component of polycarbonate plastics and epoxy resins in the modern industrial world, bisphenol A (BPA) is one of the highest volume produced industrial chemicals worldwide. BPA causes important environmental problems including endocrine disrupting effect on the organisms in aquatic environments. This study focused on the histopathological, oxidative and hematological effects of long-term BPA exposure on wild vimba bream (*Vimba vimba*) for the first time. Twenty-five fish stocked in each aquarium and exposed to 1000 µg/L BPA for four weeks. Hematological parameters of fish did not differ significantly compared to control group. The antioxidant activity of liver and gill tissues created a significant partial difference between the groups. According to the histopathological studies, intense hyperplasia and necrosis were detected in the gill tissues of the fish exposed BPA. In addition, hypertrophy and epithelial lifting symptom were partly observed. Vocalization and hypertrophic cells was determined in the liver tissues. In conclusions, this study revealed that BPA had an oxidative and especially histopathologically adverse effects on *V. vimba*, even though it did not have a hematological effect on the treated fish. Although BPA has adverse effects on the health of aquatic organisms, future studies should focus on the residue in fish meat and risk assessment on human health.

Introduction

Vimba bream (*Vimba vimba*) is known as a critically endangered species in the grayling and barbel region of the rivers in Europe (Schludermann et al., 2009). It has been noted that the population of *V. vimba*, which previously lived abundantly in the barbel regions of the streams in the Czech Republic, decreased in the 20th century, including in other countries (Lelek, 1987; Spurný et al., 2004). This decrease can be explained by various natural and anthropogenic environmental decomposition factors encountered during the anadromous migration (Lusk et al., 2005). Furthermore, *V. vimba*, a vulnerable and sensitive species, has been accepted as an endangered species in many European countries (Popovic et al., 2013). Therefore, aquaculture studies have been initiated in order to enrich the natural population of this species and awareness programs have been prepared to prevent its extinction (Lepič et al., 2019).

Migratory natural fish species such as *V. vimba* encounter many polluting factors during their migration. One of them is plastic pollution, which is generally observed in natural water resources (Aytan et al., 2021; Eryaşar et al., 2022). Plastic production is increasing day by day with an annual production of approximately 360 million tons worldwide (Gedik & Eryaşar, 2020). Future projections predict that the estimated plastic

production will be 33 billion tons in 2050 (Rochman et al., 2013). Such a high amount of production brings the concept of "plastic pollution in natural water resources and the environment" (Jambeck et al., 2015). Plastics do not only create pollution alone, but also cause the release of different phenolic groups into the environment, which are plastic precursors (Minaz et al., 2022a). As an important phenolic group, bisphenol A (BPA) is a diphenyl derivative used in the production of many plastic materials, such as baby bottles, epoxy resins and thermal paper (Bjerregaard et al., 2007; Vandenberg et al., 2009). Therefore, BPA has the potential of bioaccumulation in humans and other organisms through multiple exposures, such as ingestion, inhalation, or dermal contact (Rochester, 2013). Many studies have been published in which BPA is considered as a xenoestrogen and its reproductive effects on the endocrine system of organisms have been determined (Diler et al., 2022; Lindholst et al., 2000; Rattan et al., 2017; Smarr et al., 2016). BPA is a chemical compound of high concern by the European Union due to its reproduction toxicity (ECHA, 2017).

BPA is discharged to the aquatic ecosystem through sewage waters, industrial effluents and landfill leachate channels (Gatidou et al., 2007; Yamamoto et al., 2001). There are various studies on the presence of BPA not only in natural waters (Flint et al., 2012; Huang et al., 2017; Staples et al., 2018), but also in the muscle/meat and tissues of fish such as zebrafish, sea bass, and mullet (Eser et al., 2022; Lee et al., 2015; Mita et al., 2011; Toptancı et al., 2022; Wong et al., 2017). However, the effect of BPA on marine and estuarine native species is still not very well known (Naveira et al., 2021). Therefore, there is a need for studies on the multidimensional effects of BPA, especially for natural fish species (Holeyappa et al., 2021).

Hematological studies provide rapid results to investigate the effects of various toxic substances on organisms (Akram et al., 2021a). In addition, antioxidant activity is important for the determination of oxidative stress. Tissue degradation by toxic substances on organisms can be confirmed by histological studies (Kurtoglu et al., 2016). In this study, long-term BPA exposure on anadromous *V. vimba* was investigated. Therefore, we aimed to examine hematological parameters, antioxidant activity and histopathological effects in *V. vimba* exposed to BPA.

Material and Methods

Experimental Design and Water Quality

Trials were established in Aquaculture Application and Research Center, Recep Tayyip Erdogan University, Rize, Turkey. Fish in each trial were collected from Kürtün Dam Lake in Gümüşhane, Turkey (40°39'47"N-39°8'49"E). Twenty-four *V. vimba* (24.35±8.1 g/fish) specimens were stocked in 60 L volume aquarium 1 week before the start of the trial for adaptation. Within the scope of the study, the treatment group exposed to 1000 µg/L BPA (Sigma Aldrich, Inc. St. Louis, MO, USA; purity>99%) and the control group for four weeks were designed as triplicate (Figure 1). As we highlighted in our previous studies, 1000 µg/L BPA concentration has the potential to be toxic to fish (Minaz et al., 2022a; Minaz et al., 2022b). To eliminate the effect of stock density on antioxidant activity and blood parameters, the water volume in each aquarium was gradually reduced each week according to the stable stock density. Fish were fed at 1% of the biomass in the aquarium every 2 days to adversely affect the water quality. A 12h light and 12h dark photoperiod was applied. All aquariums were

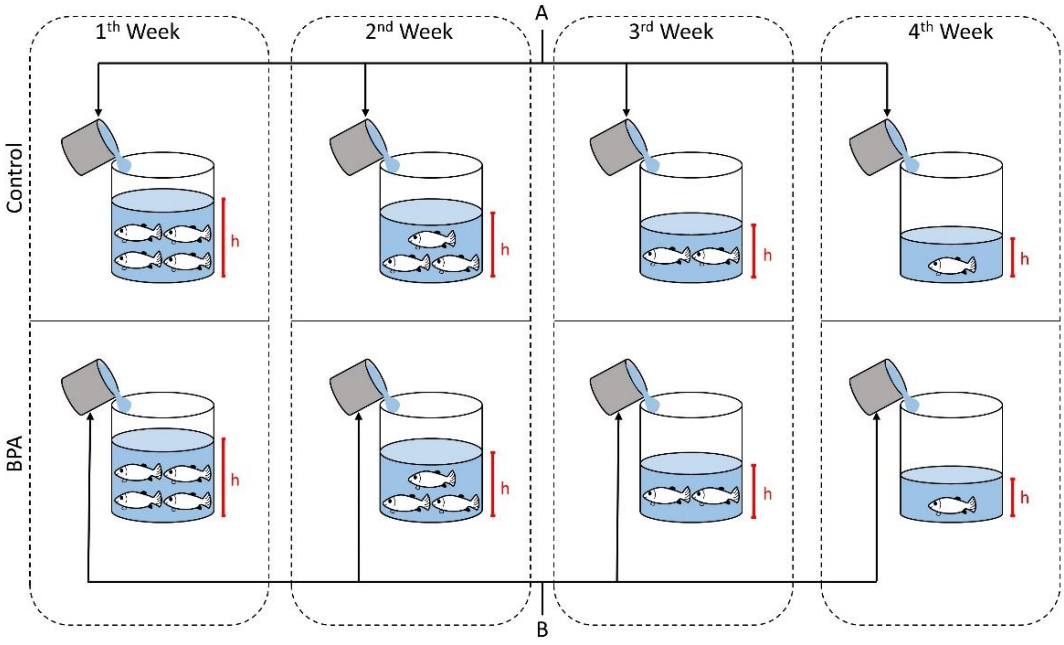

Figure 1. Schematic diagram of BPA exposure. A: water without BPA is renewed daily up to 20% of the volume, B: water with BPA is renewed daily up to 20% of the volume, h: the water volume has been reduced every week according to the stock density.

aerated with an external air pump and air stone. BPA solution was prepared by dissolving in 100% ethanol and stored at 4°C (Nane et al., 2021).

Groundwater with ‰3 salinity was used in the study. In each aquarium, 20% of the volume was changed every day. Water quality parameters were recorded daily. Water temperature (T; °C), pH, electrical conductivity (EC; µS/cm), total dissolved solids (TDS; mg/L) and dissolved oxygen (DO; mg/L) were measured in site with a portable multi-parameter (Hach, HQ40D 58258- 00). In addition, turbidity was measured in vitro using a turbidity meter (WTW, TURB550).

Hematological Parameters

Blood samples were taken from the caudal veins of the adult fish (total 72 fish from treated and control group during 4 weeks) with a 2.5 ml syringe on the same day every week. Fish were anesthetized with clove oil (60 mg/L) before blood sampling (Akram et al., 2021a). Sampled bloods were stored in EDTA K3 tubes for a short time (2 hours). Red blood cells (RBC) and white blood cells (WBC), hematocrit ratio (HCT), hemoglobin concentration (HGB) were monitored by automatic hematological blood counter (Prokan-6800VET, Shenzhen, China) (Fazio, 2019). In addition, mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC) values were recorded as erythrocyte indices. The automatic blood counter was calibrated according to *V. vimba* before trial, and then the results were verified by manual method. The automatic hematological assay counts and sizes blood cells according to electrical impedance method. In addition, HGB was detected by colorimetric method. The count principle of WBC and RBC in device is based on the measurement of changes in electrical resistance produced by a particle passing through an aperture sensor. On the other hands, adding lyse in the blood, the red blood cell is rapidly broken down and release hemoglobin. Device calculates other hematological parameters according to MCV, RBC, HGB and HCT. Hematological parameters were measured weekly in triplicate under the control of a single individual.

Oxidative Stress Indicators

Superoxide dismutase (SOD), catalase (CAT), and glutathione-peroxidase (GSH–Px) as antioxidant activity and malondialdehyde (MDA) as an oxidant indicator were investigated for liver and gill tissues. Tissues sampled weekly were washed with the physiological saline. Afterwards, the tissues were treated in 3 ml of Tris-HCL buffer solution and stored at -80°C. Gill and liver were homogenized in a motor-driven tissue homogenizer (IKA Ultra-Turrax T25 Basic; Labortechnic, Staufen, Germany). Centrifugation for 10 minutes at a rotation speed of 2000 g was used to precipitate cells and nuclei. SOD and CAT were measured in supernatants with spectrophotometric method (ShimadzuUV-1601; Shimadzu, Kyoto, Japan) (Aebi, 1974; Woolliams et al., 1983). GSH-Px was detected by spectrophotometric method using a commercial kit from Randox in an auto analyzer (Olympus AU 2700, Japan). The method was carried out according to previous study (Paglia & Valentine, 1967). MDA activity was detected from the homogenate using the double heating method (Draper & Hadley, 1990). The units for SOD, CAT, GSH-Px and MDA are stated as units per mg protein, µmol H_2O_2 metabolized per mg protein per minute, units per mg protein, and µmol per mg protein, respectively.

Histological Examinations

At the end of the fourth week, the fish were anesthetized to collect samples from the gill and liver tissues (Akram et al., 2021a). Samples were fixed in 10% neutral buffered formalin for one day. Afterwards, tissues were moved to 50% ethanol for two days. Tissues were contacted with alcohol and xylene series. Afterwards, the samples were paraffinized at +65 °C for 1 night and blocked. After the paraffin has cooled, samples with a thickness of 5 microns were taken to microscope slide from paraffin-blocked tissues using a microtome (Leica RM2125RT, United States). Slides were again subjected to xylene series and stained by hematoxylin and eosin. Finally, stained tissues on the slides were examined by light microscopy (Leice DM500, United States) and photographed by high resolution camera (Leica ICC50, United States) (Kurtoglu et al., 2016). A semi-quantitative system was used for the quantitative assessment of histopathological alterations (Bernet et al., 1999) (Table 1). Accordingly, histopathological alterations are considered in five different groups. However, among these groups, only regressive and progressive changes were observed in the current study. Each reaction pattern was

Table 1. Histopathological evaluation tools for gill and liver organs developed by Bernet et al. (1999). Importance factor (1-3) is composed of the respective organ, the reaction pattern and the alteration. Score value is a liker rating scale ranging from 0 to 6

Organ	Reaction pattern	Alteration	Importance factor	Score value	Index
Gill	Regressive changes	Architectural, structural alterations	IF_1=1	SV_1=0-6	GI_{RC}
		Necrosis	IF_2=3	SV_2=0-6	
	Progressive changes	Hypertrophy	IF_3=1	SV_3=0-6	GI_{PC}
		Hyperplasia	IF_4=2	SV_4=0-6	
Liver	Regressive changes	Necrosis	IF_5=3	SV_5=0-6	LI_{RC}
	Progressive changes	Hypertrophy	IF_6=1	SV_6=0-6	LI_{PC}

determined according to different alterations in the organs. Histopathological assessment tools scale different alterations on organs with a importance factor ranging from 1 (minimal) to 3 (marked). The score value of the alteration in each organ is determined with a likert scale between 0 (no change) and 6 (very severe). The final value for each lesion is obtained by multiplying the importance factor and the score value. The final value for each pattern is obtained by summing the evaluation scores of the lesions belonging to current pattern.

Statistical Analyzes

All data were presented in mean ± standard deviation. Kolmogorov Smirnov test was applied to measure the normality of variance in all data-set. Parametric statistical tests were consider depending on results obtained from normality of variance for all analyzes. The significant differences between the control and BPA groups for each week were determined using Student's *t*-test. A maximum p value of 0.05 was considered in order to interpret statistical differences. All data-set were analyzed by SPSS 25 software package for Windows (Version 25, IBM Corp., Armonk, New York, USA).

Results

Water Quality

Temperature (T), pH, dissolved oxygen (DO), electrical conductivity (EC) and turbidity as water quality parameter was measured daily (Table 2). Water quality parameters in the treated and control group were similar during the experiment ($p>0.05$). The high EC is due to groundwater with brackish characteristics, which is suitable for *V. vimba*. As the turbidity increased slightly, the feeding frequency gradually decreased over time. However, no mortality was observed until the end of the study.

Hematological Analyzes

Hematological parameters (WBC, RBC, HGB, HCT, MCV, MCH, and MCHC) were presented weekly in Table 3. There were no significant differences between BPA and control group for all parameters ($p>0.05$). In addition, MCV value decreased over time for both BPA and control groups. In contrast, MCHC in control and BPA groups value increased weekly.

Antioxidant and Oxidant Parameters

Figure 2 shows the antioxidant activity of gill and liver tissues in *V. vimba*. The MDA activity of gill tissue in BPA group was significantly higher than control group in third and fourth week. However, no difference was observed between the treated groups for liver tissue ($p<0.05$). The SOD activity in third week for liver tissue and in fourth week for gill tissue were affected significantly by BPA negatively ($p<0.05$). In addition, BPA was significantly lower in the CAT activity of liver tissue at the third week ($p<0.01$). Although the GSH-Px activity of gill tissue during four weeks were lower in BPA group, a significant difference was observed only in the first week ($p<0.05$).

Histopathological Findings

The effect of BPA, an important xenoestrogen, on *V. vimba* was investigated histopathologically. At the end of the experiment, liver and gill tissues of fish in the control and BPA groups were compared. Only epithelial lifting was observed in the gill tissues for control group. Epithelial lifting degradation showed similar results in

Table 2. Water quality parameters for control and BPA groups during the study

	Control	BPA
T (°C)	19.0±0.1	18.8±0.2
pH	7.2±0.4	7.3±0.4
DO (mg/L)	6.5±0.7	5.7±1.5
EC (mS/cm)	5.2±0.1	5.2±0.1
Turbidity (NTU)	9.8±7.6	9.9±8.1

Table 3. Weekly hematological parameters of *V. vimba* for control and BPA groups

	1th Week		2nd Week		3rd Week		4th Week	
	Control	BPA	Control	BPA	Control	BPA	Control	BPA
WBC (10^3/µL)	11.5±2.7	11.2±2.1	12.3±1.6	10.5±1.9	11.5±2.2	12.0±0.4	10.3±2.1	11.4±1.0
RBC (10^6/ µL)	1.9±0.7	2.0±0.1	2.3±0.1	1.9±0.3	1.9±0.1	2.1±0.1	1.9±0.2	1.9±0.1
HGB (g/dL)	13.0±2.6	12.8±1.4	14.1±1.3	11.4±1.9	12.4±1.6	12.2±0.3	11.4±1.4	12.5±0.3
HCT (%)	21.9±6.9	24.1±1.5	24.4±2.5	21.5±2.7	19.2±0.8	20.3±0.9	18.5±3.3	18.5±1.1
MCV (fL)	115.9±13.6	120.2±1.2	107.4±3.6	106.1±0.8	100.9±4.0	97.1±1.0	97.6±3.4	96.2±1.4
MCH (pg)	61.2±2.2	63.3±4.4	60.0±2.6	58.6±1.5	65.0±8.0	58.3±1.0	63.0±4.7	64.9±2.9
MCHC (g/dL)	56.5±3.2	52.8±3.6	53.7±2.8	53.6±2.0	64.5±5.8	60.1±0.9	64.8±3.6	67.6±3.8

the BPA group (Table 4). In addition, it is noteworthy that hyperplasia and necrosis are intense in the gill tissues in the BPA group. In addition, low-intensity signs of hypertrophy were also observed. Cell sizes and densities in the liver tissue of the control group are not at abnormal levels. However, especially intense vacuolization and hypertrophy symptoms were observed in the liver tissues in the fish treated with BPA. When evaluated with a statistically developed scale, regressive and progressive changes in both gill and liver tissues were observed significantly higher in BPA groups ($p<0.01$) (Table 5).

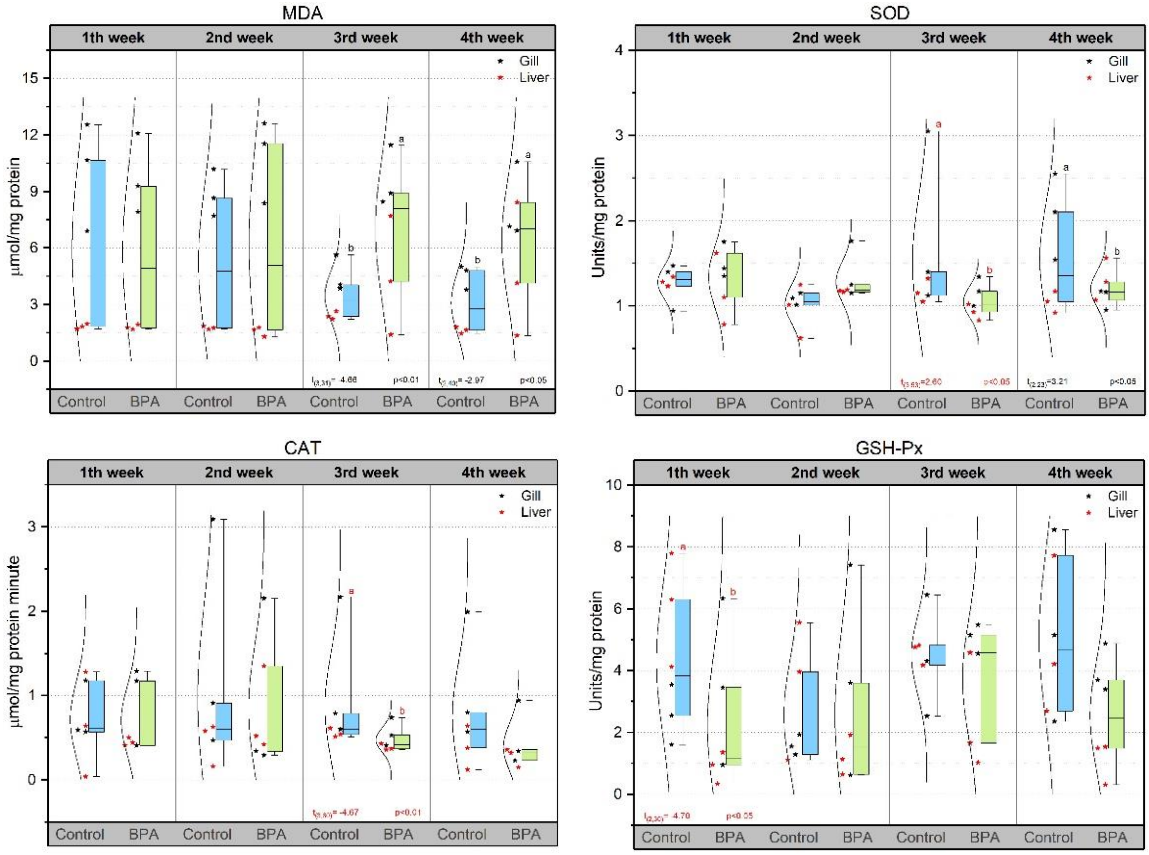

Figure 2. Weekly antioxidant activities of gill and liver tissues for control and BPA groups. Significant differences were presented by red and black letters (a and b; red for liver and black for gill).

Table 4. Severity of different histopathological changes in gill and liver tissues of *V. vimba*

Tissues	Symptoms	Severities	
		Control	BPA
Gill	Epithelial lifting	+++	+++
	Hypertrophy	-	++
	Hyperplasia	+	++++
	Necrosis	-	+++
Liver	Vacuolization	-	++++
	Hypertrophy	-	+++

(-):none, (+):mild, (++):moderate, (+++):severe, (++++):very severe

Table 5. The reaction indices of histological alteration in control and BPA groups. RC: regressive changes, PC: progressive changes, OI: Organ index

		RC	PC	OI
Gill	Control	6.58±0.88*	2.50±0.67*	9.08
	BPA	9.73±1.07*	9.56±1.43*	19.29
	t value	-7.156	-14.087	
Liver	Control	0.66±0.40*	0.27±0.16*	0.93
	BPA	7.74±0.96*	2.81±0.34*	10.55
	t value	-21.403	-21.053	

* Significant differences between groups for each reaction pattern depending on T-test ($p<0.01$).

Discussions

The exposure of anthropogenic pollutants such as BPA for fish can be always possible in natural waters. Aquatic organisms are exposed to these chemicals by ingestion and dermal contact pathway. In this context, this study for *V. vimba* focused on hematological outputs, antioxidant activity and histopathological findings under BPA exposure condition. While turbidity was high at the beginning of the study, it started to decrease after the first week sampling. Most probably, this is because at the beginning of the study the fish may have produced a mucus secretion to resist the toxic substance (Shephard, 1994). The reason for the high standard deviation is associated with the rapid decrease in turbidity over time. The fish in the BPA group may have stopped secreting mucus as they adapted to the environment. According to another approach, goblet cells that secrete mucus may have degraded (Minaz et al., 2022a). However, no conclusive results were found regarding this in histological examinations. Other water quality parameters showed similar results between groups. The electrical conductivity was observed to be partially high due to the salinity of the groundwater because it was aimed to create a suitable living environment for estuarine fish species such as *V. vimba*.

Hematological and biochemical variables well reveal the stress that may occur as a result of exposure to xenobiotic pollutants (Wei et al., 2018). In the current study, hematological parameters were examined weekly. No significant difference was observed for long term exposure between BPA and control groups. These results are similar to our previous 96-hour short term study (Minaz et al., 2022a). In another study, WBC and HGB values did not show a significant difference between the BPA groups and the control group in the first four weeks (Akram et al., 2021b). However, all blood parameters were affected by BPA, especially after 45 days of exposure. In toxicity studies, exposure duration is as important as the concentration of the toxic substance. On the other hand, the effect of the species in the alteration of hematological parameters is also remarkable (Ranzani-Paiva et al., 2003). Accordingly, we emphasize the hematological resistance of *V. vimba* against BPA. Therefore, the determination of reference values for each species is very important for the discussion of studies (Fazio, 2019). The RBC, HGB, WBC and MCH values observed in the present study showed similar results to previous studies on *V. vimba* (Lepic et al., 2014; Norousta & Mousavi-Sabet, 2013).

Even if blood parameters as a stress indicator provide rapid results, oxidative stress should be analyzed especially for chronic exposures. As the balance between reactive oxygen species (ROS) production and depletion changes, oxidative stress occurs and causes degradation of cellular biomolecules (Di Giulio et al., 1989). Especially hydroxyl radicals cause high oxidative damage biologically and toxicologically in a short span of time (Valavanidis et al., 2006). The change in MDA, SOD, CAT and GST levels is sufficient to assess the overall oxidative stress status in an organism (Sharma & Chadha, 2021). Decreases in SOD, CAT and GSH-Px levels indicate poor detoxification capacity. Conversely, high levels of MDA are problematic for antioxidant activity. This is the first study to evaluate the antioxidant activity of wild V. vimba after long-term exposure to 1000 µg/L BPA in natural waters. MDA activity revealed significant differences in the gill tissues of the fish in the BPA group, especially for the third and fourth week. Although similar differences were observed in the liver tissue, it did not show a significant difference especially in the BPA group due to the high variance. It has been previously reported that BPA increases MDA activity in zebrafish (*Danio rerio*) liver tissue (Sun et al., 2019). Similarly, high MDA was noted in zebrafish exposed to 1000 µg/L BPA (Wu et al., 2011). While the SOD activity of the gill tissues showed a significant difference at the end of the fourth week, the SOD activity of the liver tissue created oxidative stress in the third week. Similar antioxidant suppression was observed in the liver tissue of medaka fish (*Oryzias latipes*) exposed to 100 µg/L BPA (Minghong et al., 2011). In another study, SOD activity for the chronic term decreased in the gill tissue of bighead carp (*Aristichthys nobilis*), especially exposed to high BPA concentration (Akram et al., 2021b). Similar results have been observed in other previously studies (Afzal et al., 2022; Liu et al., 2020; Sharma & Chadha, 2021). Although the CAT and GSH-Px activities of the BPA group showed lower results in liver tissues, a significant difference was observed only in the first week for both (third for CAT and first for GSH-Px). We attribute that the antioxidant activity is forced to catalyze the H_2O_2 radical. BPA affected the CAT activity in liver tissues of grass carp (*Ctenopharyngodon idella*) (Faheem & Lone, 2017). Similar to our study, it has been reported that especially 1000 µg/L BPA suppresses MDA, SOD, CAT and GSH-Px in fish (Qiu et al., 2016). Partially occurring antioxidant activity in the BPA group is associated with degraded tissues and energy expenditure against oxidative stress.

Histological examination is an important biomarker that allows to evaluate a wide range of toxicity levels (Moeller, 1985). In addition, histological results reveal the relationship between molecules and organism levels (Srivastava et al., 1990). Because the gills are the sensitive entry point of contaminants into the body, gill histology provides important clues about the impact from water quality (Patnaik et al., 2013). The gills are the main organ for osmoregulation and excretion (Xing et al., 2012). On the other hand, the liver is a critical organ for detoxification and any degradation in the liver tissue may cause compromised functions in fish (M. Faheem et al., 2019). Therefore, the current study focused on the effects of BPA on these two organs. While only epithelial lifting was observed as gill degradation in the control group, the same severity of epithelial lifting was also observed in the BPA group. Hyperplasia, which was intensely observed in the BPA

group, covered the appearance of epithelial lifting. Compared to the control group, hyperplasia and congestion between the secondary lamellae was remarkably intense in the BPA group. In addition, intense necrosis was observed throughout the gill. Finally, partial hypertrophic symptoms were observed, especially at the edges of the secondary lamellae. The hyperplasia effect of BPA exposure on gills was reported in a previous study (Elshaer et al., 2013; Minaz et al., 2022b). Congestion in the secondary lamella caused by hyperplasia may have been a result from BPA exposure (Akram et al., 2021b). Necrosis degradation has been noted in the gills of goldfish exposed to BPS (Nane et al., 2021). In another study examining the toxic effects of xenobiotics, hyperplasia, congestion and hypertrophy were observed, especially in the secondary lamella of the gill tissues (Lima et al., 2018). In our previous study, severe epithelial lifting was observed in *O. mykiss* that exposed 1000 µg/L BPA concentration (Minaz et al., 2022b). In the liver tissue, vocalizations were significantly intense for the BPA group. In addition, the presence of hypertrophied cells was observed compared to the control group. Similar to our study, atrophied hepatocyte was observed in liver tissue of common carp exposed to BPA (Afzal et al., 2022). In another study, vocalization in liver tissues in the BPA group was noted (Faheem & Lone, 2017). In the BPA exposure studies on catla (*Catla catla*), vocalizations in liver tissue were reported (M. Faheem et al., 2016, 2019). Vacuolization was also observed in the livers of zebrafish exposed to BPA and perfluorooctane sulfonate (Keiter et al., 2012). Similar to our study, exposure to high concentrations of BPA has also been stated a hypertrophy effect (Akram et al., 2021b). Although supported by histopathological images, the quantitative output of the degradation in fish tissues from exposure to toxic materials more clearly reveals the severity of the damage. BPA caused regressive and progressive alterations in both gill and liver organs of the *V. vimba*. While necrosis causes the greatest contribution to the regressive change in the gill, the main factor of progressive change is the hyperplasia cells in the epithelial tissue. On the other hand, while the cause of the regressive change in the liver was vacuolization, the progressive change was caused by the hypertropic cells. In a histopathological evaluation study using similar methodology, it was reported that the largest part in the gills was hyperplasia, hypertrophy and necrosis, and the dominant factor in the liver was hyperemia and vacuolization (Saraiva et al., 2015). In another study examining the toxic effects of two different insecticides, circulatory disturbances were also observed in addition to regressive and progressive changes for the gill (Yancheva et al., 2022). While the greatest contribution of regressive change is due to necrosis, epithelial lifting contributed to progressive change. In addition, an inflammation pattern has also been observed for the liver. Similar to our study, the only contribution to the progressive change was caused by hypertrophic cells, while the biggest reason for the regressive change was vacuolar degeneration in fish exposed to high concentrations.

In conclusions, the present study revealed that long-term exposure of BPA on *V. vimba* did not create a negative effect on blood parameters, but partially negatively affected its antioxidant activity. In particular, histopathological results showed that BPA would have a negative effect on the gill and liver. The present study discussed the exposure of wild species *V. vimba* to manipulated BPA concentration under controlled conditions. For future studies, not only on the fish health and welfare, but also BPA presence in fish meat and its effects on human health are suggested as subjects worth examining.

Ethical Statement

Current study was checked and approved by the Ethical Local Committee of the Recep Tayyip Erdogan University.

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Author Contribution

M.M.: Conceptualization, Visualization, Writing - Original Draft, Data Curation; A.E.: Conceptualization, Visualization, Methodology, Writing - Review & Editing; K.A.: Validation, Writing - Review & Editing; I.D.N.: Resources, Writing - Review & Editing; Z.Z.İ.: Investigation; R.A.: Formal analysis.

Conflict of Interest

The authors have no relevant financial or non-financial interests to disclose.

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