Abstract: Malathion is one of the most commonly used pesticides in agriculture. This study was aimed to investigate the acute toxicity of malathion as an aquatic pollutant on the behavior and hematological indices in Indian carp (Cirrhinus mrigala). A static experiment was conducted and 1, 24, 48, 72 and 96 hrs LC₅₀ values of malathion for the test fish were estimated as 14.55 mg/L, 12.48 mg/L, 11.56 mg/L, 10.85 mg/L and 9.32 mg/L, respectively. During 96 hrs exposure to 9.32 mg/L of malathion, behavioral abnormalities such as hyperactivity, cough, convulsions, erratic swimming, loss of balance, rapid opercular movements, gill mucous secretion, surfacing and gulping of air were observed in the test fish. The hematological changes in exposed fish after 96 hrs exposure to malathion included a significant decrease in erythrocyte count, hemoglobin content, hematocrit, leukocyte count and a significant increase in neutrophils count as compared to the control fish. In conclusion, acute exposure to 9.32 mg/L of malathion provoked behavioral and hematological abnormalities in Indian carp which offers a valuable tool to monitor malathion induced toxicity in fish.

Introduction
Among different fresh water pollutants, pesticides are one of the most potentially harmful chemicals introduced into the environment. Organophosphate pesticides are the most commonly used pesticides in the world and require more awareness because of their possible toxic effects on non-target animals (Aktar et al., 2009). Malathion (C₁₀H₁₉O₆PS₂) is an organophosphate pesticide widely used in both agriculture and households to control insect pests affecting a number of crops, stored grains and livestock feed via ground and aerial sprays and aerosols. After its application, malathion can contaminate surface water through accidental spillage, spray drift and runoff following rain. The aquatic distribution of malathion can cause harmful effects on aquatic environment and its organisms. Malathion is less persistent in an environment under alkaline conditions and has a higher degree of persistence under acidic conditions. The half-life of malathion is up to 11 days and it degrades into malaxon which is more toxic than the parent (Martinez and Leyhe, 2004). Aquatic distribution of malathion causes significant adverse health effects on fish and other non-target animals. The toxicity potential of malathion varies in different fish and depends upon the differences in absorption, detoxification and inhibition of enzyme acetylcholinesterase (AChE) that breaks down the neurotransmitter acetylcholine so that subsequent impulses can transmit across the synapse. Inhibition of AChE drastically affects growth, feeding and reproductive behaviors and can lead to death of fish usually by asphyxiation (Sparling and Fellers, 2007). Behavioral changes are one of the most important indicators of environmental stress; while hematological parameters are important indicators of disease and are frequently used tools in toxicological
research, environmental monitoring and in the
evaluation of the pathophysiological changes in fish
under different stressful conditions (Pimpao et al.,
2007). In the last few years, there have been several
studies to investigate the malathion toxicity in
different fish species including Glossogobius giuris
(Venkataramanana et al., 2006), Opheocepalus
punctatus (Pugazhvendan et al., 2009), Oreochromis
niloticus (Al-Ghanim 2012), Clarias galipepinus
(Ahmed, 2012) and Heteropneustes fossilis (Deka
and Mahanta, 2012), but most of these studies were
confined to reporting histological changes in fish
exposed to sub-lethal concentrations of malathion
and very little attention has been paid to the acute
effects of malathion exposure on fish hematology.
Malathion is a commonly used pesticide and its
presence in fresh water reservoirs of Pakistan has
previously been reported (Mastoi et al., 2008).
However, there is a paucity of scientific
documentation regarding the effects of malathion on
local fish species. Indian carp (Cirrhinus mrigala)
is an important edible fresh water fish with substantial
economic importance and wide distribution in fresh
water reservoirs of Pakistan. Considering the
growing use of malathion in Pakistan and lack of
knowledge about its potential toxicity in local fresh
water fish fauna, present study was carried out to
determine acute toxicity of malathion and its effects
on behavior and hematological indices of C. mrigala.

Materials and Methods
Juveniles of C. mrigala weighing 20.4 ± 1.8 g and
total length of 5.5 ± 1.8 cm were obtained from
Jokhio fish farm (24°16’5″N, 67°35’55″E) Thatta,
located northeast of Karachi, Pakistan. Fish were
carried to the laboratory in plastic containers and
were acclimated to the laboratory conditions for two
weeks in a fiberglass tank containing 500 L of
continuously aerated fresh water. During this period,
temperature, pH, dissolved oxygen and photoperiod
were 22.5 ± 1.9°C, 7.5 ± 0.3, 6.8-7.5 mg/L and 12:12
hrs dark-light cycles, respectively. Fish were fed
with a commercial fish food twice a day during the
period of acclimation but were starved for 24 hrs
prior to the experiment and throughout the
experiment. Technical grade malathion with 95% active
ingredient was purchased from Edgro (Pvt.)
Ltd. Karachi and a stock solution at a concentration
of 200 mg/L was prepared by dissolving it in the
acetone. The stock solution was stored in dark bottles
at 4°C and its different dilutions were used to
determine acute toxicity, behavioral and
hematological effects on experimental fish.
After two weeks of acclimation, a static acute
toxicity test was performed. The juvenile specimens
were exposed to each of the seven different
concentrations (0.5, 1, 2, 4, 8, 16 and 32 mg/L) of
malathion to determine 96 hrs LC50 values. The
experiment was performed in triplicates in 100 L
glass aquaria each containing 20 juvenile C. mrigala.
The physicochemical indices of diluting water used
were: temperature 22.5 ± 1.9°C, pH 7.5 ± 0.3,
salinity 107 ± 3.2 mg/L, total hardness 112 ± 2.1
mg/L and dissolved oxygen 6.8-7.5 mg/L. These
water quality parameters were determined according
to the procedures described in standard methods
(APHA, 1992). Prior to the introduction of fish, the
required volume of malathion was added and water
in the aquaria was aerated for one hour to obtain a
homogenous mixture of the toxicant. Two control
sets were also run containing the same number of
fish in the same volume of water but without
malathion. Water was renewed daily and fish
mortalities were recorded after 1, 24, 48, 72 and
96 hrs of exposure. Fish were considered dead if
their gill opercular movement ceased and they could
not respond to the stimulus provided by a glass rod.
Dead fish were immediately removed from the
aquaria and LC50 values were calculated using Probit
Analysis test (Finney, 1971).
At the end of the acute toxicity test, twenty juvenile
C. mrigala were exposed to 9.32 mg/L (96 hrs LC50)
for 96 hrs in 100 L glass aquaria to determine
behavioral and hematological alterations. The
experiment was run in triplicate and two control sets
were also run concurrently. Fresh test media were
provided daily to maintain the concentrations of
malathion near to the 80% of nominal concentration.
The physicochemical characteristics of water were maintained the same as mentioned above. The behavioral changes of fish were recorded at every 12 hrs during the study and dead fish were removed from the aquaria. At the end of 96 hrs exposure period, a total of twelve surviving fish from experimental aquaria and same number of fish from control group were randomly collected using a small dip net with minimum disturbance in the water. Blood sample of each fish was collected by cardiac puncture using a 18 G needle attached to a plastic syringe. Blood was transferred into heparanized glass vials (50 IU Sodium heparin/ml of blood) and was immediately used for hematological examinations. The hematological indices examined included erythrocyte count (RBC), hemoglobin concentration (Hb), hematocrit (Hct), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentrations (MCHC), leukocyte count (WBC), leukocyte differential counts and were determined according to the unified methods for hematological examination of fish (Svobodova et al., 1991). All statistical analyses were carried out using SPSS 17.0 computer software for windows (SPSS Inc., Chicago, IL, USA). The difference in fish mortalities was analyzed by χ2 test. The values of hematological indices were presented as mean ± SD. The data for these parameters was tested for normality (Kolmogorov-Smirnov test) and analyzed by one way analysis of variance (ANOVA) to test significant differences between the hematological parameters of controlled and exposed groups and \( P<0.05 \) were considered statistically significant.

### Results

Cumulative mortality of *C. mrigala* after exposure to different concentrations of malathion at different durations of exposure is summarized in Table 1. The data clearly indicates a time and concentration-dependent significant increase in fish mortality rate \( (P<0.05 \text{ in each case}) \). The highest and fastest fish mortalities were recorded after 1 hrs exposure to the highest concentration of malathion (32 mg/L), while lowest fish mortalities were recorded after 96 hrs exposure to 1 mg of malathion. The LC50 values with 95% confidence limits of malathion for *C. mrigala* were estimated as 14.55 mg/L (13.98-15.32) for 1 hrs, 12.48 mg/L (11.91-13.39) for 24 hrs, 11.56 mg/L (10.89-12.89) for 48 hrs, 10.85 mg/L (no data as \( P>0.05 \)) for 72 hrs and 9.32 mg/L (no data as \( P>0.05 \)) for 96 hrs; and significant differences were observed in the LC10, LC50 and LC90 values recorded for different times of exposure \( (P<0.05; \text{Table 2}) \).

The behavioral response observed every 12 hrs of malathion exposure in test fish included hyperactivity, cough, convulsions, erratic swimming, loss of balance, rapid opercular movements, gill mucous secretion, surfacing and gulping of air. Subsequently, exhausted fish sank to the bottom of aquaria and died. Compared to the control group, fish exposed to 9.32

### Table 1. Cumulative mortality of juvenile *Cirrhinus mrigala* exposed to different concentrations of malathion.

<table>
<thead>
<tr>
<th>Concentrations (mg/L)</th>
<th>1 hrs</th>
<th>24 hrs</th>
<th>48 hrs</th>
<th>72 hrs</th>
<th>96 hrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>0.5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>8</td>
<td>11</td>
<td>18</td>
<td>24</td>
<td>32</td>
</tr>
<tr>
<td>4</td>
<td>20</td>
<td>24</td>
<td>30</td>
<td>32</td>
<td>40</td>
</tr>
<tr>
<td>8</td>
<td>28</td>
<td>32</td>
<td>38</td>
<td>41</td>
<td>47</td>
</tr>
<tr>
<td>16</td>
<td>78</td>
<td>84</td>
<td>90</td>
<td>96</td>
<td>100</td>
</tr>
<tr>
<td>32</td>
<td>100</td>
<td>ND</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \chi^2 )</td>
<td>1.78</td>
<td>2.01</td>
<td>2.29</td>
<td>2.78</td>
<td>3.17</td>
</tr>
<tr>
<td>( P )</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
</tr>
</tbody>
</table>

ND= no data because of 100% mortality; (–) no dead fish.
mg/L of malathion for 96 hrs showed significantly lower values for RBC count, Hb, Hct and WBC count (P<0.05); but the values recorded for MCV, MCH and MCHC were not significantly different between the two groups (Table 3). Neutrophils of exposed fish group increased significantly (P<0.05) while no significant difference was observed in the lymphocytes, monocytes, eosinophils and basophils counts of both groups (Table 4).

**Discussion**

In the present study, the 1 and 96 hrs LC50 values of malathion for juvenile *C. mrigala* were found to be 14.55 mg/L and 9.32 mg/L, respectively. In view of this, malathion can be included in a group of moderately toxic substances for this fish. An increase in the toxicity of malathion for the test fish was observed with increase in duration of exposure and concentration of pesticide. For instance 4% fish died when they were exposed to 1 mg/L of malathion for 96 hrs, whereas 100% fish died when exposed to 32 mg/L of malathion for 1 hrs. The acute toxicity of malathion varies in different fish species and ranges from few ppb to several mg/L. Office of the pesticide programme (USEPA, 2006) has reported 96 hrs LC50 values of malathion for Western mosquito fish (*Gambusia affinis*) as 0.7 ppb, for rainbow trout (*Onchorhynchus mykiss*) as 4.1 ppb, for bluegill sunfish (*Lepomis macrochirus*) as 30 ppb, for cutthroat trout (*O. clarki*) as 174 ppb, for yellow

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**Table 2.** Exposure time dependent lethal concentrations of malathion (mg/L) for juvenile *Cirrhinus mrigala.*

<table>
<thead>
<tr>
<th>Time</th>
<th>Lethal concentration values with 95% confidence limits (mg/L)*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LC0</td>
</tr>
<tr>
<td>1 hrs</td>
<td>2.41± (2.98-2.32)</td>
</tr>
<tr>
<td>24 hrs</td>
<td>2.18± (2.34-1.95)</td>
</tr>
<tr>
<td>48 hrs</td>
<td>1.75± (1.92-1.59)</td>
</tr>
<tr>
<td>72 hrs</td>
<td>1.56± (−)</td>
</tr>
<tr>
<td>96 hrs</td>
<td>1.32± (−)</td>
</tr>
</tbody>
</table>

(−) no data because of P<0.05, *Lethal concentration values in columns with different letters significantly differ (P<0.05).

**Table 3.** Hematological indices of *Cirrhinus mrigala* after 96 hrs exposure to 9.32 mg/L of malathion.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Control group (n = 12)</th>
<th>Exposed group (n = 12)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RBC (10^6/mm^3)</td>
<td>1.71 ± 0.11^a</td>
<td>1.10 ± 0.20^b</td>
</tr>
<tr>
<td>Hb (g/dL)</td>
<td>4.94 ± 0.22^a</td>
<td>2.48 ± 0.37^b</td>
</tr>
<tr>
<td>Hct (%)</td>
<td>13.42 ± 2.07^a</td>
<td>8.94 ± 1.32^b</td>
</tr>
<tr>
<td>MCV (fL)</td>
<td>214.75 ± 8.39^a</td>
<td>211.34 ± 4.74^a</td>
</tr>
<tr>
<td>MCH (pg)</td>
<td>29.42 ± 2.18^a</td>
<td>30.76 ± 1.87^a</td>
</tr>
<tr>
<td>MCHC (%)</td>
<td>24.33 ± 2.48^a</td>
<td>26.56 ± 1.96^a</td>
</tr>
<tr>
<td>WBC (10^3/mm^3)</td>
<td>36.41 ± 2.68^a</td>
<td>24.44 ± 1.65^a</td>
</tr>
</tbody>
</table>

RBC = erythrocyte count; Hb = hemoglobin concentration; Hct = hematocrit; MCV = mean corpuscular volume; MCH = mean corpuscular hemoglobin; MCHC = mean corpuscular hemoglobin concentration; WBC = leukocyte count. Different superscript letters indicate significant (P<0.05) difference between the groups.

**Table 4.** Leukocytes differential count of *Cirrhinus mrigala* after 96 hrs exposure to 9.32 mg/L of malathion.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Control group (n = 12)</th>
<th>Exposed group (n = 12)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutrophils (%)</td>
<td>13.74 ± 3.85^a</td>
<td>18.62 ± 2.15^b</td>
</tr>
<tr>
<td>Lymphocytes (%)</td>
<td>73.12 ± 4.42^a</td>
<td>72.42 ± 3.25^a</td>
</tr>
<tr>
<td>Monocytes (%)</td>
<td>11.56 ± 1.23^a</td>
<td>11.74 ± 1.65^a</td>
</tr>
<tr>
<td>Eosinophils (%)</td>
<td>7.12 ± 0.95^a</td>
<td>7.68 ± 1.05^a</td>
</tr>
<tr>
<td>Basophils (%)</td>
<td>3.41 ± 0.55^a</td>
<td>3.52 ± 0.84^a</td>
</tr>
</tbody>
</table>

Different superscript letters indicate significant (P<0.05) difference between the groups.
perch (*Perca flavescens*) as 263 ppb, for tilapia (*Tilapia mosambica*) as 2000 ppb, for common carp (*Cyprinus carpio*) as 6590 ppb and for medaka (*Oryzias latipes*) as 40,000 ppb. On the other hand, very high 96 hrs LC50 values of malathion for black bullhead (*Ameiurus melas*) as 11.8 mg/L and for Indian catfish (*Heteropneustes fossilis*) as 15.3 mg/L have also been documented (Martinez and Leyhe, 2004). The toxicity potential of pesticides changes with respect to age, size and exposure time in different fish species. The difference in the toxicity of malathion among different fish species can be attributed to the difference in susceptibility and tolerance regarding absorption, biotransformation and excretion of pesticide (Dutta et al., 1992).

Behavioral changes and hematological profile are sensitive indicators that may provide information about potential toxic effects of pesticides and other pollutants in aquatic organisms. The investigation of behavioral and hematological changes has become an important means of understanding toxicological impacts and pathological processes in fish (Singh et al., 2009). The results of present study showed that malathion exposure at a concentration of 9.32 mg/L for 96 hrs exerted a certain influence on fish behavior that include hyperactivity, seizures, erratic swimming, loss of buoyancy, increased cough rate and gill mucous secretion. These behavioral changes correspond to the observations by other authors dealing with the toxicity of organophosphate pesticides. It regards abnormal fish behavior in *Danio rerio* exposed to chlorpyrifos (Levin et al., 2004) and *C. mrigala* exposed to diazinon (Rauf and Arain, 2013). Behavioral changes in the exposed fish appear to be the manifestation of malathion toxicity. Increased surfacing and gulping of surface water appear to be an attempt by fish to overcome hypoxia and to avoid breathing in the toxic water. Erratic swimming, convulsions, loss of equilibrium and abnormal swimming in exposed fish are caused by deficiency in nervous and muscular coordination which can be attributed to the neurotoxic effects of malathion. Similar observations have been reported in *C. carpio* and fingerling *Silurus glanis* after acute exposure to dimethoate and diazinon, respectively (Singh et al., 2009; Koprucu et al., 2006). Increased mucous secretion in malathion exposed fish during present study is probably an adaptive response of fish to reduce the irritating effect of the toxicant to eliminate it through epidermal mucous secretion. Similar fish response has also been reported in *C. carpio* exposed to dimethoate (Singh et al., 2009), *C. mrigala* exposed to diazinon (Rauf and Arain, 2013) and *Labeo rohita* exposed to malathion (Patil and David, 2008). In fact, malathion as other organophosphate pesticides exerts its effects by inhibiting the activity of enzyme acetylcholinesterase that leads to the accumulation of acetylcholine in cholinergic synapses and ends up with hyperstimulation; this decreased activity of acetylcholinesterase affects optomotor responses of fish that can disrupt the overall survivability of the animal in their natural environment (Dutta et al., 1994).

In the present study, the main hematological response of *C. mrigala* after acute exposure to malathion include significantly lower RBC count, Hb concentration, Hematocrit and WBC count as compared to the control. A similar response in these hematological indices to give evidence for suppressed hemotopoiesis, followed by anemia induction has previously been reported in fish exposed to other organophosphate pesticides. It regards, changes in erythrocyte indices after exposure to chloropyrifos in *Clarias gariepinus* (Nwani et al., 2013), monocrotophos in *Catla catla* (Jeyapriya et al., 2013) and diazinon in fingerlings of *S. glanis* (Koprucu et al., 2006). Similarly, a significant decrease in erythrocyte count, hemoglobin content, hematocrit and WBC count after 96 hrs exposure to 8.15 mg/L of diazinon and 30 days exposure to 0.815 mg/L of diazinon has also been reported in immature *C. mrigala* (Rauf and Arain, 2013; Haider and Rauf, 2014). Ahirwar et al. (2012) reported decreased RBC count, hemoglobin content and WBC count in *Notopterus notopterus* following 3 hrs exposure to lethal concentrations of
Malathion, while decreased RBC count, hematocrit and hemoglobin content have also been reported in *C. gariepinus* following sub-lethal exposure to malathion (Ahmed, 2012). In consistence with the present study, a decreased RBC count, hemoglobin content and hematocrit levels in *Channa punctatus* following three days exposure to malathion and a similar response in *H. fossilis* after four days exposure to malathion has previously been reported (Parveen and Shadab, 2011; Singh et al., 2009). Malathion induced decreased RBC count, Hb content and hematocrit values in fish are indicators of anemia that can be a result of disruptive iron-synthesizing mechanism, destruction of mature erythrocytes and malfunctioning of the hemopoietic system (Adhikari et al., 2004). Since hemopoietic system of fish is mainly located in the interstitium of the kidney, the hematological response of test fish can be a result of malathion induced morphological alterations in renal interstitium of fish (Dutta, 1992).

Changes in leukocyte differential counts are recognized as sensitive indicators of environmental stress as monocytes and neutrophils generally increase while lymphocytes decrease in response to a stressor (Shah and Altindg, 2005). In the present study, the decrease in total leukocytes count and alterations in the leukocyte differential count of fish after acute exposure to malathion are in consistence with the previous reports. It regards, decreased WBC count after acute exposure to diazinon in *C. mrigala* (Rauf and Arain, 2013) and fingerlings of *S. glanis* (Kopruçu et al., 2006), *Oreochromis mossambicus* exposed to phosalaone (Ali and Rani, 2009) and *O. mykiss* treated with deltamethrin (Velisek et al., 2007). Similar to the present study, a decrease in total leukocyte count and increase in neutrophil count after five days exposure to diazinon has been reported in *C. gariepinus* (Nwani et al., 2012). Svoboda et al. (2001) reported a similar decreased non-specific immunity in *C. carpio*, following acute exposure to diazinon. In contrast to the present study, three and four days exposure to malathion induced increase in total leukocyte count in *N. notopterus* and *C. punctatus*, respectively (Ahirwar et al., 2012; Parveen and Shadab, 2011) and authors attributed this increase to the acute response of immune system due to tissue injury caused by malathion exposure in fish. However, the decrease in total WBC count of test fish after acute exposure to malathion during present study may be attributed to the rapid destruction or failure in the delivery to the circulation due to reduced production of these cells; while, increase in neutrophil count may be due to the defensive response of fish to overcome malathion induced stress in fish.

In conclusion, malathion can be classified as a moderately toxic substance for *C. mrigala*. Exposure to malathion in a concentration of 9.32 mg/L for 96 hrs was caused severe stress and resulted in significant behavioral and hematological alterations in the test fish. Malathion exposure, even in small concentrations has the potential to impair physiological activities leading to observed behavioral and hematological pattern and can ultimately lead to the death of fish. This fact should be taken into consideration when this pesticide is used in agricultural fields surrounding fresh water reservoirs to avoid malathion related toxicity in aquatic organisms.

**Acknowledgement**

Author is thankful to Miss. Qurat-Ul-Ain Aslam of Bahria University Islamabad, for her valuable comments to improve manuscript and Prof. M. Ayub Qureshi, Head Department of Zoology and Principal Govt. Superior Science College, Shah Faisal Colony, Karachi, Pakistan, for providing all the facilities for the successful completion of this study.

**References**


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چکیده فارسی

سمیت حاد و اثرات در معرض قرارگیری مالاتونین بر رفتار و شاخص‌های خون شناسی کپور هندی مرجگال (Cirrhinus mrigala)

عبدول رئوف
گروه جانورشناسی، کالج دولتی عالی علوم، کلنی شاه فیصل، کراچی، پاکستان.

چکیده:
مالاتونین یکی از مهم‌ترین آفت‌کش‌های مورد استفاده در کشاورزی می‌باشد. این مطالعه با هدف بررسی سمیت حاد مالاتونین به عنوان یکی از آلاینده‌های اکوسیستم‌های آبی بر روی رفتار و شاخص‌های خون شناسی کپور هندی مرجگال (Cirrhinus mrigala) اجرا شد. یک آزمایش استاتیک به اجرا درآمد و مقادیر 50، 42، 24 و 96 ساعت مالاتونین بر روی ماهی مورد آزمایش به‌ترتیب در غلظت‌های 1/55، 1/48، 1/26 و 1/20 میلی‌گرم در لیتر مدل می‌گردد. ناهنجاری‌های رفتاری شامل تحرک بالا، سرفه، تشنج، شنای نامنظم، از دست دادن تعادل، حرکات سریع سرپوش آبششی، ترشح موکوس آبششی، به‌سطح آب آمدن و بلعیدن هوا در ماهیان مورد آزمایش مشاهده شد. تغییرات خونی در ماهیان در معرض سم مالاتونین بعد از 96 ساعت شامل کاهش معنی‌دار در تعداد اورتیک، هموگلوبین، همانتوکریت و لوکوسیت و افزایش معنی‌دار در تعداد نوترفیل در مقایسه با ماهیان نیم‌بود. به عنوان نتیجه‌گیری می‌توان یاد کرد که قرارگرفتن ماهیان در معرض 96 میلی‌گرم در لیتر مدل‌های مالاتونین ناهنجاری‌های رفتاری و خون شناسی را در کپور هندی مرجگال محرک می‌کند که به عنوان یک مورد قرار گیری برای پژوهش نمی‌تواند مدل‌سازی کند.

کلمات کلیدی: مالاتونین، سمیت حاد، رفتار، خون شناسی، کپور هندی.