PHYSIOLOGICAL AND OXIDATIVE STRESS BIOMARKERS IN THE FRESHWATER CATFISH (*Clarias gariepinus*) EXPOSED TO PENDIMETHALIN-BASED HERBICIDE AND RECOVERY WITH EDTA.

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**Abstract**

The present study was planned aiming to investigate the effects of Pendimethalin herbicide exposure on haematological, biochemical, oxidative stress and antioxidant biomarkers in the tissue liver of catfish and recovery effects of ethylene diamine tetra acetic acid on the degree of Pendimethalin sublethal toxicity for 42 day. The experiment was carried out on (100) catfish that randomly divided into nine equal groups with five replicates: The 1st group kept as control, the 2nd group and 3rd group exposed to (5 %) and (10%) of Pendimethalin for 7 days, the 4th and 5th group exposed to (5 %) and (10%) of Pendimethalin and recovery with EDTA for 7 day, the 6th and 7th exposed to (5 %) and (10%) of Pendimethalin for 21 day, while the 8th and 9th group exposed to (5 %) and (10%) of Pendimethalin and recovery with EDTA for 14 day. Abnormal behavioral responses of the catfish and the toxic symptoms of pendimethalin exposure are described. Acute exposure to pendimethalin induced leukocytosis, hyperglobulinemia, hyperglycemia and increased lipid profile. Moreover, pendimethalin increased lipid peroxidation (LPO) and decreased levels of reduced glutathione and antioxidant enzymes; superoxide dismutase, catalase, and glutathione reductase in the liver tissue. We conclude that although pendimethalin is moderately toxic and cause significant deleterious effects on fish and aquatic invertebrates, it does not cause renal toxicity. However, this herbicide pollutant induces major disturbances to the antioxidant system; induction of oxidative stress and LPO is the proposed toxicodynamic pathway for such stress. Toxicity with Pendimethalin (Stomp) can end up in humans through the food chain. However, fish recovered with EDTA exhibited protective effect by minimizing the Pendimethalin-induced toxicity, through measured values more or less similar to the control group fish.

**Introduction:**

The pollution of rivers, lakes, and canals by chemical substances of anthropogenic origin may result in water that is unsuitable for household use, irrigation, and fish cultivation, and may negatively impact the animal communities...
living in these bodies of water in addition to the increasing uses of pesticides, which include insecticides, herbicides and fungicides, is intensifying worldwide pollution risk (Malins and Ostrander, 1991; Moraes, et al., 2007; Rudneva, 2007 and El-Sayed, et al., 2013).

Water pollution is one of the principal environmental and public health problems that Egyptian River Nile are facing and the contamination of fresh water with a wide range of pollutants has become a matter of concern over the last few decades (Canli and Kalay, 1998., Anwar, 2003 and Vutkuru, 2005). In which the Nile represents the main freshwater resource for the country, meeting nearly all demands for drinking water, irrigation, and industry. During its transit through Egypt, the river Nile receives numerous non-point and point source discharges(Osman, et al., 2010). The severity of herbicides hazards is much pronounced in the third world countries in which the use of this environmental pollutants reported to accumulate in bodies of fishes and has dangerous effects on human health through the food chain, so these pollutants is toxic and may be mutagenic or carcinogenic to human (Porte and Albaiges, 1994; Jacobs, et al., 2002).

Fishes exposed to toxicants undergo stress, which is a state of re-established homeostasis, a complex suite of mal-adaptive responses (Chrouses, 1998; Olufayo and Alade, 2012 ). Under stress, physiological and biochemical responses may be compromised, becoming detrimental to the fish’s health and well-being at which point the fish is termed distressed (Barton and Iwama, 1991).

Studies the toxicity and effects of pendimethalin herbicideson fish and aquatic organisms are limited (Ahmed and Moustafa, 2010; Abd-algadiret, et al., 2011 and El-Sharkawy et al., 2011). It is a systemic toxicant rated as moderately to extremely toxic to fish and aquatic organisms, and which can give rise to long-lasting metabolites.

Pendimethalin contains dinitroanilines, which can reportedly facilitate the formation of carcinogenic nitrosamines, a group C carcinogen (possible human carcinogen) (US EPA, 1997). Pendimethalin is the active ingredient of many commercially herbicides formulations which including the following: Stomp® 50 %, Stomp® 45.5 %, Stomp® 33 %, Prowl®, Squadron®, prowl H2O and Pendimax 3® in Egypt, while in Australia, China, Canada, Korea, Philippines, New Zealand, Europe and the USA is Stomp®, Pendimethalin®-Herbadox® and AC 9253® USEPA, (1985) and Moustafa et al., (2016). The determination of toxicity is essential for assessing the sensitivity of animals to specific toxicants, for evaluating the degree of damage to specific organs, and for assessing the extent of ensuing behavioral, physiological, and biochemical disorders.

Catfish (Clarias gariepinus) is of great commercial importance and it is the most common fresh water fish widely consumed in Egypt and Africa Farombo et al., (2008). It can therefore be a good model to study responses to various environmental contaminants due to two reasons. First this species of fish exhibits anatomical and physiological changes at the level of both respiratory and circulatory systems, owing to the presence of a ramifying organ in the peribranchial cavity for air-breathing. Secondly, this specie apart from the fact that it is found in Africa rivers also lives in temporary puddles forming in desert areas after rainy inundation, in which a large amount of pollutant rapidly accumulate Olafna et al., (2004). Catfish and aquatic animals are exposed to Pendimethalin via three ways, the first is dermally through direct absorption via the skin by swimming in the herbicide-contaminated water, the second way is breathing via direct uptake the herbicides through the gills during the respiration process, the last way is orally via drinking the herbicides- contaminated water of feeding on herbicides- contaminated preys ( Hardersen and Wratten, 1998).

Knowledge of the haematological characteristics is an important tool that can be used as an effective and sensitive index to monitor physiological and pathological changes in fishes and the exposure of chemical pollutants can induce either increase or decrease in haematological level and the lymphocytes were the most abundant type of leucocyte in the peripheral blood of C. gariepinus exposed to paraquat herbicide this was followed by the neutrophils, while the least abundant type of leucocyte was the eosinophils (Alohan, et al., 2014 and Nwani, et al., 2015 ). Erhunmwunseand Ainerua,(2013) studied the haematological profile of Juvenile catfish (Clarias gariepinus). Hematological indices and leucocyte differential count were measured in blood samples of African catfish and said that Knowledge of these haematological characteristics is an important tool that can be used as an effective and sensitive index to monitor physiological and pathological changes in fishes.

Because fish are able to uptake and retain different xenobiotic compounds from water via active or passive processes, biochemical investigations have been routinely used for monitoring the environmental exposure of fish to
contaminant, in laboratory and field studies, which are sensitive for the detection of the potential adverse effects of xenobiotics released into the environment (Almeida, et al., 2002; Sancho, et al., 2003; Shallaja and D'Silva, 2003).

The liver plays an important role in many metabolic processes such as glycemic control, detoxification of xenobiotic, synthesis of lipoproteins, hormones and enzymes (Klip and Vranic, 2006). The aquatic ecosystems are under the pressure of complex mixtures of contaminants released in the environment due to various human activities exert multiple stress effects; they originate from miscellaneous sources such as chemical and drug manufacture, domestic sewage, polymer and petrochemical-based industries, oil refineries, mining, glass blowing, battery manufacture and many others (Widianarko et al., 2000; Ueno et al., 2004 and Huska et al., 2008). Environmental contaminants such as herbicides, heavy metals and insecticides are known to modulate antioxidant defensive systems and to cause oxidative damage in aquatic organisms by ROS production. Thus the activity of antioxidant enzymes and the occurrence of oxidative damage have been proposed as indicators of pollutant-mediated oxidative stress (Li et al., 2003; Hermes-Lima, 2004 and Monterio et al., 2006). Moreover the release of ROS by phagocytic cells can be stimulated after pollutant exposure have been shown to result in increasing ROS production in subcellular fractions of various tissues, especially the liver, kidney and gills (Fatima et al., 2000; Livingstone, 2001; Schmieder et al., 2003 and Moustafa et al., 2016). Oxidative stress is one of the major factors in the pathogenesis of liver disease. Recent evidence implicates the role of oxidative stress in the pathogenesis and/or complications of these disorders (Shibata, and Kobayashi 2008; Kadenbach, et al., 2009). Fish are endowed with antioxidant defense pathways for neutralizing ROS; these pathways involve antioxidant enzymes such as superoxide dismutase (SOD), catalase (CAT), and glutathione reductase (GR), as well as non-enzymatic antioxidants such as reduced glutathione (GSH) (Gluszczak et al., 2006; Modesto and Martinez, 2010 and EL-Sayed et al., 2013).

In standard medical practice, certain medications (also known as ‘chelants’ [key-lints]) are used in specific situations to help remove high levels of certain metals from the body. The chelators bind to these metals in the blood and some body tissues causing them to be more quickly eliminated in the urine or stool. Whether the chelation medication is swallowed, or injected into the muscle or vein, depends on the type of chelation medication used and the medical situation of the patient being treated. Some practitioners of complementary medicine use medications or natural products, labeled as chelators, to treat a variety of chronic medical conditions. Chelation therapy has been scientifically proven to be beneficial treatment for poisoning (high exposure) from metals such as lead, mercury, and arsenic when carried out under competent medical supervision. It is also used to treat large amounts of iron or copper that accumulates in the body due to certain diseases according to American academy of clinical toxicology 2012. EDTA is a chelating agent which belongs to the group of Aminopolycarboxylic acids. Poison Centers list two types of EDTA, namely Na-CaEDTA (calcium-disodium ethylene diamine tetra acetic acid and Na-EDTA (ethylenediaminetetraacetic acid, also referred to as Disodium edetate) as antidotes for lead, chromium, cobalt, vanadium, zinc, cadmium and radioactive metals. The California Poison Control System lists Ca-EDTA (brandname Versenate) for heavy metal poisoning (Blaurocket et al., 2014).

Materials and methods:-
Chemicals and Reagents:-
Commercially available pendimethalin–based formulation (StompVR50% EC, BASF PLC) was used in this study. It is an orange-yellow emulsive herbicide, whose active ingredient is the pendimethalin [C13H19N3O4; N-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine] of dinitroaniline family. 25_C and aqueous photolysis of 60 days (US EPA, 1997).

Figure 1:- Chemical structure of pendimethalin.
Animals and Experimental design:-
All animal-related procedures were carried out in accordance with the Ethical Committee of UAL-Azhar University.

A total number of 100 of live catfish C. gariepinus with average body weight 250±50 g at the beginning of the experimental were obtained from Abbasa fish farm, Central Laboratory of Aquaculture (CLAR), El-Sharkya governorate, Egypt. They were transferred to the laboratory of Fishes in the animal house, Zoology Department, Faculty of Science at AL-Azhar University. About (100) African catfish average weight around between (250±25 g) at the beginning of the experiment were divided into (9) main groups according to the treatment, recovery and requirements of the experiment.

100 African catfish were randomly divided into nine equal groups and labeled as groups 1,2,3,4,5,6,7,8 and 9, each group contain 5 fishes as the following:

- **Group 1**: Control fishes, fish of this group were neither treated nor recovery by EDTA.
- **Group 2**: Fishes were treated with 5% of pendimethalin herbicide for 7 days.
- **Group 3**: Fishes were treated with 5% of pendimethalin herbicide for 7 days and recovery with ethylene diamine tetra acetic acid (EDTA) 0.3 g/L for 7 days.
- **Group 4**: Fishes were treated with 10% of pendimethalin herbicide for 7 days.
- **Group 5**: Fishes were treated with 10% of pendimethalin herbicide for 7 days and recovery with ethylene diamine tetra acetic acid (EDTA) 0.3 g/L for 7 days.
- **Group 6**: Fishes were treated with 5% of pendimethalin herbicide for 21 days.
- **Group 7**: Fishes were treated with 5% of pendimethalin herbicide and recovery with ethylene diamine tetra acetic acid (EDTA) 0.3 g/L for 21 days.
- **Group 8**: Fishes were treated with 10% of pendimethalin herbicide for 21 days.
- **Group 9**: Fishes were treated with 10% of pendimethalin herbicide and recovery with ethylene diamine tetra acetic acid (EDTA) 0.3 g/L for 21 days.

Sample preparation:-
- All samples should be prepared before reconstitution of the reagents.
- 1. Wash the liver tissue in physiological saline solution, pH 7.4.
- 2. Homogenize the tissue in 10 ml cold phosphate buffer pH 7.4.
- 3. Centrifuge the homogenate tissue at 4,000 rpm for 15 minutes at 4°C.
- 4. Collect supernatant, If not assayed immediately store the supernatant at -80°C.

Blood and liver tissue samples were obtained from fish of the studied groups at 1, 2, 3, 4, 5 and 6, 7, 8 and 9 groups of acute and chronic exposure, for the investigation of the haematological, biochemical parameters, antioxidant and oxidative stress.

**Haematological examination:-**

**Blood sampling collection:-**

Hematological examination of the catfishes were performed on surviving fishes. The body surface were cleaned and blotted dry with adsorbent paper. A first blood samples, collected from the caudal vein using disposable 3-c syringes and 21-gauge needles, were transferred into vacuette tubes containing K$_3$ EDTA solution(greiner bio-one company) as an anticoagulant for determination of red blood corpuscles (RBCs), platelets white blood cells count and deferential leucocyte count (lymphocyte, neutrophil, monocyte, eosinophil and basophil), hemoglobin concentration and percentage (Hb%), packed cell volume (PCV), mean corpuscle volume (MCV), mean corpuscle hemoglobin (MCH) and mean corpuscle hemoglobin concentration (MCHC) were estimated by cell blood counterLabomed, Inc. SK9000 Sino thinker in Zoology dep faculty of Scienceat AL-Azhar University and the result confirmed by Sysmex kx-21n automated hematology analyzer.

**Biochemical examination:-**

The second blood samples were collected from the fish caudal vein using plastic syringes in dry sterilized vials without any anticoagulants. The samples were allowed to clot at room temperature and centrifuged, then serum was separated for determination of the following parameters serum levels of transaminases, alkaline phosphatase, total protein, albumin and globulin were estimated using kits from Elitech diagnostic Comp. France. The concentrations of transaminases (ASAT and ALAT) were determined using the method of Bergmeyer et al. (1986). Serum ALP
was determined according to the method described by the **German Society for Clinical Chemistry** (1972). Serum total protein was determined according to the method described by **Gorna et al.** (1949). Serum albumin was determined according to the method described by **Doumas et al.** (1971). Plasma glucose level was determined according to the method of **Dods** (2003) using kit from Elitech diagnostic Co. France. Serum Gamma Glutamate Transaminase (γ-GT) is determined according to the method of **Rosalki, et al., 1971** using a commercial kit derived from Randox comp. Lactate dehydrogenase (LDH) activity was assayed using commercial kit from (Spainreact, Spain) according to the method of **Young and Friedman, 2001**. CPK (Creatinephospho Kinase) is mainly found in all muscle and brain tissue using kit from Elitech diagnostic Co. France CPK level was determined according to the **German Society for Clinical Chemistry** (1972).

**Lipid peroxidation and oxidative stress:**

**Sample preparation:**

All samples should be prepared before reconstitution of the reagents.

1. Wash the liver tissue in physiological saline solution, pH 7.4.
2. Homogenize the tissue in 10 ml cold phosphate buffer pH 7.4.
3. Centrifuge the homogenate tissue at 4000 rpm for 15 minutes at 4 °C.
4. Collect supernatant, If not assayed immediately store the supernatant at -80°C.

Blood samples were collected without anti-coagulants and centrifuged at 4000 r.p.m for 10 minutes to prepare serum. The sera were frozen at -20 °C until used.

Lipid peroxidation product, malondialdehyde (MDA), was measured by thiobarbituric acid (TBARS) assay, which is based on the determination of malondialdehyde (MDA), an end product of lipid peroxidation, which can react with thiobarbituric acid to yield a pink colored complex exhibiting a maximum absorption at 534nm (**Yoshioka et al., 1979**). Glutathione was determined according to the method of **Beutler et al.** (1963). This method is based on the reduction of 5, 5’-dithiobis (2 – nitrobenzoic acid) (DTNB) with glutathione (GSH) to produce a stable yellow compound. The reduced chromogen directly proportional to GSH concentration and its observance can be measured at 412 nm. The activities of CAT and SOD were estimated using kits from bio-diagnostic for research kits, Egypt. The SOD activity was assayed according to the procedure described by **Yoshioka et al., 1979** and the assay of CAT activity was determined according to the method of **Aebi** (1984). Glutathione reductase (GR) activity of the tissue homogenate was determined according to the method of **Goldberg and Spooner, 1983**. Other reagents was performed according to the instruction manual of reagent kits purchased from Biodiagnostic or / and Biotechnology Co., Dokki, and Giza, Egypt.

The statistical package for social sciences SPSS/PC computer program (version 20) was used for statistical analysis of the results. Data were analyzed using one-way analysis of variance (ANOVA). The data were expressed as mean ±S.E. Differences were considered statistically significant at (P < 0.05).

**Results:**

Data found in table (1) showed that slightly a significant increase (P<0.05) in red blood corpuscles (RBCs) in catfishes treated with 5% of Pendimethaline for 7 days only, when compared with the control group. In addition to the catfishes treated with Pendimethaline at concentration 5% and 10% and recovery with EDTA for 7 days showed a significant decrease (P<0.05) in RBCs when compared with treated groups.

Data found in table (1) showed that a significant increase (P<0.05) in white blood cells (WBCs) count in catfishes treated with concentration 5% and 10 % of pendimethaline for 7 and 21 days when compared with the control group. While, catfishes treated with concentration 5 % and 10 % of pendimethaline and recovery with EDTA for 7 days and 21 day observed a significant decrease (P<0.05) in total leucocyte count (TLC) when compared with treated groups.

Platelets found in table (1) revealed a significant decrease (P<0.05) in catfish treated with 5% of pendimethaline for 7 and 21 days when compared with the control group. While insignificant decrease in platelets count was recovered in catfishes treated with concentration 10 % of pendimethalin for 7 and 21 day when compared with treated groups. From the other point of the view the catfishes treated with 5% and 10 % of pendimethaline and recovery with EDTA for 7 and 21 days showed insignificant increase in platelets when compared with treated groups.
Statistical data of haemoglobin in table (1) observed a significant decrease in catfishes treated with concentration 5 % of pendimethalin for 21 days when compared with the control group, also the data demonstrated a significant decrease in catfish treated with 5% of pendimethalin and recovery with EDTA for 7 days when compared with treated groups, while the other data reported that a significant increase in the catfishes treated with concentration 5% of pendimethalin and recovery with EDTA for 21 days when compared with treated groups.

Table 1:- Mean values of RBCS, WBCS, PLATS and HB on catfish (Clarias gariepinus) intoxicated with pendimethalin (stomp) and recovery with EDTA at different interval periods.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Period</th>
<th>Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
<td>Stomp (5%)</td>
</tr>
<tr>
<td>RBCs × 10^6 (cell/mm^3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>1.9</td>
<td>1.94</td>
</tr>
<tr>
<td>±</td>
<td>±</td>
<td>±</td>
</tr>
<tr>
<td>S.E</td>
<td>0.07^a</td>
<td>0.06^b</td>
</tr>
<tr>
<td>%</td>
<td>0.07</td>
<td>0.06</td>
</tr>
<tr>
<td>WBCs × 10^3 (cell/mm^3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>44.25</td>
<td>78.0</td>
</tr>
<tr>
<td>±</td>
<td>±</td>
<td>±</td>
</tr>
<tr>
<td>S.E</td>
<td>2.57^a</td>
<td>2.85^b</td>
</tr>
<tr>
<td>%</td>
<td>2.57</td>
<td>2.85</td>
</tr>
<tr>
<td>Plats × 10^3 (cell/mm^3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>150.0</td>
<td>95.25</td>
</tr>
<tr>
<td>±</td>
<td>±</td>
<td>±</td>
</tr>
<tr>
<td>S.E</td>
<td>7.62^a</td>
<td>13.3^b</td>
</tr>
<tr>
<td>%</td>
<td>7.62</td>
<td>13.3</td>
</tr>
<tr>
<td>Hb (gm)</td>
<td>14.8</td>
<td>15.25</td>
</tr>
<tr>
<td>±</td>
<td>±</td>
<td>±</td>
</tr>
<tr>
<td>S.E</td>
<td>0.71^a,b,d,e</td>
<td>0.55^a,cd</td>
</tr>
<tr>
<td>%</td>
<td>0.71</td>
<td>±</td>
</tr>
</tbody>
</table>

Each value represented means of 5 records ± S.E.  
^a,b,c,d,e means comparison between all groups which the groups have the same letter mean there is no significance difference and which have different letter mean there is a significance differences.  
%: Percent of changes from control values.

Data found in table (2) showed a significant increase (P<0.05) in mean corpuscular haemoglobin (MCH) in catfishes treated with concentration 5% of pendimethalin and recovery with EDTA for 21 days when compared with the treated groups. While insignificant decrease in MCH value was revealed in groups treated with pendimethalin at concentration 5% and 10% and recovery with EDTA for 7 days, also insignificant decrease in MCH value was recorded in concentration 10% for 21 day.

Mean corpuscular haemoglobin concentration (MCHC) found in table (2) observed a significant decrease (P<0.05) in catfishes treated with concentration 5% of pendimethalin only for 7 days and 21 days when compared with the control group. While a significant increase (P<0.05) in MCHC value was showed in catfishes treated with concentration 10% of pendimethalin and recovery with EDTA for 21 when compared with the control group. From the other hand, the catfishes treated with concentration 5% and 10% of pendimethalin and recovery with EDTA for 7 days and 21 days showed a significant increase (P<0.05) in MCHC value, except the group treated with pendimethalin and recovery with EDTA at 10% for 21 day revealed insignificant decrease in MCHC value.

Statistical data of haematocrit (Hct %) in table (2) observed a significant increase (P<0.05) in catfishes treated with concentration 5% of pendimethalin for 7 days when compared with the control group, while insignificant difference in Hct value was recorded in the other groups in comparison with the control group, in contrast a significant decrease (P<0.05) was observed in concentration 5% and 10% of pendimethalin and recovery with
EDTA for 7 days. But insignificant difference in Hct value was recorded in catfishes treated with pendimethaline and recovery with EDTA for 21 day in comparison with treated groups.

**Table 2:** Mean values of blood indices (MCV, MCH, MCHC) and Hct catfish (Clarias gariepinus) intoxicated with pendimethalin (stomp) and recovery with EDTA at different interval periods.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Period</th>
<th>Groups</th>
<th>7 days</th>
<th>21 days</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
<td>Stomp p 5%</td>
<td>Recovery</td>
<td>Stomp p 10%</td>
</tr>
<tr>
<td>MCV</td>
<td>Mean</td>
<td>144.3 ± 5.76&lt;sup&gt;b&lt;/sup&gt;</td>
<td>180.16 ± 11.13&lt;sup&gt;b&lt;/sup&gt;</td>
<td>150.23 ± 2.67&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>± S.E</td>
<td>± 5%</td>
<td>± 10%</td>
<td>± 5%</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>± 5%</td>
<td>± 10%</td>
<td>± 5%</td>
</tr>
<tr>
<td>MCH</td>
<td>Mean</td>
<td>77.79 ± 1.15&lt;sup&gt;b&lt;/sup&gt;</td>
<td>80.57 ± 5.07&lt;sup&gt;b&lt;/sup&gt;</td>
<td>75.15 ± 2.48&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>± S.E</td>
<td>± 5%</td>
<td>± 10%</td>
<td>± 5%</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>± 5%</td>
<td>± 10%</td>
<td>± 5%</td>
</tr>
<tr>
<td>MCHC</td>
<td>Mean</td>
<td>53.94 ± 1.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>44.77 ± 2.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>49.98 ± 0.82&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>± S.E</td>
<td>± 5%</td>
<td>± 10%</td>
<td>± 5%</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>± 5%</td>
<td>± 10%</td>
<td>± 5%</td>
</tr>
<tr>
<td>HCT</td>
<td>Mean</td>
<td>27.52 ± 1.65&lt;sup&gt;a&lt;/sup&gt;</td>
<td>34.72 ± 1.37&lt;sup&gt;a&lt;/sup&gt;</td>
<td>26.97 ± 0.96&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>± S.E</td>
<td>± 5%</td>
<td>± 10%</td>
<td>± 5%</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>± 5%</td>
<td>± 10%</td>
<td>± 5%</td>
</tr>
</tbody>
</table>

Table (3) revealed insignificant difference in lymphocyte % in catfishes treated with concentration 5% and 10% of pendimethaline and recovery with EDTA for 7 days and 21 day in comparison with the control group. It is clear from table (3) and figure (9) that showed a significant increase (P<0.05) in lymphocyte % in catfishes treated with concentration 5% of pendimethaline and recovery with EDTA for 7 days when compared with the treated group, but insignificant difference was recorded in the other groups.

Data presented in table (3) recorded insignificant difference in neutrophils % in catfishes treated with concentration 5% and 10% of pendimethaline for 7 days and 21 day when compared with the control group. Data found in table (3) and illustrated in figure (10) showed a significant decrease (P<0.05) in neutrophil % in catfishes treated with concentration 5% of pendimethaline and recovery with EDTA for 7 days and 10% for 21 day when compared with the treated groups, but insignificant difference was recorded in the other remain groups.

Statistical data of monocytes % in table (3) a significant decrease in catfishes treated with concentration 5% and 10% of pendimethaline for 7 days and 21 day when compared with the control group, except a groups treated with pendimethalin at concentration 5% for 21 days showed insignificant decrease in monocyte percentage. Also the data showed insignificant difference in monocytes % with concentration 5% and 10% of pendimethalin and recovery with EDTA for 21 days when compared with the treated groups. Eosinophils in table (3) observed a significant decrease (P<0.05) in catfishes treated with concentration 10% of pendimethaline for 7 days, while insignificant difference was recorded at concentration 5% of pendimethalain for 7 days when compared with the control group. From other hand, the data showed a significant decrease in Eosinophils % in catfishes treated with concentration 5% of pendimethaline and recovery with EDTA for 7 days when compared with the treated groups. Insignificant difference was recorded in Eosinophils percentage in group treated
with pendimethalin at concentration 10% and recovery with EDTA for 7 day when compared with the treated groups.

Table (3): Mean values ± S.E of Differential leukocyte count (lymphocyte, Neutrophil, Monocyte and eosinophil) on catfish (Clarias gariepinus) intoxicated with pendimethalin (stomp) and recovery with EDTA at different interval periods.

<table>
<thead>
<tr>
<th>Parameters ( %)</th>
<th>Period</th>
<th>Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Control</td>
</tr>
<tr>
<td>Lymphocyte</td>
<td>Mean ± S.E</td>
<td>85.65±0.80</td>
</tr>
<tr>
<td>Neutrophil</td>
<td>Mean ± S.E</td>
<td>7.25±1.65</td>
</tr>
<tr>
<td>Monocyte</td>
<td>Mean ± S.E</td>
<td>6.25±1.10</td>
</tr>
<tr>
<td>Eosinophil</td>
<td>Mean ± S.E</td>
<td>1.25±0.41</td>
</tr>
</tbody>
</table>

Biochemical parameters:
Data found in table (4) showed a significant increase (P<0.05) in serum ALAT and ASAT enzymes activities in catfishes treated with 5% and 10% of pendimethalin for 7 and 21 day when compared with the control group. On the other hand cat fishes treated with pendimethalin at concentration 5% and 10% and recovery with EDTA showed a significant decrease (P<0.05) in serum ALAT and ASAT enzymes activities for 7 and 21 day when compared with treated groups, except group treated with Pendimethalin and recovery with EDTA at concentration 10% after 21 day showed a significant increase (P<0.05) in serum ALAT only. Where the Mean and S.E was (50.0±5.4), (81±6.1) in control group and was (166.0±5.7), (209±9.3) in catfishes treated with concentration 10% of Pendimethalin for 7 days for ALAT and ASAT respectively.

Serum alkaline phosphatase enzyme activity illustrated in table (4) demonstrated a significant increase (P<0.05) in catfishes treated with pendimethalin at concentration 5% and 10% for 7 and 21 day in comparison with the control group, except cat fishes treated with pendimethalin at concentration 5% for 21 day observed insignificant increase in serum ALP in comparison with the control group. Insignificant difference was recorded in serum ALP enzyme activity in groups treated with pendimethalin and recovery with EDTA at concentration 5% and 10% for 7 and 21 day when compared with treated groups.

Statistical data in table (4) observed insignificant increase in serum (GGT) activity in group treated with pendimethalin for 7 day at concentration 5% when compared with the control group. On contrast a significant increase (P<0.05) in serum GGT was recorded in group treated with pendimethalin at concentration 10% for 7 day.

Each value represented means of 5 records ± S.E.

a,b,c,d,e means comparison between all groups which the groups have the same letter mean there is no significance difference and which have different letter mean there is a significance change. %: Percent of changes from control values.

Biochemical parameters:
Data found in table (4) showed a significant increase (P<0.05) in serum ALAT and ASAT enzymes activities in catfishes treated with 5% and 10% of pendimethalin for 7 and 21 day when compared with the control group. On the other hand cat fishes treated with pendimethalin at concentration 5% and 10% and recovery with EDTA showed a significant decrease (P<0.05) in serum ALAT and ASAT enzymes activities for 7 and 21 day when compared with treated groups, except group treated with Pendimethalin and recovery with EDTA at concentration 10% after 21 day showed a significant increase (P<0.05) in serum ALAT only. Where the Mean and S.E was (50.0±5.4), (81±6.1) in control group and was (166.0±5.7), (209±9.3) in catfishes treated with concentration 10% of Pendimethalin for 7 days for ALAT and ASAT respectively.

Serum alkaline phosphatase enzyme activity illustrated in table (4) demonstrated a significant increase (P<0.05) in catfishes treated with pendimethalin at concentration 5% and 10% for 7 and 21 day in comparison with the control group, except cat fishes treated with pendimethalin at concentration 5% for 21 day observed insignificant increase in serum ALP in comparison with the control group. Insignificant difference was recorded in serum ALP enzyme activity in groups treated with pendimethalin and recovery with EDTA at concentration 5% and 10% for 7 and 21 day when compared with treated groups.

Statistical data in table (4) observed insignificant increase in serum (GGT) activity in group treated with pendimethalin for 7 day at concentration 5% when compared with the control group. On contrast a significant increase (P<0.05) in serum GGT was recorded in group treated with pendimethalin at concentration 10% for 7 day.
Also a significant increase (P<0.05) was showed in serum GGT activity in catfishes treated with pendimethaline at concentration 5% and 10% for 21 days in comparison with the control. Catfishes groups treated with pendimethaline at concentration 5% and 10% and recovery with EDTA for 7 and 21 day recorded insignificant decrease in serum GGT activity, except group treated with pendimethaline at concentration 10% and recovery with EDTA for 7 day showed a significant decrease (P<0.05) when compared with treated groups.

**Table (4):** Mean values ± S.E of liver functions tests on catfish (Clarias gariepinus) intoxicated with pendimethaline (stomp) and recovery with EDTA at different interval periods.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Groups</th>
<th>Period</th>
<th>Control</th>
<th>Stomp 5%</th>
<th>(5%) Recovery</th>
<th>Stomp 10%</th>
<th>(10%) Recovery</th>
<th>Stomp 5%</th>
<th>(5%) Recovery</th>
<th>Stomp 10%</th>
<th>(10%) Recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALAT (U/L)</td>
<td>Mean ± S.E</td>
<td>50.0± 5.4</td>
<td>123</td>
<td>50.2</td>
<td>± 17.4</td>
<td>166</td>
<td>± 4.7</td>
<td>114.5</td>
<td>± 5.7</td>
<td>151.7</td>
<td>± 7.4</td>
</tr>
<tr>
<td>%</td>
<td>--</td>
<td>146</td>
<td>0.4</td>
<td>233</td>
<td>129</td>
<td>203.4</td>
<td>75.4</td>
<td>45</td>
<td>75.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ASAT (U/L)</td>
<td>Mean ± S.E</td>
<td>81</td>
<td>6.1</td>
<td>10.9</td>
<td>12.1</td>
<td>209</td>
<td>9.3</td>
<td>152.7</td>
<td>11.9</td>
<td>172.5</td>
<td>7.2</td>
</tr>
<tr>
<td>%</td>
<td>--</td>
<td>117.5</td>
<td>24.0</td>
<td>158.8</td>
<td>88.5</td>
<td>112.9</td>
<td>48.3</td>
<td>157.4</td>
<td>157.4</td>
<td>95.0</td>
<td></td>
</tr>
<tr>
<td>ALP (U/L)</td>
<td>Mean ± S.E</td>
<td>49.7</td>
<td>6.1</td>
<td>4.3</td>
<td>6.3</td>
<td>82.2</td>
<td>4.3</td>
<td>83.5</td>
<td>4.8</td>
<td>57.2</td>
<td>3.8</td>
</tr>
<tr>
<td>%</td>
<td>--</td>
<td>59.9</td>
<td>39.2</td>
<td>65.3</td>
<td>68.0</td>
<td>15.0</td>
<td>16.7</td>
<td>43.2</td>
<td>27.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GGT (U/L)</td>
<td>Mean ± S.E</td>
<td>5.0</td>
<td>1.0</td>
<td>1.0</td>
<td>0.8</td>
<td>14.2</td>
<td>2.8</td>
<td>6.5</td>
<td>1.3</td>
<td>13.5</td>
<td>1.7</td>
</tr>
<tr>
<td>%</td>
<td>--</td>
<td>90</td>
<td>54</td>
<td>184</td>
<td>30</td>
<td>170</td>
<td>120</td>
<td>210</td>
<td>124</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Each value represented means of 5 records ± S.E.

Table (5) showed a significant increase (P<0.05) in serum total protein in catfishes treated with concentration 5% and 10% pendimethaline for 7 and 21 days when compared with the control group. Also, there are a significant increase (P<0.05) was recorded in total Protein level in catfishes treated with concentration 5% of pendimethaline and recovery with EDTA for 7 days when compared with the treated group, also the data found that, there are a significant increase (P<0.05) in serum total protein level in catfishes treated with concentration 10% of pendimethaline and recovery with EDTA for 21 days when compared with the treated group. While insignificant difference in the other groups.

Serum albumin level recorded in table(5) demonstrated a significant increase (P<0.05) in catfishes treated with pendimethaline at concentration 5% and 10% for 21 days when compared with the control group, while insignificant difference was recorded in serum albumin level in catfishes treated with concentration 5% and 10% of pendimethaline for 7 days when compared with the control group.

The resulted data, found in table (5) (P<0.05) in serum globulin level in catfishes treated with pendimethaline at concentration 5% and 10% for 7 days and 21 days when compared with the control group, except a group treated with Pendimethaline at concentration 5% for 21 days recorded insignificant increase when compared with the control group.

From the other hand, there are a significant increase (P<0.05) in globulin level in catfishes treated with pendimethaline at concentration 5% and recovery with EDTA for 7 days when compared with the treated group, also there are a significant increase (P<0.05) in globulin level in catfishes treated with Pendimethaline at concentration 10% and recovery with EDTA for 21 days when compared with the treated group, but insignificant differences was recorded in the other treated groups.
Table (5): Mean values ± S.E of Total protein, albumin, and globulin on catfish (*Clarias gariepinus*) intoxicated with pendimethalin (stomp) and recovery with EDTA at different interval periods.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Period</th>
<th>7 days</th>
<th>21 days</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
<td>Stomp (5%)</td>
<td>(5%) Recovery</td>
</tr>
<tr>
<td>T. Protein (g/dl)</td>
<td>Mean ± S.E</td>
<td>5.7 ± 0.19a</td>
<td>6.9 ± 0.22b</td>
</tr>
<tr>
<td>%</td>
<td>---</td>
<td>21.05</td>
<td>26.3</td>
</tr>
<tr>
<td>Albumin (g/dl)</td>
<td>Mean ± S.E</td>
<td>2.10 ± 0.02a</td>
<td>2.22 ± 0.1a</td>
</tr>
<tr>
<td>%</td>
<td>---</td>
<td>5.71</td>
<td>-2.85</td>
</tr>
<tr>
<td>Globulin (g/dl)</td>
<td>Mean ± S.E</td>
<td>3.62 ± 0.20a</td>
<td>4. ± 0.28b</td>
</tr>
<tr>
<td>%</td>
<td>---</td>
<td>29.8</td>
<td>42.8</td>
</tr>
</tbody>
</table>

Each value represented means of 5 records ± S.E. Means comparison between all groups which the groups have the same letter mean there is no significance difference and which have different letter mean there is a significance change. %: Percent of changes from control values.

Data found in table (6) showed a significant increase (P<0.05) in CPK enzyme activity in catfishes treated with concentration 5% and 10% of pendimethaline for 7 and 21 day when compared with the control group. From the other hand catfishes treated with pendimethaline at concentration 10% and recovery with EDTA recorded a significant decrease (P<0.05) in CPK enzyme activity for 7 and 10 days when compared with treated groups, while insignificant decrease in CPK enzyme activity was observed in groups treated with pendimethaline at concentration 5% and recovery with EDTA for 7 and 21 days when compared with the treated groups.

LDH enzyme activity in table (6)demonstrated a significant increase (P<0.05) in catfishes treated with concentration 5% and 10% of pendimethaline for 7 and 21 day when compared with the control group. In contrast a highly significant decrease (P<0.05) in LDH enzyme activity was showed in catfishes treated with pendimethaline and recovery with EDTA at concentration 5% and 10% for 7 days and 21 day when compared with the treated groups, except in group treated with pendimethaline at concentration 5% for 21 day which revealed that insignificant decrease in serum LDH enzyme activity when compared with the treated groups.

Plasma glucose level in table (6) revealed a significant increase (P<0.05) in catfishes treated with pendimethaline at concentration 5% and 10% for 7days and 21 day when compared with the control group. Statistical data in table (5) and figure () observed that catfishes treated with pendimethaline and recovery with EDTA at concentration 10% for 7 and 21day showed a significant decrease (P<0.05) in plasma glucose level when compared with the treated groups, while insignificant decrease in Plasma glucose level was recod in groups treated withPendimethaline and recovery with EDTA at concentration 5% for 7 and 21 day in comparison with the control group.
Table (6): Mean values ± S.E of heart functions tests & Glucose on catfish (Clarias gariepinus) intoxicated with pendimethalin (stomp) and recovery with EDTA at different interval periods.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Control</th>
<th>Stomp (5%)</th>
<th>Stomp (10%)</th>
<th>Stomp (5%) Recovery</th>
<th>Stomp (10%) Recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glucose (mg/dl)</td>
<td>Mean ± S.E</td>
<td>Mean ± S.E</td>
<td>Mean ± S.E</td>
<td>Mean ± S.E</td>
<td>Mean ± S.E</td>
</tr>
<tr>
<td>Period 7 days</td>
<td>46.81 ± 3.0</td>
<td>15.93 ± 9.9</td>
<td>147.41 ± 147.4</td>
<td>212.2 ± 116.0</td>
<td>1726.7 ± 1726.7</td>
</tr>
<tr>
<td>Period 21 days</td>
<td>46.81 ± 4.6</td>
<td>15.93 ± 7.0</td>
<td>147.41 ± 147.4</td>
<td>212.2 ± 116.0</td>
<td>1726.7 ± 1726.7</td>
</tr>
</tbody>
</table>

Antioxidant and oxidative stress in liver tissue:
Catalase enzyme activity of the catfishes showed a significant decrease (P<0.05) in groups treated with concentration 5% and 10% pendimethaline for 7 and 21 days when compared with the control group as in table (7) on the other hand, there are a significant increase (P<0.05) was recorded in catalase enzyme activity in catfishes treated with concentration 5% and 10% of pendimethaline and recovery with EDTA for 7 and 21 days when compared with the treated groups, except group treated with concentration 5% of pendimethaline and recovery with EDTA for 7 days observed insignificant increase in catalase enzyme activity in liver tissue when compared with the treated groups.

Reduced glutathione level recorded (GSH) in table (7) demonstrated a significant decrease (P<0.05) in GSH in liver tissue of catfishes treated with pendimethaline at concentration 5% and 10% for 7 days and 21 days except catfishes treated with pendimethaline at concentration 5% for 7 days showed insignificant differences in GSH level. Insignificant differences in GSH level was observed in catfishes treated with pendimethaline at concentration 5% and 10% for 7 days and 21 days recovery with EDTA for 7 and 21 days when compared with the control group. From the other hand, catfishes treated with pendimethaline at concentration 5% and 10% and recovery with EDTA for 7 days and 21 days revealed a significant increase (P<0.05) in liver (GR) level in comparison with the treated groups.

The resulted data, found in table (7) a significant decrease (P<0.05) in liver glutathione reductase (GR) level in catfishes treated with pendimethaline at concentration 5% and 10% for 7 days and 21 days when compared with the control group. From the other hand, catfishes treated with pendimethaline at concentration 5% and 10% and recovery with EDTA for 7 days and 21 days revealed a significant increase (P<0.05) in liver (GR) level in comparison with the treated groups.

MDA of the liver catfish showed a significant increase (P<0.05) in catfishes treated with concentration 5% and 10% pendimethaline for 7 and 21 days when compared with the control group as in table (8) on the other hand, there are a significant decrease (P<0.05) in (MDA) level was revealed in catfishes treated with pendimethaline at concentration 5% and 10% and recovery with EDTA for 7 days and 21 day when compared with the treated groups.

Data found in table (8) observed that a significant decrease (P<0.05) in SOD enzyme activity in the liver tissue of catfishes treated with concentration 5% and 10% pendimethaline for 7 and 21 days when compared with the control...
group, while catfishes treated with concentration 5% and 10% pendimethaline and recovery with EDTA for 7 and 21 days revealed insignificant increase in liver SOD enzyme activity when compared with treated groups.

Table (7): Mean values ± S.E of antioxidant markers in liver tissue of catfish (Clarias gariepinus) intoxicated with pendimethalin (stomp) and recovery with EDTA at different interval periods.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Period</th>
<th>7 days</th>
<th>21 days</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
<td>Stomp (5%)</td>
<td>(5%) Recovery</td>
</tr>
<tr>
<td>Catalase (U/g tissue)</td>
<td>Mean± S.E</td>
<td>13.77± 0.53c</td>
<td>11.1± 1.4b,c</td>
</tr>
<tr>
<td>%</td>
<td>--------</td>
<td>-18.9± 2.9</td>
<td>-8.02± 0.33c</td>
</tr>
<tr>
<td>Reduced glutathione (GSH)</td>
<td>Mean± S.E</td>
<td>14.7± 0.33c</td>
<td>13.8± 0.35b,c</td>
</tr>
<tr>
<td>(U/g tissue)</td>
<td>%</td>
<td>--------</td>
<td>-0.61± 0.68</td>
</tr>
<tr>
<td>Glutathione reductase (GR)</td>
<td>Mean± S.E</td>
<td>4292± 115.9b</td>
<td>4117.5± 65.2b</td>
</tr>
<tr>
<td>(%/U g tissue)</td>
<td>%</td>
<td>--------</td>
<td>-104.0± 3.06</td>
</tr>
</tbody>
</table>

Each value represented means of 5 records ± S.E. 

Discussion:-

A fundamental goal of ecotoxicology and hazard assessment is to determine the ecological effects of toxic chemicals on natural communities and ecosystems. Little information exists regarding the toxicity of pendimethalin to fish. There has been increasing interest in the use of fish as biomarkers for the effects of pollution and for the early detection of aquatic environmental contamination (van der Oost et al., 2003 and EL-Sayed et al., 2013) so, Aquatic environments are commonly impacted by various pesticides (including herbicides, fungicides, and insecticides) from different sources. Fish species are described as suitable monitors for the effects of noxious compounds because of their ecological and economical relevance (Jiraungkoorsuk et al., 2002 and Moustafa et al., 2016). In addition, changes in haematological, biochemical and cellular levels are among the most sensitive biological responses.
reported after fish exposure to aquatic pollutants (Sandriniet al., 2013 and Moustafa et al., 2016). The Present study was directed to investigate the behavioral, haematological, biochemical, antioxidants and oxidative stress effects of Pendimethalin (Stomp) herbicide on Nile catfish (Clarias gariepinus). The initial reaction of the catfish was observed in the present study is swim actively due to the effect on the nervous system; the rapidity of swimming was directly proportional to the concentration of the chemical. The stressful and erratic behaviors of the (Clarias gariepinus) also tend to indicate respiratory impairment probably due to the effect of the chemical on the gills. Fish breathe by movement of water, dissolved oxygen and any water contaminants present, in and out through their gills, so the gills are usually site of first contact of the internal organ. The observed behavioral changes and clinical toxicity signs in catfish are in agree with those reported by Ahmed and Moustafa, (2010) in which the abnormal behavioral changes in the fish mainly manifested in their respiratory and nervous systems, and appeared immediately after exposure to pendimethalin. The abnormal movements may have resulted from hypercontractions of the muscles due to cholinesterase inhibition at the highest pendimethalin concentration (El-Sharkawy et al., 2011) in addition the respiratory manifestations may have resulted from excess mucus secretions forming a thick coating on the gill tissue (Ferguson, 1989 and Attallah et al., 1997). El-Sharkawy et al., (2011) found that the introduction of Stomp herbicide into the aquatic system impaired respiration and the fish often found dead with open mouths attributing these observations to the inert components of the herbicide; as petroleum solvents (naphthalene and ethylene dichloride).

Under the stressful conditions, the catfish become hyperactive and thus require large amounts of oxygen to achieve the requirements of energy also, secrete large amounts of mucus to coat their body especially on the gills to gain relief from the irritating effects of toxicants (Pandey et al., 2009 and Ahmed, 2011). This results are in agreement with Auta and Ogueji, (2007); Okomoda and Ataguba, (2011); Marzouket al., (2012) and EL-Sayed et al., (2013).

As fish are in direct contact with the environment, only a thin epithelial membrane separates the blood of the fish from water (Hlave and Bulkey, 1980). As a matter of fact, blood is a pathophysiological reflector of the body because it is highly susceptible to internal and external environmental fluctuations. Morphological changes in blood indicate the changes in the quality of the environment and therefore the functional status of the animal exposed to toxicants (Seth and Saxena, 2003). Knowledge of the haematological characteristics is an important tool that can be used as an effective and sensitive index to monitor physiological and pathological changes in fishes and the exposure of chemical pollutants can induce either increase or decrease in haematological level eosinophils (Hawkins and Mawdesley, 2006; Schlenket al., 2008; Alohanet al., 2014 and Nwani et al., 2015).

Fish live in a very close contact with their environment, and therefore they are very vulnerable to any physicochemical changes which may be reflected in their blood parameters Wilson and Taylor, (1993) and Ndimelelet al., (2015). The obtained data showed a significant increase in RBCs, hemoglobin, hematocrits, blood indices and WBCs count in groups exposure to pendimethalin herbicide when compared to the corresponding values in control group and this may be due to it appears that the presence of greater amounts of herbicides in waters may exert a greater and more lasting effect on the hematological profile of fish. The results may also be indicative of the synergistic action of the Pendimethalin herbicide. Also this may due to haemo-concentration and polycythemia due to decrease the amount of dissolved oxygen in water or may due to Hemochromatosis in which too much iron RBCs and haemoglobin in the body causes hemochromatosis. Iron is important because it is part of hemoglobin, a molecule in the blood that transports oxygen from the lungs to all body tissues. iron may build up in the organs and cause complications, including cirrhosis, or scarring of liver tissue; diabetes, irregular heart rhythms or weakening of the heart muscle; arthritis and erectile dysfunction. The complication most often associated with hemochromatosis is liver damage. Iron buildup in the liver causes cirrhosis, which increases the chance of developing liver cancer (Bacon et al., 2011). These results are in agreement with those observed by (Velisek et al., 2009), Velisek et al., (2011), Nascimentoet al., (2012) and EL-Sayed et al., 2013). Also, these results are in agreement with Oloruntuyiet al., (2000) who reported that herbicides cause changes in the quality of water in and near sprayed areas as decrease in dissolved oxygen in the water, along with an increase in temperature, may pose threat to the survival of fish species after herbicide applications. The calculated blood indices, MCV, MCH & MCHC have particular importance in describing anemia in most animals and the increase in MCV may be attributed to the direct effect of catecholamines, cortisol, and glucose on adenylate cyclase activities in red blood cells, as a response to acute hypoxic stress (Coles et al., 1986 and Salehet al., 2016). Moreover, general decrease in MCH and MCHC could be attributed to RBCs haemolysis and the reduction of RBCs production in the haemopoietic tissues under the action of the bio-accumulated herbicide as indicated.
In our study, data showed a significant increase in WBCs count in catfishes treated with 5% and 10% of pendimethaline for 7 and 21 days when compared to the corresponding values in control group and this may due to activate the immune system or due to stress in fish by change in WBCs count and convert to leucocytosis. Leucocytes are involved in the regulation of immunological functions and protective response to stress in fish (Velisek et al., 2012). This results in agreement with Zaahkouk et al., (1996); Ayub et al., (1997); Haggag (2004) and Modesto and Martinez, (2010) who reported that Pendimethalin herbicide may activate the immune system in fish by altering levels of total leucocytes, thus signaling an adaptive immune response. In addition, the increase in WBCs may reflect the proliferation of multipotent hematopoietic cells as a consequence of chemical toxicity (Fink and Salibian, 2005) the increase in WBCs indicate that the stress condition of the fish induced by pendimethalin may cause hypoxia and gill damage. Thus, the increase in WBCs count indicate to the stress condition of fish induced by exposure to Stomp herbicide that may have produced hypoxia and gill damage (EL-Sayed et al., 2013).

Increase in WBCs count occurred as a pathological response since these WBCs play a great role during infestation by stimulating the haemopoietic tissues and the immune system by producing antibodies and chemical substances working as defense against infection (Wedmeyer and Wood, 1974; Lebelo et al., 2001; Hassen, 2002 and Masud and Singh, 2013). WBC is important cells in the immune system, because of their main defensive function. The WBCs respond immediately to the change in medium due to xenobiotoic transformation. During toxic exposure period of herbicide, the WBCs counts were enhanced. It indicates that fish can develop a defensive mechanism to overcome the toxic stress. The leukocyte profile can also be affected by different kinds of pesticides in which the present study revealed a significant increase in the number of lymphocytes this may be due to the addition of EDTA improves the haematological which can be attributed to the capability of EDTA to chelate or remove from the media and subsequently, the Pendimethalin toxicity was reduced. and this is agree with (Modesto and Martinez, 2010) in which their results revealed a significant increase in the number of lymphocytes and a reduction in the number of neutrophils after exposure to the herbicide. In our study, data showed a significant decrease in platelets count in catfishes treated with pendimethalin when compared to the corresponding values in control group and this may due to induce hepatic histological changes and bleeding and this may affect coagulation factors and clotting and this results in agreement with Neiva et al., (2010) who observed that the results demonstrate that herbicide caused changes in the platelet metabolism with an inhibitory effect on primary hemostasis and the longterm treated of rats with low doses of herbicidemay induce hepatic histological changes, the leakage of hepatic intracellular enzymes such as alanine aminotransferase and aspartate aminotransferase as well as nasal bleeding. Also, Thrombocytopenia is more likely to occur in the presence of hypersplenism associated with liver cirrhosis (Bashouret et al., 2000 and Tefferiet et al., 2005). The addition of EDTA improves the haematological parameters as platelets which can be attributed to the capability of EDTA to chelate toxic substance from the media and subsequently, the herbicide toxicity was reduced (Shalaby et al., 2011).

Biochemical parameters:

Measurements of biochemical alterations have been used to monitor the environmental exposure of fish to contaminants in both laboratory and field studies (Shailaja and D’Silva, 2003), because of the sensitivity of fish to the adverse effects of xenobiotics (Ahmad et al., 2004). The obtained data showed a significant increase in serum ALAT, ASAT, ALP, GGT enzymes activity, total protein, albumin and globulin levels in catfishes treated with pendimethaline when compared to the corresponding values in control group and this may due to increase in activities of these enzymes, reflecting the damage of the liver cells or changes in the cell membrane permeability leading to leakage of enzymes from cells to the circulation (Botisglou et al., 2008). These results are in agreement with Abd-algadiret et al., (2011) and El-Sharkawy et al., (2011) reported that Pendimethalin significantly increased serum ALAT, ASAT, ALP in fish exposed to Pendimethalin and this may due to damage of hepatocytes.

Akila et al., (1998) who assessment of liver function can be made by estimating the activities of serum SGOT, SGPT and ALP, which are originally present in higher concentration in the cytoplasm. Hepatocellular necrosis leads to the elevation of these serum marker enzymes, which are released from the liver into the blood stream (Shenoy et al., 2002). The increased levels of S.GOT, S.GPT, and S.ALP are conventional indicator of liver injury (Achliyaet al., 2004).

Hence, the elevated activities of serum ASAT and ALAT indicate liver damage or enhanced transamination. Increased transamination during herbicide challenge has been attributed to the need to meet higher energy demanded by fish (Natarajan, 1985 and Philip et al., 1995). Proteins are the most important and abundant macromolecules in
Reactive oxygen species may alter the normal balance between the ROS production and the antioxidant defense mechanism. A significant decrease in the liver catalase (CAT), superoxide dismutase (SOD), glutathione reductase (GR) activity and reduced glutathione (GSH) in catfish groups treated with Pendimethalin when compared to the corresponding values in control group, this result may be attributed to indicate elevated liver metabolic activity and albumin concentrations of (Leporinus obtusidens) and (Cyprinus carpio) exposed to (376 µg/l) clomazone herbicide and (0.2 and 2 µg/l) terbutryn for 90 days and 28, 90 days, respectively. This may be attributed to different tested chemicals and the differences in exposure periods or fish species.

**Heart functions test and glucose:-**
The obtained data showed a significant increase in CPK and LDH enzyme activity in all catfish groups exposed to herbicide when compared to the corresponding values in control group. Creatine phosphokinase (CPK) is an enzyme found in muscle, heart, gills and brain (Banaee et al., 2014). This results in agreement with Abbas et al., (2007); Velisek et al., (2009) and Doubek et al., (2010).

Creatine phosphokinase is an intracellular enzyme that catalyzes the formation of adenosine triphosphate (ATP) from creatine phosphate and adenosine diphosphate (ADP). It is therefore abundant in metabolically active tissues with significant energy demands, specifically skeletal and smooth muscle, myocardium, and brain. Three distinct isoenzyme forms of CPK have been identified, namely, CPK-MM, MB, and BB (M—muscle, B—brain) recently, One of the several biochemical markers that have been studied in an effort to improve early detection of ectopic pregnancy is creatine phosphokinase (CPK) Lott and Albott, (1986) and Kruchkovichet al., (2012).

The enzymes lactate dehydrogenase (LDH) and creatinophosph kinase (CPK) are metabolic key factors (Ocampo-set al., 1987; Gill et al., 1990; Coppes, 1992; Pelletier et al., 1994; Gilliet et al., 2000; Kurutas and Tuncer, 2000; Leopold and Loscalzo, 2000; Long et al., 2003 and Osman et al., 2007). The cytoplasmic enzyme LDH is widely used as marker of organ or tissue lesions in toxicology and in clinical chemistry and it has been used for demonstrating tissue damage in fish (Das et al., 2004a). In most cases of tissue damage, whether due to disease or toxic compound, the activity of LDH was reported to be significantly affected (Singh and Sharma, 1998). LDH is a source of the oxidised coenzyme during the period of transient anaerobiosis or a reduced form of such coenzyme during aerobiosis (Coppes, 1992). LDH plays an important role during glycolysis, and have direct effects on the development of fish (Shaklee et al., 1974). Elevated levels of this enzyme in plasma indicate a transient damage to either muscle fibers (cardiac) or other tissues in which the continuous exposure to acute herbicide concentrations resulted in significantly increased levels of CK in common carp at 96. Increased activity of CPK and LDH can be explained as a consequence of pathological changes in hepatic tissue. Catalytic activities of plasma enzymes (i.e. LDH, CK, ALT, and AST) may be used as indicator of stress reaction as the increased values indicate stress-based tissue impairment.

**Oxidative stress and antioxidants:-**
A significant decrease in the liver catalase (CAT), superoxide dismutase (SOD), glutathione reductase (GR) activity and reduced glutathione (GSH) in catfish groups treated with Pendimethalin when compared to the corresponding values in control group this may be due to decreased synthesis of (GSH) in the tissues, thereby preventing the maintenance of the homeostatic redox status in the presence of the oxidative effects that occurred after exposure to Pendimethalin. Pendimethalin also reduced (CAT) and (SOD) levels, possibly because of decreases in the rates of...
(CAT) and (SOD) reactions as a result of peroxidative damage to the liver. Regarding the effects of Pendimethalin on oxidative stress status in the liver of catfish our results indicate that Pendimethalin increased LPO and decreased levels of GSH and activities of antioxidant enzymes, especially of CAT, SOD, and GR. The herbicide significantly ($p<0.05$) decreased the GSH content and activities of CAT, GR, and SOD, and increased the MDA content in the liver.

The depletion of hepatic and gill GSH may increase oxidative stress (Luo et al., 2005); thus, the decreased GSH content in the tissue may have resulted from the consumption of GSH to reduce oxidative stress (Sharbidreet et al., 2011), as reflected in the increased MDA level, under the influence of Pendimethalin.

Moreover, the reduction in GR activity may have resulted in decreased synthesis of GSH in the tissues, thereby preventing the maintenance of the homeostatic redox status in the presence of the oxidative effects (Atli and Canli, 2010) that occurred after exposure to pendimethalin. Pendimethaline also reduced CAT and SOD levels, possibly because of decreases in the rates of CAT and SOD reactions as a result of peroxidative damage to the liver and gills, and/or excess production of ROS, as is observed in toxicity tests on freshwater fish using the herbicides clomazone (Crestani et al., 2007); Lambda cyhalothrin (Saravananet al., 2008) and atrazine (Nwaniet al., 2010). Another explanation for the increase in LPO may be that pendimethalin depletes the GSH content of tissues, which may increase the risk of oxidative stress (Luo et al., 2005) and that reduced activities of CAT, SOD, and GR, which are the first barriers against ROS, are essential for cell survival. Our results are consistent with studies indicating that CAT and SOD levels decrease in fish exposed to herbicides (Pandey et al., 2001); Sayeed et al., (2003); Crestaniet al., (2007); (Atli and Canli, 2010) and EL-Sayed et al., (2013).

Conclusion:
We conclude that pendimethalin is moderately toxic to Nile catfish. The herbicide compound induces leukocytosis as a stress response to acute exposure. Pendimethalin is also capable of inducing disturbances in the antioxidant system in a time-dependent manner, and thus oxidative stress and LPO are proposed mechanisms of the physiological response of the fish to exposure. In turn, their toxicity can end up in humans through the food chain. The suitable controlled and regular use of herbicides is recommended, to obtain the beneficial effects of these resources without polluting the environment and without leaving their residues in food and water sources with potentially negative effects on human health.

References:


