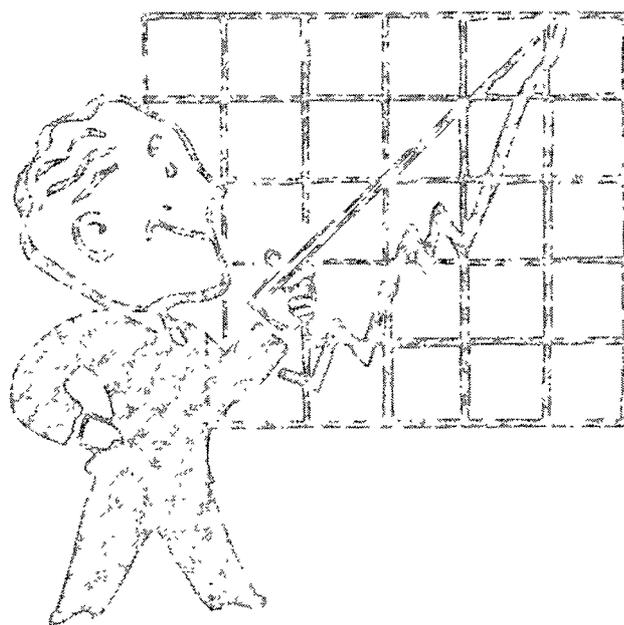
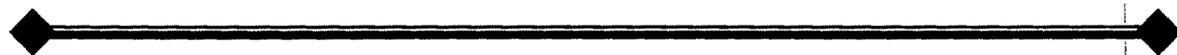


## CHAPTER – 4



# RESULTS



## 4.1 BIOCHEMICAL INVESTIGATIONS

Changes observed in lipid peroxidation products, endogenous antioxidants, other enzymes and lipids after 30 days exposure to 10, 30 and 100 ppm of lead acetate or cadmium chloride.

### 4.1.1 GENERAL OBSERVATIONS

#### 4.1.1.1 Changes in Body and Organ Weight

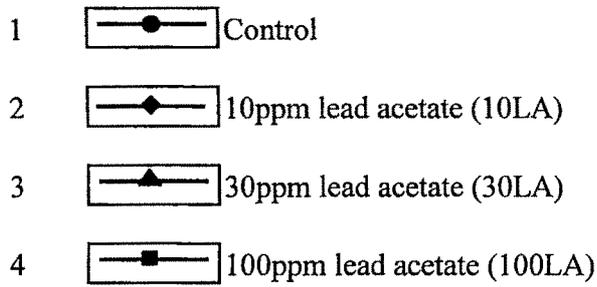
In first set of experiment there was a significant ( $p < 0.05$ ) decrease in body weight of animals during thirty days exposure to 100 ppm lead acetate (100LA, group 4) and there was no significant change in the body weight of animals during the thirty days of exposure to 10 ppm and 30 ppm of lead acetate (10LA, 30LA; group 2, 3) as compared to control animals (group 1) (Fig: 4.1).

Similarly, in second set of experiment there was a significant ( $p < 0.01$ ) decrease in body weight of animals during thirty days exposure to 100 ppm cadmium chloride (100CD, group 4) and there was no significant change in the body weight of animals during the thirty days of exposure to 10 ppm and 30 ppm of cadmium chloride (10CD, 30CD, group 2, 3) as compared to control animals (group 1) (Fig: 4.2).

In lead acetate exposed animals, there was a significant increase in the weight of **liver** and **kidney** in group 3 (30LA) ( $p < 0.05$ ) and group 4 (100LA) ( $p < 0.01$ ) as compared to group 1 (Control). Similarly, there was a significant increase in weight of **lung** ( $p < 0.05$ ) and **heart** ( $p < 0.01$ ) in group 4 (100LA) animals as compared to group 1 (Control). However, there was no significant change in weight of **brain** was observed during the thirty days of exposure (Fig: 4.3).

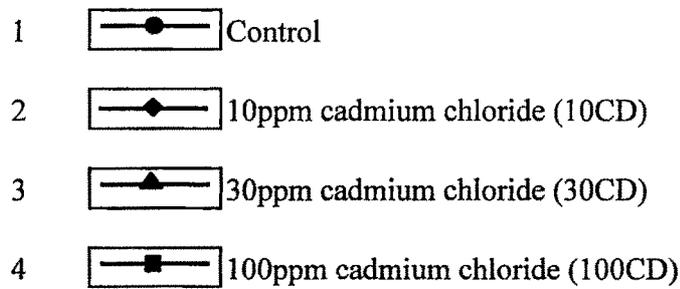
In cadmium chloride exposed animals there was a significant ( $p < 0.05$ ) increase in weight of **liver** in group 3 and 4 (30CD and 100CD) as compared to group 1 (Control). The weight of **kidney** was significantly increased in group 3 (30CD) ( $p < 0.05$ ) and group 4 (100CD) ( $p < 0.001$ ) as compared to group 1 (Control). Further, there was a significant ( $p < 0.05$ ) increase in the weight of **lung** and **heart** of group 4 (100CD) animals as compared to group 1 (Control). However, there was no significant change in the weight of **brain** in any of the group (Fig: 4.4).

**Fig: 4.1. Effect of lead acetate (LA) exposure (30 days) on body weights of rats.**



Values are expressed as mean  $\pm$  SEM for six animals in each group.  
Group 2, 3, 4 compared with group 1.  
\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

**Fig: 4.2. Effect of cadmium chloride (CD) exposure (30 days) on body weights of rats.**



Values are expressed as mean  $\pm$  SEM for six animals in each group.  
Group 2, 3, 4 compared with group 1.  
\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

Fig: 4.1

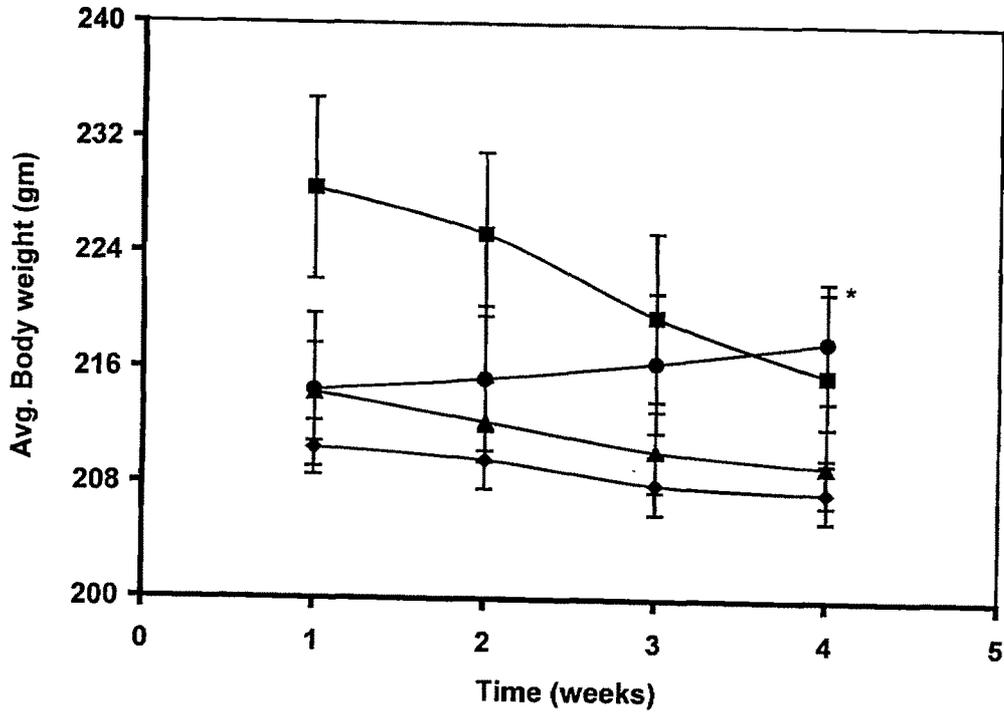
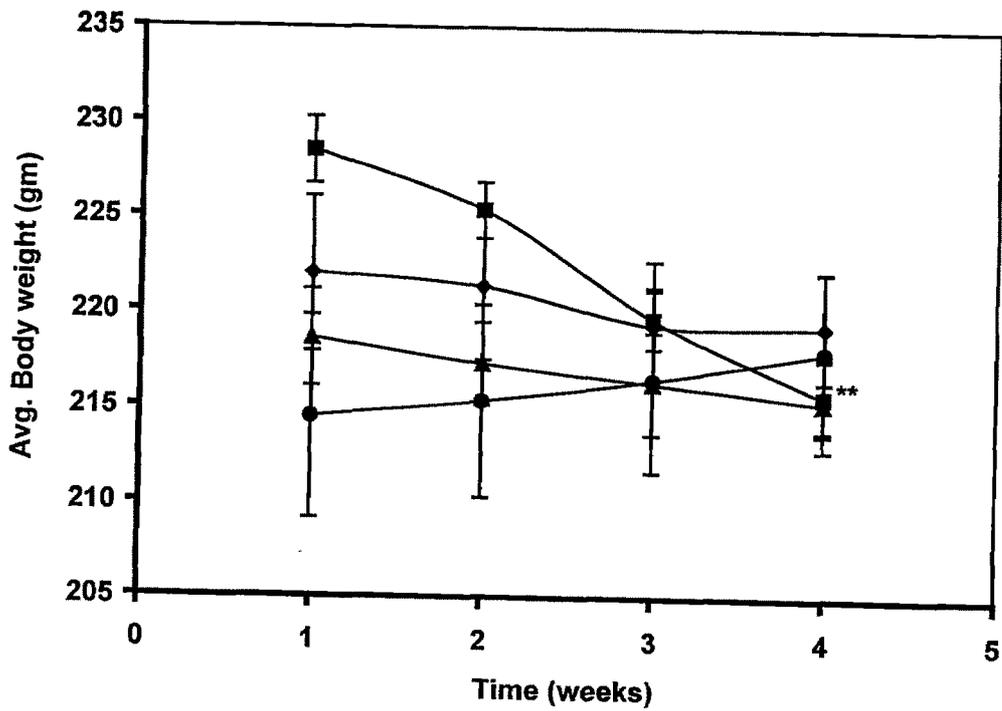
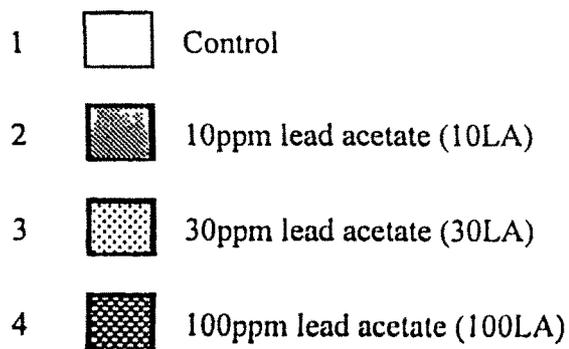


Fig: 4.2



**Fig: 4.3. Effect of lead acetate (LA) exposure (30 days) on the weight of liver, kidney, lung, heart and brain of rats.**

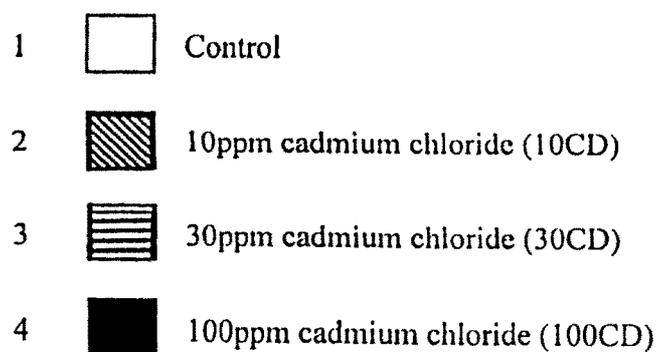


Values are expressed as mean  $\pm$  SEM for six animals in each group.

Group 2, 3, 4 compared to group 1.

\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

**Fig: 4.4. Effect of cadmium chloride (CD) exposure (30 days) on the weight of liver, kidney, lung, heart and brain of rats.**



Values are expressed as mean  $\pm$  SEM for six animals in each group.

Group 2, 3, 4 compared to group 1.

\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

Fig: 4.3

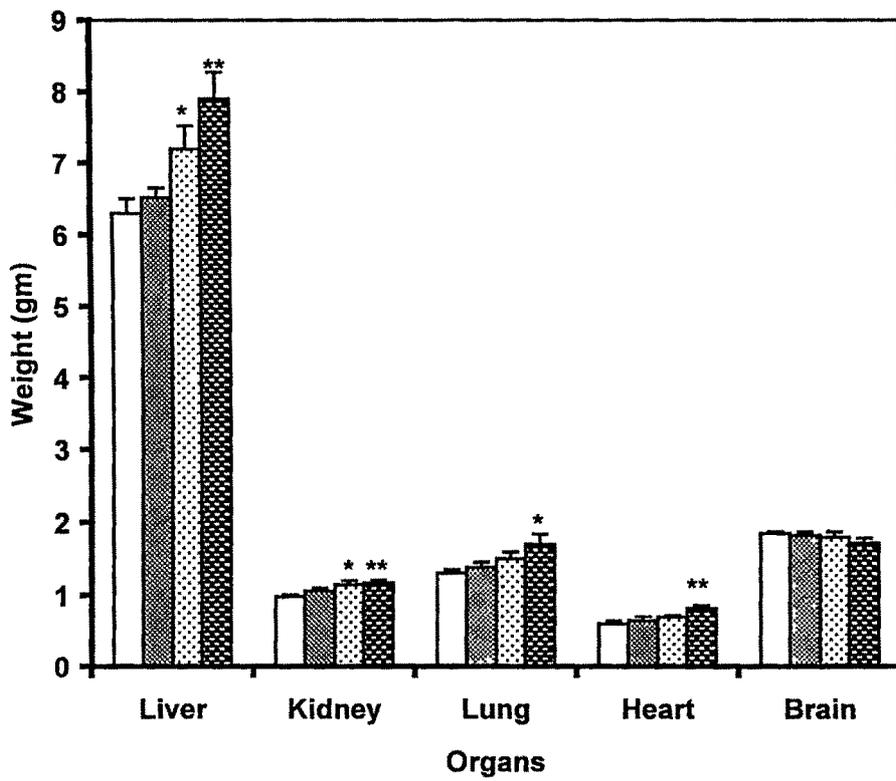
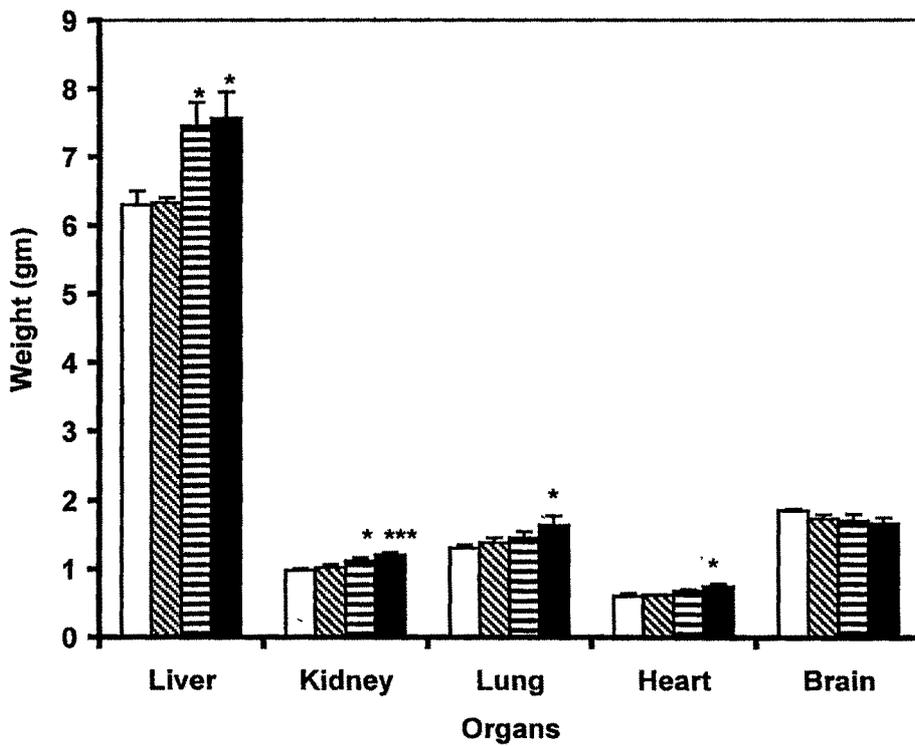


Fig: 4.4



## 4.1.2 TISSUE ESTIMATIONS

### 4.1.2.1 Changes in the Levels of Lipid Peroxidation Products

#### 4.1.2.1.1 Changes in the Levels of Malondialdehyde (MDA)

The MDA levels as a marker of lipid peroxidation were increased significantly in **liver** and **lung** of group 2 (10LA) ( $p < 0.05$ ) and group 3 & 4 (30LA & 100LA) ( $p < 0.001$ ) as compared to group 1 (Control). The MDA levels in **kidney** were significantly increased in group 2 (10LA) ( $p < 0.01$ ) and group 3 & 4 (30LA & 100LA) ( $p < 0.001$ ), while the MDA levels in **heart** were significantly ( $p < 0.001$ ) increased in group 2 (10LA), group 3 (30LA) and group 4 (100LA) as compared to group 1 (Control). However, there was no significant change in MDA levels in **brain** (Fig: 4.5) indicating that lead exposure increases the lipid peroxidation in many organs except **brain**.

In animals exposed to cadmium the MDA levels in **liver** were increased significantly in group 2 (10CD) ( $P < 0.05$ ), group 3 (30CD) ( $p < 0.01$ ) and group 4 (100CD) ( $p < 0.001$ ) as compared to group 1 (Control) (Fig. 4.6). The MDA levels in **kidney** were increased significantly ( $p < 0.05$ ) in group 2 (10CD), group 3 (30CD) and group 4 (100CD) as compared to group 1 (Control). The MDA levels in **lung** were increased significantly in group 2 & 3 (10CD & 30CD) ( $p < 0.05$ ) and group 4 (100CD) ( $p < 0.01$ ) as compared to group 1 (Control). Similarly, The MDA levels in **heart** were increased significantly ( $p < 0.01$ ) in group 2 (10CD) and group 3 & 4 (30 CD & 100CD) ( $p < 0.001$ ) as compared to group 1 (Control). However, there was no significant change in MDA levels in **brain** (Fig: 4.6).

#### 4.1.2.1.2 Changes in the Levels of Hydroperoxide (HYPX)

The HYPX levels in **liver** and **kidney** were increased significantly ( $p < 0.001$ ) in group 2 (10LA), group 3 (30LA) and group 4 (100LA) as compared to group 1 (Control). The HYPX levels in **lung** and **heart** were increased significantly ( $p < 0.001$ ) in group 3 (30LA) and group 4 (100LA) and there was no significant change was observed in group 2 (10LA) as compared to group 1 (Control). Further, there was no significant change in HYPX levels in **brain** of the treated groups as compared to group 1 (control) (Fig: 4.7).

The HYPX levels in **liver, kidney and lung** were increased significantly in group 3 (30CD) ( $p<0.05$ ) and group 4 (100CD) ( $p<0.001$ ); and there was no significant change was observed in group 2 (10CD) as compared to control. The HYPX levels in **heart** were increased significantly in group 3 (30CD) ( $p<0.05$ ) and group 4 (100CD) ( $p<0.01$ ); and there was no significant change was observed in group 2 (10CD) as compared to group 1 (Control). However, there was no significant change in HYPX levels in **brain** of the treated groups as compared to group 1 (Control) (Fig: 4.8).

#### **4.1.2.1.3. Changes in the Levels of Conjugated diene (CJDN)**

The CJDN levels in **liver, kidney, lung and heart** were increased significantly ( $p<0.001$ ) in group 2 (10LA), group 3 (30LA) and group 4 (100LA) as compared to group 1 (Control). However, there was no significant change in CJDN levels in **brain** of the treated groups as compared to control (group 1) (Fig: 4.9).

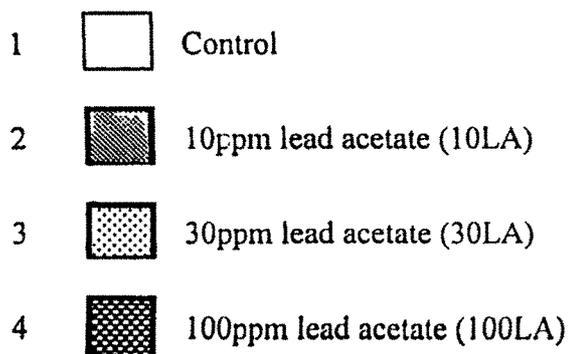
The CJDN levels in **liver and lung** were increased significantly in group 2 (10CD) ( $p<0.05$ ), group 3 and 4 (30CD and 100CD) ( $p<0.001$ ) as compared to control. The CJDN levels in **kidney** were increased significantly in group 2 (10CD) ( $p<0.05$ ), group 3 (30CD) ( $p<0.01$ ) and group 4 (100CD) ( $p<0.001$ ) as compared to control. Similarly there was a significant ( $p<0.001$ ) increase CJDN levels in **heart** of group 2 (10CD) group 3 (30CD) and group 4 (100CD) as compared to group 1 (Control). However, there was no significant change in CJDN level in **brain** of the treated groups as compared to group 1 (Control) (Fig: 4.10).

#### **4.1.2.2 Changes in the Levels of Endogenous Antioxidants**

##### **4.1.2.2.1 Changes in the Levels of Superoxide dismutase (SOD)**

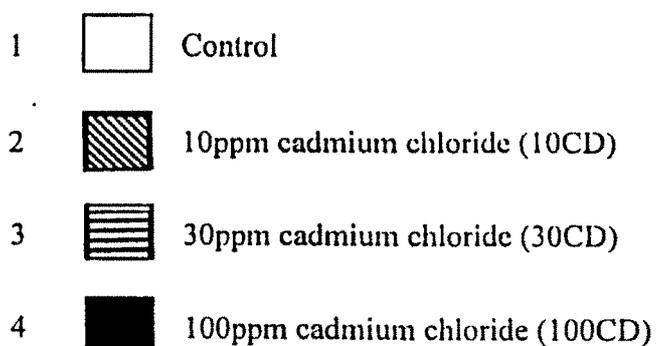
The SOD levels in **liver** were decreased significantly in group 2 (10LA) ( $p<0.05$ ), group 3 (30LA) ( $p<0.01$ ) and group 4 (100LA) ( $p<0.001$ ) as compared to group 1 (Control). The SOD levels in **kidney, lung and heart** were decreased significantly in group 2 (10LA) ( $p<0.01$ ) and group 3 & 4 (30LA & 100LA) ( $p<0.001$ )

**Fig: 4.5. Effect of lead acetate (LA) exposure (30 days) on the levels of malondialdehyde in liver, kidney, lung, heart and brain of rats.**



Values are expressed as mean  $\pm$  SEM for six animals in each group.  
Group 2, 3, 4 compared to group 1.  
\*p<0.05, \*\*p<0.01, \*\*\*p<0.001.

**Fig: 4.6. Effect of cadmium chloride (CD) exposure (30 days) on the levels of malondialdehyde in liver, kidney, lung, heart and brain of rats.**



Values are expressed as mean  $\pm$  SEM for six animals in each group.  
Group 2, 3, 4 compared to group 1.  
\*p<0.05, \*\*p<0.01, \*\*\*p<0.001.

Fig: 4.5.

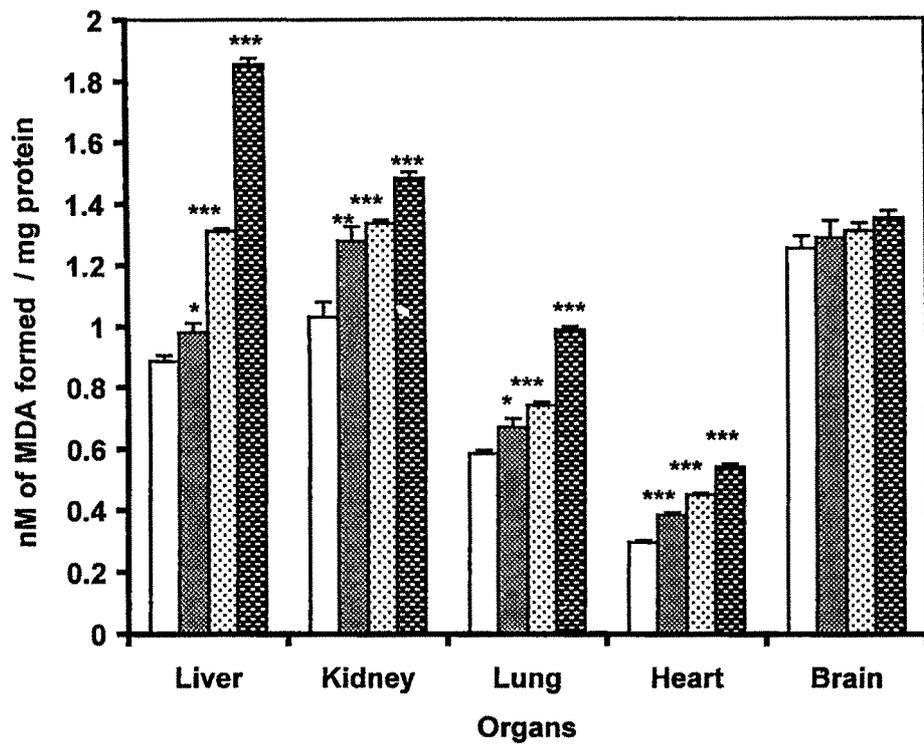
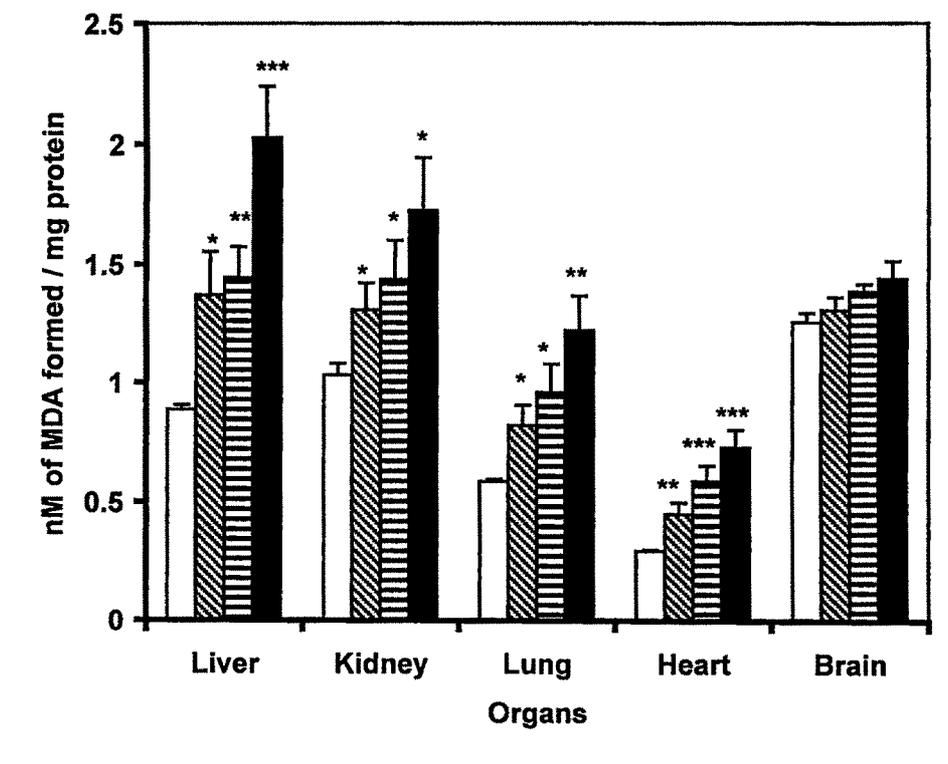
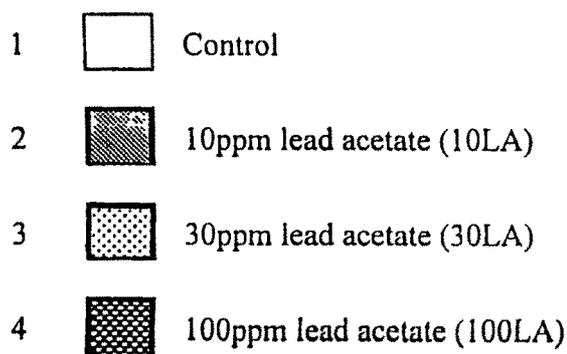


Fig: 4.6.

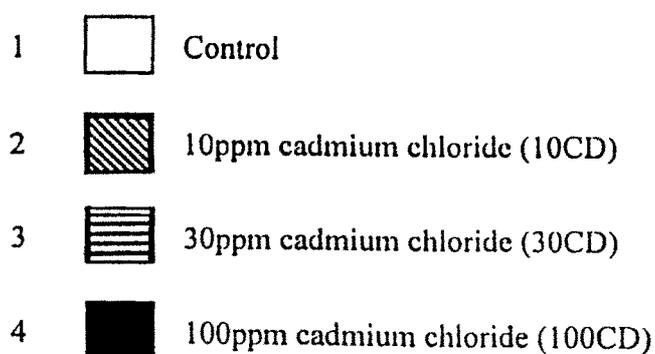


**Fig: 4.7. Effect of lead acetate (LA) exposure (30 days) on the levels of hydroperoxide in liver, kidney, lung, heart and brain of rats.**



Values are expressed as mean  $\pm$  SEM for six animals in each group.  
Group 2, 3, 4 compared to group 1.  
\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

**Fig: 4.8. Effect of cadmium chloride (CD) exposure (30 days) on the levels of hydroperoxide in liver, kidney, lung, heart and brain of rats.**



Values are expressed as mean  $\pm$  SEM for six animals in each group.  
Group 2, 3, 4 compared to group 1.  
\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

Fig: 4.7.

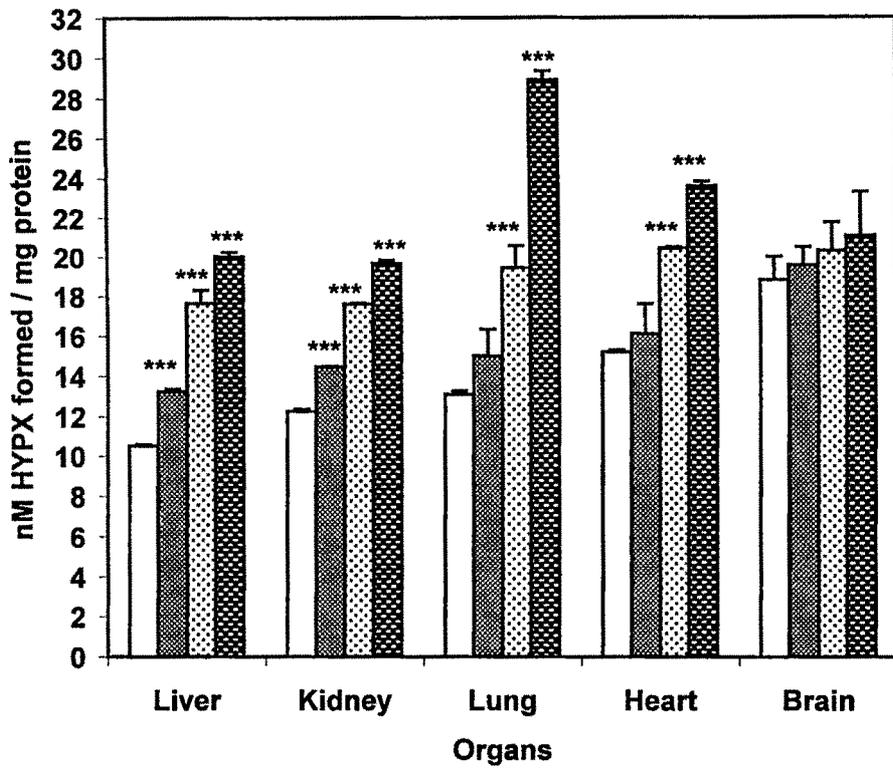
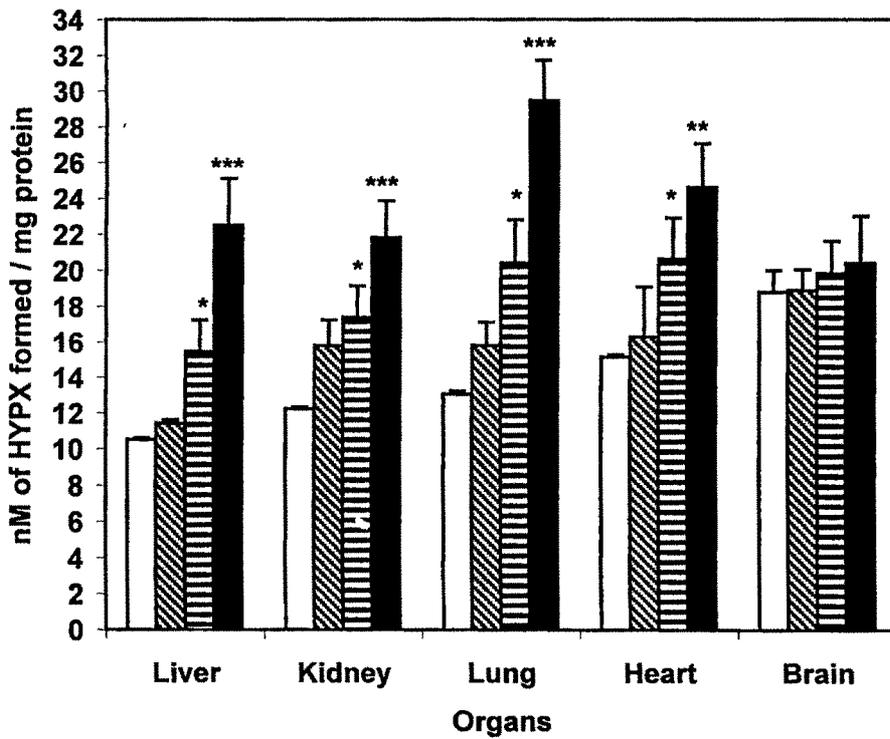
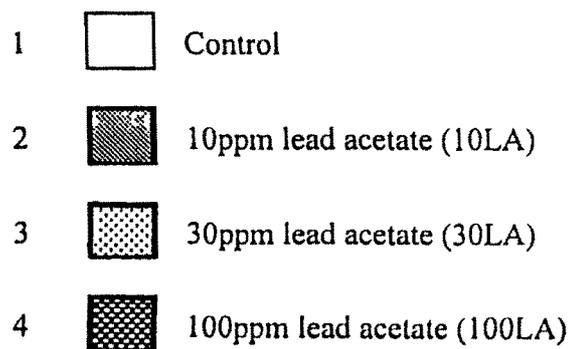


Fig: 4.8.



**Fig: 4.9. Effect of lead acetate (LA) exposure (30 days) on the levels of conjugated diene in liver, kidney, lung, heart and brain of rats.**

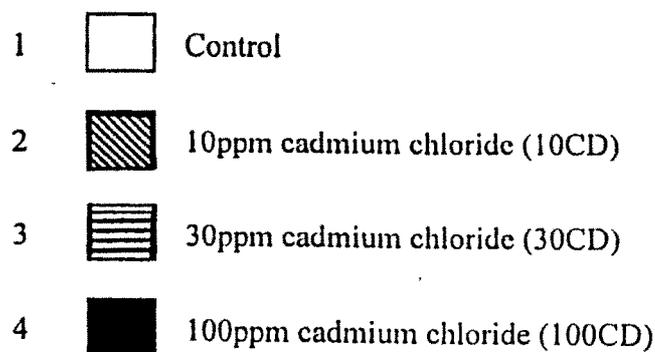


Values are expressed as mean  $\pm$  SEM for six animals in each group.

Group 2, 3, 4 compared to group 1.

\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

**Fig: 4.10. Effect of cadmium chloride (CD) exposure (30 days) on the levels of conjugated diene in liver, kidney, lung, heart and brain of rats.**



Values are expressed as mean  $\pm$  SEM for six animals in each group.

Group 2, 3, 4 compared to group 1.

\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

Fig: 4.9.

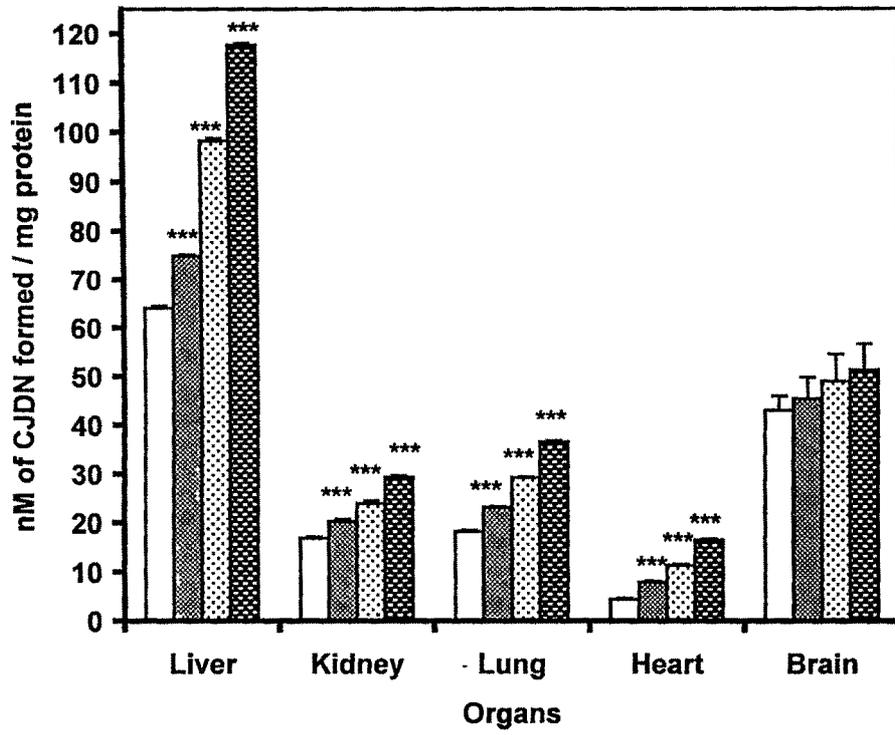
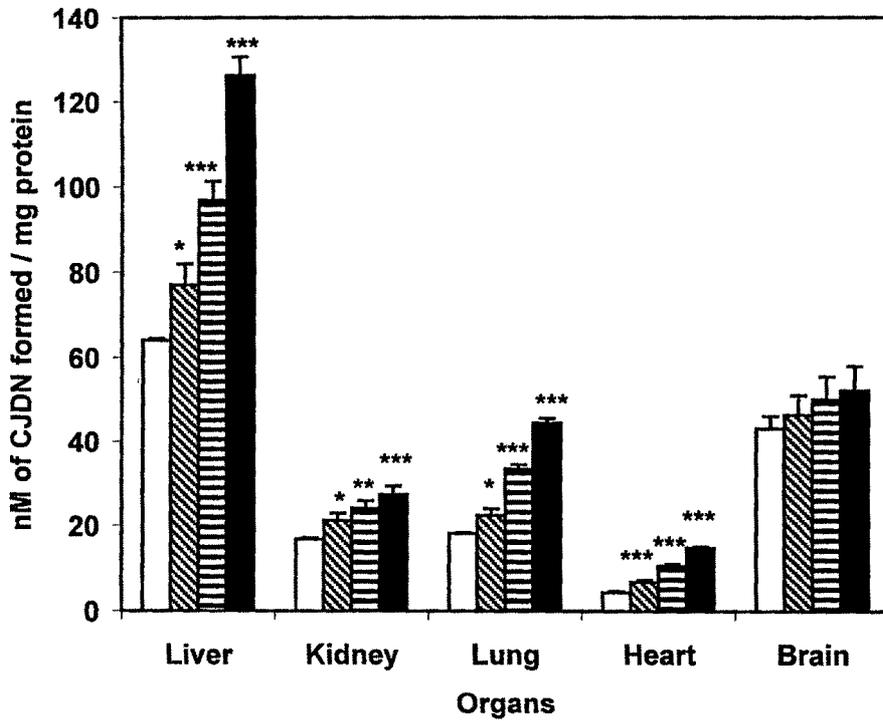


Fig: 4.10.



as compared to group 1 (Control). However, there was no significant change in SOD levels in **brain** of the treated groups as compared to group 1 (Control) (Fig: 4.11).

The SOD levels in **liver** were decreased significantly ( $p < 0.05$ ) in group 2 & 3 (10CD & 30CD) and group 4 (100CD) ( $p < 0.01$ ) as compared to control. The SOD levels in **kidney** were decreased significantly ( $p < 0.05$ ) in group 2, (10CD) and group 3 & 4 (30CD & 100CD) ( $p < 0.001$ ) as compared to control. The SOD levels in **lung** were decreased significantly ( $p < 0.001$ ) in group 3 (30CD) and group 4 (100CD) as compared to control. The SOD levels in **heart** were decreased significantly in group 2 (10CD) ( $p < 0.05$ ), group 3 (30CD) ( $p < 0.01$ ) and group 4 (100CD) ( $p < 0.001$ ) as compared to control. However, there was no significant change in the SOD levels in **brain** of the treated groups as compared to group 1 (Control) (Fig: 4.12).

#### **4.1.2.2.2 Changes in the Levels of Catalase (CAT)**

The CAT levels in **liver**, **kidney** and **lung** were decreased significantly ( $p < 0.01$ ) in group 2 (10LA) and group 3 & 4 (30LA & 100LA) ( $p < 0.001$ ) as compared to group 1 (Control). The CAT levels in **heart** were decreased significantly ( $p < 0.05$ ) in group 2 (10LA) and group 3 & 4 (30LA & 100LA) ( $p < 0.001$ ) as compared to group 1 (Control). However, there was no significant change in CAT levels in **brain** of the treated groups as compared to group 1 (Control) (Fig: 4.13).

The CAT levels in **liver**, **kidney** and **lung** were decreased significantly ( $p < 0.05$ ) in group 2 (10CD) and group 3 & 4 (30CD & 100CD) ( $p < 0.001$ ) as compared to group 1 (Control). The CAT levels in **heart** were decreased significantly ( $p < 0.01$ ) in group 2 (10CD) and group 3, 4 (30LA, 100CD) ( $p < 0.001$ ) as compared to group 1 (Control). However, there was no significant change in CAT levels in **brain** of the treated groups as compared to group 1 (Control) (Fig: 4.14).

#### **4.1.2.2.3 Changes in the Levels of Reduced glutathione (GSH)**

The GSH levels in **liver**, **kidney** and **lung** were decreased significantly ( $p < 0.001$ ) in group 2 (10LA), group 3 (30LA) and group 4 (100LA) as compared

to group 1 (Control). The GSH levels in **heart** were decreased significantly ( $p < 0.01$ ) in group 2 & 3 (10LA & 30LA) and group 4 (100LA) ( $p < 0.001$ ) as compared to group 1 (Control). However, there was no significant change in GSH levels in **brain** of the treated groups as compared to group 1 (Control) (Fig: 4.15).

The GSH levels in **liver** were decreased significantly ( $p < 0.001$ ) in group 2 (10CD), group 3 (30CD) and group 4 (100CD) as compared to group 1 (Control). The GSH levels in **kidney** and **heart** were decreased significantly in group 2 (10CD) ( $p < 0.05$ ), group 3 (30CD) ( $p < 0.01$ ) and group 4 (100CD) ( $p < 0.001$ ) as compared to group 1 (Control). Similarly, the GSH levels in **lung** were decreased significantly ( $p < 0.05$ ) in group 2 & 3 (10CD & 30CD) and group 4 (100CD) ( $p < 0.001$ ) as compared to group 1 (Control). However, there was no significant change in GSH levels in **brain** of the treated groups as compared to group 1 (Control) (Fig: 4.16).

#### **4.1.2.3 Changes in the Levels of liver Gluconeogenic Enzyme**

##### **4.1.2.3.1 Changes in the Levels of Glucose-6-phosphate dehydrogenase (G-6-PD)**

In lead exposed animals, the G-6-PD levels in **liver** were decreased significantly ( $p < 0.05$ ) in group 2 & 3 (10LA & 30LA) and group 4 (100LA) ( $p < 0.01$ ) as compared to group 1 (Control) (Fig: 4.17).

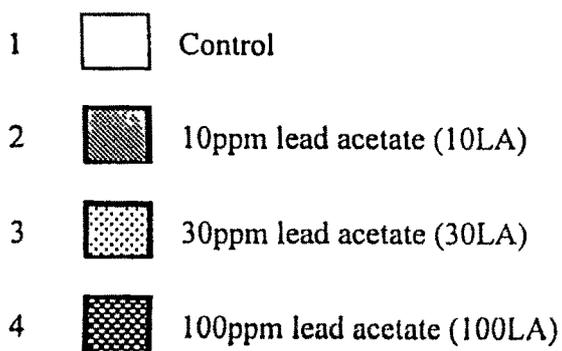
In cadmium chloride exposed animals, the G-6-PD levels in **liver** were decreased significantly in group 3 (30CD) ( $p < 0.05$ ) and group 4 (100CD) ( $p < 0.01$ ); and there was no significant change in group 2 (10CD) as compared to group 1 (Control) (Fig: 4.18).

#### **4.1.2.4 Changes in the Levels of Membrane Bound Enzymes**

##### **4.1.2.4.1 Changes in the Levels of Sodium potassium dependent ATPase ( $\text{Na}^+ - \text{K}^+$ - ATPase)**

The  $\text{Na}^+ - \text{K}^+$ -ATPase levels in **liver** were decreased significantly ( $p < 0.05$ ) in group 2 (10LA) and group 3 & 4 (30LA & 100LA) ( $p < 0.001$ ) as compared to group 1 (Control). The  $\text{Na}^+ - \text{K}^+$ -ATPase levels in **kidney** were decreased significantly ( $p < 0.001$ ) in group 2 (10LA), group 3 (30LA) and group 4 (100LA) as compared to group 1 (Control) (Fig: 4.19).

**Fig: 4.11. Effect of lead acetate (LA) exposure (30 days) on the levels of superoxide dismutase in liver, kidney, lung, heart and brain of rats.**

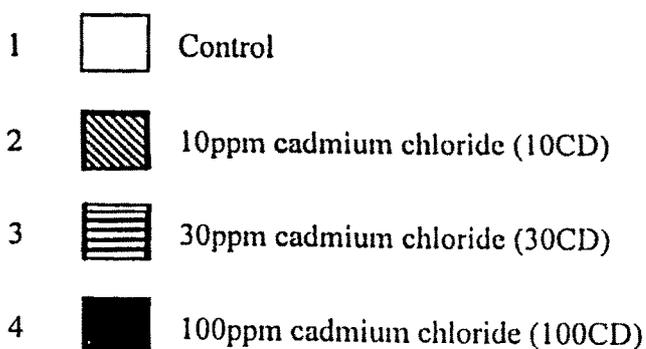


Values are expressed as mean  $\pm$  SEM for six animals in each group.

Group 2, 3, 4 compared to group 1.

\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

**Fig: 4.12. Effect of cadmium chloride (CD) exposure (30 days) on the levels of superoxide dismutase in liver, kidney, lung, heart and brain of rats.**



Values are expressed as mean  $\pm$  SEM for six animals in each group.

Group 2, 3, 4 compared to group 1.

\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

Fig: 4.11.

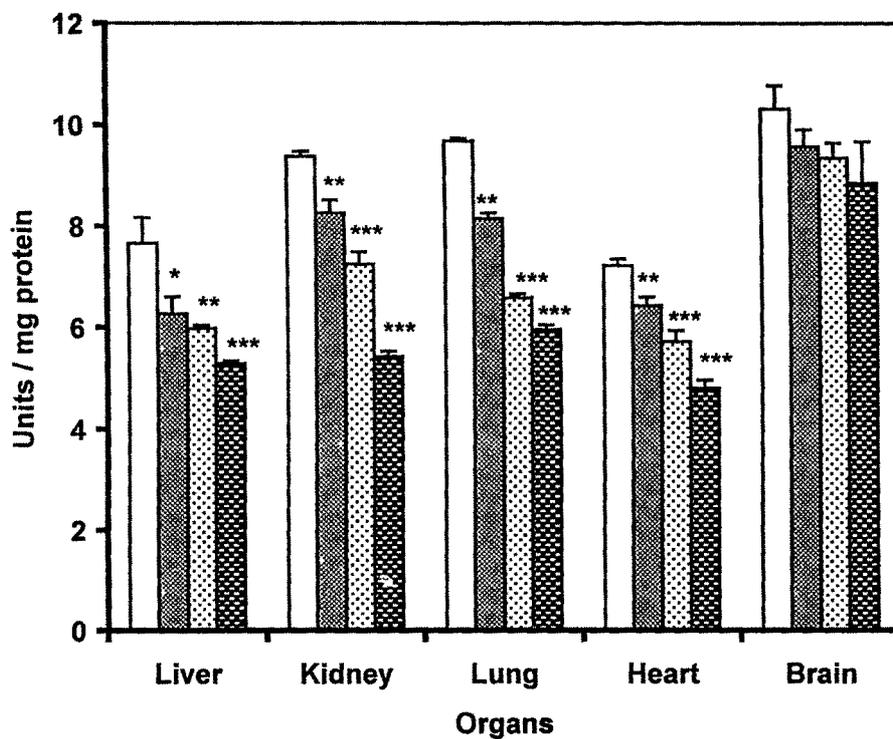
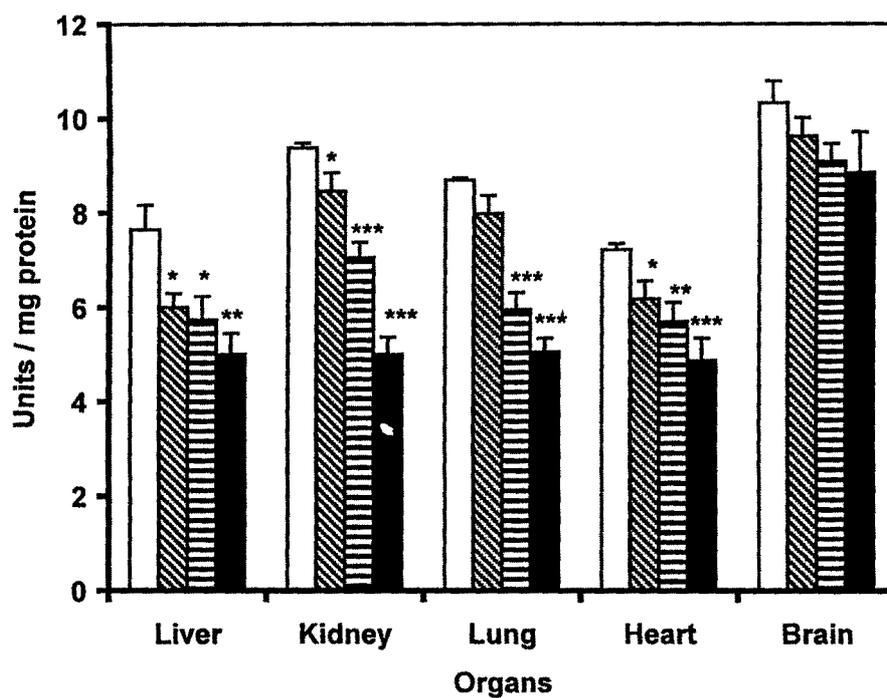
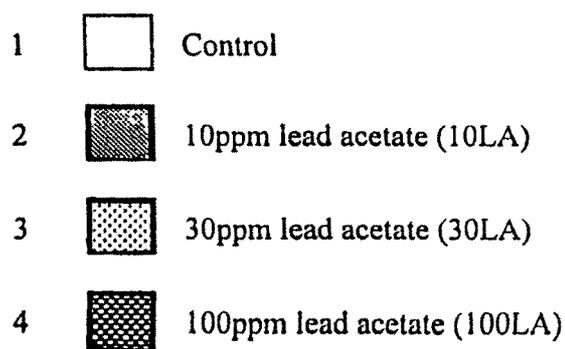


Fig: 4.12.

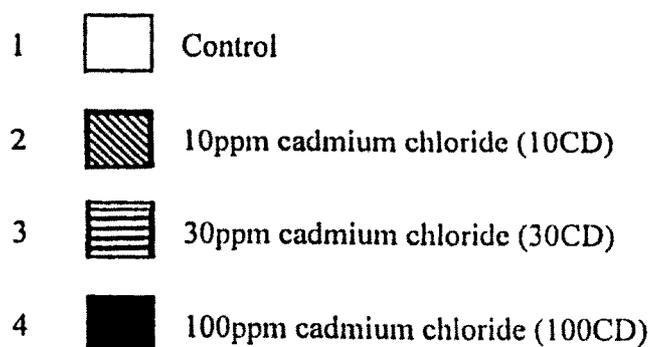


**Fig: 4.13. Effect of lead acetate (LA) exposure (30 days) on the levels of catalase in liver, kidney, lung, heart and brain of rats.**



Values are expressed as mean  $\pm$  SEM for six animals in each group.  
Group 2, 3, 4 compared to group 1.  
\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

**Fig: 4.14 Effect of cadmium chloride (CD) exposure (30 days) on the levels of catalase in liver, kidney, lung, heart and brain of rats.**



Values are expressed as mean  $\pm$  SEM for six animals in each group.  
Group 2, 3, 4 compared to group 1.  
\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

Fig: 4.13.

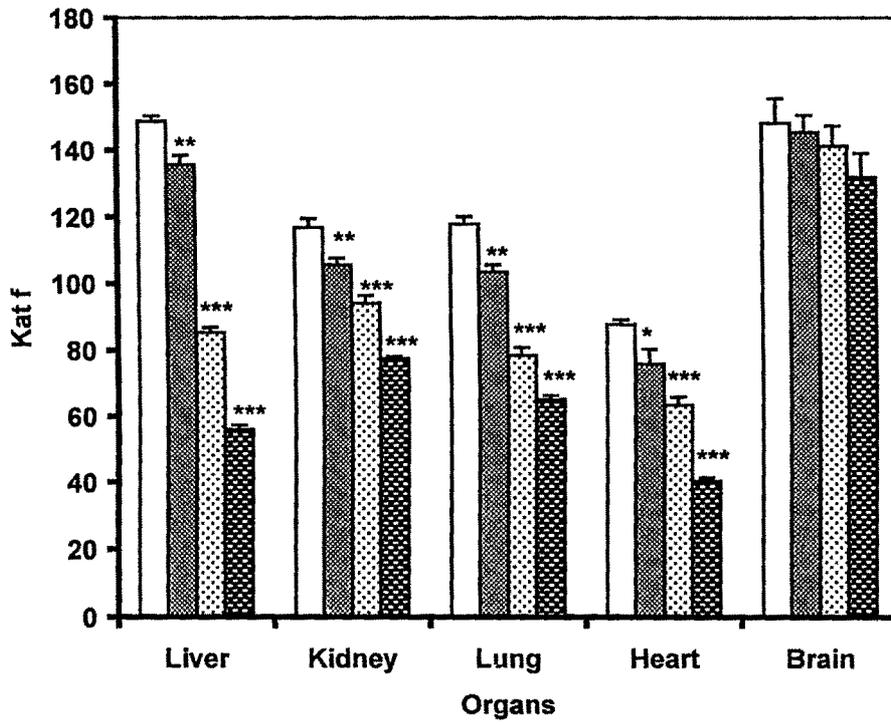
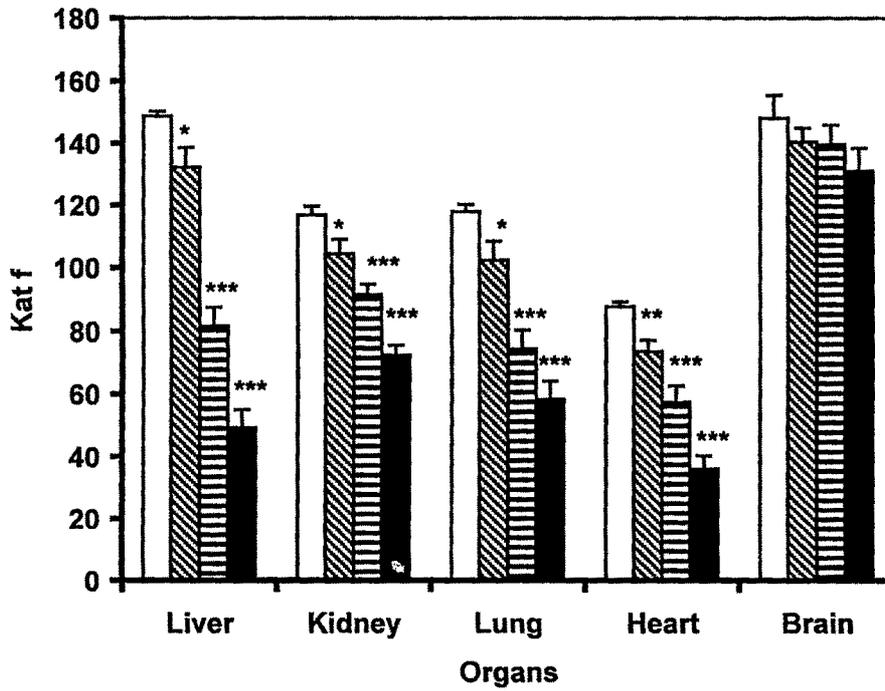


Fig: 4.14.



**Fig: 4.15. Effect of lead acetate (LA) exposure (30 days) on the levels of reduced glutathione in liver, kidney, lung, heart and brain of rats.**

- 1  Control
- 2  10ppm lead acetate (10LA)
- 3  30ppm lead acetate (30LA)
- 4  100ppm lead acetate (100LA)

Values are expressed as mean  $\pm$  SEM for six animals in each group.  
Group 2, 3, 4 compared to group 1.  
\*p<0.05, \*\*p<0.01, \*\*\*p<0.001.

**Fig: 4.16. Effect of cadmium chloride (CD) exposure (30 days) on the levels of reduced glutathione in liver, kidney, lung, heart and brain of rats.**

- 1  Control
- 2  10ppm cadmium chloride (10CD)
- 3  30ppm cadmium chloride (30CD)
- 4  100ppm cadmium chloride (100CD)

Values are expressed as mean  $\pm$  SEM for six animals in each group.  
Group 2, 3, 4 compared to group 1.  
\*p<0.05, \*\*p<0.01, \*\*\*p<0.001.

Fig: 4.15.

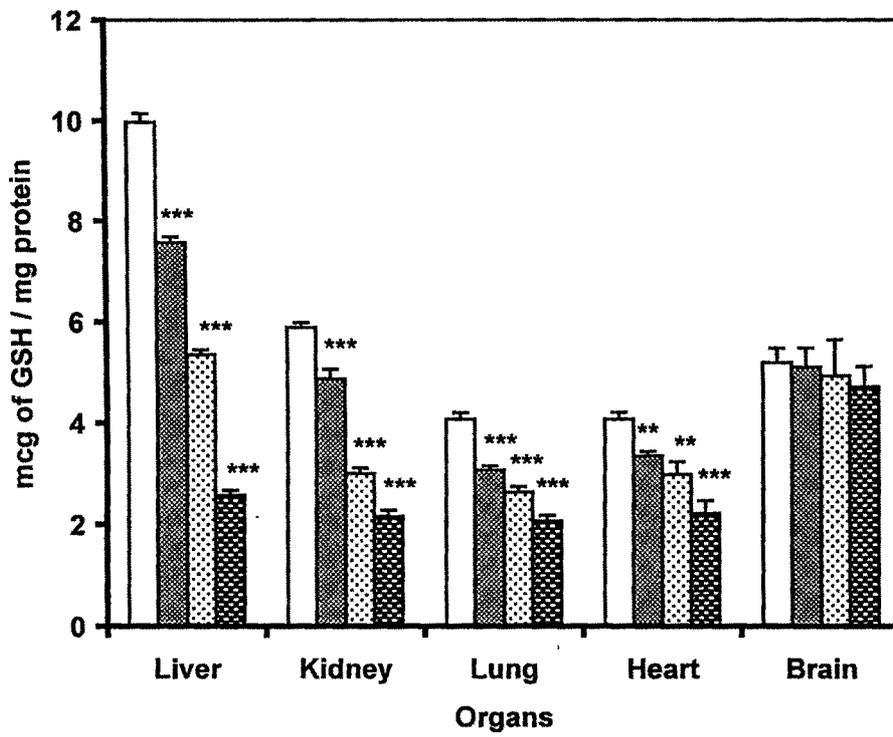
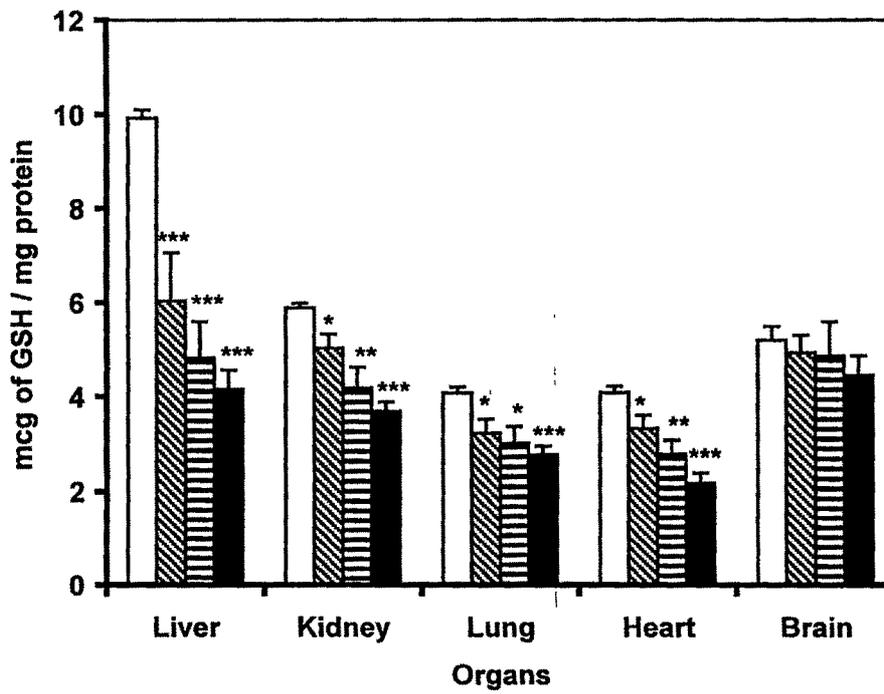


Fig: 4.16.



**Fig: 4.17. Effect of lead acetate (LA) exposure (30 days) on the levels of glucose-6-phosphate dehydrogenase in liver of rats.**

- 1  Control
- 2  10ppm lead acetate (10LA)
- 3  30ppm lead acetate (30LA)
- 4  100ppm lead acetate (100LA)

Values are expressed as mean  $\pm$  SEM for six animals in each group.  
Group 2, 3, 4 compared to group 1.  
\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

**Fig: 4.18. Effect of cadmium chloride (CD) exposure (30 days) on the levels of glucose-6-phosphate dehydrogenase in liver of rats.**

- 1  Control
- 2  10ppm cadmium chloride (10CD)
- 3  30ppm cadmium chloride (30CD)
- 4  100ppm cadmium chloride (100CD)

Values are expressed as mean  $\pm$  SEM for six animals in each group.  
Group 2, 3, 4 compared to group 1.  
\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

Fig: 4.17.

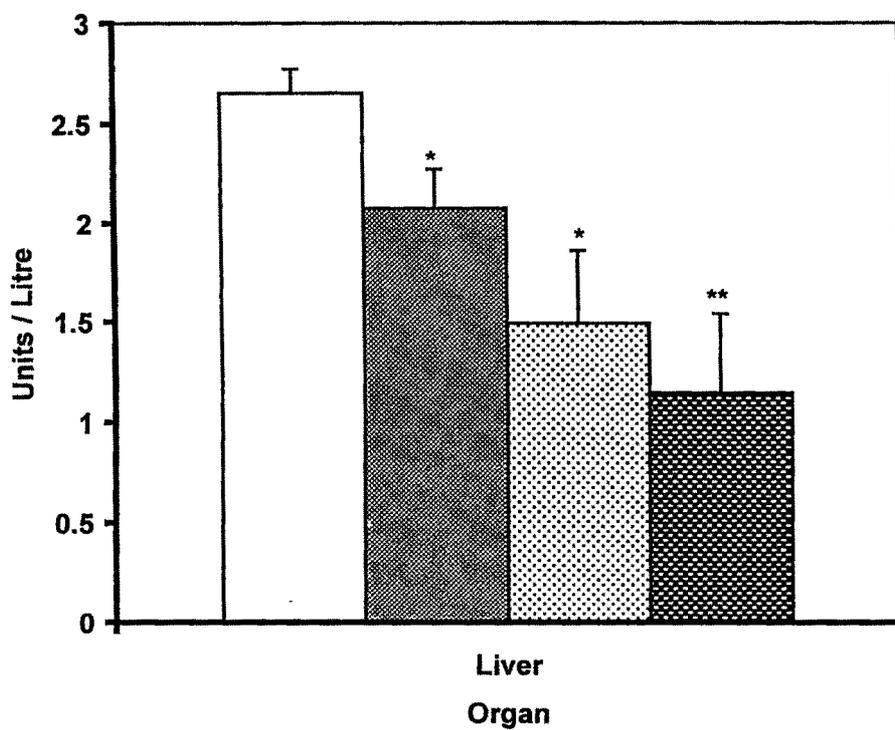
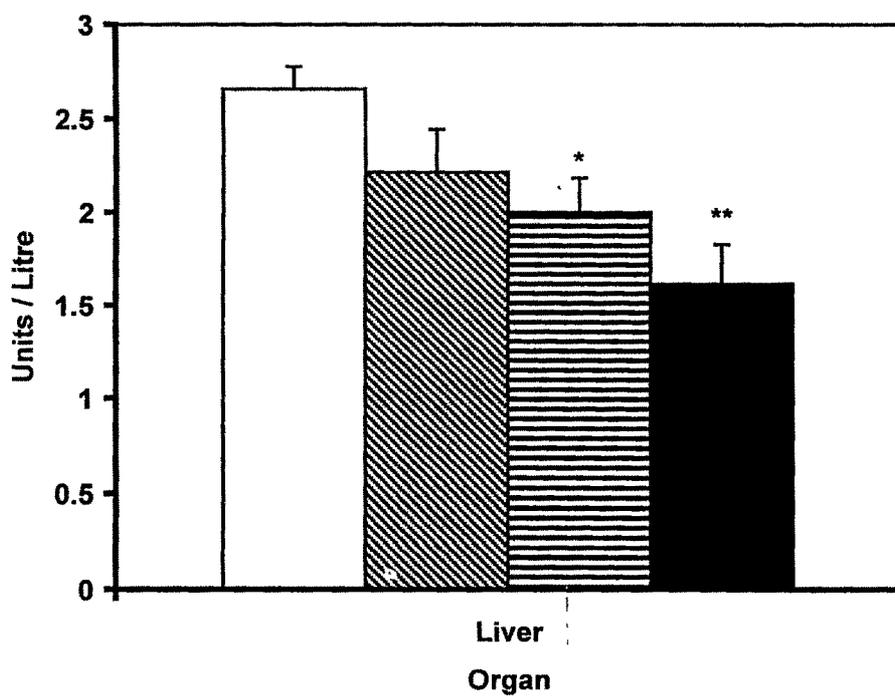


Fig: 4.18.



The Na<sup>+</sup>-K<sup>+</sup>-ATPase levels in **liver** were decreased significantly in group 3 (30CD) (p<0.05) and group 4 (100CD) (p<0.001); and there was no significant change in group 2 (10CD) as compared to group 1 (Control). The Na<sup>+</sup>-K<sup>+</sup>-ATPase levels in **kidney** were decreased significantly in group 3 (30CD) (p<0.05) and group 4 (100CD) (p<0.01); and there was no significant change in group 2 (10CD) as compared to group 1 (Control) (Fig: 4.20).

#### **4.1.2.4.2 Changes in the Levels of Calcium dependent ATPase (Ca<sup>++</sup>-ATPase)**

The Ca<sup>++</sup>-ATPase levels in **liver** were decreased significantly (p<0.05) in group 2 (10LA) and group 3 & 4 (30LA & 100LA) (p<0.001) as compared to group 1 (Control). The Ca<sup>++</sup>-ATPase levels in **kidney** were decreased significantly (p<0.001) in group 2 (10LA), group 3 (30LA) and group 4 (100LA) as compared to group 1 (Control) (Fig: 4.21).

The Ca<sup>++</sup>-ATPase levels in **liver** were decreased significantly (p<0.05) in group 3 (30CD), group 4 (100CD) (p<0.01) and there was no significant change in group 2 (10CD) as compared to group 1 (Control). The Ca<sup>++</sup>-ATPase levels in **kidney** were decreased significantly (p<0.05) in group 2 (10CD) and group 3 & 4 (30CD & 100CD) (p<0.001) as compared to group 1 (Control) (Fig: 4.22).

#### **4.1.2.4.3 Changes in the Levels of Magnesium dependent ATPase (Mg<sup>++</sup>-ATPase)**

The Mg<sup>++</sup>-ATPase levels in **liver** and **kidney** were decreased significantly (p<0.05) in group 2 (10LA) and group 3 & 4 (30LA & 100LA) (p<0.001) as compared to group 1 (Control) (Fig: 4.23).

The Mg<sup>++</sup>-ATPase levels in **liver** and **kidney** were decreased significantly in group 3 (30CD) (p<0.05) and group 4 (100CD) (p<0.01) and there was no significant change in group 2 (10CD) as compared to group 1 (Control) (Fig: 4.24).

#### **4.1.2.5 Changes in the Levels of Tissue Total Proteins (protein)**

##### **4.1.2.5.1 Changes in the Levels of Total Proteins (protein)**

The protein levels in **liver** and **heart** were decreased significantly (p<0.05) in group 3 (30LA), group 4 (100LA) (p<0.001) and there was no significant change in group 1 (10LA) as compared to group 1 (Control). The protein levels in **kidney**

**Fig: 4.19. Effect of lead acetate (LA) exposure (30 days) on the levels of sodium potassium ATPase in liver and kidney of rats.**

- 1  Control
- 2  10ppm lead acetate (10LA)
- 3  30ppm lead acetate (30LA)
- 4  100ppm lead acetate (100LA)

Values are expressed as mean  $\pm$  SEM for six animals in each group.  
Group 2, 3, 4 compared to group 1.  
\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

**Fig: 4.20. Effect of cadmium chloride (CD) exposure (30 days) on the levels of sodium potassium ATPase in liver and kidney of rats.**

- 1  Control
- 2  10ppm cadmium chloride (10CD)
- 3  30ppm cadmium chloride (30CD)
- 4  100ppm cadmium chloride (100CD)

Values are expressed as mean  $\pm$  SEM for six animals in each group.  
Group 2, 3, 4 compared to group 1.  
\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

Fig: 4.19.

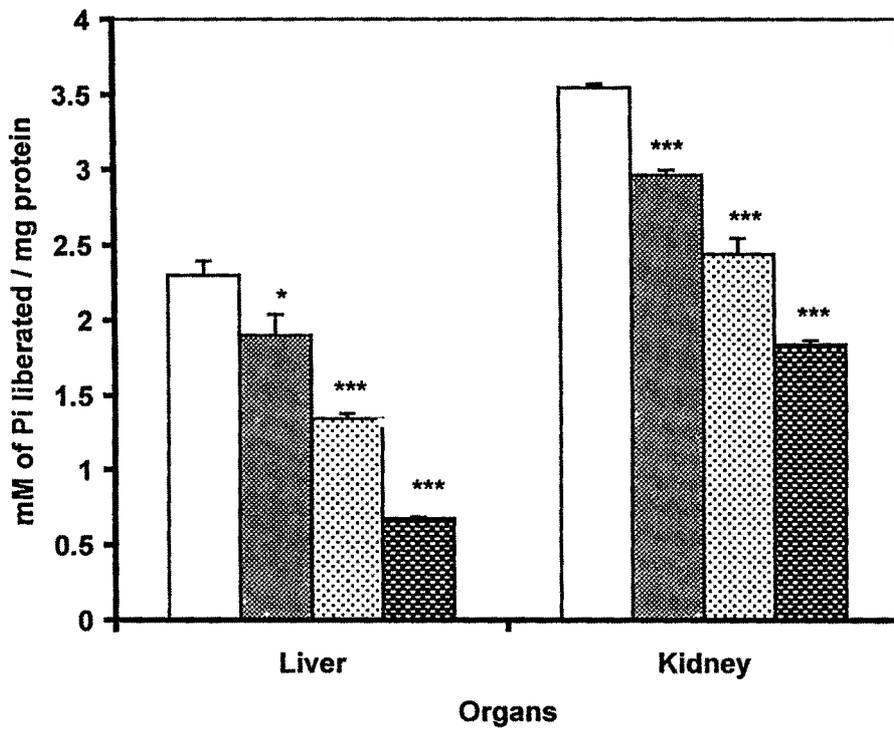
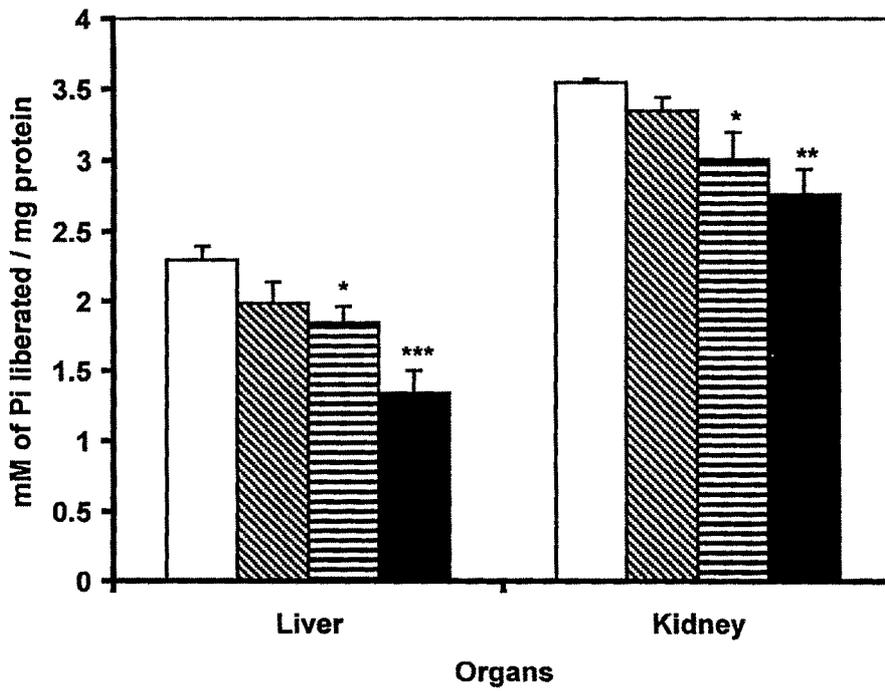
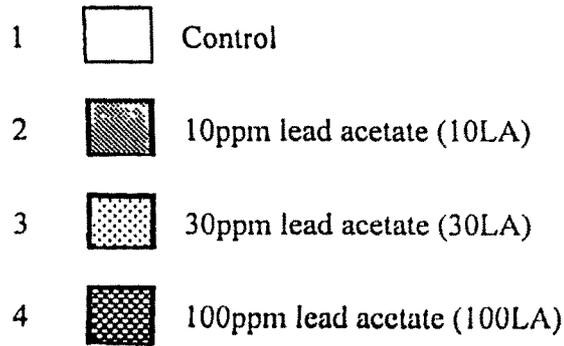


Fig: 4.20.

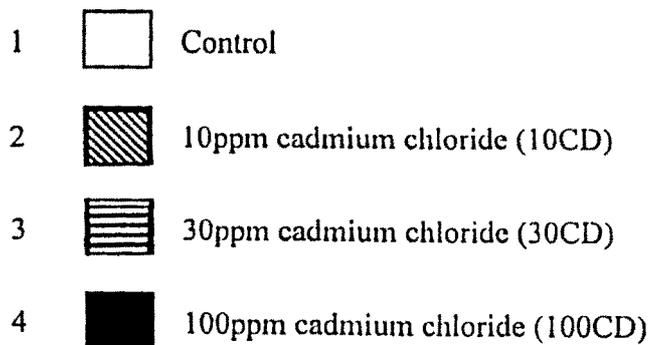


**Fig: 4.21. Effect of lead acetate (LA) exposure (30 days) on the levels of calcium ATPase in liver and kidney of rats.**



Values are expressed as mean  $\pm$  SEM for six animals in each group.  
Group 2, 3, 4 compared to group 1.  
\*p<0.05, \*\*p<0.01, \*\*\*p<0.001.

**Fig: 4.22. Effect of cadmium chloride (CD) exposure (30 days) on the levels of calcium ATPase in liver and kidney of rats.**



Values are expressed as mean  $\pm$  SEM for six animals in each group.  
Group 2, 3, 4 compared to group 1.  
\*p<0.05, \*\*p<0.01, \*\*\*p<0.001.

Fig: 4.21.

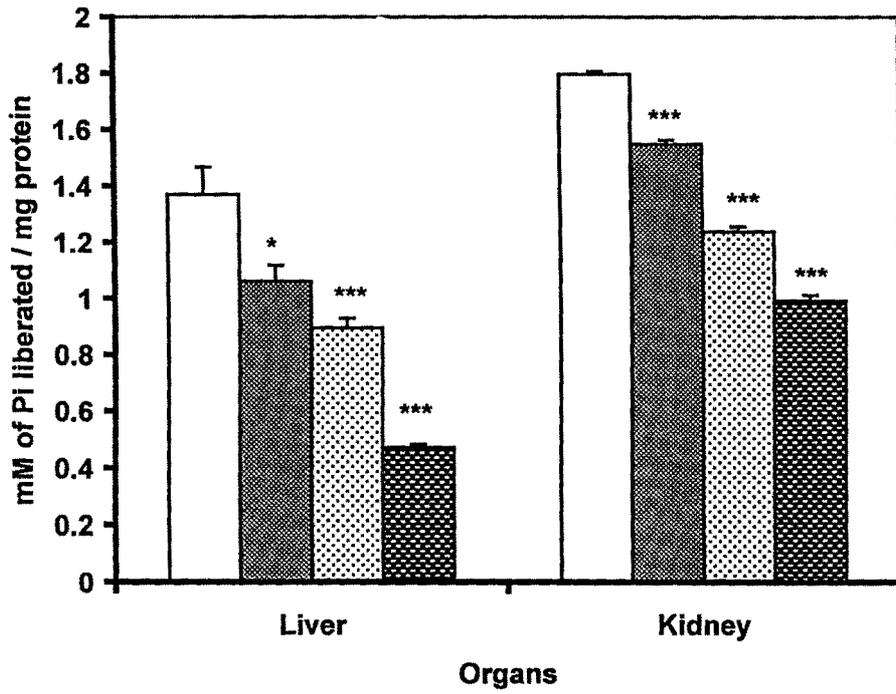
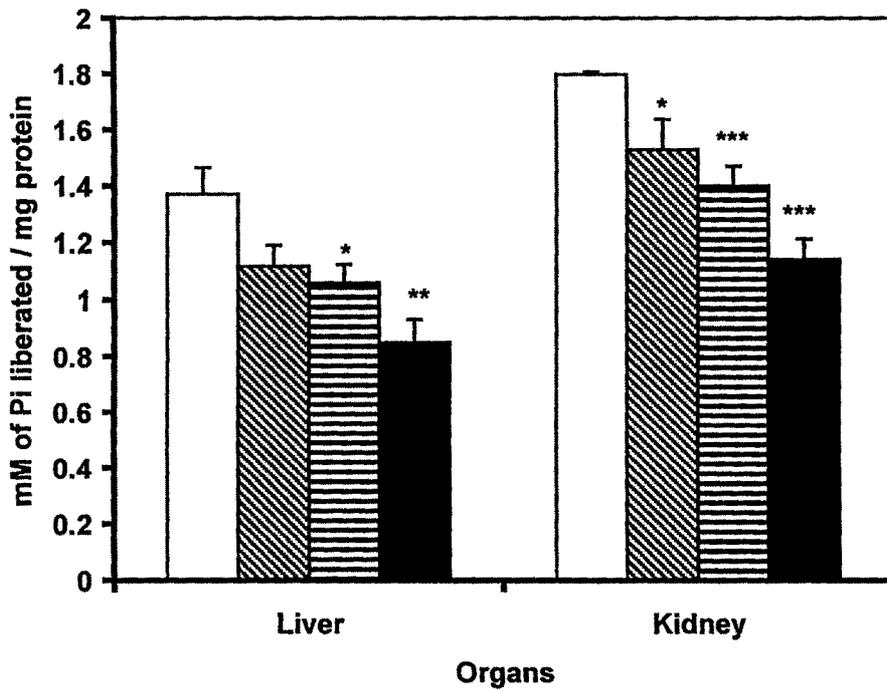


Fig: 4.22.



**Fig: 4.23. Effect of lead acetate (LA) exposure (30 days) on the levels of magnesium ATPase in liver and kidney of rats.**

- 1  Control
- 2  10ppm lead acetate (10LA)
- 3  30ppm lead acetate (30LA)
- 4  100ppm lead acetate (100LA)

Values are expressed as mean  $\pm$  SEM for six animals in each group.

Group 2, 3, 4 compared to group 1.

\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

**Fig: 4.24. Effect of cadmium chloride (CD) exposure (30 days) on the levels of magnesium ATPase in liver and kidney of rats.**

- 1  Control
- 2  10ppm cadmium chloride (10CD)
- 3  30ppm cadmium chloride (30CD)
- 4  100ppm cadmium chloride (100CD)

Values are expressed as mean  $\pm$  SEM for six animals in each group.

Group 2, 3, 4 compared to group 1.

\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

Fig: 4.23.

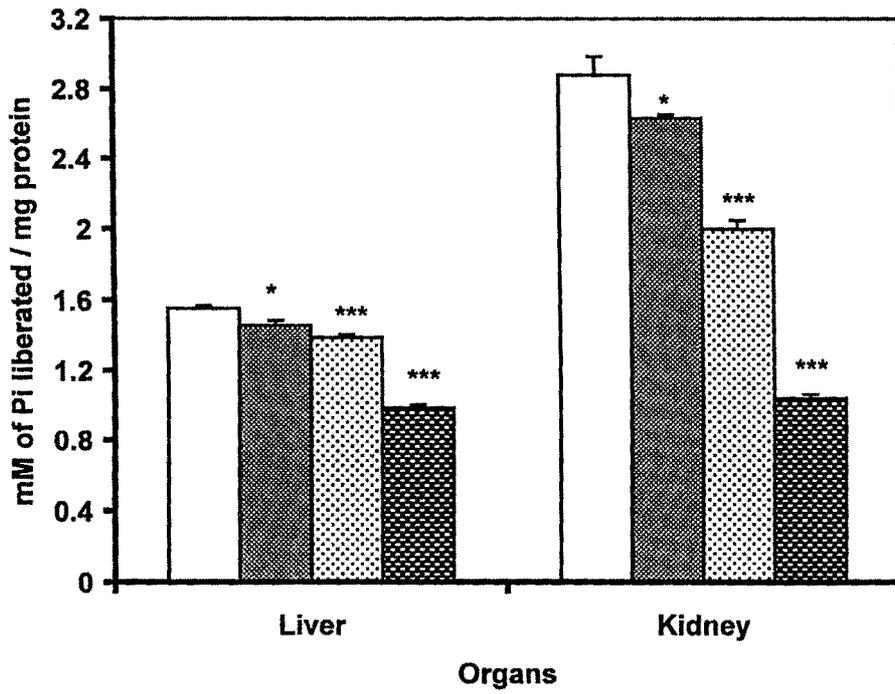
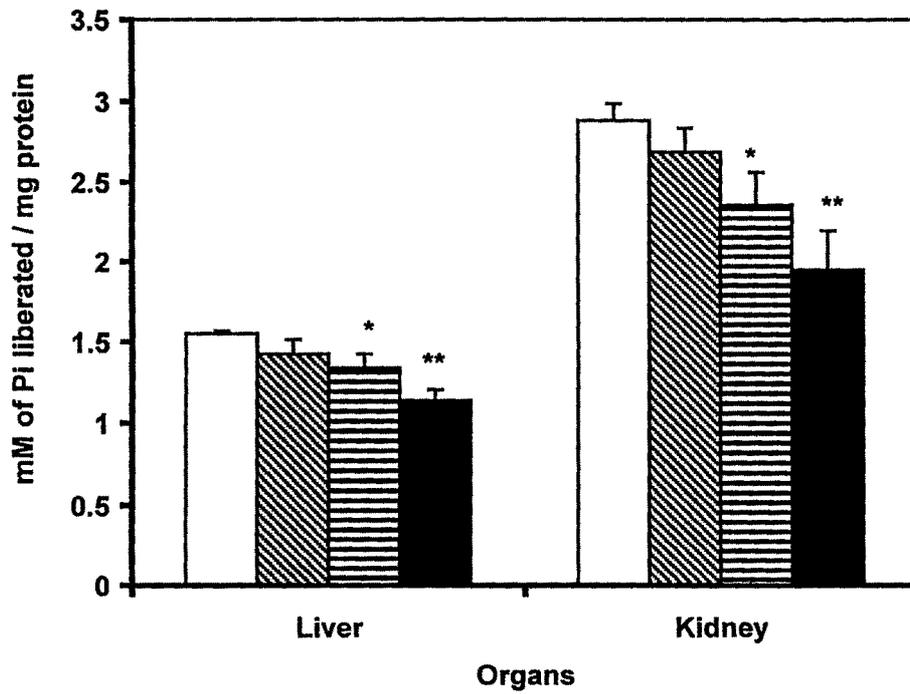


Fig: 4.24.



were decreased significantly ( $p < 0.01$ ) in group 2 (10LA) and group 3 & 4 (30LA & 100LA) ( $p < 0.001$ ) as compared to group 1 (Control). The protein levels in **lung** were decreased significantly ( $p < 0.001$ ) in group 3 (30LA), group 4 (100LA) and there was no significant change in group 1 (10LA) as compared to group 1 (Control). There was no significant change in the levels of protein in **brain** of the treated groups (Fig: 4.25).

The protein levels in **liver** were decreased significantly in group 3 (30CD) ( $p < 0.01$ ), group 4 (100CD) ( $p < 0.001$ ) and there was no significant change in group 2 (10CD) as compared to group 1 (Control). The protein levels in **kidney** were decreased significantly ( $p < 0.05$ ) in group 2 (10CD) and group 3 & 4 (30CD & 100CD) ( $p < 0.001$ ) as compared to group 1 (Control). The protein levels in **lung** were decreased significantly in group 2 (10CD) ( $p < 0.05$ ), group 3 (30CD) ( $p < 0.01$ ) and group 4 (100CD) ( $p < 0.001$ ) as compared to group 1 (Control). The protein levels in **heart** were decreased significantly in group 3 (30CD) ( $p < 0.05$ ), group 4 (100CD) ( $p < 0.001$ ) and there was no significant change in group 2 (10CD) as compared to group 1 (Control). There was no significant change in the levels of protein in **brain** of the treated groups (Fig: 4.26)

#### 4.1.2.6 Changes in the Levels of Tissue Lipids

##### 4.1.2.6.1 Changes in the Levels of Cholesterol

The cholesterol levels in **liver**, **kidney**, **lung** and **heart** were increased significantly ( $p < 0.001$ ) in group 2 (10LA), group 3 (30LA) and group 4 (100LA) as compared to group 1 (Control) (Fig: 4.27).

The cholesterol levels in **liver** and **heart** were increased significantly in group 3 (30CD) ( $p < 0.05$ ), group 4 (100CD) ( $p < 0.001$ ) and there was no significant change in group 2 (10CD) as compared to group 1 (Control). The cholesterol levels in **kidney** were increased significantly ( $p < 0.05$ ) in group 2 (10CD) and group 3 & 4 (30CD & 100CD) ( $p < 0.001$ ) as compared to group 1 (Control). The cholesterol levels in **lung** were increased significantly ( $p < 0.05$ ) in group 3 (30CD), group 4 (100CD) ( $p < 0.01$ ) and there was no significant change in group 2 (10CD) as compared to group 1 (Control) (Fig: 4.28).

#### 4.1.2.6.2 Changes in the Levels of Triglyceride

The triglyceride levels in **liver** were increased significantly ( $p<0.001$ ) group 3, 4 (30LA, 100LA) and there was no significant change in group 2 (10LA) as compared to group 1 (Control). The triglyceride levels in **kidney, lung** and **heart** were increased significantly ( $p<0.001$ ) in group 2 (10LA), group 3 (30LA) and group 4 (100LA) as compared to group 1 (Control) (Fig: 4.29).

The triglyceride levels in **liver** were increased significantly in group 3 (30CD) ( $p<0.05$ ), group 4 (100CD) ( $p<0.01$ ) and there was no significant change in group 2 (10CD) as compared to group 1 (Control). The triglyceride levels in **kidney** and **lung** were increased significantly in group 3 (30CD) ( $p<0.05$ ), group 4 (100CD) ( $p<0.001$ ) and there was no significant change in group 2 (10CD) as compared to group 1 (Control). The triglyceride levels in **heart** were increased significantly ( $p<0.01$ ) in group 4 (100CD) and there was no significant change in group 2 & 3 (10CD & 30CD) as compared to group 1 (Control) (Fig: 4.30).

#### 4.1.2.6.3 Changes in the Levels of Phospholipid

The phospholipid levels in **liver** and **heart** were increased significantly ( $p<0.01$ ) in group 2 (10LA) and group 3 & 4 (30LA & 100LA) ( $p<0.001$ ) as compared to group 1 (Control). The phospholipid levels in **kidney** and **lung** were increased significantly ( $p<0.001$ ) in group 2 (10LA), group 3 (30LA) and group 4 (100LA) as compared to group 1 (Control) (Fig: 4.31).

The phospholipid levels in **liver** were increased significantly in group 3 (30CD) ( $p<0.01$ ), group 4 (100CD) ( $p<0.001$ ) and there was no significant change in group 2 (10CD) as compared to group 1 (Control). The phospholipid levels in **kidney** were increased significantly in group 3 (30CD) ( $p<0.05$ ), group 4 (100CD) ( $p<0.001$ ) and there was no significant change in group 2 (10CD) as compared to group 1 (Control). The phospholipid levels in **lung** were increased significantly in group 3 (30CD) ( $p<0.05$ ), group 4 (100CD) ( $p<0.01$ ) and there was no significant change in group 2 (10CD) as compared to group 1 (Control). Similarly, the phospholipid levels in **heart** were increased significantly ( $p<0.05$ ) in group 3 (30CD), group 4 (100CD) and there was no significant change in group 2 (10CD) as compared to group 1 (Control) (Fig: 4.32).

**Fig: 4.25. Effect of lead acetate (LA) exposure (30 days) on the levels of protein in liver, kidney, lung, heart and brain of rats.**

- 1  Control
- 2  10ppm lead acetate (10LA)
- 3  30ppm lead acetate (30LA)
- 4  100ppm lead acetate (100LA)

Values are expressed as mean  $\pm$  SEM for six animals in each group.  
Group 2, 3, 4 compared to group 1.  
\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

**Fig: 4.26. Effect of cadmium chloride (CD) exposure (30 days) on the levels of protein in liver, kidney, lung, heart and brain of rats.**

- 1  Control
- 2  10ppm cadmium chloride (10CD)
- 3  30ppm cadmium chloride (30CD)
- 4  100ppm cadmium chloride (100CD)

Values are expressed as mean  $\pm$  SEM for six animals in each group.  
Group 2, 3, 4 compared to group 1.  
\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

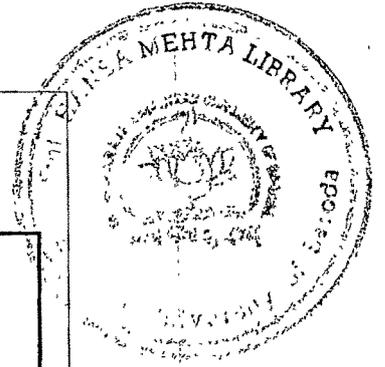


Fig: 4.25.

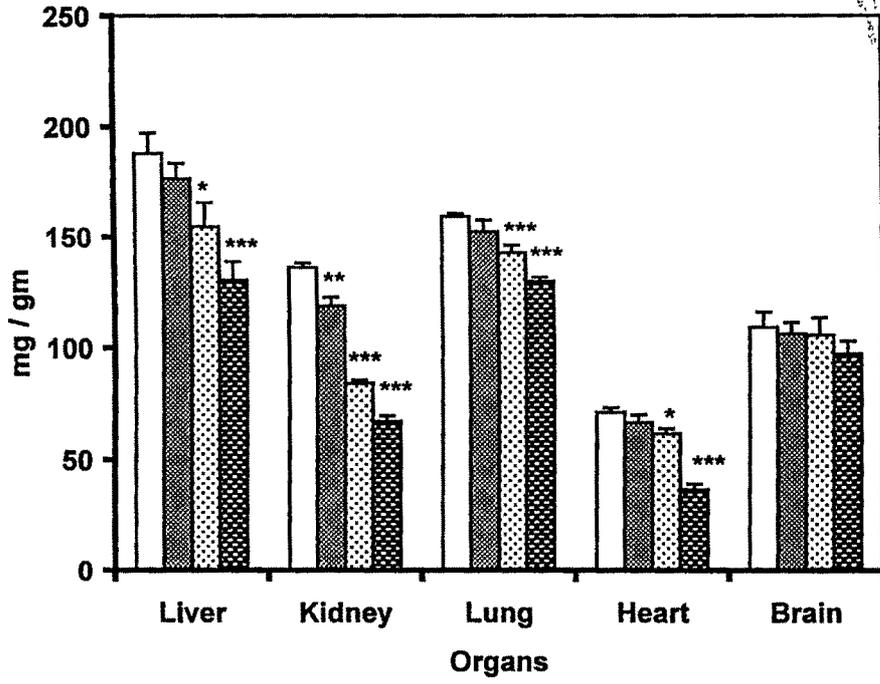
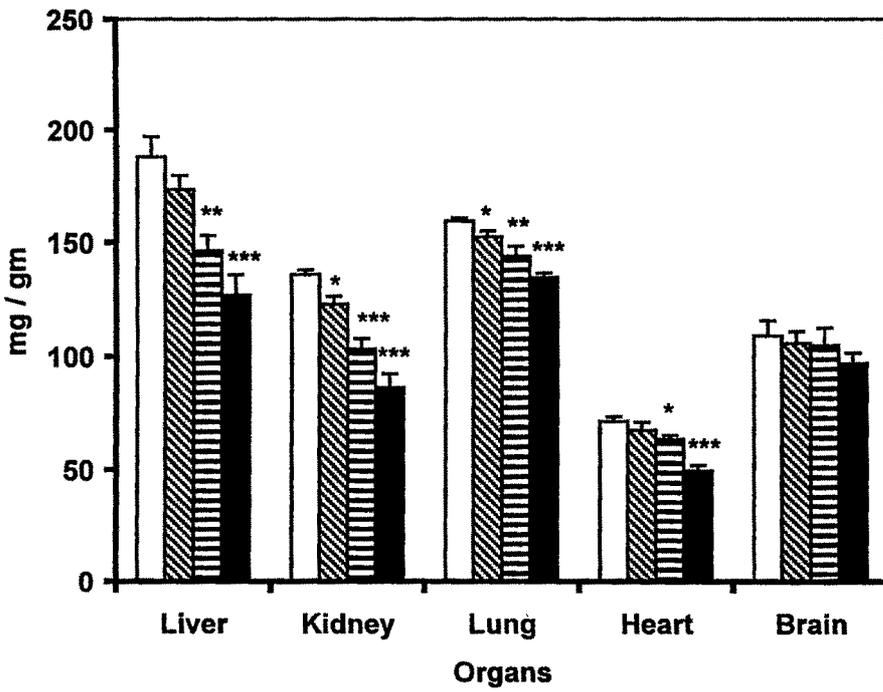


Fig: 4.26.



**Fig: 4.27. Effect of lead acetate (LA) exposure (30 days) on the levels of cholesterol in liver, kidney, lung and heart of rats.**

- 1  Control
- 2  10ppm lead acetate (10LA)
- 3  30ppm lead acetate (30LA)
- 4  100ppm lead acetate (100LA)

Values are expressed as mean  $\pm$  SEM for six animals in each group.  
Group 2, 3, 4 compared to group 1.  
\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

**Fig: 4.28. Effect of cadmium chloride (CD) exposure (30 days) on the levels of cholesterol in liver, kidney, lung and heart of rats.**

- 1  Control
- 2  10ppm cadmium chloride (10CD)
- 3  30ppm cadmium chloride (30CD)
- 4  100ppm cadmium chloride (100CD)

Values are expressed as mean  $\pm$  SEM for six animals in each group.  
Group 2, 3, 4 compared to group 1.  
\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

Fig: 4.27.

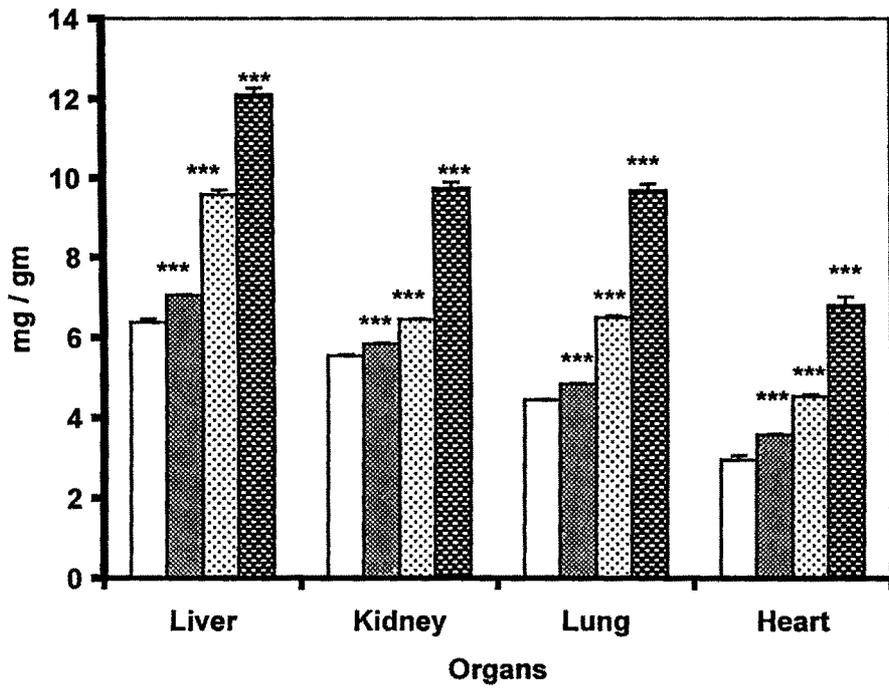
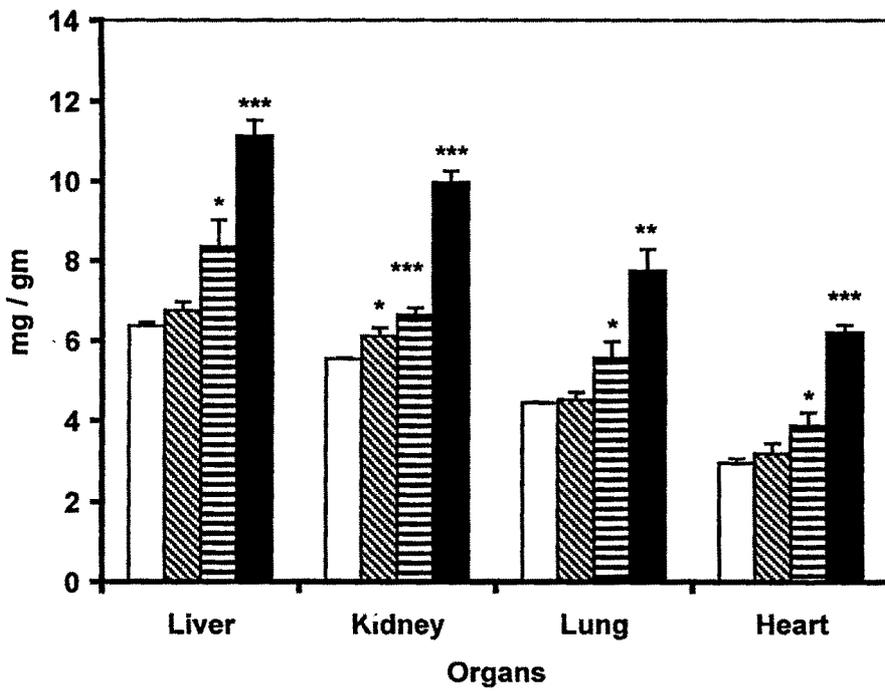
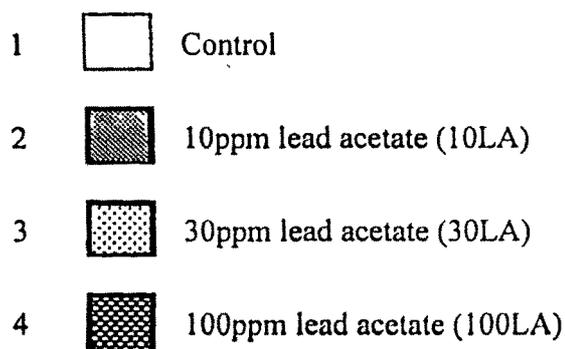


Fig: 4.28.

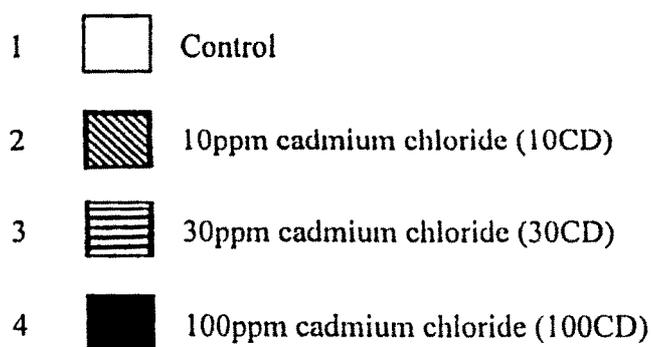


**Fig: 4.29. Effect of lead acetate (LA) exposure (30 days) on the levels of triglycerides in liver, kidney, lung, heart of rats.**



Values are expressed as mean  $\pm$  SEM for six animals in each group.  
Group 2, 3, 4 compared to group 1.  
\*p<0.05, \*\*p<0.01, \*\*\*p<0.001.

**Fig: 4.30. Effect of cadmium chloride (CD) exposure (30 days) on the levels of triglycerides in liver, kidney, lung and heart of rats.**



Values are expressed as mean  $\pm$  SEM for six animals in each group.  
Group 2, 3, 4 compared to group 1.  
\*p<0.05, \*\*p<0.01, \*\*\*p<0.001.

Fig: 4.29.

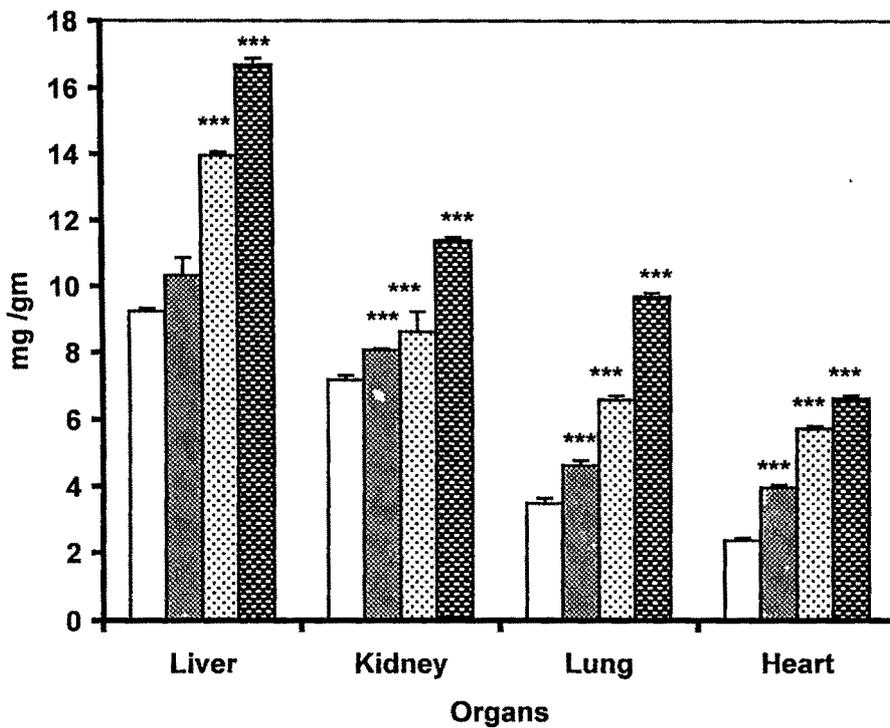
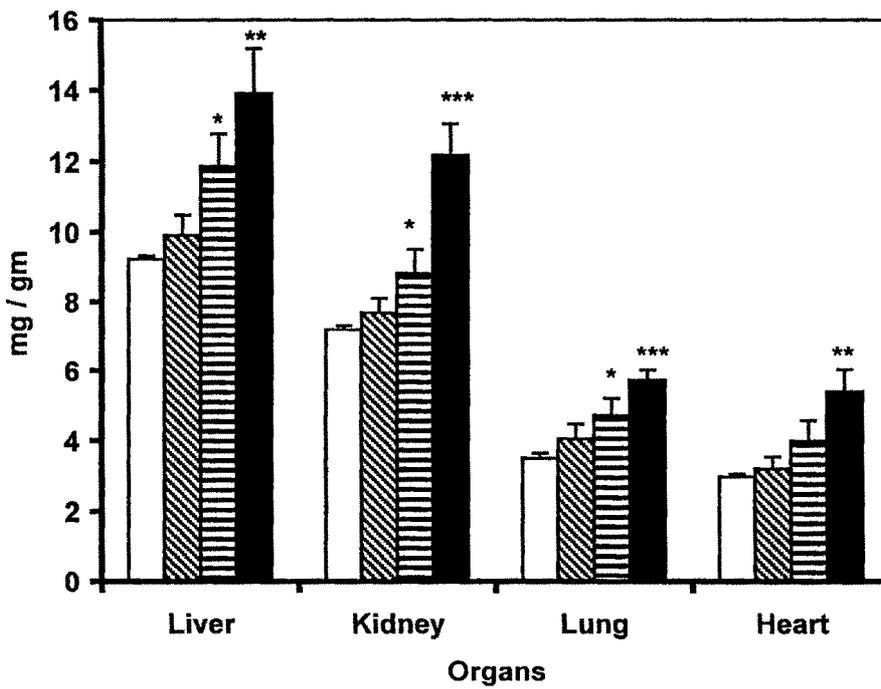


Fig: 4.30.



**Fig: 4.31. Effect of lead acetate (LA) exposure (30 days) on the levels of phospholipid in liver, kidney, lung and heart of rats.**

- 1  Control
- 2  10ppm lead acetate (10LA)
- 3  30ppm lead acetate (30LA)
- 4  100ppm lead acetate (100LA)

Values are expressed as mean  $\pm$  SEM for six animals in each group.  
Group 2, 3, 4 compared to group 1.  
\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

**Fig: 4.32. Effect of cadmium chloride (CD) exposure (30 days) on the levels of phospholipid in liver, kidney, lung and heart of rats.**

- 1  Control
- 2  10ppm cadmium chloride (10CD)
- 3  30ppm cadmium chloride (30CD)
- 4  100ppm cadmium chloride (100CD)

Values are expressed as mean  $\pm$  SEM for six animals in each group.  
Group 2, 3, 4 compared to group 1.  
\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

Fig: 4.31.

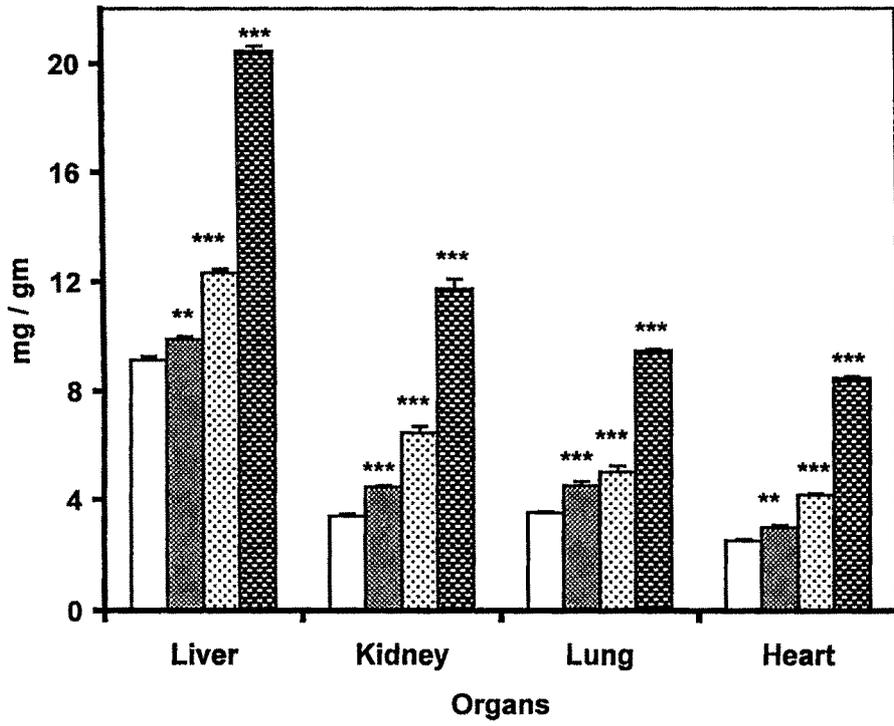
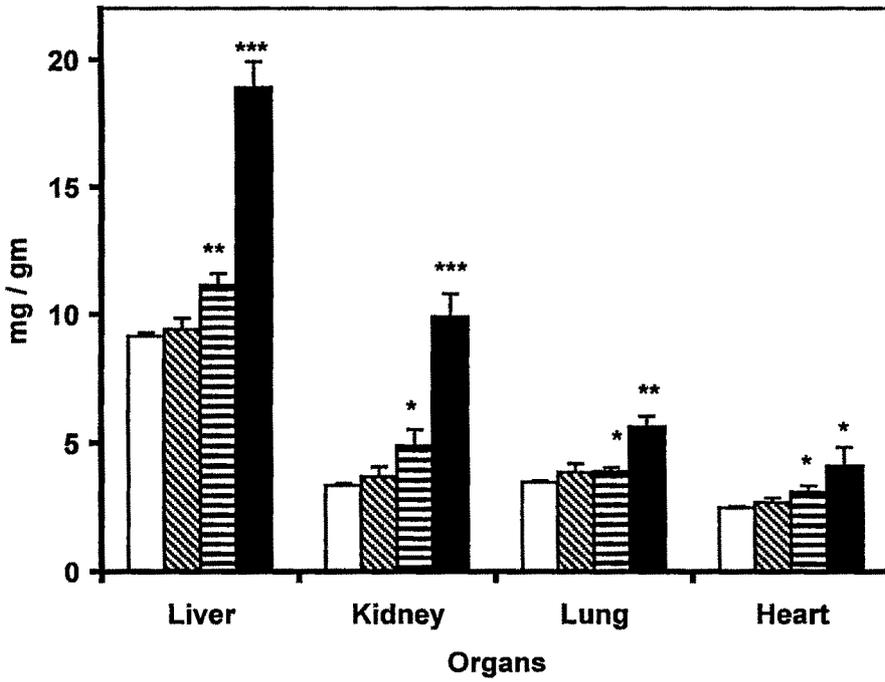


Fig: 4.32.



### 4.1.3 SERUM ESTIMATIONS

#### 4.1.3.1 Changes in the levels of Serum Glutamate Pyruvate Transaminases (GPT) and Glutamate Oxaloacetate Transaminases (GOT)

The GPT levels in serum were increased significantly ( $p < 0.05$ ) in group 2 & 3 (10LA & 30LA) and group 4 (100LA) ( $p < 0.001$ ) as compared to group 1 (Control). The GOT levels in serum were increased significantly in group 3 (30LA) ( $p < 0.05$ ), group 4 (100LA) ( $p < 0.01$ ) and there was no significant change in group 2 (10LA) as compared to group 1 (Control) (Fig: 4.33).

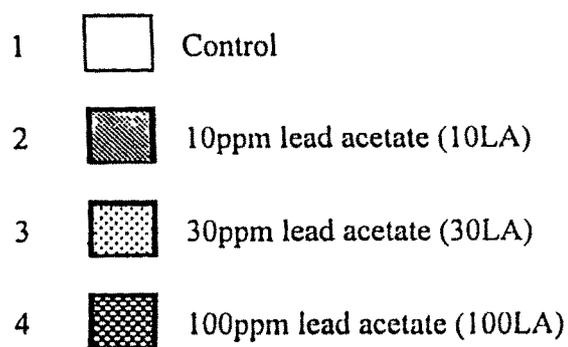
The GPT levels in serum were increased significantly group 3 (30CD) ( $p < 0.05$ ), group 4 (100CD) ( $p < 0.01$ ) and there was no significant change in group 2 (10CD) as compared to group 1 (Control). The GOT levels in serum were increased significantly in group 4 (100CD) ( $p < 0.05$ ) and there was no significant change in group 2 (10CD) and group 3 (30CD) as compared to group 1 (Control) (Fig: 4.34).

#### 4.1.3.2 Changes in the Levels of Alkaline phosphatase (Alkp) and Acid phosphatase (Acidp)

The Alkp levels in serum were increased significantly in group 2 (10LA) ( $p < 0.05$ ), group 3 (30LA) ( $p < 0.01$ ) and group 4 (100LA) ( $p < 0.001$ ) as compared to group 1 (Control). The Acidp levels in serum were increased significantly ( $p < 0.05$ ) in group 2 & 3 (10LA & 30LA) and group 4 (100LA) ( $p < 0.001$ ) as compared to group 1 (Control) (Fig: 4.35).

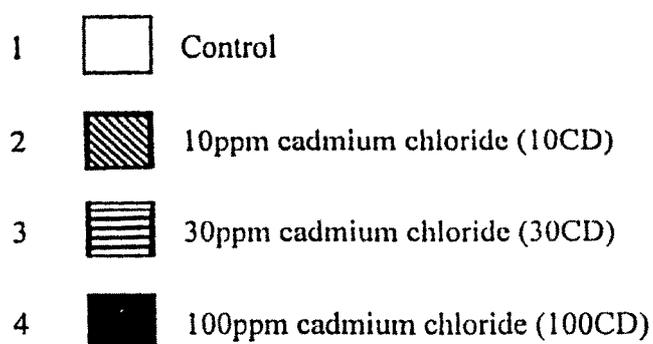
The Alkp levels in serum were increased significantly ( $p < 0.05$ ) group 2, 3 (10CD, 30CD) and group 4 (100CD) ( $p < 0.001$ ) as compared to group 1 (Control). The Acidp levels in serum were increased significantly in group 3 (30CD) ( $p < 0.05$ ), group 4 (100CD) ( $p < 0.001$ ) and there was no significant change in group 2 (10CD) as compared to group 1 (Control) (Fig: 4.36).

**Fig: 4.33. Effect of lead acetate (LA) exposure (30 days) on the levels of serum glutamate pyruvate transaminase and serum glutamate oxaloacetate transaminases of rats.**



Values are expressed as mean  $\pm$  SEM for six animals in each group.  
Group 2, 3, 4 compared to group 1.  
\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

**Fig: 4.34. Effect of cadmium chloride (CD) exposure (30 days) on the levels of serum glutamate pyruvate transaminase and serum glutamate oxaloacetate transaminases of rats.**



Values are expressed as mean  $\pm$  SEM for six animals in each group.  
Group 2, 3, 4 compared to group 1.  
\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

Fig: 4.33.

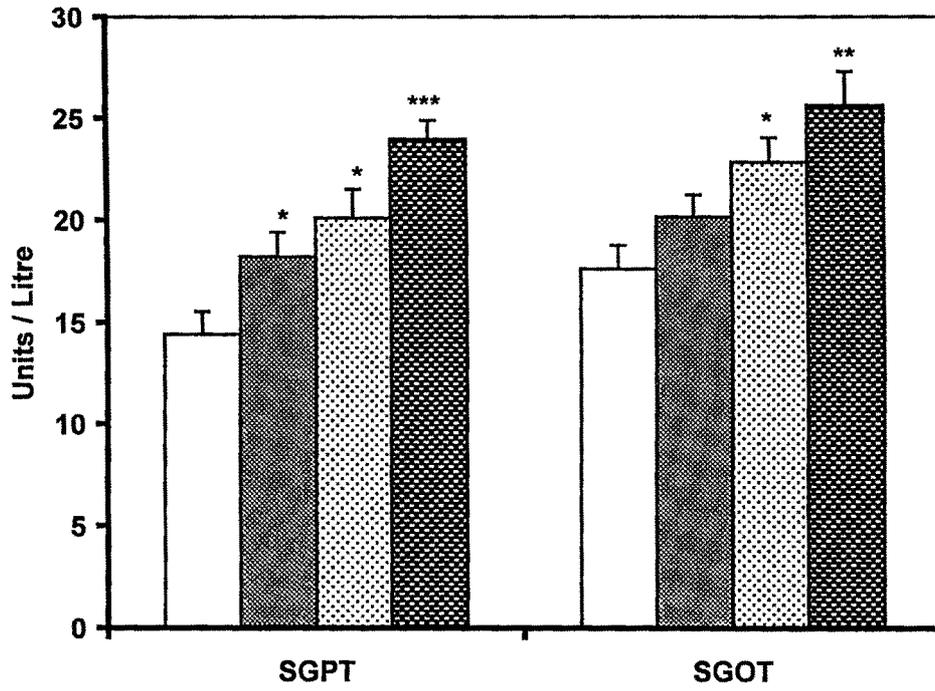
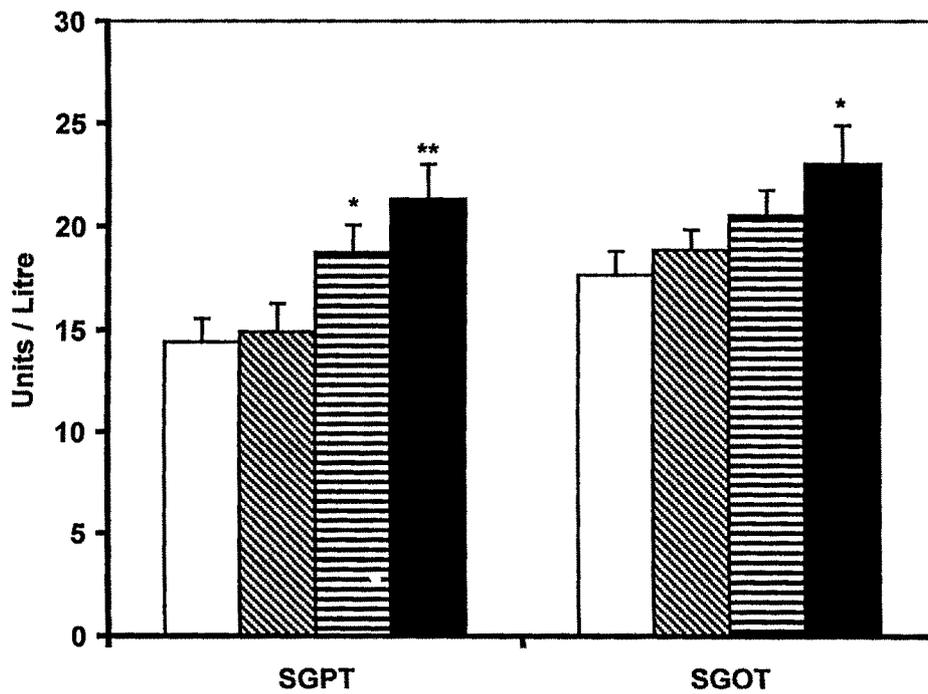


Fig: 4.34.



**Fig: 4.35. Effect of lead acetate (LA) exposure (30 days) on the levels of alkaline phosphatase and acid phosphatase in serum of rats.**

- 1  Control
- 2  10ppm lead acetate (10LA)
- 3  30ppm lead acetate (30LA)
- 4  100ppm lead acetate (100LA)

Values are expressed as mean  $\pm$  SEM for six animals in each group.  
Group 2, 3, 4 compared to group 1.  
\*p<0.05, \*\*p<0.01, \*\*\*p<0.001.

**Fig: 4.36. Effect of cadmium chloride (CD) exposure (30 days) levels of alkaline phosphatase and acid phosphatase in serum of rats.**

- 1  Control
- 2  10ppm cadmium chloride (10CD)
- 3  30ppm cadmium chloride (30CD)
- 4  100ppm cadmium chloride (100CD)

Values are expressed as mean  $\pm$  SEM for six animals in each group.  
Group 2, 3, 4 compared to group 1.  
\*p<0.05, \*\*p<0.01, \*\*\*p<0.001.

Fig: 4.35.

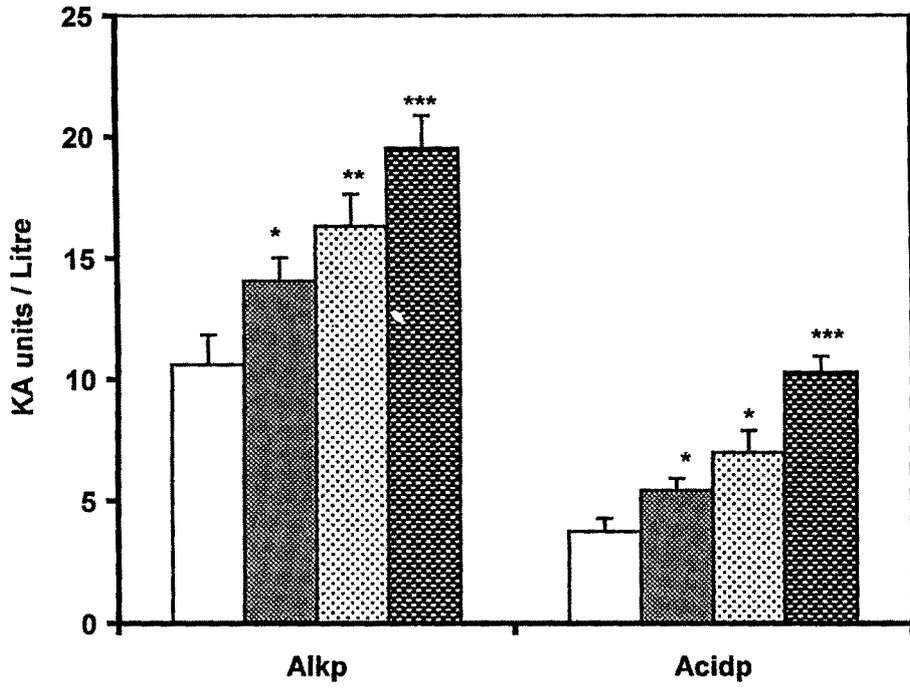
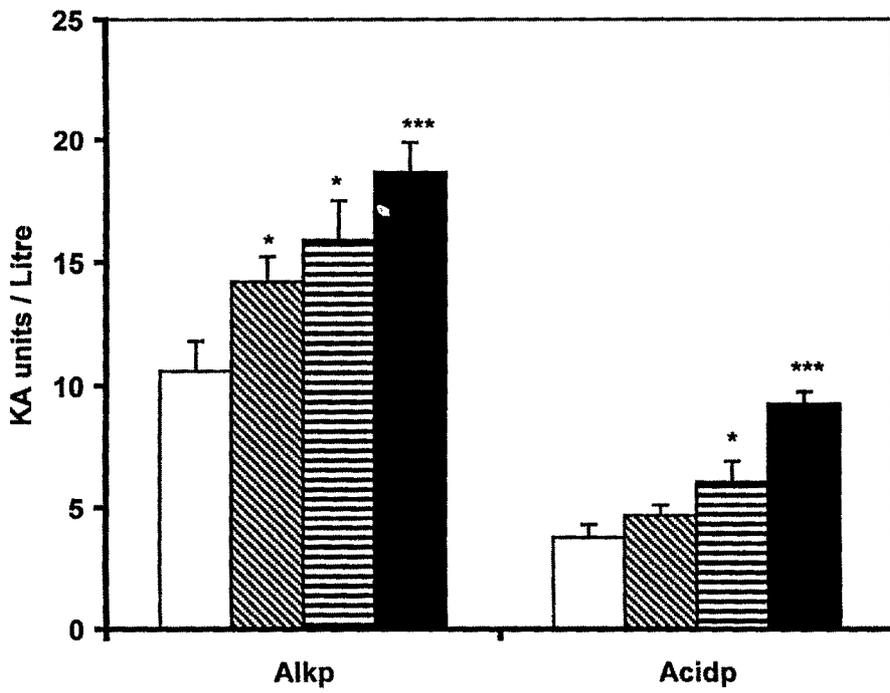


Fig: 4.36.



#### **4.1.3.3 Changes in the Levels of Lactate dehydrogenase (LDH)**

The LDH levels in **serum** were increased significantly ( $p < 0.05$ ) in group 3 (30LA) and group 4 (100LA) and there was no significant change in group 2 (10LA) as compared to group 1 (Control) (Fig: 4.37).

The LDH levels in **serum** were increased significantly ( $p < 0.05$ ) in group 3 (30CD) and group 4 (100CD) and there was no significant change in group 2 (10CD) as compared to group 1 (Control) (Fig: 4.38).

#### **4.1.3.4 Changes in the Levels of Serum Total Bilirubin (TBil) and Total Protein**

The TBil levels in **serum** were increased significantly in group 3 (30LA) ( $p < 0.05$ ), group 4 (100LA) ( $p < 0.001$ ) and there was no significant change in group 2 (10LA) as compared to group 1 (Control).

The protein levels in **serum** were decreased significantly in group 3 (30LA) ( $p < 0.05$ ), group 4 (100LA) ( $p < 0.01$ ) and there was no significant change in group 2 (10LA) as compared to group 1 (Control) (Fig: 4.39).

The TBil levels in **serum** were increased significantly in group 3 (30CD) ( $p < 0.05$ ), group 4 (100CD) ( $p < 0.001$ ) and there was no significant change in group 2 (10CD) as compared to group 1 (Control).

The protein levels in **serum** were decreased significantly ( $p < 0.01$ ) group 4 (100CD) and there was no significant change in group 2 & 3 (10CD & 30CD) as compared to group 1 (Control) (Fig: 4.40).

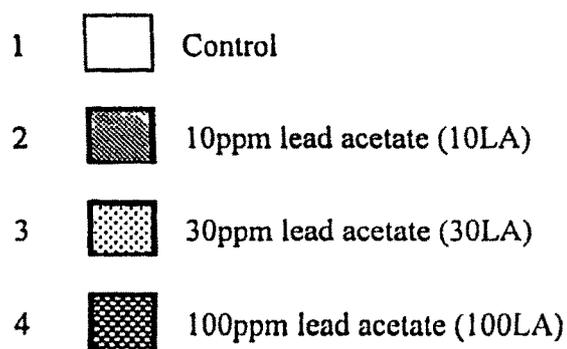
#### **4.1.3.5 Changes in the Levels of Serum Lipids**

The cholesterol levels in **serum** were decreased significantly in group 3 (30LA) ( $p < 0.05$ ), group 4 (100LA) ( $p < 0.01$ ) and there was no significant change in group 2 (10LA) as compared to group 1 (Control). The triglyceride levels in **serum** were increased significantly in group 3 (30LA) ( $p < 0.05$ ), group 4 (100LA) ( $p < 0.001$ ) and there was no significant change in group 2 (10LA) as compared to group 1 (Control). The phospholipid levels in **serum** were increased significantly in group 2 (10LA) ( $p < 0.05$ ) and group 3 & 4 (30LA & 100LA) ( $p < 0.001$ ) as compared to group 1 (Control) (Fig: 4.41).

The cholesterol levels in **serum** were decreased significantly in group 3 (30CD) ( $p < 0.05$ ), group 4 (100CD) ( $p < 0.001$ ) and there was no significant change

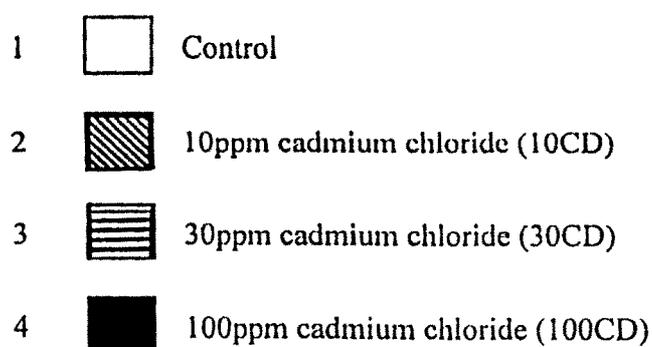
in group 2 (10LA) as compared to group 1 (Control). The triglyceride levels in **serum** were increased significantly in group 3 (30CD) ( $p < 0.05$ ), group 4 (100CD) ( $p < 0.001$ ) and there was no significant change in group 2 (10CD) as compared to group 1 (Control). The phospholipid levels in **serum** were increased significantly in group 2 (10CD) ( $p < 0.05$ ) and group 3 & 4 (30CD & 100CD) ( $p < 0.01$ ) as compared to group 1 (Control) (Fig: 4.42).

**Fig: 4.37. Effect of lead acetate (LA) exposure (30 days) on the levels of lactate dehydrogenase in serum of rats.**



Values are expressed as mean  $\pm$  SEM for six animals in each group.  
Group 2, 3, 4 compared to group 1.  
\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

**Fig: 4.38. Effect of cadmium chloride (CD) exposure (30 days) on the levels of lactate dehydrogenase in serum of rats.**



Values are expressed as mean  $\pm$  SEM for six animals in each group.  
Group 2, 3, 4 compared to group 1.  
\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

Fig: 4.37.

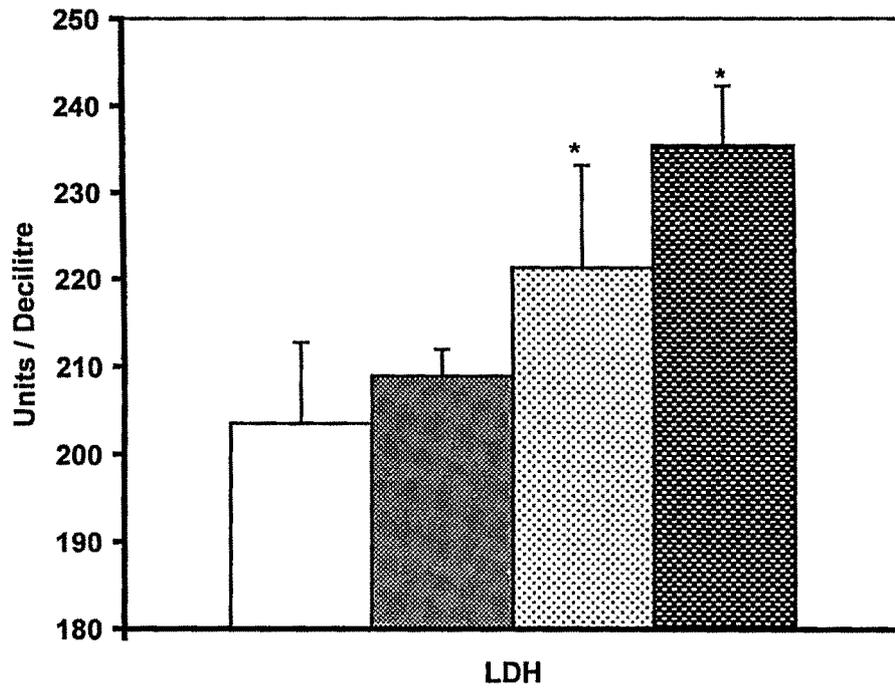
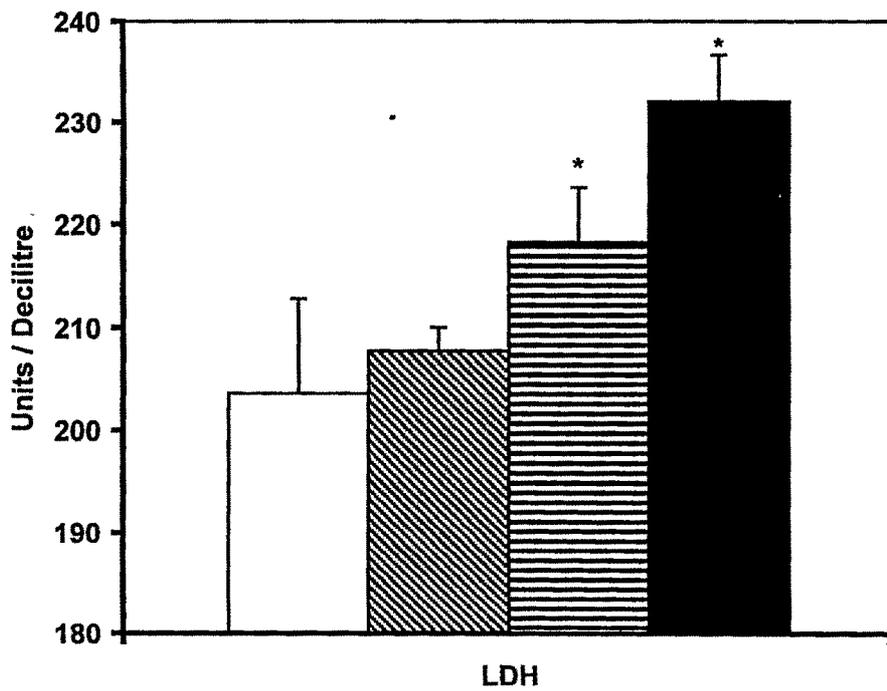
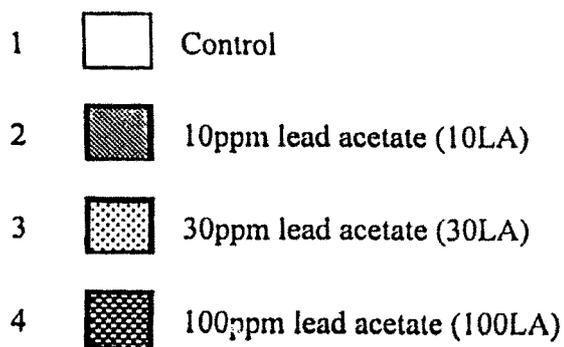


Fig: 4.38.

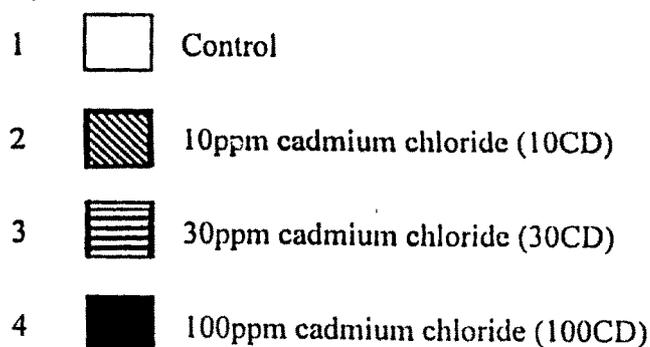


**Fig: 4.39. Effect of lead acetate (LA) exposure (30 days) on the levels of proteins (Total Bilirubin and Total Proteins) in serum of rats.**



Values are expressed as mean  $\pm$  SEM for six animals in each group.  
Group 2, 3, 4 compared to group 1.  
\*p<0.05, \*\*p<0.01, \*\*\*p<0.001.

**Fig: 4.40. Effect of cadmium chloride (CD) exposure (30 days) on the levels of proteins (Total Bilirubin and Total Proteins) in serum of rats.**



Values are expressed as mean  $\pm$  SEM for six animals in each group.  
Group 2, 3, 4 compared to group 1.  
\*p<0.05, \*\*p<0.01, \*\*\*p<0.001.

Fig: 4.39.

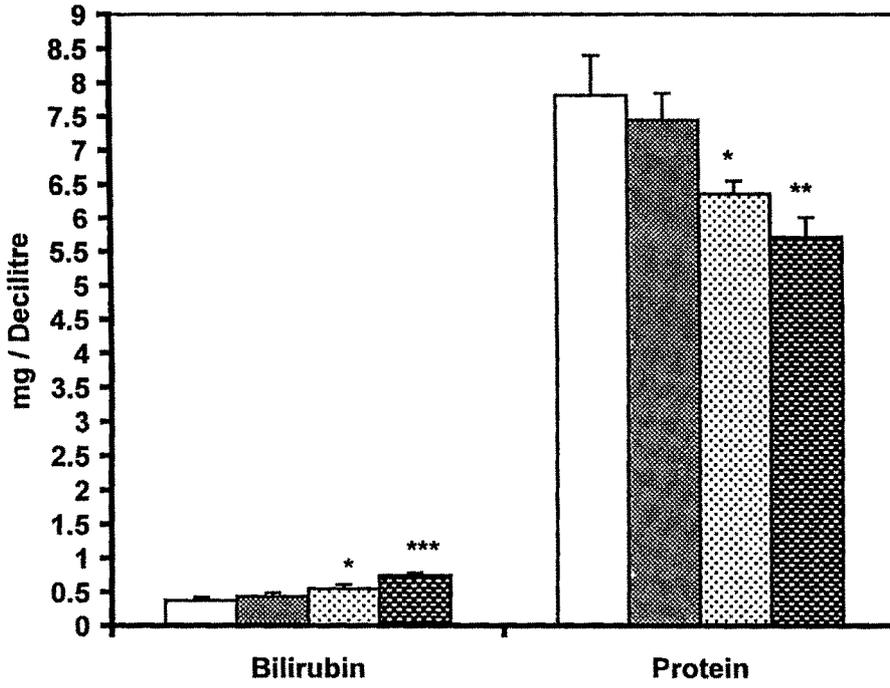
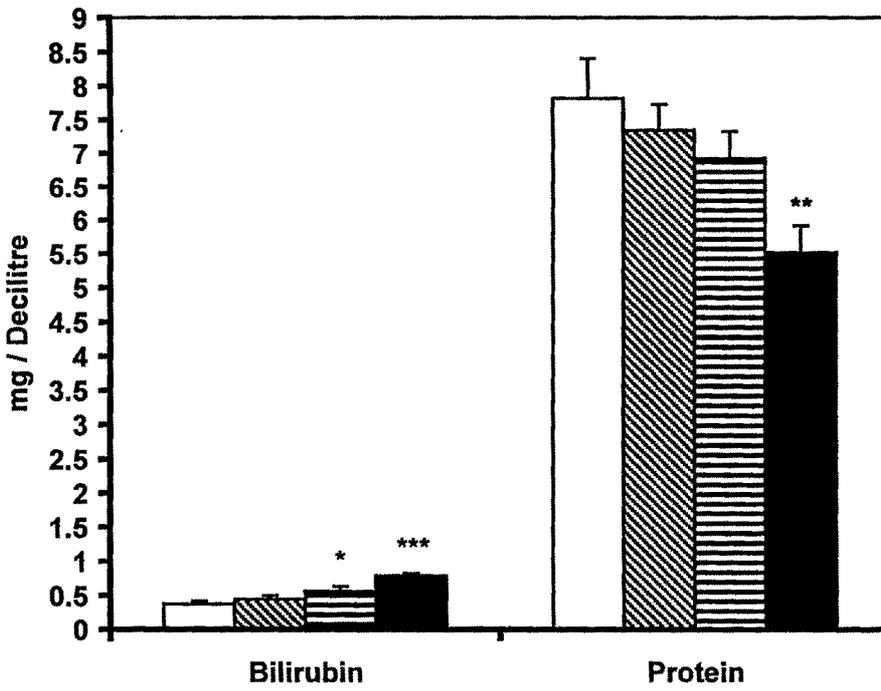


Fig: 4.40.



**Fig: 4.41. Effect of lead acetate (LA) exposure (30 days) on the levels of lipids (Cholesterol, Triglyceride and Phospholipid) in serum of rats.**

- 1  Control
- 2  10ppm lead acetate (10LA)
- 3  30ppm lead acetate (30LA)
- 4  100ppm lead acetate (100LA)

Values are expressed as mean  $\pm$  SEM for six animals in each group.

Group 2, 3, 4 compared to group 1.

\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

**Fig: 4.42. Effect of cadmium chloride (CD) exposure (30 days) on the levels of lipids (Cholesterol, Triglyceride and Phospholipid) in serum of rats.**

- 1  Control
- 2  10ppm cadmium chloride (10CD)
- 3  30ppm cadmium chloride (30CD)
- 4  100ppm cadmium chloride (100CD)

Values are expressed as mean  $\pm$  SEM for six animals in each group.

Group 2, 3, 4 compared to group 1.

\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

Fig: 4.41.

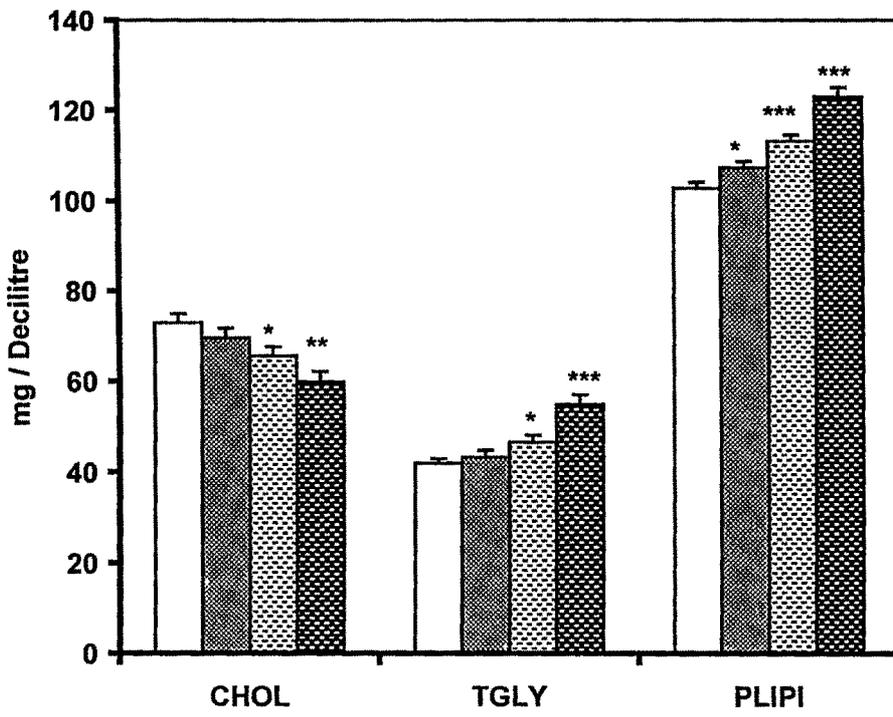
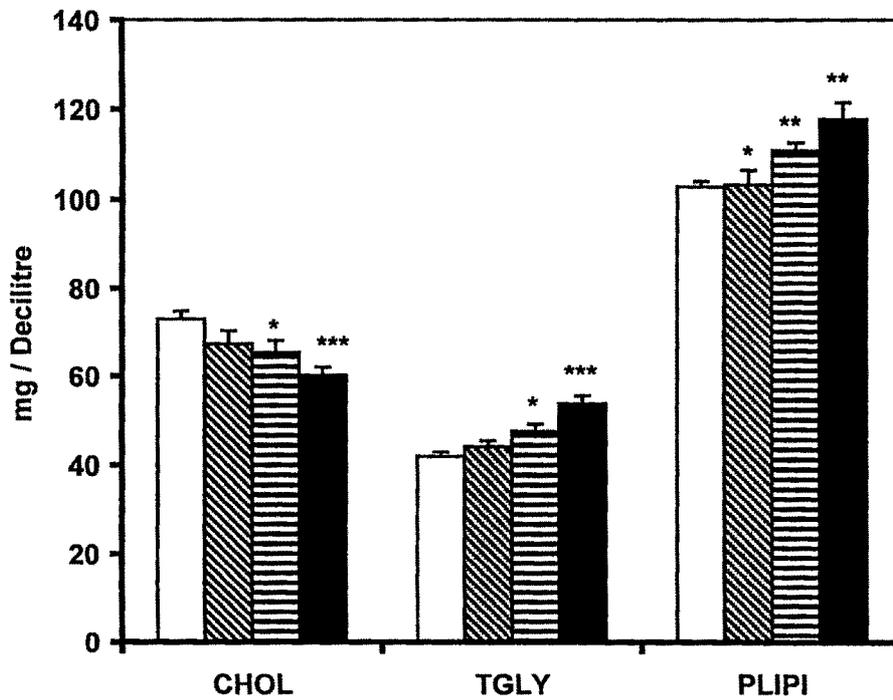


Fig: 4.42.



## 4.2 PHARMACOLOGICAL INVESTIGATIONS

Since, most of the biochemical changes in various enzymes and cellular components have occurred in animals exposed to 100 ppm of lead acetate and cadmium chloride, the pharmacological studies were carried out with 100 ppm of these metals alone and in combination with vitamin E, vitamin C or *spirulina*.

**Changes observed in lipid peroxidation products, endogenous antioxidants, other enzymes and lipids after thirty days exposure to 100 ppm of lead acetate or cadmium chloride alone and in combination with vitamin E, vitamin C or *spirulina*.**

### 4.2.1 GENERAL OBSERVATIONS

#### 4.2.1.1 Changes in Body and Organ Weights

In first set of experiment, there was a significant ( $p < 0.05$ ) decrease in body weight of animals exposed to 100 ppm lead acetate (100LA, group 2) as compared to group 1 (control) animals. There was a significant ( $p < 0.05$ ) increase in body weight of animals received vitamin E enriched diet (E, group 3), animals received *spirulina* enriched diet (SP, group 7) and animals received vitamin C enriched diet (C, group 5) as compared to control animals (group 1). However, there was no significant change in body weight in animals exposed to 100 ppm of lead acetate in combination with vitamin E, C and SP (E+100LA, group 4), (C+100LA, group 6) and (SP+100LA, group 8) as compared to animals exposed to 100 ppm of lead acetate alone (100LA, group 2) (Table- 4.1).

In second set of experiment, there was a significant ( $p < 0.01$ ) decrease in body weight of animals exposed to 100 ppm cadmium chloride (100CD, group 2) as compared to group 1 (control) animals. There was a significant ( $p < 0.05$ ) increase in body weight of animals received vitamin E enriched diet (E, group 3), animals received *spirulina* enriched diet (SP, group 7) and there was no significant change in the body weight of animals received vitamin C enriched diet (C, group 5) as compared to control animals (group 1). There was a significant ( $p < 0.05$ ) increase in body weight of animals exposed to 100 ppm of cadmium chloride in combination with vitamin E (E+100CD, group 4), there was no significant change in the body weight of animals exposed to 100 ppm of cadmium chloride in

combination with vitamin C (C+100CD, group 6) and (SP+100CD, group 8) as compared to animals exposed to 100 ppm of cadmium chloride alone (100CD, group 2) (Table- 4.2).

There was a significant increase in the weight of **liver** ( $p<0.01$ ), **kidney** ( $p<0.01$ ), **lung** ( $p<0.05$ ), **heart** ( $p<0.01$ ) and there was no significant change in weight of **brain** in group 2 (100LA) as compare to group 1 (Control). There was no significant change in weight of **liver**, **kidney**, **lung**, **heart** and **brain** of animals in group 3 (E), group 5 (C) and group 7 (SP) when compared to group 1 (Control). Administration of vitamin C in lead (100LA) exposed animals significantly ( $p<0.05$ ) decreased the weight of organs like **liver**, **kidney**, **lung** and **heart**. However, vitamin E and *spirulina* did not show any significant reduction in the weight of organs in animals exposed to 100 ppm lead acetate as compared to animals treated with lead alone. There was no significant change in weight of **brain** in the treated groups during the experiment (Table- 4.3).

There was a significant increase in the weight of **liver** ( $p<0.05$ ), **kidney** ( $p<0.001$ ), **lung**, **heart** ( $p<0.05$ ) in cadmium exposed animals and there was no significant change in weight of **brain** in group 2 (100CD) as compare to group 1 (Control). There was no significant change in weight of **liver**, **kidney**, **lung**, **heart** and **brain** of animals in group 3 (E), group 5 (C) and group 7 (SP) when compared to group 1 (Control). Administration of vitamin C in cadmium (100CD) exposed animals significantly decreased the weight of **liver** ( $p<0.05$ ), **kidney** ( $p<0.01$ ), **lung** and **heart** ( $p<0.05$ ). However, vitamin E and *spirulina* did not show any significant reduction in the weight of organs in animals exposed to 100 ppm cadmium as compared to animals treated with cadmium alone. There was no significant change in weight of **brain** in the groups during the experiment (Table- 4.4).

**Table- 4.1: Effect of 100 ppm of lead acetate (100LA) exposure (30 days) alone and in combination with antioxidants i.e. vitamin E, C or spirulina (E, C or SP) on body weight of rats during 30 days of experiment.**

**Avg. Body weight (gm / week)**

GROUP	AVERAGE BODY WEIGHT			
	I week	II week	III week	IV week
1. Control	214.500 ± 5.309	215.333 ± 5.024	216.500 ± 4.829	218.000 ± 4.131
2. 100LA	228.500 ± 2.930	225.333 ± 2.894	219.667 ± 3.930	216.667 ± 3.765 <sup>a,b</sup>
3. E	210.833 ± 3.219	214.667 ± 3.263	219.333 ± 3.480	222.500 ± 3.879 <sup>a,b</sup>
4. E+100LA	206.167 ± 3.400	204.500 ± 2.930	201.667 ± 3.242	198.167 ± 2.762
5. C	203.333 ± 2.390	204.333 ± 2.231	207.000 ± 2.266	212.167 ± 2.509
6. C+100LA	204.167 ± 2.509	201.667 ± 2.789	198.167 ± 2.798	195.667 ± 3.721
7. SP	227.000 ± 2.543	230.500 ± 2.232	233.833 ± 2.151	237.167 ± 2.182 <sup>a,b</sup>
8. SP+100LA	230.500 ± 2.349	228.500 ± 2.110	225.000 ± 2.066	224.167 ± 2.023

Values are expressed as mean ± SEM for six animals in each group.

a : Group 4, 6 and 8 as compared to group 2.

b : Group 2, 3, 5 and 7 as compared to group 1.

\*p<0.05, \*\*p<0.01, \*\*\*p<0.001.

**Table- 4.2: Effect of 100 ppm of cadmium chloride (100CD) exposure (30 days) alone and in combination with antioxidants i.e. vitamin E, C or spirulina (E, C or SP) on body weight of rats during 30 days of experiment.**

**Avg. Body weight (gm/week)**

GROUP	AVERAGE BODY WEIGHT			
	I week	II week	III week	IV week
1. Control	214.500 ± 5.309	215.333 ± 5.024	216.500 ± 4.829	218.000 ± 4.131
2. 100CD	228.500 ± 1.764	225.333 ± 1.478	219.667 ± 1.515	215.667 ± 1.966 <sup>a,b</sup>
3. E	210.833 ± 3.219	214.667 ± 3.263	219.333 ± 3.480	222.500 ± 3.879
4. E+100CD	217.333 ± 3.029	213.500 ± 3.149	209.167 ± 3.016	206.833 ± 3.280 <sup>a,b</sup>
5. C	203.333 ± 2.390	204.333 ± 2.231	207.000 ± 2.266	212.167 ± 2.509
6. C+100CD	216.667 ± 2.552	214.333 ± 2.512	212.667 ± 3.040	212.167 ± 2.857
7. SP	227.000 ± 2.543	230.500 ± 2.232	233.833 ± 2.151	237.167 ± 2.182 <sup>a,b</sup>
8. SP+100CD	232.667 ± 2.404	229.833 ± 2.301	226.833 ± 2.197	225.167 ± 2.982

Values are expressed as mean ± SEM for six animals in each group.

a : Group 4, 6 and 8 as compared to group 2.

b : Group 2, 3, 5 and 7 as compared to group 1.

\*p<0.05, \*\*p<0.01, \*\*\*p<0.001.

**Table- 4.3: Effect of 100 ppm of lead acetate exposure (30 days) alone and in combination with antioxidants i.e. vitamin E, C or spirulina (E, C or SP) on the organ weights of rats. (gm)**

GROUP	ORGAN WEIGHT				
	Liver	Kidney	Lung	Heart	Brain
1. Control	6.296 ± 0.204	0.977 ± 0.028	1.305 ± 0.046	0.602 ± 0.041	1.852 ± 0.024
2. 100LA	7.900 ± 0.367 <sup>**b</sup>	1.161 ± 0.044 <sup>**b</sup>	1.700 ± 0.138 <sup>*b</sup>	0.818 ± 0.044 <sup>**b</sup>	1.721 ± 0.064
3. E	6.361 ± 0.456	0.971 ± 0.038	1.290 ± 0.042	0.601 ± 0.037	1.809 ± 0.038
4. E+100LA	7.471 ± 0.342	1.143 ± 0.045	1.627 ± 0.119	0.778 ± 0.035	1.670 ± 0.057
5. C	5.802 ± 0.240	0.942 ± 0.048	1.242 ± 0.021	0.559 ± 0.026	1.816 ± 0.044
6. C+100LA	6.546 ± 0.480 <sup>*a</sup>	1.059 ± 0.018 <sup>*a</sup>	1.377 ± 0.042 <sup>*a</sup>	0.638 ± 0.050 <sup>*a</sup>	1.678 ± 0.066
7. SP	6.489 ± 0.445	0.973 ± 0.030	1.301 ± 0.068	0.602 ± 0.041	1.808 ± 0.071
8. SP+100LA	7.567 ± 0.470	1.173 ± 0.056	1.606 ± 0.113	0.785 ± 0.031	1.738 ± 0.081
F ratio	1.161	0.0167	0.0642	0.0159	0.0215

Values are expressed as mean ± SEM for six animals in each group.

a : Group 4, 6 and 8 as compared to group 2.

b : Group 2, 3, 5 and 7 as compared to group 1.

\* p<0.05, \*\* p<0.01, \*\*\* p<0.001.

**Table- 4.4: Effect of 100 ppm of cadmium chloride exposure (30 days) alone and in combination with antioxidants i.e. vitamin E, C or spirulina (E, C or SP) on organ weights of rats. (gm)**

GROUP	ORGAN WEIGHT				
	Liver	Kidney	Lung	Heart	Brain
1. Control	6.296 ± 0.204	0.977 ± 0.028	1.305 ± 0.046	0.602 ± 0.041	1.852 ± 0.024
2. 100CD	7.564 ± 0.386 <sup>*b</sup>	1.201 ± 0.037 <sup>***b</sup>	1.637 ± 0.140 <sup>*b</sup>	0.748 ± 0.037 <sup>*b</sup>	1.666 ± 0.083
3. E	6.361 ± 0.456	0.971 ± 0.038	1.571 ± 0.108	0.601 ± 0.037	1.809 ± 0.038
4. E+100CD	7.050 ± 0.260	1.129 ± 0.053	1.627 ± 0.119	0.742 ± 0.040	1.736 ± 0.077
5. C	5.802 ± 0.240	0.942 ± 0.048	1.242 ± 0.021	0.559 ± 0.026	1.816 ± 0.044
6. C+100CD	6.075 ± 0.542 <sup>*a</sup>	1.021 ± 0.024 <sup>***a</sup>	1.288 ± 0.069 <sup>*a</sup>	0.578 ± 0.044 <sup>*a</sup>	1.714 ± 0.073
7. SP	6.489 ± 0.445	0.973 ± 0.030	1.301 ± 0.068	0.602 ± 0.041	1.808 ± 0.071
8. SP+100CD	7.245 ± 0.485	1.177 ± 0.053	1.534 ± 0.100	0.735 ± 0.035	1.809 ± 0.074
F ratio	1.109, p<0.01	0.0168	0.0562	0.0111	0.0265

Values are expressed as mean ± SEM for six animals in each group.

a : Group 4, 6 and 8 as compared to group 2.

b : Group 2, 3, 5 and 7 as compared to group 1.

\*p<0.05, \*\*p<0.01, \*\*\*p<0.001.

## 4.2.2 TISSUE ESTIMATIONS

### 4.2.2.1 Changes in the Levels of Lipid Peroxidation Products

#### 4.2.2.1.1 Changes in the Levels of Malondialdehyde (MDA)

The malondialdehyde levels in **liver**, **kidney**, **lung** and **heart** were increased significantly in group 2 (100LA) as compared to group 1 (Control). The MDA levels in **liver**, **lung** and **heart** were decreased significantly in group 4 (E+100LA) ( $p<0.001$ ), group 6 (C+100LA) ( $p<0.01$ ) and group 8 (SP+100LA) ( $p<0.001$ ) as compared to group 2 (100LA). The MDA levels in **kidney** were decreased significantly in group 4 (E+100LA) ( $p<0.001$ ), group 6 (C+100LA) ( $p<0.05$ ) and group 8 (SP+100LA) ( $p<0.001$ ) as compared to group 2 (100LA) indicating that, the exogenous antioxidants reduced the elevated MDA levels in organs (Table-4.5).

The malondialdehyde levels were increased significantly in **liver** ( $p<0.001$ ), **kidney** ( $p<0.05$ ), **lung** ( $p<0.01$ ) and **heart** ( $p<0.001$ ) in group 2 (100CD) as compared to group 1 (Control). The MDA levels in **liver**, **lung** and **heart** were decreased significantly ( $p<0.05$ ) in group 4 (E+100CD), group 8 (SP+100CD) and there was no significant change in group 6 (C+100CD) as compared to group 2 (100CD). The MDA levels in **kidney** were decreased significantly in group 4 (E+100CD) ( $p<0.01$ ), group 8 (SP+100CD) ( $p<0.05$ ) and there was no significant change in group 6 (C+100CD) as compared to group 2 (100CD) (Table- 4.6).

#### 4.2.2.1.2 Changes in the Levels of Hydroperoxide (HYPX)

The HYPX levels in **liver**, **kidney**, **lung** and **heart** were increased significantly ( $p<0.001$ ) in group 2 (100LA) when compared to group 1 (Control). The HYPX levels in **liver** were decreased significantly in group 4 (E+100LA) ( $p<0.01$ ), group 6 (C+100LA) ( $p<0.05$ ) and group 8 (SP+100LA) ( $p<0.001$ ) as compared to group 2 (100LA). Similarly, the HYPX levels in **kidney** and **heart** were decreased significantly ( $p<0.001$ ) in group 4 (E+100LA) group 6 (C+100LA) and group 8 (SP+100LA) as compared to group 2 (100LA). However, the HYPX levels in **lung** were decreased significantly ( $p<0.001$ ) in group 4 (E+100LA), group 8

(SP+100LA) and there was no significant change in group 6 (C+100LA) as compared to group 2 (100LA) (Table- 4.7).

The HYPX levels were increased significantly in **liver** ( $p<0.001$ ), **kidney** ( $p<0.001$ ), **lung** ( $p<0.001$ ) and **heart** ( $p<0.01$ ) in group 2 (100CD) as compared to group 1 (Control). The HYPX levels in **liver**, **kidney** and **heart** were decreased significantly ( $p<0.05$ ) in group 4 (E+100CD), group 8 (SP+100CD) and there was no significant change in group 6 (C+100CD) as compared to group 2 (100CD). The HYPX levels in **lung** were decreased significantly in group 4 (E+100CD) ( $p<0.01$ ), group 8 (SP+100CD) ( $p<0.05$ ) and there was no significant change in group 6 (C+100CD) as compared to group 2 (100CD) (Table- 4.8).

#### 4.2.2.1.3 Changes in the Levels of Conjugated diene (CJDN)

The conjugated diene levels in **liver**, **kidney**, **lung** and **heart** were increased significantly ( $p<0.001$ ) in group 2 (100LA) when compared to group 1 (Control). The CJDN levels in **liver** and **lung** were decreased significantly in group 4 (E+100LA) ( $p<0.001$ ), group 6 (C+100LA) ( $p<0.05$ ) and group 8 (SP+100LA) ( $p<0.001$ ) as compared to group 2 (100LA). Similarly, the CJDN levels in **kidney** and **heart** were decreased significantly ( $p<0.001$ ) in group 4 (E+100LA) group 6 (C+100LA) and group 8 (SP+100LA) as compared to group 2 (100LA) (Table- 4.9).

The conjugated diene levels in **liver**, **kidney**, **lung** and **heart** were increased significantly ( $p<0.001$ ) in group 2 (100CD) as compared to group 1 (Control). The CJDN levels in **liver** were decreased significantly in group 4 (E+100CD) ( $p<0.001$ ), group 8 (SP+100CD) ( $p<0.05$ ) and there was no significant change in group 6 (C+100CD) as compared to group 2 (100CD). The CJDN levels in **kidney** were decreased significantly ( $p<0.05$ ) in group 4 (E+100CD), group 8 (SP+100CD) and there was no significant change in group 6 (C+100CD) as compared to group 2 (100CD). The CJDN levels in **lung** were decreased significantly ( $p<0.001$ ) in group 4 (E+100CD), group 8 (SP+100CD) and there was no significant change in group 6 (C+100CD) as compared to group 2 (100CD). Similarly, the CJDN levels in **heart** were decreased significantly in group 4 (E+100CD) ( $p<0.01$ ), group 8 (SP+100CD) ( $p<0.05$ ) and there was no significant change in group 6 (C+100CD) as compared to group 2 (100CD) (Table- 4.10).

**Table- 4.5: Effect of 100 ppm of lead acetate (100LA) exposure (30 days) alone and in combination with antioxidants i.e. vitamin E, C or spirulina (E, C or SP) on the formation of malondialdehyde in liver, kidney, lung, heart and brain of rats. (nM of MDA formed / mg protein)**

GROUP	ORGANS				
	Liver	Kidney	Lung	Heart	Brain
1. Control	0.886 ± 0.019	1.031 ± 0.049	0.585 ± 0.010	0.295 ± 0.007	1.254 ± 0.040
2. 100LA	1.856 ± 0.020 <sup>***b</sup>	1.482 ± 0.021 <sup>*** b</sup>	0.989 ± 0.010 <sup>***b</sup>	0.541 ± 0.010 <sup>*** b</sup>	1.352 ± 0.056
3. E	0.856 ± 0.007	0.985 ± 0.016	1.290 ± 0.042	0.292 ± 0.034	1.193 ± 0.039
4. E+100LA	1.430 ± 0.042 <sup>***a</sup>	1.188 ± 0.012 <sup>***a</sup>	0.528 ± 0.010 <sup>***a</sup>	0.428 ± 0.009 <sup>***a</sup>	1.303 ± 0.039
5. C	0.871 ± 0.011	1.025 ± 0.022	0.578 ± 0.086	0.294 ± 0.024	1.237 ± 0.028
6. C+100LA	1.652 ± 0.026 <sup>**a</sup>	1.372 ± 0.005 <sup>*a</sup>	0.638 ± 0.085 <sup>**a</sup>	0.464 ± 0.034 <sup>**a</sup>	1.323 ± 0.050
7. SP	0.827 ± 0.019	0.949 ± 0.053	0.493 ± 0.008	0.285 ± 0.018	1.184 ± 0.021
8. SP+100LA	1.058 ± 0.036 <sup>***a</sup>	1.100 ± 0.017 <sup>***a</sup>	0.692 ± 0.012 <sup>***a</sup>	0.331 ± 0.014 <sup>***a</sup>	1.305 ± 0.023
F ratio	232.645, p<0.001	32.113, p<0.001	16.306, p<0.001	35.566, p<0.001	0.0104

Values are expressed as mean ± SEM for six animals in each group.

a : Group 4, 6 and 8 as compared to group 2.

b : Group 2, 3, 5 and 7 as compared to group 1.

\*p<0.05, \*\*p<0.01, \*\*\*p<0.001.

**Table- 4.6: Effect of 100 ppm of cadmium chloride (100CD) exposure (30 days) alone and in combination with antioxidants i.e. vitamin E, C or spirulina (E, C or SP) on the formation of malondialdehyde in liver, kidney, lung, heart and brain of rats. (nM of MDA formed / mg protein)**

GROUP	ORGANS				
	Liver	Kidney	Lung	Heart	Brain
1. Control	0.886 ± 0.019	1.031 ± 0.049	0.585 ± 0.010	0.295 ± 0.007	1.254 ± 0.040
2. 100CD	2.027 ± 0.211 <sup>***b</sup>	1.726 ± 0.220 <sup>*b</sup>	1.220 ± 0.146 <sup>**b</sup>	0.728 ± 0.073 <sup>***b</sup>	1.307 ± 0.074
3. E	0.856 ± 0.007	0.985 ± 0.016	0.528 ± 0.010	0.292 ± 0.034	1.193 ± 0.039
4. E+100CD	1.295 ± 0.122 <sup>*a</sup>	0.942 ± 0.104 <sup>**a</sup>	0.819 ± 0.099 <sup>*a</sup>	0.371 ± 0.095 <sup>*a</sup>	1.250 ± 0.085
5. C	0.871 ± 0.011	1.025 ± 0.022	0.578 ± 0.086	0.294 ± 0.024	1.237 ± 0.028
6. C+100CD	1.832 ± 0.225	1.371 ± 0.121	1.092 ± 0.163	0.439 ± 0.083	1.394 ± 0.092
7. SP	0.827 ± 0.019	0.949 ± 0.053	0.493 ± 0.008	0.285 ± 0.018	1.184 ± 0.021
8. SP+100CD	1.335 ± 0.149 <sup>*a</sup>	1.094 ± 0.134 <sup>*a</sup>	0.800 ± 0.086 <sup>*a</sup>	0.403 ± 0.103 <sup>*a</sup>	1.237 ± 0.091
F ratio	15.334, p<0.001	10.555, p<0.001	12.022, p<0.001	10.889, p<0.001	0.0265

Values are expressed as mean ± SEM for six animals in each group.

a : Group 4, 6 and 8 as compared to group 2.

b : Group 2, 3, 5 and 7 as compared to group 1.

\* p<0.05, \*\* p<0.01, \*\*\* p<0.001.

**Table- 4.7: Effect of 100 ppm of lead acetate (100LA) exposure (30 days) alone and in combination with antioxidants i.e. vitamin E, C or spirulina (E, C or SP) on the formation of hydroperoxides in liver, kidney, lung, heart and brain of rats. (nM of HYPX formed / mg protein)**

GROUP	ORGANS				
	Liver	Kidney	Lung	Heart	Brain
1. Control	10.510 ± 0.084	12.246 ± 0.096	13.074 ± 0.175	15.190 ± 0.114	18.816 ± 1.194
2. 100LA	20.022 ± 0.219 <sup>***b</sup>	16.660 ± 0.170 <sup>***b</sup>	28.924 ± 0.430 <sup>***b</sup>	23.619 ± 0.230 <sup>***b</sup>	21.098 ± 2.237
3. E	10.403 ± 0.216	12.192 ± 0.280	12.928 ± 0.128	15.053 ± 0.093	18.471 ± 0.994
4. E+100LA	12.664 ± 0.121 <sup>**a</sup>	13.393 ± 0.280 <sup>***a</sup>	16.078 ± 0.236 <sup>***a</sup>	17.021 ± 0.115 <sup>***a</sup>	20.342 ± 1.975
5. C	10.482 ± 0.088	12.229 ± 0.205	13.069 ± 0.193	15.118 ± 0.244	18.743 ± 1.066
6. C+100LA	18.778 ± 0.419 <sup>a</sup>	16.401 ± 0.388 <sup>***a</sup>	25.838 ± 1.754	21.009 ± 0.093 <sup>***a</sup>	20.090 ± 1.876
7. SP	10.258 ± 0.221	12.523 ± 0.082	12.928 ± 0.114	14.798 ± 0.081	18.650 ± 0.981
8. SP+100LA	17.076 ± 0.611 <sup>***a</sup>	15.521 ± 0.075 <sup>***a</sup>	19.350 ± 0.283 <sup>***a</sup>	19.009 ± 0.086 <sup>***a</sup>	20.996 ± 1.714
F ratio	14.176, p<0.001	6.308, p<0.001	33.467, p<0.001	10.039, p<0.001	12.499

Values are expressed as mean ± SEM for six animals in each group.

a : Group 4, 6 and 8 as compared to group 2.

b : Group 2, 3, 5 and 7 as compared to group 1.

\* p<0.05, \*\* p<0.01, \*\*\* p<0.001.

**Table- 4.8:** Effect of 100 ppm of cadmium chloride (100CD) exposure (30 days) alone and in combination with antioxidants i.e. vitamin E, C or *spirulina* (E, C or SP) on the formation of hydroperoxides in liver, kidney, lung, heart and brain of rats. (nM of HYPX formed / mg protein)

GROUP	ORGANS				
	Liver	Kidney	Lung	Heart	Brain
1. Control	10.510 ± 0.084	12.246 ± 0.096	13.074 ± 0.175	15.190 ± 0.114	18.816 ± 1.194
2. 100CD	22.500 ± 2.602 <sup>***b</sup>	21.812 ± 2.042 <sup>***b</sup>	29.452 ± 2.250 <sup>***b</sup>	24.618 ± 2.433 <sup>**b</sup>	20.098 ± 2.237
3. E	10.403 ± 0.216	12.192 ± 0.280	12.928 ± 0.128	15.053 ± 0.093	18.471 ± 0.994
4. E+100CD	10.403 ± 0.216 <sup>*a</sup>	13.753 ± 1.837 <sup>*a</sup>	18.061 ± 1.644 <sup>**a</sup>	16.298 ± 2.331 <sup>*a</sup>	19.392 ± 2.308
5. C	10.482 ± 0.088	12.229 ± 0.205	13.069 ± 0.193	15.118 ± 0.244	18.743 ± 1.066
6. C+100CD	18.810 ± 1.800	20.387 ± 2.457	26.025 ± 1.546	16.618 ± 1.501 <sup>*a</sup>	19.189 ± 1.746
7. SP	10.258 ± 0.221	12.523 ± 0.082	12.928 ± 0.114	14.798 ± 0.081	18.650 ± 0.981
8. SP+100CD	15.624 ± 1.598 <sup>*a</sup>	15.439 ± 0.587 <sup>*a</sup>	12.912 ± 1.690 <sup>*a</sup>	17.255 ± 1.965 <sup>*a</sup>	20.378 ± 1.890
F ratio	15.568, p<0.001	11.818, p<0.001	23.368, p<0.001	8.751, p<0.001	14.466,

Values are expressed as mean ± SEM for six animals in each group.

a : Group 4, 6 and 8 as compared to group 2.

b : Group 2, 3, 5 and 7 as compared to group 1.

\* p<0.05, \*\* p<0.01, \*\*\* p<0.001.

**Table- 4.9:** Effect of 100 ppm of lead acetate (100LA) exposure (30 days) alone and in combination with antioxidants i.e. vitamin E, C or *spirulina* (E, C or SP) on the formation of conjugated diene in liver, kidney, lung, heart and brain of rats. (nM of CJDN formed / mg protein)

GROUP	ORGANS				
	Liver	Kidney	Lung	Heart	Brain
1. Control	64.018 ± 0.464	16.822 ± 0.260	18.188 ± 0.208	4.362 ± 0.288	42.961 ± 2.935
2. 100LA	117.602 ± 0.422 <sup>***b</sup>	29.265 ± 0.417 <sup>***b</sup>	36.460 ± 0.305 <sup>***b</sup>	16.429 ± 0.364 <sup>***b</sup>	51.266 ± 5.386
3. E	63.899 ± 0.268	16.588 ± 0.313	17.777 ± 0.666	4.544 ± 0.198	40.189 ± 2.313
4. E+100LA	90.234 ± 0.484 <sup>***a</sup>	19.083 ± 0.206 <sup>***a</sup>	22.753 ± 0.197 <sup>***a</sup>	7.332 ± 0.313 <sup>***a</sup>	47.445 ± 5.751
5. C	64.029 ± 0.614	16.222 ± 1.002	17.940 ± 0.453	4.692 ± 0.364	42.344 ± 2.662
6. C+100LA	105.903 ± 4.529 <sup>*a</sup>	23.011 ± 0.345 <sup>***a</sup>	32.467 ± 1.660 <sup>*a</sup>	9.151 ± 0.482 <sup>***a</sup>	46.455 ± 4.210
7. SP	63.126 ± 0.162	16.257 ± 0.169	17.667 ± 0.175	4.432 ± 0.469	41.461 ± 2.590
8. SP+100LA	79.030 ± 0.519 <sup>***a</sup>	20.850 ± 0.233 <sup>***a</sup>	25.087 ± 0.239 <sup>***a</sup>	8.233 ± 0.715 <sup>***a</sup>	48.895 ± 5.042
F ratio	14.176, p<0.001	17.491, p<0.001	43.969, p<0.001	14.602, p<0.001	6.296

Values are expressed as mean ± SEM for six animals in each group.

a : Group 4, 6 and 8 as compared to group 2.

b : Group 2, 3, 5 and 7 as compared to group 1.

\* p<0.05, \*\* p<0.01, \*\*\* p<0.001.

**Table- 4.10: Effect of 100 ppm of cadmium chloride (100CD) exposure (30 days) alone and in combination with antioxidants i.e. vitamin E, C or *spirulina* (E, C or SP) on the formation of conjugated diene in liver, kidney, lung, heart and brain of rats. (nM of CJDN formed / mg protein)**

GROUP	ORGANS				
	Liver	Kidney	Lung	Heart	Brain
1. Control	64.018 ± 0.464	16.822 ± 0.260	18.188 ± 0.208	4.362 ± 0.288	42.961 ± 2.935
2. 100CD	126.25 ± 4.405 <sup>***b</sup>	27.325 ± 1.970 <sup>***b</sup>	44.363 ± 1.052 <sup>***b</sup>	16.429 ± 0.364 <sup>***b</sup>	52.063 ± 5.737
3. E	63.899 ± 0.268	16.588 ± 0.313	17.777 ± 0.666	4.544 ± 0.198	40.189 ± 2.313
4. E+100CD	88.786 ± 3.665 <sup>***a</sup>	21.595 ± 1.405 <sup>*a</sup>	21.559 ± 1.705 <sup>***a</sup>	10.414 ± 1.229 <sup>***a</sup>	48.514 ± 5.317
5. C	64.029 ± 0.614	16.222 ± 1.002	17.940 ± 0.453	4.692 ± 0.364	42.344 ± 2.662
6. C+100CD	115.57 ± 4.145	24.710 ± 0.926	39.761 ± 2.706	12.649 ± 1.288	47.933 ± 4.053
7. SP	63.126 ± 0.162	16.257 ± 0.169	17.667 ± 0.175	4.432 ± 0.469	41.461 ± 2.590
8. SP+100CD	107.83 ± 3.224 <sup>*a</sup>	21.490 ± 1.231 <sup>*a</sup>	26.235 ± 1.855 <sup>***a</sup>	9.580 ± 1.743 <sup>*a</sup>	47.275 ± 5.954
F ratio	59.495, p<0.001	15.501, p<0.001	56.508, p<0.001	26.523, p<0.001	6.37

Values are expressed as mean ± SEM for six animals in each group.

a : Group 4, 6 and 8 as compared to group 2.

b : Group 2, 3, 5 and 7 as compared to group 1.

\*p<0.05, \*\*p<0.01, \*\*\*p<0.001.

#### 4.2.2.2 Changes in the Levels of Endogenous Antioxidants

##### 4.2.2.2.1 Changes in the Levels of Superoxide dismutase (SOD)

The SOD levels in **liver, kidney, lung** and **heart** were decreased significantly ( $p < 0.001$ ) in group 2 (100LA) when compared to group 1 (Control). The SOD levels in **liver** were increased significantly in group 4 (E+100LA) ( $p < 0.001$ ), group 6 (C+100LA) ( $p < 0.01$ ) and group 8 (SP+100LA) ( $p < 0.001$ ) as compared to group 2 (100LA). Similarly, the SOD levels in **kidney, lung** and **heart** were increased significantly ( $p < 0.001$ ) in group 4 (E+100LA) group 6 (C+100LA) and group 8 (SP+100LA) as compared to group 2 (100LA) (Table- 4.11).

The SOD levels were decreased significantly in **liver** ( $p < 0.01$ ), **kidney** ( $p < 0.001$ ), **lung** ( $p < 0.001$ ) and **heart** ( $p < 0.001$ ) in group 2 (100CD) as compared to group 1 (Control). The SOD levels in **liver** were increased significantly in group 4 (E+100CD) ( $p < 0.01$ ), group 6 (C+100CD) ( $p < 0.05$ ) and group 8 (SP+100CD) ( $p < 0.05$ ) as compared to group 2 (100CD). The SOD levels in **kidney** were increased significantly in group 4 (E+100CD) ( $p < 0.001$ ), group 6 (C+100CD) ( $p < 0.001$ ) and group 8 (SP+100CD) ( $p < 0.05$ ) as compared to group 2 (100CD). The SOD levels in **lung** were increased significantly in group 4 (E+100CD) ( $p < 0.001$ ), group 8 (SP+100CD) ( $p < 0.05$ ) and there was no significant change in group 6 (C+100CD) as compared to group 2 (100CD). However, The SOD levels in **heart** were increased significantly ( $p < 0.05$ ) in group 4 (E+100CD) (Table- 4.12).

##### 4.2.2.2.2 Changes in the Levels of Catalase (CAT)

The CAT levels in **liver, kidney, lung** and **heart** were decreased significantly ( $p < 0.001$ ) in group 2 (100LA) as compared to group 1 (Control). The CAT levels in **liver, kidney, lung** and **heart** were increased significantly ( $p < 0.001$ ) in group 4 (E+100LA) group 6 (C+100LA) and group 8 (SP+100LA) as compared to group 2 (100LA) (Table- 4.13).

The CAT levels in **liver, kidney, lung** and **heart** were decreased significantly ( $p < 0.001$ ) in group 2 (100CD) as compared to group 1 (Control). The CAT levels in **liver** and **heart** were increased significantly in group 4 (E+100CD)

( $p < 0.001$ ), group 6 (C+100CD) ( $p < 0.01$ ) and group 8 (SP+100CD) ( $p < 0.001$ ) as compared to group 2 (100CD). The CAT levels in **kidney** were increased significantly in group 4 (E+100CD) ( $p < 0.001$ ), group 8 (SP+100CD) ( $p < 0.05$ ) and there was no significant change in group 6 (C+100CD) as compared to group 2 (100CD). However, the CAT levels in **lung** were increased significantly ( $p < 0.001$ ) in group 4 (E+100CD), group 8 (SP+100CD) and there was no significant change in group 6 (C+100CD) as compared to group 2 (100CD) (Table- 4.14).

#### 4.2.2.2.3 Changes in the Levels of Reduced glutathione (GSH)

The GSH levels in **liver**, **kidney**, **lung** and **heart** were decreased significantly ( $p < 0.001$ ) in group 2 (100LA) when compared to group 1 (Control). The GSH levels in **liver** were increased significantly in group 4 (E+100LA) ( $p < 0.001$ ), group 6 (C+100LA) ( $p < 0.01$ ) and group 8 (SP+100LA) ( $p < 0.001$ ) as compared to group 2 (100LA). Similarly, the GSH levels in **kidney**, **lung** and **heart** were increased significantly ( $p < 0.001$ ) in group 4 (E+100LA) group 6 (C+100LA) and group 8 (SP+100LA) as compared to group 2 (100LA) (Table- 4.15).

The GSH levels in **liver**, **kidney**, **lung** and **heart** were decreased significantly ( $p < 0.001$ ) in group 2 (100CD) as compared to group 1 (Control). The GSH levels in **liver** were increased significantly in group 4 (E+100CD) ( $p < 0.001$ ), group 6 (C+100CD) ( $p < 0.05$ ) and group 8 (SP+100CD) ( $p < 0.01$ ) as compared to group 2 (100CD). The GSH levels in **kidney** were increased significantly in group 4 (E+100CD) ( $p < 0.001$ ), group 8 (SP+100CD) ( $p < 0.05$ ) and there was no significant change in group 6 (C+100CD) as compared to group 2 (100CD). The GSH levels in **lung** were increased significantly ( $p < 0.05$ ) in group 4 (E+100CD), group 8 (SP+100CD) and there was no significant change in group 6 (C+100CD) as compared to group 2 (100CD). However, the GSH levels in **heart** were increased significantly in group 4 (E+100CD) ( $p < 0.01$ ), group 8 (SP+100CD) ( $p < 0.05$ ) and there was no significant change in group 6 (C+100CD) as compared to group 2 (100CD) (Table- 4.16).

**Table- 4.11: Effect of 100 ppm of lead acetate (100LA) exposure (30 days) alone and in combination with antioxidants i.e. vitamin E, C or spirulina (E, C or SP) on the levels of superoxide dismutase in liver, kidney, lung, heart and brain` of rats. (Units / mg protein)**

GROUP	ORGANS				
	Liver	Kidney	Lung	Heart	Brain
1. Control	7.653 ± 0.516	9.380 ± 0.101	8.688 ± 0.050	7.212 ± 0.133	10.321 ± 0.466
2. 100LA	5.278 ± 0.058 <sup>***b</sup>	5.425 ± 0.101 <sup>*** b</sup>	5.960 ± 0.088 <sup>***b</sup>	4.798 ± 0.163 <sup>*** b</sup>	8.849 ± 0.822
3. E	7.730 ± 0.337	9.461 ± 0.102	8.854 ± 0.127	7.347 ± 0.081	10.802 ± 0.359
4. E+100LA	7.128 ± 0.058 <sup>***a</sup>	8.464 ± 0.128 <sup>***a</sup>	7.941 ± 0.062 <sup>***a</sup>	6.922 ± 0.043 <sup>***a</sup>	8.894 ± 0.834
5. C	7.666 ± 0.386	9.445 ± 0.019	8.796 ± 0.138	7.283 ± 0.154	9.492 ± 0.496
6. C+100LA	6.118 ± 0.181 <sup>**a</sup>	7.510 ± 0.184 <sup>***a</sup>	7.523 ± 0.111 <sup>***a</sup>	6.183 ± 0.113 <sup>***a</sup>	9.484 ± 0.464
7. SP	8.123 ± 0.320	9.578 ± 0.123	8.861 ± 0.138	7.733 ± 0.205	11.960 ± 0.848
8. SP+100LA	6.767 ± 0.124 <sup>***a</sup>	7.979 ± 0.291 <sup>***a</sup>	8.340 ± 0.058 <sup>***a</sup>	6.744 ± 0.120 <sup>***a</sup>	9.246 ± 0.763
F ratio	16.442, p<0.001	62.232, p<0.001	104.01, p<0.001	40.756, p<0.001	2.730

Values are expressed as mean ± SEM for six animals in each group.

a : Group 4, 6 and 8 as compared to group 2.

b : Group 2, 3, 5 and 7 as compared to group 1.

\* p<0.05, \*\* p<0.01, \*\*\* p<0.001.

**Table- 4.12: Effect of 100 ppm of cadmium chloride (100CD) exposure alone and in combination with antioxidants i.e. vitamin E, C or spirulina (E, C or SP) on the levels of superoxide dismutase in liver, kidney, lung and heart of rats during 30 days of experiment.**  
(Units / mg protein)

GROUP	ORGANS				
	Liver	Kidney	Lung	Heart	Brain
1. Control	7.653 ± 0.516	9.380 ± 0.101	8.688 ± 0.050	7.212 ± 0.133	10.321 ± 0.466
2. 100CD	5.007 ± 0.441 <sup>**b</sup>	4.996 ± 0.368 <sup>*** b</sup>	5.046 ± 0.293 <sup>***b</sup>	4.857 ± 0.478 <sup>*** b</sup>	8.849 ± 0.858
3. E	7.730 ± 0.337	9.461 ± 0.102	8.854 ± 0.127	7.347 ± 0.081	10.802 ± 0.359
4. E+100CD	6.940 ± 0.396 <sup>**a</sup>	8.023 ± 0.492 <sup>***a</sup>	7.637 ± 0.236 <sup>***a</sup>	6.627 ± 0.402 <sup>*a</sup>	8.894 ± 0.834
5. C	7.666 ± 0.386	9.445 ± 0.019	8.796 ± 0.138	7.283 ± 0.154	9.492 ± 0.496
6. C+100CD	6.433 ± 0.386 <sup>*a</sup>	7.676 ± 0.315 <sup>***a</sup>	5.792 ± 0.393	6.316 ± 0.433 <sup>*a</sup>	9.484 ± 0.464
7. SP	8.123 ± 0.320	9.578 ± 0.123	8.861 ± 0.138	7.733 ± 0.205	11.960 ± 0.848
8. SP+100CD	6.358 ± 0.392 <sup>*a</sup>	7.054 ± 0.647 <sup>*a</sup>	6.574 ± 0.587 <sup>*a</sup>	6.202 ± 0.366 <sup>*a</sup>	9.790 ± 0.824
F ratio	11.996, p<0.001	23.883, p<0.001	27.358, p<0.001	12.443, p<0.001	3.235

Values are expressed as mean ± SEM for six animals in each group.

a : Group 4, 6 and 8 as compared to group 2.

b : Group 2, 3, 5 and 7 as compared to group 1.

\* p<0.05, \*\* p<0.01, \*\*\* p<0.001.

**Table- 4.13: Effect of 100 ppm of lead acetate (100LA) exposure (30 days) alone and in combination with antioxidants i.e. vitamin E, C or spirulina (E, C or SP) on the levels of catalase in liver, kidney, lung, heart and brain of rats. (Kat f)**

GROUP	ORGANS				
	Liver	Kidney	Lung	Heart	Brain
1. Control	148.716 ± 1.663	116.849 ± 2.753	117.902 ± 2.342	87.716 ± 1.476	148.163 ± 7.394
2. 100LA	56.013 ± 1.185 <sup>***b</sup>	77.497 ± 0.675 <sup>***b</sup>	65.050 ± 1.235 <sup>***b</sup>	40.367 ± 1.089 <sup>***b</sup>	132.012 ± 7.086
3. E	154.206 ± 4.364	121.525 ± 1.095	131.230 ± 1.387	90.047 ± 4.410	148.836 ± 6.378
4. E+100LA	130.001 ± 1.307 <sup>***a</sup>	111.120 ± 2.981 <sup>***a</sup>	91.828 ± 1.436 <sup>***a</sup>	71.767 ± 0.901 <sup>***a</sup>	147.705 ± 6.559
5. C	151.403 ± 2.052	118.628 ± 2.306	126.792 ± 1.044	88.285 ± 2.504	148.648 ± 7.969
6. C+100LA	102.373 ± 2.794 <sup>***a</sup>	91.946 ± 1.873 <sup>***a</sup>	83.356 ± 3.041 <sup>***a</sup>	66.169 ± 3.024 <sup>***a</sup>	144.753 ± 6.429
7. SP	159.462 ± 3.336	125.921 ± 2.156	134.050 ± 3.113	94.561 ± 5.741	149.321 ± 7.027
8. SP+100LA	113.393 ± 1.781 <sup>***a</sup>	106.331 ± 1.268 <sup>***a</sup>	109.592 ± 2.071 <sup>***a</sup>	81.361 ± 0.787 <sup>***a</sup>	147.181 ± 8.545
F ratio	194.714, p<0.001	59.413, p<0.001	131.046, p<0.001	32.937, p<0.001	6.136

Values are expressed as mean ± SEM for six animals in each group.

a : Group 4, 6 and 8 as compared to group 2.

b : Group 2, 3, 5 and 7 as compared to group 1.

\* p<0.05, \*\* p<0.01, \*\*\* p<0.001.

**Table- 4.14: Effect of 100 ppm of cadmium chloride (100CD) exposure (30 days) alone and in combination with antioxidants i.e. vitamin E, C or spirulina (E, C or SP) on the levels of catalase in liver, kidney, lung, heart and brain of rats. (Kat f)**

GROUP	ORGANS				
	Liver	Kidney	Lung	Heart	Brain
1. Control	148.716 ± 1.663	116.849 ± 2.753	117.902 ± 2.342	87.716 ± 1.476	148.163 ± 7.394
2. 100CD	49.274 ± 5.621 <sup>***b</sup>	72.852 ± 3.138 <sup>***b</sup>	58.372 5.817 <sup>***b</sup>	36.112 ± 4.236 <sup>***b</sup>	131.166 ± 7.499
3. E	154.206 ± 4.364	121.525 ± 1.095	131.230 ± 1.387	90.047 ± 4.410	148.836 ± 6.378
4. E+100CD	133.404 ± 7.609 <sup>***a</sup>	104.076 ± 4.196 <sup>***a</sup>	105.964 ± 5.230 <sup>***a</sup>	74.957 ± 4.019 <sup>***a</sup>	147.705 ± 6.559
5. C	151.403 ± 2.052	118.628 ± 2.306	126.792 ± 1.044	88.285 ± 2.504	148.648 ± 7.969
6. C+100CD	92.864 ± 10.322 <sup>**a</sup>	81.618 ± 3.466	70.017 ± 6.753	60.366 ± 4.522 <sup>**a</sup>	144.753 ± 6.429
7. SP	159.462 ± 3.336	125.921 ± 2.156	134.050 ± 3.113	94.561 ± 5.741	149.321 ± 7.027
8. SP+100CD	116.829 ± 7.122 <sup>***a</sup>	86.525 ± 4.982 <sup>*a</sup>	86.723 ± 4.080 <sup>***a</sup>	63.881 ± 04.982 <sup>***a</sup>	147.181 ± 8.545
F ratio	42.809, p<0.001	35.231, p<0.001	40.358, p<0.001	26.394, p<0.001	6.265

Values are expressed as mean ± SEM for six animals in each group.

a : Group 4, 6 and 8 as compared to group 2.

b : Group 2, 3, 5 and 7 as compared to group 1.

\*p<0.05, \*\*p<0.01, \*\*\*p<0.001.

**Table- 4.15: Effect of 100 ppm of lead acetate (100LA) exposure (30 days) alone and in combination with antioxidants i.e. vitamin E, C or spirulina (E, C or SP) on the levels of reduced glutathione in liver, kidney, lung, heart and brain of rats. (mcg of GSH / mg protein)**

GROUP	ORGANS				
	Liver	Kidney	Lung	Heart	Brain
1. Control	9.971 ± 0.177	5.881 ± 0.098	4.070 ± 0.125	4.073 ± 0.138	5.188 ± 0.290
2. 100LA	2.570 ± 0.243 <sup>***b</sup>	2.159 ± 0.163 <sup>***b</sup>	2.064 ± 0.127 <sup>***b</sup>	2.212 ± 0.065 <sup>***b</sup>	4.706 ± 0.402
3. E	10.027 ± 0.059	5.924 ± 0.126	4.104 ± 0.154	4.020 ± 0.111	4.588 ± 0.414
4. E+100LA	8.009 ± 0.181 <sup>***a</sup>	5.316 ± 0.076 <sup>***a</sup>	3.330 ± 0.127 <sup>***a</sup>	3.214 ± 0.177 <sup>***a</sup>	5.364 ± 0.268
5. C	9.994 ± 0.228	5.884 ± 0.137	4.070 ± 0.260	4.032 ± 0.144	5.261 ± 0.369
6. C+100LA	5.001 ± 0.477 <sup>***a</sup>	5.078 ± 0.150 <sup>***a</sup>	3.353 ± 0.125 <sup>***a</sup>	3.376 ± 0.126 <sup>***a</sup>	5.300 ± 0.406
7. SP	10.270 ± 0.221	6.057 ± 0.092	4.272 ± 0.139	4.213 ± 0.110	5.543 ± 0.264
8. SP+100LA	6.983 ± 0.147 <sup>***a</sup>	5.689 ± 0.042 <sup>***a</sup>	3.585 ± 0.034 <sup>***a</sup>	3.381 ± 0.052 <sup>***a</sup>	4.928 ± 0.485
F ratio	6.560, p<0.001	8.857 p<0.001	32.264, p<0.001	25.754, p<0.001	0.973

Values are expressed as mean ± SEM for six animals in each group.

a : Group 4, 6 and 8 as compared to group 2.

b : Group 2, 3, 5 and 7 as compared to group 1.

\*p<0.05, \*\*p<0.01, \*\*\*p<0.001.

**Table- 4.16: Effect of 100 ppm of cadmium chloride (100CD) exposure alone and in combination with antioxidants i.e. vitamin E, C or spirulina (E, C or SP) on the levels of reduced glutathione in liver, kidney, lung, heart and brain of rats. (mcg of GSH / mg protein)**

GROUP	ORGANS				
	Liver	Kidney	Lung	Heart	Brain
1. Control	9.971 ± 0.177	5.881 ± 0.098	4.070 ± 0.125	4.073 ± 0.138	5.188 ± 0.290
2. 100CD	4.170 ± 0.409 <sup>***b</sup>	3.684 ± 0.199 <sup>***b</sup>	2.766 ± 0.185 <sup>***b</sup>	2.175 ± 0.208 <sup>***b</sup>	4.439 ± 0.417
3. E	10.027 ± 0.059	5.924 ± 0.126	4.104 ± 0.154	4.020 ± 0.111	4.588 ± 0.414
4. E+100CD	7.865 ± 0.497 <sup>***a</sup>	5.221 ± 0.246 <sup>***a</sup>	3.656 ± 0.262 <sup>*a</sup>	3.654 ± 0.288 <sup>**a</sup>	5.009 ± 0.442
5. C	9.994 ± 0.228	5.884 ± 0.137	4.070 ± 0.260	4.032 ± 0.144	5.261 ± 0.369
6. C+100CD	5.577 ± 0.425 <sup>*a</sup>	4.016 ± 0.548	2.889 ± 0.175	2.672 ± 0.192	4.819 ± 0.396
7. SP	10.270 ± 0.221	6.057 ± 0.092	4.272 ± 0.139	4.213 ± 0.110	5.543 ± 0.264
8. SP+100CD	5.544 ± 0.833 <sup>**a</sup>	4.808 ± 0.383 <sup>*a</sup>	3.397 ± 0.132 <sup>*a</sup>	3.266 ± 0.335 <sup>*a</sup>	4.699 ± 0.565
F ratio	25.195, p<0.001	14.29, p<0.001	12.072, p<0.001	15.316, p<0.001	1.113

Values are expressed as mean ± SEM for six animals in each group.

a : Group 4, 6 and 8 as compared to group 2.

b : Group 2, 3, 5 and 7 as compared to group 1.

\*p<0.05, \*\*p<0.01, \*\*\*p<0.001.

### **4.2.2.3 Changes in the Levels of liver Gluconeogenic Enzyme**

#### **4.2.2.3.1 Changes in the Levels of Glucose-6-phosphate dehydrogenase (G-6PD)**

The G-6PD levels in **liver** were decreased significantly ( $p < 0.01$ ) in group 2 (100LA) when compared to group 1 (Control). The G-6PD levels in **liver** were increased significantly in group 4 (E+100LA) ( $p < 0.05$ ), group 6 (C+100LA) ( $p < 0.05$ ) and group 8 (SP+100LA) ( $p < 0.01$ ) as compared to group 2 (100LA) (Table- 4.17).

The G-6-PD levels in **liver** were decreased significantly ( $p < 0.01$ ) in group 2 (100CD) as compared to group 1 (Control). The G-6-PD levels in **liver** were increased significantly ( $p < 0.05$ ) in group 4 (E+100CD), group 8 (SP+100CD) and there was no significant change in group 6 (C+100CD) as compared to group 2 (100CD) (Table- 4.18).

### **4.2.2.4 Changes in the Levels of Membrane Bound Enzymes**

#### **4.2.2.4.1 Changes in the Levels of Sodium potassium dependent ATPase ( $\text{Na}^+ - \text{K}^+ - \text{ATPase}$ )**

The  $\text{Na}^+ - \text{K}^+ - \text{ATPase}$  levels in **liver** and **kidney** were decreased significantly ( $p < 0.001$ ) in group 2 (100LA) when compared to group 1 (Control). The  $\text{Na}^+ - \text{K}^+ - \text{ATPase}$  levels in **liver** were increased significantly in group 4 (E+100LA) ( $p < 0.001$ ), group 6 (C+100LA) ( $p < 0.05$ ) and group 8 (SP+100LA) ( $p < 0.001$ ) as compared to group 2 (100LA). However, the  $\text{Na}^+ - \text{K}^+ - \text{ATPase}$  levels in **kidney** were increased significantly ( $p < 0.001$ ) in group 4 (E+100LA), group 6 (C+100LA) and group 8 (SP+100LA) as compared to group 2 (100LA) (Table- 4.19).

The  $\text{Na}^+ - \text{K}^+ - \text{ATPase}$  levels were decreased significantly in **liver** ( $p < 0.001$ ) and **kidney** ( $p < 0.01$ ) in group 2 (100CD) as compared to group 1 (Control). The  $\text{Na}^+ - \text{K}^+ - \text{ATPase}$  levels in **liver** were increased significantly in group 4 (E+100CD) ( $p < 0.05$ ), group 8 (SP+100CD) ( $p < 0.01$ ) and there was no significant change in group 6 (C+100CD) as compared to group 2 (100CD). However, The  $\text{Na}^+ - \text{K}^+ - \text{ATPase}$  levels in **kidney** were increased significantly ( $p < 0.05$ ) in group 4 (E+100CD), group 8 (SP+100CD) and there was no significant change in group 6 (C+100CD) as compared to group 2 (100CD) (Table- 4.20).

**Table- 4.17: Effect of 100 ppm of lead acetate (100LA) exposure (30 days) alone and in combination with antioxidants i.e. vitamin E, C or spirulina (E, C or SP) on the levels of glucose-6-phosphate dehydrogenase in liver of rats. (Units / Litre)**

GROUP	ORGAN
	Liver
1. Control	2.655 ± 0.120
2. 100LA	1.146 ± 0.393 <sup>**b</sup>
3. E	2.662 ± 0.223
4. E+100LA	2.111 ± 0.175 <sup>*a</sup>
5. C	2.715 ± 0.102
6. C+100LA	2.032 ± 0.024 <sup>*a</sup>
7. SP	2.717 ± 0.160
8. SP+100LA	2.401 ± 0.031 <sup>**a</sup>
F ratio	11.952, p<0.001

Values are expressed as mean ± SEM for six animals in each group.

a : Group 4, 6 and 8 as compared to group 2.

b : Group 2, 3, 5 and 7 as compared to group 1.

\* p<0.05, \*\* p<0.01, \*\*\* p<0.001.

**Table- 4.18: Effect of 100 ppm of cadmium chloride (100CD) exposure alone and in combination with antioxidants i.e. vitamin E, C or spirulina (E, C or SP) on the levels of glucose-6-phosphate dehydrogenase in liver of rats. (Units / Litre)**

GROUP	ORGAN
	Liver
1. Control	2.655 ± 0.120
2. 100CD	1.618 ± 0.214 <sup>**b</sup>
3. E	2.662 ± 0.223
4. E+100CD	2.296 ± 0.103 <sup>*a</sup>
5. C	2.715 ± 0.102
6. C+100CD	1.723 ± 0.184
7. SP	2.717 ± 0.160
8. SP+100CD	2.227 ± 0.150 <sup>*a</sup>
F ratio	11.105, p<0.001

Values are expressed as mean ± SEM for six animals in each group.

a : Group 4, 6 and 8 as compared to group 2.

b : Group 2, 3, 5 and 7 as compared to group 1.

\* p<0.05, \*\* p<0.01, \*\*\* p<0.001.

**Table- 4.19: Effect of 100 ppm of lead acetate (100LA) exposure (30 days) alone and in combination with antioxidants i.e. vitamin E, C or spirulina (E, C or SP) on the levels of sodium potassium dependent ATPase in liver and kidney of rats. (mM of Pi liberated / mg protein)**

GROUP	ORGANS	
	Liver	Kidney
1. Control	2.297 ± 0.097	3.545 ± 0.025
2. 100LA	0.672 ± 0.012 <sup>***b</sup>	1.838 ± 0.027 <sup>***b</sup>
3. E	2.323 ± 0.017	3.568 ± 0.103
4. E+100LA	1.863 ± 0.009 <sup>***a</sup>	2.561 ± 0.064 <sup>***a</sup>
5. C	2.300 ± 0.022	3.564 ± 0.131
6. C+100LA	1.092 ± 0.133 <sup>a</sup>	2.444 ± 0.062 <sup>***a</sup>
7. SP	2.368 ± 0.053	3.784 ± 0.166
8. SP+100LA	2.095 ± 0.016 <sup>***a</sup>	2.996 ± 0.018 <sup>***a</sup>
F ratio	73.633, p<0.001	58.905, p<0.001

Values are expressed as mean ± SEM for six animals in each group.

a : Group 4, 6 and 8 as compared to group 2.

b : Group 2, 3, 5 and 7 as compared to group 1.

\* p<0.05, \*\* p<0.01, \*\*\* p<0.001.

**Table- 4.20: Effect of 100 ppm of cadmium chloride (100CD) exposure alone and in combination with antioxidants i.e. vitamin E, C or spirulina (E, C or SP) on the levels of sodium potassium dependent ATPase in liver and kidney of rats. (mM of Pi liberated / mg protein)**

GROUP	ORGANS	
	Liver	Kidney
1. Control	2.297 ± 0.097	3.545 ± 0.025
2. 100CD	1.339 ± 0.160 <sup>***b</sup>	2.761 ± 0.174 <sup>**b</sup>
3. E	2.323 ± 0.017	3.568 ± 0.103
4. E+100CD	1.842 ± 0.058 <sup>a</sup>	3.202 ± 0.079 <sup>a</sup>
5. C	2.300 ± 0.022	3.564 ± 0.131
6. C+100CD	1.619 ± 0.125	2.826 ± 0.070
7. SP	2.368 ± 0.053	3.784 ± 0.166
8. SP+100CD	1.941 ± 0.057 <sup>**a</sup>	3.194 ± 0.082 <sup>a</sup>
F ratio	17.556, p<0.001	13.471, p<0.001

Values are expressed as mean ± SEM for six animals in each group.

a : Group 4, 6 and 8 as compared to group 2.

b : Group 2, 3, 5 and 7 as compared to group 1.

\* p<0.05, \*\* p<0.01, \*\*\* p<0.001.

#### 4.2.2.4.2 Changes in the Levels of Calcium dependent ATPase ( $\text{Ca}^{++}$ -ATPase)

The  $\text{Ca}^{++}$ -ATPase levels in **liver** and **kidney** were decreased significantly ( $p < 0.001$ ) in group 2 (100LA) when compared to group 1 (Control). The  $\text{Ca}^{++}$ -ATPase levels in **liver** were increased significantly ( $p < 0.001$ ) in group 4 (E+100LA), group 6 (C+100LA) and group 8 (SP+100LA) as compared to group 2 (100LA). However, the  $\text{Ca}^{++}$ -ATPase levels in **kidney** were increased significantly in group 4 (E+100LA) ( $p < 0.001$ ), group 6 (C+100LA) ( $p < 0.01$ ) and group 8 (SP+100LA) ( $p < 0.001$ ) as compared to group 2 (100LA) (Table- 4.21).

The  $\text{Ca}^{++}$ -ATPase levels were decreased significantly in **liver** ( $p < 0.01$ ) and **kidney** ( $p < 0.001$ ) in group 2 (100CD) as compared to group 1 (Control). The  $\text{Ca}^{++}$ -ATPase levels in **liver** were increased significantly in group 4 (E+100CD) ( $p < 0.05$ ) and there was no significant change in group 6 (C+100CD), group 8 (SP+100CD) as compared to group 2 (100CD). However, The  $\text{Ca}^{++}$ -ATPase levels in **kidney** were increased significantly ( $p < 0.05$ ) in group 4 (E+100CD), group 6 (C+100CD) and group 8 (SP+100CD) as compared to group 2 (100CD) (Table- 4.22).

#### 4.2.2.4.3 Changes in the Levels of Magnesium dependent ATPase ( $\text{Mg}^{++}$ -ATPase)

The  $\text{Mg}^{++}$ -ATPase levels in **liver** and **kidney** were decreased significantly ( $p < 0.001$ ) in group 2 (100LA) when compared to group 1 (Control). The  $\text{Mg}^{++}$ -ATPase levels in **liver** were increased significantly ( $p < 0.001$ ) in group 4 (E+100LA), group 8 (SP+100LA) and there was no significant change in group 6 (C+100LA) as compared to group 2 (100LA). However, the  $\text{Mg}^{++}$ -ATPase levels in **kidney** were increased significantly ( $p < 0.001$ ) in group 4 (E+100LA), group 6 (C+100LA) and group 8 (SP+100LA) ( $p < 0.001$ ) as compared to group 2 (100LA) (Table- 4.23).

The  $\text{Mg}^{++}$ -ATPase levels in **liver** and **kidney** were decreased significantly ( $p < 0.01$ ) in group 2 (100CD) as compared to group 1 (Control). The  $\text{Mg}^{++}$ -ATPase levels in **liver** were increased significantly ( $p < 0.05$ ) in group 4 (E+100CD) and there was no significant change in group 6 (C+100CD), group 8 (SP+100CD) as compared to group 2 (100CD). However, The  $\text{Mg}^{++}$ -ATPase levels in **kidney** were increased significantly ( $p < 0.05$ ) in group 4 (E+100CD), group 8 (SP+100CD) and there was no significant change in group 6 (C+100CD) and in as compared to group 2 (100CD) (Table- 4.24).

**Table- 4.21: Effect of 100 ppm of lead acetate (100LA) exposure (30 days) alone and in combination with antioxidants i.e. vitamin E, C or spirulina (E, C or SP) on the levels of calcium dependent ATPase in liver and kidney of rats. (mM of Pi liberated / mg protein)**

GROUP	ORGANS	
	Liver	Kidney
1. Control	1.370 ± 0.095	1.797 ± 0.010
2. 100LA	0.472 ± 0.011 <sup>***b</sup>	0.992 ± 0.021 <sup>***b</sup>
3. E	1.378 ± 0.038	1.800 ± 0.029
4. E+100LA	0.826 ± 0.026 <sup>***a</sup>	1.388 ± 0.023 <sup>***a</sup>
5. C	1.371 ± 0.029	1.799 ± 0.028
6. C+100LA	0.749 ± 0.011 <sup>***a</sup>	1.156 ± 0.037 <sup>**a</sup>
7. SP	1.403 ± 0.069	1.809 ± 0.035
8. SP+100LA	1.012 ± 0.014 <sup>***a</sup>	1.526 ± 0.014 <sup>***a</sup>
F ratio	53.590, p<0.001	156.561, p<0.001

Values are expressed as mean ± SEM for six animals in each group.

a : Group 4, 6 and 8 as compared to group 2.

b : Group 2, 3, 5 and 7 as compared to group 1.

\*p<0.05, \*\*p<0.01, \*\*\*p<0.001.

**Table- 4.22: Effect of 100 ppm of cadmium chloride (100CD) exposure alone and in combination with antioxidants i.e. vitamin E, C or spirulina (E, C or SP) on the levels of calcium dependent ATPase in liver and kidney of rats. (mM of Pi liberated / mg protein)**

GROUP	ORGANS	
	Liver	Kidney
1. Control	1.370 ± 0.095	1.797 ± 0.010
2. 100CD	0.849 ± 0.082 <sup>**b</sup>	1.142 ± 0.070 <sup>***b</sup>
3. E	1.378 ± 0.038	1.800 ± 0.029
4. E+100CD	1.084 ± 0.052 <sup>*a</sup>	1.449 ± 0.077 <sup>*a</sup>
5. C	1.371 ± 0.029	1.799 ± 0.028
6. C+100CD	0.787 ± 0.029	1.368 ± 0.067 <sup>*a</sup>
7. SP	1.403 ± 0.069	1.809 ± 0.035
8. SP+100CD	0.976 ± 0.061	1.401 ± 0.056 <sup>*a</sup>
F ratio	18.889, p<0.001	20.201, p<0.001

Values are expressed as mean ± SEM for six animals in each group.

a : Group 4, 6 and 8 as compared to group 2.

b : Group 2, 3, 5 and 7 as compared to group 1.

\*p<0.05, \*\*p<0.01, \*\*\*p<0.001.

**Table- 4.23: Effect of 100 ppm of lead acetate (100LA) exposure (30 days) alone and in combination with antioxidants i.e. vitamin E, C or spirulina (E, C or SP) on the levels of magnesium dependent ATPase in liver and kidney of rats. (mM of Pi liberated / mg protein)**

GROUP	ORGANS	
	Liver	Kidney
1. Control	1.552 ± 0.012	2.880 ± 0.104
2. 100LA	0.985 ± 0.018 <sup>***b</sup>	1.040 ± 0.023 <sup>***b</sup>
3. E	1.583 ± 0.017	2.927 ± 0.031
4. E+100LA	1.259 ± 0.010 <sup>***a</sup>	2.279 ± 0.040 <sup>***a</sup>
5. C	1.571 ± 0.065	2.882 ± 0.056
6. C+100LA	1.047 ± 0.063	2.126 ± 0.121 <sup>***a</sup>
7. SP	1.597 ± 0.079	3.070 ± 0.057
8. SP+100LA	1.326 ± 0.041 <sup>***a</sup>	2.716 ± 0.020 <sup>***a</sup>
F ratio	33.005, p<0.001	104.509, p<0.001

Values are expressed as mean ± SEM for six animals in each group.

a : Group 4, 6 and 8 as compared to group 2.

b : Group 2, 3, 5 and 7 as compared to group 1.

\* p<0.05, \*\* p<0.01, \*\*\* p<0.001.

**Table- 4.24: Effect of 100 ppm of cadmium chloride (100CD) exposure alone and in combination with antioxidants i.e. vitamin E, C or spirulina (E, C or SP) on the levels of magnesium dependent ATPase in liver and kidney of rats. (mM of Pi liberated / mg protein)**

GROUP	ORGANS	
	Liver	Kidney
1. Control	1.552 ± 0.012	2.880 ± 0.104
2. 100CD	1.141 ± 0.098 <sup>**b</sup>	1.944 ± 0.247 <sup>**b</sup>
3. E	1.583 ± 0.017	2.927 ± 0.031
4. E+100CD	1.407 ± 0.056 <sup>*a</sup>	2.550 ± 0.063 <sup>*a</sup>
5. C	1.571 ± 0.065	2.882 ± 0.056
6. C+100CD	1.234 ± 0.124	1.866 ± 0.123
7. SP	1.597 ± 0.079	3.070 ± 0.057
8. SP+100CD	1.224 ± 0.094	2.557 ± 0.085 <sup>*a</sup>
F ratio	10.042, p<0.001	15.522, p<0.001

Values are expressed as mean ± SEM for six animals in each group.

a : Group 4, 6 and 8 as compared to group 2.

b : Group 2, 3, 5 and 7 as compared to group 1.

\* p<0.05, \*\* p<0.01, \*\*\* p<0.001.

#### 4.2.2.5 Changes in the Levels of Protein

##### 4.2.2.5.1 Changes in the Levels of Protein

The protein levels in **liver**, **kidney**, **lung** and **heart** were decreased significantly ( $p < 0.001$ ) in group 2 (100LA) when compared to group 1 (Control). The protein levels in **liver** and **lung** were increased significantly in group 4 (E+100LA) ( $p < 0.01$ ), group 6 (C+100LA) ( $p < 0.01$ ) and group 8 (SP+100LA) ( $p < 0.001$ ) as compared to group 2 (100LA). The protein levels in **kidney** and **heart** were increased significantly ( $p < 0.001$ ) in group 4 (E+100LA), group 6 (C+100LA) and group 8 (SP+100LA) as compared to group 2 (100LA) (Table-4.25).

The protein levels in **liver**, **kidney**, **lung** and **heart** were decreased significantly ( $p < 0.001$ ) in group 2 (100CD) as compared to group 1 (Control). The protein levels in **liver** were increased significantly in group 4 (E+100CD) ( $p < 0.001$ ), group 6 (C+100CD) ( $p < 0.05$ ) and group 8 (SP+100CD) ( $p < 0.01$ ) as compared to group 2 (100CD). The protein levels in **kidney** were increased significantly in group 4 (E+100CD) ( $p < 0.001$ ), group 6 (C+100CD) ( $p < 0.01$ ) and group 8 (SP+100CD) ( $p < 0.01$ ) as compared to group 2 (100CD). The protein levels in **lung** were increased significantly in group 4 (E+100CD) ( $p < 0.01$ ), group 6 (C+100CD) ( $p < 0.01$ ) and group 8 (SP+100CD) ( $p < 0.001$ ) as compared to group 2 (100CD). The protein levels in **heart** were increased significantly ( $p < 0.01$ ) in group 4 (E+100CD), group 6 (C+100CD) and group 8 (SP+100CD) as compared to group 2 (100CD) (Table- 4.26).

**Table- 4.25: Effect of 100 ppm of lead acetate (100LA) exposure (30 days) alone and in combination with antioxidants i.e. vitamin E, C or spirulina (E, C or SP) on the levels of protein in liver, kidney, lung, heart and brain of rats. (mg / gm)**

GROUP	ORGANS				
	Liver	Kidney	Lung	Heart	Brain
1. Control	187.942 ± 9.088	135.934 ± 2.029	159.339 ± 1.372	71.139 ± 2.072	108.962 ± 6.889
2. 100LA	130.176 ± 8.505 <sup>***b</sup>	67.433 ± 2.405 <sup>***b</sup>	129.635 ± 1.918 <sup>***b</sup>	36.681 ± 2.563 <sup>***b</sup>	97.051 ± 5.851
3. E	188.446 ± 5.052	139.101 ± 11.092	163.818 ± 3.791	74.144 ± 1.974	112.462 ± 7.390
4. E+100LA	158.500 ± 2.068 <sup>**a</sup>	104.842 ± 4.124 <sup>***a</sup>	142.565 ± 2.129 <sup>**a</sup>	60.651 ± 1.961 <sup>***a</sup>	101.037 ± 8.889
5. C	188.742 ± 5.599	137.475 ± 5.547	161.985 ± 5.216	72.162 ± 2.053	110.463 ± 6.762
6. C+100LA	158.290 ± 1.626 <sup>**a</sup>	87.840 ± 1.154 <sup>***a</sup>	143.712 ± 3.767 <sup>**a</sup>	57.405 ± 1.030 <sup>***a</sup>	100.240 ± 9.274
7. SP	196.869 ± 1.367	147.387 ± 3.253	167.531 ± 4.265	77.143 ± 1.084	112.898 ± 7.401
8. SP+100LA	180.096 ± 2.432 <sup>***a</sup>	120.714 ± 3.354 <sup>***a</sup>	155.371 ± 5.231 <sup>***a</sup>	65.546 ± 1.630 <sup>***a</sup>	101.095 ± 5.852
F ratio	16.596, p<0.001	39.104, p<0.001	15.031, p<0.001	35.386, p<0.001	6.184

Values are expressed as mean ± SEM for six animals in each group.

a : Group 4, 6 and 8 as compared to group 2.

b : Group 2, 3, 5 and 7 as compared to group 1.

\*p<0.05, \*\*p<0.01, \*\*\*p<0.001.

**Table- 4.26: Effect of 100 ppm of cadmium chloride (100CD) exposure alone and in combination with antioxidants i.e. vitamin E, C or spirulina (E, C or SP) on the levels of protein in liver, kidney, lung, heart and brain of rats. (mg / gm)**

GROUP	ORGANS				
	Liver	Kidney	Lung	Heart	Brain
1. Control	187.942 ± 9.088	135.934 ± 2.029	159.339 ± 1.372	71.139 ± 2.072	108.962 ± 6.889
2. 100CD	126.869 ± 9.015 <sup>***b</sup>	86.102 ± 6.121 <sup>***b</sup>	134.654 ± 2.015 <sup>***b</sup>	49.535 ± 2.447 <sup>***b</sup>	96.772 ± 4.866
3. E	188.446 ± 5.052	139.101 ± 11.092	163.818 ± 3.791	74.144 ± 1.974	112.462 ± 7.390
4. E+100CD	173.075 ± 2.356 <sup>***a</sup>	131.747 ± 6.732 <sup>**a</sup>	142.565 ± 2.129 <sup>***a</sup>	64.741 ± 2.545 <sup>**a</sup>	102.182 ± 7.813
5. C	188.742 ± 5.599	137.475 ± 5.547	161.985 ± 5.216	72.162 ± 2.053	110.463 ± 6.762
6. C+100CD	162.087 ± 3.500 <sup>*a</sup>	118.204 ± 5.559 <sup>**a</sup>	143.712 ± 3.767 <sup>***a</sup>	62.268 ± 3.049 <sup>**a</sup>	98.586 ± 8.219
7. SP	196.869 ± 1.367	147.387 ± 3.253	167.531 ± 4.265	77.143 ± 1.084	112.898 ± 7.401
8. SP+100CD	166.903 ± 3.541 <sup>**a</sup>	116.892 ± 6.490 <sup>**a</sup>	155.371 ± 5.231 <sup>***a</sup>	62.214 ± 2.794 <sup>**a</sup>	101.775 ± 5.7212
F ratio	19.547, p<0.001	15.210 p<0.001	15.031, p<0.001	16.514, p<0.001	6.234

Values are expressed as mean ± SEM for six animals in each group.

a : Group 4, 6 and 8 as compared to group 2.

b : Group 2, 3, 5 and 7 as compared to group 1.

\* p<0.05, \*\* p<0.01, \*\*\* p<0.001.

#### 4.2.2.6 Changes in the Levels of Tissue Lipids

##### 4.2.2.6.1 Changes in the Levels of Cholesterol

The cholesterol levels in **liver**, **kidney**, **lung** and **heart** were increased significantly ( $p < 0.001$ ) in group 2 (100LA) when compared to group 1 (Control). The cholesterol levels in **liver**, **kidney**, **lung** and **heart** were decreased significantly ( $p < 0.001$ ) in group 4 (E+100LA), group 6 (C+100LA) and group 8 (SP+100LA) as compared to group 2 (100LA) (Table- 4.27).

The cholesterol levels were increased significantly in **liver** ( $p < 0.001$ ), **kidney** ( $p < 0.001$ ), **lung** ( $p < 0.01$ ) and **heart** ( $p < 0.001$ ) in group 2 (100CD) as compared to group 1 (Control). The cholesterol levels in **liver**, **kidney** and **heart** were decreased significantly ( $p < 0.05$ ) in group 4 (E+100CD) and there was no significant change in group 6 (C+100CD) and group 8 (SP+100CD) as compared to group 2 (100CD). The cholesterol levels in **lung** were decreased significantly ( $p < 0.05$ ) in group 4 (E+100CD), group 8 (SP+100CD) and there was no significant change in group 6 (C+100CD) as compared to group 2 (100CD) (Table- 4.28).

##### 4.2.2.6.2 Changes in the Levels of Triglyceride

The triglyceride levels in **liver**, **kidney**, **lung** and **heart** were increased significantly ( $p < 0.001$ ) in group 2 (100LA) when compared to group 1 (Control). The triglyceride levels in **liver**, **kidney**, **lung** and **heart** were decreased significantly in group 4 (E+100LA) ( $p < 0.001$ ), group 6 (C+100LA) ( $p < 0.05$ ) and group 8 (SP+100LA) ( $p < 0.001$ ) as compared to group 2 (100LA) (Table- 4.29).

The triglyceride levels were increased significantly in **liver** ( $p < 0.01$ ), **kidney** ( $p < 0.001$ ), **lung** ( $p < 0.001$ ) and **heart** ( $p < 0.01$ ) in group 2 (100CD) as compared to group 1 (Control). The triglyceride levels in **liver** and **heart** were decreased significantly ( $p < 0.05$ ) in group 4 (E+100CD), group 8 (SP+100CD) and there was no significant change in group 6 (C+100CD) as compared to group 2 (100CD). However, the triglyceride levels in **kidney** and **lung** were decreased significantly ( $p < 0.05$ ) in group 4 (E+100CD) and there was no significant change in group 6 (C+100CD), group 8 (SP+100CD) as compared to group 2 (100CD) (Table- 4.30).

**Table- 4.27: Effect of 100 ppm of lead acetate (100LA) exposure (30 days) alone and in combination with antioxidants i.e. vitamin E, C or spirulina (E, C or SP) on the levels of cholesterol in liver, kidney lung and heart of rats. (mg / gm)**

GROUP	ORGANS			
	Liver	Kidney	Lung	Heart
1. Control	6.373 ± 0.085	5.545 ± 0.031	4.444 ± 0.013	2.959 ± 0.108
2. 100LA	12.095 ± 0.179 <sup>***b</sup>	9.751 ± 0.150 <sup>***b</sup>	9.693 ± 0.166 <sup>***b</sup>	6.809 ± 0.213 <sup>***b</sup>
3. E	6.026 ± 0.116	5.191 ± 0.092	4.168 ± 0.079	2.807 ± 0.084
4. E+100LA	7.987 ± 0.340 <sup>***a</sup>	6.805 ± 0.280 <sup>***a</sup>	6.803 ± 0.281 <sup>***a</sup>	3.717 ± 0.212 <sup>***a</sup>
5. C	6.364 ± 0.103	5.533 ± 0.046	4.398 ± 0.034	2.776 ± 0.136
6. C+100LA	8.846 ± 0.393 <sup>***a</sup>	6.526 ± 0.107 <sup>***a</sup>	6.576 ± 0.105 <sup>***a</sup>	4.739 ± 0.098 <sup>***a</sup>
7. SP	6.179 ± 0.013	5.252 ± 0.100	3.866 ± 0.177	2.770 ± 0.030
8. SP+100LA	7.131 ± 0.068 <sup>***a</sup>	6.275 ± 0.038 <sup>***a</sup>	5.307 ± 0.060 <sup>***a</sup>	3.370 ± 0.112 <sup>***a</sup>
F ratio	11.175, p<0.001	13.551, p<0.001	20.844, p<0.001	11.109, p<0.001

Values are expressed as mean ± SEM for six animals in each group.

a : Group 4, 6 and 8 as compared to group 2.

b : Group 2, 3, 5 and 7 as compared to group 1.

\*\*\* p<0.001, \*\* p<0.01, \* p<0.05.

**Table- 4.28: Effect of 100 ppm of cadmium chloride (100CD) exposure alone and in combination with antioxidants i.e. vitamin E, C or spirulina (E, C or SP) on the levels of cholesterol in liver, kidney lung and heart of rats. (mg / gm)**

GROUP	ORGANS			
	Liver	Kidney	Lung	Heart
1. Control	6.373 ± 0.085	5.545 ± 0.031	4.444 ± 0.013	2.959 ± 0.108
2. 100CD	11.124 ± 0.398 <sup>***b</sup>	9.968 ± 0.289 <sup>***b</sup>	7.734 ± 0.545 <sup>***b</sup>	6.208 ± 0.185 <sup>***b</sup>
3. E	6.026 ± 0.116	5.191 ± 0.092	4.168 ± 0.079	2.807 ± 0.084
4. E+100CD	9.331 ± 0.649 <sup>*a</sup>	7.733 ± 0.857 <sup>*a</sup>	6.083 ± 0.329 <sup>*a</sup>	5.015 ± 0.479 <sup>*a</sup>
5. C	6.364 ± 0.103	5.533 ± 0.046	4.398 ± 0.034	2.776 ± 0.136
6. C+100CD	10.637 ± 0.668	9.082 ± 0.905	7.283 ± 0.377	6.104 ± 0.568
7. SP	6.179 ± 0.013	5.252 ± 0.100	3.866 ± 0.177	2.770 ± 0.030
8. SP+100CD	11.047 ± 1.366	9.302 ± 1.057	6.273 ± 0.322 <sup>*a</sup>	5.936 ± 0.593
F ratio	18.979, p<0.001	16.833, p<0.001	23.553, p<0.001	24.900, p<0.001

Values are expressed as mean ± SEM for six animals in each group.

a : Group 4, 6 and 8 as compared to group 2.

b : Group 2, 3, 5 and 7 as compared to group 1.

\*p<0.05, \*\* p<0.01, \*\*\* p<0.001.

**Table- 4.29: Effect of 100 ppm of lead acetate (100LA) exposure (30 days) alone and in combination with antioxidants i.e. vitamin E, C or spirulina (E, C or SP) on the levels of triglyceride in liver, kidney lung and heart of rats. (mg / gm)**

GROUP	ORGANS			
	Liver	Kidney	Lung	Heart
1. Control	9.232 ± 0.097	7.185 ± 0.114	3.482 ± 0.152	2.963 ± 0.078
2. 100LA	16.689 ± 0.191 <sup>***b</sup>	11.386 ± 0.100 <sup>***b</sup>	9.678 ± 0.109 <sup>***b</sup>	6.622 ± 0.091 <sup>***b</sup>
3. E	9.267 ± 0.125	7.256 ± 0.121	3.626 ± 0.128	2.958 ± 0.296
4. E+100LA	11.937 ± 0.141 <sup>***a</sup>	9.169 ± 0.105 <sup>***a</sup>	5.739 ± 0.084 <sup>***a</sup>	4.902 ± 0.149 <sup>***a</sup>
5. C	9.264 ± 0.328	7.208 ± 0.258	3.497 ± 0.120	2.980 ± 0.258
6. C+100LA	15.762 ± 0.317 <sup>*a</sup>	9.975 ± 0.439 <sup>*a</sup>	8.447 ± 0.527 <sup>*a</sup>	5.623 ± 0.354 <sup>*a</sup>
7. SP	9.253 ± 0.166	7.193 ± 0.102	3.502 ± 0.125	2.967 ± 0.283
8. SP+100LA	11.672 ± 0.191 <sup>***a</sup>	8.093 ± 0.217 <sup>***a</sup>	4.218 ± 0.145 <sup>***a</sup>	3.499 ± 0.299 <sup>***a</sup>
F ratio	7.691, p<0.001	2.194, p<0.01	4.801, p<0.001	4.378, p<0.001

Values are expressed as mean ± SEM for six animals in each group.

a : Group 4, 6 and 8 as compared to group 2.

b : Group 2, 3, 5 and 7 as compared to group 1.

\*p<0.05, \*\*p<0.01, \*\*\*p<0.001.

**Table- 4.30: Effect of 100 ppm of cadmium chloride (100CD) exposure alone and in combination with antioxidants i.e. vitamin E, C or spirulina (E, C or SP) on the levels of triglyceride in liver, kidney lung and heart of rats. (mg / gm)**

GROUP	ORGANS			
	Liver	Kidney	Lung	Heart
1. Control	9.232 ± 0.097	7.185 ± 0.114	3.482 ± 0.152	2.963 ± 0.078
2. 100CD	13.899 ± 1.286 <sup>**b</sup>	12.173 ± 0.872 <sup>***b</sup>	5.713 ± 0.292 <sup>***b</sup>	5.380 ± 0.634 <sup>**b</sup>
3. E	9.267 ± 0.125	7.256 ± 0.121	3.626 ± 0.128	2.958 ± 0.296
4. E+100CD	10.791 ± 0.497 <sup>*a</sup>	9.661 ± 0.541 <sup>*a</sup>	4.452 ± 0.471 <sup>*a</sup>	3.524 ± 0.334 <sup>*a</sup>
5. C	9.264 ± 0.328	7.208 ± 0.258	3.497 ± 0.120	2.980 ± 0.258
6. C+100CD	12.787 ± 1.247	11.337 ± 0.936	5.528 ± 0.617	3.969 ± 0.403
7. SP	9.253 ± 0.166	7.193 ± 0.102	3.502 ± 0.125	2.967 ± 0.283
8. SP+100CD	10.630 ± 0.483 <sup>*a</sup>	10.827 ± 1.419	4.720 ± 0.425	3.120 ± 0.486 <sup>*a</sup>
F ratio	11.101, p<0.001	13.604, p<0.01	10.778, p<0.001	9.665, p<0.001

Values are expressed as mean ± SEM for six animals in each group.

a : Group 4, 6 and 8 as compared to group 2.

b : Group 2, 3, 5 and 7 as compared to group 1.

\*p<0.05, \*\* p<0.01, \*\*\* p<0.001.

#### 4.2.2.6.3 Changes in the Levels of Phospholipid

The phospholipid levels in **liver, kidney, lung and heart** were increased significantly ( $p < 0.001$ ) in group 2 (100LA) when compared to group 1 (Control). The phospholipid levels in **liver, kidney, lung and heart** were decreased significantly ( $p < 0.001$ ) in group 4 (E+100LA), group 6 (C+100LA) and group 8 (SP+100LA) as compared to group 2 (100LA) (Table- 4.31).

The phospholipid levels were increased significantly in **liver** ( $p < 0.001$ ), **kidney** ( $p < 0.001$ ), **lung** ( $p < 0.01$ ) and **heart** ( $p < 0.05$ ) in group 2 (100CD) as compared to group 1 (Control). The phospholipid levels in **liver and lung** were decreased significantly ( $p < 0.05$ ) in group 4 (E+100CD), group 8 (SP+100CD) and there was no significant change in group 6 (C+100CD) as compared to group 2 (100CD). Similarly, the phospholipid levels in **kidney** were decreased significantly in group 4 (E+100CD) ( $p < 0.05$ ), group 8 (SP+100CD) ( $p < 0.01$ ) and there was no significant change in group 6 (C+100CD) as compared to group 2 (100CD). However, there was no significant change in phospholipid levels in **heart** in group 4 (E+100CD), group 6 (C+100CD) and group 8 (SP+100CD) when compared (Table- 4.32).

#### 4.2.3 SERUM ESTIMATIONS

##### 4.2.3.1 Changes in the levels of Serum Glutamate Pyruvate Transaminases (GPT) and Glutamate Oxaloacetate Transaminases (GOT)

The GPT levels in **serum** were increased significantly ( $p < 0.001$ ) in group 2 (100LA) as compared to group 1 (Control). The GPT levels in **serum** were decreased significantly in group 4 (E+100LA) ( $p < 0.01$ ), group 6 (C+100LA) ( $p < 0.05$ ) and group 8 (SP+100LA) ( $p < 0.01$ ) as compared to group 2 (100LA). The GOT levels in **serum** were increased significantly ( $p < 0.01$ ) in group 2 (100LA) as compared to group 1 (Control). The GOT levels in **serum** were decreased significantly ( $p < 0.05$ ) in group 4 (E+100LA), group 6 (C+100LA) and group 8 (SP+100LA) as compared to group 2 (100LA) (Table- 4.33).

**Table- 4.31: Effect of 100 ppm of lead acetate (100LA) exposure (30 days) alone and in combination with antioxidants i.e. vitamin E, C or spirulina (E, C or SP) on the levels of phospholipid in liver, kidney lung and heart of rats. (mg / gm)**

GROUP	ORGANS			
	Liver	Kidney	Lung	Heart
1. Control	9.141 ± 0.136	3.397 ± 0.079	3.516 ± 0.047	2.515 ± 0.047
2. 100LA	20.453 ± 0.197 <sup>***b</sup>	11.750 ± 0.356 <sup>***b</sup>	9.488 ± 0.060 <sup>***b</sup>	8.488 ± 0.060 <sup>***b</sup>
3. E	9.154 ± 0.245	3.406 ± 0.074	3.563 ± 0.084	2.546 ± 0.093
4. E+100LA	10.471 ± 0.132 <sup>***a</sup>	6.506 ± 0.135 <sup>***a</sup>	4.805 ± 0.298 <sup>***a</sup>	4.134 ± 0.120 <sup>***a</sup>
5. C	9.173 ± 0.221	3.409 ± 0.065	3.564 ± 0.188	2.547 ± 0.153
6. C+100LA	10.527 ± 0.062 <sup>***a</sup>	7.724 ± 0.130 <sup>***a</sup>	6.429 ± 0.332 <sup>***a</sup>	5.996 ± 0.051 <sup>***a</sup>
7. SP	9.146 ± 0.087	3.378 ± 0.079	3.479 ± 0.084	2.327 ± 0.120
8. SP+100LA	10.112 ± 0.069 <sup>***a</sup>	5.996 ± 0.051 <sup>***a</sup>	4.361 ± 0.189 <sup>***a</sup>	3.261 ± 0.267 <sup>***a</sup>
F ratio	11.029, p<0.001	6.537, p<0.001	3.382, p<0.001	3.625, p<0.001

Values are expressed as mean ± SEM for six animals in each group.

a : Group 4, 6 and 8 as compared to group 2.

b : Group 2, 3, 5 and 7 as compared to group 1.

\* p<0.05, \*\* p<0.01, \*\*\* p<0.001.

**Table- 4.32: Effect of 100 ppm of cadmium chloride (100CD) exposure alone and in combination with antioxidants i.e. vitamin E, C or spirulina (E, C or SP) on the levels of phospholipid in liver, kidney lung and heart of rats. (mg / gm)**

GROUP	ORGANS			
	Liver	Kidney	Lung	Heart
1. Control	9.141 ± 0.136	3.397 ± 0.079	3.516 ± 0.047	2.515 ± 0.047
2. 100CD	18.903 ± 1.014 <sup>***b</sup>	9.897 ± 0.908 <sup>***b</sup>	5.316 ± 0.417 <sup>***b</sup>	4.121 ± 0.716 <sup>ab</sup>
3. E	9.154 ± 0.245	3.406 ± 0.074	3.563 ± 0.084	2.546 ± 0.093
4. E+100CD	14.377 ± 1.525 <sup>a</sup>	7.144 ± 0.372 <sup>a</sup>	3.936 ± 0.373 <sup>a</sup>	3.543 ± 0.340
5. C	9.173 ± 0.221	3.409 ± 0.065	3.564 ± 0.188	2.547 ± 0.153
6. C+100CD	15.158 ± 1.673	8.265 ± 0.434	5.097 ± 0.253	3.584 ± 0.340
7. SP	9.146 ± 0.087	3.378 ± 0.079	3.479 ± 0.084	2.327 ± 0.120
8. SP+100CD	14.592 ± 1.101 <sup>a</sup>	7.006 ± 0.692 <sup>**a</sup>	4.065 ± 0.196 <sup>a</sup>	3.718 ± 0.339
F ratio	21.009, p<0.001	32.664, p<0.001	12.784, p<0.001	9.527, p<0.001

Values are expressed as mean ± SEM for six animals in each group.

a : Group 4, 6 and 8 as compared to group 2.

b : Group 2, 3, 5 and 7 as compared to group 1.

\* p<0.05, \*\* p<0.01, \*\*\* p<0.001.

The GPT levels in **serum** were increased significantly ( $p<0.01$ ) in group 2 (100CD) as compared to group 1 (Control). The GPT levels in **serum** were decreased significantly ( $p<0.05$ ) in group 4 (E+100CD), group 8 (SP+100CD) and there was no significant change in group 6 (C+100CD) as compared to group 2 (100CD). The GOT levels in **serum** were increased significantly ( $p<0.05$ ) in group 2 (100CD) as compared to group 1 (Control). The GOT levels in **serum** were decreased significantly ( $p<0.05$ ) in group 4 (E+100CD), group 8 (SP+100CD) and there was no significant change in group 6 (C+100CD) as compared to group 2 (100CD) (Table- 4.34).

#### **4.2.3.2 Changes in the Levels of Serum Alkaline phosphatase (Alkp) and Acid phosphatase (Acidp)**

The Alkp levels in **serum** were increased significantly ( $p<0.001$ ) in group 2 (100LA) as compared to group 1 (Control). The Alkp levels in **serum** were decreased significantly in group 4 (E+100LA) ( $p<0.01$ ), group 6 (C+100LA) ( $p<0.05$ ) and group 8 (SP+100LA) ( $p<0.01$ ) as compared to group 2 (100LA). The Acidp levels in **serum** were increased significantly ( $p<0.001$ ) in group 2 (100LA) as compared to group 1 (Control). The Acidp levels in **serum** were decreased significantly in group 4 (E+100LA) ( $p<0.01$ ), group 6 (C+100LA) ( $p<0.001$ ) and group 8 (SP+100LA) ( $p<0.01$ ) as compared to group 2 (100LA) (Table-4.35).

The Alkp levels in **serum** were increased significantly ( $p<0.001$ ) in group 2 (100CD) as compared to group 1 (Control). The Alkp levels in **serum** were decreased significantly in group 4 (E+100CD) ( $p<0.05$ ), group 6 (C+100CD) ( $p<0.05$ ) and group 8 (SP+100CD) ( $p<0.01$ ) as compared to group 2 (100CD). The Acidp levels in **serum** were increased significantly ( $p<0.001$ ) in group 2 (100CD) as compared to group 1 (Control). The Acidp levels in **serum** were decreased significantly in group 4 (E+100CD) ( $p<0.01$ ), group 6 (C+100CD) ( $p<0.05$ ) and group 8 (SP+100CD) ( $p<0.01$ ) as compared to group 2 (100CD) (Table- 4.36).

**Table- 4.33: Effect of 100 ppm of lead acetate (100LA) exposure (30 days) alone and in combination with antioxidants i.e. vitamin E, C or spirulina (E, C or SP) on the levels of serum glutamate pyruvate and glutamate oxaloacetate transaminases of rats. (Units / Litre)**

GROUP	SERUM ENZYME	
	GPT	GOT
1. Control	14.416 ± 1.120	17.617 ± 1.156
2. 100LA	23.965 ± 0.929 <sup>***b</sup>	25.626 ± 1.668 <sup>**b</sup>
3. E	14.839 ± 0.872	17.943 ± 1.004
4. E+100LA	19.585 ± 1.293 <sup>**a</sup>	21.029 ± 1.162 <sup>a</sup>
5. C	14.019 ± 0.812	17.039 ± 1.055
6. C+100LA	18.851 ± 0.889 <sup>a</sup>	20.566 ± 0.984 <sup>a</sup>
7. SP	14.662 ± 1.098	17.562 ± 1.092
8. SP+100LA	18.509 ± 1.474 <sup>**a</sup>	20.696 ± 1.226 <sup>a</sup>
F ratio	13.642, p<0.001	10.853, p<0.001

Values are expressed as mean ± SEM for six animals in each group.  
a : Group 4, 6 and 8 as compared to group 2.  
b : Group 2, 3, 5 and 7 as compared to group 1.  
\* p<0.05, \*\* p<0.01, \*\*\* p<0.001.

**Table- 4.34: Effect of 100 ppm of cadmium chloride (100CD) exposure alone and in combination with antioxidants i.e. vitamin E, C or spirulina (E, C or SP) on the levels of serum glutamate pyruvate and glutamate oxaloacetate transaminases of rats. (Units / Litre)**

GROUP	SERUM ENZYME	
	GPT	GOT
1. Control	14.416 ± 1.120	17.617 ± 1.156
2. 100CD	21.311 ± 1.692 <sup>**b</sup>	23.0160 ± 1.868 <sup>*b</sup>
3. E	14.839 ± 0.872	17.943 ± 1.004
4. E+100CD	16.542 ± 0.885 <sup>a</sup>	18.096 ± 1.092 <sup>a</sup>
5. C	14.019 ± 0.812	17.039 ± 1.055
6. C+100CD	20.846 ± 1.951	19.640 ± 1.400
7. SP	14.662 ± 1.098	17.562 ± 1.092
8. SP+100CD	16.550 ± 0.746 <sup>a</sup>	18.610 ± 0.567 <sup>a</sup>
F ratio	10.278, p<0.001	7.830, p<0.001

Values are expressed as mean ± SEM for six animals in each group.  
a : Group 4, 6 and 8 as compared to group 2.  
b : Group 2, 3, 5 and 7 as compared to group 1.  
\* p<0.05, \*\* p<0.01, \*\*\* p<0.001.

**Table- 4.35: Effect of 100 ppm of lead acetate (100LA) exposure (30 days) alone and in combination with antioxidants i.e. vitamin E, C or spirulina (E, C or SP) on the levels of alkaline and acid phosphatase in serum of rats. (KA Units / Litre)**

GROUP	SERUM ENZYME	
	Alkp	Acidp
1. Control	10.599 ± 1.226	3.762 ± 0.541
2. 100LA	19.541 ± 1.327 <sup>***b</sup>	10.291 ± 0.654 <sup>***b</sup>
3. E	10.894 ± 0.950	3.897 ± 0.557
4. E+100LA	15.173 ± 1.392 <sup>**a</sup>	5.830 ± 0.727 <sup>**a</sup>
5. C	10.848 ± 1.136	3.624 ± 0.302
6. C+100LA	14.235 ± 1.032 <sup>*a</sup>	5.609 ± 0.717 <sup>***a</sup>
7. SP	10.827 ± 0.573	5.319 ± 0.430
8. SP+100LA	14.199 ± 0.763 <sup>**a</sup>	5.493 ± 0.755 <sup>**a</sup>
F ratio	12.738, p<0.001	15.142, p<0.001

Values are expressed as mean ± SEM for six animals in each group.

a : Group 4, 6 and 8 as compared to group 2.

b : Group 2, 3, 5 and 7 as compared to group 1.

\* p<0.05, \*\* p<0.01, \*\*\* p<0.001.

**Table- 4.36: Effect of 100 ppm of cadmium chloride (100CD) exposure alone and in combination with antioxidants i.e. vitamin E, C or spirulina (E, C or SP) on the levels of alkaline and acid phosphatase in serum of rats. (KA Units / Litre)**

GROUP	SERUM ENZYME	
	Alkp	Acidp
1. Control	10.599 ± 1.226	3.762 ± 0.541
2. 100CD	18.640 ± 1.247 <sup>***b</sup>	9.260 ± 0.489 <sup>***b</sup>
3. E	10.894 ± 0.950	3.897 ± 0.557
4. E+100CD	14.729 ± 1.207 <sup>*a</sup>	6.123 ± 0.621 <sup>**a</sup>
5. C	10.848 ± 1.136	3.624 ± 0.302
6. C+100CD	14.498 ± 1.074 <sup>*a</sup>	7.106 ± 0.673 <sup>*a</sup>
7. SP	10.827 ± 0.573	5.319 ± 0.430
8. SP+100CD	13.366 ± 0.753 <sup>**a</sup>	5.900 ± 0.688 <sup>**a</sup>
F ratio	11.379, p<0.001	14.628, p<0.001

Values are expressed as mean ± SEM for six animals in each group.

a : Group 4, 6 and 8 as compared to group 2.

b : Group 2, 3, 5 and 7 as compared to group 1.

\* p<0.05, \*\* p<0.01, \*\*\* p<0.001.

#### 4.2.3.3 Changes in the Levels of Lactate dehydrogenase (LDH)

The LDH levels in **serum** were increased significantly ( $p < 0.05$ ) in group 2 (100LA) as compared to group 1 (Control). The LDH levels in **serum** were decreased significantly in group 4 (E+100LA) ( $p < 0.05$ ), group 6 (C+100LA) ( $p < 0.01$ ) and group 8 (SP+100LA) ( $p < 0.05$ ) as compared to group 2 (100LA) (Table- 4.37).

The LDH levels in **serum** were increased significantly ( $p < 0.05$ ) in group 2 (100CD) as compared to group 1 (Control). The LDH levels in **serum** were decreased significantly in group 4 (E+100CD) ( $p < 0.01$ ), group 6 (C+100CD) ( $p < 0.05$ ) and group 8 (SP+100CD) ( $p < 0.05$ ) as compared to group 2 (100CD) (Table- 4.38).

#### 4.2.3.4 Changes in the Levels of Serum Total Bilirubin (TBil) and Total Protein (protein)

The TBil levels in **serum** were increased significantly ( $p < 0.001$ ) in group 2 (100LA) as compared to group 1 (Control). The TBil levels in **serum** were decreased significantly ( $p < 0.05$ ) in group 4 (E+100LA), group 6 (C+100LA) and group 8 (SP+100LA) as compared to group 2 (100LA). The protein levels in **serum** were decreased significantly ( $p < 0.01$ ) in group 2 (100LA) as compared to group 1 (Control). The protein levels in **serum** were increased significantly ( $p < 0.05$ ) in group 4 (E+100LA), group 6 (C+100LA) and group 8 (SP+100LA) as compared to group 2 (100LA) (Table- 4.39).

The TBil levels in **serum** were increased significantly ( $p < 0.001$ ) in group 2 (100CD) as compared to group 1 (Control). The TBil levels in **serum** were decreased significantly in group 4 (E+100CD) ( $p < 0.01$ ), group 6 (C+100CD) ( $p < 0.05$ ) and group 8 (SP+100CD) ( $p < 0.01$ ) as compared to group 2 (100CD). The protein levels in **serum** were decreased significantly ( $p < 0.01$ ) in group 2 (100CD) as compared to group 1 (Control). The protein levels in **serum** were increased significantly in group 4 (E+100CD) ( $p < 0.05$ ), group 8 (SP+100CD) ( $p < 0.01$ ) and there was no significant change in group 6 (C+100CD) as compared to group 2 (100CD) (Table- 4.40).

**Table- 4.37: Effect of 100 ppm of lead acetate (100LA) exposure (30 days) alone and in combination with antioxidants i.e. vitamin E, C or spirulina (E, C or SP) on the levels of lactate dehydrogenase in serum of rats. (Units / Decilitre)**

GROUP	LDH
1. Control	203.587 ± 9.183
2. 100LA	235.475 ± 6.825 <sup>*b</sup>
3. E	202.879 ± 8.022
4. E+100LA	213.628 ± 2.843 <sup>*a</sup>
5. C	204.604 ± 5.739
6. C+100LA	199.300 ± 8.430 <sup>***a</sup>
7. SP	204.254 ± 9.819
8. SP+100LA	215.798 ± 3.927 <sup>*a</sup>
F ratio	7.675, p<0.001

Values are expressed as mean ± SEM for six animals in each group.

a : Group 4, 6 and 8 as compared to group 2.

b : Group 2, 3, 5 and 7 as compared to group 1.

\* p<0.05, \*\* p<0.01, \*\*\* p<0.001.

**Table- 4.38: Effect of 100 ppm of cadmium chloride (100CD) exposure alone and in combination with antioxidants i.e. vitamin E, C or spirulina (E, C or SP) on the levels of lactate dehydrogenase in serum of rats. (Units / Decilitre)**

GROUP	LDH
1. Control	203.587 ± 9.183
2. 100CD	232.077 ± 4.614 <sup>*b</sup>
3. E	202.879 ± 8.022
4. E+100CD	208.220 ± 3.263 <sup>***a</sup>
5. C	204.604 ± 5.739
6. C+100CD	216.990 ± 4.159 <sup>*a</sup>
7. SP	204.254 ± 9.819
8. SP+100CD	216.980 ± 2.116 <sup>*a</sup>
F ratio	9.153, p<0.001

Values are expressed as mean ± SEM for six animals in each group.

a : Group 4, 6 and 8 as compared to group 2.

b : Group 2, 3, 5 and 7 as compared to group 1.

\* p<0.05, \*\* p<0.01, \*\*\* p<0.001.

#### 4.2.3.5 Changes in the Levels of Serum Lipid

The cholesterol levels in **serum** were decreased significantly ( $p < 0.01$ ) in group 2 (100LA) as compared to group 1 (Control). The cholesterol levels in **serum** were increased significantly ( $p < 0.05$ ) in group 4 (E+100LA), group 6 (C+100LA) and group 8 (SP+100LA) as compared to group 2 (100LA). The triglyceride levels in **serum** were increased significantly ( $p < 0.001$ ) in group 2 (100LA) as compared to group 1 (Control). The triglyceride levels in **serum** were decreased significantly ( $p < 0.05$ ) in group 4 (E+100LA), group 6 (C+100LA) and group 8 (SP+100LA) as compared to group 2 (100LA). The phospholipid levels in **serum** were increased significantly ( $p < 0.001$ ) in group 2 (100LA) as compared to group 1 (Control). The phospholipid levels in **serum** were decreased significantly ( $p < 0.05$ ) in group 4 (E+100LA), group 6 (C+100LA) and group 8 (SP+100LA) as compared to group 2 (100LA) (Table- 4.41).

The cholesterol levels in **serum** were decreased significantly ( $p < 0.001$ ) in group 2 (100CD) as compared to group 1 (Control). The cholesterol levels in **serum** were increased significantly in group 4 (E+100CD) ( $p < 0.05$ ), group 6 (C+100CD) ( $p < 0.01$ ) and group 8 (SP+100CD) ( $p < 0.05$ ) as compared to group 2 (100CD). The triglyceride levels in **serum** were increased significantly ( $p < 0.001$ ) in group 2 (100CD) as compared to group 1 (Control). The triglyceride levels in **serum** were decreased significantly ( $p < 0.05$ ) in group 4 (E+100CD), group 6 (C+100CD) and group 8 (SP+100CD) as compared to group 2 (100CD). The phospholipid levels in **serum** were increased significantly ( $p < 0.01$ ) in group 2 (100CD) as compared to group 1 (Control). The phospholipid levels in **serum** were decreased significantly ( $p < 0.05$ ) in group 4 (E+100CD), group 8 (SP+100CD) and there was no significant change in group 6 (C+100CD) as compared to group 2 (100CD) (Table- 4.42).

**Table- 4.39: Effect of 100 ppm of lead acetate (100LA) exposure (30 days) alone and in combination with antioxidants i.e. vitamin E, C or spirulina (E, C or SP) on the levels of total bilirubin and total protein in serum of rats. (mg / Decilitre)**

GROUP	SERUM CONSTITUENT	
	TBil	Protein
1. Control	0.374 ± 0.043	7.816 ± 0.588
2. 100LA	0.745 ± 0.036 <sup>***b</sup>	5.720 ± 0.295 <sup>***b</sup>
3. E	0.371 ± 0.040	7.949 ± 0.581
4. E+100LA	0.591 ± 0.053 <sup>*a</sup>	6.668 ± 0.282 <sup>*a</sup>
5. C	0.379 ± 0.042	7.959 ± 0.582
6. C+100LA	0.565 ± 0.052 <sup>*a</sup>	6.812 ± 0.281 <sup>*a</sup>
7. SP	0.373 ± 0.031	8.015 ± 0.588
8. SP+100LA	0.597 ± 0.042 <sup>*a</sup>	6.600 ± 0.252 <sup>*a</sup>
F ratio	13.725, p<0.001	9.045, p<0.001

Values are expressed as mean ± SEM for six animals in each group.

a : Group 4, 6 and 8 as compared to group 2.

b : Group 2, 3, 5 and 7 as compared to group 1.

\*p<0.05, \*\*p<0.01, \*\*\*p<0.001.

**Table- 4.40: Effect of 100 ppm of cadmium chloride (100CD) exposure alone and in combination with antioxidants i.e. vitamin E, C or spirulina (E, C or SP) on the levels of total bilirubin and total protein in serum of rats. (mg / Decilitre)**

GROUP	SERUM CONSTITUENT	
	TBil	Protein
1. Control	0.374 ± 0.043	7.816 ± 0.588
2. 100CD	0.790 ± 0.037 <sup>***b</sup>	5.524 ± 0.397 <sup>***b</sup>
3. E	0.371 ± 0.040	7.949 ± 0.581
4. E+100CD	0.574 ± 0.054 <sup>**a</sup>	6.706 ± 0.291 <sup>*a</sup>
5. C	0.379 ± 0.042	7.959 ± 0.582
6. C+100CD	0.647 ± 0.053 <sup>*a</sup>	6.222 ± 0.207
7. SP	0.373 ± 0.031	8.015 ± 0.588
8. SP+100CD	0.598 ± 0.040 <sup>**a</sup>	7.587 ± 0.517 <sup>**a</sup>
F ratio	15.085, p<0.001	8.767, p<0.001

Values are expressed as mean ± SEM for six animals in each group.

a : Group 4, 6 and 8 as compared to group 2.

b : Group 2, 3, 5 and 7 as compared to group 1.

\*p<0.05, \*\*p<0.01, \*\*\*p<0.001.

**Table- 4.41: Effect of 100 ppm of lead acetate (100LA) exposure (30-days) alone and in combination with antioxidants i.e. vitamin E, C or spirulina (E, C or SP) on the levels of lipids in serum of rats. (mg / Decilitre)**

GROUP	SERUM LIPIDS		
	CHOL	TGLY	PLIPI
1. Control	72.944 ± 1.929	41.976 ± 1.005	102.902 ± 1.270
2. 100LA	59.871 ± 2.286 <sup>**b</sup>	54.970 ± 2.099 <sup>***b</sup>	122.983 ± 2.171 <sup>***b</sup>
3. E	72.556 ± 1.939	42.320 ± 0.985	103.100 ± 1.662
4. E+100LA	68.120 ± 2.340 <sup>*a</sup>	45.963 ± 2.168 <sup>*a</sup>	114.824 ± 2.127 <sup>*a</sup>
5. C	72.723 ± 1.925	42.317 ± 0.920	103.341 ± 1.306
6. C+100LA	69.279 ± 2.854 <sup>*a</sup>	46.969 ± 1.464 <sup>*a</sup>	117.257 ± 1.273 <sup>*a</sup>
7. SP	72.758 ± 2.059	42.803 ± 0.908	103.191 ± 1.318
8. SP+100LA	67.028 ± 1.229 <sup>*a</sup>	46.499 ± 1.933 <sup>*a</sup>	116.150 ± 1.233 <sup>*a</sup>
F ratio	9.478, p<0.001	12.111, p<0.001	27.729, p<0.001

Values are expressed as mean ± SEM for six animals in each group.

a : Group 4, 6 and 8 as compared to group 2.

b : Group 2, 3, 5 and 7 as compared to group 1.

\* p<0.05, \*\* p<0.01, \*\*\* p<0.001.

**Table- 4.42: Effect of 100 ppm of cadmium chloride (100CD) exposure alone and in combination with antioxidants i.e. vitamin E, C or spirulina (E, C or SP) on the levels of lipids in serum of rats. (mg / Decilitre)**

GROUP	SERUM LIPIDS		
	CHOL	TGLY	PLIPI
1. Control	72.944 ± 1.929	41.976 ± 1.005	102.902 ± 1.270
2. 100CD	60.098 ± 1.982 <sup>***b</sup>	53.801 ± 1.764 <sup>***b</sup>	117.775 ± 3.654 <sup>**b</sup>
3. E	72.556 ± 1.939	42.320 ± 0.985	103.100 ± 1.662
4. E+100CD	69.512 ± 2.771 <sup>*a</sup>	45.518 ± 2.158 <sup>*a</sup>	106.956 ± 3.002 <sup>*a</sup>
5. C	72.723 ± 1.925	42.317 ± 0.920	103.341 ± 1.306
6. C+100CD	69.529 ± 1.841 <sup>**a</sup>	48.681 ± 1.449 <sup>*a</sup>	114.699 ± 2.000
7. SP	72.758 ± 2.059	42.803 ± 0.908	103.191 ± 1.318
8. SP+100CD	65.888 ± 1.626 <sup>*a</sup>	45.715 ± 1.892 <sup>*a</sup>	107.647 ± 2.632 <sup>*a</sup>
F ratio	9.145, p<0.001	12.007, p<0.001	10.927, p<0.001

Values are expressed as mean ± SEM for six animals in each group.

a : Group 4, 6 and 8 as compared to group 2.

b : Group 2, 3, 5 and 7 as compared to group 1.

\* p<0.05, \*\* p<0.01, \*\*\* p<0.001.

### 4.3 TOXICOLOGICAL INVESTIGATIONS

#### 4.3.1 Changes in the Levels of Lead and Cadmium in Tissues

After the thirty days of exposure to lead acetate the levels of this metal were significantly ( $p < 0.001$ ) increased in **liver, lung, heart and brain** in group 2 (10LA), group 3 (30LA) and group 4 (100LA) as compare to group 1 (Control). Similarly, the levels of lead in **kidney** were significantly increased in group 2 (10LA) ( $p < 0.01$ ), group 3 (30LA) and group 4 (100LA) ( $p < 0.001$ ) as compare to group 1 (Control) (Fig: 4.43).

After thirty days exposure to cadmium chloride the levels of this metal were significantly ( $p < 0.001$ ) increased in **liver** of group 2 (10CD), group 3 (30CD) and group 4 (100CD) as compare to group 1 (Control). The levels of cadmium in **kidney and lung** were significantly increased in group 2 (10CD) ( $p < 0.05$ ), group 3 (30CD) and group 4 (100CD) ( $p < 0.001$ ) as compare to group 1 (Control). Similarly, the levels of cadmium in **heart** were significantly increased in group 2 (10CD) ( $p < 0.05$ ), group 3 (30CD) ( $p < 0.01$ ) and group 4 (100CD) ( $p < 0.001$ ) as compare to group 1 (Control). Further, the levels of cadmium in **brain** were significantly increased in group 3 (30CD) ( $p < 0.01$ ), in group 4 (100CD) ( $p < 0.001$ ) and there was no significant change in the deposition of cadmium in **brain** of rats in group 2 (10CD) as compare to group 1 (Control) (Fig: 4.44).

The levels of lead in **liver, brain** ( $p < 0.05$ ) and **kidney, lung, heart** ( $p < 0.001$ ) were decreased significantly in animals treated with combination of lead and vitamin C (group 6, C+100LA) as compare animals exposed to lead alone (group 2, 100LA) indicating vitamin C decreasing the deposition of lead in the tissues. But there were no significant changes in levels of lead in **liver, kidney, lung, heart and brain** in group 4 (E+100LA) and in **liver, kidney, lung and heart** in group 8 (SP+100LA) as compare to group 2 (100LA). Interestingly, there was a significant ( $p < 0.05$ ) decrease in levels of lead in **brain** in group 8 (SP+100LA) as compare to group 2 (100LA) (Table- 4.43).

The levels of cadmium in **liver, lung** ( $p < 0.01$ ) and **kidney, heart, brain** ( $p < 0.05$ ) were decreased significantly in group 6 (C+100CD) as compare to group 2 (100CD) indicating vitamin C decreasing the deposition of cadmium in the tissues. But there were no significant change in the levels of cadmium in **liver,**

**kidney, lung, heart and brain** in group 4 (E+100CD) and group 8 (SP+100CD) as compare to group 2 (100CD) (Table- 4.44).

#### 4.3.2 Histopathological Changes

Histopathological examination of **liver, kidney, lung and heart** showed the pathological changes after exposure to lead and cadmium for thirty days. These changes were found to be dose dependent. There were no significant histopathological changes in **liver, kidney, lung and heart** of animals exposed to 10 and 30 ppm of lead acetate and cadmium chloride.

There were prominent histopathological changes in **liver** of animals exposed to 100 ppm of lead acetate and cadmium chloride. The major feature of lead (Fig: 4.45B) and cadmium (Fig: 4.46B) induced histopathological changes includes lesion in **liver** induced by repeated exposure to lead and cadmium. These include early changes like dilation of rough endoplasmic reticulum, increase in perichromatic granules, loss of membrane associated ribosomes and generalized hydropic changes (swelling) with loss of cristae, pyknotic nuclei and clumps of coagulated chromatin. The overall appearance is a fatty **liver**. The nucleus was found to shrunken as compare to control animals. There was a prominent shrinking of nucleolus and nucleus, in addition to the pyknosis of nuclei due to the lead and cadmium exposure. The dilation of cytoplasm gave an appearance of empty cell. There was overall fatty infiltration (vacuoles) in hepatic cells along with the hydropic changes (swelling). It was also noticed that the cytoplasmic material pushed towards the periphery of the cell due to fatty infiltration. In short it can be said that there was a complete disruption of cellular architecture. The hydropic changes and fatty infiltration were the main reason for the weight increase in the organs. There were signs of cellular enlargement, rupture and coalescence of adjacent expanded cells which altogether shown a formation of fatty cyst. There were few signs of inflammatory mediators infiltration in the portal tracts with spillover into the adjacent parenchyma. The degree of inflammation in cadmium-exposed animals was higher than in lead exposed animals. The infiltration of polymorphonuclear neutrophil, and lymphocytes is more in cadmium-intoxicated **liver** than the lead intoxicated one.

Vitamin E, vitamin C or *spirulina* administration did not alter the ultrastructural features in **liver** in normal animals. But supplementation of these compounds to the

animals exposed to lead or cadmium significantly decreased the severity of damage to the **liver**. There was no significant change in the disruption of cellular architecture in the **liver** of animals exposed to lead or cadmium in combination with vitamin E, vitamin C or *spirulina*. There was a partial lipid deposition and mild degree of swelling (seen by less number of vacuoles between the cells) in animals exposed to lead and cadmium administration of vitamin E, vitamin C or *spirulina* significantly prevented the injury to the **liver** cells. There was a reduction in hydropic changes and fatty infiltration in animals exposed to lead and cadmium in combination with vitamin E (Fig: 4.45C & 4.46C), vitamin C (Fig: 4.45D & 4.46D). There was less degree of damage to the **liver** cell observed in *spirulina* supplementation to lead and cadmium exposed rats, but shrinkage of nucleolus and nucleus were found, along with mild architectural damage (Fig: 4.45E & 4.46E).

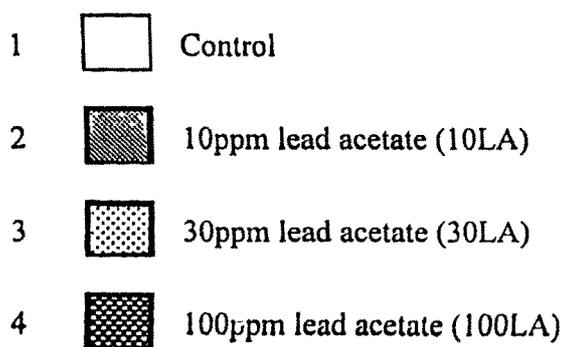
The histopathological examination of **kidney** indicated that the swelling in the renal tubular epithelial cells of animals exposed to lead (Fig: 4.47B) or cadmium (Fig: 4.48B). In the present study, there was a enlargement of **kidney** and inflammation in the renal cells due to exposure to lead and cadmium, especially to proximal convoluted tubules. In addition to these lesions, the **kidney** showed marked cystic dilation of the proximal convoluted tubule. Granular debris was seen in tubular lumena along with fatty infiltration. Supplementation of vitamin E, vitamin C or *spirulina* did not show any changes in the normal animals. But there were protective changes shown in the **kidney** of animals given lead acetate or cadmium chloride in combination with vitamin E, vitamin C or *spirulina* especially in terms of decreased fatty deposition and decrease in tubular epithelial swelling (hydropic changes). Lead and cadmium induced renal damage was protected by the co-administration of vitamin E (Fig: 4.47C & 4.48C), vitamin C (Fig: 4.47D & 4.48D) and *spirulina* (Fig: 4.47E & 4.48E).

The histopathological examination of **lung** showed hyperemia along with the interstitial inflammation, which was more pronounced in animals exposed to cadmium (Fig: 4.50B) than lead (Fig: 4.49B). There was a generalized widening of the alveolar septa. The peribronchial lymphoid hyperplasia was observed in the **lung** of animals exposed to lead and cadmium, which might be because of lymphocytic infiltration in the tissues. Supplementation of vitamin E (Fig: 4.49C & 4.50C) and vitamin C (Fig: 4.49D & 4.50D) completely protected the **lung** from the aforementioned toxic effects due to the exposure of lead and cadmium. But

supplementation of *spirulina* could not prevent the hyperemia and lymphocytic infiltration in the **lungs** (Fig: 4.49E & 4.50E).

The histopathological examination of **heart** reveals some inflammatory invasion in of animals exposed to lead (Fig: 4.51B) or cadmium (Fig: 4.52B). There was a significant enlargement of **heart**. The mild degree of cellular swelling, which is known as the minor response to injury and cytoplasmic disruption were observed in the cardiac cells of animals exposed to lead and cadmium. Supplementation of vitamin E (Fig: 4.51C & 4.52C) and vitamin C (Fig: 4.51D & 4.52D) significantly reduced the lead and cadmium induced histopathological changes in **heart** in terms of decreased swelling and cytoplasmic disruption. Supplementation of *spirulina* to the animals exposed to lead and cadmium has significantly decreased the cytoplasmic disruption in the **heart** but no change in the cellular swelling (Fig: 4.51E & 4.52E).

**Fig: 4.43. The levels of lead in liver, kidney, lung, heart and brain after thirty days exposure to lead acetate.**

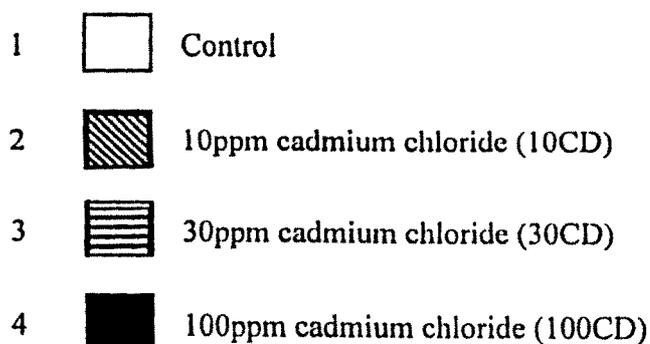


Values are expressed as mean  $\pm$  SEM for six animals in each group.

Group 2, 3, 4 compared to group 1.

\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

**Fig: 4.44. The levels of cadmium in liver, kidney, lung, heart and brain after thirty days exposure to cadmium chloride.**



Values are expressed as mean  $\pm$  SEM for six animals in each group.

Group 2, 3, 4 compared to group 1.

\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

Fig: 4.43.

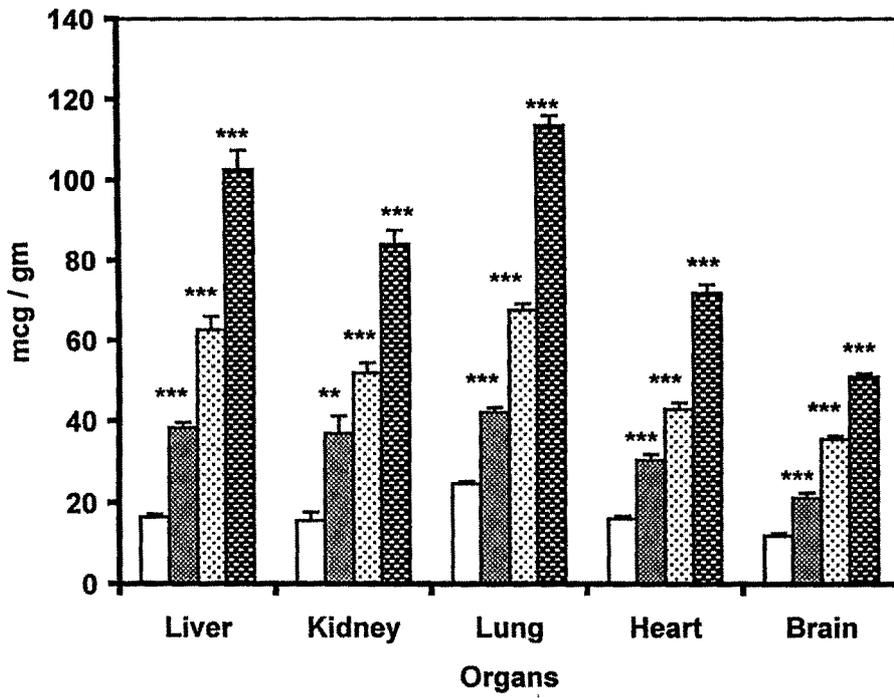
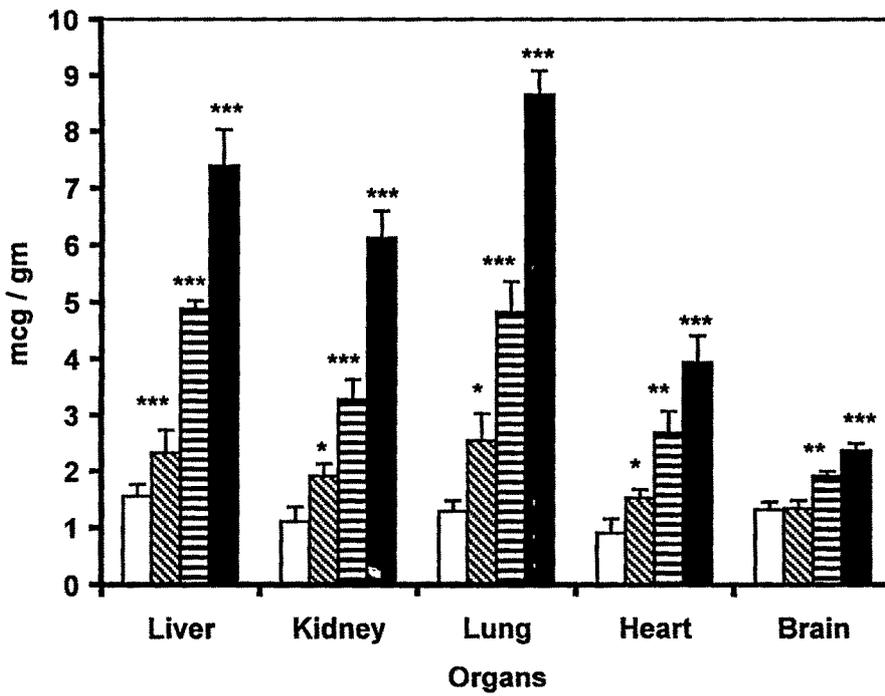


Fig: 4.44.



**Table- 4.43: Effect of 100 ppm of lead acetate (100LA) exposure (30 days) alone and in combination with antioxidants i.e. vitamin E, C or spirulina (E, C or SP) on the levels of lead in liver, kidney, lung, heart and brain of rats. (mcg / gm)**

GROUP	ORGANS				
	Liver	Kidney	Lung	Heart	Brain
1. Control	16.433 ± 0.792	15.600 ± 2.047	24.667 ± 0.543	16.067 ± 0.688	11.860 ± 0.691
2. 100LA	102.587 ± 4.761 <sup>***b</sup>	84.120 ± 3.439 <sup>***b</sup>	113.537 ± 2.447 <sup>***b</sup>	71.873 ± 2.153 <sup>***b</sup>	51.002 ± 0.808 <sup>***b</sup>
3. E	15.867 ± 0.565	14.650 ± 0.964	26.333 ± 0.467	14.017 ± 0.669	11.450 ± 0.889
4. E+100LA	88.280 ± 4.488	76.325 ± 4.682	110.278 ± 2.932	69.675 ± 3.235	43.348 ± 4.923
5. C	15.133 ± 0.726	14.422 ± 1.132	22.700 ± 1.136	11.667 ± 1.365	11.523 ± 0.480
6. C+100LA	81.263 ± 6.502 <sup>*a</sup>	58.404 ± 2.773 <sup>***a</sup>	70.433 ± 5.419 <sup>***a</sup>	56.805 ± 1.492 <sup>***a</sup>	38.659 ± 4.974 <sup>*a</sup>
7. SP	13.967 ± 0.418	14.842 ± 1.093	23.700 ± 1.949	14.300 ± 0.853	11.778 ± 0.662
8. SP+100LA	91.588 ± 2.954	75.100 ± 2.791	107.876 ± 3.866	66.636 ± 3.919	19.177 ± 2.273 <sup>*a</sup>
F ratio	135.072, p<0.001	106.513, p<0.001	220.592, p<0.001	160.235, p<0.001	44.362, NS

Values are expressed as mean ± SEM for six animals in each group.

a : Group 4, 6 and 8 when compared with group 2.

b : Group 2, 3, 5, and 7 when compared with group 1.

\* p<0.05, \*\* p<0.01, \*\*\* p<0.001.

**Table- 4.44: Effect of 100 ppm of cadmium chloride (100CD) exposure alone and in combination with antioxidants i.e. vitamin E, C or spirulina (E, C or SP) on the levels of cadmium in liver, kidney, lung, heart and brain of rats. (mcg / gm)**

GROUP	ORGANS				
	Liver	Kidney	Lung	Heart	Brain
1. Control	1.557 ± 0.202	1.110 ± 0.259	1.293 ± 0.185	0.903 ± 0.185	1.335 ± 0.135
2. 100CD	7.383 ± 0 0.646 <sup>***b</sup>	6.122 ± 0.471 <sup>***b</sup>	8.653 ± 0.424 <sup>***b</sup>	3.943 ± 0.476 <sup>***b</sup>	2.377 ± 0.138 <sup>***b</sup>
3. E	1.522 ± 0.147	1.002 ± 0.121	1.173 ± 0.148	0.955 ± 0.153	1.307 ± 0.130
4. E+100CD	7.240 ± 0.812	5.956 ± 0.358	7.667 ± 0.388	3.766 ± 0.396	2.195 ± 0.127
5. C	1.680 ± 0.171	0.885 ± 0.180	1.182 ± 0.143	0.818 ± 0.158	1.313 ± 0.148
6. C+100CD	4.393 ± 0.297 <sup>**a</sup>	4.961 ± 0.168 <sup>*a</sup>	6.272 ± 0.352 <sup>**a</sup>	2.597 ± 0.363 <sup>*a</sup>	1.812 ± 0.211 <sup>*a</sup>
7. SP	1.4500 ± 0.152	1.039 ± 0.146	1.259 ± 0.198	0.986 ± 0.124	1.290 ± 0.133
8. SP+100CD	6.662 ± 0.606	5.850 ± 0.507	7.153 ± 0.539	3.533 ± 0.641	1.778 ± 0.213
F ratio	6.697, p<0.001	5.274, p<0.001	9.182, p<0.001	5.274, p<0.001	0.267, NS

Values are expressed as mean ± SEM for six animals in each group.

a : Group 4, 6 and 8 when compared with group 2.

b : Group 2, 3, 5, and 7 when compared with group 1.

\*p<0.05, \*\*p<0.01, \*\*\*p<0.001.

**Fig.- 4.45: Photomicrographs showing liver of rats after the following treatments.  
(Magnification 40 X)**

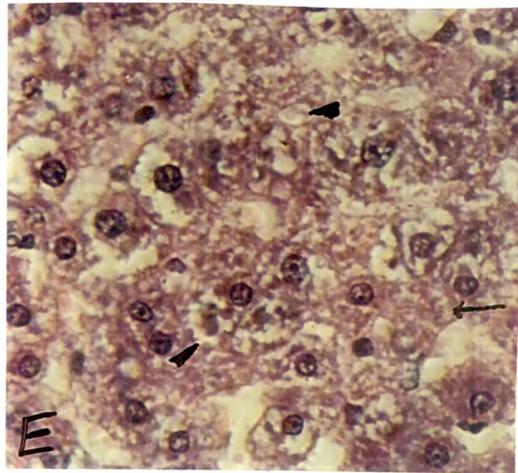
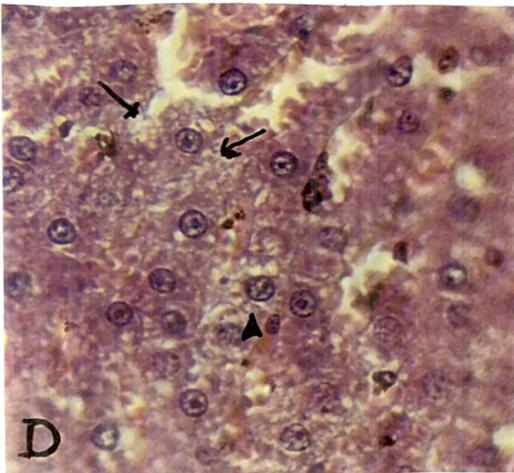
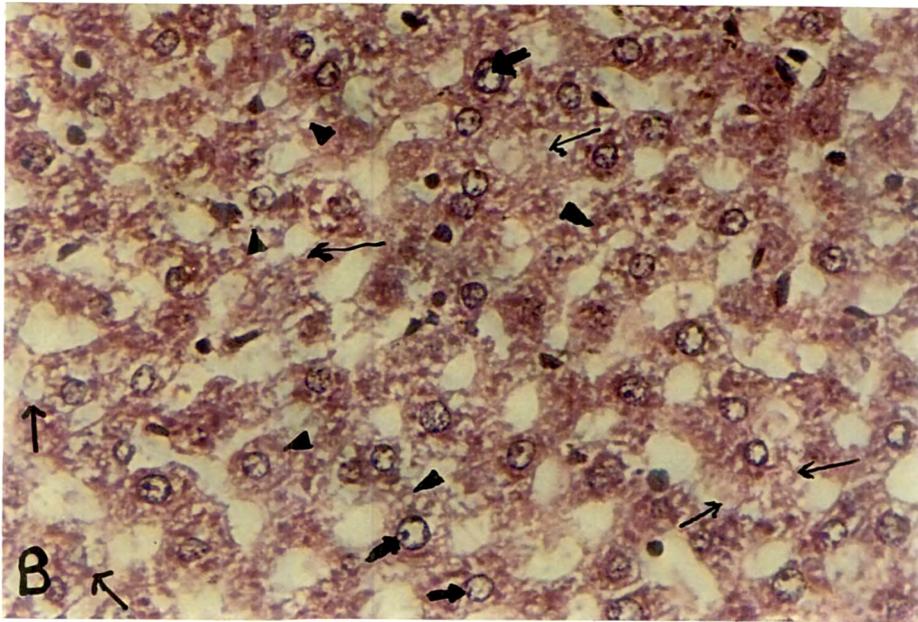
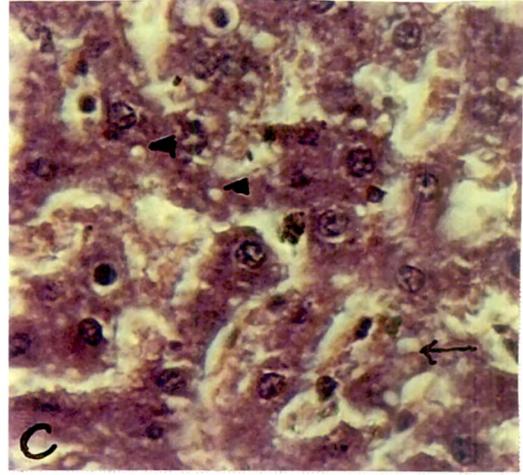
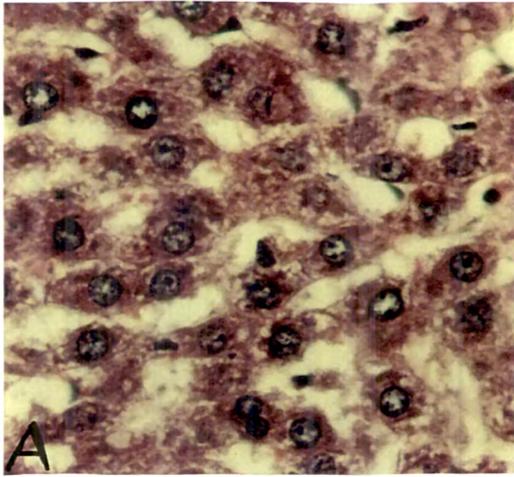
- A. Control
- B. 100 ppm Lead acetate
- C. Vitamin E + 100 ppm Lead acetate
- D. Vitamin C + 100 ppm Lead acetate
- E. *Spirulina* + 100 ppm Lead acetate

▶ Hydropic changes

▣→ Pyknotic nuclei

→ Fatty infiltration

Fig: 4.45



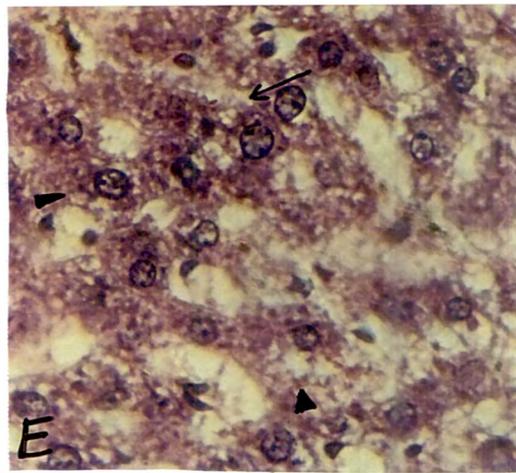
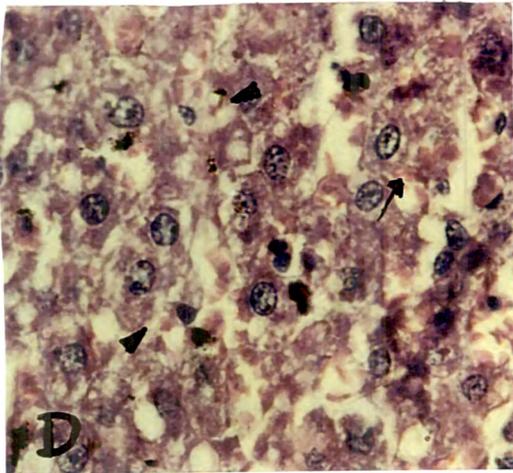
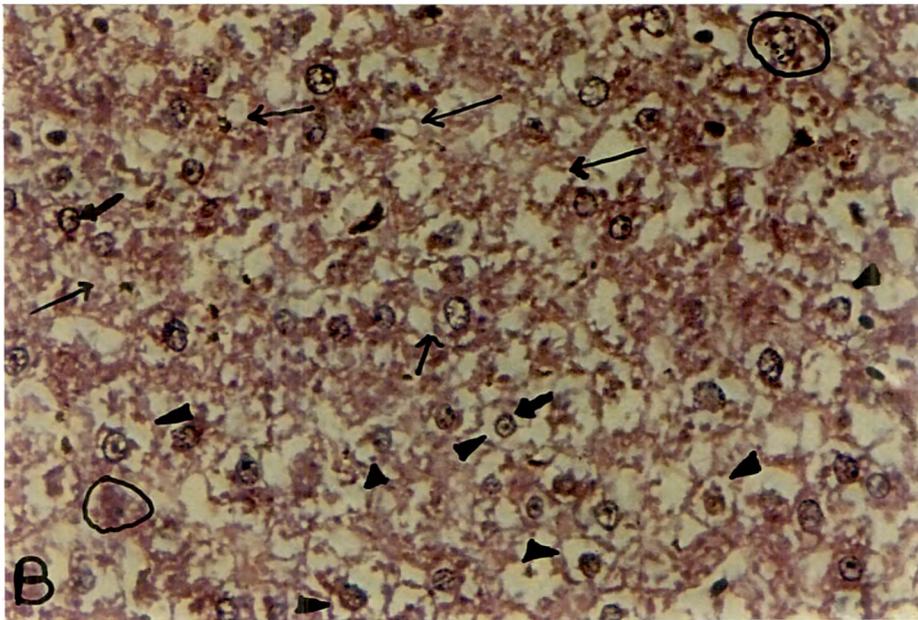
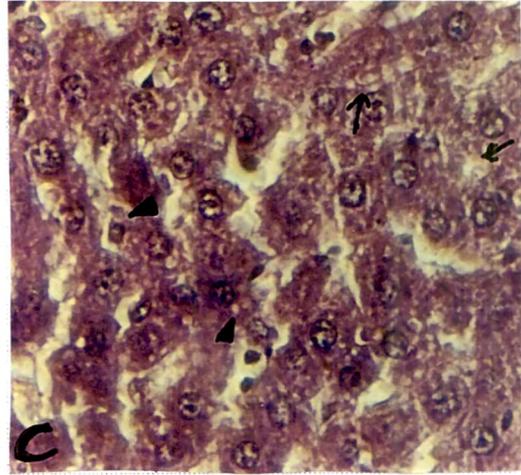
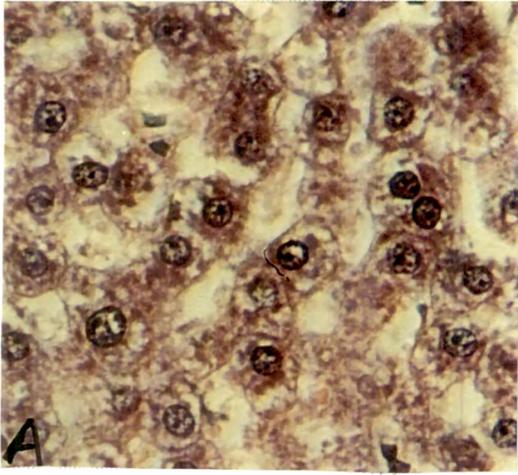
**Fig.- 4.46: Photomicrographs showing liver of rats after the following treatments.**

**(Magnification 40 X)**

- A. Control
- B. 100 ppm Cadmium chloride
- C. Vitamin E + 100 ppm Cadmium chloride
- D. Vitamin C + 100 ppm Cadmium chloride
- E. *Spirulina* + 100 ppm Cadmium chloride

- ▶ Hydropic changes
- ➡ Pyknotic nuclei
- Fatty infiltration
- Inflammatory cells (WBCs)

Fig: 4.46



**Fig.- 4.47: Photomicrographs showing kidney of rats after the following treatments.**

**(Magnification 10 X)**

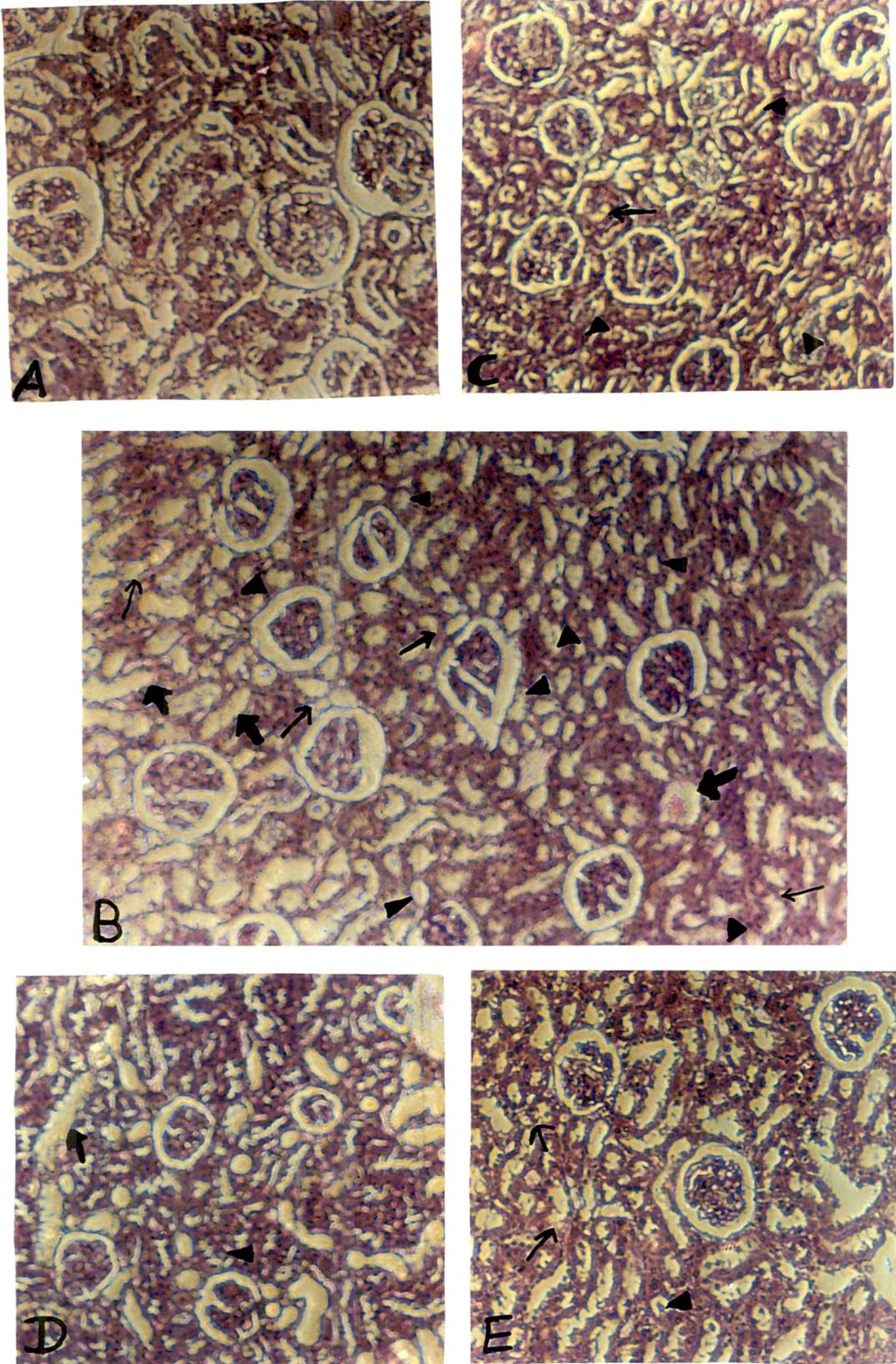
- A. Control
- B. 100 ppm Lead acetate
- C. Vitamin E + 100 ppm Lead acetate
- D. Vitamin C + 100 ppm Lead acetate
- E. *Spirulina* + 100 ppm Lead acetate

▶ Hydropic changes

➡ Dilated proximal tubule

→ Fatty infiltration

Fig: 4.47



**Fig.- 4.48: Photomicrographs showing kidney of rats after the following treatments.**

**(Magnification 10 X)**

- A. Control
- B. 100 ppm Cadmium chloride
- C. Vitamin E + 100 ppm Cadmium chloride
- D. Vitamin C + 100 ppm Cadmium chloride
- E. *Spirulina* + 100 ppm Cadmium chloride

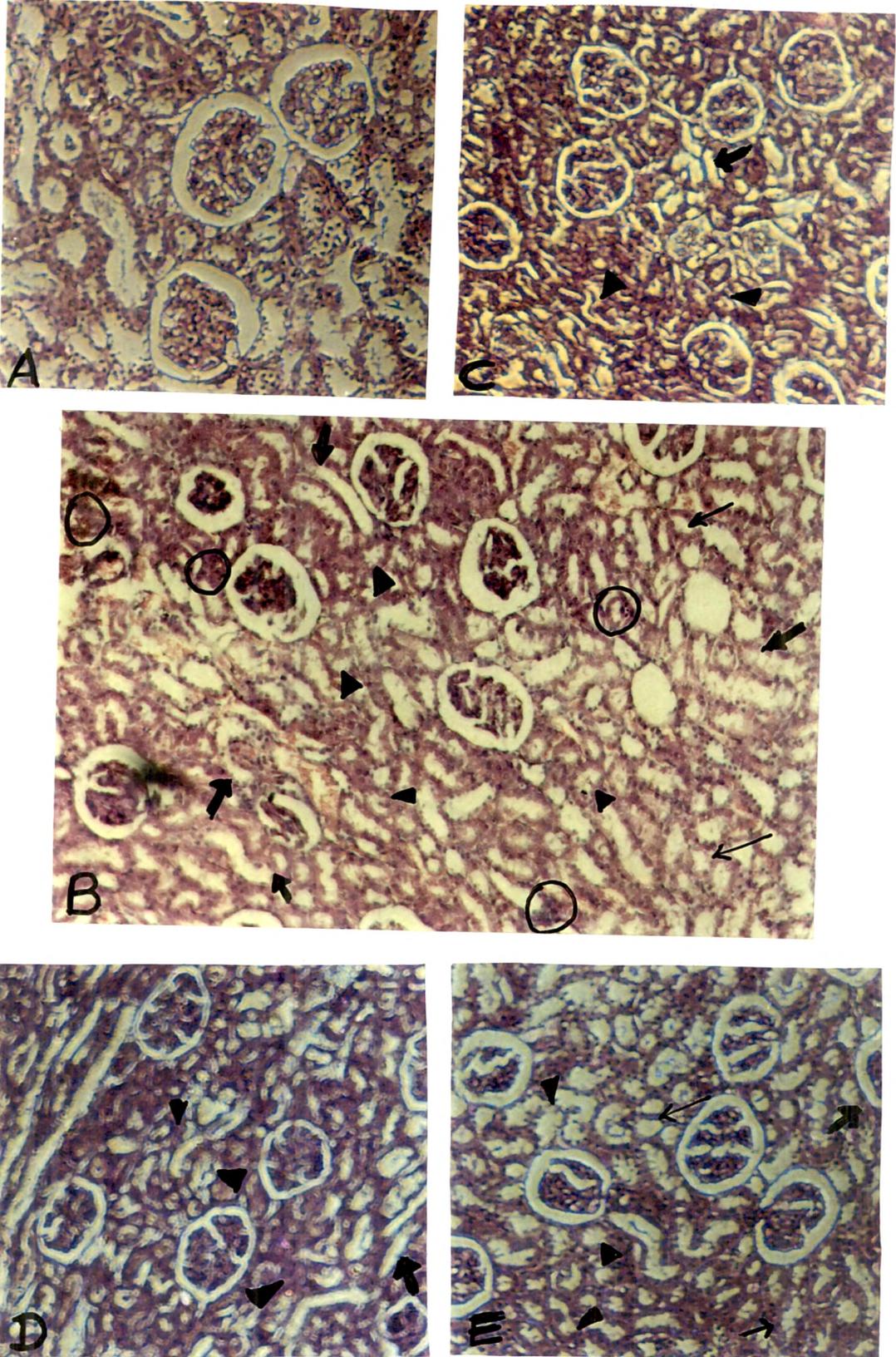
▶ Hydropic changes

➡ Dilated proximal tubule

→ Fatty infiltration

○ Inflammatory cells (WBCs)

Fig: 4.48



**Fig.- 4.49: Photomicrographs showing lung of rats after the following treatments.**

**(Magnification 10 X)**

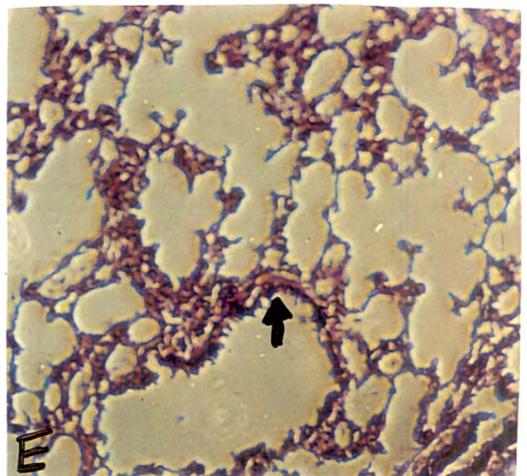
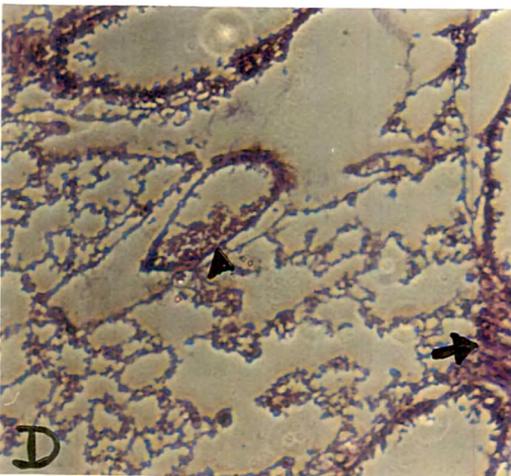
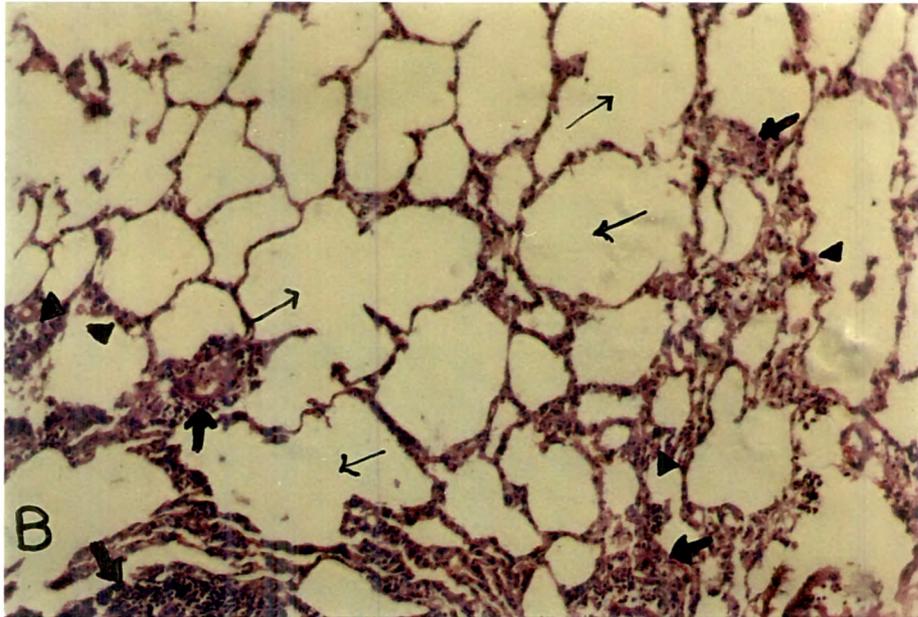
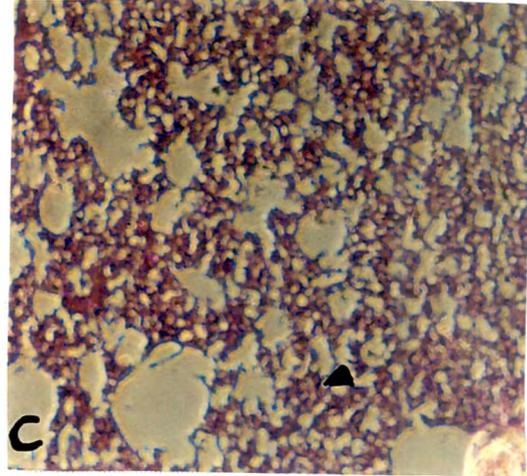
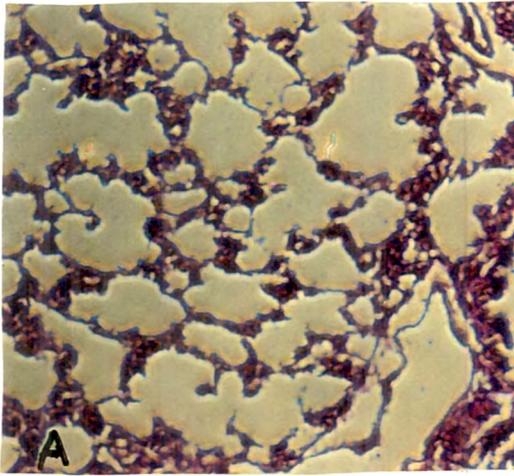
- A. Control
- B. 100 ppm Lead acetate
- C. Vitamin E + 100 ppm Lead acetate
- D. Vitamin C + 100 ppm Lead acetate
- E. *Spirulina* + 100 ppm Lead acetate

▶ Hyperemia

➡ Peribronchial lymphoid hyperplasia

→ Widened alveolar septa

Fig: 4.49



**Fig.- 4.50: Photomicrographs showing lung of rats after the following treatments.**

**(Magnification 10 X)**

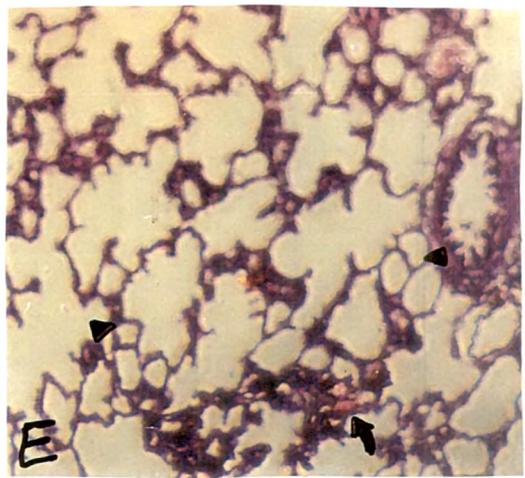
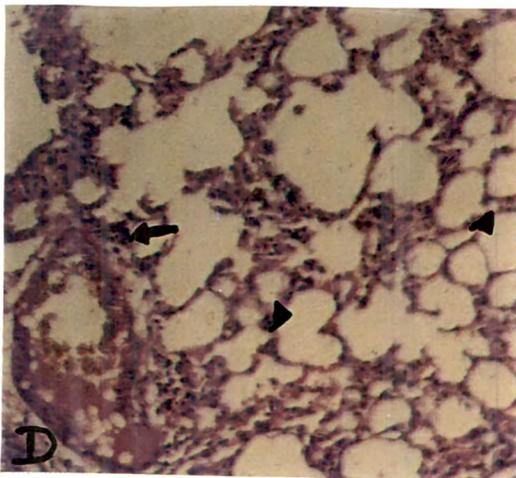
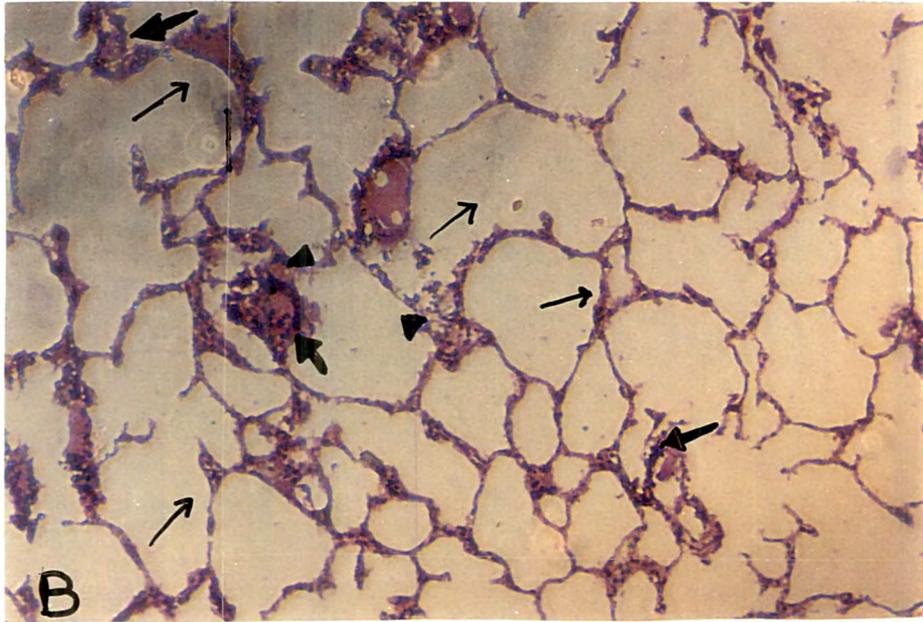
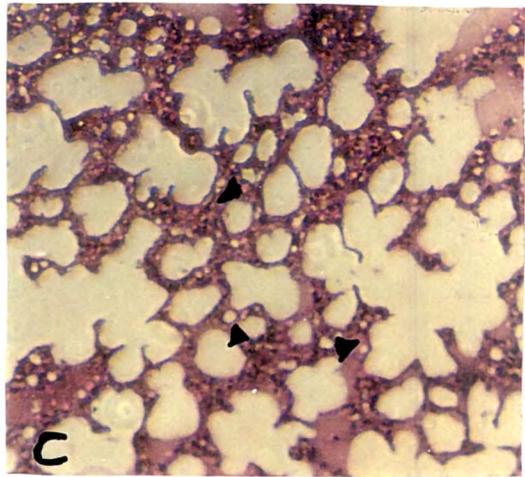
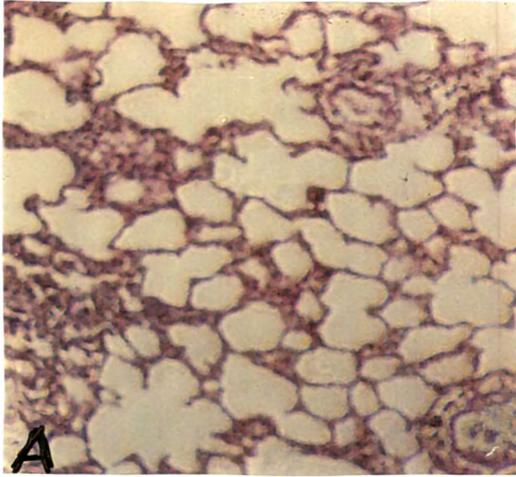
- A. Control
- B. 100 ppm Cadmium chloride
- C. Vitamin E + 100 ppm Cadmium chloride
- D. Vitamin C + 100 ppm Cadmium chloride
- E. *Spirulina* + 100 ppm Cadmium chloride

▶ Hyperemia

➡ Peribronchial lymphoid hyperplasia

→ Widened alveolar septa

Fig: 4.50



**Fig.- 4.51: Photomicrographs showing heart of rats after the following treatments.**

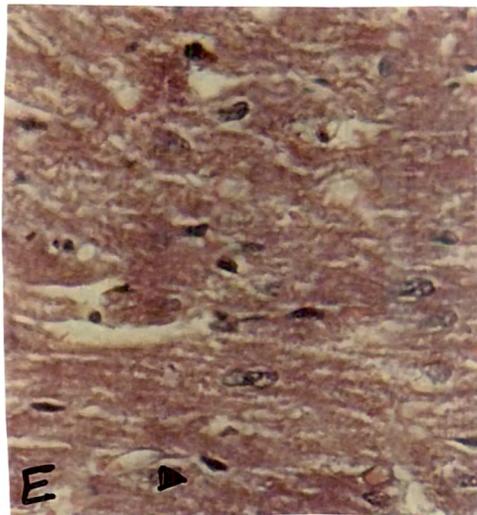
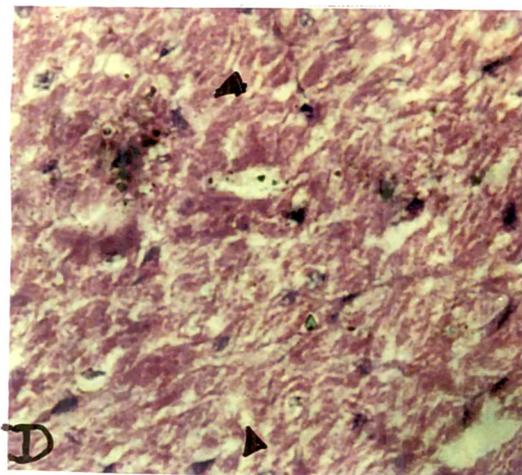
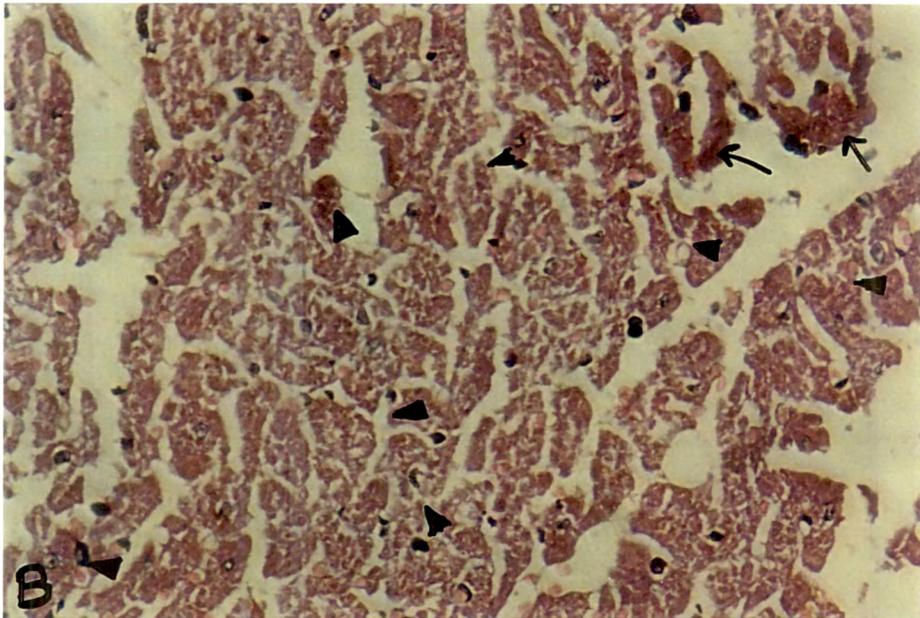
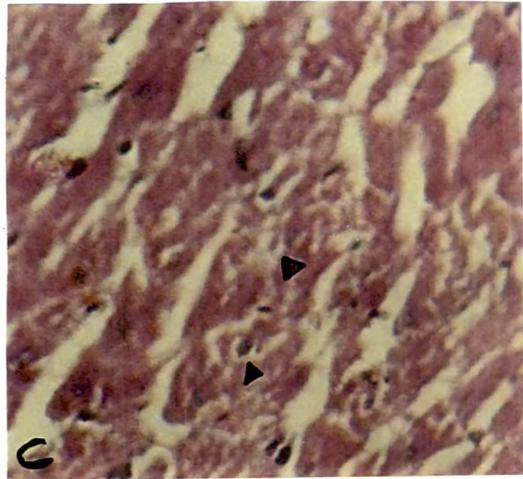
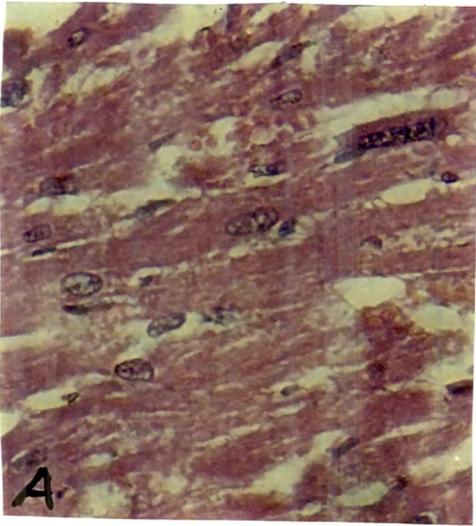
**(Magnification 40 X)**

- A. Control
- B. 100 ppm Lead acetate
- C. Vitamin E + 100 ppm Lead acetate
- D. Vitamin C + 100 ppm Lead acetate
- E. *Spirulina* + 100 ppm Lead acetate

▶ Swelling

→ Occasional inflammatory cells

Fig: 4.51



**Fig.- 4.52: Photomicrographs showing heart of rats after the following treatments.**

**(Magnification 40 X)**

- A. Control
- B. 100 ppm Cadmium chloride
- C. Vitamin E + 100 ppm Cadmium chloride
- D. Vitamin C + 100 ppm Cadmium chloride
- E. *Spirulina* + 100 ppm Cadmium chloride

▶ Swelling

→ Occasional inflammatory cells

Fig: 4.52

