

# Detection of Public Health Risks of Cadmium Chloride Residues That Experimentally Injected in Albino Male Rabbits

Raad J. Hammadi

Department of Public Health, College of Veterinary Medicine, University of  
Diyala, Iraq

Corresponding author: [raad.j@uodiyala.edu.iq](mailto:raad.j@uodiyala.edu.iq)

ORCID: <https://orcid.org/0009-0005-8916-2536>

**Important dates:** Received: 17-APRIL-2026; Accepted: 26- May-2026; Published: June-2026

## Abstract

The proteins of animal consider important source for human nutrition include meats, liver and kidney that contents essential amino acids and other bioactive ingredients, Cadmium chloride which causes environmental pollution is a worldwide serious problem, the importance of current study to explain the effects of cadmium chloride accumulation in the liver and kidney which reflex the carcasses quality in polluted areas. ( 15 ) albino male rabbits were unsystematically and equal divided into three groups, 1<sup>st</sup> group considered control, 2<sup>nd</sup> group received single dose weekly 0.67 mg/kg of CdCl<sub>2</sub> for 75 days, 3<sup>rd</sup> group received three doses weekly 0.67 mg/kg CdCl<sub>2</sub> for 75 days, the blood samples were collected at day 75 of experiment for biochemical assay of serum total protein, serum urea, serum creatinine, Alanine amino transferase ( ALT ), Aspartate amino transferase ( AST ), Alkaline phosphatase ( ALP ). Also, liver & kidney samples were taken at 75 days for histopathological examination. The results in 2<sup>nd</sup> & 3<sup>rd</sup> group showed significant increase in total protein, urea, creatinine, AST and ALT while significantly decrease of ALP, the histopathological changes on liver in 2<sup>nd</sup> & 3<sup>rd</sup> group showed infiltration of inflammatory cells, vacuolation with necrosis of hepatocytes, while in kidney at 2<sup>nd</sup> & 3<sup>rd</sup> group showed tubular degeneration, severe necrosis of proximal tubules, these changes considered dangerous due to level of CdCl<sub>2</sub> is elevated compared to normal limit in kidney and liver, consuming the meat and edible organs of farm animals that exposed cadmium contamination may be risk on human health and public health, according to the danger index.

**Keywords:** Cadmium chloride, public health risk, peritoneal injection, biochemical assays and pathological changes



This is an open access article licensed under a [Creative Commons Attribution- NonCommercial 4.0 International License](https://creativecommons.org/licenses/by-nc/4.0/).

## Introduction

Meat is regarded as a vital component of our diet and is mostly made up of proteins, lipids, and necessary nutrients. It is also an excellent source of vitamins, phosphorus, zinc, and iron. (Akan *et al.*, 2010; Nkansah & Ansah, 2014). Meats and edible organs of carcasses as liver and kidney are considered a complete source of nutritional sources protein for most populations due to they contain all of essential amino acids that the body needs to function, contain vitamins and minerals, which are micronutrients that aid in the release of energy from these macronutrients and carry out a variety of tasks like cellular damage repair, wound healing, and immune system support (Gleason, 2021). The chemical composition of meat depends on both kind and degree of the feeding animal (Munoz-Olives and Camara, 2001). The need for mineral compounds depends on the age, physiological state and feed intake as well as on living conditions. Meat is a very important human food; therefore, it may potentially accumulate toxic minerals and represents one of the sources of heavy metals for humans (Baykov *et al.*, 1996). Some metals such as Cd are movable in plants and may become accumulated in roots leaves. So, grazing animals may potentially be highly exposed to these elements through ingestion of polluted soil, vegetation, drinking water and possibly also via inhalation (María Domínguez *et al.*, 2009).

Food is typical primary cause of heavy metal exposure for humans. The WHO has concluded low amounts of some metals, like cadmium and lead, can caused diseases in people after reviewing research on food additives and their toxicity on an ongoing basis. (Gonzalez-Weller *et al.*, 2006). (Anetta *et al.*, 2015) conducted that the average values for cadmium in cattle meat were higher than the expecting normal values, further state that Cd concentrations in meat depend on the concentration of Cd in the animal feed. (Saskia *et al.*, 2014) suggested that 40% of the livers and 85% of the kidneys of all inspected cows were above the European limit for cadmium. Based on the existing minimum risk levels (MRLs) for chronic oral exposure, as well as, they recommended that a person of 70 kg should not eat more than 150 g cow meat per day because of the metal's levels in the muscles.

Since beef, goats, and lamb are the most widely available meat sources, people frequently and extensively eat them, as well as their byproducts such offal. Certain flesh tissues, like the kidney, liver, and muscle of the aforementioned organisms, are regarded as delicacies and are frequently eaten raw without any additional processing. Regrettably, environmental contamination is increasing and poses numerous risks to both humans and animals (Yabe *et al.*, 2011; Ihedioha *et al.*, 2013), where the prevalence of numerous harmful elements, including lead (Pb) and cadmium (Cd), which are mostly airborne and can be deposited by dust into water, soil, and plants which ruminants graze on it, might be attributed to the high pace of industrialization (Okorafor & Amadiali, 2015). Additionally, because of their careless eating habits, particularly

during times of famine, sheep, cows, and horses employed as admirable markers of contamination on plants (Bala *et al.*, 2013). Long-term ingestion of the kidney, liver, and lungs of goats and sheep with elevated levels of Zn, Cu, and Cd has been linked to metal toxicity and buildup in humans (Akoto *et al.*, 2014).

A hazardous heavy metal that contaminates the environment and endangers the health of people and animals, cadmium is an essential trace element that is present in the body in trace amounts and whose absence has no effect on key functions. Due to its extensive use in numerous industries, including the plastics industry, the production of dyes, phosphate fertilizers, metal alloys, battery electrodes, and others, it is hard to prevent exposure to this metal because it is present in water, soil, food and air. The application of phosphate fertilizers raises its level in the soil which in turn raises the concentration of it in plants and consequently its transfer through food to animals and humans (Matovic *et al.*, 2015).

Mortality studies have provided the majority of data regarding the impact of environmental contaminants on aquatic life. Cellular damage to various organs or disruptions in biochemical and physiological processes within an organism after exposure to toxin in environment are frequently poorly understood. As a result, little is known about how toxicants work and what kills aquatic species that have been poisoned. Predicting the possible environmental impact of certain compounds requires a deeper comprehension of these mechanisms. Given that various environmental contaminants are anticipated to have varying effects on biological systems based on their unique chemical characteristics (Kumar *et al.*, 2019; Prakash & Verma, 2021).

Heavy concentrations of metal in milk and dairy products can be used as markers of pollution in the food chain and atmosphere since they differ significantly between regions with manufacturing activities and environmentally sanitary districts (Gonzalez-Montana *et al.*, 2012).

As a result of the extensive use of different metals in contemporary civilization over the years, metals and metal components of our national environment, there is a straightforward possibility of exposure to harmful metals both inside and outside of the workplace. The well-known hepatotoxic toxin cadmium chloride. Numerous arguments support the idea that oxidative stress contributes to the liver damage caused by cadmium chloride. Glutathione is depleted by CdCl<sub>2</sub> and antioxidant enzyme activity is inhibited in the liver tissue. Metals both of in vitro and in vivo cause peroxidation of lipid. So, the Cadmium chloride (CdCl<sub>2</sub>) is an important chemical of heavy metals with a wide spread that threatens the environment and causes poisoning when it accumulates inside the body of living organisms, causing pollution to the environment and global concern (Chung *et al.*, 1996). The aims of present study to investigate the effect of cadmium

chloride on the liver and kidneys of male albino rabbits as an indicator of its risk to public health.

## Materials and methods

Fifteen albino male rabbits weighing between 1.8 – 2.25kg were utilized in the current investigation. They were obtained from a veterinarian's animal house at Diyala University's Vet. Medicine College for two weeks, and had the right temperature and ventilation. Rabbits were provided with food grass and pellets, water, and natural illumination. Cadmium chloride was bought from Merck Company (Germany) and dissolved in saline solution. 0.67 mg/kg was the concentration that was utilized according to (Bench *et al.*, 1999).

**Experiment design:** Three groups of rabbits were randomly, there were five rabbits in each group: 1).The control first group was given grass with pellets.; 2) 2<sup>nd</sup> group: Cadmium Chloride was injected intraperitoneally (IP) at a dose of 0.67 mg/kg once a week on Tuesdays for 75 days; and 3) 3<sup>rd</sup> group: Cadmium Chloride was injected intraperitoneally (IP) at a dose of 0.67 mg/kg three doses per week on Sundays, Tuesdays, and Thursdays for 75 days.

**Blood collection:** The blood was drawn from the heart after 75 days of labor and put in a test tube. It was then allowed to coagulate and clot for 15 minutes in the refrigeration before being centrifuge for 15 minutes at 500 rpm to separate the serum and kept at -20<sup>C</sup> for analysis.

**Biochemical analysis:** The biochemical analysis parameters including:

- 1- Estimation of serum total protein (mg/ ml).
- 2- Estimation of serum urea ( mg / dl ).
- 3- Estimation of creatinine ( mg/ dl ).
- 4- Determination of aspartate amino transferase ( AST ) ( U / L ).
- 5- Determination of alanine amino transferase ( ALT ) ( U / L ).
- 6- Determination of alkaline phosphatase ( ALP ) ( U / L ).

The all-biochemical assays were done with commercial reagents and worked at private laboratory in Baghdad.

**Pathological procedures:** On day 75 of the experimental study, all animals were sacrificed in accordance with ethics protocol, given a little ether anesthesia, and had their liver and kidney carefully dissected. They were then immediately fixed in 10% neutral formalin that was stored in upwardly graded ethanol (70, 80, 90, and 100) for the first round and second run, followed by xylene, embedded in paraffin, stained with hematoxylin and eosin (H&E) stains (Bancroft & Gamble, 2008).

**Statistical analysis:** All data were statistically analyzed using SPSS Version 17 (2010) software. One-way ANOVA is one testing method used for group evaluations. P-values below 0.05 indicated statistical significance. The means  $\pm$  standard error (SE) were used to express the data (Leech *et al.*, 2014).

**Ethics approval:** This study was conducted after obtaining approval from the animal research ethics committee at the College of Vet. Medicine, University of Diyala, and in accordance with ARRIVE guidelines for animal experimentation, with consideration given to minimizing animal suffering.

**Results:**

**Biochemical analysis:**

The third group's serum total protein (mg/ml) was significantly higher than that of the first and second groups. Additionally, compared to the first and second groups, the third group's urea (mg/dl) exhibited a considerable increase. As can be seen in the table below, the third group's creatinine (mg/dl) level significantly increased when compared to the first and second groups.

Table 1: The level of serum total protein, urea and creatinine in albino male rabbits.

Groups	total protein(mg/ml)	Urea (mg/dl)	Creatinine (mg/dl)
1 <sup>st</sup> group	16.45 ± 1.33 c	39.20 ± 1.35 c	0.71 ± 0.09 c
2 <sup>nd</sup> group	25.10 ± 1.09 b	42.20 ± 1.15 b	0.89 ± 0.02 b
3 <sup>rd</sup> group	42.65 ± 2.28 a	49.10 ± 2.85 a	0.99 ± 0.08 a

Number 5 for each group with significantly different (P<0.05).

In AST ( U/L ) showed a significant increase in the 3<sup>rd</sup> group compare with the 1<sup>st</sup> & 2<sup>nd</sup> group. ALT ( U/L ) revealed elevated significant in the 3<sup>rd</sup> group compared with the 1<sup>st</sup> & 2<sup>nd</sup> group. While the serum ALP ( U/L ) exhibited a significant severe decrease in the 3<sup>rd</sup> group compared with the 1<sup>st</sup> & 2<sup>nd</sup> group, see the below table.

Table 2: The level of AST , ALT and ALP in albino male rabbits.

groups	AST ( U/L )	ALT ( U/L )	ALP ( U/L )
1 <sup>st</sup> group	67.24 ± 3.10 c	49.20±12.09c	118.04 ± 3.50 a
2 <sup>nd</sup> group	199.15± 2.25 b	178.10±19.30b	76.03 ± 2.85 b
3 <sup>rd</sup> group	510.95 ± 2.65a	480.11± 20.65 a	41.03 ± 3.10 c

Number 5 for each group with considerably different (P<0.05).

**Pathological changes:** The 1<sup>st</sup> group, not showed significant any pathological lesions, its normal hepatic cells, normal sinusoid & normal central vein ( fig. 1 ), also normal glomeruli (tuft & capsule ) & normal tubular epithelium ( proximal ) ( fig. 2 ).

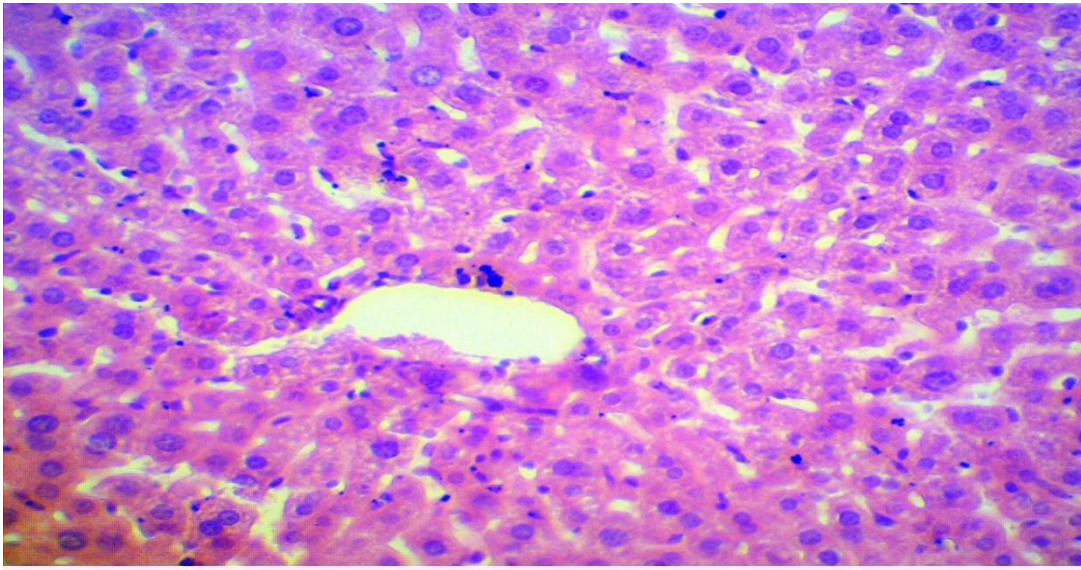


Figure 1: Histomorphological section of liver in 1<sup>st</sup> group expressions normal hepatic cells, normal sinusoid & normal central vein. (H&E stain, X20).

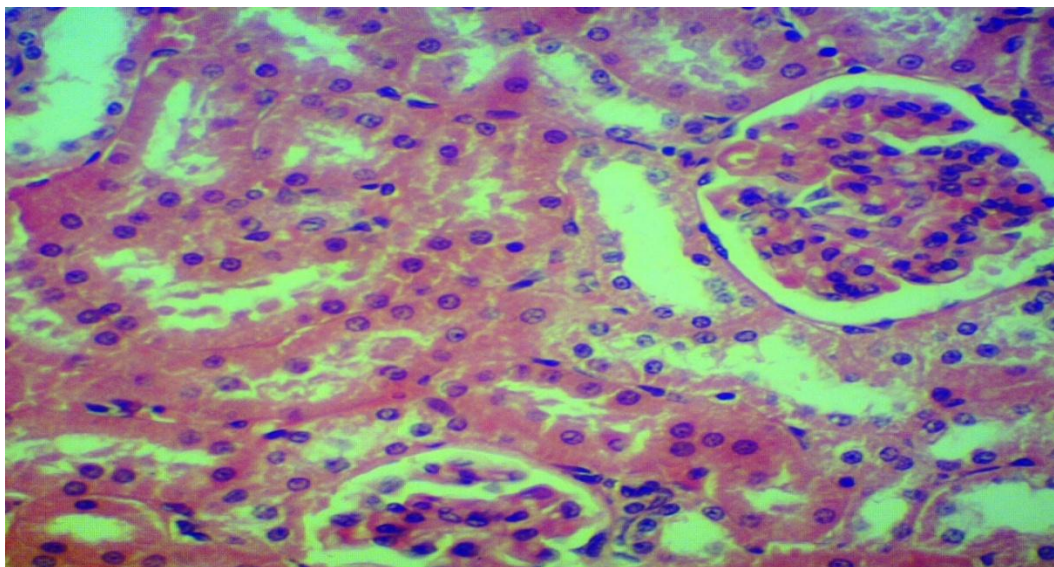


Figure 2: Histomorphological section belong to kidney in 1<sup>st</sup> group shows normal glomeruli (tuft & capsule ) & normal tubular epithelium ( proximal ) (H&E stain,20x ).

In 2<sup>nd</sup> group of liver showed sever infiltration of inflammatory cells, vacuolation, with mild necrosis of hepatocytes ( fig. 3 & 4 ), in kidney showed severe infiltration of inflammatory cells, tubular degeneration with cystic dilation of proximal tubules ( fig. 5 & 6 ).

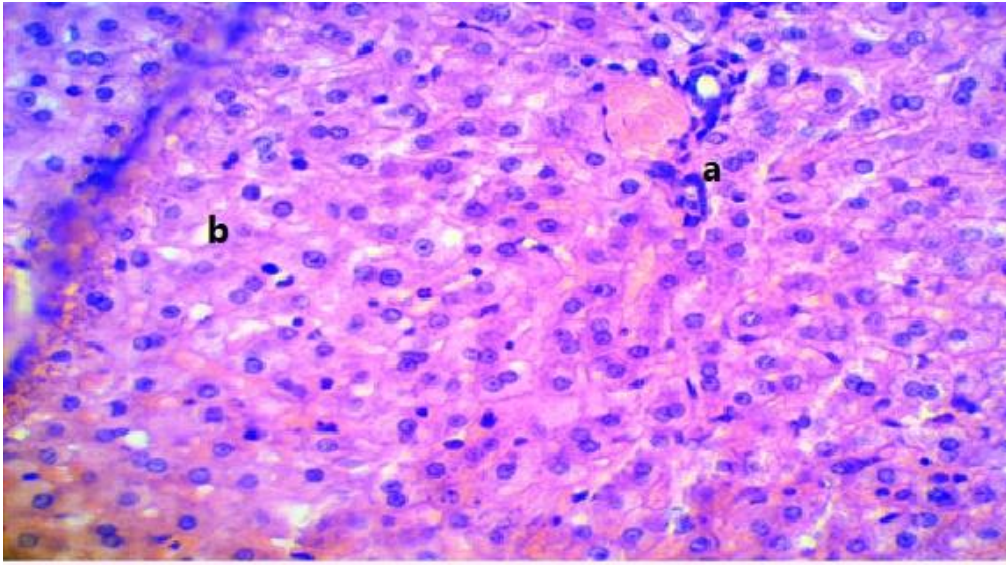


Figure 3: Histomorphological section belong to liver in 2<sup>nd</sup> group shows severe of inflammatory cells infiltration (a) vacuolation (b) ( X40, H&E stain ).

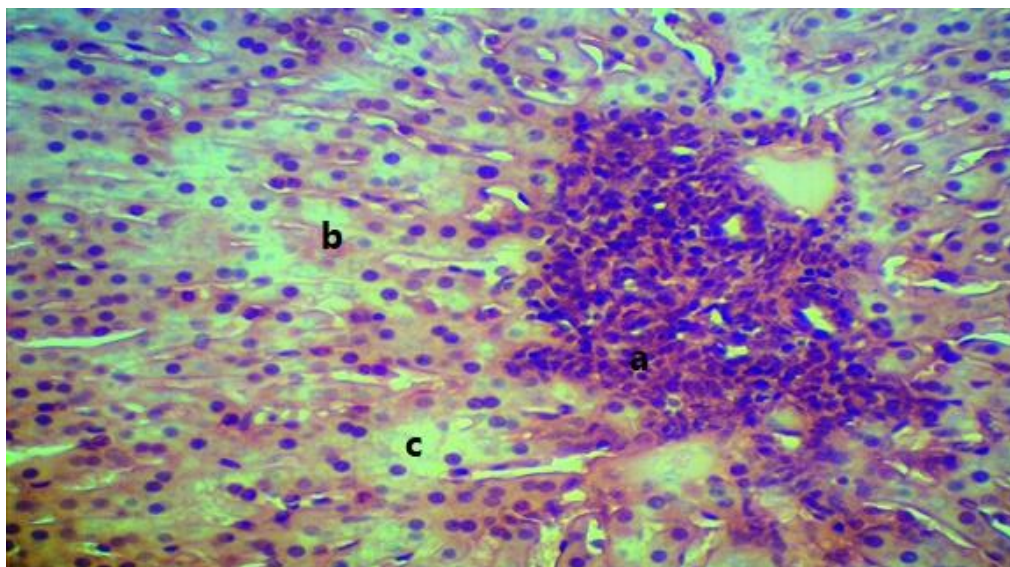


Figure 4: Histomorphological section belong to liver in 2<sup>nd</sup> group shows severe infiltration of inflammatory cells (a) slight necrosis (b) 7 vacuolation (c) (H&E stain,X20 ).

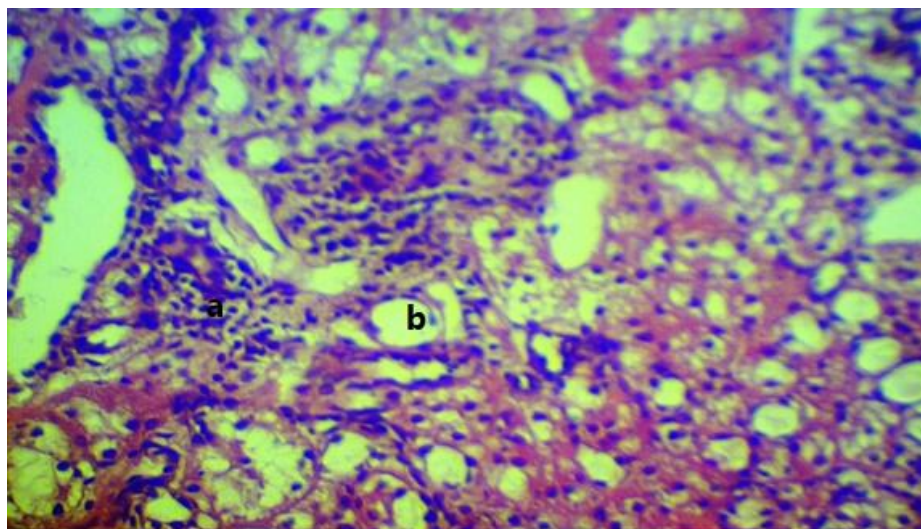


Figure 5: Histomorphological section belong to kidney in 2<sup>nd</sup> group shows severe infiltration of inflammatory cells (a) cystic dilation of proximal tubules (b) (H&E stain,X20 ).

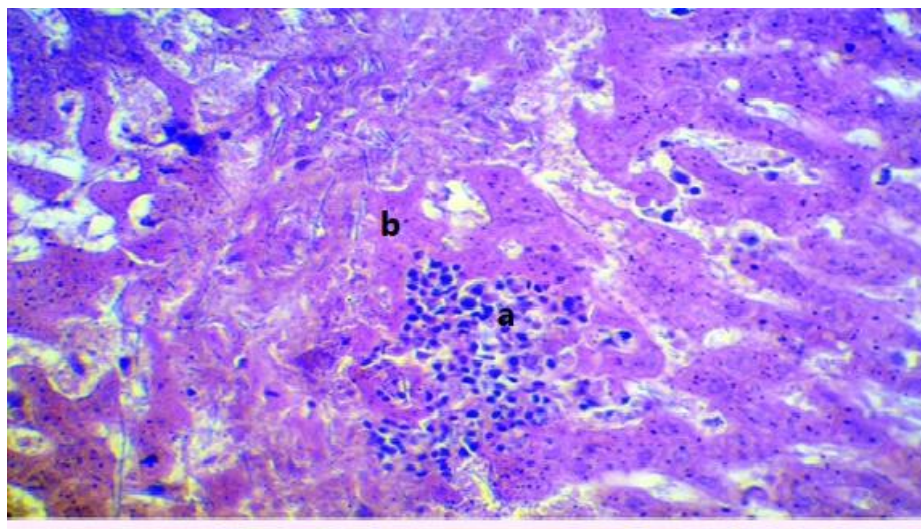


Figure 6: Histomorphological section belong to kidney in 2<sup>nd</sup> group shows severe inflammatory cells (a) tubular degeneration (b) (H&E stain,X20 ).

In 3<sup>rd</sup> group of liver showed vacuolation, severe hepatic necrosis, central vein congestion & severe infiltration of lymphocytes ( fig. 7 & 8 ), in kidney showed hemorrhage, degenerated glomeruli with infiltration of inflammatory cells ( fig. 9 ),

degeneration and necrosis of proximal tubules with severe infiltration of inflammatory cells ( Fig. 10).

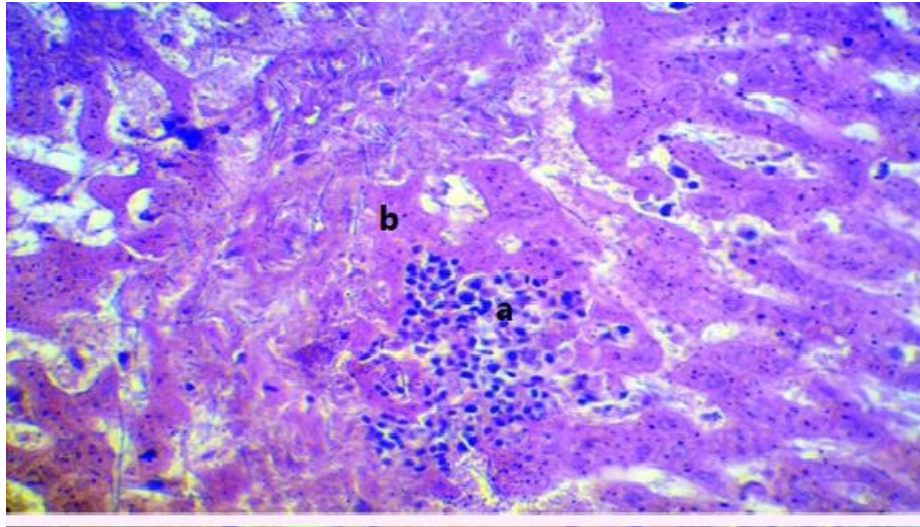


Figure 7: Histomorphological section belong to liver in 3<sup>rd</sup> group shows severe infiltration of inflammatory cells (a), hepatic necrosis (b) (H&E stain,X20 ).

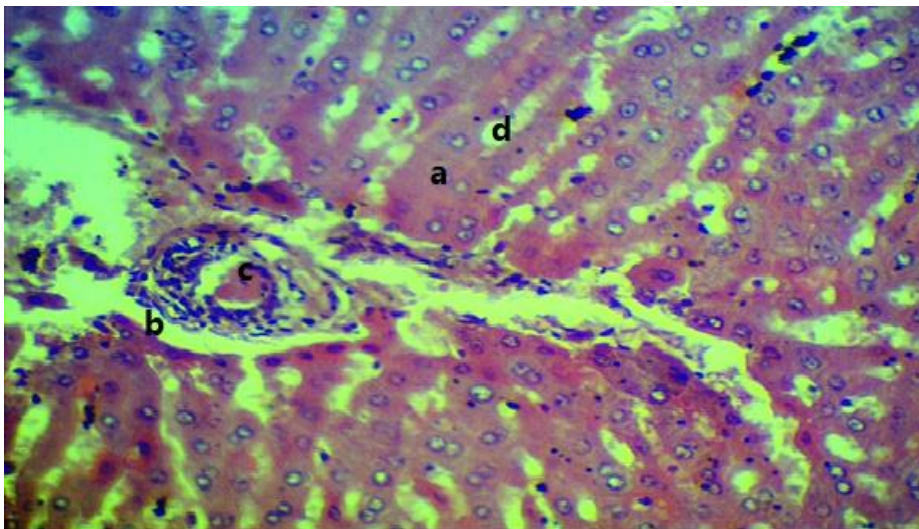


Figure 8: Histomorphological section belong to liver in 3<sup>rd</sup> group shows (a) severe hepatic necrosis (b), lymphocytic infiltration (c), central vein congestion (d) vacuolation (H&E stain, X20).

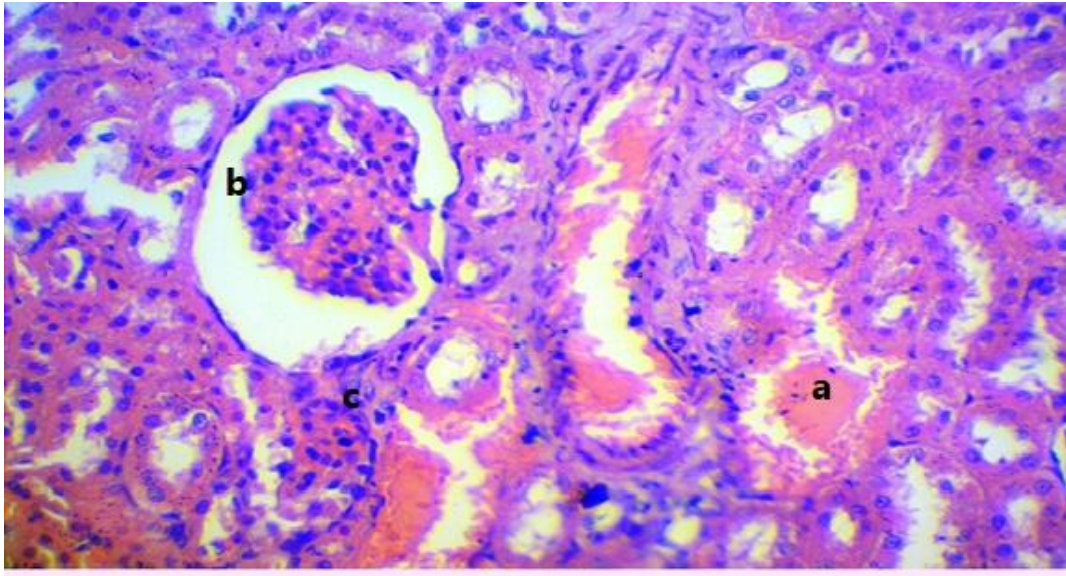


Figure 9: Histomorphological section belong to kidney in 3<sup>rd</sup> group shows hemorrhage (a), degenerated glomeruli (b), inflammatory cells infiltration (c) (H&E stain,X20 ).

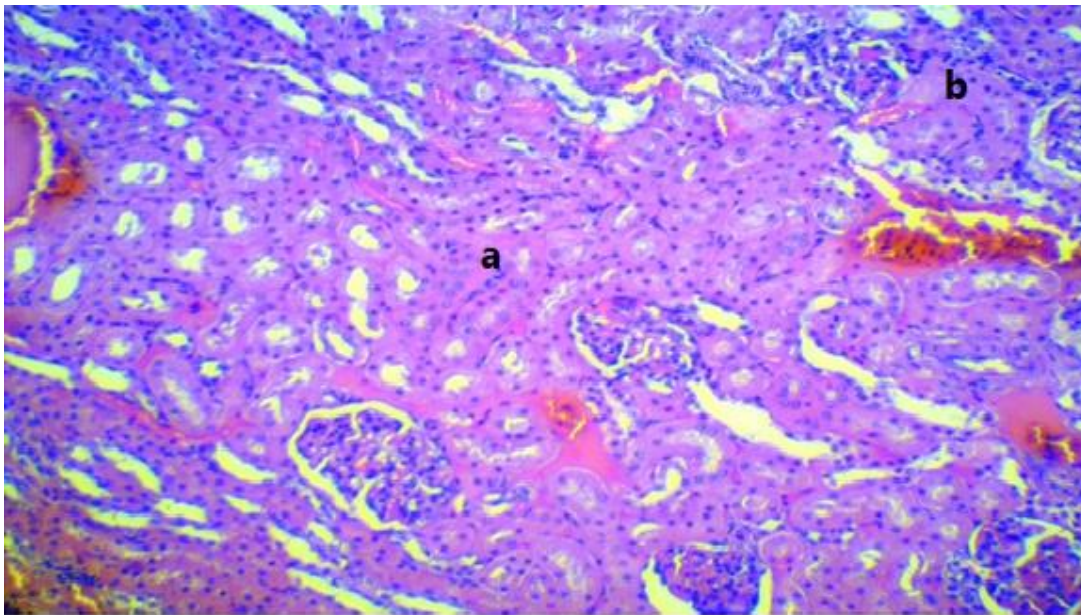


Figure 10: Histomorphological section belong to kidney in 3<sup>rd</sup> group shows severe degeneration and necrosis of proximal tubules(a), severe infiltration of inflammatory cells (b) (H&E stain, X20).

### Discussion:

In this experiment, it was found that there is an accumulation of cadmium in rabbits organs. To confirm, a histopathological and biochemical testing were performed on the kidney and liver because they are more affected by heavy toxic metals (Cadmium).

According to histopathological testing we found that the level of kidney damage in rabbit was higher than that detected in liver. Our results reflect that long exposure the livestock to cadmium may risk for health by cadmium accumulation in different tissues such as kidney, liver & muscle.

Our results agree with (Majid, 2018) was found a significant number of metals to be higher than the maximum permissible limit, and continuous monitoring of these metals is recommended to avoid their dangerous transmission to humans through food of animal origin.

The presence of heavy metals in living things able to have varying degrees of negative consequences on the digestive, nervous, cardiovascular, gastric and endocrine system as well as brain, liver, kidney, testis, muscles and adipose tissues. It has been shown that different amount of heavy metals can inhibit or slow the growth of a vary bacteria. Since bacteria are crucial for both host health and disease as well as food digestion, the harmful effects of heavy metal on microbes are receiving more and more attention (Nath *et al.*, 1984).

The biochemical and physiological tasks connected with the liver, brain and kidney imply that they are particularly prone to harm to metabolic process like as detoxification, storage and excretion of Xenobiotics and their metabolites, liver and kidney are regarded as essential organ (Poli *et al.*, 2022).

The current study showed rise in serum urea & creatinine levels, this result agree with (Kouadria *et al.*, 2020), who showed the creatinine and urea rise evaluated the renal and hepatic function as well as glomerular cell infiltration and that an rise in case of cadmium contamination the urea and creatinine through hepatic and kidney dysfunction in addition hepatic damage. Enzymatic activity of transaminases (ATS,ALT) also increased, however ALP activity significantly decreased when compare to the control group, these results agree with (Noel *et al.*, 2006; Matovic *et al.*, 2011) who showed transaminases (AST,ALT) have increased in enzymes implies damage is described by the leaking of enzymes from the tissue duo to altered membrane permeability to the plasma.

Treatment with Cd also weakens the cell membrane structurally and functionally, greatly increasing permeability and allowing hepatic enzyme to flow into the blood. Furthermore, a marked a rise in the plasma levels of albumin and bilirubin after Cd poisoning proved liver damage. Since these enzymes are leaking from the liver cytosol

toward blood stream, the elevated activity of AST and ALT in plasma can be indorsed to this (Ciobanu *et al.*, 2015).

Based on the finding of the current research study, the determined that Cd intoxicated caused toxicity of nephron, which resulted in increase of several metabolites in this tissue, ultimately causing renal injury and organismal death. The kidneys are essential for executing biotransformation activities as well as for the removal of different metabolites and unaltered medicine (Genchi *et al.*, 2020).

According to our analysis of histopathological sections from the second and third group, cadmium toxicity was evident in tissue damage and injury to the liver and kidney. These variations are brought on by increase in the lipid peroxidation, which causes an oxidative stress and the activation of cellular inflammation as well as the breakdown of lipid products (Rana *et al.*, 1996).

One of the most important toxic roles for the heavy metals such as cadmium and Acetothioamide is oxidative stress which promotes the generation of reactive oxygen species (Humadi *et al.*, 2019), free oxygen radicals have been implicated in a number of studies as the cause of these modification (Jamakala & Rani, 2014). In fact, these radicles have the ability to disperse to cytoplasm across the membranes in order to destroy cell components far away from their source of synthesis or to extent neighboring cells (Waalkers *et al.*, 1985).

This study discussed the detrimental effects of Cd residue on farm animals, including the internal edible organs and corpses of sheep, goats, and cattle and the hazard effects, suggests that eating the liver and kidney of any farm animal may be harmful to human health.

Cadmium is a hazardous element that has damaging effects on both humans and the environment. Organic production systems pay special attention to the presence of these elements, and according to the applicable regulation, meat can have up to 0.05% of these elements per kilogram (Maulvault *et al.*, 2015; Hurtado-Barroso *et al.*, 2019; Ciobanu *et al.*, 2021).

### **Conclusion:**

This finding confirmed that cadmium is a dangerous chemical that damages and negatively impacts the liver and kidney in terms of public health. Additionally, the hazard index suggests that eating the liver and kidney of any farm animal may be dangerous for human health.

### **Recommendation:**

1-Using preventative and control methods to lessen the impact of cadmium on the community and public health.

2-With the assistance of public nonprofit organization, public education about the harmful effects of heavy metals in the land, water and food is advised through lectures, TV and social media.

**Acknowledgment:**

The authors would especially want to thank the medical team and the staff at the University of Diyala, Iraq's College of Veterinary Medicine's Animal House. The authors also expressed gratitude to the pathology department staff at the College of Veterinary Medicine, University of Diyala, Iraq, for their assistance and the resources they made available for the work.

**Novelty statement:**

The novelty of this study to explain the toxic effects of cadmium chloride and public health risk in the liver & kidney after exposure to long time (75 days) by using relevant dose & different animal model.

**Authors contribution:**

These authors each contributed equally.

**References:**

- Akan JC, Abdulrahman FI, Sodipo OA, Chiroma YA (2010). Distribution of heavy metals in the liver, kidney and meat of beef, mutton, caprine and chicken from Kasuwan Shanu market in Maiduguri Metropolis, Borno State, Nigeria. *Research Journal of Applied Sciences, Engineering and Technology*, 2(8):743-748  
<https://www.researchgate.net/publication/49593820> Distribution of Heavy Metals in the Liver Kidney and Meat of Beef Mutton Caprine and Chicken from Kasuwan Shanu Market in Maiduguri Metropolis Borno State Nigeria
- Akoto, O., Bortey-Sam, N., Nakayama, S. M., Ikenaka, Y., & Baidoo, E. (2014). Distribution of heavy metals in organs of sheep and goat reared in Obuasi: A gold mining town in Ghana  
<https://www.researchgate.net/publication/303543948> Distribution of Heavy Metals in Organs of Sheep and Goat Reared in Obuasi A Gold Mining Town in Ghana
- Lukáčová, A., Lopašovsk½, L., Kňazická, Z., & Golian, J. (2015). Concentration of cadmium in meat and selected meats products. *Journal of microbiology, biotechnology and food sciences*, 4(special issue 3 (Food Sciences)), 102-105.  
<https://doi.org/10.15414/jmbfs.2015.4.special3.102-105>
- Bala A, Muhammad LU, Pewan SB, Ahmed MS, Muhammad M, Junaidu AU, Saulawa, MA (2013). Determination of lead (Pb) residue in kidney, liver and muscle of slaughtered cattle in Jos Central Abattoir, Plateau State, Nigeria. *J. of Environ. Sci.*

- Toxicology and Food Technology (ISOR-JESTFT), 7(6): 48-51.  
<https://www.iosrjournals.org/iosr-jestft/papers/vol7-issue6/H0764851.pdf>
- Bancroft JD and Gamble M. (2008). Theory and practice of histological techniques. Elsevier health sciences.
- Baykov, B. D., Stoyanov, M. P., & Gugova, M. L. (1996). Cadmium and lead bioaccumulation in male chickens for high food concentrations. Toxicological & Environmental Chemistry, 54(1-4), 155-159.
- Bench G, Corzett, MH, Martinelli R, Balhorn R (1999). Cadmium concentrations in the testes, sperm, and spermatids of mice subjected to long-term cadmium chloride exposure. Cytometry: The Journal of the International Society for Analytical Cytology, 35(1): 30-36. [https://doi.org/10.1002/\(SICI\)1097-0320\(19990101\)35](https://doi.org/10.1002/(SICI)1097-0320(19990101)35)
- Chung FL, Chen HJ, Nath RG (1996). Lipid peroxidation as a potential endogenous source for the formation of exocyclic DNA adducts. Carcinogenesis, 17(10): 2105-2111. <https://doi.org/10.1093/carcin/17.10.2105>.
- Ciobanu C, Solcan C, Anton A, Solcan G, Cuciureanu R (2015). Effect of Selenium Supplementation on Serum Amylase, Lactate Dehydrogenase and Alkaline Phosphatase Activities in Rats Exposed to Cadmium or Lead. Cercetări agronomice în Moldova, 47(4). URI: <https://repository.uaiasi.ro/xmlui/handle/20.500.12811/1760>
- Ciobanu MM, BOIȘTEANU PC, Munteanu M, Târziu D, Rațu RN, Postolache AN (2021). Bioavailability of heavy metals (Pb and Cd) in wild roe deer meat. Scientific Papers. Series D. Animal Science, 64(2).
- Genchi G, Sinicropi MS, Lauria G, Carocci A, Catalano A (2020). The effects of cadmium toxicity. International journal of environmental research and public health, 17(11): 3782. <https://doi.org/10.3390/ijerph17113782>
- Gleason A (2021). Meat Science: Nutritional Aspects
- González-Montaña JR, Senís E, Gutiérrez A, Prieto F (2012). Cadmium and lead in bovine milk in the mining area of the Caudal River (Spain). Environmental monitoring and assessment, 184: 4029-4034.
- González-Weller D, Karlsson L, Caballero A, Hernández F, Gutiérrez A, González-Iglesias T, Hardisson A (2006). Lead and cadmium in meat and meat products consumed by the population in Tenerife Island, Spain. Food additives and Contaminants, 23(8): 757-763. <https://doi.org/10.1080/02652030600758142>
- Hurtado-Barroso S, Tresserra-Rimbau A, Vallverdú-Queralt A, Lamuela-Raventós RM (2019). Organic food and the impact on human health. Critical reviews in food science and nutrition, 59(4): 704-714. <https://doi.org/10.1080/10408398.2017.1394815>

- Ihedioha JN, Okoye CO. Ihedioha, J. N, Okoye CO (2013). Dietary intake and health risk assessment of lead and cadmium via consumption of cow meat for an urban population in Enugu State, Nigeria. *Ecotoxicology and environmental safety*, 93: 101-106. <https://doi.org/10.1016/j.ecoenv.2013.04.010>
- Jamakala OB, Rani AU (2014). Mitigating role of zinc and iron against cadmium induced toxicity in liver and kidney of male albino rat: a study with reference to metallothionein quantification. *International Journal of Pharmacy and Pharmaceutical Sciences*, 6(9): 411-17.
- Kouadria M, Djemli S, Tahraoui A (2020). Hepatoprotective effect of Zinc and Magnesium against subchronic Cadmium toxicity on biochemical, histopathological and neurobehavioral parameters in Wistar rats. *Journal of Animal Behaviour and Biometeorology*, 8(1): 63-73. <http://dx.doi.org/10.31893/jabb.20009>
- Kumar A, Prakash S, Parmar A, Bajpeyee AK (2019). Effect of cadmium on fresh water teleost, *Heteropneustes fossilis* (Bloch). *Brain*, 11(20.10): 41-06.
- Barrett, K. C., Leech, N. L., & Morgan, G. A. (2014). *IBM SPSS for intermediate statistics: Use and interpretation*. Routledge.
- Hashemi, M. (2018). Heavy metal concentrations in bovine tissues (muscle, liver and kidney) and their relationship with heavy metal contents in consumed feed. *Ecotoxicology and environmental safety*, 154, 263-267.
- Domínguez, M. T., Madrid, F., Marañón, T., & Murillo, J. M. (2009). Cadmium availability in soil and retention in oak roots: potential for phytostabilization. *Chemosphere*, 76(4), 480-486.
- Matović V, Buha A, Bulat Z, Đukić-Ćosić D (2011). Cadmium toxicity revisited: focus on oxidative stress induction and interactions with zinc and magnesium. *Arhiv za higijenu rada i toksikologiju*, 62(1): 65-75. <https://doi.org/10.2478/10004-1254-62-2011-2075>
- Matović V, Buha A, Đukić-Ćosić D, Bulat Z (2015). Insight into the oxidative stress induced by lead and/or cadmium in blood, liver and kidneys. *Food and Chemical Toxicology*, 78: 130-140. <https://doi.org/10.1016/j.fct.2015.02.011>
- Maulvault AL, Anacleto P, Barbosa V, Sloth JJ, Rasmussen RR, Tediosi A, Marques A (2015). Toxic elements and speciation in seafood samples from different contaminated sites in Europe. *Environmental research*, 143: 72-81. <https://doi.org/10.1016/j.envres.2015.09.016>
- Muñoz-Olivas, R., & Cámara, C. (2001). Speciation related to human. Trace element speciation for environment, food and health, 331.
- Nath R, Prasad R, Palinal VK, Chopra RK (1984). Molecular basis of cadmium toxicity. *Progress in food & nutrition science*, 8(1-2): 109-163.

- Nkansah MA, Ansah JK (2014). Determination of Cd, Hg, as, Cr and Pb levels in meat from the Kumasi central abattoir. *International journal of scientific and research publications*, 4(8): 1-4
- Noël L, Huynh-Delerme C, Guérin T, Huet H, Frémy JM, Kolf-Clauw M (2006). Cadmium accumulation and interactions with zinc, copper, and manganese, analysed by ICP-MS in a long-term Caco-2 TC7 cell model. *Biometals.*, 19: 473-481.
- Okorafor KA, Amadi P (2015). Concentrations of some metals in kidneys and liver of goats slaughtered at Atakpa Abattoir, Calabar South, Cross Rivers State, Nigeria. *Biosciences Research in Today's World*, 1(1): 90-96
- Poli V, Madduru R, Aparna Y, Kandukuri V, Motireddy SR (2022). Amelioration of cadmium-induced oxidative damage in wistar rats by Vitamin C, zinc and N-acetylcysteine. *Medical Sciences*, 10(1): 7.  
<https://doi.org/10.3390/medsci10010007>
- Prakash, S., & Verma, A. K. (2021). Effect of water pollutants on the Snake headed fish, *Channa punctatus* collected from the Sawan Nallaha, Balrampur, UP. *International Journal of Fauna and Biological Studies*, 8(1), 38-42.  
<https://ssrn.com/abstract=3777207>
- Rana SV, Singh R, Verma S (1996). Protective effects of few antioxidants on liver function in rats treated with cadmium and mercury.
- Waalkers MP, Kasprzak KS, Ohshima M, Poirier LA (1985). Protective effects of zinc acetate toward the toxicity of nickelous acetate in rats. *Toxicology*, 34(1): 29-41.  
[https://doi.org/10.1016/0300-483X\(85\)90076-9](https://doi.org/10.1016/0300-483X(85)90076-9)
- Yabe J, Nakayama SM, Ikenaka Y, Muzandu K, Ishizuka M, Umemura T (2011). Uptake of lead, cadmium, and other metals in the liver and kidneys of cattle near a lead-zinc mine in Kabwe, Zambia. *Environmental Toxicology and Chemistry*, 30(8): 1892-1897. <https://doi.org/10.1002/etc.580>
- Roggeman, S., De Boeck, G., De Cock, H., Blust, R., & Bervoets, L. (2014). Accumulation and detoxification of metals and arsenic in tissues of cattle (*Bos taurus*), and the risks for human consumption. *Science of the Total Environment*, 466, 175-184.
- Humadi, A. A., Al-Kaisei, B. I., Humadai, T. J., & Al-Ezzy, A. I. A. (2019). Toxicopathological, Cytogenetic Effects of Acetothioamide on Female Albino Mice Reproductive System. *Open Access Maced J Med Sci. Med. Sci*, 7(23), 1-5.