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Research Article

Histopathological Alterations in Cardiac and Pulmonary Tissues Following Solder Paste Fume Inhalation in Wistar Rats

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Abstract

Occupational exposure to solder paste fumes is common among handset repairers and workers in electronic and industrial settings, particularly in underdeveloped countries where protective measures are often lacking. Despite known health concerns, experimental evidence on the histopathological effects of solder paste fumes on vital organs remains limited. This study investigated the impact of chronic inhalation of solder paste fumes on the heart and lungs of Wistar rats. Forty rats were divided into control (n = 12) and exposed (n = 28) groups. The exposed group inhaled solder paste fumes at a dose of 0.18 g twice daily for eight weeks. Tissue samples were collected at two-week intervals for histopathological evaluation. Results revealed hyperemia and distortion of cardiac muscle fibers in the hearts of exposed rats, while lung tissues showed severe degenerative and necrotic changes in alveolar sacs and ducts. These findings demonstrate that prolonged inhalation of solder paste fumes causes significant cardiac and pulmonary tissue damage, highlighting serious cardiovascular and respiratory risks. The study underscores the importance of implementing appropriate occupational safety measures to protect individuals routinely exposed to solder fumes.

Keywords

Histopathology, Heart, Lung, Solder Paste, Rats

1. Introduction

Solder paste is a critical material used in the electronics industry for soldering electronic components onto printed circuit boards (PCB) [1]. Surface mount technology (SMT) techniques, which entail soldering components with tiny lead spacing onto PCBs, are the main applications for solder paste. Higher component density, smaller boards, and better

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electrical performance are just a few benefits of SMT soldering [2]. Using surface junction technology instead of through-hole technology is one of the most popular trends in the design and production of contemporary electronics packages and assemblies [3]. Many pollutants are produced in toxic vapors during the soldering process at rates that can result in both immediate and long-term health issues [4]. Approximately over one million workers globally perform welding as part of their work responsibilities [5]. The human body is poisoned by a variety of fumes produced during metal welding, including formaldehyde and metal vapors like lead (Pb) and stannum (Sn) [6]. According to epidemiological research, these fumes and gases pose a major risk to workers' health [7] and the potential of colophony to cause pulmonary diseases has been reported. However, research on soldering-related electronics workers has shown mixed findings [8].

The risk of developing occupational asthma symptoms to be significantly higher in electronics workers exposed to soldering in comparison to those not exposed [9]. Welding fumes may be carcinogenic to people, according to the International Agency for Research on Cancer (IGRC), although this conclusion was based on insufficient data in laboratory animals and limited evidence in humans [9]. Full-time welders frequently experience respiratory side effects, such as bronchitis, airway inflammation, altered lung function, lung fibrosis, and even an increased risk of lung cancer [10]. In vivo studies reported that welding fume is toxic both to mammalian and mutagenic cells [5]. A considerable decline in lung function is also linked to long-term exposure to welding fumes. There is mounting evidence that exposure to welding fumes may be linked to a higher risk of cardiovascular disease [11]. Excessive prevalence of respiratory symptoms has been linked to occupational exposure to soldering fumes and gases. bronchial asthma, lower respiratory tract symptoms include coughing, phlegm production, wheezing, and abnormalities in pulmonary function, and irritative symptoms of the nose and throat [12, 13]. Environmental regulations, such as the Restriction of Hazardous Substances (RoHS) directive, have led to the development and increased usage of lead-free solder pastes [14]. Research has been done on the pulmonary effects of solder fume exposure in electronics workers, although the findings have been mixed [8].

Solder paste has been used widely across Nigeria especially in areas of global system for mobile communication (GSM) repair and the effect of this on respiratory and cardiovascular system is yet to be documented in the study area. The study is aimed at establishing the histological changes associated with exposure to solder paste fumes in the cardiopulmonary systems. The study will provides information on the histological changes associated with exposure to solder paste fumes in the lung and heart. It will also provide an insight on the possible effect of exposure to solder paste fumes and create awareness on the need for the use of protective equipment.

2. Materials and Methods

2.1. Materials

Materials used during the experiment include solder paste obtained from ANYIBEST ®, Gas cylinder, light source (Match stick and Lighter), Face mask, Hand gloves, Weighing balance, Nylon sheath, 5ml syringe, Ketamine and Xylazine, Cotton, 10% Formaldehyde and sample bottles.

2.2. Study Area

The research was carried out during September and October of 2023. The study was carried out in the Usmanu Danfodiyo University city campus complex in Sokoto, which is situated in Sokoto State's Sokoto North Local Government Area. Sokoto State is situated between latitudes 120N and 13058N and longitudes 408E and 6054E in the far northwest of Nigeria. Due to its position, it borders Zamfara to the east, Kebbi to the west and southwest, and the Republic of Niger to the north. It has a total land area of over 32,000 square kilometers [15].

2.3. Study Design

Forty (40) Wistar rats were employed. The rats were divided into two groups: the treatment group (28 rats) and the control group (12 rats). Eight (8) weeks was the intended duration of the experiment.

2.4. Ethical Approval

The Faculty Animal Research and Ethics Committee (FAREC) of Usmanu Danfodiyo University, Sokoto's Faculty of Veterinary Medicine was consulted for ethical permission (UDUS/FAREC/AUP-R15/2024). The National Institute of Health's (NHI) criteria for the care and use of animals were followed in all procedures involving animals.

2.5. Experimental Animals

For the investigation, forty (40) Wistar rats were kept in a three-step iron cage that was specifically manufactured for practical purposes. The rats were divided into two groups: the experimental group (28 rats) and the control group (12 rats). During the experiment, commercial poultry feed (Topfeed®) and borehole water were given to the animals without restriction. They were acclimatized for one weeks [16] and maintained at room temperature of (25 ± 4°C) and humidity (40 – 60%) on a normal 12-h light-dark cycle [17].

2.6. Exposure to Solder Paste

Five grams of solder paste were measured for each exposure to determine how much was utilized. The fume was created by heating the solder paste on a metal plate. Over the

course of eight weeks, the rats were inhaled 0.18g of solder paste fume twice a day (morning at 8:00 am and evening at 5:00 pm) for seven (7) minutes. The initial weight of each rat was taken before the commencement of the experiment and repeated weekly throughout the experimental period. This process of exposure was maintained for eight (8) weeks, and after every two (2) weeks, tissue sample was collected by randomly selecting three (3) rats from the control group and seven (7) rats from the experimental group.

2.7. Lung and Heart Tissues Collection

The rats were euthanized using 40 mg/ kg of Ketamine and 5 mg/ kg of Xylazine and samples were collected through Postmortem procedure. Samples were preserved using 10% Formaldehyde.

3. Results

Histopathological examination was performed to evaluate structural changes in cardiac and pulmonary tissues of Wistar rats following solder paste fume inhalation. Heart and lung tissue samples were fixed in 10% formalin (neutral buffered), which were processed using routine histopathological techniques, sectioned, and stained with hematoxylin and eosin (H & E). A light microscope was used to examined the histological sections under for evidence of tissue architecture disruption, inflammatory cell infiltration, vascular congestion, edema, cellular degeneration, and other pathological changes. The observations were documented and compared between control and exposed groups to determine the histopathological impact of solder paste fume inhalation on cardiac and pulmonary tissues.

The finding showed normal architecture of the heart muscle at two week is presented in Figure 1 (control). Comparison with the exposed group revealed multiple area of hyperemia and distorted cardiomyocytes as shown in Figure 1 (treated).

The normal lung architecture is presented in Figure 2 (control). Areas of necrosis in the lungs were evident at two weeks of exposure as presented in Figure 2 (treated).

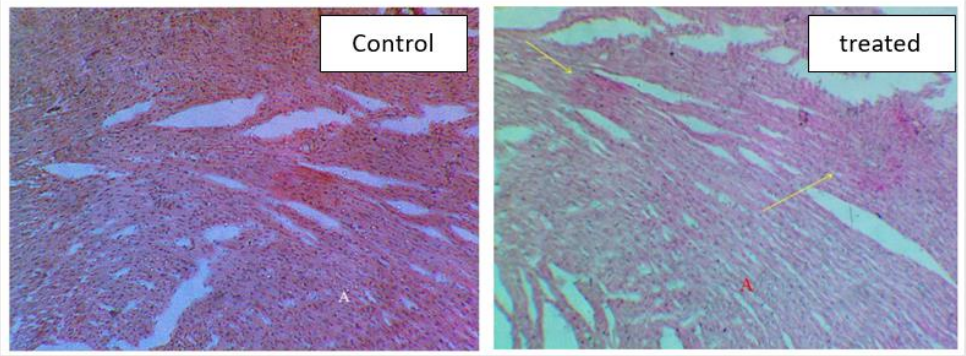

Figure 1. *Control: Showing Cardiomyocytes of the control group with normal histological architecture of the heart at two weeks exposure. treated: Showing distorted Cardiomyocytes, multiple arrows showing areas of hyperemia at two weeks exposure.*

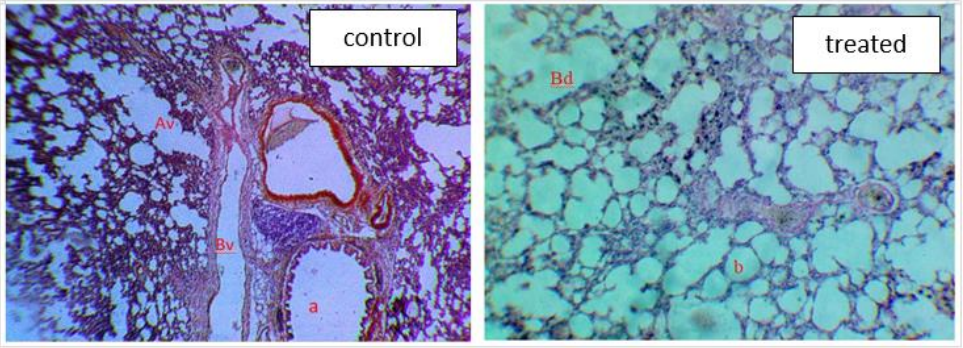

Figure 2. *Control: showing normal alveolar tree (a), the Alveolar duct (Av), and blood vessels (Bv) of the control group at two weeks exposure. treated: showing alveolar sac (b) and alveolar duct of sample specimen showing necrotic changes at two weeks exposure.*

At 4 weeks of exposure, there was evidence of necrosis in the cardiomyocytes as displayed in Figure 3 (treated) as compared to control Figure 3 (control).

Evidence of necrosis and multiple dilatation of alveolar sacs were found in the lungs as presented in Figure 4 (treated) as

compared to control Figure 4 (control)

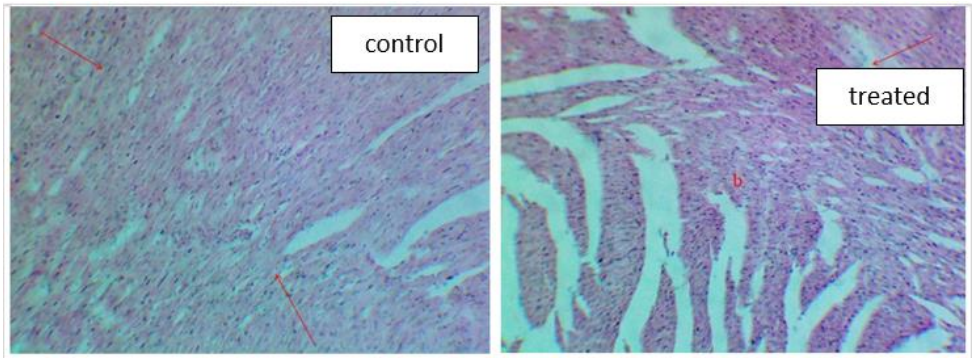

Figure 3. *Control: multiple arrows showing cardiac muscle cells of the control group at four weeks exposure. treated: showing cardiomyocytes with arrow showing necrotic area at four weeks exposure.*

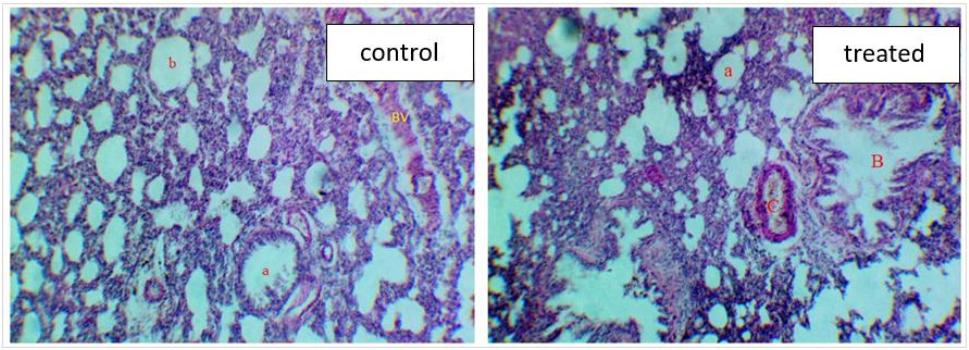

Figure 4. *Control: showing alveolar tree (a), the Alveolar sac (b), and Blood vessels (Bv) of the control group at four weeks exposure. while treated: Alveolar sac (a), Alveolar tree (B) and Blood vessels (C); showing degenerative changes of sample specimen at four weeks exposure.*

At six week of exposure, arears of hyperemia in heart muscle were visible as shown in Figure 5 (treated) as compared to control Figure 5 (control).

Evidence of necrosis and severe dilatation in the lungs are presented in Figure 6 (treated) as compared to control Figure 6 (control).

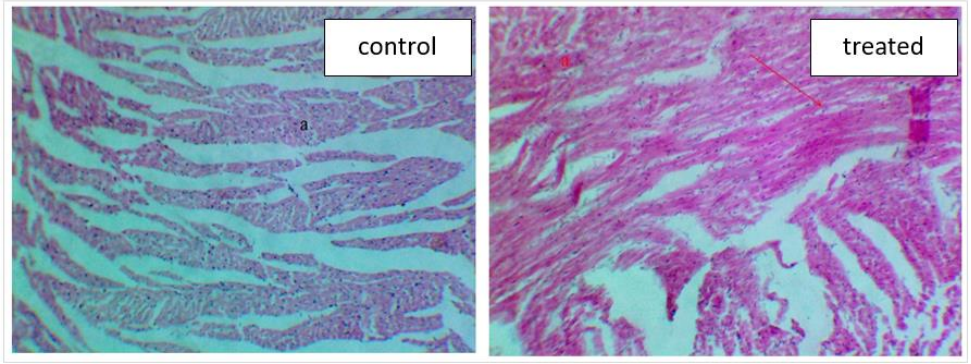

Figure 5. *Control: Showing cardiomyocytes of the control group with normal histological architecture of the heart at six weeks exposure. treated: Showing Cardiomyocytes with arrow showing areas of severe hyperemia at six weeks exposure.*

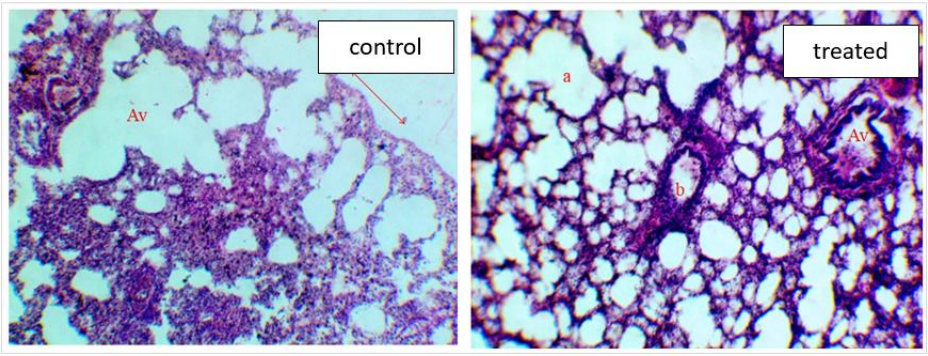

Figure 6. *Control: Showing alveolar duct, with arrow showing the epithelial lining of the control group at six weeks exposure. treated: showing degenerative changes of alveolar sac (a), blood vessels (b) and alveolar tree (Av) of sample specimen at six weeks exposure.*

Histological slides of exposure at eight weeks revealed hyperemic changes in the cardiac muscle as presented in Figure 7 (treated) as compared to control Figure 7 (control).

Likewise, necrotic changes and severe dilatation of the air sacs were observed in the lungs as presented in Figure 8 (treated) as compared to control Figure 8 (control).

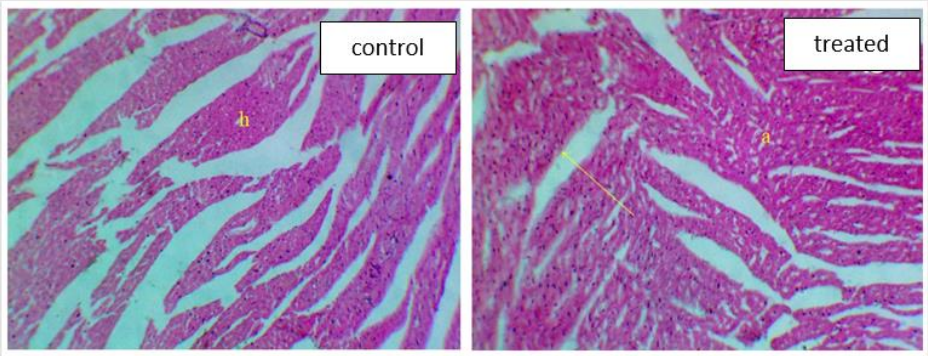

Figure 7. *Control: showing cardiomyocytes of the control group with normal histological architecture of the heart at eight weeks exposure (h). treated: showing cardiomyocytes (a) with arrow showing areas of severe hyperemia at eight weeks exposure.*

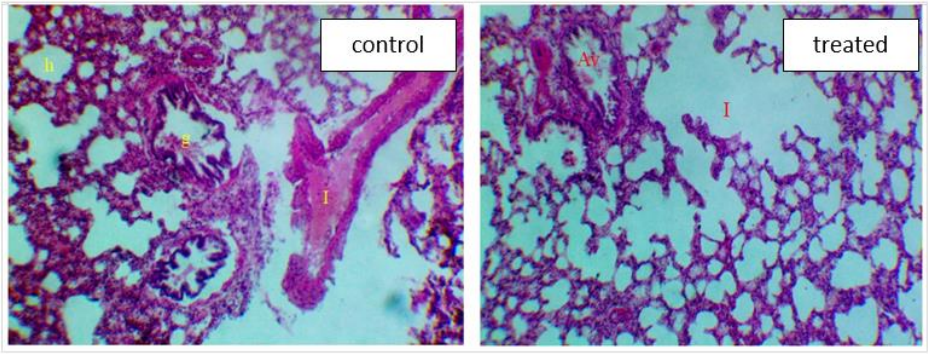

Figure 8. *Control: showing alveolar tree (g), the alveolar sac (h) and blood vessels (I) of the control group at eight weeks exposure. treated: alveolar sac (a), alveolar tree (Av) with degenerative changes of sample specimen at eight weeks exposure. while blood vessels surrounded with necrotic changes and multiple dilations of the air sacs.*

4. Discussion

Exposure to solder fumes presented discernible alterations, notably areas of hyperemia within cardiomyocytes which is suggestive of inflammatory response that could disorganize the cardiac function. This response could be due to chemical interaction of particles in the fume and membrane proteins which

changed the conformity and permeability of the membrane thereby triggering inflammatory reaction in the earlier weeks of exposure, this supports the finding of Reza et al [18]. Necrotic changes observed at the later phase of exposure could be due to extensive interaction between the particles in the fume and membrane biomolecules thereby affecting the functionality of membrane lipids leading to free influx extracellular and efflux of intracellular materials resulting in cell death.

The necrotic changes in the lungs could be due to loss of membrane integrity resulting from damage due to physical interaction between the particles in the fume and membrane architectural compounds resulting in pneumonitis and eventually necrosis. This conforms with the findings of Hameed et al [19]. the continuous exposure could lead to accumulation of the particles within the cell leading to dilatation and eventual necrosis of the alveoli. This conforms with the findings of Courtney [20] but contradicts the finding of Gupta et al [21].

5. Conclusion

In conclusion, solder paste fume constitutes potential hazard as it causes cellular damage in the heart and lung tissues of exposed rats.

Abbreviations

PCB	Printed Circuit Boards
SMT	Surface Mount Technology
Pb	Lead
Sn	Stanum
RoHS	Restriction of Hazardous Substances
GSM	Global System for Mobile Communication
FAREC	Faculty Animal Research and Ethics Committee

Author Contributions

Ashiru Dahiru: Conceptualization, Visualization, Writing – original draft

Bashir Saidu: Supervision, Validation

Jabir Muhammad Ahmad: Resources

Nafisat Abdulazeez: Writing – original draft

Zaid Shehu: Visualization

Shurhabilu Ja'afar: Methodology

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Keating, M. (2012). Introduction to Solder Paste. IPC – Association Connecting Electronics Industries.

[2] Tummala, R. R., Rymaszewski, E. J. and Klopfenstein, A. G. (1997). Microelectronics Packaging Handbook. 3rd edition.

[3] Ndukwe, E. (2003). The role of telecommunication in national development.' The Guardian, 38.

[4] Arab, M. R., Mirzaei, R., Karimi, M., & Mashhadi, R. (2010). *The study of histological effects of solder fumes in rat lungs*. *Iranian Journal of Basic Medical Sciences, 13*, 63–68. https://doi.org/10.22038/ijbms.2010.5085

[5] Antonini, J. M., Leonard, S. S., Roberts, J. R., Solano, Lopez, C., Young, S. H. and Shi, X. (2005). Effect of stainless steel manual arc welding fume on free radical production, DNA damage and apoptosis. Molecular and Cellular Biochemistry 279(1-2): 17-23. https://doi.org/10.1007/s11010-005-8211-6

[6] Pippen, D. L. (1999). A primer on hand soldering electronic connections. New Mexico State University Press. 1–10.

[7] Borska, L., Fiala, Z., Smejkalová, J., & Tejral, J. (2019). Health risk of occupational exposure in welding processes I: Genotoxic risk. Acta Medica (Hradec Králové, Czech Republic), 46(1), 25–29. https://doi.org/10.14712/18059694.2019.5

[8] Mendy, A., Gasana, J., Forno, E., Vieira, E. R., & Dowdye, C. (2012). Work-related respiratory symptoms and lung function among solderers in the electronics industry: A meta-analysis. Environmental Health and Preventive Medicine, 17(3), 183–190. https://doi.org/10.1007/s12199-011-0236-8

[9] Palmer, K. and Crane, G. (1997). Respiratory disease in workers exposed to colophony solder flux fumes: Continuing health concerns. Occupational Medicine. 47(8): 491-6. https://doi.org/10.1093/occmed/47.8.491

[10] Yu, I. J., Song, K. S., Maeng, S. H., Kim, S. J., Sung, J. H. and Han, J. H. (2004). Inflammatory and genotoxic responses during 30 day welding fume exposure period. Toxicology Letters. 154(1-2): 105-15. https://doi.org/10.1016/j.toxlet.2004.07.009

[11] Kim, J. Y., Chen, J. C., Boyce, P. D. and Christiani, D. C. (2005). Exposure to welding fumes is associated with acute systemic inflammatory responses. Occupational Environmental Medicine. 62(3): 157-63. https://doi.org/10.1136/oem.2004.014795

[12] Mozaffari, S., Heibati, B., Jaakkola, M. S., Lajunen, T. K., Kalteh, S., Alimoradi, H., Nazari, M., Karimi, A., & Jaakkola, J. J. K. (2023). Effects of occupational exposures on respiratory health in steel factory workers. Frontiers in Public Health, 11, Article 1082874. https://doi.org/10.3389/fpubh.2023.1082874

[13] Patwa, A. and Shah, A. (2015). Anatomy and physiology of respiratory system relevant to anaesthesia. Indian Journal Anaesthesia. 59(9): 533–541. https://doi.org/10.4103/0019-5049.165849

[14] IPC (2015). Association Connecting Electronics Industries. IPC J-STD-005 Requirements for Soldering Pastes.

[15] ICT Directorate Sokoto State Government (2023). https://sokotostate.gov.ng/history-ofsokoto/the-land/ retrieved 15-07-2023.

[16] Tonetto, S., Weikop, P., Brudek, T., & Thomsen, M. (2023). Behavioral and biochemical effects of alcohol withdrawal in female C3H/HeNRj and C57BL/6JRj mice. Frontiers in Behavioral Neuroscience, 17. https://doi.org/10.3389/fnbeh.2023.1143720

[17] Barnhart, C. D., Yang, D., & Lein, P. J. (2015). Using the Morris water maze to assess spatial learning and memory in weanling mice. PLoS ONE, 10(4). https://doi.org/10.1371/journal.pone.0124521

[18] Reza, R. and Singh, G. (2010). Heavy Metal Contamination and Its Indexing Approach for River Water. International Journal of Environmental Sciences Technology, 7, 785-792. https://doi.org/10.1007/BF03326187

[19] Hameed, R., V., R., Cleetus, M., Augustine, J., & R., D. (2022). *Soldering fume exposure as a cause of acute hypersensitivity pneumonitis. European Journal of Pharmaceutical and Medical Research, 9*(4), 123–129.

[20] Courtney, D. (1985). Health hazards of soft soldering in the electronics industry. Reviews on Environmental Health, 5(1), 1–26. https://pubmed.ncbi.nlm.nih.gov/294419/

[21] Gupta, B. N., Rastogi, S. K., Husain, T., Mathur, N., & Pangtey, B. S. (1991). A study of respiratory morbidity and pulmonary function among solderers in the electronics industry. American Industrial Hygiene Association Journal, 52(2), 45–51. https://doi.org/10.1080/15298669191364316