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Review Report

An Integrative Review of Laboratory Accidents among Metallurgical Technicians: Types, Causes, Effects and Prevention Strategies

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Abstract: Prevention, they say, is cheaper, easier and better than curing. It is from this maxim that this study was conceptualized. Metallurgical laboratory accidents are an issue of great concern because it not only affect the productivity and economic growth of an organization but also the physical, mental, and entire wellbeing of the victim. This study was aimed at reviewing the types and causes of metallurgical laboratory accidents, their effects, and their preventive measures. It was concluded that if the identified preventive measures are strictly adhered to, the prevalence of such accidents would be curtailed tremendously.

Keywords: Accident, Alloys, Characterization, Metals, Metallurgical laboratory, Testing

1. Introduction

A compartment that is well ventilated, lighted and equipped with analytical facilities, equipment and tools for characterizing and testing metals and their alloys and composites is regarded as a metallurgical laboratory (ML) (Vinarcik, 2009). Properties of metals tested in a typical metallurgical laboratory are manifold (Reardon, 2011). As can be seen in Figure 1, machines for testing hardness, tensile strength and microstructure are obtainable in a metallurgical lab. Other equipment like muffle furnace for heating of materials (Gouthama et al., 2016), lathe machines for cutting, grinding drilling, knurling, and threading of components (Reddy & Prakash, 2020), and polishing machine for sample preparations are all obtainable in a metallurgical lab. The significance of metallurgical laboratories cannot be over emphasized as they are utilized by so many industries like aeroplane, automobile, electrical, electronic, structural, medical, and energy. It is at metallurgical laboratories that the quality and safety of metals and metallic alloys and composites are tested and certified (García-Toraño et al., 2014). Sensitive devices like surgical blades, aerospace nozzles and sensors, electronic and computer chips are all tested and characterized in metallurgical laboratories. There are other essential microstructural characterizations that are carried out in an ML. The equipment and their functions include: i) optical microscopes (Davidson & Abramowitz, 2002) (used for obtaining an enlarged view of a very tiny structure which cannot be visualized with ordinary eyes like corrosion and wear details on a metallic material). ii) Scanning electron microscopes (SEM) (used for obtaining magnification of micro/ nano substances in 3D image which differentiates it from optical microscope. More so, it uses electron beams which has shorter wavelength than light beam being used by optical microscope, hence, SEM is stronger and more powerful in getting the detailed interpretation of tiny materials than optical microscope (Goldstein et al., 2017). It is usually used in obtaining the chemical composition of materials in material science and metallurgy, biological sciences and nanotechnology). iii) Energy-dispersive spectroscopy (EDS) (used in obtaining the chemical composition of materials along with SEM but goes further to obtain the quantity of trace elements and impurities present by generating a spectrum of energy which shows the quantity of all the element therein). iv) X-ray diffraction (XRD) machine (this gives the chemical composition and crystal structure of a material).

Laboratory operations in an ideal ML can be divided into four main stages, namely: (a) preparation of samples, (b) characterization and testing (C) reportage, and (d) quality control. In the first stage which is preparation of sample, operations include cutting of material, grinding and polishing of materials to mirror image, and fixing the sample to run a particular test. The next stage is characterization or testing. If it is microstructure, the sample is mounted on an optical microscope, SEM or XRD equipment. But if it is testing, like hardness for instance, the sample is fixed on the hardness tester and tested. After analysis, the results generated are recorded and reported. Thereafter, quality control inspection on the equipment and results are conducted to ensure precision and reliability.

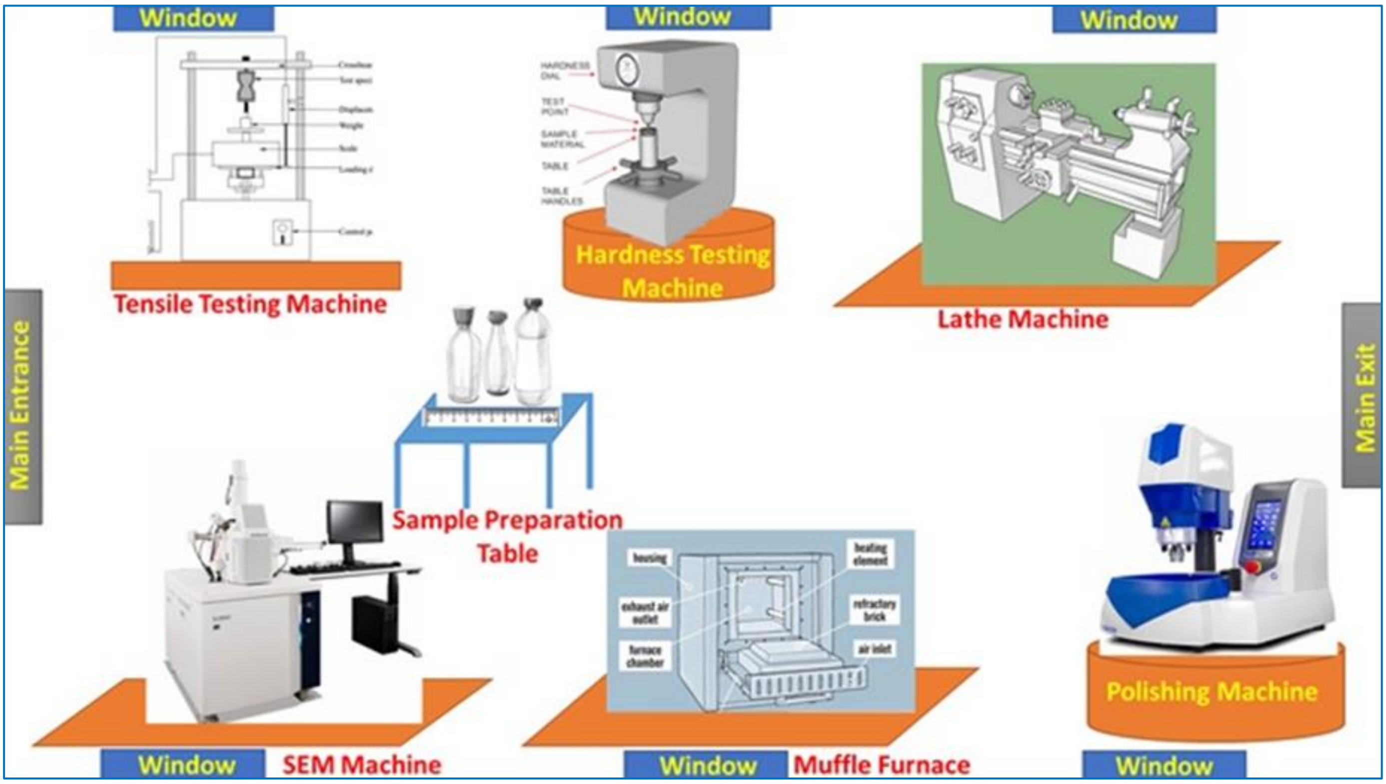

Figure 1: Sketch of a Typical Metallurgical Laboratory

According to (Vernidub, Klypin, Novokshchenova, Panarina, & Pirusskii, 2001), the Principal aim of establishing a metallurgical lab is to guarantee the superiority, control and purity of metals and alloys used in industrial and other applications. The said industries need metals and alloys with some specifications. Some application in the aerospace and automotive industries require metals with high strength, low density and high thermal, wear and corrosion resistance (Campbell Jr, 2011). However, metals required in production of surgical equipment and medical implants must possess high quality, purity, toughness, wear and corrosion resistance (Chen & Thouas, 2015; Javaid & Haleem, 2018). Also, metals for kitchen utensils like knife and spoons should have low density, high wear resistance, high corrosion resistance and high resistance to chemicals (White, Howarth, & Delport, 2013), hence, the application of stainless steel and Al in the production of kitchen knives and pots because of their corrosion resistance (Metikoš-Huković, Babić, Grubač, Petrović, & Lajçi, 2011; Ujah, Popoola, Popoola, & Aigbodion, 2020). It is through metallurgical testing that those metals are certified fit for their various applications. The testing is imperative to forestall catastrophic consequences accruing from using sub-standard components, devices or finished products. Design and development of novel alloys are conducted in metallurgical labs. Through the invention of robust superior alloys, the efficiency of metal works can be upgraded. Meanwhile, cost saving through energy conservation is achieved through testing and optimization of process parameter of metallurgical processes in the lab. Metallic material's reliability and safety in service are ensured through metal testing in the lab. Through metal testing, prospective imperfections which can evoke failure of metal components and cause accidents, wounds and possible infections are prevented (Tallam et al., 2007).

Despite the positive attributes and contributions of metallurgical labs, there are still negative effects of the ML. Metals and alloy testing require experienced technicians and expensive equipment (Marines et al., 2003). So, using these skillful manpower and facility may increase the production cost of materials and so, increase the production cost and subsequently result to higher cost of goods and services. Testing may introduce unnecessary bottleneck into production and distribution of goods because it takes a lot of time. Another negative effect of metallurgical lab is the health issue of electromagnetic radiations as they are emitted by most microstructural characterization equipment like XRD and SEM. These radiations are carcinogenic and very hazardous to internal tissues and organs (Yakymenko & Sidorik, 2010); while most metallurgical wastes disposed are radioactive, non-biodegradable and hazardous to the humans, land, aquatic and terrestrial habitats. The frequently experienced accidents in metallurgical laboratories are connected with the usage of the facilities, tools and machines together with handling of hazardous chemicals and substances. Common accidents include burns, bone fracture, cuts, respiratory discomfort, and etc. In the subsequent sections, the causes, effects and prevention of laboratory accidents will be discussed.

2. Problem Statement and Study Rationale

Metallurgical laboratories deal with materials and techniques which can pose health and safety risks when handled without adequate precautions (DiBerardinis, Baum, First, Gatwood, & Seth, 2013). Those encounters include exposure to electromagnetic radiations, high temperatures, red hot molten metals and machines, corrosive and lethal chemicals, sharp and piercing metals, metal dusts and fillings, and other poisonous substances. Most equipment used in the lab pose serious danger if not properly handled. Accidents in the laboratory come in the form of burns, bruises, fractures, blindness, toxic chemical spillage and so many other types of wounds. Hence, the need for metallurgical laboratories to be in the possession of all-inclusive safety policy and programs. These should include intensive drilling and tutoring of all laboratory personnel, maximum compliance to safety protocols, and strict adherence to the use of personal protective equipment (PPE) when stepping into the laboratory, and especially when working with hazardous materials and/or machines. Finally, emergency protocols for handling an accident victim should be put in place, ensuring that all laboratory personnel are well-trained with the protocol. So, the rationale behind this study is that after investigating the sources of the accidents in metallurgical laboratories and projecting ways of preventing them, the rate, severity and number of accidents in the lab would drastically reduce. Even though, metallurgical laboratory was the main focus of the study, but the information from this study will benefit almost all engineering laboratory personnel as they encounter similar equipment and materials.

3. Review Questions

(a) What are the possible causes of accidents in the laboratories?
(b) What are the types of accidents prevalent in metallurgical laboratories?
(c) What effects do metallurgical laboratory accidents have on the victims?
(d) What are ways of preventing or reducing laboratory accidents?

4. Materials and Methods

The resource materials for this integrative review were sourced from Scopus and google scholar data bases. The author based the search on peer-reviewed published books, articles and conference papers that worked on the following topics: metallurgical laboratory equipment, causes of accidents in the metallurgical labs, types of accidents in the metallurgical labs, safety protocols in metallurgical labs, prevention of metallurgical lab accidents, effects of metallurgical lab accidents and personal protective equipment to prevent laboratory accidents. There was no time limit placed on the articles that were reviewed because discussions on accident are not time dependent.

5. Results and Discussion

5.1. Types and Causes of Metallurgical Laboratory Accidents

i) *Burns from handling of hot metals and corrosive acids/chemicals:* Red hot metals from the furnace can accidentally drop on the foot or any part of Technicians and inflict severe burn on the body. Steps taken when this occurs in a lab include checking the degree of the burn and take adequate measures. For first degree burns which affect only the outermost layer of the skin, they manifest as red spots (Figure 2a), inflict severe pain, and sometimes swell up on the skin. The first treatment is applying running water for 15 – 20 minutes or applying cold pasty compress. If it is second-degree burns, the depth of the burns affects the second layer of skin and are always more severe (Figure 2b). In this case, the spot should be cooled with water or pasty compress, and treated by a medical practitioner with appropriate antibiotics and burn medics. The most severe of them all is the third-degree burns (Figure 2c) which affects both the skin and internal muscles. It is recommended that this type of burn is handled by only medical professionals. They are the most serious and should always be treated by a medical expert (Lu et al., 2017; Reed, 2007).
ii) *Cuts and bruises:* Moving parts of ML machines may accidentally catch the fingers of a machine operator and inflict bruises and cuts. Less-severe bruises and cuts (Figure 2e) can be cured at home by applying very chilled water or ice on the affected spot for 15 – 20 minutes to ease off pain and swelling. Then, appropriate antibiotics will be applied, together with ensuring that the sore is kept clean and away from flies by using sterilized bandage. But if the bruises or cuts are severe, experts and

professionals should be approached immediately for medical attention (Mlambo, Parkar, Naude, & Cromarty, 2022).
iii) *Fracture of the bone:* On the wet floor of the lab, a ML worker may slip off the ground, fall and break his/her leg or arm. A rotating machine, like the lathe may accidentally break the wrist of an inexperienced operator. In short, there are so many operations and practices in the metallurgical laboratory which may accidentally result to bone fracture (Figure 2d). If the fractured bone is exposed, a sterile dressing should be applied to the area to prevent infection. When bone fracture occurs to an operator in a laboratory, the best practice is to seek for professional medical personnel. The only fist aid which can be given to the victim is to apply a sterilized dressing of the wound to forestall possible infection. Dumville et al., (2016) rightly opined that dressing wounds promptly helps to prevent possible invasion of infection.
iv) *Respiratory irritation:* Respiratory irritation is mostly experienced in metallurgical laboratories as one is experiences huge doses of smokes and nano particles. Breathing in these substances can result to watery nose, sneezing, coughing, and runny eyes (Higashi et al., 2014). In extreme conditions, respiratory irritation can culminate into struggling to breath or at worse, respiratory failure. Besides these less-severe warnings, protracted exposure to these smokes and particles may lead to "chronic obstructive pulmonary disease (COPD) (Figure 2f) and lung cancer" (Grahn et al., 2021).
v) *Eye irritation:* The substances in a metallurgical lab that can bring about eye irritation include fumes from concentrated acids, bases and metals. Other eye irritants are smokes (fumes) from metal welding and those from muffle furnace. As the smokes impinge on the eyes, they evoke a number of issues like stinging, watery eye, redness of the eye, swelling of the eye and etc. In extreme doses of the smoke and prolonged exposure to the irritants, they can cause corneal ulcer (Figure 2g) or blindness (Loh & Agarwal, 2010; Okoshi et al., 2015).
vi) *Irradiation disease*: For the facts that metallurgical laboratory workers/technicians are exposed to electromagnetic radiations accruing from radioactive metals and some equipment, they are susceptible receive heavy doses of those particles. These overdose usually manifests in a variety of symptoms such as nausea, vomiting, hair loss (Figure 2h), anemia, and fatigue (Akbal & Balik, 2013). In severe cases, it leads to destruction of internal cells, organs and tissues, and can cause cancer or death (Makropoulou, 2016).
vii) *Electrical shocks:* Electrical shocks can be caused by faulty wiring, ungrounded equipment, and exposed live wires. More so, metallurgical technician without proper training in electrical safety may be a victim of electrical shocks because his action of omission or commission. Electrical shocks can cause paralysis, burns and even death (Koumbourlis, 2002). Shown in Figure 2 is the images of some accidents prevalent in metallurgical laboratories.

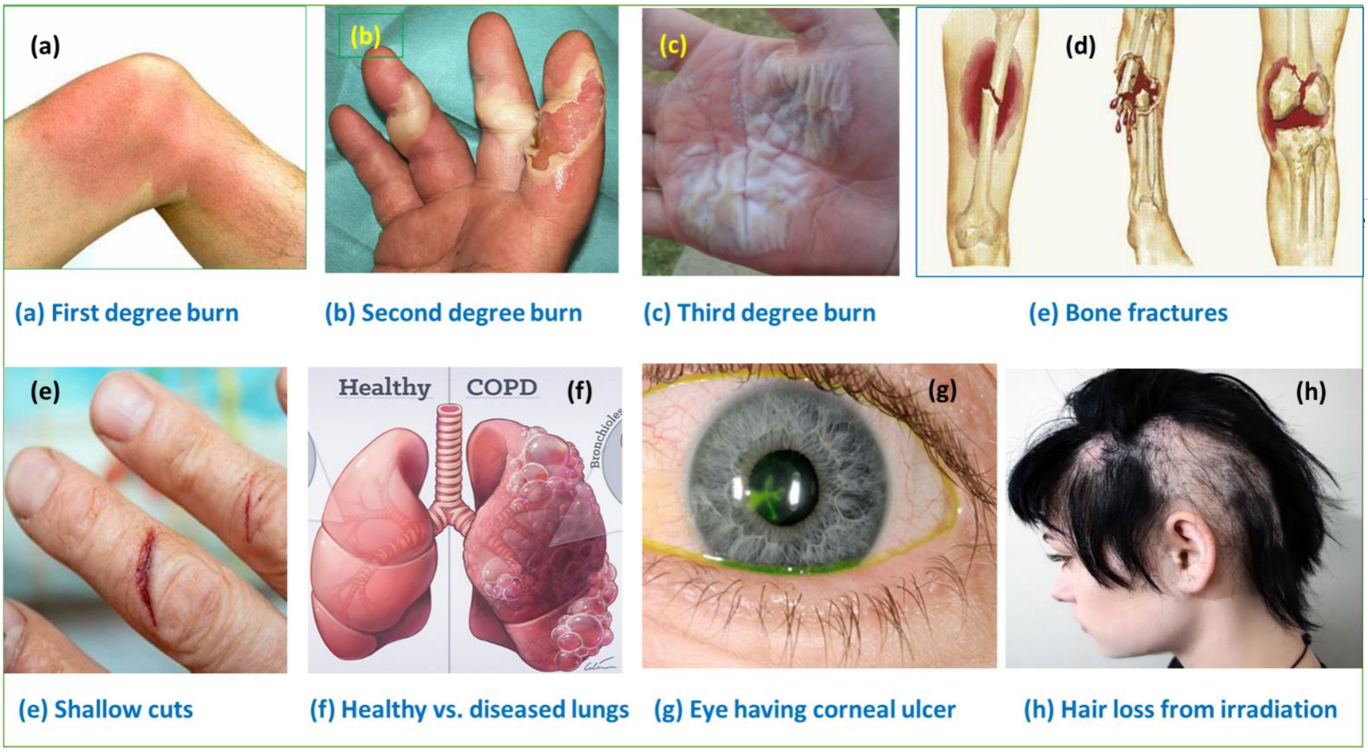

Figure 2: Images of some Metallurgical Laboratory Accidents: (a) First degree burn, (b) Second degree burn, (c) Third degree burn, (d) Bone fractures (e) Small cuts, (f) Lung infected by chronic obstructive pulmonary disease, (g) Eye troubled by corneal ulcer, and (h) Hair losses from excess exposure to electromagnetic irradiation

5.2. Effects of Metallurgical Laboratory Accidents

a) *Physical effect:* The physical effects of metallurgical laboratory accidents differ and are a function of the degree of the accident, which can be burns, cuts, bruises, broken bones, dislocations, eye irritation or nose irritation, in minor cases (Harris & Flaherty, 2010). For more severe cases like chemical spills or electric shocks, the physical wounds can result to permanent disfigure, loss of sight, loss of hearing, or even death. Early medical attention is the only panacea. It is recommended to seek for the hands of professionals and experts when the degree of accident is high.

b) *Psychological effects:* The shock and trauma of a metallurgical lab's accident victim can culminate into worry, depression, and post-traumatic stress disorder (PTSD) (Fekadu, Mekonen, Belete, Belete, & Yohannes, 2019). It is very necessary to identify and tackle these psychological effects head on because they can impact a lasting effect on the victim's welfare. Seeking the attention of a counsellor in collaboration with the family, contemporaries and mates will be very imperative in handling the psychological effects of the victim. The victim is equally encouraged to take a break from work and rest so as to recover more quickly (Linton, 2005).

c) *Emotional effects:* The emotional implications of metallurgical laboratory accidents are very difficult to deal with. Most often, the victims are filled with the mood of guiltiness, rage, humiliation, and sorrow (Kowalski-Trakofler & Vaught, 2012). These feelings are especially hard to deal with in a situation where life was lost or one was severely wounded. Besides the emotional aspect on the victim, his inter personal relationship with family and friends is affected. Support and counselling from an expert, family and loved ones is a good balm to heal the emotions of such accident victim.

d) *Economic effects:* According to Beevis and Slade (1970), there exists direct and indirect costs accruing from metallurgical laboratory accidents. Direct costs are as follows: the cost of medical care, lost wages, and property damage; while indirect costs are the cost of training replacement operators, lost productivity, and repair of damaged equipment or facilities. Some minor costs include the dent on the laboratory's reputation and integrity.

e) *Social effects:* Metallurgical laboratory accidents can lead to a loss of trust/confidence in the industry about the security of life of metallurgical workers, coupled with attitudinal change of mind in the community on metallurgical work (Cannon, Edel, Grassie, & Sawley, 2003). This can have enduring effects on individuals and communities. When this situation occurs, it behooves of the management to work assiduously in restoring the confidence of people back to the organization. This can be achieved through open communiqué, transparency, and a pledge to creating security of life and property top priority.

5.3. Prevention of Metallurgical Laboratory Accidents

i) *Proper orientation and training of machine operators and all the workers:* Technicians ought to be conversant with the machines operations in order to avert avoidable accidents. All workers should be educated on the appropriate use of personal protective equipment. With proper orientation, potential hazardous supplies, equipment and consumables can be detected and knowledge of how to handle them acquired.

ii) *Strict adherence to safety protocols:* Adhering to safety protocols is another effective process of preventing accidents in a metallurgical laboratory. Safety protocols are put in place to decrease the menace of accidents through mapping out clear policy and measures to be strictly adhered to. By adhering to these safety rules and regulations, occurrence of accidents will drastically reduce (Hale, 1990).

iii) *Regular maintenance and inspections of equipment:* Regular inspections and maintenance can also aid in identifying possible or imminent hazards and make sure that all equipment is in good working condition so as to prevent accidents in the lab. It equally helps to identify propagating cracks, corrosion and other developing defects and replace or repair them in order to avert sudden collapse which may destroy the equipment and injure or kill the operator. It was Saurin (2016) who opined that inspection is the key to preventing accidents.

iv) *Provision of emergency plans and facilities:* Emergency plans must be put in place to take care of possible hazards like acid spills or catastrophic breakdown of machinery. Such plans include stages of evacuation and informing adequate agencies on the incident of an emergency, like fire. Moreover, metallurgical lab must be in the possession of essential facilities like fire extinguishers, eye wash stations, and first aid kits (Laboratories, 1982). Those facilities most be handy and well-serviced, while all operators and workers must be educated on best practices to use the facilities.

v) *Establishment of communication channels between workers and supervisors:* Communication is a necessity for averting accidents in a metallurgical laboratory. Workforces must be encouraged to freely report safety concerns and issues in their work places and machines, while their supervisors ought to be ready and willing to hear and take care of their safety issues. When there are no lapses in communication among the workforces and supervisors/managers, safety issues can be recognized early enough before they degenerate into accidents. According to Kaur (2017), effective communication removes the risk of misunderstandings and confusion which are the precursors to accidents.

vi) *Performing risk evaluation to recognize potential hazards:* This comprises recognizing all possible hazards, both existing hazards and imminent hazards which would occur in the future. After identification of the hazards, they must be assessed. This involves evaluating the possibility and degree of each impending hazard. After assessment, adequate actions must be implemented to forestall the accident. So, recognition, assessment, evaluation and appropriate action on the imminent hazards are the key ways of averting metallurgical laboratory accidents.

vii) *Provision of personal protective equipment:* PPE like goggles, gloves, and respirators are very essential in preventing most metallurgical accidents. These protect the sensitive parts of the body and help to reduce the degree of wound even if there is an occasion of accident.

viii) Provision of regular safety training for workers: Consistent training would ensure that workers are updated with the most recent safety practices and measures. It can equally enhance the tradition of safety in the workplace.

ix) *Putting in place a reporting system for near misses and incidents:* When workforces are allowed to report near misses, it would boost the knowledge of early recognition of possible hazards before they become accidents. Near misses are referred to caution-signs (Okwelle & Normakoh, 2019) that a device or facility is not functioning as it should, and by taking care of them early enough, more catastrophic accident and breakdown will be averted.

x) *Entertaining a zero-tolerance strategy for unsafe practices:* When workforces are aware of the stringent penalties for risky operational practices, it would help to imbibe a safe working culture devoid of hazardous possibilities. This is achieved by projecting unambiguous rules and regulations, promulgating penalties for rule violations, and making sure that all the workers are loyal to the same standards. A zero-tolerance rule delivers a strict memo that safety is a top priority (Marron Jr, 2015), and inspires workforces to take safety seriously. Through this policy, most accidents are prevented.

6. Conclusion

Metallurgical laboratory accidents are hydra-headed. The effects they have on the victims are numerous. But the good thing is that ways to avert possible accidents are manifold. There are the less severe accidents like bruises, cuts, strains which can be treated at home with cold running water and some antibiotics. However, more severe accidents like bone fracture, third-degree burns and electric shocks are encouraged to be treated by medical experts only. There are several effects of metallurgical laboratory accidents that were identified in this study. They included the emotional, psychological, economic, social and physical effects. Moreover, there were many preventive measures for ML accidents, among which included proper orientation and training of machine operators and all the workers, strict adherence to safety protocols, regular maintenance and inspections of equipment, provision of emergency plans and facilities, entertaining a zero-tolerance strategy for unsafe practices and etc. It these measures are strictly adhered to, accident occurrence in ML will be curtailed greatly.

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Conflict of Interest

No potential conflict of interest.

Author Contributions

COU conceived and developed the research, wrote the paper, collected and analyzed the data.

Data Availability Statement

The datasets generated and/or analyzed in this article are contained in it.

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References

Akbal, A., & Balik, H. H. (2013). Investigation of Antibacterial Effects of Electromagnetic Waves Emitted by Mobile Phones. *Polish Journal of Environmental Studies, 22*(6). 1589-1594.

Beevis, D., & Slade, I. (1970). Ergonomics—costs and benefits. *Applied Ergonomics, 1*(2), 79-84. https://doi.org/10.1016/S0003-6870(70)80004-7

Campbell Jr, F. C. (2011). *Manufacturing technology for aerospace structural materials*. Elsevier.

Cannon, D., Edel, K. O., Grassie, S., & Sawley, K. (2003). Rail defects: an overview. *Fatigue & Fracture of Engineering Materials & Structures, 26*(10), 865-886.

Chen, Q., & Thouas, G. A. (2015). Metallic implant biomaterials. *Materials Science and Engineering: R: Reports, 87*, 1-57. https://doi.org/10.1016/j.mser.2014.10.001

Davidson, M. W., & Abramowitz, M. (2002). Optical microscopy. *Encyclopedia of Imaging Science and Technology, 2*(1106-1141), 120.

DiBerardinis, L. J., Baum, J. S., First, M. W., Gatwood, G. T., & Seth, A. K. (2013). *Guidelines for laboratory design: health, safety, and environmental considerations*. John Wiley & Sons.

Dumville, J. C., Gray, T. A., Walter, C. J., Sharp, C. A., Page, T., Macefield, R., . . . Blazeby, J. (2016). Dressings for the prevention of surgical site infection. *Cochrane Database of Systematic Reviews*(12). https://doi.org/10.1002/14651858.CD003091.pub4

Fekadu, W., Mekonen, T., Belete, H., Belete, A., & Yohannes, K. (2019). Incidence of post-traumatic stress disorder after road traffic accident. *Frontiers in Psychiatry, 10*, 519. https://doi.org/10.3389/fpsyt.2019.00519

García-Toraño, E., Tzika, F., Burda, O., Peyrés, V., Mejuto, M., Crespo, T., . . . Svec, A. (2014). Ionising radiation metrology for the metallurgical industry. *International Journal of Metrology and Quality Engineering, 5*(3), 301. https://doi.org/10.1051/ijmqe/2014010

Goldstein, J. I., Newbury, D. E., Michael, J. R., Ritchie, N. W., Scott, J. H. J., & Joy, D. C. (2017). *Scanning electron microscopy and X-ray microanalysis*. Springer.

Gouthama, T., Harisha, G., Manjunatha, Y., Kumara, S. M., Srinath, M., & Lingappa, M. S. (2016). *M*elting of tin using muffle furnace and microwave energy and its characterization. *IOP Conference Series: Materials Science and Engineering*. 149 (2016) 012100. https://doi.org/10.1088/1757-899X/149/1/012100.

Grahn, K., Gustavsson, P., Andersson, T., Lindén, A., Hemmingsson, T., Selander, J., & Wiebert, P. (2021). Occupational exposure to particles and increased risk of developing chronic obstructive pulmonary disease (COPD): A population-based cohort study in Stockholm, Sweden. *Environmental Research, 200*, 111739. https://doi.org/10.1016/j.envres.2021.111739

Hale, A. R. (1990). Safety rules ok?: Possibilities and limitations in behavioural safety strategies. *Journal of occupational accidents, 12*(1-3), 3-20. https://doi.org/10.1016/0376-6349(90)90061-Y

Harris, T. L., & Flaherty, E. G. (2010). Bruises and skin lesions. In: *Child abuse and neglect: diagnosis, treatment, and evidence. 1st Ed. St. Louis (Mo). Elsevier Saunders*, pp. 239-251.

Higashi, T., Kambayashi, Y., Ohkura, N., Fujimura, M., Nakanishi, S., Yoshizaki, T., . . . Michigami, Y. (2014). Exacerbation of daily cough and allergic symptoms in adult patients with chronic cough by Asian dust: A hospital-based study in Kanazawa. *Atmospheric Environment, 97*, 537-543. https://doi.org/10.1016/j.atmosenv.2014.01.041

Javaid, M., & Haleem, A. (2018). Additive manufacturing applications in orthopaedics: a review. *Journal of Clinical Orthopaedics and Trauma, 9*(3), 202-206. https://doi.org/10.1016/j.jcot.2018.04.008

Kaur, J. (2017). Ambiguity related misunderstanding and clarity enhancing practices in ELF communication. *Intercultural Pragmatics, 14*(1), 25-47. https://doi.org/10.1515/ip-2017-0002

Koumbourlis, A. C. (2002). Electrical injuries. *Critical Care Medicine, 30*(11), S424-S430.

Kowalski-Trakofler, K. M., & Vaught, C. (2012). Psycho-Social issues in mine emergencies: the impact on the individual, the organization and the community. *Minerals, 2*(2), 129-168. https://doi.org/10.3390/min2020129

Laboratories, N. F. P. A. T. C. o. C. (1982). *Fire protection for laboratories using chemicals* (Vol. 45). National Fire Protection Association.

Linton, S. J. (2005). Understanding pain for better clinical practice: a psychological perspective.

Loh, K., & Agarwal, P. (2010). Contact lens related corneal ulcer. *Malaysian Family Physician: the official journal of the Academy of Family Physicians of Malaysia, 5*(1), 6-8..

Lu, J., Yang, M., Zhan, M., Xu, X., Yue, J., & Xu, T. (2017). Antibiotics for treating infected burn wounds. *The Cochrane Database of Systematic Reviews, 2017*(7), CD012084. https://doi.org/ 10.1002/14651858.CD012084.pub2

Makropoulou, M. (2016). Cancer and electromagnetic radiation therapy: Quo Vadis? *arXiv preprint arXiv:1602.02077*. https://doi.org/10.48550/arXiv.1602.02077

Marines, I., Dominguez, G., Baudry, G., Vittori, J.-F., Rathery, S., Doucet, J.-P., & Bathias, C. (2003). Ultrasonic fatigue tests on bearing steel AISI-SAE 52100 at frequency of 20 and 30 kHz. *International Journal of Fatigue, 25*(9-11), 1037-1046. https://doi.org/10.1016/S0142-1123(03)00161-0

Marron Jr, J. (2015). The evolution of zero tolerance policies: a case study of four high schools in the Silicon Valley (Doctoral dissertation, California State University, Sacramento). http://hdl.handle.net/10211.3/139505

Metikoš-Huković, M., Babić, R., Grubač, Z., Petrović, Ž., & Lajçi, N. (2011). High corrosion resistance of austenitic stainless steel alloyed with nitrogen in an acid solution. *Corrosion Science, 53*(6), 2176-2183. https://doi.org/10.1016/j.corsci.2011.02.039

Mlambo, S. S., Parkar, H., Naude, L., & Cromarty, A. D. (2022). Treatment of acute wounds and injuries: Cuts, bites, bruises and sprains. *SA Pharmaceutical Journal, 89*(1), 12-18. https://hdl.handle.net/10520/ejc-mp_sapj_v89_n1_a5

Okoshi, K., Kobayashi, K., Kinoshita, K., Tomizawa, Y., Hasegawa, S., & Sakai, Y. (2015). Health risks associated with exposure to surgical smoke for surgeons and operation room personnel. *Surgery Today, 45*, 957-965. https://doi.org/10.1007/s00595-014-1085-z

Okwelle, P. C., & Normakoh, J. (2019). Assessment of health, safety and environment procedures in technical collegesâ€™ workshops in Rivers State. *International Journal of Innovative Scientific & Engineering Technologies Research, 7*(1), 1-6.

Reardon, A. C. (2011). *Metallurgy for the Non-metallurgist*. Asm International.

Reddy, A. C., & Prakash, G. (2020). Lab Manual for Metrology and Machine Tools. https://doi.org/10.35543/osf.io/azp8q

Reed, D. (2007). Third-Degree Burn by Tincture of Iodine—A Case Study. *AAOHN Journal, 55*(10), 393-394.

Saurin, T. A. (2016). Safety inspections in construction sites: A systems thinking perspective. *Accident Analysis & Prevention, 93*, 240-250. https://doi.org/10.1016/j.aap.2015.10.032

Tallam, R. M., Lee, S. B., Stone, G. C., Kliman, G. B., Yoo, J., Habetler, T. G., & Harley, R. G. (2007). A survey of methods for detection of stator-related faults in induction machines. *IEEE Transactions on Industry Applications, 43*(4), 920-933. https://doi.org/10.1109/TIA.2007.900448

Ujah, C., Popoola, A., Popoola, O., & Aigbodion, V. S. (2020). Influence of CNTs addition on the mechanical, microstructural, and corrosion properties of Al alloy using spark plasma sintering technique. *The International Journal of Advanced Manufacturing Technology, 106*, 2961-2969. https://doi.org/10.1007/s00170-019-04699-7

Vernidub, O., Klypin, B., Novokshchenova, S., Panarina, N., & Pirusskii, M. (2001). The Testing Center Metaltest–a Guarantor of Quality Control for Metal Products. *Metallurgist, 45*(9-10), 414-416. https://doi.org/10.1023/A:1017940610581

Vinarcik, E. J. (2009). *Applying lean manufacturing principles & tools to laboratory operations* (0148-7191). SAE Technical Paper 2009-01-1191, 2009. https://doi.org/10.4271/2009-01-1191.

White, R., Howarth, D., & Delport, W. (2013). *CORROSION-RESISTANT*. Paper presented at the Materials Engineering: Proceedings of the First International Symposium, University of the Witwatersrand, Johannesburg, South Africa, November 1985.

Yakymenko, I., & Sidorik, E. (2010). Risks of carcinogenesis from electromagnetic radiation of mobile telephony devices. https://dspace.nuft.edu.ua/jspui/handle/123456789/15576

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