Sri Lanka Journal of Forensic Medicine, Science & Law — May 2025;16(Special Issue):26-30
DOI: https://doi.org/10.4038/sljfmsl.v16i5.8016

CASE REPORT

A RARE CASE OF ELECTROCUTION DUE TO DIRECT CURRENT (DC) GENERATED BY A SOLAR PANEL: A CASE REPORT

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ABSTRACT

Electric hazards in the workplace are common in developing countries, where most of them are caused by alternating current. Here we present a rare case of high-voltage direct current electrocution in a solar panel worker. The severity of electric injuries depends on multiple factors. Alternating current is four to six times more likely to cause death than direct current. However, high-voltage direct current could result in a fatal outcome occasionally. Therefore, it's important to know the differences in pathophysiological impacts between alternative and direct current. A solar panel worker in an industrial setting accidentally shocked himself while wearing only shoes as protective equipment and was pronounced dead at the scene. Postmortem examination disclosed torn-off garments, typical joule-burns, singeing of hair, arc-burns and other burns of multiple degrees. Internal examination revealed organ congestion, whereas histological examination revealed elongation of cells of the lower layers of the burnt epidermis. The urine multi-drug screening test was negative, and no further toxicological analysis was performed. The cause of death due to electrocution was made based on the circumstances, scene visit findings, postmortem examination, histological examination and toxicological analysis. High-voltage and high-amperage electricity is deadly from either alternating or direct current. Where there is a massive expansion in the solar power field, it's necessary to have protective measures to prevent such untimely deaths.

Keywords: *Direct current; electric injury; solar power*

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ARTICLE HISTORY
Received: 24.12.2024
Received in revised form: 21.02.2025
Accepted: 22.02.2025
Available online: 30.05.2025

INTRODUCTION

Workplace electricity accidents are a common occupational hazard in developing countries like Sri Lanka, owing to improper occupational training and lack of safety measures[1]. Electrocution by direct current (DC) cases are scarcely reported in the local setup. In contrast to alternating current (AC), DC causes less harm at similar voltages. For DC to produce a significant bodily injury, it should be a high-voltage direct current (HVDC) electrocution. According to the Federal Statistical Office of Germany, between 2006 and 2015, electrical injuries by DC stood at 5.1%–8.15% out of all

electrical injuries. There are only a few reported cases of death by DC worldwide[2].

We present a case of electrocution by DC, where a "solar panel worker" got electrocuted while attaching a series of solar panels in an industrial setting. He lacked proper training, and no personal safety measures were employed. A postmortem examination was performed, which revealed classic features of electrocution with extensive burn injuries.

CASE HISTORY

A 19-year-old male solar panel worker accidentally electrocuted himself while connecting a series of solar panels in an industrial setting without proper protective equipment. Co-workers heard an explosion and found a "junction box" of a solar panel on fire (Fig. 1) and a shattered solar panel, with the worker lying supine in the vicinity.

Figure 1: Junction box of the shattered solar panel that was ignited.

He was pronounced dead at the scene, and the body was brought to the mortuary for postmortem examination. Torn-off garments were seen over the right arm, right side back of the chest, and right gluteal area. A typical "Joule burn" with a collapsed blister was seen over the right palm with a clenched fist, which was the entry point (Fig. 2). Second-degree burns were seen involving the right distal forearm and right arm up to the axilla (Fig. 3). Axillary hair was partly singed. The "crocodile-skin" appearance due to arc burn was seen over the right mid-forearm up to the elbow joint (Fig. 4).

Figure 2: Joule burns of the right palm shown by arrows (white), corresponding with the entry point of the current.

Figure 3: Burns of the right arm extending up to the axillary region.

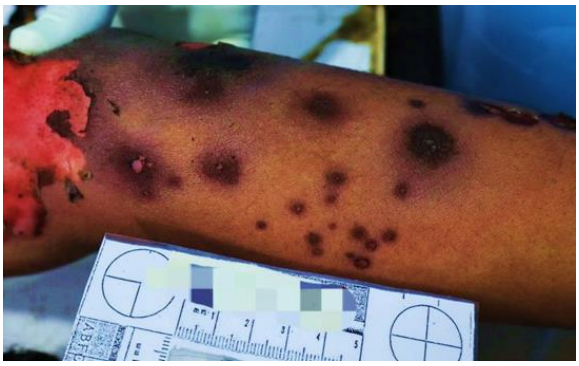

Figure 4: Arc burns on the right forearm produced by arcing of the current, giving rise to the "crocodile skin" appearance.

A third-degree burn was seen over the left gluteal region, underneath the burnt and torn clothing. Internal examination revealed slight congestion of the brain. Petechial haemorrhages were seen on the visceral pleura and epicardium. Musculoskeletal dissection did not reveal any soft tissue injuries or fractures. A urine multi-drug screening test was performed and was negative for common substances of abuse. No further toxicological analysis was done.

Histological examination of the heart did not reveal any abnormalities. Skin sections from the area of burns showed elongation of cells of the lower layers of the epidermis with micro-blister formation. A conclusion of "death by electrocution" was made, taking into consideration the scene and postmortem findings, toxicological analysis, and histological examination.

DISCUSSION

The severity of electric injuries mainly depends on the voltage and amperage of the current, type of current (AC/DC), resistance provided, duration of contact, pathway of the current through the body, and environmental factors[2].
Alternative current (AC) is four to six times more likely to cause death than direct current (DC), partly due to its "hold-on" effect and increased ability to cause cardiac dysrhythmias[3].

Physiological impacts of AC and DC currents are different[6]

•Threshold of perception: AC: 0.5 mA, DC: 2 mA
•Let-go threshold: AC: 10 mA, DC: 75 mA (In a 70 kg adult)
•Threshold for ventricular fibrillation: AC: 40 mA, DC: 140 mA
• Life-threatening voltage: AC: 50 V, DC: 120 V

Photovoltaic electricity produces 0.6 V through a single cell at 25°C. The average amperage produced by solar panels is 10A, whereas the voltage of a single panel stands at 40V–50V[4]. Multiple solar panels are connected in series to increase the voltage (average domestic circuit: 600V-1000V, average industrial circuit: 1kV-10kV)[4].

As long as solar panels are exposed to light, they produce potentially lethal amounts of DC electricity *(DC danger zone)*[4]. In this case, more than 10 panels had been connected in series, generating a current of 10A-13A and a voltage of 500V–1000V. The high amount of DC traveling in a one-way direction creates a strong contraction when it contacts the body, making it difficult to break free[4]. Any attempt to break the load from the source may result in the current arcing and causing a spark lesion. Multiple spark lesions give rise to a "crocodile skin" appearance. At 1000V, the current will jump a few millimetres, and at 100kV, about 35cm, producing a very high temperature (4000°C)[4,9].

Most deaths occur due to cardiac arrhythmia (ventricular fibrillation) as a result of the current passing through the heart. The pathway of the current will depend on the relative resistance of potential exit points and tends to take the shortest route between entry and exit points[9]. Since this worker had worn protective shoes, the current was thought to have entered through the right hand and exited through the left buttock.

A less common mode of death is where the diaphragm and intercostal muscles get paralysed due to the current passing through the thorax. These deaths occur due to cessation of respiration, leading to hypoxia, where signs of congestive heart failure can be found[9]. Rarely can the current enter through the brain, paralysing the brainstem and ultimately leading to cardiorespiratory arrest. In this case, there is a high probability of cardiac arrhythmia being the mode of death[9].

Non-electrical trauma also accounts for a considerable number of electricity-associated injuries. Falling from heights or being flung over after being electrocuted can result in fractures and other life-threatening injuries.

Regarding cutaneous electric marks, there may be instances where no skin lesions are found at

the entry and exit points. Therefore, it is important to obtain a detailed history regarding the incident, do a proper scene visit, and conduct a thorough postmortem examination, including toxicological and histological analysis, before confirming death by electrocution. Deaths due to electrocution can occur without any external or internal signs, highlighting the importance of excluding other possible causes of death.

This 19-year-old worker was employed without proper training or standard protective gear such as hard hats, safety gloves, safety glasses, and arc-flash clothing. This emphasises lapses in standards and legislation of the solar industry in Sri Lanka, which may be in part due to its rapid growth and high demand[5,7]. Finally, compensation for the next of kin of the deceased through workmen's compensation is a matter to be addressed.

CONCLUSION

High-voltage and high-amperage electricity is deadly, whether from an AC or DC source. Accidental electrocution is an expected occupational hazard for solar panel workers. With the rapid growth of the solar panel industry in Sri Lanka, it is important to update workers to prevent such accidents and untimely deaths. Thus, guidelines and hazard prevention training for the solar panel industry are a need of the hour.

ACKNOWLEDGMENTS

None.

CONFLICTS OF INTEREST

The author declared no conflicts of interest.

ETHICAL ISSUES

The presented case was conducted for medico-legal purposes, and the findings were used for academic purposes, according to the institutional guidelines without divulging the identity of the individual.

SOURCES OF SUPPORT

None.

AUTHOR CONTRIBUTIONS

CDK: Conception or design of the work; the acquisition, analysis, and interpretation of data for the work; drafting the work and revising it critically for important intellectual content; final approval of the version to be published. **AMATRKA:** Conception or design of the work; the acquisition, analysis, and interpretation of data for the work; drafting the work and revising it critically for important intellectual content; final approval of the version to be published. **CKR:** Conception or design of the work; the acquisition, analysis, and interpretation of data for the work; drafting the work and revising it critically for important intellectual content; final approval of the version to be published.

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