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CASE REPORT

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Cases of fatal electrocution due to contact between carbon fibre fishing rods and overhead power lines

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Abstract

Background Electrocution caused by electricity conducted via overhead power lines carries a high risk to health and life. With the introduction and proliferation of conductive carbon fibre fishing tackle, severe and fatal electrocution occurs due to accidental contact with overhead transmission lines.

Case presentation The paper presents three cases of men who died due to electrocution from a conductive fishing rod, which occurred in the same fishery over several years. The deaths occurred on the spot in two cases despite rapid rescue efforts. One of the men died in the hospital the following day due to developing severe complications. Additionally, all of the victims were under the influence of alcohol at the time of the incident. During postmortem diagnosis, skin lesions were identified as signs of electric shock on the hands and feet in each case. To the best of the authors' knowledge, there is no similar case series available in the literature where several almost identical fatal electrocutions occurred in the same place as a result of contact of a fishing rod with overhead power lines.

Conclusions Action is needed to avoid similar incidents and to increase safety in the vicinity of power lines.

Keywords Fishing, Electrocution, Carbon fibre rods, Electrical lesions, Accident, Overhead electrical line, Case series

Background

Nowadays, as well as being known for hundreds of years as a means of obtaining food, angling has also become a popular leisure and recreational activity (Czarkowski et al. 2012; Scheufele and Pascoe 2022). In Poland, the number of anglers is estimated to be around 1.5 million, and the organisation that unites and organises angling is the Polish Angling Association (Czarkowski et al. 2017). In addition, each angler has to have a fishing licence issued by the local government authorities after passing a particular exam. Technological development and access to modern materials enabled angling equipment to be modified over time (Wang et al. 2007). Some of the most commonly used rods are made of carbon fibre, which has gained popularity for its lightness, flexibility, and durability (Sun and Deng 2011). However, one of the characteristics of carbon fibre components is that they are electrically conductive, which in some cases can be dangerous (Taipalus et al. 2001; Kwon et al. 2016). This is particularly important when fishing in the vicinity of overhead power lines, when a several-meter-long rod may come into contact with the wire during deployment or swinging, resulting in immediate electrocution (Logan 1993; Wang et al. 2007; Ngajilo and Jeebhay 2019). Another contributing factor to electrocution is the water

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and damp conditions around the fishing site (Kiryakova et al. 2014; Popa et al. 2022). In Polish legislation, the Act on Inland Fisheries defines angling regulations. However, it does not specify what a fishery is and where it can be designated but only defines the conditions under which fishing is prohibited. Furthermore, the exclusions outlined in the Act do not mention the surrounding energy infrastructure.

Case presentation

All the incidents occurred in the same fishery in the Wielkopolska Province in Poland. The pond is a private artificial reservoir anglers use as a recreational fishing place. Medium-voltage power lines (15000 V) hang over the banks of the reservoir at a height from the ground of 6.10 to 8.50 m. There are no signs warning of the risk of electrocution due to the proximity of the transmission lines or signs prohibiting fishing in the vicinity of the pond.

Case 1

In June 2011, around midday, a 56-year-old man went fishing. While fishing, a carbon fibre rod measuring more than 8 m accidentally came into contact with power lines above the angler's position. After being electrocuted, the man managed to scream and inform others standing nearby about the incident, and then he lost consciousness and developed convulsions and wheezing. Then after noticing the lack of breathing, witnesses to the incident began basic life support measures, such as maintaining the airway patency and chest compressions. Additionally, an ambulance was called. Upon arrival, the resuscitation was continued by qualified medical staff. Despite the quick rescue measures taken by the witness of the incident and the emergency medical team, the man was pronounced dead about an hour after due to asystole and circulatory failure. Authorities have been informed about the case and the body was transferred to the Department of Forensic Medicine in Poznan. The autopsy revealed very abundant and highly saturated bluish-cherry-coloured post-mortem lividity, myocardial hypertrophy, and atherosclerosis of the coronary arteries. In addition, lesions were found on the palmar surface of the right hand and its fingers I, II, and III (Fig. 1), the right thigh, and the first toe of the left foot in the form of foci of the indurated epidermis of greyish-white-brown colour, embanked and protruding above the skin level and well demarcated from the unchanged skin, up to 1 cm in diameter, identified as electrical mark. Histopathological examination of the sections taken from lesions confirmed the nature of the changes as being caused by electric current. The cause of death was electrocution. In addition, the toxicological examination showed the presence of ethyl alcohol in the body at a concentration of 120 mg/dL in the blood and 160 mg/dL in the urine. Analysis of blood and urine did not reveal any other psychoactive or psychotropic substances.

Fig. 1 Electrical burns of the right hand representing points of entry of electricity

Case 2

In August 2013, in the early morning while preparing fishing equipment, a telescopic rod made of carbon fibre, measuring approximately 7 m, a 47-year-old man was electrocuted due to contact with medium-voltage overhead lines running over the pond. The victim was aware of the risks associated with the conductivity of electricity through carbon fibre and the angler's previous death due to being electrocuted in the exact location. Immediately after the incident, the man got up all by himself, spoke a few words, and then lost consciousness. Witnesses helped the unconscious man and called an emergency medical team. The man was pronounced dead on the spot, and his body was then transferred to the Department of Forensic Medicine in Poznan for an autopsy. In addition, a multi-fragment rod fracture occurred during the incident (Fig. 2). Postmortem examination revealed the presence of abundant reddish-purple postmortem lividity, hepatic steatosis, and generalised congestion of internal organs, together with moderate pulmonary oedema and moderate lipid infiltration of the inner membrane of the coronary arteries. The palmar surfaces of both hands and fingers showed extensive red-bottomed epidermal defects with hard yellowish-black curled fragile edges up to 4 cm in diameter identified as sites of current penetration into the man's body. In addition, similar epidermal defects, extending to the subcutaneous tissue, with fragile black edges and confluent foci of the altered fragile epidermis of pale cream colour, were found on the anterior surface of the right lower leg and the lateral and medial edges of the right and left foot, particularly intensified in the toe

Fig. 2 Multi-fragment carbon fiber fishing rod fracture

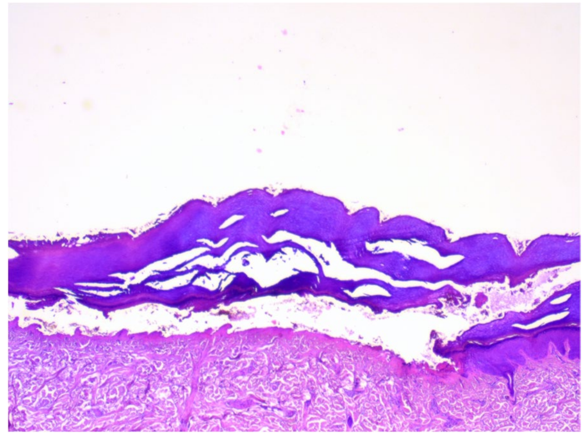

Fig. 4 Complete separation of the epidermis from the dermis and denaturation of collagen (haematoxylin and eosin)

and metatarsal areas (Fig. 3). Electrical energy at the site of increased resistance at the exit of the current from the body and grounding caused the lesions. The typical appearance on histopathological examination (including complete separation of the epidermis from the dermis, denaturation of collagen, and formation of microblisters) of the sections confirmed the lesions' aetiology (Fig. 4). A transverse fracture of the sternal body with a bleeding hypophysis was also identified as a complication of chest compressions during resuscitation. A toxicological examination revealed 110 mg/dL alcohol in the blood and 150 mg/dL in the urine. Analysis for the presence of other psychoactive and psychotropic substances in blood or urine was negative. The passing of the electric current was the cause of death.

Case 3

In July 2022, in the afternoon, the emergency medical team was called to a 30-year-old man due to electrocution. The incident occurred as a result of hooking about a 7-m telescopic rod made of carbon fibre on power lines. For the first 20 min, CPR was carried out by witnesses of the event. Examination of the patient by the emergency medical team revealed sudden cardiac arrest in the mechanism of pulseless electrical activity (PEA), rescue activities in accordance with relevant resuscitation guidelines were undertaken, and after an hour of resuscitation on-site, the patient was transported to the hospital. The on-site CT scan showed features of cerebral oedema. The patient was transferred to the intensive care unit due to cardiorespiratory instability. The patient was intubated and required mechanical ventilation. Additionally, continuous noradrenaline infusion was necessary due to cardiac arrhythmias. Furthermore, the pupils were wide and reactive to light. In the following hours, an attempt was made to perform a bronchoscopy due to changes in the lungs found in the imaging examination. Features of multiple organ failure and significant acidosis were also observed, which was a reason for haemodialysis. A toxicological test performed at admission to the hospital showed 41 mg/dL of ethyl alcohol in the blood. No other psychoactive substances were found in the blood. The death occurred the following day, 12 h after being admitted to the hospital, due to progressive multi-organ failure. The body was transferred to the Department of Forensic Medicine in Poznan. The autopsy showed very abundant livor mortis, congestion of internal organs, and rib fractures as a consequence of rescue operations. On the skin of the palmar surface of the right hand in the area of the withers of the thumb, a defect of epidermis measuring 3.5 × 2.5 cm was found, with exposure of the dermis, with hardened edges with denaturation features and burns of gray-whitish colour. In addition, on the plantar surface of the right foot in the area of the forefoot and toes, several small foci of denaturation of whitish epidermis with a diameter of up to 0.4 cm were found. Specimens were taken from the skin lesions for histological

Fig. 3 Electrical burn of feet representing exit sites of electricity

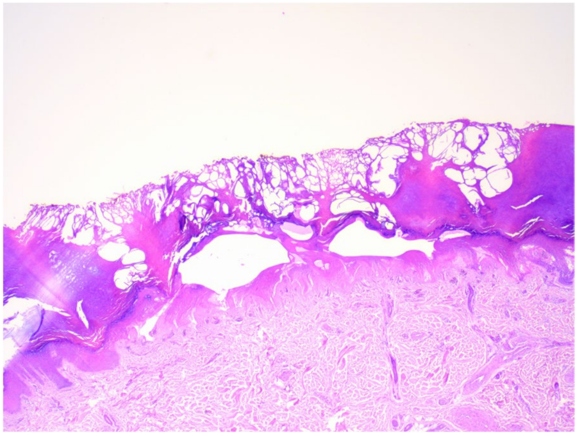

Fig. 5 Separation of the epidermis from the dermis and microblisters (haematoxylin and eosin)

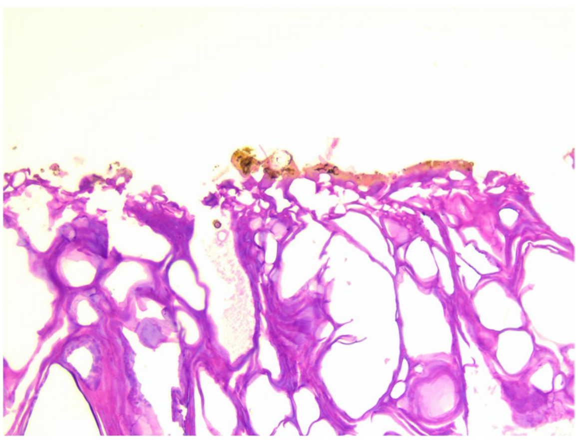

Fig. 6 Upper part of the epidermis with microblisters and charring of the surface (haematoxylin and eosin)

examination, which showed small foci of metal on the surface of the stratum corneum (skin metallisation), focal separation of the epidermis from the dermis with the presence of cavities, directional positioning of the nuclei, which characterises the typical features of the molecule of electric current (Figs. 5 and 6). Due to hospitalisation during which intensive therapy and hemodialysis were performed, post-mortem toxicological tests were waived due to the possibility of bias. Multiple organ failure due to electric current was established as the mode of death, confirming the clinical diagnosis.

Discussion

Fishing rod electrocution risk

Circumstantial factors

An increase in the frequency of angler electrocution has been observed since the widespread use of carbon fibre rods (Chi et al. 1996; Messina et al. 1999; Wang et al. 2007; Fodor et al. 2011; Kiryakova et al. 2014). Victims tend to be adult males with an average age of over 30 years, which is largely predominantly in the demographic profile of anglers (Chi et al. 1996; Taylor 2002; Wang et al. 2007; Fodor et al. 2011; Czarkowski et al. 2017). Table 1 presents a collection of previously published case reports. Similar incidents are most likely to occur during warm months and on non-working days, a large number of anglers due to favourable conditions and many anglers (Taylor 2002; Wang et al. 2007). In addition, each victim was clearly under the influence of alcohol, which may have affected critical risk assessment and impaired coordination, predisposing to accidentally touching an electric line (Mongrain and Standing 1989; Raszeja et al. 1993). Furthermore, an additional risk factor is that the length of the rod is often greater than the required minimum height of the wire from the ground (Kiryakova et al. 2014). In Poland, the PN-75/E-05100 standard defines the minimum height of the cable from the ground. According to its provisions, a line with characteristics corresponding to a power line running over this exact fishery should be at least 5.1 m above the ground. In these cases, the measured height of the wire above the ground always exceeded 6 m, and the length of every rod exceeded 7 m, which significantly increases the chances of contact when unfolding the rod or taking a swing. In addition, shock can occur despite the lack of direct contact of the rod with the non-insulated live line due to the formation of an electric arc or during a thunderstorm (Logan 1993; Fodor et al. 2011; Valença-Filipe et al. 2014). A case of fatal paralysis due to contact between a fishing rod and a catenary line has also been described, requiring differentiation from a hit by a train that occurred postmortem (Preuss et al. 2020).

Carbon fiber rod factors

Carbon fibres are obtained by thermal treatment, specifically pyrolysis, from an organic substrate such as polyacrylonitrile or synthetic cellulose fibres (Polok-Rubiniec et al. 2018). The thermal treatment produces graphite crystals with a hexagonal structure. The graphite content of the carbon fibre structure determines Young's modulus value and strength properties. Based on the carbon content, they are divided into graphite fibres with a higher content and carbon fibres containing correspondingly less carbon. Carbon fibres are obtained in the form of long, very thin strands of approximately 10 μm in diameter. The ability of carbon fibres, and the fabrics and ultimately composites constructed using them, to conduct electricity is due to the properties of the graphite crystals and the free electrons (Gumuła and Błażewicz 2004). The electrical properties of the composite exhibit anisotropy due

Table 1 Collation of cases of electrocution caused by contact of a carbon fibre fishing rod with overhead power lines

Case reports						
Study	Age [years]	Gender	Type of cable	Outcome		
Clarke et al. 1990	18	Male	Overhead power lines	Burns covering 18% of the body surface, especially on the hands, chest, right groin and feet, amputation of the right lower limb below the knee due to necrosis resulting from thrombosis		
Logan 1993	43	Male	Railway traction	Burns 40% of the body surface		
	26	Male	Overhead power lines	Burns at the point of entry and exit of the current from the body, located on the left hand and right heel		
	62	Male	Overhead power lines	Minor electrical burns		
Preuss et al. 2020	56	Male	Railway traction	Electrical lesions on the right hand and feet, death due to ventricular fibrillation after electrocution		
Original research						
Study	Number of cases	Mean age [years]	Gender	Average total burn surface area	Mortality rate	Other findings
Chi et al 1996	9	40.44	89% (8/9) male 11% (1/9) female	45%	22.2%	The point of entry of the current into the body was most often the hands, and the exit point was the feet
Wang et al. 2007	42	44.33	100% male	22.2%	2.4%	59.5% of patients had burns on less than 10% of the body surface, the point of entry of the current into the body was most often the hands, and the exit point was the feet
Fodor et al. 2011	8	37	100% male	48.2% (high voltage, > 1000 V) 9.1% (low voltage, < 1000 V)	25%	Burns were most often located on the upper and lower limbs as the point of entry and exit of the current

to the arrangement of the fibres in the composite and the relationship between measurements of electrical properties and the mechanical state of the composite (Zhao et al. 2019). Despite the obvious advantages of carbon fibre, an unfavourable parameter is the so-called impact strength, i.e., resistance to mechanical impulse loads. The measure of impact strength is the mechanical destruction energy related to a unit area. In the case of carbon fibre, the impact strength is not high. Carbon fibre composites using carbon fibres are also not characterised by a high impact strength. Impact tests were carried out for different fibre arrangements in the composite, epoxy resins, and two impact velocities. The results obtained demonstrate the low impact resistance of the tested composite structures (Tarpani et al. 2009) and where the causes of rod breakage during electrocution should be sought. Electrical overload of the rod, in the case under consideration, a conductor with a certain impedance, triggers the mechanical failure of a carbon fibre composite rod subjected to an electric current. A high current flowing through the rod results in an increase in the temperature of the composite according to the Joule-Lentz law. The carbon fibre matrix, usually an insulator, is destroyed, and the current flows between adjacent fibres. Carbon fibres are resistant to high temperatures, up to 3500 °C. In the case of a matrix made of epoxy resin, its thermal stability is limited by a temperature of about 200 °C. In the composite, there is an electrical breakdown of the layers that are insulators, i.e., a thermo-mechanical destruction of the composite structure. The destruction of the rod is dynamic, lasting a fraction of a second, which manifests itself as the cracking of the composite structure. The matrix of the composite melts under the influence of high temperatures. The result of the electro-mechanical destruction of the carbon composite rod is its disintegration and residue in the form of free carbon fibre strands. Tests on glass fibre and carbon fibre composites subjected to an electrical pulse showed no visible damage to the materials tested after the pulsed electrical loading. However, the mechanical properties deteriorated (Williams et al. 2022). However, burnout and delamination were also described, depending on the composition of the composite and the current parameters (Filik et al. 2021). In addition, the rod may be mechanically damaged, when through a sudden and strong contraction of skeletal muscles caused by the flow of current, causing rapid movement of the rod and hitting with great force on the elements of the environment or electrical wires. In such cases, the damage will be of a mechanical nature, i.e., it will have different characteristics than in the case of damage due to the action of electricity.

Human body resistance factors

In the cases analysed, the electrocution occurred from the victim's hands holding the rod blank to his legs and was indirect. Indirect paralysis results from the connection of the transmission cable, through the carbon composite rod, to the human body. In the event of paralysis, the electric current flows through the human body, which is a resistor between the transmission wire and the earth. It should be noted that the human body impedance in a short-circuit in a medium-voltage line is a significant value, resulting in serious injury to the body subjected to the electric shock current. The effects of the electric current on the human body depend on the value of the current, the time of exposure to the electric shock current and the frequency in the case of alternating current. The value of the human body's resistance, depending on the conditions, is estimated in the literature to be 1–3 kΩ, a significant value compared to other parts of the transmission line. The epidermis is characterised by the highest resistance value, resulting in body burns caused by the release of heat energy during current flow with areas of high resistance (Heyduk et al. 2015). The described electrical properties of the human body are individually dependent and can vary considerably from one person to another. An additional factor that has a significant influence on the course of electric shock is environmental conditions. The situation looks different in the case of a dry environment and in the case of a humid environment. The man-substrate system's resistance is an important factor influencing the electric shock current's value. Here the type of footwear matters (Bała and Hadryś 2018). The resistance of footwear results in uncontrolled electrical discharges and destruction when the so-called residual voltage is exceeded. Everyday footwear does not protect against the effects of electric shock. Cases of severe electrical injuries and deaths due to rod contact with power lines have been reported in the literature, including among children (Clarke and Moss 1990; Kiryakova et al. 2014). In addition, electrofishing, which involves fishing with prior stunning of fish by passing electricity through water, is a new phenomenon that has also resulted in reported fatalities (Bohlin et al. 1989; Popa et al. 2022).

Type of current

The effects of electrocution depend on the type of current (direct or alternating), the intensity, the size of the charge, the duration of exposure, and the type of exposure (Di Nunno et al. 2003; Teresiński and Wydawnictwo Lekarskie PZWL 2019). Alternating current shock poses a much greater risk than direct current (Popa et al. 2022). It is due to the current frequency directly affecting the electrical function and function of the heart and causing muscle contraction, including the diaphragm and intercostal muscles, leading to blocked respiratory movements (Di Nunno et al. 2003).

Rod electrocution sequalae

Furthermore, in addition to the direct effects of current flow through tissues and organs, there may be mechanical injury due to the strong and violent contraction of skeletal muscles and thermal injury due to the conversion of electrical energy to heat due to resistance flow (Mansueto et al. 2021). Common sequelae of electrocution due to rod contact with power lines reported in the literature include skin burns and arterial congestion resulting in extensive tissue necrosis, which may require amputation of fingers or limb (Clarke and Moss 1990; Fodor et al. 2011). Skin burns are often localised to the extremities, particularly the hands and feet. However, they can reach up to 85% of the body surface, with an average burn area of between 20 and 50% (Logan 1993; Chi et al. 1996; Wang et al. 2007; Fodor et al. 2011; Kiryakova et al. 2014), resulting in the need for surgical intervention and increasing the risk of secondary wound infections (Fodor et al. 2011). A mortality rate of up to about 5% has been described in electrocution cases above 1 kV (Arnoldo et al. 2004). In fatal electrocutions, death usually occurs as a result of myocardial damage together with rhythm disturbances due to current flow leading to haemodynamic failure (Di Nunno et al. 2003; Wang et al. 2007; Kiryakova et al. 2014). One of the most frequently observed life-threatening arrhythmias after electric shock is ventricular fibrillation and asystole (Bailey et al. 2001; Fodor et al. 2011; Kiryakova et al. 2014). Death by respiratory failure associated with rapid and severe contraction of the respiratory muscles is also possible. Suppose the current passes through the head and central nervous system. In that case, there may be enough paralysis of the bulbar nerve and the medulla oblongata's vegetative centres, directly resulting in death from cardiopulmonary failure (Di Nunno et al. 2003; Kiryakova et al. 2014; Parvathy et al. 2016; Popa et al. 2022). Death from causes related to loss of consciousness due to electrocution should also be considered (Fodor et al. 2011). These include drowning due to falling face down into a body of water where fish were caught or severe craniocerebral injury caused by a fall on a hard surface (Di Nunno et al. 2003; Wang et al. 2007; Struck and Steen 2009; Fodor et al. 2011). A life-threatening complication of electrocution is also severe kidney damage due to extensive muscle damage with the release of myoglobin, as well as multiple organ failure and sepsis (Clarke and Moss 1990; Chi et al. 1996; Holt and Moore 2000; Gouda and Bastia 2010; Ivanov et al. 2015; Baumeister et al. 2015). It is also important to bear in mind the possibility of clothing catching fire during an electric shock (Chi et al. 1996; Fodor et al. 2011; Kiryakova et al. 2014).

Postmortem examination

In postmortem examination, it is crucial to look for electric marks formed by the passage of current through an area of increased resistance and a subsequent local increase in temperature (Kuhtic 2012; Kiryakova et al. 2014). Macroscopically, the nevus of the current usually assumes an oval shape or corresponds to a reflection of the shape of the conductor. It is harder than the surrounding skin, usually yellow-white to black, with a sunken centre, visible tissue denaturation, and rolled-up edges (Raszeja et al. 1993; Mansueto et al. 2021). Due to the sometimes atypical morphological picture, resembling thermal or mechanical trauma, it is essential to confirm the aetiology of the lesion by histopathological examination (Raszeja et al. 1993). On microscopic evaluation, blurring and brightening of the epidermal structure and the formation of cavities sometimes resembling honeycombs are noticeable (Raszeja et al. 1993). In addition, a wavy grain sign is noted, resulting from swirled and palisaded elongated cells of the basal layer of the epidermis (Raszeja et al. 1993). During contact with the conductor, metal ions can penetrate the skin (known as metallisation), distinguishable using histological staining (Raszeja et al. 1993). In addition, skin lesions may show some heterogeneity depending on the mode of origin (Wang et al. 2007). In the case of direct contact with a conductor, a key role is played by a significant increase in temperature due to current flow through the skin with a higher electrical resistance, forming cavities due to rapid heating and evaporation of water (Kiryakova et al. 2014). In the case of an electric arc, the pulse duration is shorter, and due to the current-induced breakdown of gases, the process temperature is higher (Wang et al. 2007). In addition, the changes induced by the action of the flame when clothing is ignited require differentiation (Wang et al. 2007). However, there are known cases of fatal electrocution without leaving a visible trace of the current (Kiryakova et al. 2014). Importantly, the passage of an electric current through the body may not produce other specific indicative changes in organs detectable at autopsy (Mansueto et al. 2021; Popa et al. 2022).

Conclusions

Using carbon fibre fishing gear near power lines is a significant hazard. High voltage alternating current shock due to contact of the rod with uninsulated wires can lead to extensive burns and tissue necrosis requiring amputation or even death. It is also essential to draw attention to the impact of alcohol on critical judgement and motor coordination. In addition, the organisation of fisheries in the vicinity of transmission lines needs to be standardised. Planned and existing fisheries must be reviewed, especially those with similar incidents requiring visible warning signage or closure. Fishing equipment made of electrically conductive materials should be marked, preferably with a permanent sign constantly reminding the user of the risks, and accompanied by a description of the rules for safe use. Consideration should also be given to design changes to reduce conductivity or improve insulation to improve safety conditions for use.

Abbreviation

PEA Pulseless electrical activity

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Authors' contributions

SR was a major contributor in writing the manuscript, made a comprehensive assessment of the collected case reports, and performed postmortem examinations. PŚ performed the autopsy and other post-mortem analyses. MO assessed the technical aspects of overhead power lines and fishing rods. DR performed the histological examination. BB prepared the manuscript and assessed available patient medical records. ŻŻ assessed medical assistance provided in life-threatening situations and consulted on issues related to medical assistance after an electric shock. CŻ supervised the project, performed postmortem examinations, corrected the manuscript, and managed the research group. All authors read and approved the final manuscript.

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Ethics approval and consent to participate

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Consent for publication

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Competing interests

The authors declare that they have no competing interests.

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References

Arnoldo BD, Purdue GF, Kowalske K, Helm PA, Burris A, Hunt JL (2004) Electrical Injuries: a 20-Year Review. J Burn Care Rehabil 25(6):479–484. https://doi.org/10.1097/01.BCR.0000144536.22284.5C

Bailey B, Forget S, Gaudreault P (2001) Prevalence of potential risk factors in victims of electrocution. Forensic Sci Int 123(1):58–62. https://doi.org/10.1016/S0379-0738(01)00525-4

Bała M, Hadryś D (2018) Wpływ rodzaju obuwia na rezystancję układu człowiek-podłoże. Zesz Nauk Wyższej Szk Zarządzania Ochr Pr W Katowicach

Baumeister R, Mauf S, Laberke P, Krupp A, Thali MJ, Flach PM (2015) A fatal case of electrocution with unique forensic radiological postmortem findings. Forensic Sci Med Pathol 11(4):589–595. https://doi.org/10.1007/s12024-015-9716-2

Bohlin T, Hamrin S, Heggberget TG, Rasmussen G, Saltveit SJ (1989) Electrofishing — Theory and practice with special emphasis on salmonids. Hydrobiologia 173(1):9–43. https://doi.org/10.1007/BF00008596

Chi L, Ning YD, Jun QF, Zhong C, Hua SY (1996) Electrical injuries from graphite fishing rods. Burns 22(8):638–640. https://doi.org/10.1016/S0305-4179(96)00045-9

Clarke AM, Moss ALH (1990) Severe electrical injury from a graphite fishing rod. Injury 21(2):120–121. https://doi.org/10.1016/0020-1383(90)90072-3

Czarkowski TK, Turkowski K, Kupren K, Hakuć-Błażowska A, Żarski D, Kucharczyk D, Kozłowski K (2012) Rybactwo śródlądowe–rolnicza i pozarolnicza forma zagospodarowania obszarów wiejskich. Acta Sci Pol Adm Locorum 11(3):29–41

Czarkowski TK, Wołos A, Kapusta A, Kupren K, Mickiewicz M (2017) Zmiany w polskim wędkarstwie na przestrzeni ostatnich 40 lat: połowy, opinie i preferencje oraz aspekty socjoekonomiczne współczesnego wędkarza. In: Działalność Podmiotów Rybackich Wędkarskich w 2017 Roku, Instytut Rybactwa Śródlądowego p 99–121

Di Nunno N, Vimercati L, Viola L, Vimercati F (2003) A Case of Electrocution During Illegal Fishing Activities. Am J Forensic Med Pathol 24(2):164–167. https://doi.org/10.1097/01.PAF.0000070001.59275.08

Filik K, Karnas G, Masłowski G, Oleksy M, Oliwa R, Bulanda K (2021) Testing of conductive carbon fiber reinforced polymer composites using current impulses simulating lightning effects. Energies 14(23):7899. https://doi.org/10.3390/en14237899

Fodor L, Bota IO, Abbas Y, Fodor M, Ciuce C (2011) Electricity and fishing - a dangerous mix. Burns 37(3):495–498. https://doi.org/10.1016/j.burns.2010.09.010

Gouda H, Bastia B (2010) Acute renal failure following electrocution. Indian J Med Sci 64(1):45. https://doi.org/10.4103/0019-5359.92488

Gumuła T, Błażewicz S (2004) Właściwości elektryczne kompozytów włókna węglowe-węglik krzemu. Mater Ceram 56(3):103–107

Heyduk A, Boron S, Joostberens J, Pielot J (2015) Empiryczny model impedancji ciała ludzkiego na potrzeby oceny zagrożenia niebezpiecznym dla zdrowia i życia porażeniem prądem elektrycznym. Zesz Nauk Organ ZarządzaniePolitechnika Śląska 79:67–76

Holt S, Moore K (2000) Pathogenesis of renal failure in rhabdomyolysis: the role of myoglobin. Nephron Exp Nephrol 8(2):72–76. https://doi.org/10.1159/000020651

Ivanov B, Iordache IV, Bratu IC, Bordeianu I, Caraban BM (2015) Electrocutions – therapeutic management - results. ARS Medica Tomitana 21(4):186–190. https://doi.org/10.1515/arsm-2015-0043

Kiryakova T, Alexandrov A, Jelev L, Minkov M, Timonov P, Nikolov D, Gergov G, Hristov S (2014) Cases of death due to electrocution of fishermen using carbon fishing rods – morphological aspects. Sci Technol IV 1:146–149

Kuhtic I (2012) Electrical mark in electrocution deaths - a 20-years study. Open Forensic Sci J 5(1):23–27. https://doi.org/10.2174/1874402801205010023

Kwon D-J, Shin P-S, Kim J-H, Wang Z-J, DeVries KL, Park J-M (2016) Detection of damage in cylindrical parts of carbon fiber/epoxy composites using electrical resistance (ER) measurements. Compos Part B Eng 99:528–532. https://doi.org/10.1016/j.compositesb.2016.06.050

Logan MA (1993) Electrical burns caused by fishing rod contact with overhead electric cables: a potential hazard to fishermen. Burns 19(6):535–537. https://doi.org/10.1016/0305-4179(93)90017-3

Mansueto G, Di Napoli M, Mascolo P, Carfora A, Zangani P, Pietra BD, Campobasso CP (2021) Electrocution stigmas in organ damage: the pathological marks. Diagnostics 11(4):682. https://doi.org/10.3390/diagnostics11040682

Messina R, Bertino M, Franco M, Boschi G (1999) Accidental electric injuries using carbon fibre fishing rods. Medicolegale findings, technical construction of materials and safety precaution. Minerva 119:185–192

Mongrain S, Standing L (1989) Impairment of cognition, risk-taking, and self-perception by alcohol. Percept Mot Skills 69(1):199–210. https://doi.org/10.2466/pms.1989.69.1.199
Ngajilo D, Jeebhay MF (2019) Occupational injuries and diseases in aquaculture – a review of literature. Aquaculture 507:40–55. https://doi.org/10.1016/j.aquaculture.2019.03.053
Parvathy G, Shaji CV, Kabeer KA, Prasanth SR (2016) High-voltage electrocution causing bulbar dysfunction. J Neurosci Rural Pract 07(03):453–455. https://doi.org/10.4103/0976-3147.181479
Polok-Rubiniec M, Włodarczyk-Fligier A, Chmielnicki B, Jurczyk S (2018) Konstrukcyjne kompozyty polimerowe z napełniaczami węglowymi. Przetw Tworzyw 24(5):5–14
Popa MF, Mihai ML, Deacu S, Vasile M, Nicolescu AE, Halichidis S (2022) Electrofishing electrocution: case study in forensic medicine. Romanian J Leg Med 30(2):93–99. https://doi.org/10.4323/rjlm.2022.93
Preuss V, Vennemann B, Klintschar M (2020) Just another railway fatality. Int J Legal Med 134(5):1785–1790. https://doi.org/10.1007/s00414-020-02247-7
Raszeja S, Nasiłowski W, Markiewicz J (1993) Medycyna sądowa: podręcznik dla studentów. Państ. Zakład Wydawnictw Lekarskich, Warszawa
Scheufele G, Pascoe S (2022) Estimation and use of recreational fishing values in management decisions. Ambio 51(5):1275–1286. https://doi.org/10.1007/s13280-021-01634-7
Struck MF, Steen M (2009) Electrical shock, burns, and near drowning: unhappy triad in accidental powerline fishing. J Burn Care Res 30(3):542. https://doi.org/10.1097/BCR.0b013e3181a28fbf
Sun LN, Deng Z (2011) The carbon fiber composite materials application in sports equipment. Adv Mater Res 341–342:173–176. https://doi.org/10.4028/www.scientific.net/AMR.341-342.173
Taipalus R, Harmia T, Zhang MQ, Friedrich K (2001) The electrical conductivity of carbon-fibre-reinforced polypropylene/polyaniline complex-blends: experimental characterisation and modelling. Compos Sci Technol 61(6):801–814. https://doi.org/10.1016/S0266-3538(00)00183-4
Tarpani JR, Maluf O, Gatti MCA (2009) Charpy impact toughness of conventional and advanced composite laminates for aircraft construction. Mater Res 12(4):395–403. https://doi.org/10.1590/S1516-14392009000400004
Taylor AJ (2002) Fatal occupational electrocutions in the United States. Inj Prev 8(4):306–312. https://doi.org/10.1136/ip.8.4.306
Teresiński G, Wydawnictwo Lekarskie PZWL (2019) Medycyna sądowa, 1st edn. PZWL, Warszawa
Valença-Filipe R, Egipto P, Horta R, Braga JM, Costa J, Silva A (2014) Electrical burns in sports fishing: A case report. Burns 40(7):e53–e56. https://doi.org/10.1016/j.burns.2014.02.018
Wang F, Chen X-L, Wang Y-J, Chen X-Y, Guo F, Sun Y-X (2007) Electrical burns in chinese fishermen using graphite rods under high-voltage cables. J Burn Care Res 28(6):897–904. https://doi.org/10.1097/BCR.0b013e318159e695
Williams M, Tilles JN, Paquette J, Samborsky D, Clem P (2022) Effects of lightning on pultruded carbon fiber wind blades. J Phys Conf Ser 2265(2):022080. https://doi.org/10.1088/1742-6596/2265/2/022080
Zhao Q, Zhang K, Zhu S, Xu H, Cao D, Zhao L, Zhang R, Yin W (2019) Review on the electrical resistance/conductivity of carbon fiber reinforced polymer. Appl Sci 9(11):2390. https://doi.org/10.3390/app9112390

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