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Research Article

Occupational safety risks during maintenance of telecommunication towers

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Abstract

Paper aims: Conduct a set of case studies on risk management in telecommunication companies, in order to reduce the risks of accidents.

Originality: The present study furthers the discussion of risk management during the maintenance of telecommunication towers.

Research method: Three teams were assessed during their maintenance work. The risks of accidents were identified through self-made questionnaires and the checklist structured from 95 items from Brazilian regulatory and technical norms. The analysis was conducted by using the Hazard Rating Number and the OHSAS hierarchy of risk control, finally comparing the results with the OSHA´s potential draft of the standard addressing telecommunication tower safety.

Main findings: The main risks of accidents were: falling objects; falls from height; electrocution; and attacks from animals. Only 20% of occupational safety items were in conformity.

Implications for theory and practice: Suggestions on control measures were given and discussed for all four risks of accidents.

Keywords

Telecommunication tower safety. Antenna tower safety. Risk management. Falling objects. Falls from height.

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1. Introduction

The globalization and modern lifestyle require high utilization of technologies for long-distance communication, independent of the location on which humans might be encountered. To attend to this need, telecommunication companies spread its service throughout the world, building structures for implementing transmitting devices (antennas). Currently, it is estimated that there are 97.296 mobile telephone stations in Brazil (Agência Nacional de Telecomunicações, 2020; Teleco – Inteligência em Telecomunicações, 2020), and 1,018,132 antennas located on top of the structures in the USA (National Institute for Occupational Safety and Health, 2004). Such antennas are normally mounted on roof perimeters of existing buildings or on telecommunication towers. The towers may be of several types and range in height from 100 to 2,150 feet (from 30.5 to 655 m) or more: monopole (from 30.5 to 61 m); self-supporting (30.5 to 122 m); and guyed (30.5-655 m).

As the number of telecommunication towers increase, so will the number of workers in such a highly specialized construction and maintenance work. The new towers are built in pieces and mounted onsite through the use of cranes. After towers are erected, maintenance activities include reinforcing the structure, painting the steel structure, changing bulbs, and troubleshooting malfunctioning equipment, upgrading antennas, and installing new antennas on existing towers (National Institute for Occupational Safety and Health, 2004). The preferred method for accessing telecommunication towers is to use fixed ladders with attached climbing devices, ensuring protection during ascent and descent of the structure. However, as materials are sometimes bulky or heavy, they are normally hoisted to the height where they will be installed (Occupational Safety and Health Administration, 2014).

The OSHA estimation is that in the USA alone, there are from 10,000 to 29,000 workers involved in construction and maintenance of telecommunication towers, including communications workers, painters, steel erectors, and electrical and electronic equipment repairers. All of them are normally exposed to various occupational safety and health risks, including falls, structural collapses, struck-by hazards, worker fatigue, radio frequency exposure, inclement weather (including extreme heat and cold), electrical, and cuts and lacerations due to the use of sharp, heavy tools and materials. Therefore, it is essential that these maintenance workers are physically fit, comfortable working at height, have a responsible attitude, able to communicate clearly with other personnel, aware of their own limitations, fully aware of the hazards related to the machinery which they are required to maintain, that are properly instructed and trained, familiar with working at height procedures, fully aware of manufacturers instruction manual, familiar with the construction site and associate hazards, and trained and competent to previously inspect and correctly use necessary personal protective equipment (Tower Crane Interest Group, 2008).

Although the real effect of the exposure to electromagnetic fields is still not very well understood, traditionally used antennas may exceed reference levels for workers and the general public when working in close vicinity (Alanko et al., 2008). With the development and implementation of new technologies such as 5G networks, the public interest increased (Wiart et al., 2019) as such transmitting devices could have a greater impact on health. This will therefore pose new challenges on the evaluation and management of exposure to electromagnetic fields. Nevertheless, the highest occupational risk for construction and maintenance workers continues to be safety-related.

The data show that there is a high risk of accidents associated with telecommunications towers work. The average annual ratio of injuries to fatalities in telecommunications towers for the years from 2006 to 2017 was 8.4 (Occupational Safety and Health Administration, 2018). Most of the identified fatal accidents included falls from height, tower collapses and electrocutions, with the following contributing factors: hoist failure; truck-crane failure; inadequate fall protection; failure to attach the lanyard to the tower; terminal devices on the lanyard that are not compatible with tower components; attachment of lanyard to unstable tower components; failure to ride the line under prescribed conditions; inadequate worker training; and potential fatigue and repetitive strain (National Institute for Occupational Safety and Health, 2004). All of the mentioned accidents at work could have been prevented by applying adequate risk management measures, however, there is a high number of electrical and telecommunication installation companies which don’t implement safety and health management systems (Vila et al., 2020).

Due to high risks to which maintenance workers of telecommunication towers are exposed, and a low number of studies in relation to occupational risks management, the aim of this study was to conduct a set of case studies in order to identify, analyze and evaluate risks and give suggestions on control measures which should be applied in order to eliminate or reduce the risks of accidents.

2. Materials and methods

The study was conducted in Recife, Brazil, on workers dealing with the maintenance of telecommunication towers - installing antennas. In total, three teams from different companies participated in the study, each team having three workers (totalizing a number of nine workers): the supervisor; the technician; and the support worker. The types, weight and dimensions of installed antennas were illustrated in table 1.

Table 1. Antenna characteristics.

Team	Antenna type	Weight (kg)	Dimensions (cm)
1	KATHRIEN 80010767	≈31	144 x 37.7 x 16.9
2	RFS APXVBBLL15X-C-I20	≈33	185 x 58.5 x 28.0
3	ODV-065R15NB18JJ02-G	≈34	196.5 x 49 x 27.0

The fluxogram of a working day with activities usually performed by teams participating in the maintenance of telecommunication antennas was illustrated in Figure 1.

For the purpose of this study, it was decided to use the directives given by ISO 31000 (Associação Brasileira de Normas Técnicas, 2009) for conducting the risk assessment process, which was divided into: risk identification; risk analysis and risk evaluation. Afterward, suggestions were given in order to suggest possible measures for an effective risk control.

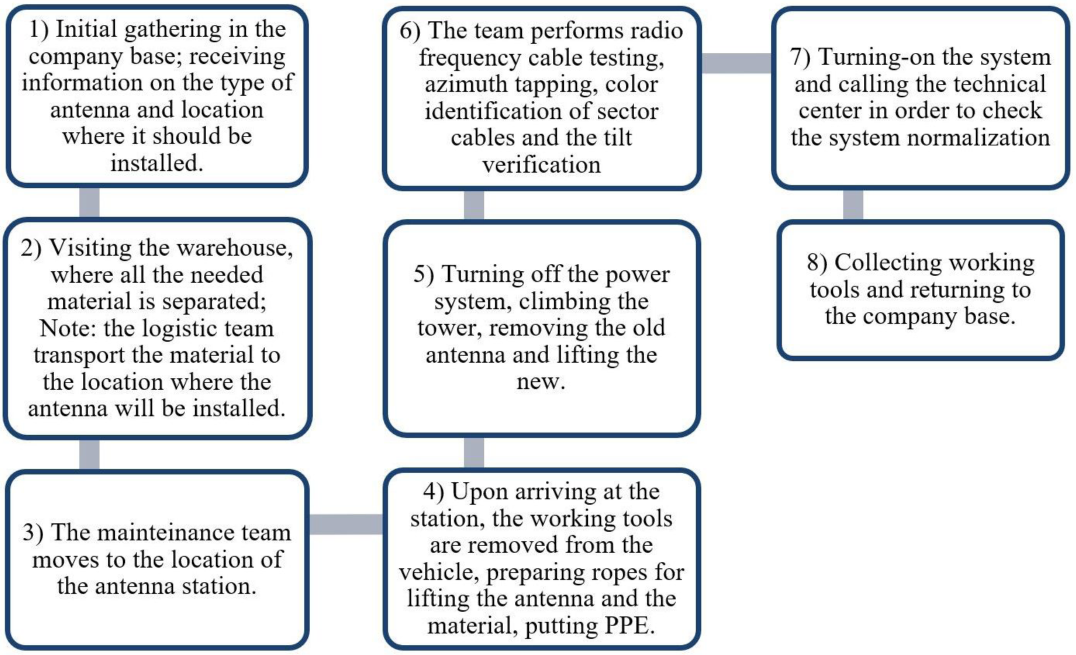

Figure 1. Fluxogram of a working day and activities.

2.1. Risk identification

For identification of risks of accidents, it was decided to structure two questionnaires and one checklist.

The Questionnaire 1 (enclosed as Appendix A) was developed in order to evaluate maintenance workers. The questionnaire had 26 questions on general information of workers: names, function, weight and height, experience in the working activity, safety trainings which they undertook, and others.

The Questionnaire 2 (enclosed as Appendix B) was developed in order to evaluate employers. The questionnaire had 15 questions on general information of the company: the number of workers, working period, safety procedures and trainings in use, the supervision of workers, accidents which occurred in the past, and others.

The Checklist (enclosed as Appendix C) was used in order to effectively identify sources of safety risks associated with the maintenance process and the equipment in use during the working activity. The checklist was structured according to the methodology Barkokebas (Barkokébas Junior et al., 2004), including a series of questions based on items from current Brazilian norms, adding answers for each item: Conform (C), Non-Conform (NC), Not Applicable (NA), and when necessary, giving additional observations.

For the purpose of this study, a checklist was structured containing 95 items from four Brazilian regulatory norms (NR) and one technical norm (NBR): NR 6 on Personal Protective Equipment with 9 questions (Escola Nacional da Inspeção do Trabalho, 2018a); NR 7 on the Program of medical control of occupational health with 6 questions (Escola Nacional da Inspeção do Trabalho, 2018b); NR 10 on Safety in services related to electrical installations with 7 questions (Escola Nacional da Inspeção do Trabalho, 2016a); NR 35 on Working at heights with 67 questions (Escola Nacional da Inspeção do Trabalho, 2016b); NBR 5419 (Associação Brasileira de Normas Técnicas, 2001) on Protection of structures against lightning strikes with 6 questions.

2.2. Risk analysis and evaluation

After identification, the risks were analyzed and evaluated by using the Hazard Rating Number (HRN) as illustrated in Table 2. The risks were quantified by the Risk Classification (RC), which was calculated by multiplying the degree of severity (DS), the exposure frequency (EF), the probability of damage occurring (PD), and the number of people at risk (NP).

Table 2. Hazard Rating Number.

Level		degree of severity (DS)		exposure frequency (EF)		probability of damage occurring (PD)		number of people at risk (NP)		HRN with risk classification
Low	1	no damage (0)	1	rarely (0.1)	1	impossible – will not occur (0)	1	1-2 people (1)	1	from 0 to 5 (the risk is negligible)
	2	slight scratch, injury or bruise (0.1)	2	annual (0.5)	2	almost impossible - only in extreme circumstances (0.033)				
	3	injury, laceration or moderate disease (0.5)	3	monthly (1)	3	not expected - although conceivable (1)	2	3-7 people (2)	2	recommended improvement action for RC from 5 to 50 (the risk is low)
Medium	4	injury, minor fracture or mild - temporary illness (2)	4	weekly (1.5)	4	possible - but it is not common to occur (2)	3	8-15 (4)		
	5	more serious injury, fracture or illness - temporary (4)			5	some chance - may occur (5)				
	6	injury, loss of limb, eye or hearing - permanent (6)	5	daily (2.5)	6	likely - it would not be a surprise or something unexpected (8)	4	16-50 people (8)	3	improvement action required for RC from 50 to 500 (the risk is high)
High	7	loss of two limbs or eyes - permanent (10)	6	hourly (4)	7	expected (10)	5	more than 50 people (12)	4	improvement action required for RC above 500 (the risk is unacceptable)
	8	fatality (15)	7	constantly (5)	8	certainly - no doubt (15)				

2.3. Risk control

Suggestions on risk control measures were applied for all safety risks identified, analyzed and evaluated during the risk assessment process. For this purpose, it was decided to follow the hierarchy of risk control, a widely accepted concept followed by main occupational safety and health authorities worldwide, including ISO and OHSAS (Barkokébas Junior et al., 2020). First were given suggestions on how the risks could be eliminated, then giving possible preventive measures (substitution and engineering measures), and finally giving possible reduction measures (administrative and Personal Protective Equipment (PPE)).

3 Results and discussion

The analyzed telecommunication towers were located in different parts of the city and sometimes in the nearby county area. As the towers were randomly distributed, workers often visit some locations and towers for the first time. As workers are not familiar with the specifics of the location and towers, it is therefore needed to well plan and organize the activity prior to conducting any maintenance work. Additionally, support from local persons would benefit to improving occupational safety and health and even shortening the working period.

3.1. Risk identification

Through the participation of nine maintenance workers, it was realized that although each team consisted of a supervisor, a technician, and a support-worker, they all participated in all phases of the maintenance of antennas, being therefore exposed to same occupational risks. All participants had a high-school educational level. All of the participants reported to have been trained for working at heights. Main results from the questionnaire 1 and 2 were illustrated in Table 3.

Table 3. Main results from the questionnaires 1 and 2.

Questionnaire 1 – with workers			Team 1	Team 2	Team 3	Mean	*±SD
Working experience	Supervisors	Total (years)	10	13	11	11.33	1.53
		Present activity (years	More than five years				
	Technician	Total (years)	5	8	7	6.67	1.53
		Present activity (years)	From one to five years				
	Support-worker	Total (years)	2	6	4	4.00	2.00
		Present activity (years)	Less than three years				
Working time	Daily (hours)		12	10	9	10.33	1.53
	Weekly (hours)		72	60	54	62.00	9.17
	Monthly (hours)		288	240	216	248.00	36.66
	Rest (days per month)		12	10	9	10.33	1.53
Questionnaire 2 – with employers			**Company 1**		**Company 2**		**Company 3**
General information	Workers (number)		11		21		16
	Education (level)		high school		high school		high school
	Working experience		Mean 6		Mean 7		Mean 5
Accidents	In the company		no		no		Yes (minor)
	From wild animals		no		no		Yes (minor)
Safety and health measures	Inspections during working activities		no		no		no
	Who supervise the OSH during the activity		Team leader		Team leader		Team leader
	Existence of PPE checklist		no		no		no
	Existence of the Preliminary Risk Analysis		no		no		no

*SD = Standard Deviation.

As shown in Table 3, supervisors were the most experienced from the team, with 11.33±1.53 years of experience. The technician had 6.67±1.53, while the support-worker had a mean of 4 years of experience. As it could be noticed from the Table 3, although safety and health measures were applied poorly, with no risk analysis, no inspections or existence of PPE checklist, it could be noticed that there were only few minor registered accidents in company three, while other two companies didn't have any cases of accidents.

The results from the checklist, as one of the methods used for risk identification, were illustrated in Figure 2. There were 76 items in non-conformity (80% of the checklist): the items in relation with PPE; Electrical installations; and most of the questions related to working at heights. There were 19 items in conformity (20% of the checklist): items related to the medical control; and some items related to working at heights.

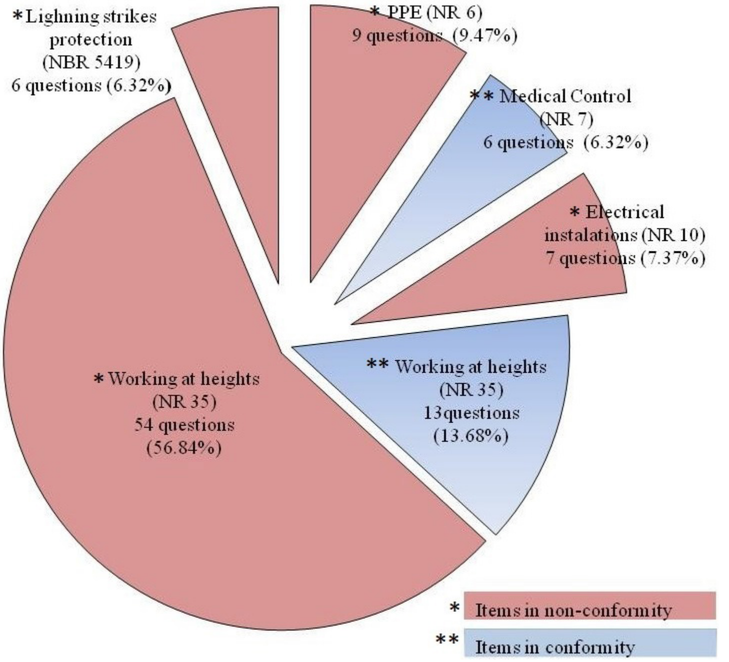

Figure 2. Checklist results.

The items from the section of *"NR6 - Personal Protective Equipment (PPE)"* were all in non-conformity didn't have required characteristics, or were not available for using. The occupational health certificates required by the *"NR7 - Medical control"* were all in conformity.

All items required by the *"NR10 - Electrical safety"* were in non-conformity as: no one undertook trainings on electrical safety, including the identification and evaluation of risks and precautions; no trainings for first aid assistance; the risk analysis was never conducted prior to working activities. Maintenance workers didn't have access to circuit breakers for by de-energizing accessed parts.

The items from *"NBR 5419 on Protection of structures against lightning strikes"* (Associação Brasileira de Normas Técnicas, 2001) were all in non-conformity: the metallic structure of the roof was not interconnected with the catchment subsystem; the cables from the catchment subsystem were not installed in the perimeter of the system, nor connected to the descending subsystem; the subsystem was not connected to the grounding subsystem; the grounding electrodes were not at least 1.0 meter away from the building's external walls.

Most of items from the checklist (67 items, 70.52%) were in relation to the *"NR 35 - Working at heights".* From those 67 items, 79.1% were in non-conformity, while only 20.9% were in conformity. The non-conformity for all three companies was in relation to: no prior studies on how the work at height is carried-out; no supervision if adequate control measures for working at height have been implemented; no prior authorization was issued and no procedures for working at height; no training for carrying work at heights; workers were not previously trained and approved in theoretical and practical training for working at heights with a workload of at least 8 hours; the workers were not trained how to use PPE for working at heights; no trainings for first aid assistance. The risk analysis didn't consider: the location on which the service was conducted; the signalization; anchorage points; meteorological conditions; the inspection of the utilization of collective and personal protective equipment; the risk of falling objects; communication systems; if the worker was connected to the anchorage system throughout the period of working at heights; availability of an emergency team; among other questions. The conformity was in relation to: periodic biennial training in procedures, conditions and work operations with a workload of at least 8 hours; the periodic health assessment of those working at heights; the equipment for working at heights; the items in relation to the safety harness for working at heights and its correct use.

3.2. Risk analysis and evaluation

The identified risks of accidents with its classification according to the HRN = LO x FE x DPH x NP, were illustrated in Table 4. The risks of falling objects and falls from height were classified as *"high"*, electrocution as *"unacceptable"*, while attacks from wild animals as *"low"*.

All of the risks classified in Table 4 as high (falling objects and falls from height) and unacceptable (electrocution) should be put as priority in applying risk control measures, as those risks pose serious risk for the safety and health of involved workers.

Table 4. Classification and Hazard Rating Number of identified risks.

Risk type		degree of severity (DS)		exposure frequency (EF)		probability of damage occurring (PD)		number of people at risk (NP)		HRN with risk classification	
Falling objects	tools	8	fatality (15)	7	constantly (5)	4	*possible (2)	2	3-7 people (2)	3	300 (high)
	antenna	8	fatality (15)	7	constantly (5)	4	*possible (2)	2	3-7 people (2)	3	300 (high)
Falls from height		8	fatality (15)	7	constantly (5)	4	*possible (2)	2	3-7 people (2)	3	300 (high)
Electrocution		8	fatality (15)	6	hourly (4)	5	some chance - may occur (5)	2	3-7 people (2)	4	600 (Unacceptable)
Attacks from wild animals		5	more serious injury, fracture or illness - temporary (4)	4	weekly (1.5)	4	*possible (2)	2	3-7 people (2)	2	24 (low)

*possible (2) = possible - but it is not common to occur (2).

3.3. Risk control

Previous studies were consulted in order to give suggestion on control measures for classified risks. Some measures control all of the classified risks, while some measures are specific for each risk.

In Table 5 were suggested control measures for falling objects and falls from height. As it was noticed in one study conducted on injuries from falling objects (Grivna et al., 2015), peak time of injury was from 10 am to 1 pm. The study suggested this could be related to tiredness and sleepiness of workers which increased as the lunch time approximated. The time of increased number of injuries could also be correlated with heat stress, as this time also represent peak in air temperatures. These are all factors which could be taken in consideration when planning the working activities. The same study found that falling objects most commonly affect/injure the extremities of the human body. The most affected were the upper extremities in 38.3%, followed by lower extremities in 37.6% and head/neck in 19.5%. This is important to consider, as it shows that hard hats (helmets) would only partially minimize the consequences of a falling object, and showing the importance of boots with protective cap and other PPE.

Although falls could occur from different heights (including sitting or standing height), the falls from height (above 2 meters from the ground) are of particular interest for the occupational risk management. Falls from height can result in serious injuries or even death, even when the person didn't fall directly on his head/neck. As concluded by one study (Zlatar et al., 2019), falls from height between 3 and 6.1m most commonly resulted in temporary disability (52% of analyzed cases), while in some cases even with permanent disability (15%) and

Table 5. Suggested control measures for falling objects and falls from height.

Control Measures		*Falling objects (antenna/tools)	*Falls from height
Elimination Substitution		In some cases, it would be possible to use drones to minimize the work at heights, but this solution would not be applicable for all activities conducted at telecommunication towers (therefore this would offer only partial risk elimination).	
Engineering Isolate (rope off) the area, where fall or drop hazards may exist. For antennas: Install a mini electric winch for hoisting the antenna. For tools: Utilization of tool lanyards for preventing tolls from falling. Ensure toe boards are in place and inspected frequently.		Always use adequate equipment and tools to perform the service and add adequate lighting in the working area.	
		Install adequate guardrails and barriers.	
		Install ladder cages and a ladder fall arrest system (vertical cable lifeline).	
Administrative	Procedures	Conduct a work in accordance to the project for equipment installation and a specific technical responsibility note. Develop procedures and a work plan, work as a team and remain vigilant of these procedures at all times. Organize a plan and procedures for emergency cases. Whenever possible, conduct working activities in good weather (avoiding strong winds and rain).	
		Keep all material from a leading edge. Remove items from all loose or unsealed pockets, especially top shirt pockets, such as phones, pens, and tools. Do not hang objects over guardrails.	
	Supervision	Develop periodic audit verifications. Release of work permits. Ensure supervisory guidance. Conduct initial onsite inspection check-lists and daily inspection check-lists. Conduct daily occupational safety and health meetings with workers prior to conducting the activity.	
	Training and certification	Training for the correct use of all working equipment (including personal protective equipment).	
		Training for the implementation procedures of all specific services and how to give first aid assistance.	
		Training for working at heights.	
	Signalization	Warning labels informing workers use personal protective equipment.	
		Use warning labels regarding risks of falling objects.	Use warning labels regarding risks of falls from height.
	Medical exams	Conduct necessary medical exams, with adequate certificate and the identification badge.	
Personal Protective Equipment Wear hard hats and boots with protective cap.		Inspect all PPE on regular basis to confirm if it still meets manufacturers' recommendations. Purchase, supply and registered all personal protective equipment.	
		Wear slip resistant shoes, work restraint systems, fall arrest systems, horizontal lifelines (lanyard, anchor and hook)	

*Sources: *Falling objects* (Bastos et al., 2019; Grivna et al., 2015); *Falls from height* (Bastos et al., 2019; Zlatar et al., 2019).

death (25%). As the falling height increased, so did the severity of consequences, where falling from heights above 9.1m resulted in death in 73% of analyzed cases. As telecommunication antennas are normally put-on high altitudes (building roofs and towers), falls represent high risks which would normally result in death consequences.

When analyzing the cases of accidents of falls from height (Zlatar et al., 2019), it was noticed that in 98% of cases there were more failed risk control measures (missing or not adequately applied measures). This means that in the majority of cases, falls from height were not a coincidence or an unlucky event, but a result of various failed risk control measures. Non-adequate or non-existing procedures of work were present in 81.6% of analyzed accidents of falls from height, while engineering measures such as handrails, barriers and edge protection in 65.8% of cases. It is probable that analyzing accidents from other types of risks would lead to similar conclusions, indicating procedures of work as one of the main failed risk control measures.

In Table 6 were suggested control measures for electrocutions and attacks from wild animals. The risk of electrocutions was classified by the HRN as *"unacceptable risk"*, normally resulting from unsafe equipment or installation, unsafe environment and unsafe work practices (Occupational Safety and Health Administration, 2020). Electrocution is, along with falls and the impact of falling objects, one of the main causes for occupational fatal accidents (International Labour Organization, 2003).

Table 6. Suggested control measures for electrocutions and attacks from wild animals.

<table>
<tr><th colspan="2">Control Measure</th><th>*Electrocution</th><th>*Attacks from wild animals</th></tr>
<tr><td colspan="2">Elimination</td><td colspan="2">In some cases, it would be possible to use drones to minimize the work at heights, but this solution would not be applicable for all activities conducted at telecommunication towers (therefore this would offer only partial risk elimination).</td></tr>
<tr><td colspan="2">Substitution</td><td colspan="2">Additionally, the risk of electrocution might be eliminated by de-energizing or insulating before all works.</td></tr>
<tr><td colspan="2" rowspan="2">Engineering
Ensure electrical parts are adequately isolated.
Ensure proper grounding.</td><td colspan="2">Always use adequate equipment and tools to perform the service and add adequate lighting in the working area.</td></tr>
<tr><td>Isolate with barriers or fences the area of the antenna.</td><td></td></tr>
<tr><td rowspan="12">Administrative</td><td rowspan="4">Procedures</td><td colspan="2">Conduct a work in accordance to the project for equipment installation and a specific technical responsibility note. Develop procedures and a work plan, work as a team and remain vigilant of these procedures at all times. Organize a plan and procedures for emergency cases. Whenever possible, conduct working activities in good weather (avoiding strong winds and rain).</td></tr>
<tr><td>· An electrical hazard survey should be conducted at jobsite to identify potential electrical hazards and intervention measures before work.</td><td>· Maintain the area of the antenna in good condition (mowing the lawn on periodic basis).</td></tr>
<tr><td>· Lock-out and tag-out all electrical parts.</td><td>· In wild areas, make noise to keep animals distant.</td></tr>
<tr><td></td><td>· The workers should not approach wild animals, give them room for animals to escape.</td></tr>
<tr><td>Supervision</td><td colspan="2">Develop periodic audit verifications. Release of work permits. Ensure supervisory guidance. Conduct initial onsite inspection check-lists and daily inspection check-lists. Conduct daily occupational safety and health meetings with workers prior to conducting the activity.</td></tr>
<tr><td rowspan="3">Training and certification</td><td colspan="2">Training for the correct use of all working equipment (including personal protective equipment).</td></tr>
<tr><td colspan="2">Training for the implementation procedures of all specific services and how to give first aid assistance.</td></tr>
<tr><td>Training for electrical safety to enhance the electrical hazard cognition and the avoidance of unsafe conditions in workplace.</td><td>Training for safety with wild animals. Be aware of which animals could be expected in the working area, where the animals could be hided and what to do in case of fronting one. Some animals and insects might have built their nests or hives in holes and parts of the antenna.</td></tr>
<tr><td rowspan="2">Signalization</td><td colspan="2">Warning labels informing workers use personal protective equipment.</td></tr>
<tr><td>Use warning labels regarding risks of electrocution.</td><td>Use warning labels regarding risks of attacks from wild animals.</td></tr>
<tr><td rowspan="2">Medical exams</td><td colspan="2">Conduct necessary medical exams, with adequate certificate and the identification badge.</td></tr>
<tr><td></td><td>Be vaccinated against possible wild animals' attacks (anti rabies, anti-tetanus vaccinations, among others).</td></tr>
<tr><td colspan="2" rowspan="2">Personal Protective Equipment
Well-designed non-conductive personal protective equipment.</td><td colspan="2">Inspect all PPE on regular basis to confirm if it still meets manufacturers' recommendations. Purchase, supply and registered all personal protective equipment.</td></tr>
<tr><td>Wear long sleeved shirt and jeans, wear gloves and boots.</td><td></td></tr>
</table>

**Sources:* Electrocution (Pereira et al., 2019; Zhao et al., 2015); Attacks from wild animals (Martins et al., 2018).

In order to contribute in the reduction of the number of accidents, OSHA developed a potential draft of the standard addressing telecommunications tower safety (Occupational Safety and Health Administration, 2018). The draft defined the minimum safety training for all employees working on telecommunications tower worksites, including trainings related to fall arrest system, environmental hazard recognition, electrical hazard recognition, first aid training, job hazard analysis. The perspective standard should also include topics such as assignment and roles training for authorized climber/rescuer, competent climber/rescuer, qualified rigger, hoist operator, crane operator, recordkeeping, worksite conditions (job hazard analysis, toolbox talks, rigging, hoisting, and gin pole use), environmental hazards (weather hazards, wildlife, worksite locations), safe work practices (general, structural work on telecommunications towers), considerations related to communication and structural alterations and/or modifications, fall protection (duty to have 100 percent fall protection; personal fall arrest systems; safety climb systems), support equipment requirements (hoisting, use of cranes in telecommunications tower work activities), structural requirements for telecommunication towers (structural loading considerations and tower inspection requirements), and the use of Unmanned Aerial Vehicles.

Further on, the occupational safety and health should be considered already at the initial phase, by applying the concept of prevention through design, which would provide a cheaper and a more effective risk control for towers and similar constructions. This could be achieved through Building Information Modeling (BIM) or similar platforms, which were already successfully used for different phases of the construction and maintenance process (Zlatar & Barkokébas Junior, 2018) for automatic, semi-automatic and manual identification and analysis of risks (Burgos da Rocha Leão et al., 2019). Such platforms were mostly used in managing risks of falls from height, falling objects and electrocutions. However, recent applications show BIM could be used even during the maintenance phase and for assessing exposure to noise levels (Tan et al., 2019) which show a range of perspectives for the application on telecommunication towers for assessing exposures to thermal environments or electromagnetic fields, or, adequately position the antenna to avoid excessive exposure of workers and the general public to radiofrequency fields .

The current study has several limitations. It is important to take in consideration that in additional to the mentioned risks of accidents, there are a number of health risks which should be additionally evaluated: ergonomic risks (musculoskeletal disorders); non-ionizing radiation (electromagnetic and solar); microclimate (thermal environment: hot or cold) among others. All these risks should be considered when assessing the risks to which the maintenance workers are exposed. This study was based only on data collected from nine workers and three companies. The present study had no access to buildings; therefore, it only considered maintenance of antennas on towers. Future studies could conduct additional studies on maintenance of antennas located on building roofs. Due to only few publications on the topic, more studies are needed regarding occupational safety and health in construction and maintenance of telecommunication towers.

5 Conclusions

The number of telecommunication towers is increasing worldwide, with expectations for them to continue to increase as the demand for service requires. This increase will mean that more workers will be participating in construction and maintenance activities of telecommunication towers.

These activities present high risks for occupational safety, namely related to falling objects (antennas and tools), falls from height, electrocutions, and attacks from wild animals. However, through the risk management process, as suggested through this study, it is possible to eliminate and/or minimize the risks. For this purpose, it is first important to apply different methods and techniques in order to identify, analyze and evaluate the risks, and then apply adequate control measures.

From the results of the current studies, it can be concluded that evaluated cases of maintenance activities in telecommunication towers have poor occupational safety conditions, with only 20% of considered items being in conformity, and 80% in non-conformity. This is in accordance with the findings from other encountered studies, which lead to accidents and fatal consequences.

The safety on telecommunication towers should be first improved through the concept of "Prevention Through Design", where new technologies as the Building Information Modeling (BIM) and similar could be applied. For this purpose, the current study offered suggestions for risk control measures. In addition, it would be beneficial to consult the suggestions developed by OSHA trough the potential draft of the standard addressing telecommunications tower safety.

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Appendix A. Questionnaire applied to professionals who perform maintenance on antennas in telecommunications towers.

Item	Question	Answer
1	Name	
2	What is your education level?	() Elementary School () High School () University
3	Admission date	______/______/______
4	Function	
5	Hours	Daily: _______ ; Weekly: _______ Monthly: _____ ; Days off: ___
6	Weight	
7	Height	
8	Number of Years with experience in the activity	
9	Date of last training	_____/______/______
10	Have you ever suffered an accident at work? Which? For how long were you on sick leave?	
11	What is your marital status?	()Not married ; () Married
12	Are you an employee of?	() Operator ; () Subcontracted company
13	Do you have training for working at height?	() yes ; () no
14	Did you do any additional tower maintenance training?	() yes ; () no
15	Is training for working at height valid?	() yes ; () no
16	How long of experience in this field?	() Less than 3 months () 3-6 months () 6-12 months () 1-5 years () More than 5 years
17	How many hours do you normally work?	() 4 hours () 8 hours () More than 8 hours
18	How many hours do you normally rest per day?	() 4 hours () 8 hours () More than 8 hours
19	How many meals a day do you eat?	()1 () 2 () 3 () 4 () 5 () More than 5.
20	What is the time when meals are usually taken (breakfast, lunch and dinner)?	1. Coffee __:___ 2. Lunch __:___ 3. Dinner __:___
21	Have you ever suffered any type of accident while performing this activity? If so, what was the accident?	() yes ; () no Which?____________________
22	Have you ever suffered any attack from snakes, spiders, scorpions or centipedes when performing the service? If so, from which animal?	() yes ; () no Which?____________________
23	How many people are on your maintenance team?	
24	Are there people who are hired locally to help with the activity? If so, what is her role?	() yes ; () no Which?____________________
25	Is there an inspection by the occupational safety technician when they are carrying out the activity? If so, how often does the safety technician visit the site?	() yes ; () no Which?____________________
26	Was a Daily Safety Dialogue held prior to the start of the activity?	() yes ; () no

Appendix B. General company information.

Item	Question	Answer
1	How many employees does the company have?	
2	Do you use your own or outsourced team to perform the antenna maintenance activity?	
3	What is your education level?	
4	How many hours do teams work per day?	
5	How many hours do teams rest per day?	
6	Does everyone on the team have training in working at height according to NR 35? Is it valid?	
7	What is the average experience of teams in this field?	

Appendix B. Continued...

Item	Question	Answer
8	Have there been any accidents at work with your team? If so, what was the accident? What was the cause, how many people, how long ago, what preventive measures were adopted?	
9	Has any worker ever suffered any kind of attack by poisonous animals during the execution of the services? Such as: snake, spider, scorpion or centipede.	
10	How many teams and how many people are part of each team in the activity?	
11	In case of outsourcing the service, do you know if there is hiring of people locally to help the activity? If so, what is the function?	
12	Is there an inspection by the occupational safety technician when they are carrying out the activity? If so, how often does the security technician visit the site?	
13	Is there someone guiding safety procedures for teams performing the service?	
14	Is there a PPE Checklist?	
15	Has the Preliminary Risk Analysis of the activity been prepared?	

Appendix C. Checklist das Normas Regulamentadoras and NBR 5419.

CHECKLIST NR 6 - Personal Protective Equipment - PPE			
Item	Description	C/NC/NA	Observation
6.2	The Personal Protective Equipment – PPE comes with the indication of the Certificate of Approval - CA.		
6.9.2	Is the validity of the Certificate of Approval – CA of the PPE in force?		
6.3	Does the company provide risk-appropriate PPE?		
6.3	Does the company provide employees with PPE in perfect condition and working order?		
6.6.1	Does the company require the use of PPE?		
6.6.1	Does the company guide and train the worker on the proper use, storage and conservation of PPE?		
6.6.1	Does the company register the provision of PPE to the worker through books, records or electronic system?		
6.7.1	Does the employee use PPE only for its intended purpose?		
6.7.1	Is the employee responsible for guarding and preserving the PPE?		
CHECK-LIST NR 7 – Occupational health medical control program			
Item	Description	C/NC/NA	Observation
7.4.4	Is the Occupational Health Certificate – OHS issued?		
7.4.4.3	Does the OHS have the worker data?		
7.4.4.3	Does the OHS have the existing specific occupational hazards or the absence of them?		
7.4.4.3	Does the OHS have an indication of the medical procedures to which the worker was submitted, including the complementary exams and their respective dates?		
7.4.4.3	Does the HSO contain the name and CRM of the coordinating physician?		
7.4.4.3	Is there a field in the HSO indicating whether the worker is able or unable to perform his duties?		
CHECK-LIST NR 10 - Security in electricity facilities and services			
Item	Description	C/NC/NA	Observation
10.6.5	Does the person responsible for performing the service have the duty to suspend activities when he/she finds a situation or unforeseen risk condition, whose immediate elimination or neutralization is not possible?		
10.8.9	Are workers with activities not related to electrical installations developed in a free zone and in the vicinity of the controlled zone, as defined by NR-10, formally instructed with knowledge that allows them to identify and assess their possible risks and take appropriate precautions?		
10.11.7	Before starting team work, do its members, together with the person responsible for performing the service, perform the Preliminary Risk Assessment (PRA) of the work?		

C = Compliance; NC = Non Compliance; NA = Not applicable.

Appendix C. Continued...

10.8.8	Did the workers receive a basic NR-10 course?		
10.8.8.1	Has the company granted authorization in the form of NR-10 to trained or qualified workers and to qualified professionals who have participated with satisfactory evaluation and use of the courses listed in ANNEX II of NR-10?		
10.8.8.2	Is there a biennial refresher training and whenever there is a change of function or change of company, return to work or inactivity for a period exceeding three months and significant changes in electrical installations or change of methods, processes and work organization?		
10.12	Does the staff have emergency training?		
CHECK-LIST NR 17 - Ergonomics (Brasil, 2018)			
Item	**Description**	**C/NC/NA**	**Observation**
17.1	Before starting activities, do workers perform gymnastics at work?		
17.1.2	Is there an ergonomic analysis of the work?		
17.2.1.1	In the transport and unloading of materials made by impulsion or traction, is the physical effort made by the worker compatible with his/her strength capacity and that it does not compromise his/her health or safety?		
17.3.2	Do they have dimensional characteristics that enable proper positioning and movement of body segments?		
17.5.3.2	Is the lighting designed to prevent glare, annoying reflections, shadows and excessive contrast?		
CHECK-LIST NR 35 - Work at height			
Item	**Description**	**C/NC/NA**	**Observation**
35.4.6.1	Are there operational procedures for routine work at height activities?		
35.2.1	Does the company have a prior study of the conditions at the place where work will be carried out at height?		
35.2.1	Does the company adopt the necessary measures to monitor compliance with the protection measures established in this Standard for contracted companies?		
35.2.1	Do workers have access to up-to-date information on risks and control measures?		
35.2.1	Does the company guarantee that any work at height will only start after the protection measures defined in NR 35 have been adopted?		
35.2.1	Does the company ensure the suspension of work at heights when it finds an unforeseen risk situation or condition, whose immediate elimination or neutralization is not possible?		
35.2.1	Does the company establish an authorization system for workers to work at heights?		
35.2.1	Does the company ensure that all work at heights is carried out under supervision, the form of which will be defined by the risk analysis according to the peculiarities of the activity?		
35.2.2	Do workers comply with the expedited procedures regarding work at height, collaborating with the employer?		
35.2.2	Are workers instructed to ensure their safety and health and that of other people who may be affected by their actions or omissions at work?		
35.2.1	Has the employer promoted training of workers to carry out work at height?		
35.2.2	Were workers trained and approved in theoretical and practical training to work at heights with a workload of at least 8 hours?		
35.4.8	Is all documentation relating to work at height on file?		
35.2.2	Do workers contribute to safety at work at heights?		
CHECK-LIST NR 35 - Work at height			
Item	**Description**	**C/NC/NA**	**Observation**
	IN THE TRAINING PROVIDED, WORKERS WERE SUBMITTED TO APPROACHES ON:		
35.3.2	The rules and regulations applicable to working at height?		
35.3.2	Risk analysis and impeding conditions?		
35.3.2	Potential risks inherent in working at heights and prevention and control measures?		
35.3.2	Personal Protective Equipment for work at heights: selection, inspection, conservation and limitation of use?		
35.3.2	Discussions about typical accidents at work at heights?		
35.3.2	Conduct in emergency situations, including notions of rescue techniques and first aid?		
	THE EMPLOYER PERFORMS PERIODIC BIENAL TRAINING WHENEVER ANY OF THE FOLLOWING SITUATIONS OCCURS:		
35.3.3	Change in work procedures, conditions or operations?		

C = Compliance; NC = Non Compliance; NA = Not applicable.

Appendix C. Continued...

35.3.3	Did the periodical biennial training have a minimum workload of eight hours, according to the syllabus defined by the employer?		
35.3.5.1	Is the training carried out preferably during normal working hours, and is the training time valid for all purposes as effective working time?		
35.3.6	Is the training given by instructors with proven proficiency in the subject, under the responsibility of a qualified professional in occupational safety?		
35.3.7	At the end of the training, is a certificate issued containing the name of the worker, program content, workload, date, location of the training, name and qualification of instructors and signature of the person responsible?		
35.3.7.1	Is the certificate given to the worker and a copy filed at the company?		
35.4.1	Is all work at height planned, organized and carried out by a trained and authorized worker?		
35.4.1.2	Does the company assess the health status of workers who work at heights?		
35.4.1.2	Are the examinations and evaluation system part of the Occupational Health Medical Control Program - PCMSO included in it?		
35.4.1.2	Is the assessment carried out periodically, considering the risks involved in each situation?		
35.4.1.2.1	Is the aptitude to work at heights included in the worker's occupational health certificate?		
35.4.3	Is all work at heights carried out under supervision, the form of which will be defined by the risk analysis according to the peculiarities of the activity?		
35.4.4	Does the execution of the service consider external influences that may change the conditions of the workplace already foreseen in the risk analysis?		
35.4.5	Is all work at height preceded by Risk Analysis?		
CHECK-LIST NR 35 - Work at height			
Item	**Description**	**C/NC/NA**	**Observation**
	THE RISK ANALYSIS (AR) MADE BY THE COMPANY, IN ADDITION TO THE RISKS INHERENT TO WORKING AT HEIGHTS, CONSIDERS:		
35.4.5.1	The location where the services will be performed and its surroundings?		
35.4.5.1	Isolation and signage around the work area?		
35.4.5.1	The establishment of systems and anchorage points?		
35.4.5.1	Adverse weather conditions?		
35.4.5.1	The selection, inspection, form of use and limitation of use of collective and individual protection systems, in compliance with current technical standards, manufacturers' guidelines and the principles of impact reduction and fall factors?		
35.4.5.1	The risk of falling materials and tools?		
35.4.5.1	The simultaneous works that present specific risks?		
35.4.5.1	Compliance with the health and safety requirements contained in other regulatory standards?		
35.4.5.1	Additional risks?		
35.4.5.1	The impeding conditions?		
35.4.5.1	Emergency situations and rescue and first aid planning, in order to reduce the worker's inert suspension time?		
35.4.5.1	The need for a communication system?		
35.4.5.1	The form of supervision?		
35.4.6	Are non-routine work activities at heights previously authorized by means of a Work Permit?		
35.4.7.1	For non-routine activities are the control measures evidenced in the Risk Analysis and Work Permit?		
35.4.8	Is the Work Permit issued, approved by the person responsible for authorizing the permit, made available at the place of execution of the activity and, at the end, closed and filed in order to allow its traceability?		
35.4.8.2	Is the Work Permit valid for the duration of the activity, restricted to the work shift, and may it be revalidated by the person responsible for approval in situations where there are no changes in the established conditions or in the work team?		
xxx	Are PPE's, accessories and anchoring systems specified and selected considering their efficiency, comfort, the load applied to them and the respective safety factor in antenna maintenance?		
35.4.5.1	In the selection of PPE, are additional risks considered, in addition to the risks to which the worker is exposed?		
xxx	Are inspections done periodically, on the use of PPE, accessories and anchorage systems?		

C = Compliance; NC = Non Compliance; NA = Not applicable.

Appendix C. Continued...

CHECK-LIST NR 35 - Work at height			
Item	**Description**	**C/NC/NA**	**Observation**
35.5.6.1	Is it a routine inspection of all PPE, accessories and anchoring systems carried out before starting to work?		
35.5.6.2	Are the results of periodic and routine inspections recorded on acquisition when PPE, accessories and anchorage systems are refused?		
35.5.6.3	Are the PPE, accessories and anchorage systems that present defects, degradation, deformations or suffer impacts from falling unusable and discarded? The exception is when their restoration is provided according to national technical standards or, in their absence, international standards.		
35.5.9.1	Is the safety belt the parachute type? Is it equipped with a device for connection to an anchorage system?		
35.5.2	Is the anchoring system established by Risk Analysis?		
35.5.11	Does the worker remain connected to the anchorage system throughout the period of exposure to the risk of falling?		
35.5.11.1	Are the lanyard and fall arrest device fixed above the level of the worker's waist, adjusted to restrict the fall height and ensure that, in the event of an occurrence of fall, it minimizes the chances of the worker colliding with an inferior structure?		
35.5.11	Does the energy absorber have a drop factor greater than 1?		
35.5.10	Does the energy absorber have a lanyard longer than 0.9m?		
35.5.2	Is the anchorage point selected by a legally qualified professional, is it resistant to withstand the maximum applicable load, is it inspected for integrity before use?		
35.6.1	oes the employer provide emergency response personnel for work at heights? Note: The team can be own, external or composed of workers who perform the work at height, depending on the characteristics of the activities.		
35.6.2	Does the employer ensure that staff have the resources needed to respond to emergencies?		
35.6.3	Are emergency response actions that involve working at height included in the company's emergency plan?		
35.6.4	Are the people responsible for carrying out the rescue measures able to perform the rescue, provide first aid and have physical and mental fitness compatible with the activity to be performed?		
CHECK-LIST NBR 5419 - Protection of structures against lightning (Associação Brasileira de Normas Técnicas, 2001)			
Item	**Description**	**C/NC/NA**	**Observation**
5.1.1	Are the roof's metallic structures interconnected with the LPS capture subsystem?		
5.1.1	Verify, when the capture subsystem is of the mesh type, whether the cables/ribbons are installed on the perimeter of the entire coverage, with emphasis on the location of the capture elements in corners, corners, edges and significant protrusions?		
5.1.2	Check whether the LPS descent subsystem is interconnected to the LPS capture subsystem?		
5.1.2	Check, when possible, if the intermediate rings are properly connected to the LPS descending subsystem?		
5.1.2	Check whether the LPS descent subsystem is interconnected to the grounding subsystem?		
5.1.3	Check, when possible, that the grounding electrodes are located at least 1.0 meter away from the external walls of the building?		

C = Compliance; NC = Non Compliance; NA = Not applicable.