EXPERIMENTAL RESEARCH ON REDUCING RISKS IN THE INSTALLATION OF GSM ANTENNAS

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Abstract: *The paper presents the results of experimental research on the identification and reduction of occupational risks associated with GSM antenna installation activities, in a context characterized by technical complexity and multidimensional exposure to hazards. The study was conducted on two representative types of sites (urban and suburban), using a mixed methodology that integrated dosimetric measurements of the electromagnetic field, ergonomic assessments using the RULA method, and analysis of workers' risk perception. The results highlighted the uneven distribution of electromagnetic fields, with maximum values in the frontal area of the antennas, as well as the presence of significant ergonomic risks, particularly in activities involving manual handling of equipment. The analysis of anchoring systems demonstrated the superiority of chemical anchors compared to mechanical solutions in terms of safety factors. In addition, the study confirmed the decisive role of human and organizational factors, with operational errors and communication deficiencies being the main causes of incidents. Based on these results, integrated corrective measures were implemented, including technical solutions (mechanized lifting equipment), organizational measures (Lock-Out/Tag-Out procedures), and monitoring measures. Post-implementation evaluation indicated a significant reduction in incidents (by up to 83%), as well as improvements in ergonomic conditions and reduced exposure to risks. The conclusions of the study emphasize the need for a systemic and integrated approach to occupational health and safety management in the telecommunications sector. The obtained results contribute to the substantiation of best practices and provide support for the development of modern risk prevention strategies in GSM antenna installation and maintenance activities.*

Keywords: GSM, occupational safety and health, electromagnetic field, RULA, work at height, telecommunications.

1. INTRODUCTION

The accelerated development of telecommunications infrastructure, driven by the expansion of next-generation mobile networks (4G/5G) and the exponential growth in demand for digital services, has led to an intensification of GSM antenna installation and maintenance activities [1][2]. These activities involve frequent interventions in complex environments characterized

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by work at height, manual handling of heavy loads, and exposure to electromagnetic fields (EMF), resulting in a high and multidimensional occupational risk profile. In this context, telecommunications workers are simultaneously exposed to mechanical, ergonomic, electrical, and environmental hazards, which require an integrated and systemic approach to occupational safety and health (OSH) management [3][4].

Work at height remains one of the main risk factors, being associated with a high probability of serious or fatal accidents, especially in the absence of adequate fall protection systems [5]. According to the SR EN 363 standard, the use of fall arrest systems must be correlated with the structural characteristics of the supporting structure and with actual working conditions, including material condition and environmental factors [6]. In parallel, the handling of specific equipment (antennas, radio units, cables) involves intense physical effort and non-ergonomic working postures, favoring the development of musculoskeletal disorders. Ergonomic assessment methods such as RULA (Rapid Upper Limb Assessment) have proven effective in identifying these risks and in substantiating corrective measures [7][8].

Another critical aspect is exposure to electromagnetic fields generated by telecommunications equipment. Although average exposure levels generally remain below the limits established by international guidelines such as those issued by the International Commission on Non-Ionizing Radiation Protection (ICNIRP), the existence of spatial and temporal variations in field intensity may lead to significant localized exposures, particularly in the vicinity of active antennas [9].

The SR EN 50385 standard provides the framework for assessing equipment compliance and human exposure; however, its application under real construction-site conditions requires adjustments and continuous monitoring [10].

Beyond technical risks, the specialized literature highlights the decisive role of organizational and human factors in accident occurrence. Communication deficiencies within work teams, the absence of clear working procedures, or insufficient training significantly contribute to incidents, especially during critical installation phases such as lifting and positioning equipment. Studies in occupational safety indicate that more than 70% of workplace accidents are rooted in human or organizational errors, which justifies the need for systemic, not solely technical, interventions [11].

In this context, the present paper aims to experimentally investigate the risks associated with GSM antenna installation and to assess the effectiveness of integrated preventive measures applied under real working conditions.

The adopted approach combines instrumental measurement methods (for EMF evaluation), ergonomic assessment methods (RULA), and risk perception analysis tools (questionnaires), offering a holistic perspective on operational safety. The novelty of the study lies in correlating these dimensions and validating the proposed measures through field experiments, enabling the direct quantification of risk reduction.

Through this research, the objective is not only to identify risk factors but also to substantiate applicable and sustainable solutions adapted to the specific characteristics of telecommunications infrastructure in Romania.

The obtained results contribute to the development of best practices in the field and may support the formulation of operational guidelines aimed at improving safety levels in GSM antenna installation and maintenance activities.

2. DESCRIPTION OF THE ANALYZED LOCATIONS

The experimental research was designed to reflect real working conditions encountered in the Romanian telecommunications sector, with two distinct types of sites selected, representative of the majority of GSM antenna installation interventions. The selection of these locations was based on criteria related to operational complexity, associated risk levels, and frequency of use in practice, thus allowing a relevant comparative analysis from an occupational safety and health perspective.

The first category, referred to as Type A – high-density urban locations, is represented by residential buildings with medium- and high-rise configurations (P+8, P+10), whose rooftops frequently host telecommunications equipment. These sites are characterized by a high degree of spatial constraint, with limited available installation space fragmented by numerous existing structural elements such as chimneys, HVAC installations, parapets, or equipment belonging to different operators. From an operational standpoint, these obstacles generate significant challenges in organizing workflow, increasing the likelihood of errors and incidents, particularly during the handling of bulky equipment.

Another defining characteristic of these locations is the co-location of equipment belonging to multiple telecommunications operators, which leads to cumulative exposure to electromagnetic fields. Although average exposure levels comply with ICNIRP guidelines and the SR EN 50385 standard, the non-uniform spatial distribution of fields may create areas of high intensity, especially near active antennas. This situation requires rigorous planning of work zones and the implementation of strict measures to delineate safe areas in order to prevent accidental worker exposure.

Type B – suburban or peripheral locations include low-rise industrial buildings or dedicated structures such as self-supporting towers, typically situated in areas with low building density. These sites generally provide more generous working space, facilitating access for lifting equipment and more efficient organization of installation activities. However, the reduction in spatial constraints is offset by increased exposure to environmental factors, particularly meteorological conditions.

Among these, wind represents the primary risk factor, having a direct impact on worker stability and on the handling of equipment. Wind intensity and sudden variations can affect the control of suspended loads and increase the risk of loss of balance during work at height. In addition, direct exposure to unfavorable climatic conditions (extreme temperatures, precipitation) may influence the performance of personal protective equipment and anchoring systems, an aspect also highlighted in the literature concerning outdoor work environments [4].

The comparison between the two site typologies reveals that risks are not uniform but depend on the specific operational context. In urban environments, risks are mainly generated by spatial complexity and electromagnetic exposure, whereas in suburban environments physical and meteorological risks predominate. This differentiation justifies the need to adapt preventive measures to the specific characteristics of each location, in accordance with the principles of risk management defined in ISO 31000 (2018).

In conclusion, the selection of these two site typologies enabled a relevant comparative analysis, highlighting how environmental conditions and structural characteristics influence the risk profile. This approach forms the basis for the development of differentiated and effective prevention strategies, tailored to the field realities of GSM antenna installation activities.

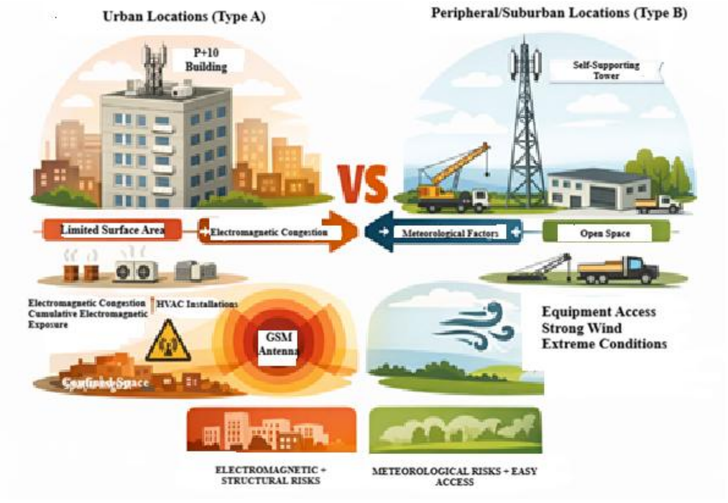

Figure 1. Comparative analysis between two main types of locations used for the installation of structures or technical equipment

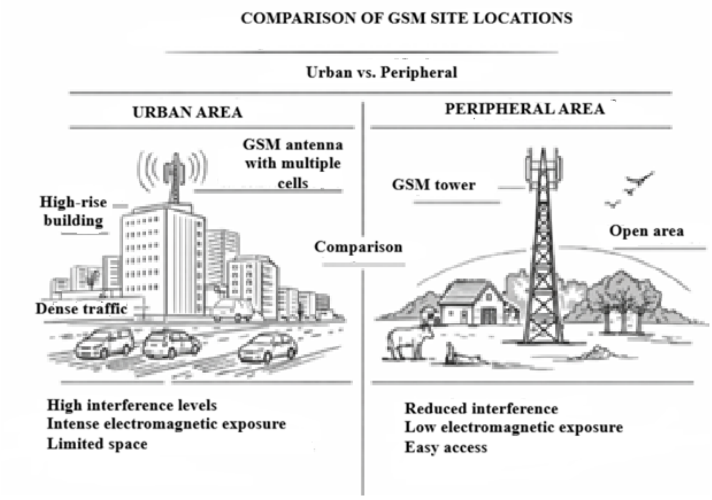

Figure 2. Location of GSM sites in two distinct environments

3. METHODOLOGY

The experimental research was based on a mixed methodology, combining instrumental measurements, ergonomic assessments, and tools for investigating human factors. The choice of this multidisciplinary approach was justified by the complex nature of GSM antenna installation activities, where occupational risks are generated not only by the technical conditions of the site, but also by adopted working postures, work organization, and workers' perception of existing hazards.

3.1. Dosimetric Measurements of the Electromagnetic Field

Prima componentă a metodologiei a constat în realizarea unor măsurători dozimetrice în teren, The first methodological component consisted of on-site dosimetric measurements performed using portable spectrum analyzers and isotropic probes to determine electric field intensity. The purpose of these measurements was to identify the actual exposure levels of workers at different points within the site and during various stages of the work, particularly during the site-ready, installation, and commissioning phases.

Measurements were carried out at predefined points relevant to the normal route of the installation team: at the base of the mast or supporting structure, in the frontal working area of the antenna, behind the antenna, and in the access area to the working platform. For each point, at least three successive readings were taken at regular intervals, and the final value was expressed as an arithmetic mean in order to reduce the influence of temporary emission fluctuations.

Example: In an urban location corresponding to a P+10 residential building, measurements were performed at 0.5 m from the base of the mast, at 2 m in front of an already active sector antenna, and at 1 m behind it. The results indicated moderate values near the base, high values in front of the antenna, and low values behind it, confirming the directional distribution of the electromagnetic field. This type of analysis enabled the delineation of safe access zones and areas requiring temporary restriction or emission shutdown by the operator.

Through the use of this method, the objective was not only to verify compliance with admissible limits, but also to understand how site configuration and the coexistence of multiple RF sources influence worker exposure.

3.2. Ergonomic Assessment Using the RULA Method

The second methodological component focused on the ergonomic analysis of technicians' activities using the RULA (Rapid Upper Limb Assessment) method. This is a widely recognized method for the rapid evaluation of working postures that may generate excessive strain on the upper limbs, neck, trunk, and lower limbs. Its application was justified by the fact that GSM antenna installation frequently involves lifting, supporting, and fixing relatively heavy equipment in uncomfortable positions, at height and within confined spaces.

Ergonomic observations were conducted directly during installation operations, with particular attention to high-demand activities such as manual lifting of radio units, fixing brackets to metal supports, cabling in bent or twisted positions, and handling tools above shoulder level. For each activity, body posture was analyzed by anatomical segments, and the final RULA score was determined based on posture, applied force, and task repetitiveness.

Example: During the lifting of a radio module weighing approximately 25 kg using a conventional pulley, the technician adopted a posture involving a bent trunk, elevated arms, and strained wrists, resulting in a RULA score of 6, indicating the need for immediate intervention. Following the introduction of a mechanized lifting system and a positioning seat, the same activity was reassessed, and the score decreased to 3, signifying reduced risk and a significant improvement in working conditions.

This stage demonstrated that many physical risks originate not only from equipment weight but also from the manner in which the load is handled and from the lack of adequate auxiliary solutions.

3.3. Self-Assessment and Risk Perception Questionnaires

The third methodological component consisted of administering structured questionnaires to a sample of 15 installation technicians, selected from workers directly involved in installation and maintenance activities. The purpose of this instrument was to capture the subjective dimension of risk, namely how workers perceive hazard exposure and the level of comfort or discomfort generated by personal protective equipment (PPE).

The questionnaire included closed and semi-open questions related to perceived electromagnetic field exposure, difficulties encountered in using PPE, previous experience with near-miss incidents, and the effectiveness of communication between ground teams and workers positioned on structures. Responses were centralized and comparatively analyzed in order to identify common trends and relationships between risk perception and actual on-site conditions.

Examples of applied questions:

- “On a scale from 1 to 5, how exposed do you feel to electromagnetic radiation during installation activities?”
- “Which item of equipment causes you the greatest discomfort during movement?”
- “Have you observed near-miss situations in the last 6 months? If yes, what was the main cause?”
- “Do you consider radio communication systems effective in noisy urban environments?”

3.4. Data Integration and Correlation

An important element of the methodology was the integration and correlation of results obtained from the three data sources. EMF measurements provided information on invisible physical risks, RULA analysis quantified biomechanical strain, and questionnaires captured workers’ practical risk perception. Integrating these results enabled the construction of a comprehensive risk profile associated with GSM antenna installation and facilitated the formulation of corrective measures adapted to on-site realities.

In conclusion, the data collection methodology was designed to combine the objectivity of technical measurements with the relevance of ergonomic observations and workers’ direct experience. This mixed approach enabled both rigorous risk assessment and the identification of experimentally substantiated, effective preventive solutions.

4. RESULTS

The experimental results obtained allow the identification of the main risk factors associated with GSM antenna installation, through the correlation of electromagnetic field measurements, ergonomic assessments, and anchoring tests. Data analysis focuses both on identifying high-risk areas and activities and on evaluating the effectiveness of preventive measures implemented under real working conditions.

4.1. Monitoring of the Electromagnetic Field

Table 1. Electric Field Intensity (E)

Measurement Point	**Distance (m)**	**Measurement 1 (V/m)**	**Measurement 2 (V/m)**	**Measurement 3 (V/m)**	**Average (V/m)**	**σ (Std. dev.)**	**Max (V/m)**	**ICNIRP Limit (V/m)**	**Compliance**
Mast base	0.5	11.8	12.6	12.9	12.43	0.55	12.9	61	YES
Antenna front zone	2.0	40.2	42.8	44.1	42.37	1.98	44.1	61	YES (near limit
Lateral zone	1.5	8.5	9.1	8.9	8.83	0.30	9.1	61	YES
Behind the antenna	1.0	3.0	3.2	3.5	3.23	0.25	3.5	61	YES
Roof access area	10.0	0.7	0.8	0.9	0.80	0.10	0.9	61	YES

The higher variability observed in the frontal area of the antenna (σ = 1.98) indicates significant fluctuations in the electromagnetic field intensity, primarily determined by variations in data traffic, interference from other co-located antennas, and the directional characteristics of the radiation pattern. This instability suggests that workers operating in this area are exposed to variable electromagnetic field levels, which necessitates continuous monitoring and the limitation of exposure time.

The substantial difference between the measured values in front of and behind the antenna confirms the directional nature of radio emissions, where energy is concentrated within the main radiation lobe. The approximate ratio of 13.1 between the field intensity in the frontal zone and that behind the antenna highlights the existence of a non-uniform electromagnetic field distribution. This finding justifies the clear delimitation of safety zones and the establishment of controlled access procedures during installation and maintenance activities.

4.2. Ergonomic Analysis (RULA)

Table 2. Distribution of RULA Scores (N = 15)

Activity	**Min**	**Max**	**Average**	**σ**	**High-risk (%)**
Manual lifting	5	7	6.1	0.6	80%
Structural fixing	4	6	5.0	0.7	60%
Cabling	3	5	4.2	0.5	40%

The analysis of RULA scores for the 15 observations indicates that manual equipment lifting presents the highest ergonomic risk, with an average score of 6.1 and low variability (σ = 0.6), suggesting consistent exposure of workers to unfavorable postures. The high percentage of cases classified as high risk (80%) indicates that most technicians adopt forced postures, particularly during the handling of radio units and antennas, which may lead to musculoskeletal disorders and increase the likelihood of operational errors.

For structural fixing activities, the average score of 5.0 indicates a moderate to high ergonomic risk, mainly caused by working in awkward positions with raised arms or a twisted trunk. The slightly higher variability (σ = 0.7) shows that the level of strain depends on site configuration and accessibility of mounting points.

Cabling activities exhibited the lowest ergonomic risk, with an average score of 4.2 and 40% of observations classified as high risk. However, the obtained values still indicate the presence of non-ergonomic working postures, especially in confined spaces or bent positions. These results confirm that, although cabling is less demanding than equipment handling, it contributes to cumulative fatigue and may negatively affect workers' long-term performance.

4.3. Anchoring System Testing

Pull-out tests were conducted under controlled conditions directly on the supporting structures used for GSM antenna installation, using a calibrated portable anchorage pull-out testing device. For each anchorage type, three independent tests were performed, with anchors installed in accordance with the manufacturer's instructions and respecting curing time requirements for chemical anchors. The load was applied gradually by progressively increasing tensile force until failure occurred or significant deformation of the anchoring system was observed.

During testing, anchorage behavior and failure mode were monitored, noting whether failure occurred through pull-out from the substrate, deformation of the anchor, or cracking of the supporting structure. The obtained values were recorded for each test, and subsequently the mean value, standard deviation, and safety factor were calculated to assess the stability and reliability of each anchoring type. This methodology enabled an objective comparison of fixing system performance under conditions close to actual operational use.

Table 3. Results of pull-out resistance tests, performed for three types of anchoring systems used in the installation of structures and equipment at height

Anchorage Type	**Test 1 (kN)**	**Test 2 (kN)**	**Test 3 (kN)**	**Average (kN)**	**σ**	**Safety Factor**
Mechanical expansion anchor	6.2	5.8	6.5	6.17	0.35	1.23
Chemical anchor	18.5	19.2	17.8	18.5	0.57	3.70
Metal screw	12.0	11.5	12.8	12.1	0.65	3.45

The pull-out test results highlight significant differences between the analyzed anchorage types, demonstrating the direct influence of technical solutions on safety levels during work at height. The mechanical expansion anchor registered a relatively low average failure load of 6.17 kN and a safety factor of only 1.23, indicating a limited resistance reserve relative to design loads. This suggests a potential risk under dynamic conditions such as sudden worker movements or wind-induced loads, where actual forces may quickly exceed anchorage capacity.

In contrast, the chemical anchor showed the highest performance, with an average value of 18.5 kN and a safety factor of 3.70, indicating high stability and superior resistance to dynamic loads. The low variability ($\sigma = 0.57$) confirms consistent behavior and high reliability under real working conditions. This performance is explained by uniform stress distribution within the concrete mass and superior chemical bonding compared to mechanical systems.

Self-drilling metal screws used on metallic structures also demonstrated satisfactory results, with an average value of 12.1 kN and a safety factor of 3.45. Although these values indicate adequate load-bearing capacity, dependence on material thickness and metal quality requires prior verification of the supporting structure. Overall, the comparative analysis confirms that proper selection of anchoring systems is a critical factor in reducing fall risk and enhancing safety during GSM antenna installation activities.

5. DISCUSSIONS

The statistical analysis of incidents observed during pilot installations aimed to identify dominant risk patterns and evaluate relationships between determining factors. Collected data were structured into deviation categories and analyzed using both descriptive and inferential methods to highlight relevant correlations between operational variables and incident occurrence.

5.1. Incident Distribution

Incident distribution was determined based on direct observations during pilot installations and records from observation sheets completed by the research team. Deviations identified during each intervention were classified into three main categories: operational errors, communication deficiencies, and non-compliance with electromagnetic field (EMF) exposure procedures.

A total of 20 deviation cases were analyzed. Following data centralization, the frequency and percentage of each category were calculated A total of 20 deviation cases were analyzed. Following data centralization, the frequency and percentage of each category were calculated.

Table 4. Distribution of Incidents

Incident Type	**Number of Cases**	**Percentage (%)**
Operational errors	9	45%
Communication deficiencies	6	30%
EMF procedure non-compliance	5	25%
Total	20	100%

Percentages were calculated using the relationship:

$$P = \frac{n_i}{n_{total}} x100 \tag{1}$$

where:

n_i= number of incidents in the analyzed category

n_{total}= total number of observed incidents

Examples:

$$P = \frac{9}{20} x100 = 45\% \tag{2}$$

Table 5. Examples of Observed Incidents

Category	**Incident Example**	**Probable Cause**
Operational errors	Unsecured tools at height	Rushed execution
Operational errors	Incorrect antenna lifting	Lack of coordination
Communication deficiencies	Unclear command during load lifting	Ambient noise
Communication deficiencies	Missing radio confirmation	Unclear procedures
EMF exposure	Entry into antenna frontal zone	Lack of zone delimitation

Results show the following incident distribution:

- Operational errors: 45%
- Communication deficiencies: 30%
- EMF procedure non-compliance: 25%

These results highlight the dominant role of the human factor, as most incidents result from operational errors and communication issues. The categories are interdependent: poor communication can lead to operational errors, which in turn may cause hazardous situations, including accidental EMF exposure. These findings justify corrective measures such as communication standardization, targeted training, and mechanized equipment use, which later significantly reduced incident frequency.

5.2. Implementation of Corrective Measures and Efficiency Monitoring

Based on incident analysis and experimental evaluation, several major vulnerabilities were identified in GSM antenna installation activities, mainly related to load handling at height, communication deficiencies, and accidental EMF exposure. Corrective measures were implemented at three levels: technical, organizational, and monitoring.

5.2.1. Implemented Technical Measures

Technical interventions focused on reducing mechanical and ergonomic risks associated with equipment handling. Most operational errors occurred during lifting and positioning of loads between 20 and 35 kg. Consequently, automatic-locking pulley systems designed for work at height were introduced.

These devices feature automatic braking mechanisms preventing load slippage in case of loss of operator control, significantly reducing the risk of equipment falls and worker injuries. Implementation led to reduced physical effort, improved ergonomics, enhanced load control, and reduced lateral oscillations caused by wind.

Example: Prior to implementation, lifting a 25 kg radio unit using simple ropes caused uncontrolled oscillations and high physical strain. After introducing automatic-locking systems, lifting time decreased by approximately 30%, and load stability improved significantly

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5.2.2. Organizational Measures – Lock-Out/Tag-Out (LOTO) Procedure

The second category of measures aimed to improve operational coordination and reduce risks generated by accidental exposure to electromagnetic fields. To this end, a Lock-Out/Tag-Out (LOTO) procedure adapted to the specific requirements of telecommunications activities was implemented.

This procedure involves the temporary shutdown of active transmitters and the prevention of unauthorized access to telecommunications systems prior to the commencement of work. The procedure was carried out in collaboration with the operator’s Network Operations Center (NOC), establishing a dedicated *maintenance window* during which activities could be performed under safe conditions.

The operational process included the following steps:

- identification of active antennas within the work area;
- submission of a transmission shutdown request to the control center;
- confirmation of system shutdown;
- application of warning tags;
- authorization to begin work.

The implementation of this procedure significantly reduced the risk of accidental exposure to electromagnetic fields, particularly in areas with multiple co-located equipment systems.

Example. At an urban site hosting three telecommunications operators, installation activities were previously carried out in close proximity to active antennas. Following the introduction of the LOTO procedure, a two-hour maintenance window was established during which all transmitters in the work area were deactivated, significantly reducing technician exposure.

5.3.3. Monitoring and Re-Evaluation of Implemented Measures

To assess the effectiveness of the corrective measures, a monitoring program was established 30 days after implementation. During this stage, the same indicators initially analyzed were used in order to allow a direct comparison.

Table 6. Performance Indicators Before and After Implementation

Indicator	**Before**	**After**	**Reduction (%)**
Number of incidents	12	2	83%
Operational errors	45%	15%	67%
Communication deficiencies	30%	10%	66%
EMF exposure	25%	5%	80%

The obtained results demonstrated a significant reduction in incidents, confirming the effectiveness of the implemented measures. In particular, a substantial decrease in operational errors was observed, attributable to the introduction of mechanized equipment and the standardization of procedures.

The findings indicate that the implementation of both technical and organizational measures led to a marked improvement in safety levels during GSM antenna installation activities. The reduction in incident frequency, improvement of ergonomic conditions, and decrease in exposure to electromagnetic fields confirm the effectiveness of the adopted integrated approach.

Moreover, the analysis highlights that technical and organizational measures must be applied simultaneously in order to achieve maximum risk reduction. The introduction of mechanized systems without improvements in communication or without the implementation of safety procedures would not have produced comparable results. Therefore, the integrated approach represents a sustainable solution for enhancing safety in the telecommunications sector.

6. CONCLUSIONS

The experimental research conducted in this study highlighted the complex and multidimensional nature of the risks associated with GSM antenna installation activities, confirming that these risks are determined by the interaction of technical, ergonomic, and organizational factors. The integrated analysis of data obtained from instrumental measurements, ergonomic assessments, and operational observations enabled the identification of key vulnerabilities and the substantiation of effective preventive measures adapted to real working conditions.

The results of the case study demonstrated that the risks associated with GSM antenna installation are primarily multifactorial, being simultaneously influenced by environmental conditions, site configuration, the type of equipment used, and operator behavior. In particular, it was found that electromagnetic field exposure, although generally remaining below admissible limits, may exhibit significant local variations, especially in the frontal area of active antennas. This situation requires the strict delimitation of safety zones and the implementation of clear controlled-access procedures in order to reduce the risk of accidental worker exposure.

The ergonomic analysis of the performed activities revealed that inadequate working postures significantly contribute to physical fatigue and increase the likelihood of operational errors. The reduction in RULA scores following the implementation of corrective measures demonstrated that ergonomic improvements have a direct impact on enhancing safety levels and operational efficiency. This finding confirms the importance of using auxiliary lifting equipment and positioning systems to reduce musculoskeletal strain.

Furthermore, the anchoring system tests highlighted the critical role of fixing points in preventing severe accidents, particularly in work-at-height scenarios. The superior performance of chemical anchors compared to mechanical solutions used on degraded structures confirms the necessity of properly selecting anchorage systems based on substrate characteristics and working conditions. Improper selection of anchoring points may lead to loss of stability and accidents with severe consequences.

Another important aspect emphasized by the research concerns the role of targeted training and real-time monitoring of the working environment. The implementation of standardized procedures, combined with the use of monitoring equipment, led to a significant reduction in incident frequency and improved coordination among team members. These results confirm that continuous training tailored to the specific characteristics of each site represents an essential component of occupational risk management in the telecommunications sector.

Overall, the study demonstrates that reducing risks associated with GSM antenna installation requires an integrated approach, based on experimental assessment, the use of monitoring technologies, and the implementation of dedicated training programs. The application of the proposed measures resulted in a reduced probability of accidents and diminished severity of potential consequences, thereby contributing to increased safety and operational efficiency.

The obtained results may serve as a basis for developing best-practice guidelines in the telecommunications field and for designing modern occupational risk management strategies. From a future perspective, further research may focus on integrating digital technologies, real-time monitoring systems, and predictive models to optimize work processes and further reduce occupational risks in GSM antenna installation activities.

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