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Improvement of the Preliminary Risk Analysis (PRA) integrated to the Ishikawa Diagram for risk prevention in civil construction.

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ABSTRACT

The main objective of this work is to analyze and evaluate the risks in the activities and processes developed in a civil construction work focused on the sanitation area, through the improvement of the Preliminary Risk Analysis (PRA) integrated with the Ishikawa Diagram, seeking to reduce the subjectivity of the PRA technique, in addition to identifying and characterizing the existing risks in the activities performed by workers, the probability of their occurrence, the level and intensity of the risks, and also having the necessary recommendations for each observed risk. Daily monitoring was carried out at all stages of the executive process of the activities explored to identify the risks to be analyzed for the constitution of the PRAi (Ishikawa diagram integrated with the PRA). Based on the PRAi results, the incidence of physical, ergonomic and accident risks was observed. Based on this research, it became clear the importance of identifying the risks existing in the activities observed and the necessary protection measures to mitigate or even eliminate risks in the work environment, improving safety, quality of life, and, consequently, productivity.

Palavras-chave: Ishikawa diagram; Risk management; Management in civil construction; Workplace safety; Analise Preliminar de Risco – APR.

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1. INTRODUCTION

The Preliminary Risk Analysis (PRA) is a risk analysis methodology widely used to identify possible hazards and risks in the work environment. It is also possible to apply the tool to identify the best choices in different business scenarios, helping in decision making, avoiding failures and eventual accidents in activities (YAN; XU, 2019; HFAIEDH et al., 2017; REZAIAN; JOZI; ZAREDAR, 2016).

PRA is extensive and can be applied in different sectors and scenarios. Hfaiedh et al. (2017) used PRA to detect medical errors in the process of administering intravenous medications to infants and children, analyzing risk events, considering human, environmental, logistical, and hygienic errors, among others. Based on the developed risk plan, 17 critical situations were observed in 69 risk scenarios, and with the development and application of the risk response plan, the probability of critical failures was reduced from 17% to 0%.

Monforte, Oliveira and Rocha (2015) used different risk analysis methodologies, including PRA, to analyze the welding process in a shipyard located in Rio de Janeiro, Brazil; the authors concluded that the tool presented satisfactory results regarding the identification of possible risks in the activity studied.

On the other hand, in processes with a high level of complexity, PRA may present weaknesses in its application. This is because it is a qualitative tool, with a large margin of error and imprecision, which can easily lead to an erroneous assessment due to the high subjectivity (ZHAO; ZHAO; TIAN, 2009, QU; WANG; ZUO, 2014; YAN; XU, 2019).

Monforte, Oliveira and Rocha (2015) reinforce that to reduce the subjectivity of PRA, measures such as meetings with workers, analysis of the entire work process, in-depth knowledge of the production stages, in addition to a multidisciplinary team to identify possible failures are necessary.

Therefore, it is clear the need to improve the methodology in question. Some authors suggest integrating one or more tools in the search for the elimination of subjectivity (BAYBUTT, 2018; JAYAPRASAD et al., 2018; MONFORTE, OLIVEIRA and ROCHA, 2015; ONOFRE et al., 2021).

Another tool widely used to analyze possible failures is the Ishikawa Diagram (JAYAPRASAD et al., 2018; HOłA et al., 2017; VARZAKAS, 2016). For this research, the PRA tool was combined with the Ishikawa Diagram, called PRAi.

2. METHODOLOGY

2.1 Object of study and collection of initial information

The research analyzed the pipe laying stage in essential sanitation work. The pipe used was ductile iron with a diameter of 800 mm, used to transport treated water to the population of Londrina in Paraná, Brazil.

Previously, two meetings were held with the work teams. The first group was with the workers, highlighting the difficulties of the work and the perspective of possible failures during the activities. The second meeting was one-on-one and anonymous, allowing some workers to express their opinions without feeling oppressed by the employer.

After the meetings and survey of possible failures highlighted by the workers, the monitoring of the stage of laying the pipes was carried out. At no time were interventions made in the activities, allowing all possible failures in the work environment to be observed.

2.2 Preparation of the PRAi tool

The elaboration of the PRAi, the concepts of the PRA were used, where through tables, values are established for different levels of probability and severity. The multiplication of these results in the value for risk assessment, determining whether it is considered a Tolerable (T), Moderate (M), or Not Tolerable (NT) risk. Such tables are presented in Figures 1, 2 and 3, and were developed based on the work of França, Toze and Quelhas (2008); Qu, Wang and Zuo (2014); Monforte, Oliveira and Rocha (2015); Rezaian, Jozi and Zaredar (2016); Lee and Park (2017); Torrecilhas et al. (2019)

Figure 1 – Category of risks in terms of probability

	Category		Description	Criteria
Probability	1	Extremely Remote	The chances of any damage occurring are meagre.	One time every two years
	2	Remote	There is a minimal probability of damage occurring.	One time every one year
	3	Improbable	There is a moderate probability that some damage will occur.	One time every six months
	4	Probable	There is a high probability that some damage will occur.	One time every three months
	5	Frequent	There will undoubtedly be some damage.	One time a month

Figure 2 – Category of risks in terms of severity

	Category		Description	Economic Criteria in US Dollar
Severity	1	Light	Non-injury accidents (trips, scratches, light collisions, etc.)	less than 500
	2	moderate	Accidents where the worker is required to be away, however disabling injuries, do not occur (minor cuts, light sprains, ailments)	between 500 to 1,000
	3	large	Lost time accidents and disabling injuries without loss of limbs (severe sprains, fractures, deep cuts, infections)	between 1,000 to 5,000
	4	severe	Lost time accidents and disabling injuries, with loss of limbs (loss of a finger, arm, leg, eye, etc.)	between 5,000 to 12,000
	5	catastrophic	Accidents causing death or permanent disability	greater than 12,000

Figure 3 – Risk assessment matrix

	Category		Risk assessment matrix				
Probability	5	Frequent	5	10	15	20	25
	4	Probable	4	8	12	16	20
	3	Improbable	3	6	9	12	15
	2	Remote	2	4	6	8	10
	1	Extremely Remote	1	2	3	4	5
Category			Light	moderate	large	severe	catastrophic
			1	2	3	4	5
Severity							

1 to 5	Tolerable risk (T)
6 to 12	Moderate Risk (M)
15 to 25	Risk Not Tolerable (NT)

For the integration of the Ishikawa Diagram in the PRA, the following concepts were considered: (i) method, (ii) material, (iii) labour, (iv) machine and (v) environment.

When analyzing the method concept, the work methodology was observed, considering the organization of activities and execution modes. As for the workforce analysis, the employees' capacity was verified, and whether or not they had mastery and knowledge of the activities performed. In the machine concept, the types of equipment used to prepare the activities were verified, considering the revisions, integrity and functionality. Moreover, the locations and conditions in which the activities were performed were observed in terms of the environment.

With the integration of these two techniques, it was possible to prepare the risk control and diagnosis spreadsheet, PRAi, where the columns of (i) procedures are presented: referring to activities performed; (ii) specific source: application of the Ishikawa Diagram methodology to identify possible failure scenarios; (iii) the causative agent: referring to the explanation of the agent causing the failure; (iv) consequence: addressing the likely consequences if the risk is effective; (v) risk: framing the type of risk to which the worker is exposed (physical, chemical, biological, accidental and/or ergonomic); (vi) probability: value assigned to risk probability (Figure 1); (vii) severity: value assigned to risk severity (Figure 2); (viii) risk level: identification of the risk level based on the result of the multiplication of severity and probability, and consulted by the risk matrix table (Figure 3).

After the preparation, completion and analysis of the data from the PRAi spreadsheet, responses to the identified risks were developed, presenting possible solutions and measures to mitigate and/or eliminate the risks in each activity performed.

3. RESULTS AND DISCUSSIONS

During the period of observation of the activities, the following scenarios were identified: the pipeline was lifted through a strap and moved by the excavator arm (Figures 4a and 4b), while an employee stayed inside the trench without the presence of the retaining wall, that protects in the event of a landslide.

Figure 4 – Pipe laying and lifting

a) Piping with lifting strap; **b)** Employee guiding piping for laying in ditch.

In the observation of the activities, acts of recklessness were identified. One of the employees, who worked inside deep trenches, refused to stay inside the collective protection equipment, the "ditch shield" a containment cage to protect against landslides (Figure 5).

Figure 5 – Employee inside the "ditch shielding" and without the use of the "ditch shielding"

a) and **b)** Employees inside the containment shield; **c)** Employees without the use of containment shielding.

After analyzing the activities, the PRAi risk analysis table was prepared (Figure 6). It highlights the risk levels, according to the risk matrix, and the measures to be taken to prevent possible failures and accidents at the place where the activities are carried out.

Figure 6 – Risk assessment PRAi

Procedure	Specific source	Causing Agent	Consequence	Risk Type	Probability	Severity	Risk Level		Risk Response
Pipe laying, service performed inside deep trenches	Method	Ditch without landslide protection	worker buried	Accident	5	5	25	NT	Use of ditch shielding; Train workers and the machinery operator.
		Working close to slopes		Accident	5	5	25	NT	
		Machinery operation close to the edge of the trench	Machinery collapse and fall	Accident	5	5	25	NT	Avoid excess weight near the edges of the ditches. Insert a limitation band for the operator; Work cautiously and without sudden movements with machinery when operations close to the edge are required.
		A worker near the pipeline during laying	Crushing of limbs	Accident	5	4	20	NT	Train workers and the machinery operator.
	Material	Worn, old or loaded lifting sling	Pipe fall on the worker	Accident	3	5	15	NT	Material inspection checklist before starting activities.
	Manpower	Inexperienced worker	Activity overload on other workers, bad behaviour inside ditches	Ergonomic	1	4	4	T	Conducting worker training.
		Overconfident worker	They expose themselves and other colleagues to risky situations	Accident	2	5	10	M	
		Stay close to machinery and suspended materials	Falling materials, or accidents involving machinery	Accident	5	4	20	NT	Awareness training.
	Machine	Noise emission from machinery	Noise	Physical	5	2	10	M	Provision of ear protectors; Awareness training.
		Staying close to workers and suspending materials	Falling materials, or accidents involving workers	Accident	5	4	20	NT	Awareness training; Limitation of space for workers to stay.
	Environment	Rainy weather	Ditch flooding, a worker may be buried or unable to get out due to slippery mud	Accident	4	5	20	NT	Avoid working at the bottom of a trench with rain or very wet (unstable) soil; Conducting worker training.
			Soil saturation, collapse	Accident	4	5	20	NT	
		Solar radiation	light burns	Physical	5	1	5	T	Provision of safety equipment: Sunscreen, hat, long-sleeved clothing and pants

The use of the PRAi tool made it possible to identify 13 risk scenarios in the laying process of FD DN800 pipes, with 15.38% tolerable risks, 15.38% moderate and 69.23% of non-tolerable risks. The latter being necessary immediate control measures.

Carrying out a verification of the risks by procedures performed, it can be observed that there is a predominance of risks of the Accident type with 76.92%, followed by physical risks (15.38%) and ergonomic (7.69%).

There is a more significant predominance of unacceptable risks in activities where the worker is close to or inside ditches. Isolating the identification of risks by the methodology of the Ishikawa Diagram, it is possible to observe that the critical (non-tolerable) risk factors are concentrated in the Method, Material and Environment.

The work environment itself is a dangerous place; it puts the worker's life at risk. However, safety measures must be taken to reduce the risks present in the work method and the materials used.

To mitigate the risks, it is necessary to invest in team training aimed at the correct positioning and use of heavy machinery during pipe laying activities, seeking to reduce the risk of soil collapsing due to overloads.

Regarding the materials used, it is evident the need to inspect the launch belts, verifying their conditions of use maximum load capacity, among other aspects that may interfere with the quality and resistance of the material.

4. CONCLUSION

PRA demonstrated its efficiency in identifying different risks in different scenarios found, thanks to the help of the integration of the Ishikawa Diagram. In this way, the PRAi tool presented a satisfactory result, allowing the observation of risk scenarios and identifying the risks inherent to the activities.

The aspects that need more attention were focused on the methodology of how the activities are carried out and the environment, which presents inherent risks, since they are activities that involve risks of collapse, burial, lifting of heavy materials, among others presented in this study.

Behaviours of employees who resisted the use of protective equipment were observed, deserving greater attention from management and safety at work, applying training and using personal protective equipment according to current legislation.

Also, the importance of raising awareness among employees and the company when health and safety in the work environment is highlighted.

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