









standards and maximum permissible limits defined by D.S. 055-2010-EM of the Ministry of Energy and Mines [22].

Furthermore, it can be seen that the increase in metal content was only more pronounced at point RmAnt2, which, as indicated in Fig. 2, is downstream of the river under analysis, which helped us to determine the contamination produced by the waste slides.

Finally, a comparative graph (Fig. 4) with the six chemical elements (Aluminum, Arsenic, Manganese, Cooper, Iron and Lead) was developed, in which the values obtained before and

after the accident are shown for point RMant2, since this is the area where the variation in content occurred with a higher average of the values concerning the three scenarios. Finally, it was observed that the most critical metal contents are aluminum and iron, which greatly exceed the Maximum Allowable Limit or MPL; at the same time, all the criteria were increased and exceeded the proposed limits, except for the case of Cooper  $C_4$ , where there was an increase, but the limits were not exceeded.

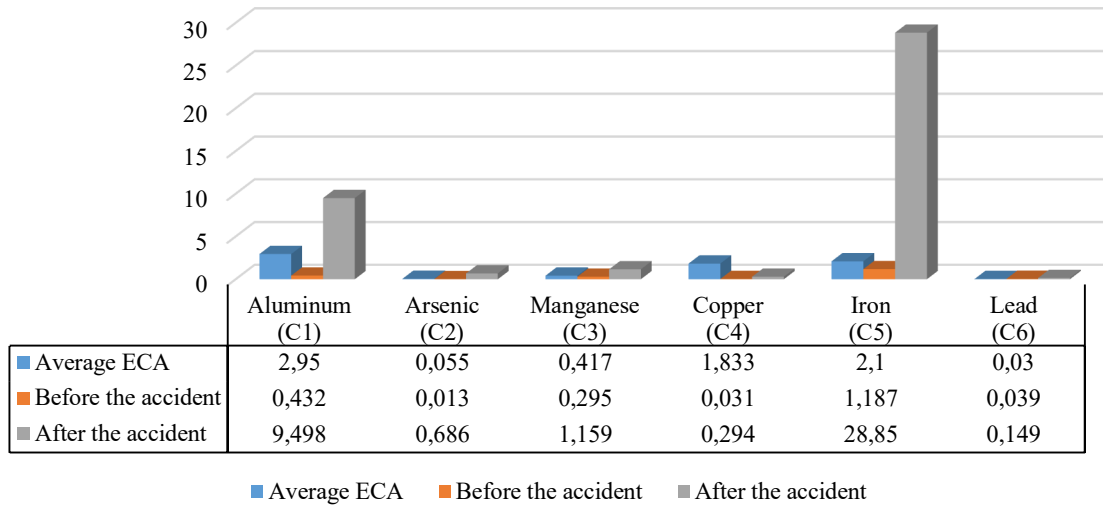


Fig. 4 Metal content at the RMant2 sampling point

### B. About the Methodology

Regarding the Grey Clustering methodology, its usefulness and versatility against the development of analysis with limited amounts of data were confirmed. This was particularly beneficial as the existing results were for two sampling points that were very well located as these enabled the analysis before and after the tailings spill into the Mantaro River. This feature differentiates it from other methodologies that could have been applied in the study, such as Delphi, Shannon entropy, and AHP, since the objective of the investigation was to determine the contamination of the Mantaro River quantitatively due to the accident that occurred on July 2019. Some of the advantages of the methodology are described below.

- Since environmental conflict is a fickle and subjective social issue, one of the criteria for its evaluation must be its cost [23]; in this regard, it should be noted that an approach of the Grey Clustering methodology fully covers this need since it would have a lower cost than the statistical approach, as the sample size influences the research field expense [24].
- It has been demonstrated that the predictive accuracy of the Grey Model is generally superior to that of the regression model by contrasting the mistakes in the predictions of both models and the real sightings [20].
- Compared to other methodologies, the theory of Grey Systems highlights the exploration of those objects that handle clear expansions and uncertain intent [20].

### IV. CONCLUSIONS

In the case study, two points from Mantaro River, RMant1 and RMant2, were determined as good and moderate-quality water respectively before the accident, and the point after the accident, RmAnt2 showed a poor quality. In addition, the information of this study is highly recommended to be made known to the Peruvian citizens, especially those who reside or circulate in the affected area, and their local authorities for them to take the necessary precautions and measures.

Finally, for future studies, it is suggested to analyze each point of the Mantaro River and show the points where the accident had more impact on creating some mitigation technique. This analysis can be done when the respective authorities display all the results of every point of the Mantaro River before and after the accident. In addition, the grey clustering method could be tested on other environmental accidents.

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