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REVISIONES

A review on research on health and safety of mining families in San Jorge, Colombia

Una revisión sobre investigaciones en salud y seguridad de familias mineras del San Jorge, Colombia

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ABSTRACT:

Introduction: This article aimed to analyze the contributions of research related to relevant variables on the current state of safety and health of families of San Jorge by mercury from mining activities, allowing to glimpse possible future consequences to the health of the communities of Ayapel - Córdoba in the Colombian Caribbean from the meanings and practices developed and systematized in the different sources of information.
Methodology: The review was carried out from 2010 to 2022 and was conducted through a systematic literature review and meta-analysis following PRISMA using different descriptors in the Scopus, Scielo and PUBMED databases, as well as in the Colombian regulations.
Results: socio-environmental, socioeconomic and health and disease categories were obtained where it revealed that primary publications were evidently analytical and sociodemographic, which reveal different socio-environmental and symptomatological problems associated with the toxicity and genotoxicity of mercury coming mainly from artisanal and illegal mining.
Conclusions: Conclusions: The studies conducted primarily focus on the department of Córdoba, highlighting the need for research in other regions of the country, with a focus on public health. This implies addressing the raised issue and properly addressing it, theorizing it from other scientific disciplines and from the perspective of public health, promoting new interdisciplinary research lines with the aim of preventing and providing timely knowledge about the health impacts on populations engaged in such practices.

Keywords: Environmental Pollution; Mercury Poisoning; Systematic Review; Public Health; Mining Industry.

RESUMEN:

Introducción: Este artículo tuvo como objetivo analizar los aportes de investigaciones relacionadas con variables relevantes sobre estado actual de seguridad y salud de familias del San Jorge por mercurio provenientes de actividades mineras, permitiendo vislumbrar posibles consecuencias futuras

a la salud de las comunidades de Ayapel – Córdoba en el Caribe colombiano a partir de los significados y prácticas desarrolladas y sistematizadas en las diferentes fuentes de información.
Metodología: La revisión estuvo comprendida entre 2010- 2022 mediante una revisión sistemática de literatura y metaanálisis según PRISMA utilizando diferentes descriptores en las bases de datos Scopus, Scielo y PUBMED, así como en la normativa colombiana.
Resultados: Se obtuvieron las categorías socioambiental, socioeconómica y de salud y enfermedad en donde se evidencia que las publicaciones primarias son evidentemente analíticas y sociodemográficas, las cuales develan diferentes problemas de tipo socioambiental y sintomatológicas asociadas a la toxicidad y genotoxicidad del mercurio proveniente principalmente de la minería artesanal e ilegal.
Conclusiones: Los estudios realizados se concentran principalmente en el departamento de Córdoba, mostrando la necesidad de realizar investigaciones en otras zonas del país enfocadas desde la salud pública. Lo anterior implica incidir sobre la problemática planteada y que se suma debidamente abordada y teorizada desde las otras disciplinas científicas y desde la Salud pública auspiciando nuevas líneas investigativas interdisciplinares con el objetivo de prevenir y brindar conocimiento oportuno sobre las afectaciones en la salud de las poblaciones que realizan este tipo de prácticas.

Palabras clave: Contaminación Ambiental; Intoxicación por mercurio; Revisión sistemática; Salud Pública; Industria minera.

INTRODUCTION

Since minerals are the basis of most industries, mining is practiced in almost every country in the world[1]. In some cases, they serve as a significant source of foreign investments and dividends representing a major share of the world's GDP[2]. The business model of the mining industry focuses on adding economic value to the earth's resources through a series of activities that begin with the extraction of mineralized material and continue with the conversion of a derivative product of higher purity for commercialization[3]. These activities have effects on the economy, the environment, the workforce and social conditions, not only in the nations or regions where mining takes place, but also on a global scale[4].

One of the metals of greatest economic value is gold[5,6]. However, its relative scarcity and the effort required to extract it from nature generate a high market value, representing about 80% of all the ore produced worldwide[7]. Due to the current global economic crisis, countries are looking to increase their gold-related activities as a way to keep their economies stable during times of significant instability[8]. This has led to an increase in the extraction of this precious mineral in several parts of the Americas[2].

In Colombia, gold production has increased from 35.8% tons in 2015 to 53.6% tons in 2020 and is expected to increase in this decade by a further 51%, due to the fact that it is considered essential for the country's economic growth[2]. One of the most popular methods for the extraction of this metal is gold mining, through amalgamation with mercury; the latter presents derivations in various states of agglomeration[6,9]. However, these products have a high heavy metal content and toxicity potential, which tend to be absorbed by living beings through bioaccumulation due to their slow elimination by the organism[10].

Artisanal gold mining occurs in several parts of the country[1], particularly in the area of Ayapel, Córdoba, where studies have focused on analyzing this scourge in its population. This area is located in the northeastern corner of Colombia where the San Jorge River and the Ayapel swamp are located[10,11]. Currently, Ayapel has a total population of 56,082 inhabitants. Its economy is based on agriculture (52%) and

mining (27%), which is carried out in the area surrounding the river. These environmental problems affect water quality due to mercury contamination[10], as well as risks of instability in quarries and deterioration of the topsoil without any possibility of recovery due to the lack of organic soil protection[6,8]. These procedures negatively impact ecological processes, alter productivity, decrease biodiversity and affect the health of people exposed to these contaminants[8,10].

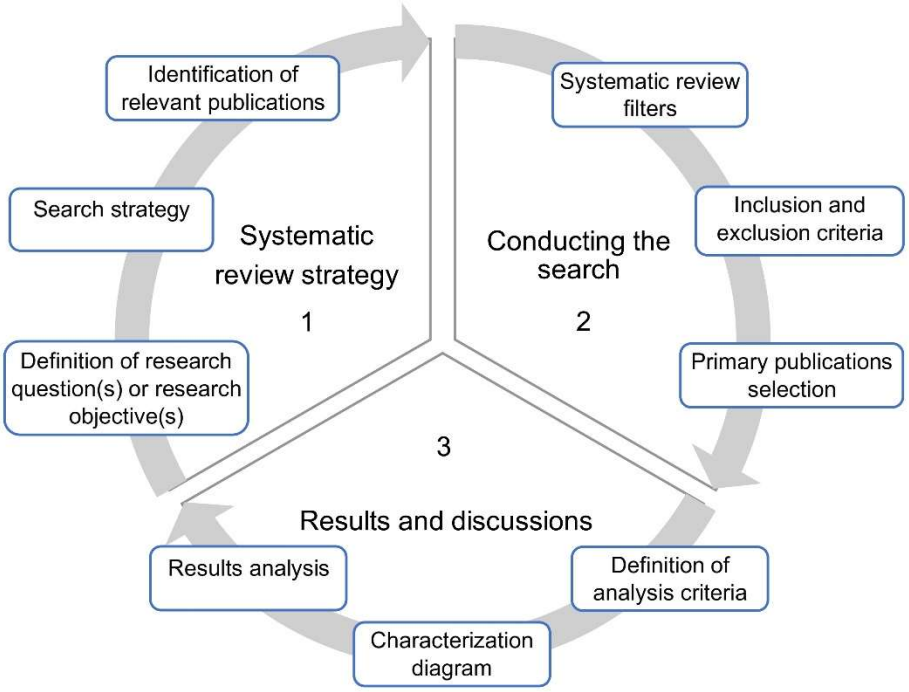
By virtue of the above, the full development of this study focused on analyzing the contributions of research related to relevant variables on the current state of safety and health of families of San Jorge by mercury from mining activities through a systematic review of literature (hereinafter SLR) that allow glimpsing possible future consequences to the health of the communities of Ayapel - Córdoba based on the meanings and practices developed and systematized in the different sources of information.

METHODOLOGY

This research used a path of processes and sub-processes to carry out the SLR, which is shown in Figure 1 and contains the following sections: (i) systematic review strategy: in this process the objective or research question was defined, the search strategy was created and relevant publications were identified; (ii) conducting the search: here the publications not relevant to the study were systematically filtered based on the inclusion and exclusion criteria, selecting the primary or analytical publications and (iii) results and discussions: where the analysis criteria were defined, the characterization scheme was carried out and the results were analyzed.

Regarding the qualitative analysis, the aim was to analyze and interpret the different sources of information in response to the objective of this research. Subsequently, the complete study builds an understanding of possible future consequences to the health of these communities based on the meanings and and practices developed, through patterns statistically framed as signs or signals.

Figure 1: RSL process and sub-process routing



Note: Authors' elaboration.

Systematic review strategy

The strategy used was based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Protocols (PRISMA)[12], which are based on describing rational, hypothesized and planned methods of SLR, providing the reasons why it is performed, from a pre-established methodological and analytical point of view, avoiding biases and arbitrary decisions during its performance[12].

Search Strategy

The information search was performed using words in English and Spanish using Boolean operators "AND" or "AND/WITH" to include and connect all the specified terms. OR" was also used to broaden the search to yield information on one or both of the specified terms, separating two of the three terms by possible combinations. All information was searched limiting it to titles, summary or abstract, conference manuscripts, book chapters and articles published in scientific journals presented in international databases using PUBMED, Scielo and Redalyc with the following search terms: family strategy, family coping, family functionality (functioning), family connectedness, family risk, mitigation strategies, family resilience, family stress, family adaptation + health, using MeSH terms for English language databases and DeCS terms for Spanish language databases.

Identification of relevant publications

The identification of relevant publications for this study was performed using search strings in digital libraries to reduce bias during the review (Table 1). Therefore, keywords related to the object of study of this research were used, adjusting to the formats of the selected databases. Subsequently, the information was filtered based on previously established inclusion and exclusion criteria, since the "all fields" option

was initially enabled, which meant that the terms could be located within the article, title, abstract and keywords, further broadening the spectrum of publications associated with the study.

Table 1: Databases and search strings for the RSL

Databases	Search strings
Scopus	"Illegal mining"; "Health Y/CON Familias de Ayapel".
Scielo	"Health AND/WITH Families of Ayapel"; "Mercury poisoning OR Mining in Ayapel" AND "MeSH".
PUBMED	"Health AND/WITH Families of Ayapel"; "Mercury poisoning OR Mining in Ayapel" AND “DeCS”

Systematic review filters

During the selection of the primary publications, the following review filters were carried out: (i) a review of the titles, summary or abstract of the published research was carried out and (ii) the publications that passed the first filter were subjected to a reading of the entire document. Finally, the following inclusion and exclusion criteria were applied to all the final studies in order to select the studies that were finally analyzed.

Inclusion and exclusion criteria

Eligible documents were scientific publications related to mercury intoxications in mining areas of Ayapel - Córdoba. Also, research related to the health of families in these areas. Likewise, all publications on prevention, safety and health related to mercury intoxications from quantitative, qualitative or mixed studies.

On the other hand, publications that were not related to the objective of this research or the inclusion criteria were excluded. In addition, research in which social, journalistic or informal communication studies were carried out was not taken into account. Likewise, publications whose content was not related to the search chains and studies in which the participant population was not defined in terms of families in Ayapel - Córdoba were also excluded.

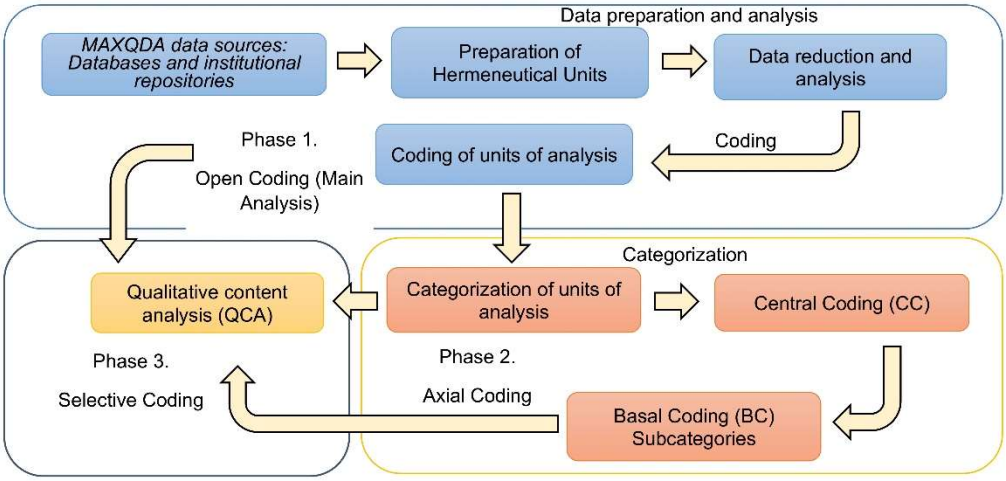
Qualitative data analysis to obtain categories of analysis

Subsequently, a qualitative content analysis (hereinafter QCA)[13] was performed, which was used for the in-depth review of the primary publications already obtained from the previous phase. The analysis of the emerging categories was obtained from the data, generating discussions and interpretations which were contrasted with the theoretical framework used in this research, enriching the process and avoiding bias among the data. The internal reliability of this research was reflected in the results obtained through the use of data triangulation by contrasting different sources of information. Such confrontations were useful comparisons aimed at limiting the effect of excessive extrapolations and hasty conclusions.

In addition, an information filtering system was used, taking into account the theoretical and methodological assumptions of Creswell & Poth[14], which allowed for more descriptive and interpretative observations during the analysis of the data from the different sources of information. To achieve the first objective of this research in

the QCA, the following successive phases were followed: (i) pre-analysis, (ii) categorization, (iii) selective or analytical coding and (iv) triangulation by contrasting information from the referential framework and according to the research problem. The steps followed to analyze the data are detailed below and are shown in Figure 2.

Figure 2. Qualitative data analysis plan



This phase consisted of organizing the information content from the different sources and databases into hermeneutic or analytical units in which content analytical rules and step-by-step models were followed without using quantification[13]. The purpose was to operationalize and systematize the initial ideas, in order to make a precise outline of the development of successive operations in the analysis plan. In this phase, the data were segmented according to the analysis segments obtained and their nature in the choice of the different databases, the formulation of the research objectives and the development of information patterns that support the interpretation of the data[13]. The specific content was then grouped and separated so that it would be relevant to the object of study of the research. Therefore, the data were reduced through the open coding process, to obtain concepts and ideas that contain the origin of the data and show the thoughts, conceptions and meanings.

Phase 2. Categorization

In this phase of the QCA process, axial coding was carried out, which consisted of deepening the conceptualizations around an emerging central category and analytical support subcategories. In addition, it allowed the collection of new data needed to achieve greater definition or concurrence of the codes belonging to the generated category. To identify the relationship between the initial codes, the researchers compared the coding classifications with the object of study and the research framework.

Phase 3. Selective or analytical coding

In the QCA phase, the codes most relevant to the object of study of the research were compared and contrasted with the referential framework. In this sense, they were compared and contrasted with the theoretical framework through the use of selective or analytical analysis, which generated deeper and more critical discussions and interpretations for the research.

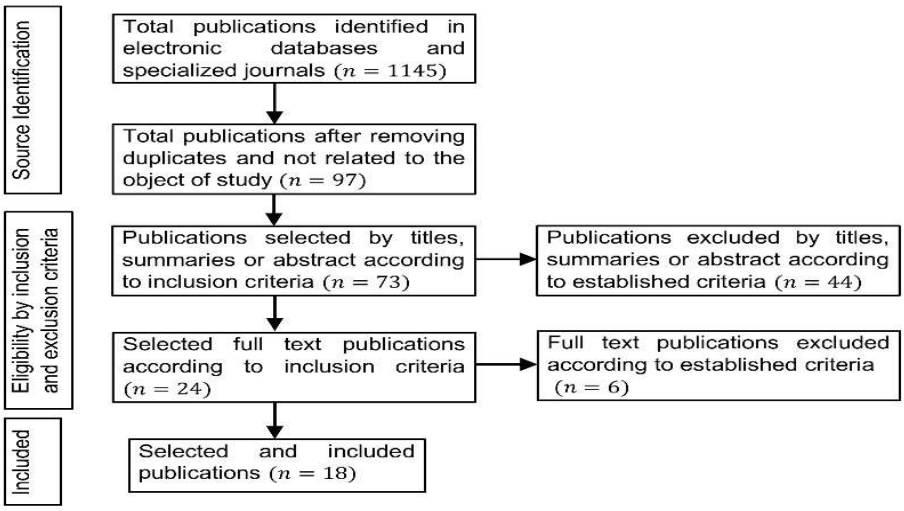
Phase 4. Triangulation by contrast of information

The process of triangulation by contrasting information made it possible to gather and dialectically cross-reference all the information pertinent to the object of study of the research, which in essence constitutes the corpus of analytically grounded results[13]. It also made it possible to use different points of view, guaranteeing greater precision in the analysis and increasing the validity of the results obtained and contrasting data from different sources, thus offering the complementarity required for this type of study[13].

RESULTS

The results of the above search show a total of 18 articles selected as primary publications. Figure 3 shows a flow chart of the search strategy according to PRISMA.

Figure 3. Flow chart of the search strategy according to PRISMA.



It should be clarified that three central categories were established for the analysis of the content of the publications (Table 2), of which twelve documents correspond to the Socio-environmental (SE) category, three for Socio-economic (SEc) and an equal number for Health and disease (HD), without considering the time range and that no distinction is made between languages because it constitutes a broader search possibility, in addition to using Google Scholar for the search, it helped to provide many more documents of interest for the present study.

Table 2: Analysis of the qualitative content of primary publications

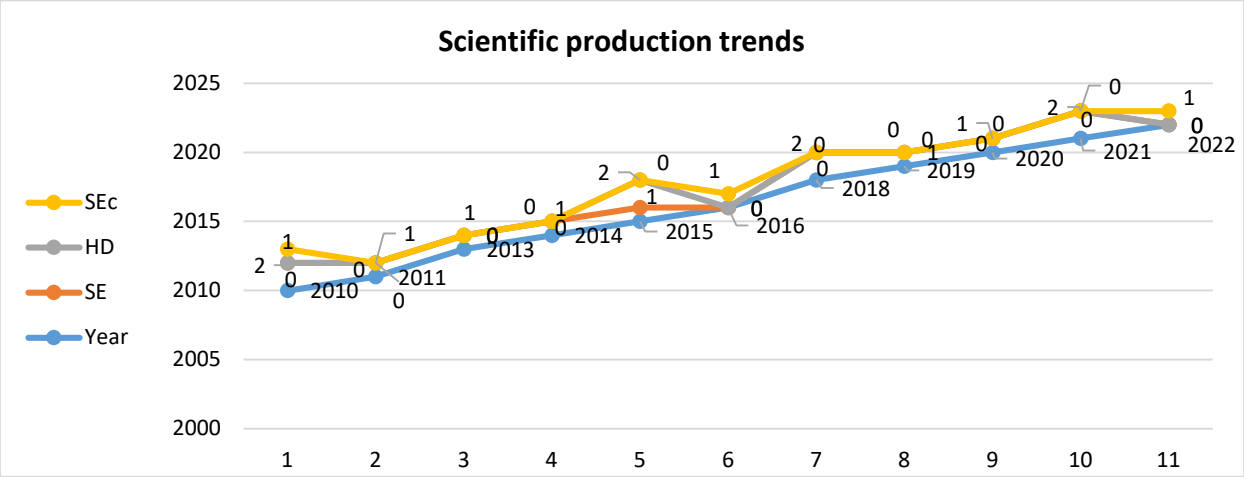
Analysis categories	Subcategory	Number of publications	Percentage (%)
Socio-environmental	Culture	3	16,667
	Mining waste management	2	11,111
	Physicochemical analysis	7	38,889
Socioeconomic	Tensions between mining and environment	1	5,556

	Boundaries between artisanal and illegal mining	1	5,556
	Internal armed conflict	1	5,556
Health and disease	Methyl mercury intoxication	2	11,111
	Occupational health, safety and security	1	5,556
	Total	**18**	**100%**

The analysis of the eighteen documents selected from the questions in Table 1, led to the following premises regarding the trends of scientific production in recent years for the topic of interest, a constant production is observed in the period 2010-2020 and a development of productivity over the years with a tendency to more research work between the period 2019-2020, because for the year 2021, the trend decreases to two publications as shown in Figure 4. In Colombia, the department where the analyzed publications prevail corresponds to Córdoba, since eight of the eighteen publications were made taking into account this territory.

In second place are the departments of Antioquia with an accumulated production of five publications, in third place, Bolivar and Bogota with three publications which were in collaboration with several universities and researchers.

Figure 4: Trends in scientific production for the 18 primary publications



Note: The trend in scientific production was delimited from 2010 to 2022. The categories abbreviated in the figure correspond to SEc: Socioeconomic, HD: Health and Disease and SE: Socioenvironmental.

With regard to the language of the publications, Spanish is the most widely used with a total of fifteen research papers compared to English, which has three publications. Regarding the most scientifically relevant research, journal articles have the greatest impact in terms of the number of citations found. This was to be expected, according to the type of publications registered in the findings of these investigations, because the theses in repositories of the Editorial Fund of the National University of Colombia (unal.edu.co) and the University of Córdoba (unicordoba.edu.co) do not have the same impact as articles in journals such as Public Health, Biomedical, Revista Colombiana de Biotecnología, Rev MVZ Córdoba. The list of primary publications that

met the inclusion and exclusion criteria are detailed in Table 3, which also shows the categories obtained from the in-depth review using qualitative content analysis (QCA).

Table 3. Primary publications selected for results analysis

References	Primary publications	Categories
Marrugo J, Lans E, Benítez L. (2010).	Finding of mercury in fish in the Ciénaga de Ayapel, Córdoba[7].	Socio-environmental
Gracia H. L, Marrugo N. J, Alvis R. E. (2010).	Mercury contamination in humans and fish in the municipality of Ayapel, Córdoba, Colombia[10].	Health and disease
Marrugo J, Benítez LN, Olivero J, Lans E, Gutiérrez FV. (2010)	Distribución espacial y estacional del mercurio en la Ciénaga de Ayapel, región de la Mojana, Colombia[15].	Socio-environmental
Madero, A., & Marrugo, J. (2011).	Detection of heavy metals in cattle in the Sinú and San Jorge river valleys Department of Córdoba, Colombia[16].	Socio-environmental
Rúa Cardona AF, Flórez Molina MT, Baena JP. (2013)	Spatial and temporal variation in the contents of mercury, lead, chromium and organic matter in sediment from the wetland complex of Ayapel, Córdoba, northwestern Colombia[17].	Socio-environmental
Díaz-Arriaga FA. (2014)	Mercury in gold mining: impact on water sources for human consumption[18].	Socio-environmental
Calao CR, Marrugo JL. (2015)	Genotoxic effects in human population associated with heavy metals in the region of La Mojana, Colombia[6].	Health and disease
Casas IC, Gómez E, Rodríguez LM, Girón SL, Mateus JC. (2015)	Towards a national plan for the control of mercury health effects in Colombia[19].	Health and disease
Argumedo, M. P., Vergara, C., Vidal, J. V., & Marrugo, J. L. (2015).	Evaluation of mercury concentration in raw and cooked rice (Oryza sativa) from the municipality of San Marcos-Sucre and the gold zone in the municipality of Ayapel-Córdoba[20].	Socio-environmental
Aponte, C. A. E. (2016).	Ciénaga de Ayapel, a water tributary in trouble[21].	Socioeconomic
Carreño Acosta, J. A. (2017).	Evaluation of mercury concentrations in groundwater in the municipality of Ayapel, Córdoba(22).	Socio-environmental
Muñoz Nieto, D. M. (2018)	Preliminary study on mercury transport and its interaction in water, atmosphere and sediment systems. Case study: Ayapel swamp, department of Córdoba[23].	Socio-environmental
Hernández, M., & de Hoyos, K. (2018).	State of the art of mercury concentration in foods from northern Colombia(1).	Socio-environmental

Torres Pérez, M. P., Vitola Romero, D., & Pérez Cordero, A. (2019).	Bioremediation of mercury and nickel by endophytic bacteria from aquatic macrophytes[24].	Socio-environmental
Simanca, Y., & Marrugo, J. L. (2020)	Determination of mercury (Hg) in fish species in Ayapel (Córdoba-Colombia) and risk analysis for human consumption[25].	Socio-environmental
Méndez F, Zapata AM. (2021)	Armed conflict, contamination and health risks: a risk assessment of three sources of environmental exposure associated with the conflict in Colombia[26].	Socioeconomic
Pedraza, M. L. (2021).	Diagnosis of mercury and arsenic contamination in bocachico (prochilodus magdalenae) and blanquillo catfish (sorubim cuspicaudus) in the Ciénaga de Ayapel and the risk of exposure associated with their consumption[27].	Socio-environmental
Pedraza, M. L., & Ramírez, A. J. E. (2022).	The legacy of Arsenic and Mercury in the Ramsar swamp complex of Ayapel, (Córdoba, Colombia): approach to the Magdalena-Cauca macrobasin[28].	Socioeconomic

DISCUSSION

From the socio-environmental and socio-economic category, a common denominator was evidenced in the primary publications, which were the different problematic situations caused by this type of practices in the communities surrounding the area of Ayapel-Córdoba, which base their economy on the artisanal exploitation of this material using mercury[10]. Consequently, there are health affectations that generate damage at a social level, such as contamination of water and the food they consume[9]. For this reason, from a social relevance point of view, the possible future consequences to the health of these communities based on the meanings and practices developed and systematized in the different sources of information would allow revealing the cost-benefit of these practices in relation to the health of their inhabitants[6-8,19]. To this end, public health care should be established so that all people can have access to it[9]. This includes, from the findings of this research, that the main sources of mercury intoxication are food, air quality, swamp water and cultivation soil. Therefore, it is necessary to identify the health effects that these communities may suffer, taking into account that even today this activity continues to be the livelihood of families[7]. This is so that governmental entities can intervene in this population to establish social and public health roadmaps[28] so that these communities that show symptoms as a result of methyl mercury poisoning[6,23] can have alternatives from social policies that help and directly attack these problems of inequality. From the Health and Disease category, the general vision of the health symptoms caused by methyl mercury intoxication in people working in artisanal gold mining in the area of Ayapel-Córdoba is highlighted, which can affect the community and put their lives at risk through the handling of mercury[6,27]. The aforementioned

implies to have an impact on the problem that has been duly addressed and theorized from other scientific disciplines, with the objective of preventing diseases and health affectations in the populations of Ayapel-Córdoba. In addition, although the toxicology of mercury has been widely studied[6,9], its impact on the health of the population has not been addressed as it should[29]. For example, the costs attributable to the environmental burden of disease have not been quantified and qualified considering exposed subgroups[2]. Neither has the burden of disease approach developed and applied by the World Health Organization (WHO), the World Bank and the Harvard School of Public Health[30] which allows estimating the health status of a population at a given time[15,27]. The above interventions have been increasingly used in public health to support political decision making[24,27], combines several dimensions of disease and allows comparison of hazards, diseases, years and populations, and offers ways to monitor public health problems. The negative impact of mercury on artisanal mining in Colombia is well documented by the Mercury Program of the United Nations Industrial Development Organization[10,24], but the use of mercury remains persistent[10,25]. The strong connection of these populations such as Ayapel - Córdoba with their ancestral lands and social poverty makes communities refuse to migrate to other areas[10]. However, the relevant information to characterize this population from the socio-environmental, socioeconomic and health and disease point of view, categories found in this study, establishes the relationships between analytical concentrations of methyl mercury in the population, artisanal and illegal gold mining and clinical manifestations associated with mercury exposure in families that depend on this exercise. The above has made it possible to glimpse possible sustainable management and efficient use of natural resources, reduce the generation of toxic pollutant waste such as mercury and liquids associated with this product[8] and the sustainable practice of companies and communities, taking into account the nature and social, educational and economic benefits of the population.

CONCLUSIONS

The categories revealed in this study: Socio-environmental, Socioeconomic and health and disease allowed relating the viability, feasibility and need of the inhabitants of Ayapel - Córdoba and the insufficient environmental and social protection related to gold mining and public health. In addition, the analysis of primary publications in allowed linking the increasing number of cases of newborns with degenerative and genotoxic health effects. Also, the characteristic symptoms of these manifestations such as vision deficiencies in young children and adults over 60 years of age who experience uncontrollable tremors. Therefore, it would increase the social relevance of the study, as it relates the interest, not only nationally but globally, in addressing this type of complex problems to prevent the spread of diseases and damage to the environment.

From each of the categories established in this study, the following aspects can be highlighted as relevant for future research. Regarding the Health and disease category, it is expected that the affected families will learn about the problems and therefore improve the quality of life of the people who work in artisanal gold mining. Likewise, the identification of the Socio-environmental category shed light on the different problems related to the health effects generated by the exposure to mercury of people working in artisanal gold mining, for the implementation of policies and decision making.

Finally, from the Socioeconomic category, it was possible to evidence in the primary publications the prevailing generation of new lines of research on mercury contamination and the health effects generated by the exposure to this element of people working in artisanal gold mining, from the point of view of environmental contamination and its implications on human health.

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