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Residential Exposure to Power Plants as a Potential Breast Cancer Risk Factor: A report of Miguel Aleman, Sonora, Mexico

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ABSTRACT

Background: Breast cancer is a common female cancer worldwide. Well-established risk factors represent approximately 40% of the variability in cancer incidence, leaving a great number of other factors that could contribute to carcinogenesis. One of those is the residential exposure to electromagnetic fields (EMF) produced by electric power plants. Sonora is a state in Mexico with a high incidence of breast cancer. Miguel Aleman, a community of scarce resources in Sonora, represents a population of interest due to its high morbidity and mortality of breast cancer cases. The aim of this study is to provide evidence of residential exposure to EMF as a possible breast cancer risk factor in Miguel Aleman.

Methods: We created a breast cancer database with cases collected from hospitals and used GeoData (version 1.8) to localize active electric power plants. For this analysis, inclusion criteria were breast cancer cases of at least 10 years of residence in Miguel Aleman. Foreign cases or those of recent residence in Miguel Aleman were excluded from the present analysis. For the geospatial analysis, neighborhoods were used as a geographical unit for the identification of breast cancer clusters.

Results: Geospatial analysis indicates a Moran's I = 0.014 and two breast cancer clusters. One of them is a High-High (H-H) cluster, and the other one is a High-Low (H-L), both with a pseudo-p-value < 0.018 (permutations: 999). Those two clusters have the highest population density in terms of breast cancer cases, and there is an electric power plant inside of them. Non-exposure to EMF was estimated in terms of a distance (meters). The model indicates a minimum of 1400 meters to that of an electric power plant to consider non-residential exposure to EMF.

Conclusion: This research work provides evidence of two cancer clusters as residentially exposed to EMF, a potential breast cancer risk factor.

KEYWORDS: Breast cancer; Electromagnetic fields; Spatial statistics; Moran's I

ABBREVIATIONS: EMF: Electro Magnetic Fields; GWAS: Genome Wide Association Studies; CAZMEX: Consortium Arizona Mexico Arid Environments; INE: National Electoral Institute

INTRODUCTION

Breast cancer is the most common female cancer worldwide Bray et al. [1]. There are several well-established breast cancer risk factors. Those can be classified as non-modifiable, such as age and inherited mutations Lima et al. [2], and modifiable risk factors like obesity, parity, red meat consumption, alcohol consumption Picon-Ruiz et al.

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[3]; Rainey et al. [4], and environmental exposure to hazards Gray et al. [5]. Genome-wide association studies (GWAS) relate 14% of the familiar risk to breast cancer Michailidou et al. [6]. This leaves 86% of risk factors that remain to be determined, like dietary factors and environmental hazard exposure. There is data indicating that a diet high in fruit and vegetables decreases breast cancer risk Hunter [7]. Another factor, moderate intake of alcohol is associated with an increased risk for cancer development Singletary et al. [8]. Cigarette smoking has been associated with an increased breast cancer risk Dossus et al. [9].

Other potential factors, like residential exposure to electromagnetic fields (EMF), remain to be elucidated. Those include chronic exposure to electrical power plants and power lines. There is a meta-analysis of 29 studies of adult brain tumors in relation to occupational exposures to EMF Kheifets et al. [10]. A more recent study suggested residential proximity to power lines as a risk factor for brain tumor development (OR 2.94, 95% CI 1.28-6.75) and gliomas (OR 4.96, 95% CI 1.56-15.77); Carles et al. [11]. Another study in California suggested a trend of an increased risk of childhood leukemia with residential exposure to power lines within 50 m of a transmission line over 200 kV (OR 1.4, 95% CI 0.7 -2.7) Crespi et al. [12]. Research in the UK observed a similar trend for childhood cancers and residential proximity to power lines within 50 m of an overhead line (OR = 0.73, 95% CI 0.42-1.26 for acute lymphoblastic leukemia; OR 0.75, 95% CI 0.45 - 1.25 for all leukemias; OR = 1.08, 95% CI 0.56-2.09 for central nervous system cancers; OR = 0.92, 95% CI 0.64-1.34 for all malignancies UK Childhood Cancer Study Investigators [13]. Another pooled analysis evaluated the association between childhood leukemia and residential exposure to overhead power lines, finding an imprecise risk for residences located within 50 m of 200+ kV lines Amoon et al. [14].

Breast cancer risk, however, has not been fully explored in relation to residential exposure to EMF. A hypothesis suggests EMF exposure suppresses melatonin production, and that melatonin is protective against breast cancer Brainard et al. [15]. There is a review considering 35 residential and occupational studies evaluating the association between EMF and breast cancer. This review found no statistical association between EMF and breast cancer risk Kheifets et al. [16]. A more recent review evaluated epidemiological studies and found little or no overall effect of EMF exposure, with a potential trend for estrogen receptor-positive breast tumors for premenopausal women Feychting et al. [17].

A meta-analysis evaluated the residential exposure to extremely low (ELF)-EMF and found no significant association between ELF-EMF exposure with female breast cancer Chen et al. [18]. Another comprehensive review found eleven occupational studies linking breast cancer risk with high EMF exposure (OR 1.98 for premenopausal women in occupations with high EMF exposure; OR 2.17 for women working as telephone installers, repairers, and line workers; OR 1.65 for women working as system analysts/programmers; OR 1.40 for telegraph and radio operators; and OR 1.27 for telephone operators), but eight studies had inconsistencies regarding assessing residential exposure Caplan et al. [19]. A large population-based, case-control, multi-state study in the US evaluated cumulative EMF exposure with breast cancer risk but found no overall association rather than a modest increase for occupational EMF exposure among Wisconsin-only women (RR 1.18, 95% CI 1.03 - 1.35); McElroy et al. [20]. A case-control study conducted in Long Island evaluated residential EMF exposure and breast cancer risk but found no statistically significant association Schoenfeld et al. [21]. A case-control study in Sweden evaluated EMF occupational exposure (0.30 microT or more) and breast cancer risk, with no significant association for exposed women (OR 1.01, 95% CI 0.93-1.10); Forssén et al. [22].

Other research works found evidence suggesting EMF exposure as a breast cancer risk factor. Occupational exposure to EMF was evaluated as a potential risk factor for a cohort of breast cancer women in the US Loomis et al. [23]. Findings indicate a higher breast cancer mortality among electrical workers in comparison to other occupations (OR 1.38, 95% CI 1.04-1.82). The risk was limited to electrical workers-only, and the study encourages further investigation Loomis et al. [23]. A similar Norwegian study evaluated occupational exposure to EMF in radio and telegraph operators, finding a standardized incidence ratio (SIR) for breast cancer of 1.30 (95% CI 1.05-1.58). The research evaluated exposures to 405 kHz-25 MHz and to 50 Hz in two age groups (<50 and 50+) and found an OR 1.78 (95% CI 0.59-5.41) and OR 2.37 (95% CI 0.88 - 6.36) in those women with the highest cumulative exposure Kliukiene et al. [24]. Younger women had a higher risk of estrogen receptor positive breast cancers, while older women (50+) had a higher risk for estrogen receptor-negative breast cancer Kliukiene et al. [24].

A later study by the same group found an increased breast cancer risk for women residentially exposed to EMF (50 Hz) when compared to unexposed women (OR 1.58, 95% CI 1.30-1.92); Kliukiene et al. [25]. Exposed women had an OR of 1.33 (95% CI 0.93-1.90) and an OR of 1.40 (95% CI 0.78-2.50) for ER-positive and ER-negative breast cancers when compared to unexposed women Kliukiene et al. [25]. In addition, women with occupational exposure had an OR of 1.13 (95% 0.91-1.40) when compared to women without occupational exposure to EMF Kliukiene et al. [25]. A case-control study in Sweden evaluated EMF exposure before breast cancer diagnosis and estimated the relative risk for breast cancer Feychting et al. [26]. Findings estimated a Risk Ratio (RR) of 1.0 (95% CI 0.7-1.5) for women, and a RR of 2.1 (95% CI 0.3-14.1) for men. Estrogen receptor-positive female breast cancers had a RR of 1.6 (95% CI 0.6-4.1) if EMF exposure was that of 0.1 microT or higher. For women younger than 50, this RR increased to 7.4 (95% CI 1.0-178.1); Feychting et al. [26]. Another study evaluated the hypothesis of a higher breast cancer risk for women exposed to 60-Hz magnetic fields compared to unexposed women in four states in the US Coogan et al. [27]. Findings indicated an increased OR for women highly exposed to EMF, where premenopausal women were at higher risk (OR 1.98, 95% CI 1.04-3.78) than postmenopausal women highly exposed to EMF (OR 1.33, 95% CI 0.82-2.17) Coogan et al. [27]. Literature, however, has not reached a consensus regarding EMF exposure and breast cancer risk. More investigations are required to fully assess this question. In the present study, we focus on Miguel Aleman, a community with health disparities and a high incidence of breast cancer within Sonora state, Mexico. The aim of this work is to provide evidence of a potential association between residential exposure to EMF produced by electric power plants and breast cancer incidence.

MATERIALS AND METHODS

Study Population

This study was derived from a previous observational retrospective study Villa-Guillen et al. [28]. Briefly, a breast cancer database was constructed using REDCap platform Harris et al. [29], using clinical cases of female breast cancers from the period of 2013 to 2019 at local hospitals in Hermosillo, Sonora, Mexico. Those hospitals were the following: Hospital General del Estado de Sonora Dr. Ernesto Ramos Bours, Centro Estatal de Oncología Dr. Ernesto Rivera Claisse, CIMA, Hospital San José, and Clínica del Noroeste. Clinical data was de-identified using the Safe Harbor method HHS [30], in accordance with national LFM [31] and international HHS regulations DOF [32] for the protection and privacy of human subjects. All breast cancers collected were from women with at least 10 years of residence in Miguel Aleman.

Inclusion Criteria

Breast cancer database included only female cancers of current residents at Miguel Aleman, this by an ID-verifiable residential address as registered at the National Electoral Institute (INE) of Mexico, or by their medical insurance card.

Exclusion Criteria

Breast cancer database excluded male breast cancers, female cancers other than breast, former Miguel Aleman residents or foreigners, and non-ID-verifiable residential addresses according to their INE or to their medical insurance card.

Residential Information

Breast cancer database included current and former neighborhood(s), and current and former zip code(s). For this work, we considered the oldest neighborhood of residence (≥10 years old), as ten years is the minimal time-latency for tumor development. This study did not collect private addresses to comply with national and international regulations for the protection and privacy of human subjects.

Ethics Statement

The present research work was reviewed and approved by the Institutional Review Boards (IRB) of the following hospitals: Hospital General del Estado de Sonora Dr. Ernesto Ramos Bours, Centro Estatal de Oncología Dr. Ernesto Rivera Claisse, CIMA, Hospital San José, and Clínica del Noroeste. This study was IRB-approved by the Secretary of Health of Sonora, and IRB-approved by the University of Sonora. This research work is classified as without risk for the individual according to Article 17 of the General Law of Health for Clinical Research, Mexico SS [33].

Statistical Analysis

Spatial statistics is the tool used in this work for environmental exposure analysis Anselin [34] using the neighborhood as a geographical unit. The variable of interest is the density of breast cancer cases per neighborhood. The aim is to identify high-density neighborhoods surrounded by low-density neighborhoods, because that fact could be associated with a potential hazard increasing breast cancer risk. The methodology consists of several steps:

Step 1: To identify the population at-risk for breast cancer in each neighborhood. This information is obtained from the INEGI Census 2010 INEGI [35].

Step 2: To obtain the number of breast cancer cases per neighborhood. This information is obtained from the following local hospitals: Hospital General del Estado de Sonora Dr. Ernesto Ramos Bours, Centro Estatal de Oncología Dr. Ernesto Rivera Claisse, CIMA, Hospital San José, and Clínica del Noroeste.

Step 3: To define the variable of *breast cancer density = (# of cases/Risk population) *10,000*, which is used for the spatial analysis of potential breast cancer clusters identified as High-High (H-H) or High-Low (H-L) spots.

Step 4: To obtain visual representations of the results. In addition, the range of spatial interaction is calculated, which is used to suggest a "safe" distance of EMF sources, this last one for health prevention purposes.

RESULTS

Table 1: Variables used in the analysis.

Neighborhood	Risk Population (Number)	Breast Cancer Cases	BC-Density
Jesus Garcia	1207	1	8.28
Pueblo Nuevo	235	0	0
Las Granjas	129	0	0
26 de Octubre	289	1	34.6
Flores Magon	166	0	0
Jesus Garcia	111	0	0
Insurgentes	744	0	0
Nuevo Triunfo	768	3	39.06
Centro	365	0	0
Nueva Esperanza	65	4	615.38
Emiliano Zapata	192	0	0
Aguayo Porchas	1211	3	24.77
Antonio Mendez	325	0	0
Las Palmas	1657	2	12.07
Luis Donaldo Colosio	1138	0	0
Salvador Alvarado	335	0	0
Solidaridad	733	0	0
Lazaro Cardenas	514	0	0
Infonavit	354	0	0
Guadalupe Victoria	137	0	0
Manuel J Clouthier	157	0	0

The main result is the identification of two interesting regions, where the number of cases could be overexpressed and potentially constitute a breast cancer cluster. Table 1 contains the variables used in the analysis: Neighborhood, Number of women older than 18 (population considered at risk), Breast Cancer Cases per Neighborhood, and Breast Cancer Density (BC_Density). The analysis is performed using the Breast Cancer Density variable.

Moran's I is a graph that could be used to identify interesting "regions". In the present case, an interesting region is one in which its density is relatively different in comparison with the surrounding regions.

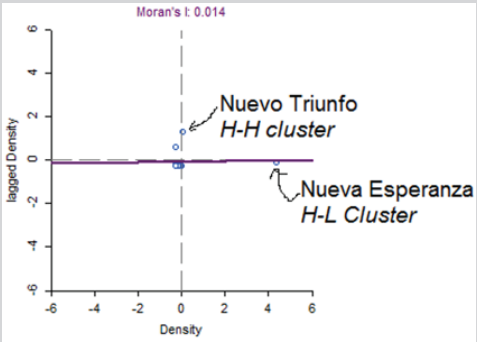

Figure 1: Moran's I graph.

In the Moran scatter plot in Figure 1, the points are formed by the density of the neighborhood and the average of the neighboring regions (Lagged variable). There are several possible combinations of values: Low-Low (L-L), High-Low (H-L), Low-High (L-H), and High-High (H-H). The breast cancer densities are on the horizontal axis, and their spatially lagged counterparts are on the vertical axis. The values of the density and their spatially lagged variable are given in standard deviations units (over Table 1, the original values are given). Using GeoDa software, it is obtained Moran's I = 0.014, and the graph suggests possible High-High or Low-High regions. The names of those regions are Nueva Esperanza (H-L) and Nuevo Triunfo H-H), with a pseudo-p-value < 0.018 (permutations:999). Those two neighborhoods (Figure 2,3) had an increased breast cancer density, surrounded by neighborhoods of low density. Both neighborhoods constitute a breast cancer cluster. The common characteristic between them is the presence of an electric power plant, a source of EMF. This residential proximity provides evidence of a potential association between residential exposure to EMF and breast cancer risk.

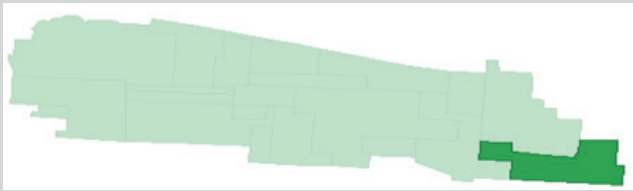

Figure 2: Map of Miguel Aleman. Nueva Esperanza.

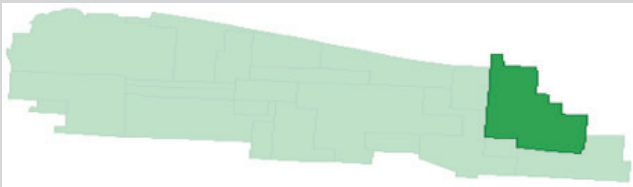

Figure 3: Map of Miguel Aleman. Nuevo Triunfo.

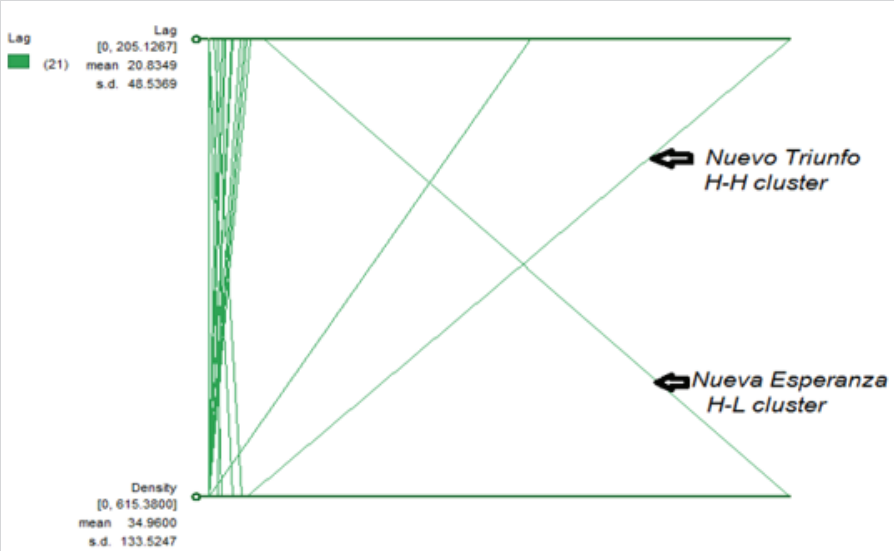

Figure 4: Breast cancer density and its lagged variable.

The parallel coordinate plot (Figure 4) shows the variable density and its lagged variable, enhancing the big difference between them. Nueva Esperanza and Nuevo Triunfo are the extreme observations pointed out in the graph. Note their outstanding differences. That behavior could be produced by the electric power plant. The remaining regions have no electric power plants and are considered as non-exposed regions to EMF. Moreover, those regions have no hospital records of breast cancer cases up to the present year.

Range of Interaction

What is the range of influence of the process? A way to visualize global spatial autocorrelation is to use a measure of dissimilarity (v_{ii}) for the variable density.

$$v_{ij}=\sqrt{(d_i-d_j)}$$

The objective is to find the distance that corresponds to the maximum dissimilarity. The graph should increase with distance

(Tobler's law) up to the point where the range of interaction is reached. In the present case, such distance is approximately 1400 meters (Figure 5). Such distance or greater could be considered a safe distance (for breast cancer risk prevention) from an electric power plant. A spatial correlogram was constructed to verify this result (correlogram not shown).

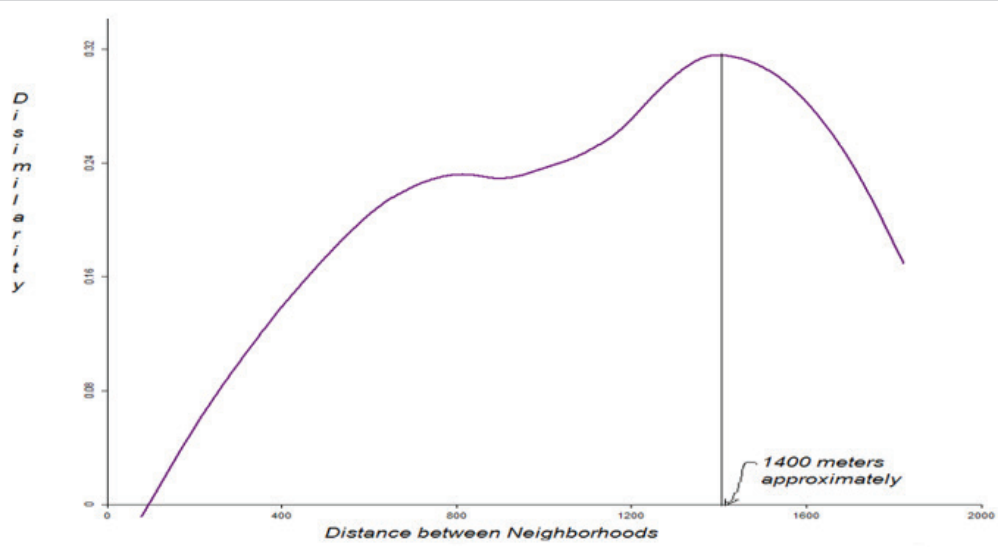

Figure 5: Scatter plot of smoothed distance.

DISCUSSION

The main purpose of this work is to present evidence of an association between residential exposure to EMF (produced by electric power plants) and breast cancer risk. Moran's I graph was built in order to identify EMF-exposed neighborhoods targeted previously as breast cancer clusters in Miguel Aleman, Sonora. The identified regions were pointed out using a parallel coordinate plot with the variables of density, and lagged density. Additionally, a smoothed distance scatter plot is used to obtain a safe residential distance that of an EMF source. Findings of this work identified (1) EMF-exposed regions with a high breast cancer risk, and (2) the minimal distance required from an electric power plant to reduce residential EMF-exposure. This last one is considered as a "safe distance" for reducing breast cancer risk related to a residential EMF-exposure in Miguel Aleman, Sonora, Mexico.

STRENGTHS AND LIMITATIONS

This work has several limitations regarding the identification of possible breast cancer risk factors. In addition to magnetic fields produced by the electric power plant, which is the risk factor analyzed in this work, there could be additional cancer risk factors like chemical exposures, smoking, obesity, alcohol consumption, and genetic mutations not accounted for in this analysis. Further works are needed to evaluate modifiable and non-modifiable breast cancer risk factors in Miguel Aleman, Mexico.

CONCLUSION

For Miguel Aleman residents, there is evidence of a possible association between the EMF produced by the power plant within the region, and the increased number of breast cancer cases. The Moran's I observed, I=0.014 (pseudo p-value <0.018) is very small. However, there are two outstanding neighborhoods, Nueva Esperanza, and Nuevo Triunfo, with the behavior of a cancer cluster. These neighborhoods are characterized by a high density of breast cancer cases and are surrounded by those with a low density of cases. More studies evaluating non-modifiable and modifiable breast cancer risk factors are required to fully evaluate cancer risk for Miguel Aleman's residents. Public health preventive measures are recommended for vulnerable populations considered at high-risk for breast cancer development in Miguel Aleman, Sonora, Mexico.

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