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Anthropogenic Pollution of Groundwater and Its trends in Malwa Region of Punjab: A Correlational Study with Cancer Incidence

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Abstract

Groundwater in the MALWA region of Punjab becomes contaminated because of excess use of fertilizers and pesticides. The objective of this study is to compare previous research and determine the trends related to consuming contaminated groundwater in various districts of the MALWA region and its potential correlation with cancer incidence on human health over the years. Data for this study was obtained from published articles and reports. For the statistical analysis, data for the "number of cancer cases" and concentration of "arsenic", "fluoride" and "uranium" in groundwater are collected to check the correlation between metal concentration in groundwater and the number of cancer cases. From 2006 to 2023, an increase in cancer cases alongside fluctuations in arsenic, uranium, and fluoride levels were reported in previous studies. However, the strength and significance of this relationship vary across the different independent variables. For arsenic concentration, there is a moderate positive and uranium concentration shows a stronger positive correlation with cancer patients. Groundwater contamination poses serious health risks due to industrial waste, pesticides, and natural sources. Elevated levels of carcinogens like arsenic, uranium, and fluoride correlate positively with increased cancer cases. Urgent action is required to analyze and treat groundwater and reduce pesticide use. Also, implementing alternative water sources and toxin removal systems is crucial to safeguard public health.

Keywords: Arsenic, Cancer, Contamination, Fluoride, Groundwater, Uranium.

Introduction

Groundwater is an essential freshwater reserve that makes up approximately 97% of the world's freshwater supply. Its broad use in the household, industrial, and agricultural domains highlights its important role in several areas of life on Earth. As per the "United Nations Sustainable Development Report" of 2017, around 2.2 billion people on the earth are not having access to safe drinking water. Ensuring access to clean water and sanitation is the key goal of the 2030 Agenda for Sustainable Development, as it is estimated that by that time, water scarcity may affect 700 billion people worldwide. Concerns about declining water quality and imminent water scarcity pose a severe threat to the world's population. The majority of people on the planet get their drinking water primarily from groundwater (1). According to the 2015 report from the United Nations (UN), groundwater, constituting 0.61% of the overall water resource, provides drinking water and 43% of the world's irrigation needs. Groundwater levels are deteriorating due to rising demand for water for industrial, agricultural, and drinking needs. This is an important concern for the twenty-first century (2).

Regrettably, throughout the past several decades, a serious problem with water quality has emerged that the entire globe is currently dealing with. The situation is made worse by the speed at which urbanization and industrialization are increasing, which is contaminating freshwater supplies everywhere. The increasing pollution levels provide a significant obstacle, making life extremely tough for all living beings as they struggle to cope with deteriorating water quality.

Numerous health risks have arisen as a result of the existence of heavy metals and ions. Any metal that has a specific density greater than 5 g/cm3 is considered a heavy metal, and the term "heavy metal contamination" describes the existence of these metals in the surroundings. Because of their extended biological half-lives and water solubility,

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these metals are hazardous to human health. For example, chromium in drinking water, arising from natural sources and human activities, poses potential carcinogenic risks, particularly respiratory cancers (3). Being exposed to arsenic during early life is linked to elevated risks of developing cancers and other diseases in adulthood (4). Excessive fluoride intake leads to primary health issues such as dental fluorosis, skeletal fluorosis, and bone deformities observed in both children and adults (5). Another study found that uranium in groundwater increases the risk of cancer in humans. This problem must be addressed and mitigated quickly to protect ecosystems and ensure the health of all life forms that depend on freshwater supplies (6).

Famine was a major worldwide problem in the 20th century, resulting in an estimated 70 million deaths (7). Famine is a socioeconomic process that causes the weakest, most marginalized, and most vulnerable groups in a community to become impoverished faster until they are unable to support themselves as a group (8). From the perspective of Indian history, there were 22 significant famines in British colonial India between 1770 and 1900. Particularly well-known was the 1943 Bengal famine, which claimed three million lives. However, the "Green Revolution" began in India during these same years, specifically in 1966–1967.

The shift from famine to the green revolution is a long journey that many poor countries throughout the world have made. India had both the Green Revolution and times of hunger in the previous century. Although the Green Revolution was a major factor in reducing global hunger, it also brought out new environmental problems. After independence, India had to import food grains in the 1950s and 1960s to meet the demands of its expanding population. As a result, the government implemented agricultural policies meant to increase the output of food grains to ensure national food security. The Indian government deliberately chose areas that could produce the most food grains at the lowest possible cost. As a result, funds for agricultural development were allocated to states like Punjab, Gujarat, Andhra Pradesh, and Tamil Nadu, with Punjab taking the lead in this endeavor. Although the first output boom was mostly caused by increasing the amount of land under cultivation, the notable 18.36 million tons rise in food grain production between 1971 and 2005 was principally attributed to the extensive use of inputs such as pesticides, herbicides, fertilizers, and insecticides.

The extensive use of agricultural inputs, particularly pesticides, use patterns have undergone a significant change, rising from 3300 metric tons in 1975 to 6900 metric tons in 2005 (9). But there is a price for this development of agricultural methods. Several studies have brought attention to the startlingly high rate of health problems in Punjab, such as a high rate of cancer, delayed puberty, early aging, mental disorders and reproductive health difficulties including infertility. This emphasizes how intricately agricultural development tactics interact with possible health effects, calling for a thorough investigation of the long-term viability and health effects of intensive farming practices.

There is evidence linking exposure to fluoride, arsenic, uranium, chromium, and chloride to a higher risk of cancer. Bone cancer has been linked to fluoride. Groundwater contains arsenic, which can cause cancer of the skin, lungs, bladder, and liver. Lung cancer may result from exposure to chromium in industrial operations. Drinking water containing chloride may contribute to disinfection byproducts that cause cancer. Lung and kidney cancer have been related to uranium consumption. Therefore, strict oversight and control are essential to reduce the risk of cancer from these drugs.

Punjab comprises 23 districts, geographically organized into the Majha, MALWA and Doab regions. These districts are officially distributed among five divisions: Patiala, Rupnagar, Jalandhar, Faridkot, and Ferozepur (10). In this study MALWA region of Punjab "Barnala, Bathinda, Ferozepur, Fazilka, Faridkot, Ludhiana, Moga, Mansa, Sri Muktsar Sahib, Patiala, Sangrur, Malerkotla" is chosen, and the effects on human health of groundwater pollution caused by human activity and the existence of heavy metals are examined.

MALWA's agricultural land makes up about 86% of its total area, and irrigation there is heavily dependent on groundwater (11). In addition, the region uses more pesticides and fertilizers than any other area in the nation (12). Overuse of fertilizers and chemicals has caused them to seep into groundwater, changing the physicochemical properties of the water. Chemical and fertilizer use are the main causes of groundwater pollution in the area (13). Furthermore, the incidences of cancer, aging, infertility, mental disorder and premature graying of hair have made groundwater quality monitoring and assessment necessary. Furthermore, it is concerning how government regulations and policies impact the health problems in this area.

It is discovered that the groundwater in Punjab's MALWA region is unfit for irrigation and drinking, threatening the health of the people living there. Children in the area are particularly vulnerable to methemoglobinemia, a blood disorder resulting in insufficient oxygen delivery to cells. The Water Quality Index (WQI) reveals alarming results that 80% of water samples were found to be unsafe for drinking. Similarly, the majority of samples are unsuitable for irrigation. Only 35% of samples from the eastern and around 22% from the western MALWA region are fit for irrigation.

In India, Punjab is known for its high cancer rates (14). In Punjab, MALWA and Doaba have the highest rates of cancer patients with 107.4 and 88.1 cases per lakh population, respectively. There have been about 3300 recorded cancer-related fatalities in these areas reported by "Punjab's Cancer Cases Exceed National Average, Chandigarh News," 2013 (15). According to recent studies, 2.25 million Indians are estimated to be living with cancer, and 7,85,000 individuals have died from the disease to date. Additionally, it is estimated that 11,57,000 new cases of cancer are reported annually (16).

The purpose of the study is to evaluate and quantify risks to health related to drinking contaminated groundwater. It is anticipated that the concentrations of arsenic, fluoride, uranium, etc. in the groundwater is much higher than the safe levels established by the "Bureau of Indian Standards" and the "World Health Organization" in the Malwa region. This elevated contamination is believed to be a significant factor contributing to the higher risk of cancer among the people in the Malwa region. Additionally, it is also expected that reproductive and mental disorders are two other major health issues caused because of the presence of heavy metals in the MALWA region.

The purpose of this study is to comprehensively analyze the trends in groundwater contamination in the Malwa region, focusing on contaminants such as uranium, arsenic, and fluoride, and their probable relation with cancer incidence. This research is important due to the region's requirement of groundwater as a primary drinking source and the increasing concern over the long-term health impacts of exposure to these toxic substances. By synthesizing findings from prior studies and examining the correlation between contaminant levels and cancer rates. So, the primary objective of this study is to compare previous studies and determine the trends connected to the intake of contaminants in the groundwater in certain MALWA districts and its potential correlation with cancer incidence on human health over the years.

Methodology

Data for this study were obtained from published articles and reports, refer the tables in appendix. To ensure a thorough search for relevant scientific studies, specific keywords related to exposure and disease outcome were employed. Keywords for exposure include "Uranium," "Arsenic," "Fluoride," and "contaminated groundwater," while the outcome is represented by the term "cancer." Google Scholar and PubMed were used to search for scientific papers. Furthermore, possible literature listed in the reference lists of the found research were investigated. The citations from potentially eligible studies were exported using a citation manager (EndNote), where duplicate articles were removed.

Databases were subjected to the final search algorithm, which used Boolean operators and suitable criteria for inclusion and exclusion. The resulting number of articles from 2000–2023 was determined after implementing the final algorithm. (Uranium OR Arsenic OR Fluoride) AND (''contaminated groundwater'' OR ''polluted drinking water'' OR ''contaminated potable water'' OR "contaminated water" OR "polluted water") AND (cancer OR tumor OR carcinogenic OR carcinogenicity (17).

A comprehensive systematic search was conducted across four major databases, including PubMed, Web of Science, Science Direct, and Google Scholar, yielding a total of 218 articles. Following the initial search, a rigorous screening process was undertaken to identify relevant studies. First, articles were screened by title and abstract, resulting in the exclusion of 39 articles and retention of 179 articles for further evaluation.

Next, the full texts of the remaining 179 articles were assessed for eligibility, leading to the exclusion of an additional 92 articles due to various reasons such as inaccessibility of full texts, non-English language, and failure to meet the inclusion criteria. Furthermore, 30 articles were removed due to duplicate records or similar findings. After applying the inclusion and exclusion criteria, 57 articles were deemed suitable for inclusion in the systematic review and analysis.

Statistical Analysis

Statistical analyses were performed with the SPSS software version 16.0 and Microsoft Excel computer programs. First, the sample distribution was checked by using the Shapiro–Wilk statistic and observed that values were lower than 0.05 for all of the variables. Subsequently, a descriptive analysis was performed to present the trend over the years. Pearson correlation coefficient (r values) was employed to identify relationships between groundwater pollutant concentration with the total number of cancer cases. Ordinary least square was applied between Cancer patients as the dependent variable and groundwater concentrations (Arsenic, Uranium, Fluoride) as independent variables. Significance was considered at $p < 0.05$.

Results

Table 1 shows an overall increase in malignancy cases from 2006 (327 cases) to a peak in 2014 (622 cases), followed by a decline in 2015 (505 cases) and a further drop to 358 cases in 2019. Female cases steadily rose from 156 in 2006 to 396 in 2014, indicating a growing trend, though there was a decrease to 272 in 2019. Male cases showed fluctuations, peaking in 2013 (249 cases) before significantly dropping to 86 by 2019. While earlier years had a more balanced gender distribution, female cases increasingly surpassed male cases from 2011 onwards, highlighting a shift in the pattern of malignancy detections over the years.

Table 1: Number of Patients of Various Malignancies Detected over a Period of Ten Years in Histopathology (18, 19)

Year	Total	Female	Male
2006	327	156	171
2007	376	174	202
2008	360	180	180
2009	330	157	173
2010	350	188	162
2011	374	220	154
2012	456	262	194
2013	570	321	249
2014	622	396	226
2015	505	287	218
2019	358	272	86

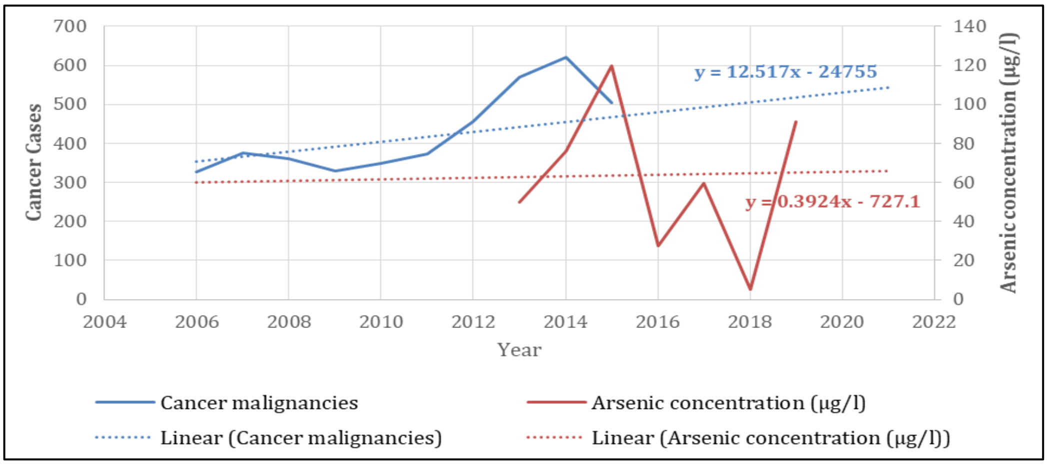

Figure 1: Positive Trend between Cancer Cases and Arsenic Concentration

Figure 1 demonstrates a positive increasing trend in cancer cases alongside a relatively slight upward trend in arsenic concentration. This suggests a potential link between arsenic exposure and the incidence of cancer. Arsenic, a naturally occurring element in groundwater, is known to be carcinogenic, and even low levels of exposure over time can contribute to adverse health effects, including cancer development. While the increasing trend in arsenic concentration is comparatively modest, its presence in drinking water sources warrants careful attention due to its potential health risks. Continued monitoring and mitigation efforts are essential to minimize arsenic exposure and mitigate associated health concerns, particularly in regions where arsenic contamination is prevalent.

Figure 2 reveals a concerning correlation between the number of cancer cases and fluoride concentration over the years, indicating a positive increasing trend in both. This suggests a potential association between fluoride exposure and the incidence of cancer. The observed trend underscores the importance of carefully monitoring fluoride levels in drinking water and assessing its potential impact on public health. Further research is necessary to comprehensively understand the relationship between fluoride exposure and cancer incidence, enabling policymakers to implement appropriate measures to safeguard public health.

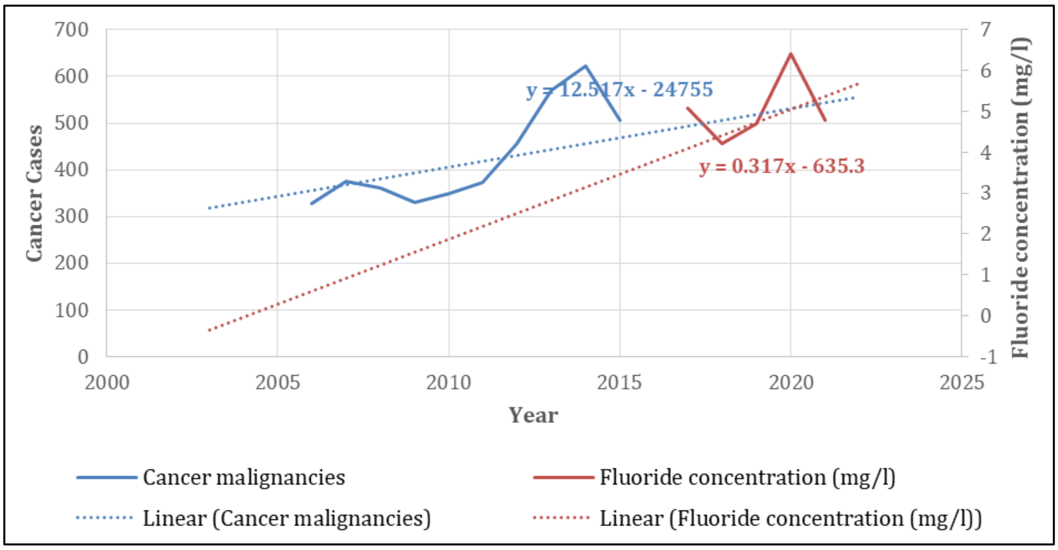

Figure 2: Positive Trend between Cancer Cases and Fluoride Concentration

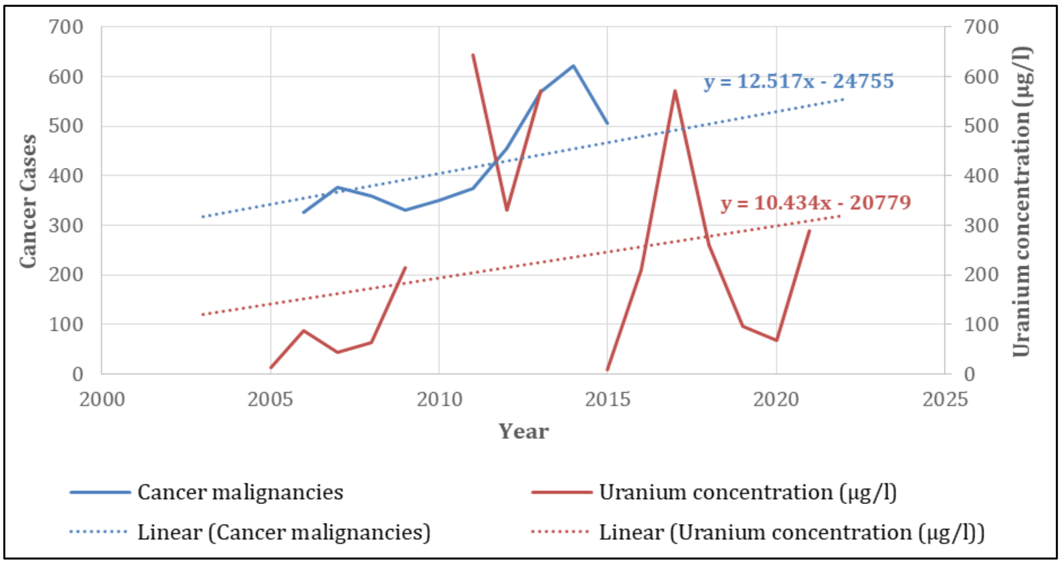

Figure 3: Positive Trend between Cancer Cases and Uranium Concentration

Figure 3 shows that there is a notable positive trend between the number of cancer cases and uranium concentration in the groundwater of the MALWA region. This correlation suggests a potential relationship between uranium exposure through drinking water and the incidence of cancer in the area. The increasing uranium concentration in the groundwater may be a contributing factor to the rising number of cancer cases observed.

Table 2 presents the Pearson correlation coefficient (r) between groundwater pollutant concentration and the total number of cancer cases. For arsenic concentration (μg/l), the correlation coefficient with the total number of cancer cases is 0.384, suggesting a positive correlation, although the relationship is not statistically significant with a p-value of 0.273. Regarding uranium concentration (μg/l), there is a moderate positive correlation with total the total number of cancer cases, indicated by an r-value of 0.479. However, the correlation is not statistically significant, as reflected by the p-value of 0.136. For fluoride concentration (μg/l), there is a weak positive correlation with the total number of cancer cases in patients, with an r-value of 0.176. The correlation between fluoride concentration and the number of cancer cases is not statistically significant, as indicated by the high p-value of 0.706.

Table 2: Pearson Correlation Coefficient (r) between Groundwater Pollutant Concentration with Number of Cancer Cases

		Total no of cancer cases	**Arsenic concentration (μg/l)**	**Uranium concentration (μg/l)**	**Fluoride concentration (μg/l)**
Total number of cancer cases	r	1			
	P value				
Arsenic concentration (μg/l)	r	0.384	1		
	P value	0.273			
Uranium concentration (μg/l)	r	0.479	0.149	1	
	P value	0.136	0.682		
Fluoride concentration (μg/l)	r	0.176	0.474	0.652	1
	P value	0.706	0.282	0.113	

Table 3: Distribution of Finding of Previous Studies about Arsenic Concentration in Groundwater in Different Areas of Malwa Region

Area of Study	**Year**	**Metals found**	**Concentration range μg/l**	**Reference**
Bathinda	2013a	Arsenic	>10	(20)
Bathinda	2013	Arsenic	5 – 5	(21)
Bathinda, Moga, and Faridkot	2014	Arsenic	16 – 76	(22)
Bathinda, Mansa, Faridkot, Firozpur, Sangrur, Moga, and Patiala	2015	Arsenic	2.2 – 120	(23)
Bathinda	2016	Arsenic	2.28 – 27.47	(24)
Bathinda, Mansa, Faridkot and Ferozepur	2017	Arsenic	1 – 59.6	(13)
Bathinda, Mansa, Muktsar Faridkot Ferozepur, Sangrur, Moga, and Barnala	2017	Arsenic	2 – 12	(25)
Bathinda, Mansa, Muktsar and Faridkot	2017	Arsenic	4.35 – 23.94	(26)
Bathinda	2018	Arsenic	0.44–5.15	(27)
Ludhiana	2019	Arsenic	0 – 21	(20)

Ferozepur, Patiala, and Rupnagar	2019e	Arsenic	16 – 91	(6)
South Western part of Punjab	2019	Arsenic	27.59	(18)
Bathinda, Barnala, and Ludhiana	2021	Arsenic	0.5 – 28.7	(28)
Bathinda	2021a	Arsenic	2.1 – 83.87	(29)

Table 3 indicates varying levels of arsenic concentration in groundwater across different areas of the Malwa region over several years. In Bathinda, arsenic levels were consistently detected, with concentrations ranging from as low as 0.44 µg/l in 2018 to over 83.87 µg/l in 2021, often exceeding the safe limit of 10 µg/l. Broader studies covering multiple districts, such as Bathinda, Mansa, Faridkot, and others, revealed even wider ranges, reaching up to 120 µg/l in 2015. The data shows a persistent issue of arsenic contamination across several districts, with some areas like Ferozepur, Patiala, and Rupnagar showing concentrations as high as 91 µg/l in 2019.

Table 4 shows varying fluoride concentrations in groundwater across different areas of the Malwa region over several years. Fluoride levels ranged widely, from as low as 0.08 mg/l in Ludhiana (2021) to as high as 10.5 mg/l in Moga (2011), exceeding the recommended safe limit of 1.5 mg/l in many cases. Patiala showed fluctuating concentrations, with levels as high as 4.12 mg/l in 2018 and 2.4 mg/l in 2023. Several areas, such as Faridkot, Bathinda, and the southwestern part of Punjab, reported fluoride levels exceeding the safe limit, indicating ongoing contamination issues.

Table 4: Distribution of Finding of Previous Studies about Fluoride Concentration in Groundwater in Different Areas of Malwa Region

Area of Study	Year	Metals found	Concentration range mg/l	Reference
Patiala	2010	Fluoride	2.8	(30)
Moga	2011	Fluoride	0.09 –10.5	(31)
Patiala	2015	Fluoride	0.98	(32)
Faridkot	2018	Fluoride	0.23 -4.2	(33)
Sangrur	2018	Fluoride	0.15 – 1.2	(33)
Patiala	2018	Fluoride	0.19 –4.12	(33)
Rupnagar	2018	Fluoride	0.11 –1.03	(33)
Mohali	2018	Fluoride	0.31 – 1.52	(33)
Fazilka	2018	Fluoride	0.32 – 3.1	(33)
Barnala	2018	Fluoride	0.37 – 2.3	(33)
Punjab (WHO)	2018	Fluoride	0.6 – 1.5	(33)
South Western part of Punjab	2019	Fluoride	4.7	(18)
Patiala	2019	Fluoride	4.12	(34)
Firozpur	2018, 2019	Fluoride	0.14 - 1.21	(29), (33)
Muktsar	2020	Fluoride	0.39 – 6.4	(35)
Bathinda	2020	Fluoride	1.50	(36)
Patiala	2020	Fluoride	1.1	(37)
Ludhiana	2021	Fluoride	0.08 – 2.75	(28)
Patiala	2021	Fluoride	1.3	(38)
Bathinda	2021	Fluoride	029 -4.79	(39)
Mansa	2021	Fluoride	0.4 - 2.0	(40)
Patiala	2023	Fluoride	2.4	(41)

Table 5: Distribution of Finding of Previous Studies about Uranium Concentration in Groundwater in Different Areas of Malwa Region

Area of Study	Year	Metals found	Concentration range μg/l	Reference
Amritsar	2003	Uranium	45.59	(42)
Muktsar and Ferozepur	2005	Uranium	11.74	(42)
Mansa and Bathinda	2017	Uranium	2.3 – 357	(43)
Bathinda	2006	Uranium	2 - 87.5	(44)
Malwa Region	2007	Uranium	5.41 – 43.39	(45)
Bathinda, Mansa	2007	Uranium	7 - 316	(46)
Malwa region of Punjab	2007	Uranium	17.33	(45)
Bathinda and Mansa	2009	Uranium	0.9-63.1	(47)
Bathinda, Mansa, Faridkot, and Firozpur	2011	Uranium	0.2 – 644	(48)
Punjab	2011	Uranium	73.1	(48)
Muktsar	2012	Uranium	4.5 – 330	(49)
Malwa Region	2013	Uranium	13.9 – 172.	(50)
Faridkot, Bathinda, and Mansa	2016	Uranium	0.13 – 676	(51)
Bathinda, Mansa, Firozpur and Faridkot	2012	Uranium	3.2 – 60. 5	(52)
Bathinda	2013	Uranium	0.48 – 571.7	(20)
Punjab	2015	Uranium	8.73	(20)
Mansa	2016	Uranium	0.13 – 1340	(53)
Mansa	2016	Uranium	211.2	(53)
Faridkot and Muktsar	2017	Uranium	3 – 190	(35)
Bathinda, Mansa, Faridkot, Firozpur, Sangrur, Moga and Patiala	2019	Uranium	2.47 – 366	(6)
Bathinda, Mansa, Faridkot and Firozpur	2017	Uranium	0.5 – 571.7	(13)
Bathinda, Mansa, Firozpur, and Faridkot	2018	Uranium	1.78 – 261	(20)
South Western part of Punjab	2019	Uranium	96.56	(18)
Patiala	2020	Uranium	66.9	(37)
Bathinda	2021	Uranium	8.98 – 289.53	(18)
Bathinda, Barnala, and Ludhiana	2021	Uranium	0.5 – 432	(28)
Patiala and Punjab	2023	Uranium	66.94	(41)

Table 5 reveals significant variability in uranium concentrations in groundwater across various areas of the Malwa region over the years. The levels range from as low as 0.13 μg/l in Faridkot, Bathinda, and Mansa (2016) to an extremely high 676 μg/l in the same regions during the same year, with frequent occurrences of concentrations exceeding the recommended safe limit of 30 μg/l set by the World Health Organization. Particularly high uranium levels were observed in Bathinda, Mansa, and Firozpur, with peaks of 644 μg/l in 2011 and 571.7 μg/l in 2017. Other areas such as the southwestern part of Punjab and Patiala also showed significant contamination, with concentrations reaching 96.56 μg/l in 2019 and 66.9 μg/l in 2020, respectively.

Discussion

Human health issues such as nausea, vomiting, diseases of the skin, neurological disorders, kidney stones, liver illnesses dental, and skeletal fluorosis can arise from drinking water contaminated with these substances (54, 55). When consumed repeatedly over extended periods of time, several of these contaminants have been found to be one of the main causes of cancer in humans (56). Numerous research using epidemiological surveys have found links between specific drinking water pollutants and various cancer types (54). India is deeply concerned about the prevalence of carcinogenic substances in drinking water (13). About 3.9 million individuals in India suffer from cancer, making it one of the country's top causes of death, according to the NRCP "National Registry Cancer Program" 2016 report. The MALWA region of Punjab, has come into focus due to the high incidence of cancer cases in the area. Formerly referred to as the "food bowl of the nation," this area is now recognized as India's "Cancer Capital" (57). Other health problems that have been reported primarily in this area include early graying of the hair, developmental delays, infertility, premature aging, neurological, behavioral, and reproductive abnormalities, as well as miscarriages (57, 58). High quantities of arsenic, fluoride, and uranium have been discovered in groundwater, suggesting that this is one of the main causes of the high cancer incidents (13). In these areas, the vast majority of people rely on groundwater for their drinking needs. Thus, it's critical to keep an eye on the quality of the drinking water while investigating how much of the local cancer rate is caused by it. US EPA (US Environmental Measurements and Modeling) methodologies can be used to determine the carcinogenic or non-carcinogenic health risk resulting from consuming contaminated water. Despite the fact that a number of studies have already documented the cancer epidemiology, health risk assessment, and groundwater quality, there is still a need for a comprehensive coordinated investigation of the cancer occurrence and the quality of groundwater, source allocation of contaminants, and health risk assessment of those contaminants in South West Punjab's agriculturally active villages (53).

Over the years, we have observed changes in cancer cases alongside shifts in the concentrations of these groundwater pollutants. From 2007 to 2011, we noticed an increase in cancer cases alongside fluctuations in arsenic, uranium, and fluoride levels. In subsequent years, although cancer cases may vary, the levels of these pollutants demonstrate inconsistent patterns of increase, decrease, or stability. Notably, 2017 stands out with the highest number of cancer cases, coinciding with elevated levels of arsenic, uranium, and fluoride. However, more recent years also present concerning trends, particularly in 2018 and 2019, where cancer cases continue to rise alongside notably high levels of uranium.

In the present study, analysis reveals a relationship between groundwater concentrations of arsenic, uranium, and fluoride and the number of cancer cases. However, the strength and significance of this relationship vary across the different independent variables. For arsenic and uranium concentration, there is a positive association with the number of cancer cases. While fluoride shows a small but positive correlation with the number of cancer cases.

Conclusion

In India and other nations, groundwater is a sustainable source of drinking water. The main contributors to the contamination of drinkable groundwater include untreated industrial waste fluids, overuse of pesticides, and geological and chemical processes. It is extremely concerning that levels of Group I carcinogens, including pesticides, radioactive elements, and trace metals, have been found in groundwater above allowable limits. As a result, it is essential to conduct a thorough investigation of groundwater with a focus on carcinogens, design a comprehensive plan for preventing groundwater intrusion, and treating drinking water to remove these contaminants. Previous studies have documented an increase in cancer cases, which coincided with elevated levels of arsenic, uranium, and fluoride. In this study, secondary data have reported the correlation between groundwater concentrations of these substances and the overall incidence of cancer. Specifically, arsenic and fluoride concentration has been found to exhibit a moderate positive correlation with cancer patients, while uranium concentration demonstrates a more pronounced positive correlation. These findings suggest a potential association between increased levels of arsenic and uranium in groundwater and higher risk of cancer, highlighting the importance of further research in this area. It's important to carefully study the groundwater and focus on harmful substances that can cause cancer. We should also educate people about using fewer pesticides and being careful with water to protect our health. The region's alternative surface water-based drinking supply needs to be improved in order to satisfy the drinking water scarcity and lessen health issues. Reverse osmosis units must also be developed in order to eliminate other toxics like fluoride and uranium. Programs for raising awareness and educating people about water and health issues, as well as the restricted use of pesticides, must be implemented.

Abbreviation

UN: United Nations,

WQI: Water Quality Index,
μg/l: Micrograms per liter.

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Author Contributions

The author confirms sole responsibility for the manuscript preparation.

Conflict of Interest

The author declares that there is no conflict of interest.

Ethics Approval

The study does not require any ethics approval.

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