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Research Article

An Evidence based Research on Presence of Carcinogens and Increasing Spurts of Cancer Cases in Vaigai River Basin, India

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Abstract— Water is an inevitable part of living organisms. Water pollution is a serious environmental threat to people who consume, enter, and wash in contaminated water. The aim is to study the quantified levels of carcinogens in the environment, according to IARC Classification such as Arsenic, Benzene, Cadmium, Hexavalent Chromium, Cobalt, Nickel, Lead, Nitrite/Nitrate, and Phosphates and their correlation with increased spikes of cancer cases across districts that lie along Vaigai River Basin, Tamil Nadu, India. A Systematic literature review for cross-sectional studies that provided information about groundwater quality was carried out using six databases, "Researchgate, PubMed, Elsevier Science Direct, Wiley Online Library, Medline, and SpringerLink" from 2012 to 2022. The TNCRP report from 2021 was used as the basis for calculating the proportion of all cancer cases in the relevant district. Based on the Newcastle Ottawa Scale, a quality assessment was conducted. The results show the presence of high concentrations of carcinogens in the groundwater and sediments collected near the industries, commercial zones, and agricultural land. The significant association between exceeding the permissible limit of various heavy metal elements and compounds and the percentage of cancer cases at that particular site has been established in this study. Vaigai River is highly polluted such that the heavy metal concentration has already entered the human food chain. Oral findings commonly associated with chronic toxicity of carcinogenic heavy metals are listed which serves as an alarming signal to adapt to a healthy lifestyle and dietary modifications as required.

Keywords — Heavy metals, Carcinogens, Industrialization, Environmental Pollution, Cancer, Vaigai, Madurai.

1. Introduction

According to a modeling study published in Nature journal, 5.5 million people around the world by 2100 could be possibly exposed to polluted water [1]. Climate change aggravates both water scarcity and water-related natural disasters like floods and droughts since increased temperature disrupts rainfall patterns. As per SDG Report 2022, about 2 million people don't have access to safe drinking water. A rising sea level is projected to lead to an increase in the salinization of groundwater, resulting in a decrease in freshwater available to the human race due to global warming. Water pollution is a serious environmental threat to people who consume, enter, and wash in contaminated water. People who ingest water contaminated with chemical toxins, pesticides, and fertilizers are at elevated risk of cancer, hormonal imbalances, modified brain function, weakened immune systems, and reproductive, respiratory, and cardiovascular issues.

International Agency for Research on Cancer (IARC), 2022 lists more than 500 toxic substances known to cause cancer in humans. Among these arsenic, benzene, cadmium, hexavalent chromium, lead, nickel, cobalt, nitrite, nitrate, and phosphates are excessively present beyond the WHO, 2013 standard limits of drinking water in the districts of Tamil Nadu, India.

Vaigai is a river that flows through the towns of Madurai, Theni, and Dindigul. It empties into the Palk Bay of Bengal in Ramanathapuram District. South Tamil Nadu's industrial and educational center is Madurai. Numerous production facilities are located in the city, including those for granite, rubber, chemicals, and automobiles. Large-scale industry has developed in the suburbs. Industries such as cotton spinning and weaving, transportation equipment manufacturing, tobacco, and sugar production are included. Small-scale hand-loom industries have also made Madurai famous. According to the New Indian Express newspaper dated June 16, 2022, large volumes of untreated domestic sewage from the nearby village of Sellur in Madurai city were discharged directly into the Vaigai River. The incident was reported to the press several times within a year by an environmental activist. Consequently, Sewage Treatment Plants (STP) was installed to resolve this concern. However, during an audit, it

was found that STP was not functionally serving the purpose and untreated sewage water was visibly letting into the river. Unbiased and strict monitoring should be mandated at regular intervals to overcome these menaces.

Although cancer is a multifactorial disease, alcohol, smoking, radiation, hereditary background, various anthropogenic activities and standalone high-risk population such as children below 18 years of age and pregnant women are more susceptible to mutagenesis, the main objective of the study is to find whether the carcinogens listed in the IARC classification has any impact on the incidence of cancer cases in the Vaigai flowing cities. Researchers also describe oral findings commonly produced by people who are chronically exposed to carcinogens and provide possible preventive strategies that can be implemented to protect the nation from the deadly disease 'Cancer'.

2. Materials and Method

2.1 Information sources: The systematic review was conducted following PRISMA guidelines from the year 2012 until 2022 through the following databases: PubMed, ResearchGate, Elsevier Science Direct, SpringerLink, Wiley online library, and Medline.

2.2 Search strategy: The combinations of words concerning 'Vaigai' or 'Cancer' or 'water pollution' or 'soil pollution' or 'industrial effluents' or 'carcinogens' or 'toxic pollutants' or 'heavy metal status' or 'Environmental health' were used to search studies.

2.3 Inclusion criteria: We included cross-sectional studies conducted in the Vaigai River in Madurai and other nearby districts such as Dindigul, Theni, Ramanathapuram, and Virudhungar districts. Full-text original articles that were available electronically were included. The research includes studies that made use of standardized measuring instruments. Based on the Newcastle Ottawa Scale, a quality assessment was conducted [2].

2.4 Exclusion criteria: Accidental exposure to toxic substances was excluded from the study. Excluded were studies carried out by the Tamil Nadu Pollution Control Board.

2.5 Data extraction and synthesis: From 25 articles that met the eligibility criteria 11 studies were chosen for further investigations after being filtered through qualitative analysis.

2.6 Methodology: We referred IARC's lists of classifications of carcinogens to understand various carcinogens and organs affected. We examined a range of literature to determine the existence and concentration of carcinogens in the districts of Madurai, Dindigul, Theni, Ramanathapuram, and Virudhungar. Later, we compared these values with WHO/BIS/CEQG drinking water standards. The percentage of all cancer cases reported in the districts of Madurai, Dindigul, Theni, Ramanathapuram, and Virudhungar were determined by dividing total number of cases for each cancer type as per Tamil Nadu Cancer Registry Project Report, 2021 and dividing it by 38(all districts). Based on the percentages obtained, we correlated how carcinogens contribute to increased prevalence of cancer in places where they are present in excess.

2.7 Related work:
Quite few studies have been done on the similar area of interest, with the authors showing the following correlation between contaminated water and cancer rates: Noyyal and Cauvery River Basin [3,4]. As part of the study, the team has also analyzed the misue of pesticides [5] and examined the connection between fruits and vegetables contaminated with pesticides and an increased prevalence of cancer cases in Tamil Nadu [6].

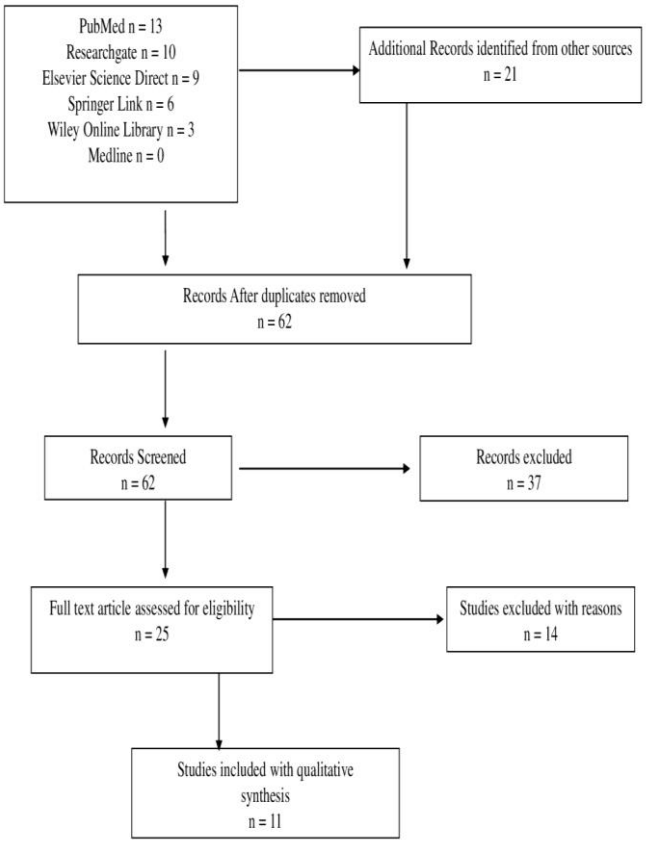

Figure 1: PRISMA Guidelines

3. Results and Discussion

Table 1. Analyzing publications on the prevalence of carcinogenic substances in the Vaigai River Basin, how they were measured, and the outcomes that were attained.

Author Year	Study Duration	Sample Size Sample Site	Methods of Measurements	Carcinogen	Results	Normal Permissible Limit

Place of Study						**(PL) WHO (2013)**
Bharathy S et al; 2019 Vaigai river, Madurai [7]		Water samples and fish every month for one year - 4 different sites of the Vaigai River	Atomic Absorption Spectro-photometer	Lead Nickel Chromium Fishes: Catla Catla Tilapia Kidney Liver Muscles Gills	Site 1: 2.06±0.52 Site 2: 1.23±0.55 Site 3: 0.42±0.10 Site 4: 0.31±0.11 Site 1: 2.23±0.63 Site 2: 2.11±0.52 Site 3: 2.04±0.51 Site 4: 1.57±0.32 Site 1: 0.67±0.07 Site 2: 0.37±0.05 Site 3: 0.03±0.04 Site 4: 0.28±0.03 Kidney & Liver Muscles & gills Pb>Ni>Cd>Cr Cd>Pb>Ni>Cr Pb>Cd >Cr>Ni Cd>Pb>Cr >Ni	0.01mg/l 3mg/l 0.05mg/l
Sasirekha N et al; 2015 Madurai [8]	Mar-May2013 (summer) Oct-Dec2013 (rainy season)	Green leaves Amaranthus Dubius, Basella Aalba, Alternanthera Sessilis - Sellur Munichalai Theppakulam Iravathanallur Vandiyur	Atomic Absorption Spectro-photometer Perkin Elmer 400	Cadmium(ppm)	**Amaranthus Dubius:** Sellur-Summer- 1.591 Rainy- 1.877 Munichalai- Summer- 1.513 Rainy- 1.763 Thepakulam- Rainy- 1.512 Summer- 1.372 Iravathanallur- Rainy-1.329 Summer- 0.933 Vandiyur- Summer- 1.055 Rainy- 1.421 **Basella Alba:** Sellur-Summer- 1.258 Rainy- 1.561 Munichalai- Summer- 1.209 Rainy- 1.501 Thepakulam- Rainy-1.435 Summer- 0.822 Iravathanalur- Rainy-1.116 Summer- 0.718 Vandiyur- Summer- 0.774 Rainy- 1.247 **Alternanthera Sessilis:** Sellur-Summer- 1.347 Rainy- 1.634 Munichalai- Summer- 1.256 Rainy- 1.608 Theppakulam- Rainy-1.462 Summer- 1.043 Iravathanallur- Rainy-1.179 Summer- 0.856 Vandiyur- Summer- 0.963 Rainy- 1.339	IS (Awashthi 2000) 1.5ppm
Senthil Kumar M et al; 2013 Madurai [9]	Jan – Mar, 2011	120 Ground Water samples - 6 Commercial sites 10 Residential sites	High-pressure liquid Chromatography with Class VP software.	Benzene	Commercial sities: Jan 2011-0.100mg/L Feb 2011-0.138mg/L Mar 2011-0.060mg/L Residential sites: All 9 sites-BDL-0.01-0.03mg/L North car street-0.100mg/L	0.01mg/L

Mohamed Hanipha M et al; 2014 Dindigul [10]	Nov 2012	Groundwater samples from bore wells - 23 sampling sites	APHA standards	Lead Cadmium Chromium	0.02 to 0.17mg/l, exceeds at all sites 0.02 to 0.15mg/l, exceeds at Dindigul taluk office, Mariamman kovil, Begambur mosque, Govt industrial estate, Cauvery water tank. 0.02 to 0.12mg/l	WHO1992 0.01mg/l 0.1mg/l 0.05mg/l
Chidambaram S et al; 2014 Dindigul [11]	post-monsoon (Jan 2009) and pre-monsoon (June 2009).	43 handpumps/ borewells across the districts	APHA 1995. Inductively Coupled Plasma- Mass Spectrophotometer (ICP-MS)	Chromium (ppm) Nickel Cobalt Arsenic Cadmium Lead	PRM-0.02-0.033 POM-0.021-0.094 PRM-0.054-0.142 POM-0.036-0.259 PRM-1.7-6.32 POM-1.38-13.14 PRM-4.24-21.96 POM-4.68-22.04 PRM-0.1-10.96 POM-0.06-15.86 PRM-0.08-0.18 POM-0.068-0.23	WHO (2008) 0.05 0.07 - 0.01 - 0.01
Sarala Thambavani D et al; 2012 Dindigul [12]	Oct 2011 to Feb 2012	18 urban soil - Kodagnar river basin residential site (Lakshmana puram) traffic site (bus stand) industrial site (tannery)	Flame Atomic Absorption Spectro-photometer	Lead (mg/kg) Cadmium Chromium	Control site- 0.17-0.80 Traffic site-0.81-0.98 Industrial site-0.734-0.992 Control site-0.003-0.038 Traffic site-0.030-0.22 Industrial site-0.018-0.154 Control site-0.72-1.12 Traffic site-0.51-1.36 Industrial site-1.30-4.74	Critical limit:100mg/kg 3mg/kg 50-200mg/kg
Abdul Vahith R et al; 2022 Ramanatha -puram [13]	Nov-2019 to May-2020	30 ground water samples	APHA 1995	Nitrate	80mg/l	45mg/l
Sathees Kumar et al; 2020 Ramanatha -puram [14]		46 ground water samples	Handheld GPS equipment	Nitrate Nitrite	0-75mg/l 0-2mg/l	45mg/l 0.1mg/l
Anand M et al; 2013 Ramanatha -puram [15]		Valinokkam east coastal region : four fish species namely Dussumieria Acuta, Tenuaslosa Ilisha, Sardinella Longiceps and Caranx Hippos	Inductively Coupled Plasma-Optical Emission Spectroscopy (ICP-OES)	Lead Cadmium Nickel Cobalt	0.25-0.69ppm 0.24-0.47ppm 0.01-0.05ppm 0.001-0.005ppm (Max at gills)	 0.05µg/g
Velayutham Raja et al; 2021 Virudhu -nagar [16]	post-monsoon period (Jan 2018)	20 borewell groundwater Sampling sites – 6km from each station	Atomic Absorption Spectro-photometer (AAS) Eqs. 9 and 10	Cadmium (mg/l) Chromium Cobalt Lead Nickel Carcinogenic risk	0.03-0.05 0.02-0.23 0.05-0.26 0.11-0.96 0.19-0.44 $5.66*10^{-03}$ - $1.56*10^{-02}$ with avg. $8.62*10^{-03}$	BIS 2012 – 0.003 0.05 - 0.01 0.02 10^{-6} to10^{-4}
Umamageswari TSR et al; 2016 Virudhu -nagar [17]		Groundwater samples - 8 sampling sites: Aruppukottai Kariapatti Rajapalayam Sattur Sivakasi Srivilliputhur Tiruchuli Virudhunagar	APHA 1989 Atomic Absorption Spectro-photometer (GCB-Avanta).	Lead Cadmium	Elevated in Rajapalayam, Srivilliputhur and Trichulli BDL	IS – 0.05mg/l 0.01mg/l
Mutkrishnan S et al; 2014 Virudhu		Agricultural soil samples Viswanatham a	Atomic Absorption Spectroscopy	Nickel Lead Chromium	0.1371ppm 0.1370ppm 0.0270ppm	

-nagar [18]		village in Sivakasi taluk		Cadmium	0.0068ppm	
Nirmala T et al; 2020 Theni [19]	January 2017	water samples from Thamaraikulam Pond	Atomic Absorption Spectro-photometer	Chromium Lead	0.0013mg/l 0.0045mg/l	WHO-0.0028mg/l 0.0015mg/l

Table 2. The Percentage of cancer cases and their correlation to high concentrations of carcinogens in the Vaigai River Basin.

District	Carcinogens	Mean range obtained[a]	Normal value[b]	Cancer site (IARC, 2022)	Percentage of cancer cases TNCRP (2021)
Madurai	Cadmium	0.718-1.877	1.5	Lung, prostate & kidney	Lung – 4.5% Prostate – 2.9% Kidney – 3.2% Leukemia – 9.2% NHL – 4.2% MM – 4.8% Stomach – 3.6% Nasal cavity– 3%
	Lead	1.005±0.32	0.01	Stomach	
	Nickel	1.9875±0.495	0.02	Nasal and paranasal cavity & Lung	
	Chromium	0.3375±0.047	0.05	Nasal and paranasal cavity & Lung	
	Benzene	BDL-0.138	0.01	Lung, leukemia, NHL & Multiple Myeloma	
Dindigul	Chromium	0.02-4.74	0.05	Nasal and paranasal cavity & Lung	Nasal cavity – 4% Prostate – 2.3% Kidney – 2.8% Lung –2.8% Stomach – 2.6% Bladder – 2.6% Skin – 1.9% Liver – 2.8%
	Cadmium	0.02-15.86	0.003	Lung, prostate & kidney	
	Lead	0.02-0.992	0.01	Stomach	
	Nickel	0.036-0.259	0.02	Nasal and paranasal cavity & Lung	
	Cobalt	1.38-13.14	0.05	Lung	
	Arsenic	4.24-22.04	0.01	Bladder, lung, skin, prostate, kidney & liver	
Ramanathapuram	Cadmium	0.24-0.47	0.003	Lung, prostate & kidney	Nasal cavity – 1.6% Prostate – 1.3% Kidney – 0.6% Lung –1.1% Stomach – 1.8%
	Lead	0.25-0.69	0.01	Stomach	
	Nickel	0.01-0.05	0.02	Nasal and paranasal cavity & Lung	
	Cobalt	0.001-0.005	0.05	Lung	
	Nitrite	0-2	0.1	Stomach	
	Nitrate	0-80	45	Stomach	
Virudhunagar	Chromium	0.02-0.23	0.05	Nasal and paranasal cavity & Lung	Nasal cavity – 2% Prostate – 1.4% Kidney – 1.7% Lung – 1.9% Stomach – 2%
	Cadmium	BDL-0.05	0.003	Lung, prostate & kidney	
	Lead	0.11-0.96	0.01	Stomach	
	Nickel	0.19-0.44	0.02	Nasal and paranasal cavity & Lung	
	Cobalt	0.05-0.26	0.05	Lung	
Theni	Chromium	0.0013	0.05	Nasal and paranasal cavity & Lung	Nasal cavity– 3.6% Lung – 1.7% Stomach – 1.8%
	Lead	0.0045	0.01	Stomach	

Source: [a]Mean value of carcinogens obtained from different studies described in the Table 1; Units: water-mg/l; soil-mg/kg.
[b]WHO 2013 standard limits for drinking water; Units – mg/l.

Table 3. Quality Assessment: New Castle Ottawa Scale

AUTHOR & YEAR	SELECTION				COMPARABI-LITY	OUTCOME	
	Representativeness of the samples	Sample size	Non-respondents	Ascertainment of the exposure		Assessment of the outcome	Statistical test
Bharathy S et al	*	-	-	*	*	**	-
Sasirekha N et al	*	*	-	*	*	**	-
Senthil Kumar M et al	*	*	-	*	*	**	*
Mohamed Hanipha M et al	*	*	-	*	*	**	*
Chidambaram S et al	*	*	-	*	*	**	*
Sarala Thambavani D et al	*	*	-	*	*	**	*
Anand M et al	*	*	-	*	*	**	*
Velayutham Raja et al	*	*	-	*	*	**	*
Umamageswari TSR et al	*	*	-	*	*	**	*
Mutkrishnan S et al	*	*	-	*	*	**	-
Nirmala T et al	*	*	-	*	*	**	-

Source: Adapted Newcastle Ottawa Scale from Modesti PA et al [7].

4. Interpretation

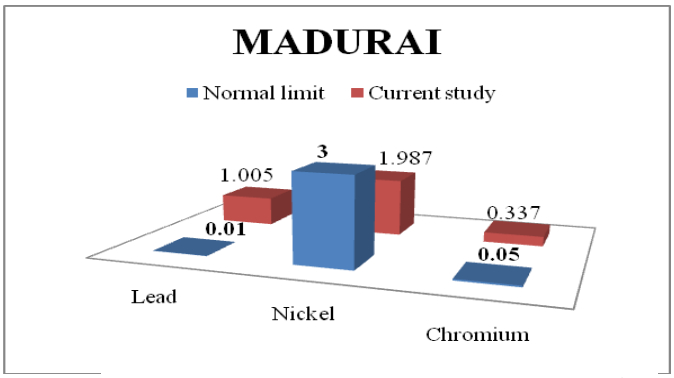

Figure 2: Graph showing heavy metal concentration in water samples from Vaigai River, Madurai district, as compared with normal limits established by the World Health Organization.

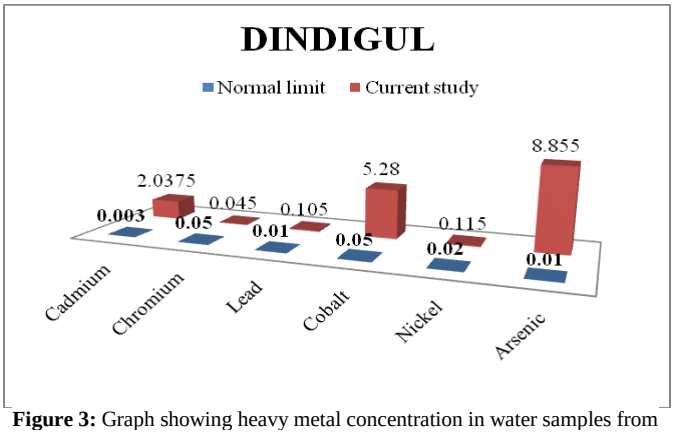

Figure 3: Graph showing heavy metal concentration in water samples from Dindigul district, as compared with normal limits established by the World Health Organization.

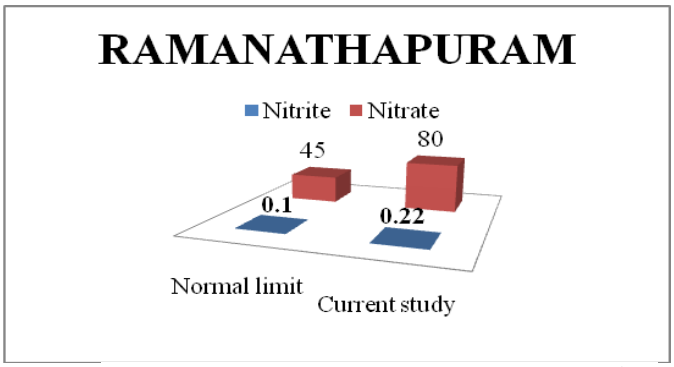

Figure 4: Graph showing heavy metal concentration in water samples from Ramanathapuram district, as compared with normal limits established by the World Health Organization.

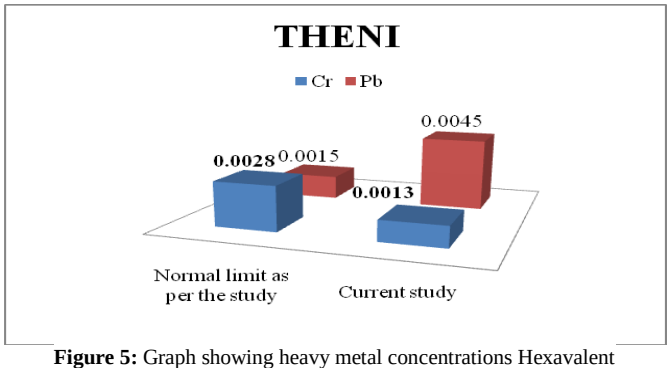

Figure 5: Graph showing heavy metal concentrations Hexavalent chromium(Cr) and Lead(Pb) in water samples from Theni district, as compared with normal limits established by the World Health Organization.

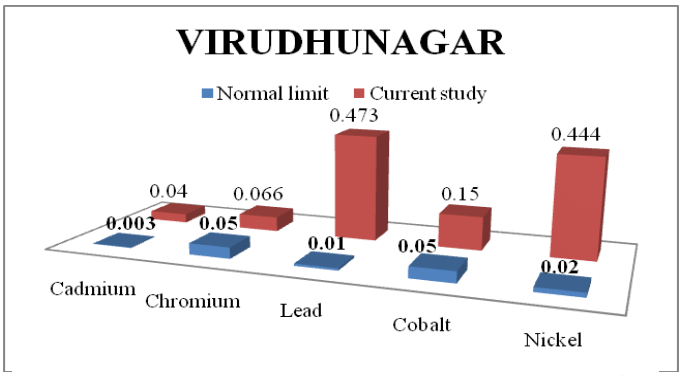

Figure 6: Graph showing heavy metal concentration in water samples from Virudhunagar district, as compared with normal limits established by the World Health Organization.

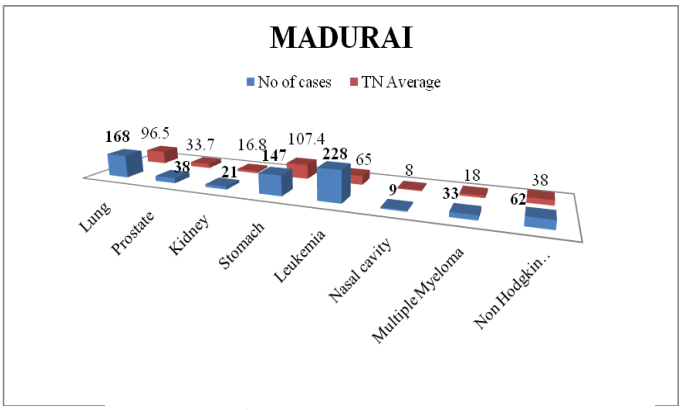

Figure 7: A comparison of cancer types and numbers recorded in Madurai district with the Tamil Nadu average.

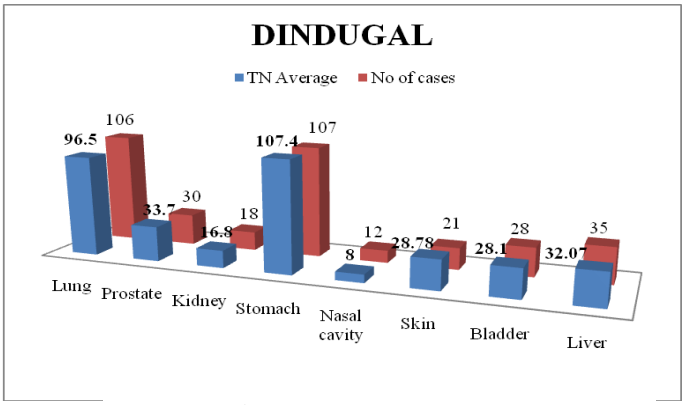

Figure 8: A comparison of cancer types and numbers recorded in Dindigul district with the Tamil Nadu average

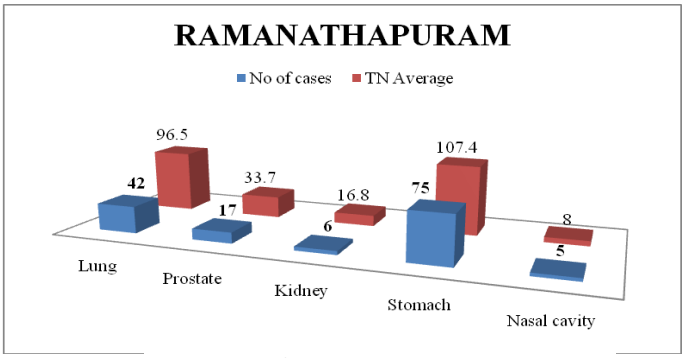

Figure 9: A comparison of cancer types and numbers recorded in Ramanathapuram district with the Tamil Nadu average

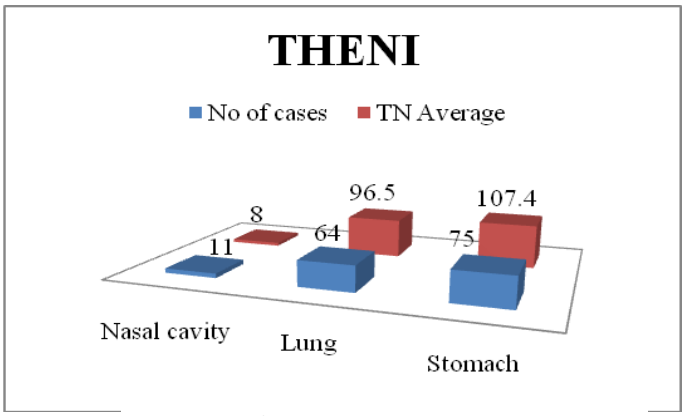

Figure 10: A comparison of cancer types and numbers recorded in Theni district with the Tamil Nadu average

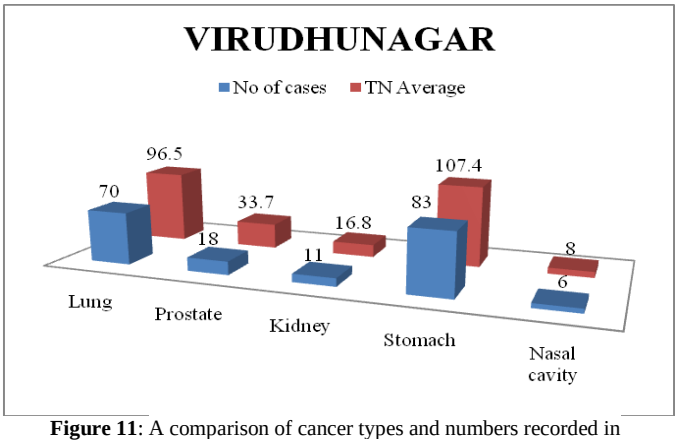

Figure 11: A comparison of cancer types and numbers recorded in Virudhunagar district with the Tamil Nadu average

5. Discussion

Madurai Corporation removes water hyacinth from the Vaigai River annually in June. However, according to reports from the Times of India on June 5, 2023, environmental groups contend that preventing water intrusion would be a better solution than eliminating water hyacinth. The presence of high concentrations of Benzene in groundwater was reported by Senthil Kumar et al in 2017. Maximum concentration was found in North Veli Street. Possible sources of benzene are leakage of hydrocarbon from nearby petrol bunks, vehicular emission, and smoking [9]. The findings indicate that the levels of cadmium, chromium, lead, nickel, and benzene in the Madurai district are 100 times higher than the allowable limit. These results are consistent with the district's known instances of leukemia, stomach cancer, and lung cancer. Elevated concentrations of cadmium, chromium, lead, nickel, and benzene may be induced due to automotive, textile, and plastic industries in the district. Vaigai River is highly polluted such that the heavy metal concentration has already entered the human food chain. Heavy metal concentration in the Vaigai River was estimated in four different sites along with underwater aquatic organisms [7]. Sasirekha et al 2015 study showed the bioaccumulation of cadmium in green leaves collected from five different sites among which green leaves collected from Sellur had the greatest concentration [8]. High concentration in Sellur may be due to the intrusion of untreated sewage and domestic wastewater into the groundwater system and the use of this contaminated water for agricultural activity. Nevertheless, Anand M et al. conducted a study in Ramanathapuram district in 2013 that found the concentration of heavy metals in fish was Pb>Cd>Ni>Co in the muscle, gill, and kidney, with the highest concentrations accumulating in the gills and kidneys, and the lowest concentration accumulating in the muscle tissue. [15]. Even though the levels of heavy metals in the food samples did not surpass the acceptable limits, biological monitoring, and assessment of the levels of heavy metals in fish meat for consumption should be conducted regularly to guarantee food safety in the future due to the persistence of heavy metals in the environment and the importance of fish in the diet of humans, especially in coastal regions. Additionally, the current study shows that cadmium and lead levels were significantly above it, and nickel levels were just marginally above it while cobalt levels were within the acceptable range. People living in Ramanathapuram depend mostly on agriculture for their livelihood, which might explain the high nitrite levels. The district has a much lower cancer incidence rate, which is consistent with the extent of pollution. Among the few districts with very few cancer cases in 2017 were Ramanathapuram and Theni. When compared to other districts, Theni indicates the least polluted status where the levels of lead and chromium are well within the allowable limits. Mohamed Hanipha M et al, 2014 showed the presence of lead, chromium, and cadmium beyond the permissible limit in residential and industrial sites in the Dindigul district [10]. The study was supported by Sarala Thambavani D et al 2012 study, which found that traffic and industrial sites are highly populated in Dindigul [12]. Chidambaram S et al 2014 study conducted in Dindigul revealed that the groundwater was more highly polluted during the post-monsoon season than the pre-monsoon season [11]. Overall, the present study's cumulated result indicates that the levels of chromium, lead, and nickel are exceedingly high. Arsenic, cobalt, and cadmium levels are far beyond recommended thresholds. As seen in Fig. 8, the number of instances of lung, stomach, and nasal cavity cancer is higher than the norm, which is precisely in line with the district's carcinogenicity levels. Umamageswari TSR et al study in 2016 in Virudhunagar showed elevated levels of lead in Rajapalayam, Srivilliputhur, and Trichulli suggesting the possible reason might be due to overuse of lead-containing pesticides or fertilizers [17]. Lead and nickel levels in the current research are significantly higher than acceptable limits, while malignancies of the stomach, lungs, and nasal cavity are within typical bounds.

ASTDR's toxicology profiles provide information on antidotes for lead, chromium VI, chronic nickel intoxication, arsenic poisoning, and cadmium toxicity. A study by Surya Rajeev Nair et al in 2021 found that Indian Gooseberry consumption improved oral hygiene, which might reverse most of the problems listed in Table 4 [20].Using Quercetin as a treatment for cadmium toxicity in quail, Ameer M. Taha et al demonstrate the potential of Quercetin in alleviating the cadmium and improving quail health [21]. Similarly, According to a study conducted by Malaya Ranjan Mahananda and co-workers in 2022, Indian Siris are effective at extracting chromium from contaminated waters [22].

Table 4: Due to the fact that the mouth is a mirror of the entire body, chronic heavy metal poisoning frequently causes oral symptoms, as seen in the following table [23,24]

HEAVY METALS	ORAL PRESENTATIONS
CADMIUM	Bone resorption Osteoporosis Yellowing of teeth
CHROMIUM	Oral lichenoid reaction Lichen Planus Erosion and discoloration of teeth Gingivitis/ Periodontitis
ARSENIC	Rain drop pigmentation Hyperpigmentation Hyperkeratosis Squamous Cell Carcinoma Basal Cell Carcinoma
NICKEL	Oral lichenoid reaction Lichen Planus Hypersensitivity reactions
LEAD	Chronic plumbism Metallic taste Lead hue Astringency
COBALT	Oral lichenoid reaction Lichen Planus

There are limitations to generalizing the results due to the paucity of cancer case records across the district. Although there is a limited amount of data, more precise studies are needed due to cancer's multifactorial nature.

5. Conclusion

To reduce environmental pollution, precautionary measures should be taken and inter-departmental collaborations to be made among government, industries, health care workers, food safety department, and sanitary workers as suggested, industrial sectors that produce Cadmium, chromium VI, cobalt, nickel, and lead as by-products are recommended to follow zero waste strategy, Reverse Osmosis and use of magnetic nanoparticles filtration; Agricultural sector where arsenic, nitrite/nitrate, phosphates, cadmium and chromium VI used are recommended to follow phytoremediation methods to reduce the toxicity. The Food Safety Department needs to ensure that fertilizers and pesticides are not contaminating foods such as fruits, vegetables, nuts, or species. A monitoring program of farmers' practices by the Entomology/Toxicology Department of Agriculture would prevent overuse of fertilizers and pesticides. Composting, material recycling, and thermal treatment (incineration, biogas generation) can be used to manage municipal, corporate, and household wastes.

Data Availability

The article includes references to the data that supported the findings of the study. Full-text articles can be provided upon request.

Conflict of Interest

Authors declare that they do not have any conflict of interest.

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Authors' Contributions

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Rajmohan M: Calculations and Graphical representation of data

Prabu D: Title selection, Data quality assessment and methodology

Sindhu R: Review and corrections in the manuscript

Dinesh Dhamodhar: Data quality assessment and plagiarism check.

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