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Fact-finding Analysis on Carcinogenic Compounds and Its Impact on Spurts of Cancer Cases in Bhavani River Basin, Tamil Nadu, India - Evidence-Based Research

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ABSTRACT

Background: Toxic effluents from various industries, agricultural sectors, and domestic waste products released directly into the river systems act as promoters of carcinogenesis.
Aim: The study aimed to identify the presence of carcinogens in the river Bhavani and determine their impact on the number of cancer cases in the Bhavani flowing districts of Tamil Nadu, namely Nilgiris and Erode.
Materials and Method: Carcinogens were identified based on the "International Agency for Research on Cancer" lists of carcinogens with cancer sites. The concentration of potential carcinogens such as cadmium, hexavalent chromium, nickel, lead, arsenic, nitrite/nitrate, and phosphates are evaluated in Nilgiris and Erode through cross-sectional studies published from 2014 to 2020. Their levels were compared with the WHO standard limit for drinking water. Tamil Nadu Cancer Registry Project Report 2021 was used to calculate the percentage of cancer cases reported in each district contributing to the overall Tamil Nadu.
Results: The results show that Nilgiris is slightly polluted with Nickel (0.062) and phosphates (0.925) that correspond to fewer number of cancer cases in the district compared to Tamil Nadu average status. As the river flows by Erode, the water gets highly contaminated with cadmium, chromium lead, and nickel more 1000 times the permissible limit and the results corresponds to elevated number of cancer cases compared to Nilgiris.
Conclusion: A clear relationship exists between the number of cases reported and the concentration levels of carcinogenic compounds.

Keywords: Heavy metals, Cancer, Environmental pollution, Industrial effluents, Toxic elements, Water resources, Soil contamination, Carcinogenesis

INTRODUCTION

Water is an inevitable component of human life. 97% of the Earth's water is salt water and 3% is fresh water. For a given population, water scarcity results from an increased demand for available freshwater resources in a given area. It is estimated that 1.6 billion people face an economic water shortage, meaning poor management of water resources or lack of water

infrastructure that is made available for public use. 1.2 million People face absolute or physical scarcity of water where the use of water resources outpaces the supply.[1,2] It is estimated that nearly half of the world's population will live in the water-stressed area by 2025.[3] Human use of freshwater resources has steadily grown over the past few decades. The trend is likely to remain the same with the increased growth of population leading to widened usage of fresh water for domestic, agricultural, industrial and recreational purposes.

Three of the most important global risks impacting humanity are weapons of mass destruction, extreme weather events, and water crises.[4] Changes in climatic events are due to global warming with an increasing population and pollution. The agricultural, industrial, and municipal sectors account for 70%, 19%, and 11% of global pollution, respectively.[5] Overusing agricultural fertilizers, pesticides, and insecticides intended to increase yield dispenses large quantities into the groundwater systems. Industries dump millions of tons of waste by-products like carcinogenic chemicals and heavy metals directly without being treated into the river bodies. According to the WHO 2017 report, 2.1 billion people lack access to a safe and reliable drinking water supply at home.[3]

The River Bhavani rises from the Nilgiri hills of the Western Ghats, coursing towards the Erode district in Tamil Nadu, India. The river drains into Cauvery at "Mookkudal- a union of three rivers, Cauvery, Bhavani, and Amaravati," a place in Erode district. Approximately 90% of the river water is used for agriculture and domestic purposes. The Bhavani Sagar Dam, officially known as Keel Bhavani Anai, is one of the largest earthen dams in the world. It is a multi-purpose dam that stores water for irrigation, generates electricity, and supplies drinking water. Erode is known for textile manufacturing and turmeric cultivation. The other major industries include dyeing, electroplating, foundry, and metal casting industries. Discharge of untreated effluents directly into the Bhavani River and Kalingarayan Canal continues. Every month, Bhavanisagar River has been continuously reported in the newspaper about the black and foul odor emanating from the river. Over 2000 people, including politicians, members of farmers' associations, and social welfare organizations, protested and demanded that the government take necessary actions to prevent pollution. The protesters submitted a petition to the Executive Engineer, Water Resources Department, Bhavanisagar Dam Division, demanding action against polluting industries.[6] As the pollutant level in the river accumulates risk of developing various non-communicable diseases, including cancer, increases as many pollutants are known to be human carcinogens. Our aim is to correlate the quality of water and the number of cancer cases reported in the respective districts. This study tries to investigate the various carcinogen levels in the river, understanding the risk of cancer cases in the districts where Bhavani flows through and possible preventive strategies that can be implemented in order to protect the nation from the deadly disease "Cancer" and the nation's natural resources.

MATERIALS & METHODS

Information sources:

By PRISMA guidelines, the following electronic databases were searched from 2014 until 2020: PubMed, Wiley online library, Elsevier Science Direct, SpringerLink, ResearchGate, and Medline. Among 129 articles collected, 56 full-text articles were independently assessed. After assessing for eligibility with inclusion and exclusion criteria, removing duplicates and others, a total of 7 articles fulfilling the inclusion criteria were included in the study. The search strategy for the databases below is shown in Figure 1.

Search strategy:
The search strategies included Boolean operators for the following combinations of keywords: 'Bhavani' or 'Environmental toxicity' or 'carcinogens' or 'heavy metal intoxication' or 'toxic pollutants' or 'heavy metal status' or 'Industrial contaminants' or 'Occupational exposure' or 'water pollution' or 'soil pollution' or 'industrial effluents.'

Inclusion criteria:
We included studies conducted in the Bhavani River and the respective districts supplied by them, as well as those available electronically. Original studies that were published in English with available full text were included. Studies that used standardized measurements and validation tools were included in the study. Studies that have been carried out with appropriate statistical analysis were included in the study.

Exclusion criteria:
Exposure to toxic substances due to accidental spillage was excluded from the study. Studies undertaken by the Tamil Nadu Pollution Control Board were excluded.

Data extraction and synthesis:
For studies that met the eligibility criteria, the following data was collected: Citation (author/year), study area, study duration, number and type of samples (air/water/soil) collected, carcinogens found in the samples, method of testing samples and test result values. The values were compared with standardized normal limits WHO/BIS/CEQG set for drinking water sources, air, and soil. Quality assessment was carried out using the Newcastle Ottawa Scale.[7]

METHODOLOGY

We used IARC lists of classification of carcinogens, Volumes 1-133, to enumerate the group of carcinogens along with the cancer site.[8] Carcinogens exceeding the standard limit were checked for their carcinogenic potential, and cancer sites showed sufficient and limited evidence in humans by IARC lists of classification of carcinogens and by cancer site, respectively.[9] In the first part of the study, cross-sectional studies were systematically reviewed to determine the presence of carcinogens in the Bhavani River Basin from 2014 to 2020. Based on previous literature, the second part of the study calculated the average level of each carcinogen in Erode and Nilgiris. An analysis of the percentage of all types of cancer cases reported in the districts Nilgiris and Erode, where Bhavani flows, was conducted using the Tamil Nadu Cancer Registry Project Report (TNCRP) 2021, published by the Cancer Institute, Adyar and the state health department.[10] The percentages obtained were then used to find the association between the excessive presence of carcinogens and their contribution to the increased prevalence of cancer.[11,12]

RESULTS

According to Figure 1, 7 of the 129 full-text articles that were screened met the eligibility criteria for inclusion in the study. The concentrations of heavy metals are elevated in almost all of the studies. As shown in Table 1, the levels of Nickel, Nitrite, Nitrate, Phosphate in Nilgiris district were slightly higher than WHO standards for drinking water, while cadmium, chromium, lead, nickel and nitrite levels in Erode were much beyond the standard limit.

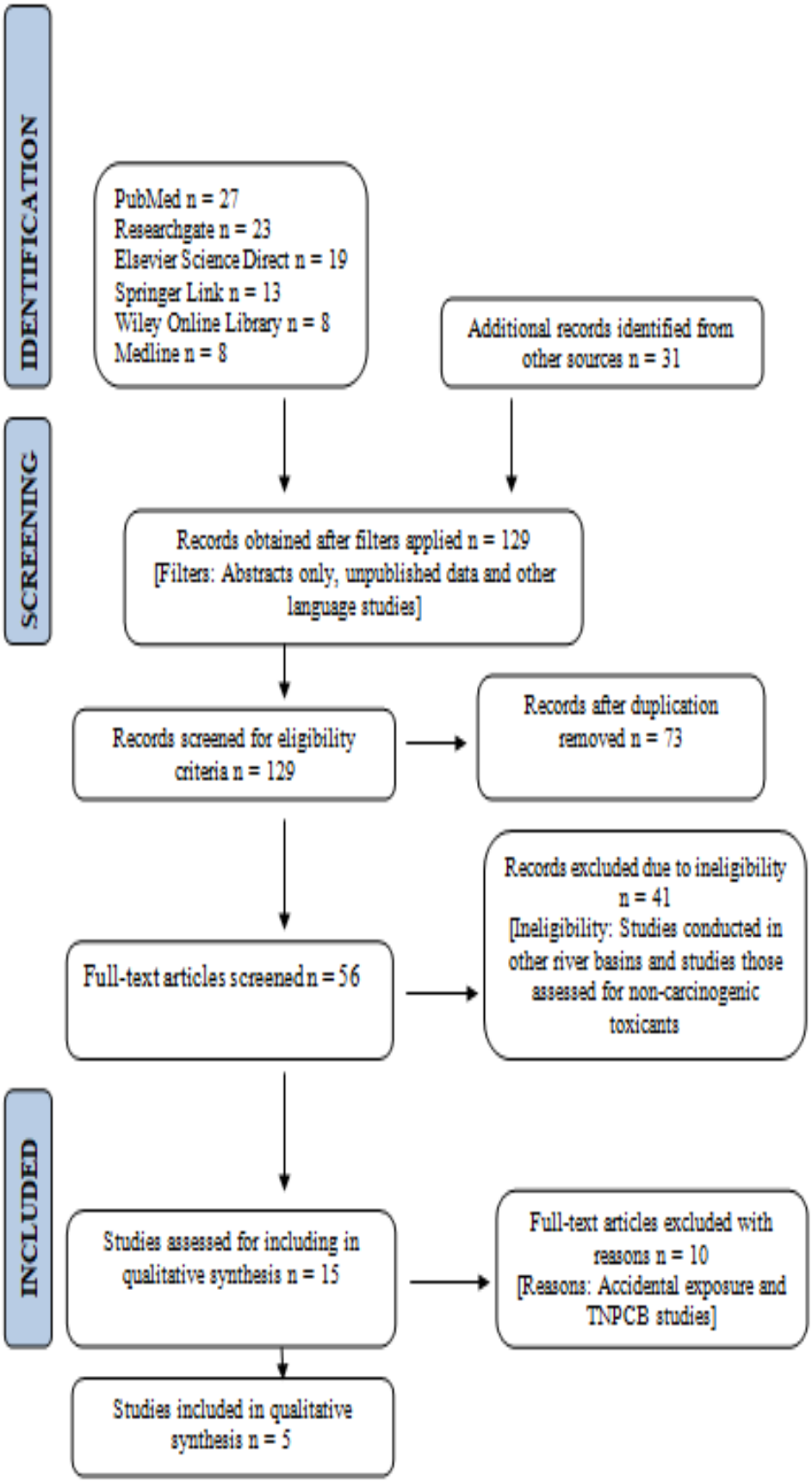

Figure 1: Flow diagram showing the number of studies identified, screened, assessed for eligibility, excluded, and included in the systematic review.

Table 1: Review of articles on carcinogenic agents and their method of assessment

Author	Place of Study	Study Duration	Methods of Measurements	Year of Publication	Sample Size	Sample Site	Carcinogen	Results (mg/l = ppm)	Normal Permissible Limit (P.L.)
Anusiya Devi N et al.[13]	Nilgiris	Jan 2013 – Dec 2014	Atomic absorption Spectrophotometer using Perkin Elmer AA 3300 Model	2015	Collected every month during the course of study	4 sources of Pykara lake	Nickel (mg/l)	Station I - 0.010-0.090 Station II – 0.015-0.097 Station III – 0.13-0.096 Raw effluents – 0.026-0.097	IS 10500 – 0.01mg/l
							Chromium (mg/l)	Station I - 0.018-**0.096** Station II – 0.019-**0.099** Station III – 0.017-**0.098** Raw effluents – 0.030-0.097	WHO-0.050mg/l
Ilavarasan N et al.[14]	Nilgiris	June 2012 Feb 2013	Water quality index Statistical analysis-environmetric method.	2016	Collected during summer and winter season	5 locations: Entrance of the lake. Between the lake entrance and the boat entrance. At the boat entrance. Middle of the lake. Exit for the lake.	Nitrate	Summer: 5-**12**mg/dm^3 Winter: 4-7mg/dm^3	E.P.A. – 10mg/l
							Nitrite	Summer: 0-**3mg/dm^3** Winter: 0-**4mg/dm^3**	EPA – 1mg/l
							Phosphate	Summer: 0-**2mg/dm^3** Winter: **1-2mg/dm^3**	WHO – 1mg/l (1999)
Abdul Bari J et al.[15]	Erode	Pre-monsoon season		2014	25 groundwater samples	Bhavani taluk	Nitrates	1 to **218 mg/l**	WHO – 45mg/l
Venu VS et al.[16]	Erode		DTPA extractable by adopting Lindsay and Norvell's procedure	2019	40 soil samples in mulberry-cultivated soils	Gobichettipalaym, Nambiyar, Bhavani, Antiyur, Perundurai, Sathyamangalam, Modakurichi, Thingalur.	Chromium Cadmium Nickel Lead	**1.20 to 117.4ppm** **6.6 to 120.6ppm** **6.4 to 73.6ppm** **4.6 to 119.8ppm**	0.05ppm 0.003ppm 0.02ppm 0.01ppm

Divahar R et al.[17]	Kalingarayan Canal, Erode	Jan 2014 – Dec 2016.	Water Quality Index using Phenol disulponic acid.	2020	9 groundwater samples	Panjalingapuram Kolathupalayam1,11 Unjalur 1, 11 Perumparai Vadakupudupalayam1& 11 Sallikadu	Nitrates	Vadakupudupalayam 1: **54.3 to 57.8 mg/l** Vadakupudupalayam 11: **47.6 to 50.3 mg/l**	WHO - 45 mg/l

TABLE 1 shows the review of articles on the method of measurement of a particular carcinogen and the results obtained at specific sites as given by Anusiya Devi K et al, Ilavarasan N et al, Abdul Bari J et al, Venu VS et al and Divahar R et al

TABLE 2: Percentage of cancer cases and their association with carcinogen levels in the Bhavani River

District	Carcinogens[11]	Mean range obtained	Normal value	Cancer site[s]	Percentage of cancer cases
Nilgiris	Nickel	0.010-0.097	0.02	Nasal cavity and paranasal cavity & Lung	Stomach - 0.50% Lung - 0.50% Leukemia – 0.50% Nasal cavity and paranasal cavity- 0.3%
	Chromium	0.017-**0.099**	0.05	Nasal cavity and paranasal cavity & Lung	
	Nitrate	4-**12**mg/dm^3	EPA-10mg/l	Stomach	
	Nitrite	0-**4mg/dm^3**	EPA-1mg/l	Stomach	
	Phosphate	0-**2mg/dm^3**	-	Leukemia	
Erode	Nitrates	1 to **218**	45	Stomach	Nasal cavity and paranasal cavity – 4.3% Prostate – 3.5% Kidney – 2.8% Lung – 2.8% Stomach – 2.5%
	Cadmium	**6.6 to 120.6ppm**	0.003	Lung, Prostate & Kidney	
	Lead	**4.6 to 119.8ppm**	0.01	Stomach	
	Chromium	**1.20 to 117.4ppm**	0.05	Nasal cavity and paranasal cavity & Lung	
	Nickel	**6.4 to 73.6ppm**	0.02	Nasal cavity and paranasal cavity & Lung	

TABLE 2 represents the spurts of cancer cases in the districts along the Bhavani River.

Source: [a]Mean value of carcinogens was the cumulated score of different studies described in the Table 1; Units – mg/l.

[b]Mean score was compared with WHO 2013 standard limits for drinking water; Units – mg/l.

[c]Cancer site – Individual risk of cancer for each carcinogen was noted with the reference from "List of classifications by cancer sites with sufficient or limited evidence in humans, IARC Monographs Volumes 1-132. WHO 2022".[8]

[d]Percentages of cancer cases – TNCRP 2021 report. Percentages of cancer cases were calculated from the number of cancer cases reported in TNCRP 2021.[9]

From table 2, mean value was calculated for each carcinogen in the districts of Erode and Nilgiris. The value was considered as an average level obtained and plotted against the normal limit set by WHO 2013 as a bar chart represented in Figure 2 and 3.

FIGURE 2: Graphical representation of heavy metal concentration in Nilgiris district supplied by Bhavani compared with the normal limit of WHO standards, followed by figure 2.1, which shows the number of cancer cases recorded in the district compared with Tamil Nadu's Average count.

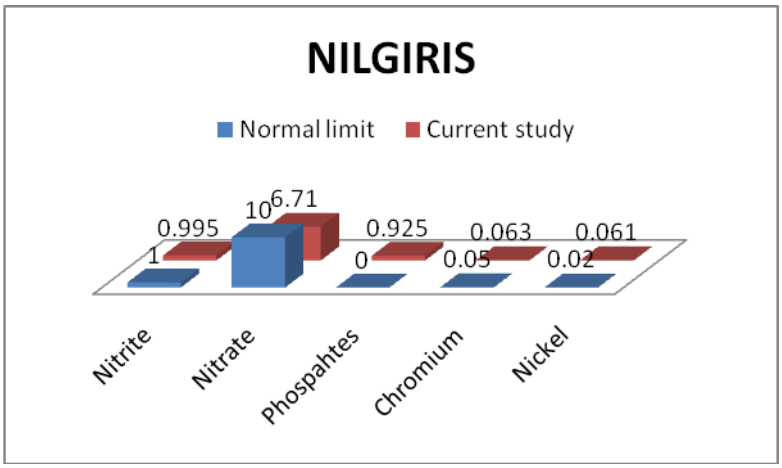

Figure 2

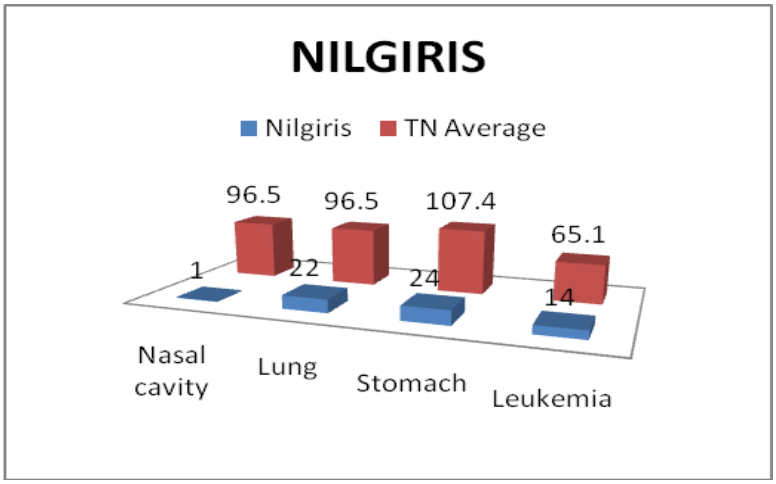

Figure 2.1

FIGURE 3: Graphical representation of heavy metal concentration in Erode district supplied by Bhavani compared with the normal limit of WHO standards, followed by figure 3, which shows the number of cancer cases recorded in the district compared with Tamil Nadu's average count.

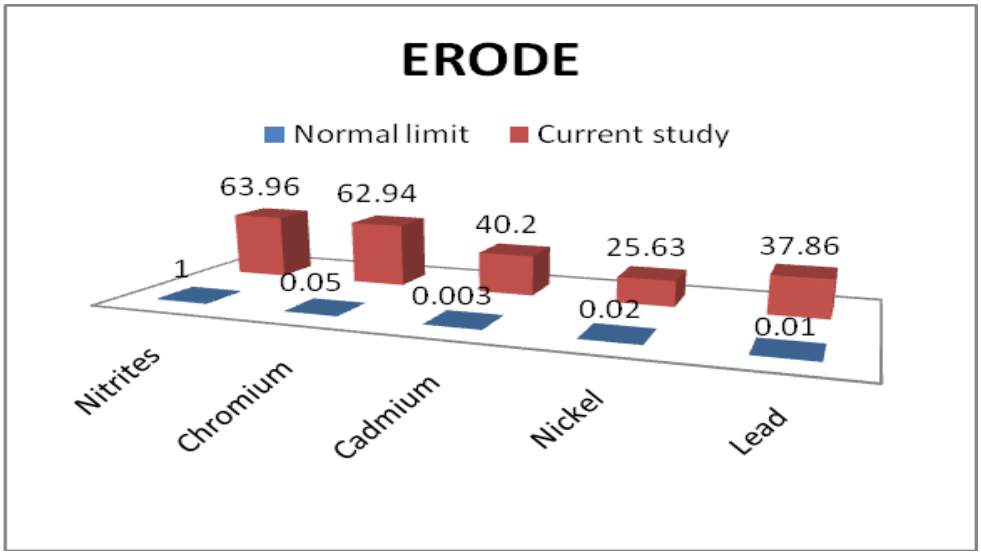

Figure 3

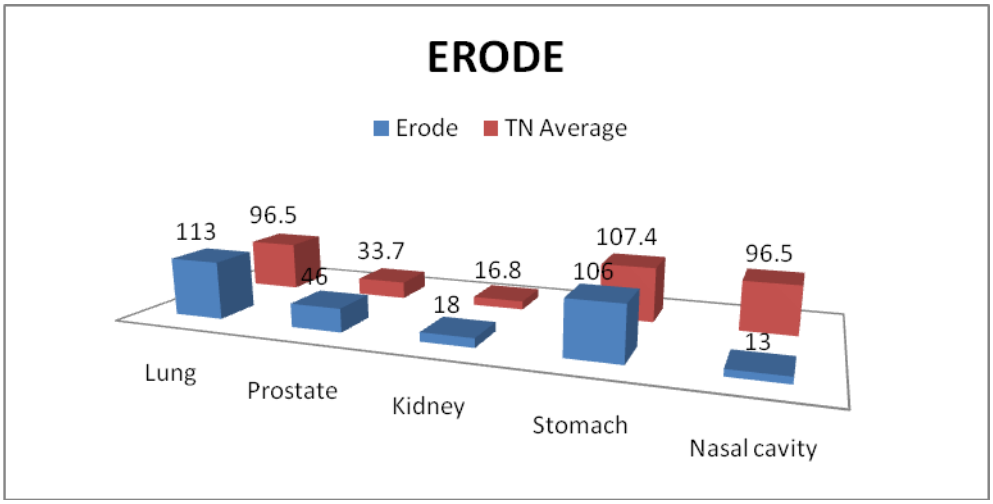

Figure 3.1

TABLE 3: QUALITY ASSESSMENT: NEWCASTLE OTTAWA SCALE[7]

AUTHOR & YEAR	SELECTION				COMPARE--BILITY	OUTCOME	
	Representativeness of the samples	Sample size	Non- respondents	Ascertainment of the exposure		Assessment of the outcome	Statistical test
Anusiya Devi N et al	*	*	NA	**	*	**	-
Ilavarasan N et al.	*	*	NA	**	*	**	*
Abdul Bari J et al.	*	-	NA	*	*	*	*
Venu VS et al.	*	*	NA	**	*	**	-
Divahar R et al.	*	*	NA	**	*	**	*

Representativeness of the samples
***Truly or somewhat representative of the target**
Sample size

***Justified and satisfactory**
Ascertainment of the exposure
****Validated measurement tool**
***Non-validated measurement too**

Comparability
Comparable outcome groups
Outcome
****Independent blind assessment/ Record linkage**

***Self report**
Statistical test
***Statistical test is appropriate**
Statistical test is not appropriate

TABLE 4: Since the oral cavity is the reflection of the entire body, oral manifestations are commonly elicited in cases of chronic toxicity of heavy metals, such as the following table[21,22]

Heavy metals	Oral presentations
Cadmium	Bone resorption - Osteoporosis Yellowing of teeth?
Chromium VI	Oral Lichenoid Reaction (ORL) Lichen Planus (LP) Erosion and discoloration of the teeth Gingivitis/ Periodontitis
Arsenic	Rain-drop pigmentation Hyperpigmentation Hyperkeratosis Squamous Cell Carcinoma Basal Cell Carcinoma
Nickel	Oral Lichenoid Reaction (ORL) Lichen Planus (LP) Hypersensitivity reactions
Lead	Chronic plumbism Metallic taste Lead hue Astringency

TABLE 5: The following are the precautionary measures recommended for reducing the impact of carcinogens in the environment:

SECTORS	CARCINOGENS	PREVENTIVE MEASURES
Industries	Cadmium, chromium VI, nickel and lead	Zero waste strategy Reverse Osmosis Use of magnetic nanoparticle filtration
Agriculture	Arsenic, nitrite/nitrate, phosphates, cadmium and Chromium VI	Food Safety Department should ensure that foods such as fruits, vegetables, nuts, and species are not contaminated with either fertilizers or pesticides. Entomology/Toxicology Department of Agriculture should monitor farmers' overuse of fertilizers and pesticides. In case of soil contamination, Phytoremediation methods are used to reduce toxicity.
Municipal/ Corporation/ Domestic waste	Arsenic, benzene, and trace amounts of nickel, lead, cadmium, and chromium VI	Mini sewage treatment plants, Material recycling, thermal treatment like incineration, biogas generation, composting.

TABLE 6: The following are recommended dietary modifications for individuals in reversing the abnormal levels of carcinogens in the body based on Toxicology profiles, ATSDR.[23,24]

CARCINOGENS	INCREASE THE LEVELS OF VITAMINS AND MINERALS	RECOMMENDED DIET
Cadmium	Iron and zinc	Greens, Nuts and seeds, Liver, Fish, Meat, and dairy products
Chromium VI	Calcium and magnesium	Broccoli, Cabbage, Lady’s finger, Bananas, Oranges and dairy products
Nickel	Iron and magnesium	Greens, Beans, Peas, Bananas, Nuts & Seeds, Liver and dairy products
Lead	Iron, calcium, zinc, and	Nuts & Seeds, Oranges, Grapes,

	vitamin C	Watermelon, Greens, Tomato, Potato, Broccoli, Cabbage, Lady's finger, Fish, Meat, Liver and dairy products
Arsenic	Vitamin A, B9, E, and selenium	Papaya, Watermelon, Wheat germ, Nuts and seeds, Carrots, Greens, Sweet potato, Broccoli, Pumpkin, Cauliflower, Spinach, Chickpeas, Peas, Brown rice, Eggs, Chicken, Liver, Fish, and dairy products
Nitrite/nitrates/ phosphates	Include all vitamins and mineral-rich foods	Greens, Mushrooms, Peanuts, Soya beans, Cereals, and Legumes, including all the items mentioned above.

DISCUSSION

World Economic Forum estimated that 70% of surface water in India is not suitable for human consumption, and every day, about 40 million liters of wastewater enter the river system without being properly treated. Based on a World Bank report, the release of pollution lowers G.D.P. growth by up to one-third, sometimes even up to half of G.D.P. growth in developing countries like India, with a 9% reduction in agricultural revenues and a 16% drop in downstream farm yields.[4]

May 2023, SIPCOT affected people welfare association in Erode district filed a complaint against industries discharging effluents directly into Bhavanisagar river which turned out be black and odorous. Tamil Nadu Pollution Control Board (TNPCB) collected samples from the dam's inlet and discharge points and reported that the pollution levels are within the I.S. 10500:2012 for drinking water and stated that the industries are continuously being monitored.[18] The findings contrast with the present, where the levels of cadmium, Chromium, lead, nickel, nitrite, nitrate, and phosphates are beyond the permissible limits in Erode.

According to Anusiya Devi et al. (2015), the study demonstrated the monthly variations in heavy metals of Pykara Lake in Nilgiris for two years from Jan 2013 to Dec 2014. Water sources were collected from four sources of Pykara Lake at Ooty. The values of Chromium were slightly higher than the maximum contaminant level. Elevated levels of Chromium can result from illegal gold mining industries in Nilgiris.[13] Similarly, N. Illavasaran et al. (2016) assessed the water quality using the water quality index on Ooty in the Nilgiris district. They considered various parameters among which the levels of Phosphates, Nitrates, and Nitrites are slightly elevated. Contamination of phosphates is mainly due to domestic waste and nitrates/nitrites due to farmers' agricultural misuse of pesticides and fertilizers to increase the yield. The government should force the agricultural department to educate farmers about the misuse of pesticides and fertilizers and impose newer techniques like phytoremediation methods to remove any presence of excess toxic substances like Chromium in the soil. The water quality index of Ooty Lake showed heavy pollution during the winter season and moderately polluted during the summer season. The variation is due to the inflow of plastic and organic waste into the water body. As we noticed, the concentration of carcinogens is less.[14] Surprisingly, the number of cancer cases is also less in the Nilgiris district, where the river originates, but as it flows through Erode, the pollution level increases simultaneously, and cancer cases also increase. According to Venu VS (2019), a study conducted in the mulberry-cultivated soil in Erode, the highest Chromium, lead, and cadmium concentration was recorded in Thingalur, and nickel levels were recorded in Nallampatti. The study suggested that high Cadmium levels in the soil might be due to fertilizers and metal-based pesticides in crops.[16]

Similarly, R. Divahar et al. (2020) and Abdul Bari et al. (2014) studies conducted in Erode in 6-year intervals showed nitrate concentration beyond the permissible limit of WHO standards in drinking water in Vadakupudupalayam, Kolathupalayam, and

Perumparai in Kalingarayan canal and Bhavani taluk. Odaikkattur, Sullimedu, and Palatholuvu villages in Perundurai taluk, located close to SIPCOT units, have recorded black, foamy, and foul-smelling water.[15,17] Adding on to the factors, high-risk populations such as young children, pregnant women, very old age people, and those who consume tobacco and other products are more susceptible to mutagenesis.[19,20]

The government should take immediate action on the role, emphasizing all industries to follow the zero liquid discharge method, a water treatment process where effluents are separated from the fluid component. The municipality is advised to install mini sewage treatment plants at various appropriate locations in the city. As boiling water does not remove heavy metals like arsenic, cadmium, Chromium, lead, and nickel, people should make sure that they install reverse osmosis systems in their homes.

Whenever these signs and symptoms are noted, either by a dentist or by people themselves, they are advised to get a diagnosis done by a health care professional without any delay and follow dietary modifications as recommended in Table 6.

The study is hardly generalizable due to the research gap in the site/zone/area-specific collection of samples and the availability of cancer case records only for the entire district. Irrespective of limited data, the results show a strong association; hence, more precise studies are expected, as cancer is a multifactorial disease.

CONCLUSION

The study's result clearly elicits the evidence behind the concentration levels of carcinogenic compounds and the number of cases reported. The river originates from Nilgiris, the place known for plantation with only a handful of industries and fewer populations where the nitrite, nitrate, and phosphate levels are only slightly elevated, and the cancer cases reported are the least among other districts in Tamil Nadu state. In the case of densely populated Erode, where there are numerous industries such as dying, textile, and printing, the concentration levels attain a peak, with the cancer cases hitting the maximum. Government should assign special food safety inspectors to ensure the human consuming foods are free from pesticides and fertilizers.

Declaration by Authors

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