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Presence of Carcinogenic compounds in Palar-Thenpennai River Basin and its Impact on increasing spurts of cancer cases in Northern Tamil Nadu, India – An evidence based fact analysis

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Abstract

Water contamination is currently one of the biggest concerns for every country as it depends directly on the nation's economy and public health. The aim is to find if there is any association between the presence of carcinogens in Palar-Thenpennai river basin, Tamil Nadu, and increasing spurts of cancer cases in the Palar-Thenpennai supplying northern parts of Tamil Nadu namely Chennai, Thiruvallur, Kancheepuram, Thiruvannamalai, Ranipet and Cuddalore districts. The "Lists of carcinogens with cancer site" published by the International Agency for Research on Cancer were used to identify carcinogens. The cross-sectional studies included in the study are from the year 2007 to 2022. The levels of potential carcinogens, including phosphates, nickel, lead, arsenic, cadmium, hexavalent chromium, and nitrite/nitrate, are tracked. Their levels were compared with the WHO standard limit for drinking water. The percentage of cancer cases was determined using data from the Tamil Nadu Cancer Registry Project Report 2021. The results show a strong association between contamination level and cancer prevalence in Chennai, Thiruvallur, and Kancheepuram districts. Evidence shows the presence of carcinogens in the fish samples collected in the Gadilam River in Cuddalore district meaning that the contamination has already entered into the human food chain.

Keywords: Heavy metals, Carcinogens, Industrialization, Water Pollution, Cancer.

Introduction

We're seeing cancer risk estimated at about 100,000 cases for the U.S.–due to drinking water contaminants at levels that currently meet requirements, lead author, Sydney Evans, a science analyst at the Environmental Working Group. They conducted the study which was published in the journal Heliyon in 2019, looking for 22 carcinogens in the US municipal drinking water system which serves 279 million people. Approximately 4-lifetime cancer cases per 100,000 people was the total cumulative lifetime cancer risk predicted by the study[1].

According to the SDG 2020 report, at the current rates, 1.6 million people will have safe drinking water by 2030. We need to speed up to four times from the present state to achieve SDG 6. Around 3 million don't know about the quality of drinking water due to lack of monitoring[2].

According to the Global Burden of Disease Report 2019, pollution is solely responsible for 9 million deaths per death corresponding to one in every six death worldwide[3]. The importance of urbanization and industrial safety to the growth of a country and its people cannot be overstated.

Numerous industrial processes result in the untreated discharge of chemical waste into the environment. When groundwater becomes polluted it poses a big difficulty in cleaning it. Anthropogenic activities due to overpopulation also contribute to the rapid increase in contamination poses a serious threat to groundwater quality. This study reviews the levels of carcinogenic compounds in the groundwater from previous studies and aims to find the association between the levels and the increase in cancer cases in the respective districts as per TNCRP report 2021[4].

Materials and Methods

Search Strategy: In accordance with PRISMA guidelines, the following electronic databases were searched from 2007 until 2022: PubMed, Wiley online library, Elsevier Science Direct, Springer Link, and Research Gate with the help of Boolean operators for the following combinations of keywords: 'Palar' or 'Thenpennai' or 'Cancer' or 'Carcinogens' or 'heavy metal intoxication' or 'toxic pollutants' or 'Industrial contaminants' or 'Occupational exposure' or 'water pollution' or 'soil pollution' or 'industrial effluents.' *Study location:* Chennai is the capital city of the Indian State of Tamil Nadu. It is a significant hub for trade, culture, the economy, and education in South India. A cosmopolitan city inculcated with historical, cultural, and intellectual development with distinct components of the highest form of Dravidian civilization. It is the smallest and most densely populated district in the state. The major source of water for the city is from two reservoirs namely Poondi Reservoir and Chembarabakkam Lake diverted from the Palar River. The northern part of Tamil Nadu is supplied by the Palar and Thenpennai rivers. The Towns of Vaniyambadi, Ambur, Gudiyatham, Vellore, Katpadi, Arcot, Ranipet, Walajapet, Kanchipuram, Chengalpattu, and Kalpakkam are located on the banks of the Palar River. On the banks of the South Pennar (Thenpennai) river are several significant cities, including Bangalore, Hosur, Krishnagiri, Kaveripattinam, and Cuddalore. This is the second-longest river in Tamil Nadu.

Inclusion criteria: We included studies conducted in the Palar and Thenpennai rivers in Chennai and other nearby districts such as Thiruvallur, Kancheepuram, Thiruvannamalai, Ranipet, and Cuddalore supplied by them. Included were original research studies that had complete texts accessible and were published in English. The analysis includes studies that made use of validation tools and standardized measuring techniques. The study includes research that was conducted using relevant statistical analysis.

Exclusion criteria: Incidents where exposure to harmful compounds happens as a result of unintentional spills were not included in the research. Research conducted by the Tamil Nadu Pollution Control Board was not included.

Methodology: For studies that met the eligibility criteria was collected. The data were compared to the standardized normal limits for drinking water sources, air, and soil established by WHO/BIS/CEQG. We included the category of carcinogens together with the cancer site using the IARC lists of categorization, Volumes 1-133[5,6]. Carcinogens that exceeded the standard limit were examined for their propensity to cause cancer and for cancer sites according to the IARC's lists of carcinogen classifications and cancer site classifications, respectively. Based on the Tamil Nadu Cancer Registry Project report 2021, the percentage of all cancer cases recorded in the districts of Chennai, Thiruvallur, Kancheepuram, Thiruvannamalai, Ranipet, and Cuddalore was determined[4]. The average number of cancer cases in each district in Tamil Nadu was determined by dividing the total number of cancer cases in all 38 districts in the state by 38[7].

Results and Discussion

Table-1 shows the review of publications based on the results obtained as given by Saubhagya Rajan Mahapatra et al, Sridhar SGD et al, Silambarasan K et al, Chandrasekar V et al, Jayashree R et al, Meenakshi P et. al, Prabhu Dass Batvari et. al, Uma T et. al, Mohana P et. al, Kistan Andiyappan et. al and Ambedkar G et. al.

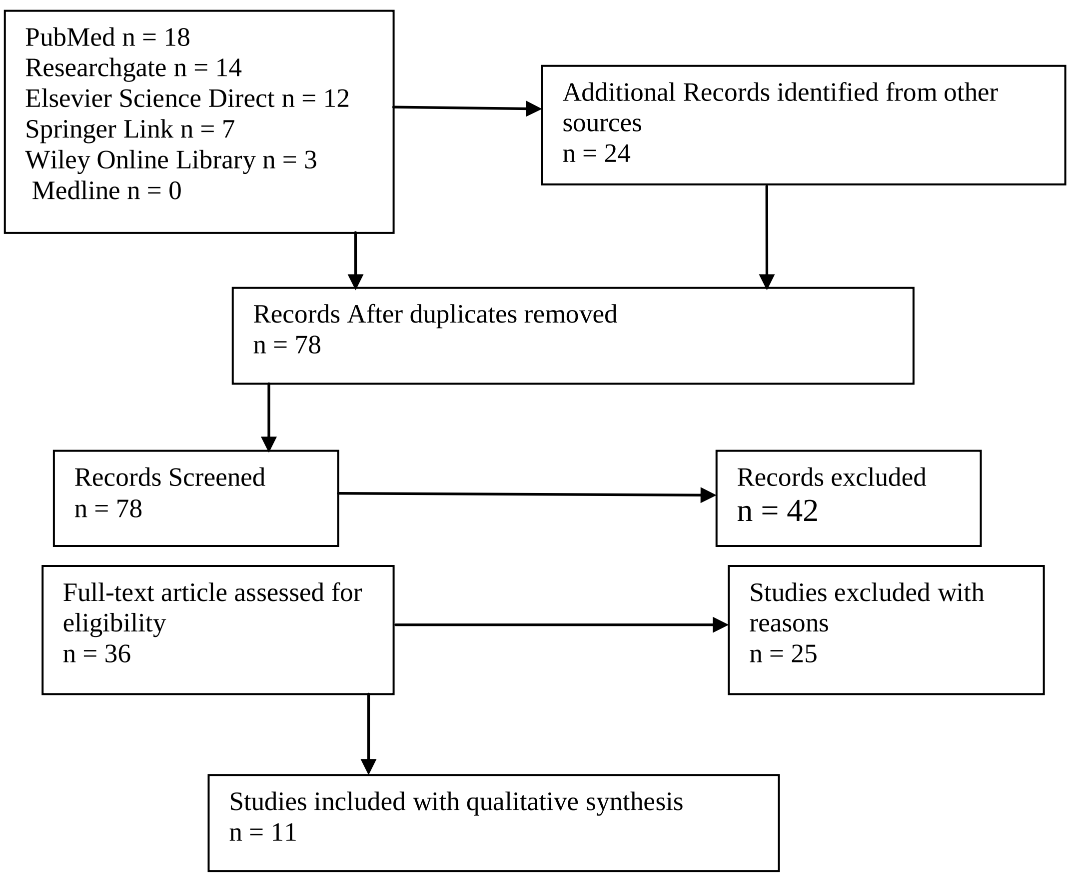


Figure-1: The number of studies found, reviewed, evaluated for eligibility, excluded, and included in the systematic review is displayed in a PRISMA flowchart.

Table-1: Examining publications about the existence of carcinogenic substances in the Palar and Thenpennai River Basin, their evaluation process, and the outcomes attained.

Author Year Place of Study	Study Duration	Sample Size Sample Site	Methods of Measurements	Carcinogen	Results	Normal Permissible Limit (PL) WHO/BIS
8	Jun 2015 – Jan 2016	54 ground water samples; 38 bore wells; 16 dug wells Northern suburbs of Chennai	Atomic absorption flame emission spectrophotometer, AAFES - 700	Chromium	0.019-0.539mg/l	WHO 2004 (mg/l) 0.05
				Nickel	0.014-0.22mg/l	0.02
				Lead	0.065-0.423mg/l	0.01
9	Jun 2014 – Jan 2015	30 ground water samples from bore wells and dug wells From Besant Nagar to Sathankuppam, South Chennai	Atomic absorption Spectrophotometer	Chromium	PRM:0.229 to 0.971mg/l POM:0.363 to 1.484mg/l	BIS 2012 (mg/l) 0.05,
				Cobalt	PRM:0.085 to 0.565mg/l POM:0.273 to 0.83mg/l	No relaxation
				Nickel	PRM:0.093 to 0.549mg/l POM:0.001 to 0.695mg/l	0.02
				Lead	PRM:0.112 to 0.594mg/l POM:0.031 to 0.781mg/l	0.01
10		Water and sediment samples Stations: I – Ekatuthangal; II – Guindy; III – Saidapet; IV – Kotturpuram	Atomic absorption Spectrophotometer for water samples. ICP-AES (Inductive Coupled – Atomic Emission Spectroscopy) For sediment samples	Lead	Waters Samples: 0.02 to 0.06µg/l Maxi at station I: 0.06µg/l	WHO 2004 – 0.01mg/l
				Cadmium	0.21 to 0.38µg/l Maxi at station II: 0.38	0.05mg/l
				Lead	µg/l Sediments: 0.26 – 0.42 µg/g	Target values of soil 85µg/g
				Cadmium	0.52 – 0.73µg/g	0.8µg/g
11		37 ground water Samples – bore and Open wells hand pump Coastal taluks of Thiruvallur district	Atomic absorption Spectrophotometer	Chromium	0.001 to 0.09mg/l Maxi at New Manali – 0.09mg/l	BIS 2012 0.05
				Nickel	0.001 to 0.03mg/l Maxi at Arasur & Telugu colony – 0.03mg/l	0.07
12		31 ground water Samples Arumbakkam Kellanur Vilapakkam Komakambedu Valliyur Melanur Othikadu Pungathur Talakancheri Poondi union Muttukadu Kandigai Keelakarai Aranvoyal Kunnapakkam Sirukadal Ramapuram Thandalam Thiruninravoor Chittatur	Method described by Veeraiah and Durga Prasad, 1996.	DDT	Open wells - pp-DDT 14g/l Bore wells - pp-DDT 4.2g/l	DDT – 1 µg/l
				HCH	Open wells - alpha HCH 8.6g/l, beta HCH 5.4g/l, gamma HCH 9.8g/l and delta HCH 11.6g/l. Bore wells - alpha HCH 4.6g/l, gamma HCH 6.3g/l and delta HCH 7.9g/l	HCH – 1 µg/l
13	Mar 2017 – Jan 2018	17 pound water Samples - Residential, Industrial Low and high population areas		Lead Arsenic	<0.1mg/l	0.1mg/l 0.05mg/l

14		Water samples collected from three different locations Chemberambakkam lake water	Atomic Absorption Spectrophotometer.	Cadmium	0.147-0.187mg/l	WHO0.003
				Chromium	0.019 – 0.035mg/l	0.05
				Cobalt	0.030 – 0.084mg/l	0.05
				Nickel	0.030 – 0.084mg/l	0.02
				Lead	0.02 – 0.296mg/l	0.01
15		Ground water samples Lake water Pudhupettai dye industry effluent – Nadhapettai lake in Kancheepuram Sugarcane mill effluent-Cheyyar, Thiruvanamalai	Spectrophotometric Method, APHA 1995 Stannous chloride method APHA 1995	Lead(mg/l)	Lake water- 14.98 Dye – 20.3 Sugarcane -1.6	WHO - 0.010mg/l
				Cadmium	Lake water- 2.43 Dye- 3.45 Sugarcane- 2.37	WHO- 0.003mg/l
				Arsenic	Lake water- 0.66 Dye- 0.33 Sugarcane- 0.03	WHO, 0.01 mg/L(PL)
				Nickel	Lake water- 0.26 Dye-0.05 Sugarcane-0.4	WHO – 0.02mg/l
				Chromium	Lake water-0.97 Dye-2.23 Sugarcane- 0.01	WHO- 0.05mg/l
16	Pre-monsoon Post-monsoon	44 ground water samples Arani taluk	Atomic absorption Spectrophotometer using Perkin Elmer AA 700 Model	Lead	Pre-monsoon-0.03mg/l Post-monsoon- 0.017	WHO - 0.010mg/l
				Nickel	Pre-monsoon- 0.071 Post-monsoon- 0.044	0.02mg/l
				Chromium	Pre-monsoon- 0.076 Post-monsoon- 0.042	0.050mg/l
17	May-17	Seven soil samples tannery region agricultural area residential zone	Atomic Absorption Spectroscopy	Chromium (mg/kg)	Tannery: 59.45–1524.26	EC, 1986 410.59
				Lead	5.28–92.58	26.19
				Cadmium	1.04–5.86 Agri: BDL Residential: BDL	1.025
18	Jan 2010-Dec 2010	Water Sediment Fishes Gadilam river Channa punctatus, Mystus vittatus, Mugil cephalus, Heteropnustes fossilis, Chanos chanos	ELICO SL – 176 Double beam Atomic Absorption Spectrophotomter (AAS)	Cadmium Chromium Lead	Water (mg/l): 1.46±0.054 0.70±0.026 0.46±0.018	WHO- 0.003mg/l 0.05mg/l 0.010mg/l
				Cadmium Chromium Lead	Sediment (mg/kg) 1.64±0.048 0.94±0.040 0.48±0.014	WHO 0.005ppm 0.15mg/kg 2.0mg/kg
				Cadmium Chromium Lead	Fishes (mg/kg): Channa Punctatus 1.04±0.024 - 1.60±0.068 0.58±0.016 - 0.30±0.011 0.28±0.010 - 0.38±0.016	
				Cadmium Chromium Lead	Mystus Vittatus 0.98±0.031 - 1.40±0.056 0.38±0.014 - 0.80±0.037 0.22±0.010 - 0.68±0.032	
				Cadmium Chromium Lead	Mugil Cephalus 0.80±0.026 - 1.26±0.053 0.62±0.025 - 1.18±0.042 0.40±0.011 - 0.58±0.020	
				Cadmium Chromium Lead	Heteropnustes Fossilis 0.64±0.022 - 0.90±0.038 0.56±0.021 - 1.10±0.031 0.24±0.018 - 0.62±0.029	
				Cadmium Chromium Lead	Chanos Chanos 0.54±0.023 - 1.10±0.045 0.34±0.016 - 0.90±0.032 0.28±0.011 - 0.64±0.026	

Table-2: The correlation between the carcinogen levels in the Palar-Thenpennai River and the percentage of cancer cases.

District	Carcinogens	Mean range obtained[a]	Normal value[b]	Cancer site[7]	Percentage of cancer cases[5]
Chennai	Cadmium	0.21 to 0.38µg/l	0.003	Lung, Prostate & Kidney	Prostate – 17% Lung – 11.8% Kidney - 11.1% Stomach – 9.5% Nasal cavity – 7%
	Chromium	0.019-1.484	0.05	Nasal cavity and paranasal cavity & Lung	
	Lead	BDL-0.781	0.01	Stomach	
	Cobalt	0.085-0.83	0.05	Lung	
	Nickel	0.001-0.695	0.07	Nasal cavity and paranasal cavity & Lung	
Thiruvallur	Chromium	0.001 to 0.09mg/l	0.05	Nasal cavity and paranasal cavity & Lung	NHL – 9.7% Lung – 7.4% Liver – 6.5% Testis – 4.5% Nasal cavity– 4%
	Nickel	0.001 to 0.03mg/l	0.07	Nasal cavity and paranasal cavity & Lung	
	DDT	4.2-14g/l	1 µg/l	Liver, bile duct, testis, NHL	
	HCH	4.6- 11.6g/l	1 µg/l	NHL	
Kancheepuram	Cadmium	0.147 – 2.43	0.003	Lung, Prostate & Kidney	Liver – 9.1% Prostate – 8.75% Kidney - 8.46% Nasal cavity – 8.36% Stomach – 8.15% Bladder – 7.89% Lung – 7.65% Skin – 6.85
	Chromium	0.019 –2.23	0.05	Nasal cavity and paranasal cavity & Lung	
	Lead	BDL –20.3	0.01	Stomach	
	Cobalt	0.015 – 0.099	0.05	Lung	
	Nickel	0.030 –0.26	0.07	Nasal cavity and paranasal cavity & Lung	
	Arsenic	0.33-0.66	0.01	Bladder, Lung, Skin, Prostate, Kidney & Liver	
Thiruvannamalai	Chromium	0.042-0.076	0.05	Nasal cavity and paranasal cavity & Lung	Stomach – 4.3% Nasal cavity– 3.3% Lung – 2.8%
	Lead	0.017-0.03	0.01	Stomach	
	Nickel	0.044-0.071	0.07	Nasal cavity and paranasal cavity & Lung	
Ranipet	Cadmium	1.04 – 5.86	0.003	Lung, Prostate & Kidney	Kidney - 6.1% Prostate – 6% Nasal cavity– 6% Lung – 5.8% Stomach – 5.5%
	Chromium	59.45 – 1524.26	0.05	Nasal cavity and paranasal cavity & Lung	
	Lead	5.28 – 92.58	0.01	Stomach	
Cuddalore	Cadmium	1.46±0.054	0.003	Lung, Prostate & Kidney	Stomach – 4.8% Prostate – 3.5% Kidney - 3.4% Nasal cavity– 3% Lung – 2.9%
	Chromium	0.70±0.026	0.05	Nasal cavity and paranasal cavity & Lung	
	Lead	0.46±0.018	0.01	Stomach	

Source: [a]Cumulated score of carcinogens calculated from different studies described in Table 1; Units – mg/l. [b]Mean score was compared with WHO 2013 standard limits for drinking water; Units – mg/l.

Table-3: Quality assessment: Newcastle Ottawa scale.

Referees	Selection				Outcome		
	Representativeness of the samples	Sample size	Non-respondents	Ascertainment of the exposure	Comparability	Assessment of the outcome	Statistical test
8	*	*	NA	*	*	**	*
9	*	*	NA	*	*	**	*
10	*	*	NA	*	*	**	-
11	*	*	NA	*	*	**	-
12		*	NA	*	*	**	-
13	*	*	NA	*	*	**	*
14	*	-	NA	*	*	**	-
15	*	-	NA	*	*	**	*
16	*	*	NA	*	*	**	-
17	*	-	NA	*	*	**	*
18	*	*	NA	*	*	**	*

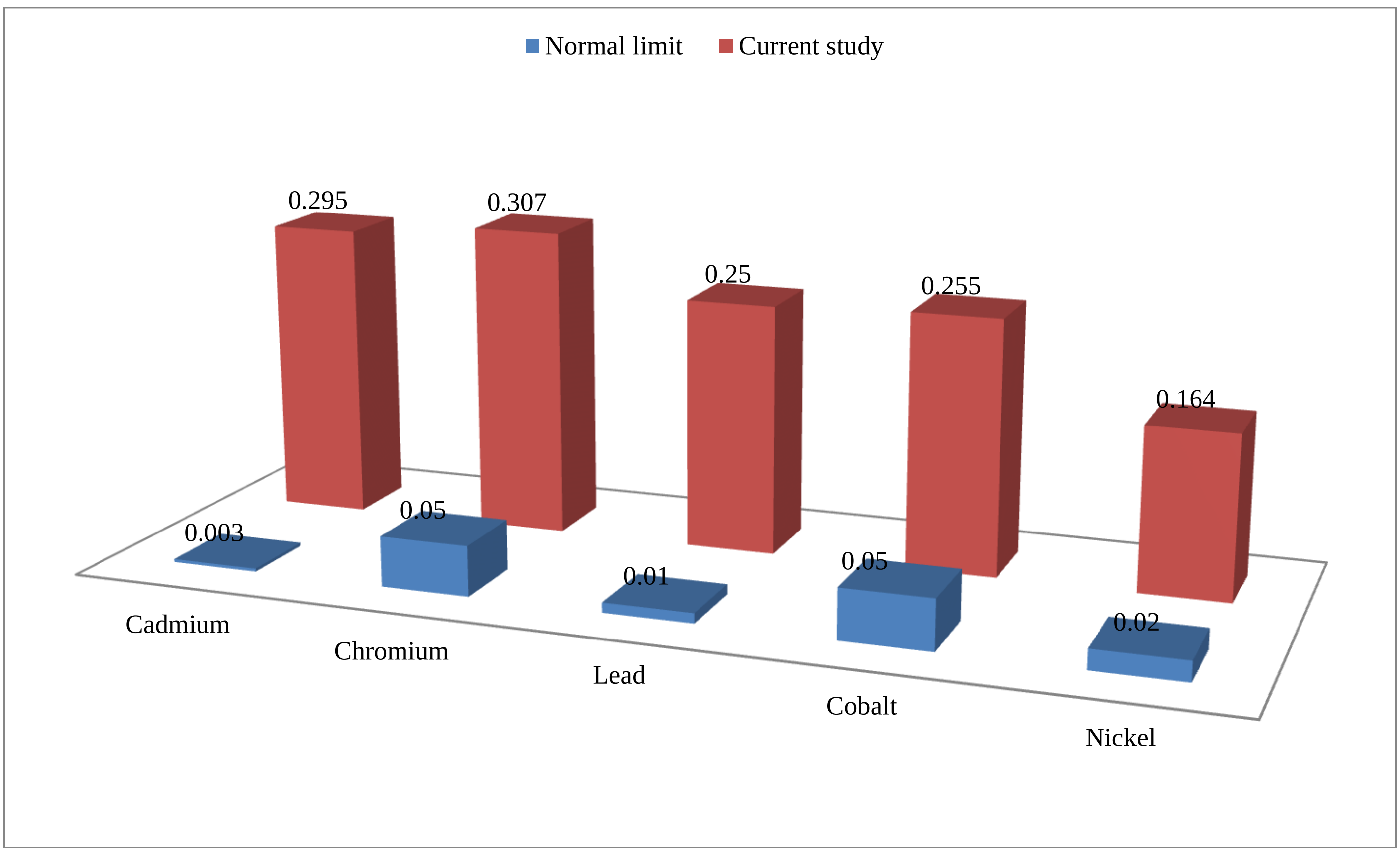


Figure-2: Bar chart showing the concentration of heavy metals in water samples from the Chennai district in comparison to the WHO's normal level.

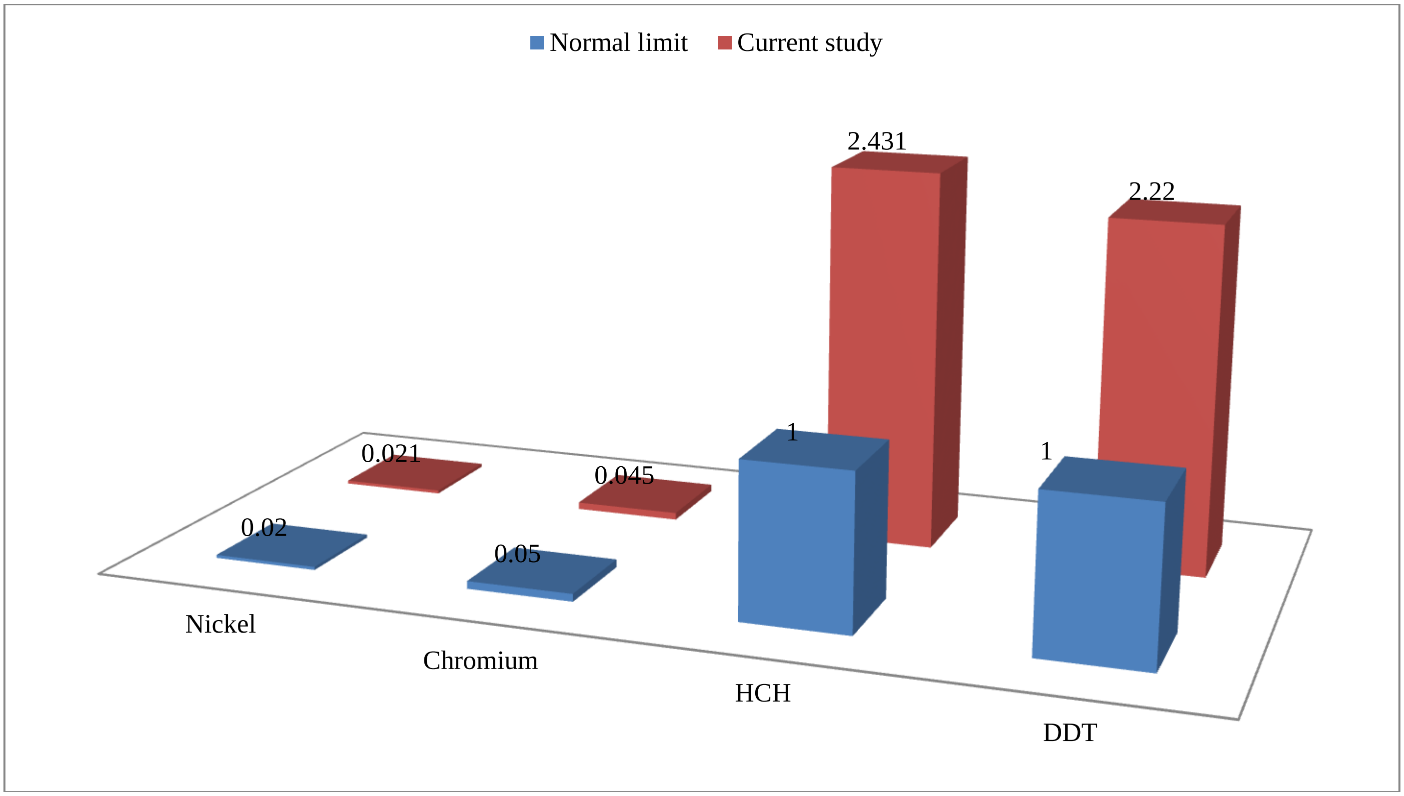


Figure-3: Bar chart showing the concentration of heavy metals in water samples from the Thiruvallur district in comparison to the WHO's normal level.

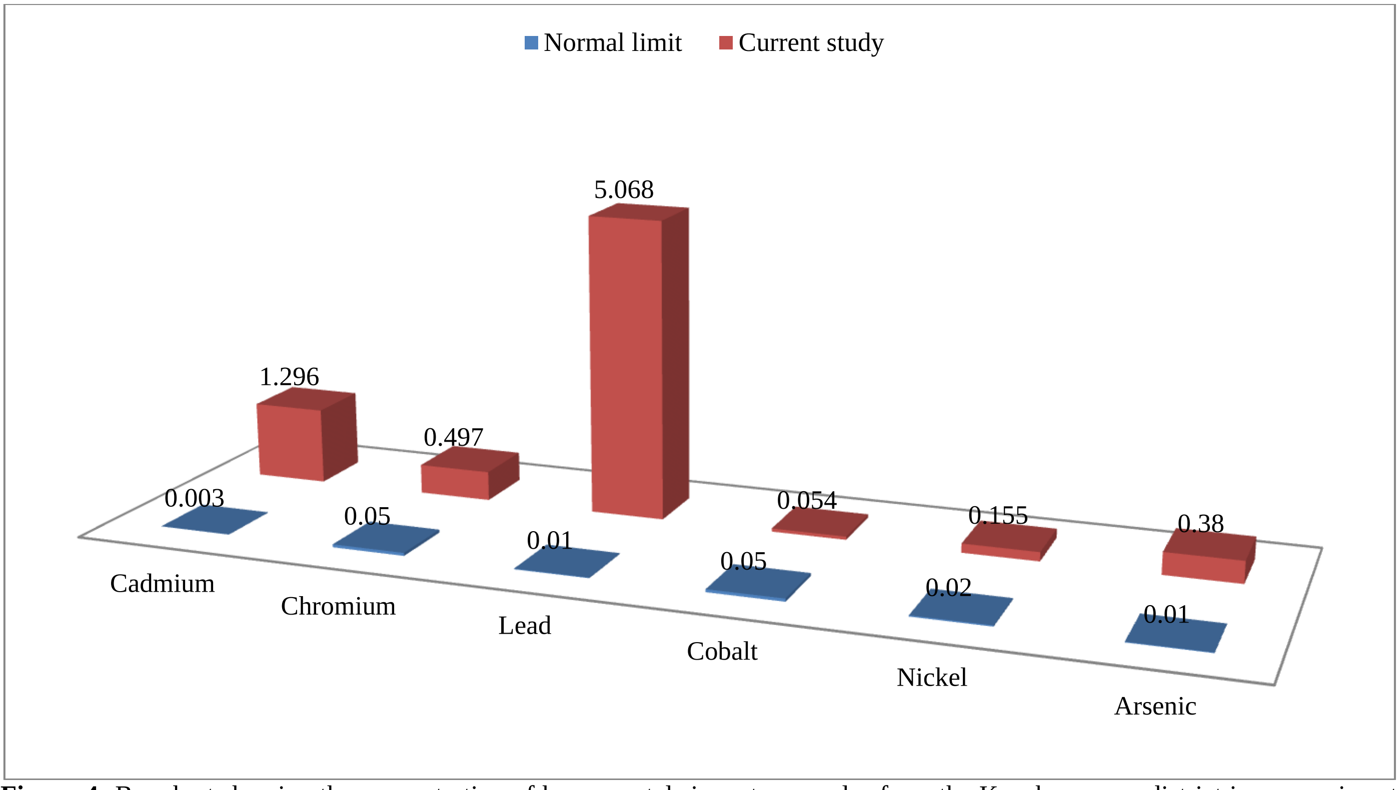


Figure-4: Bar chart showing the concentration of heavy metals in water samples from the Kancheepuram district in comparison to the WHO's normal level.

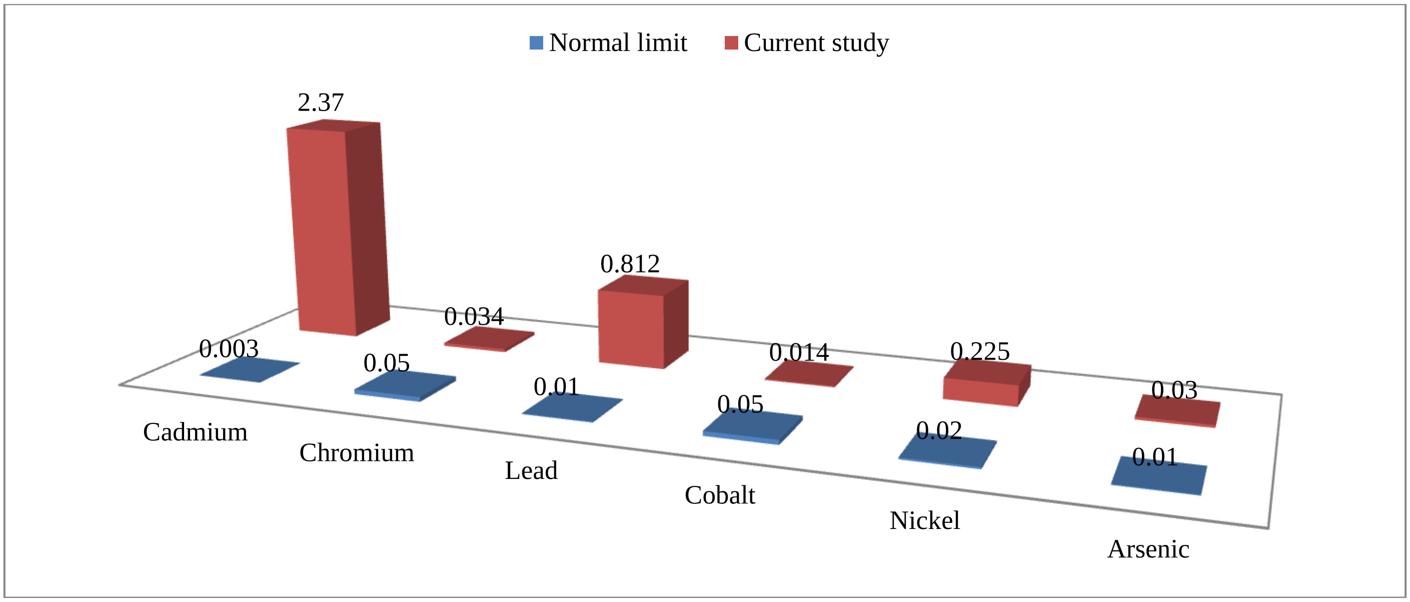
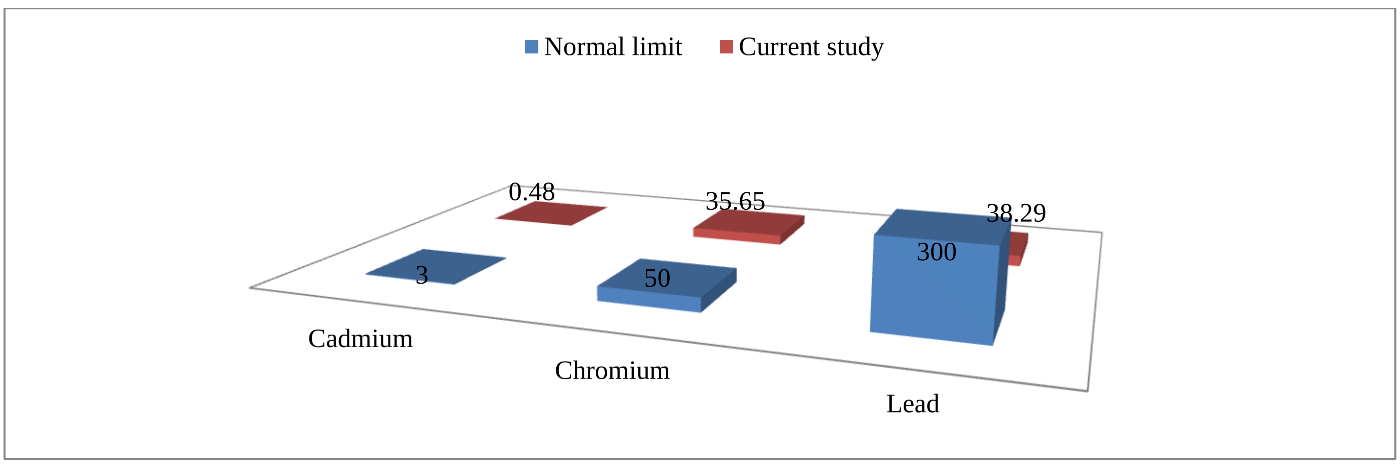
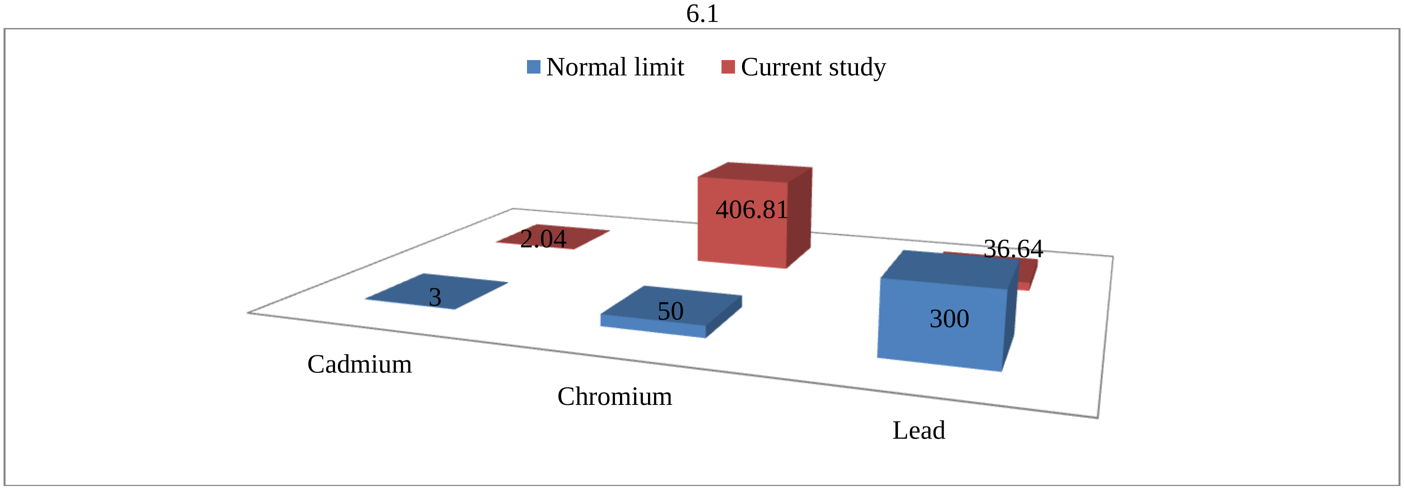


Figure-5: Bar chart showing the concentration of heavy metals in water samples from the Thiruvannamalai district in comparison to the WHO's normal level.



6.1



6.2

Figure-6: Bar chart showing the concentration of heavy metals in water samples from the Ranipet district – residential (6.1) and tannery (6.2) in comparison to the WHO's normal level.

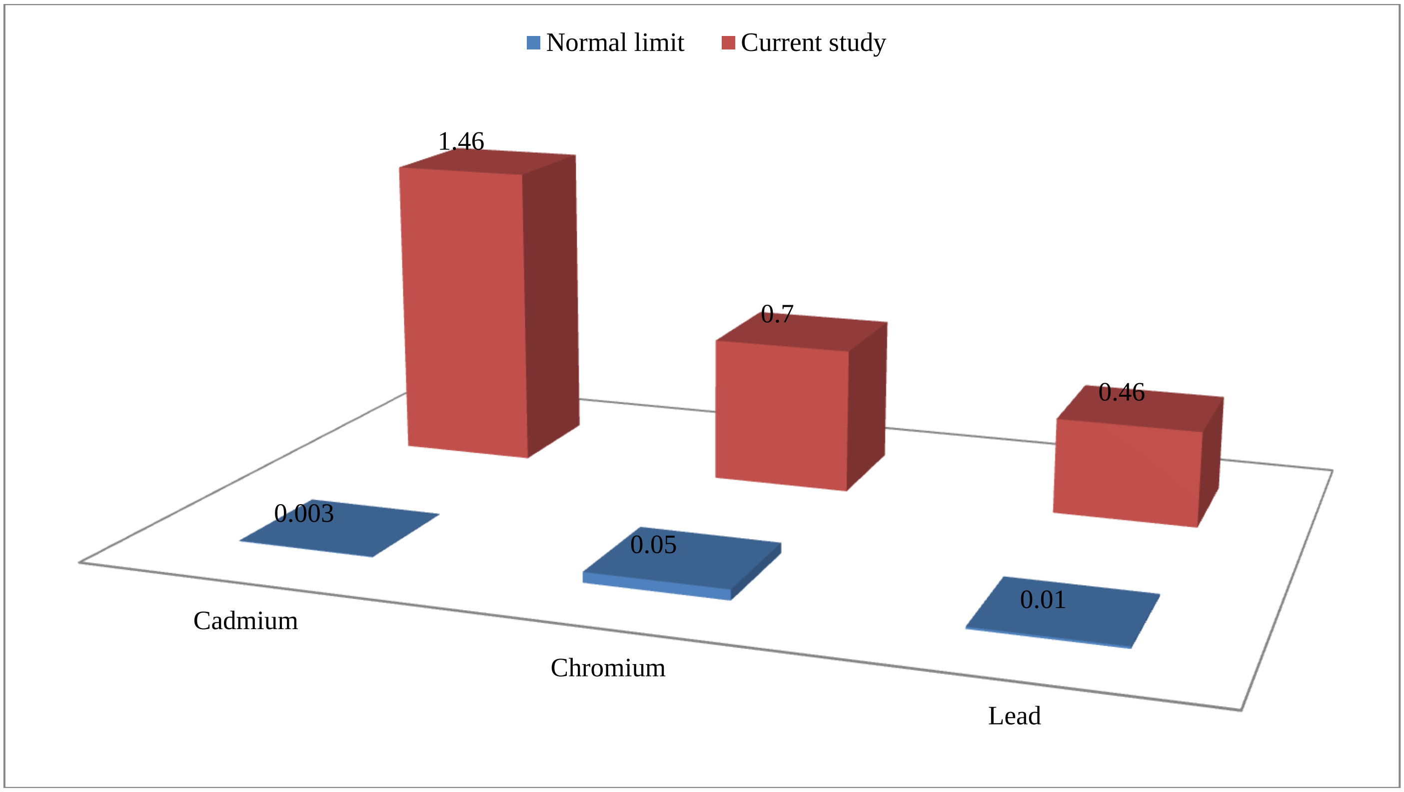


Figure-7: Bar chart showing the concentration of heavy metals in water samples from Cuddalore district in comparison to the WHO's normal level.

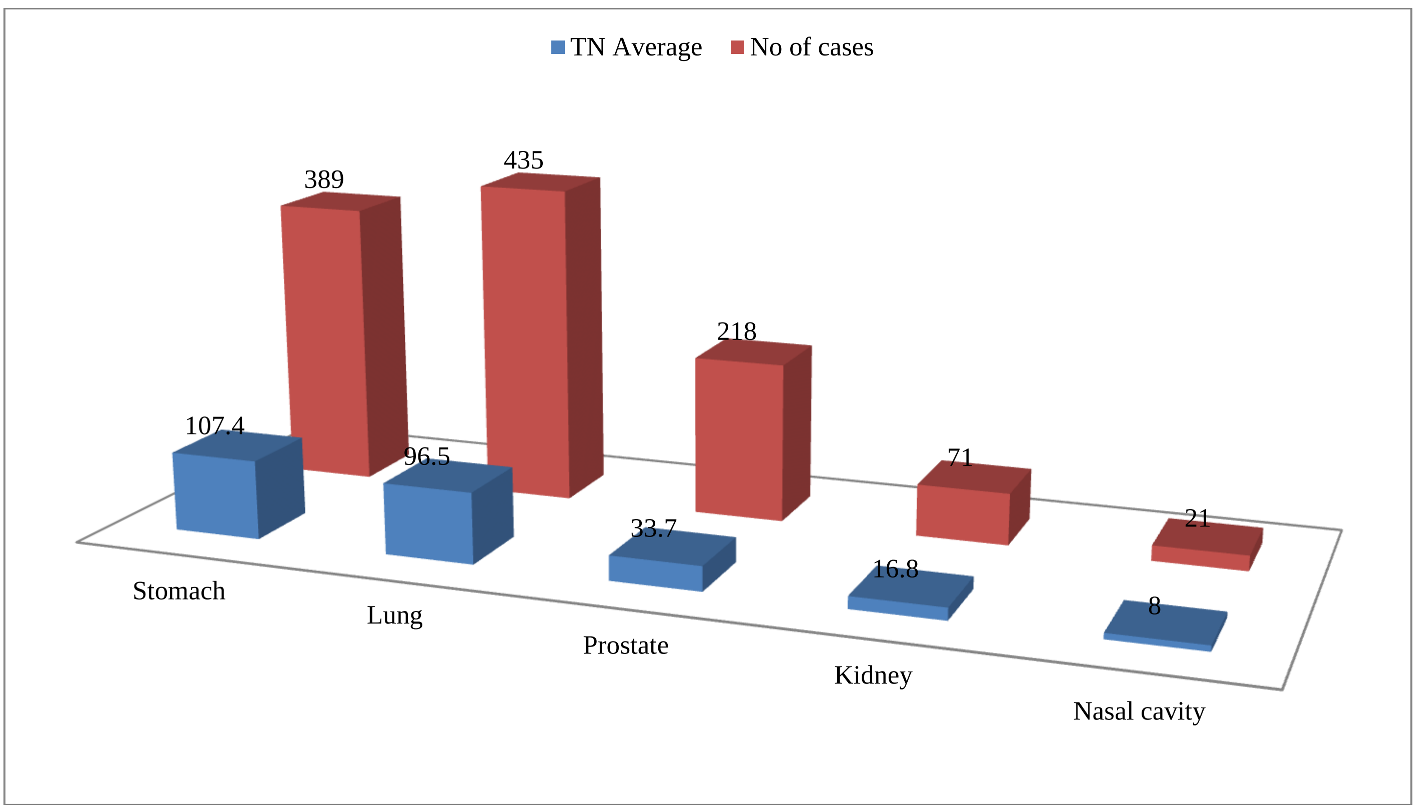


Figure-8: The number of cancer cases registered in Chennai district in comparison to the Tamil Nadu average.

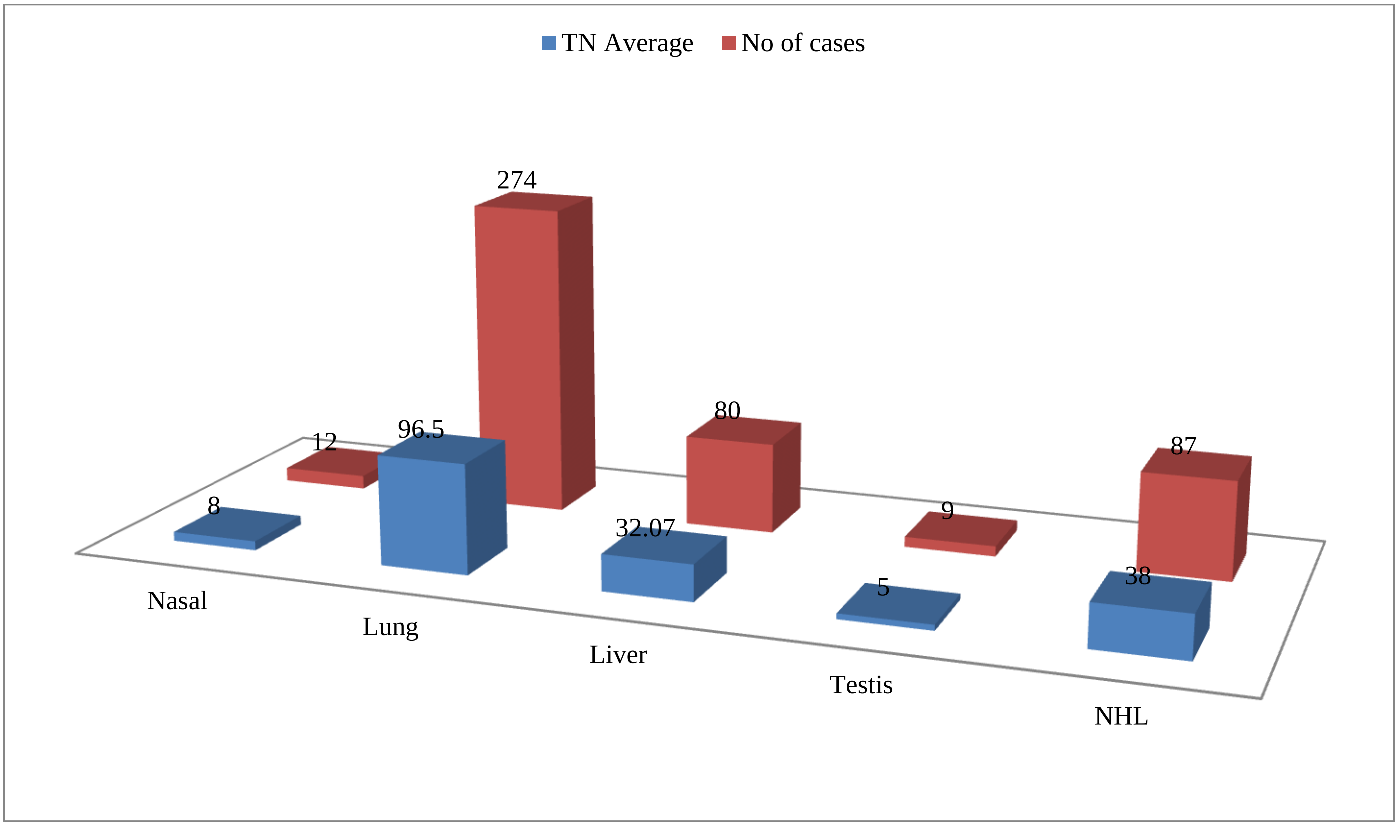


Figure-9: The number of cancer cases registered in Thiruvallur district in comparison to the Tamil Nadu average.

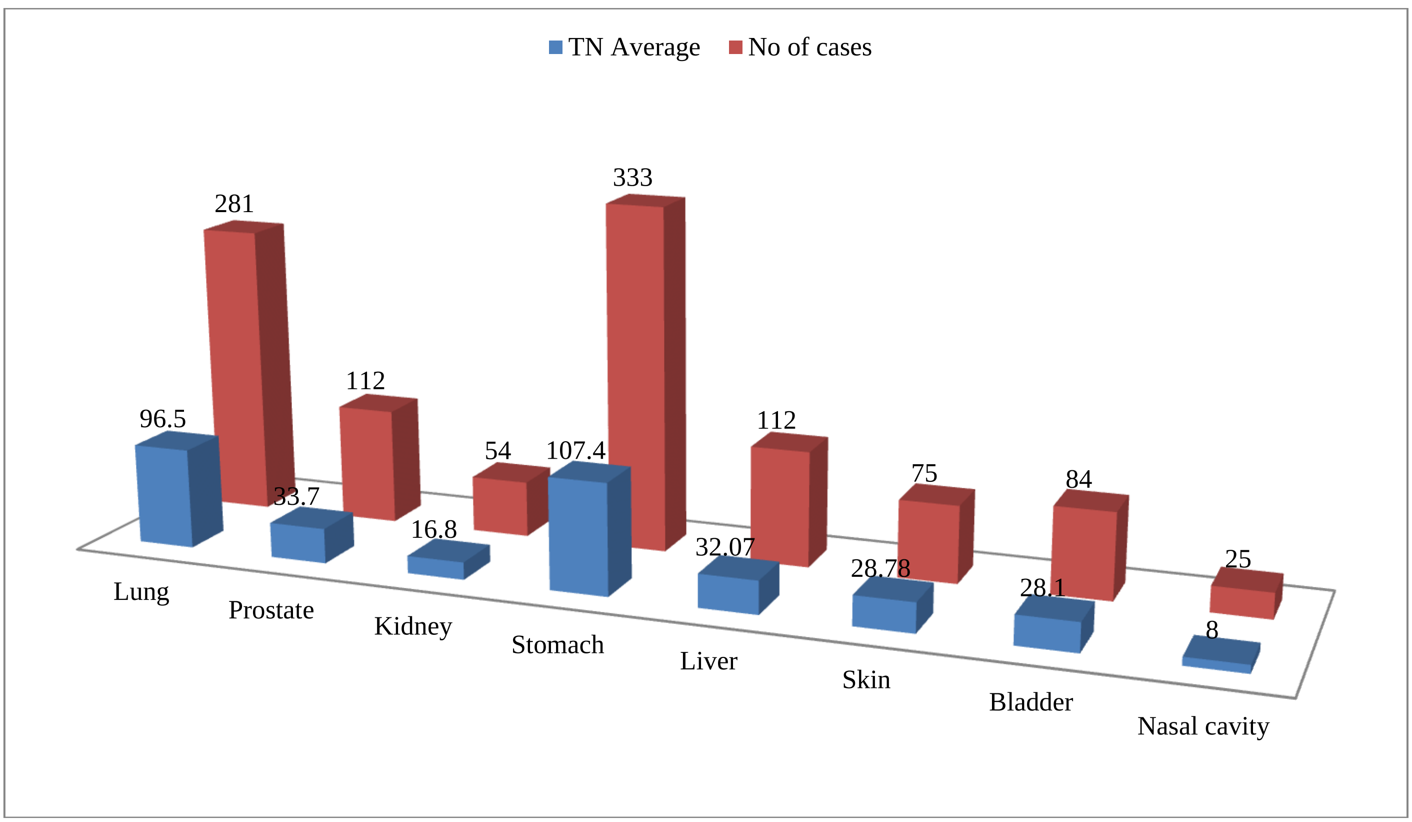


Figure-10: The number of cancer cases registered in Kancheepuram district in comparison to the Tamil Nadu average.

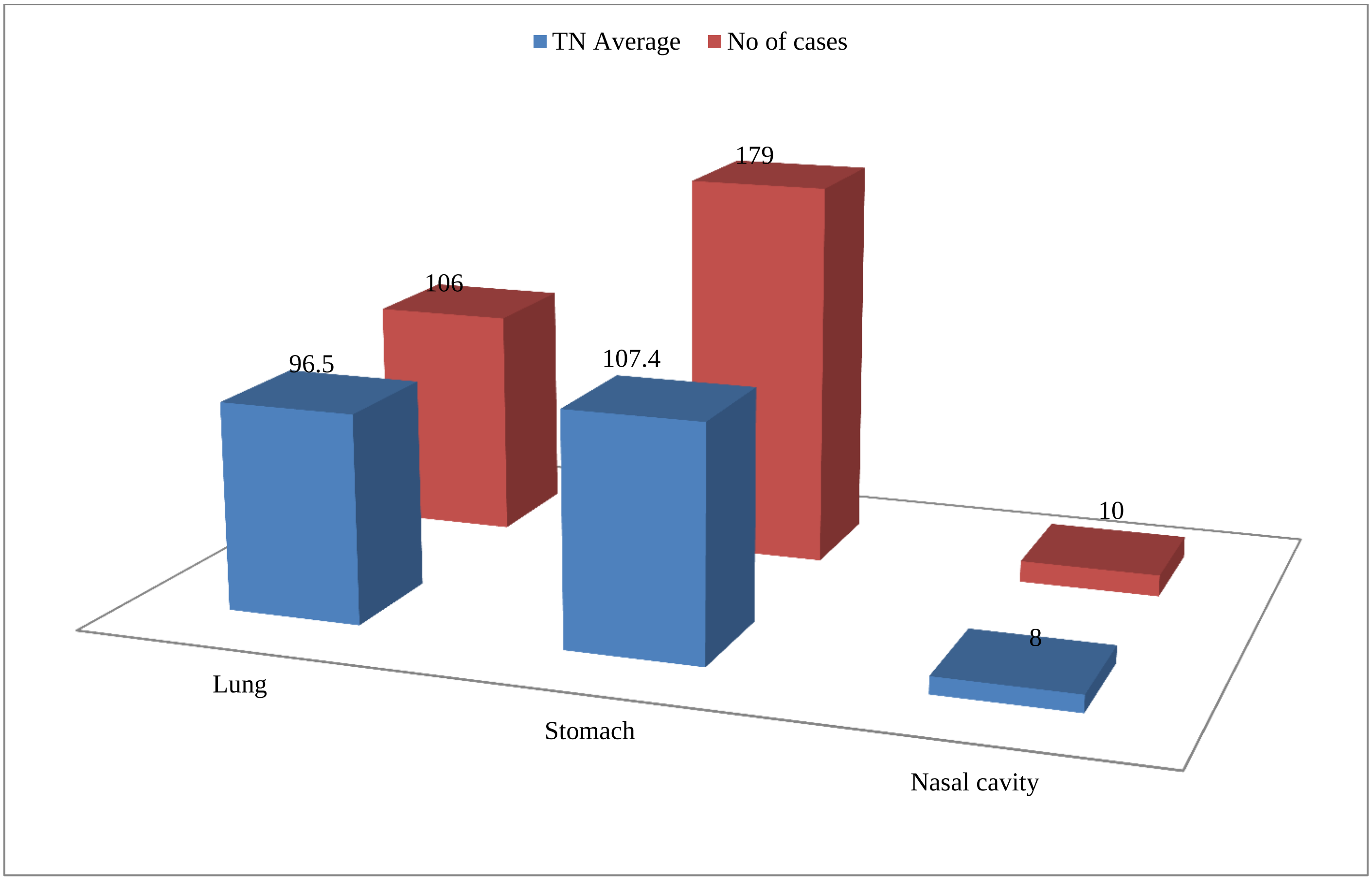


Figure-11: The number of cancer cases registered in Thiruvannamalai district in comparison to the Tamil Nadu average.

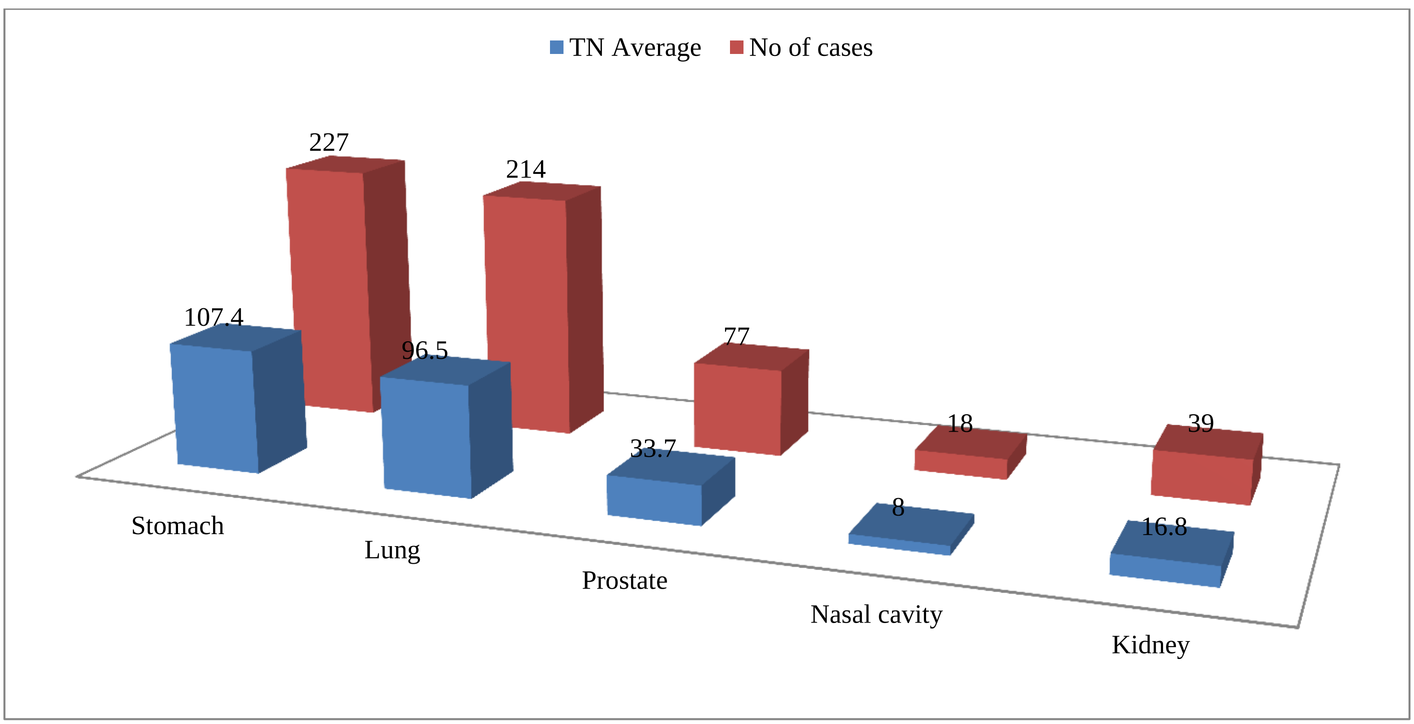


Figure-12: The number of cancer cases registered in Ranipet district in comparison to the Tamil Nadu average.

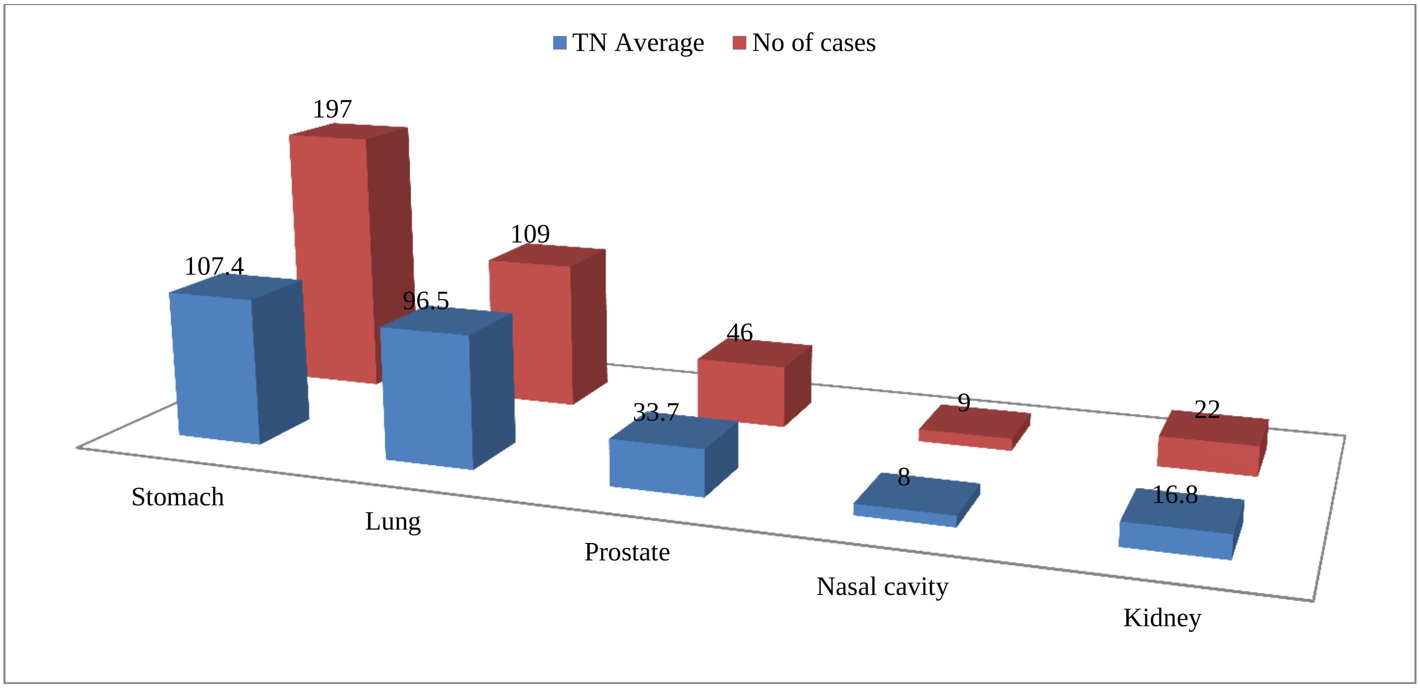


Figure-13: The number of cancer cases registered in Cuddalore district in comparison to the Tamil Nadu average.

Discussion: "It's official: Chennai's rivers are dead" perturbing news was published in The Times of India dated on Jan 18, 2023[19]. The lead of the news stated that all the water bodies that run across the city such as Adyar River, Cooum River, and Buckingham Canal are unfit for any domestic needs. Tamil Nadu Pollution Control Board collected samples in Adyar and Cooum rivers under the National River Conservation Programme and found that river bodies were contaminated with metals, phosphates, and nitrates. Paromita Chakraborty et al 2023, the study revealed the excess presence of antibiotics in the Buckingham Canal since the canal is narrower with less flow and the study was published in the newspaper[20].

In Saubhagya Ranjan Mahapatra et. al study, average concentration levels of heavy metals during pre-monsoon season were in the order of Cr > Pb > Ni and Pb > Cr > Ni during post-monsoon season[8] whereas, S. G. D. Sridhar et. al study observed the average concentration levels of heavy metals during pre-monsoon season in the order: Cr > Ni > Pb and Cr > Pb > Ni during post-monsoon season [9]. The increase in the concentration of lead is due to the influence of agricultural practices, industrial areas, and leaching from waste disposal sites. Nickel contamination is mainly due to industrial emissions, usage of phosphate fertilizers, combustion of diesel oil and fuel oil, automobile emissions, electric power utilities, and disposal of sewage sludge. Higher concentrations of chromium are from the manufacturing units of metallic and other alloys and pigment manufacturing. Silambarasan et al demonstrated the excessive presence of cadmium and lead in water samples in all the sites with the maximum in Guindy and Ekkatuthangal; similarly in Kotturpuram and Ekkatuthangal in sediment samples[10]. Chandrasekar V et. al study in Thiruvallur revealed the maximum concentration of chromium in New Manali town and Virchoor while the maximum concentration of nickel is noted in Arasur and Telugu colony[11]. Jayashree et al in study elicited the residues of DDT, HCH, and their derivatives in groundwater samples higher than the recommended values. The study suggests a few possible reasons for contamination such as indiscriminate use, untimely application, low-quality formulations, and the absence of crop rotations. Proper agricultural practices including the advent of pest-resistant, transgenic rice not requiring early application of pesticides and also the use of neem and other bio-pesticides can resolve the problem[12]. Uma T et. al in 2016 study found that nitrate levels were higher in dye industry effluent[15]. Kistan Andiyappan et. al study concluded that chromium contamination in the locality of the tannery was higher in all seven samples. Lead content was found more abundant in the superficial layer of point TA-1, the presence of lead in soil could be due to the release of lead by automobiles using leaded petrol and other industries[17]. G Ambedkar et. al study showed the presence of cadmium, chromium, and lead in water and sediment samples. The study found the presence of heavy metals in fishes available for human consumption in the Gadilam River near Vichoor, Cuddalore district[18].

Since the mouth is a mirror of the entire body, persistent heavy metal exposure frequently causes oral signs. Chronic exposure to these heavy metals either through ingestion or inhalation can be diagnosed through simple oral screening. Chronic exposure to cadmium causes bone resorption and osteoporosis; chromium may cause Oral Lichenoid Reaction (ORL), Lichen Planus (LP), erosion, discoloration of the teeth, and Gingivitis/ Periodontitis; arsenic causes Rain-drop pigmentation, hyperpigmentation, hyperkeratosis, Squamous Cell Carcinoma and Basal Cell Carcinoma; chronic exposure to nickel may present with Oral Lichenoid Reaction (ORL), Lichen Planus (LP) and hypersensitivity reactions; lead causes Chronic plumbism, metallic taste, lead hue and astringency.

Every heavy metal can be treated with an appropriate antagonist as part of the remediation process. As per the Agency for Toxic Substances and Disease Registry (ASTDR) Toxicology profiles[22], the best counteracts for lead are iron, calcium, zinc, and vitamin C foods rich in nuts, seeds, oranges, grapefruits, watermelon, greens, tomato, potato, broccoli, cabbage, lady finger, fish, meat, liver, and dairy products, as well as Indian gooseberries[21], which have an excellent antimicrobial property and boost the body's immune system against various diseases. Increased consumption of calcium and magnesium-rich foods, such as broccoli, cabbage, lady fingers, bananas, oranges, and dairy products, is recommended in cases of chromium VI poisoning. The greatest alternatives for long-term nickel poisoning are foods high in iron and magnesium, such as beans, peas, bananas, liver, dairy products, and nuts and seeds. Likewise, adding more vitamin A, B9, E, and selenium-rich foods that include papaya, watermelon, wheat germ, nuts & seeds, carrots, greens, sweet potatoes, broccoli, pumpkin, cauliflower, spinach, chickpeas, peas, brown rice, eggs, chicken, liver, fish, and dairy products to the diet is advised for chronic arsenic poisoning. Iron and zinc, which are abundant in greens, nuts, and seeds, liver, fish, meat, and dairy products, are antidotes for cadmium.

In an attempt to reduce environmental pollution precautionary measures for industrial sectors which 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 is responsible for making sure that no fertilizer or pesticide has contaminated foods, including fruits, vegetables, nuts, and species. The Toxicology Department of Agriculture needs to keep an eye on farmers' excessive use of pesticides and fertilizers. Municipal trash may be handled by setting up small sewage treatment facilities, recycling materials, and thermal treatment methods including composting, incineration, and biogas production.

The main limitation of the study is that obtaining site-specific samples and having access to cancer case records for only the entire district prevent the generalization of the study due to a research gap.

Conclusion

According to this systematic review, excessive presence of carcinogens is associated with a higher carcinogenic potential in the general population. The evidence and proofs which corroborate each other lead us to realize that human negligence has led to this point, resulting in people who haven't developed any causative habits falling for this trap and losing their lives. This needs to be addressed by the Government of Tamil Nadu and the concerned authorities.

References

1. Sydney Evans, Chris Campbell and Olga, V. Naidenko. (2019). Cumulative risk analysis of carcinogenic contaminants in United States drinking water. *Heliyon*., 5(9), E02314.

2. Report (2020). The Sustainable Development Goals Report. https://unstats.un.org/sdgs/report/2020/The-Sustainable-Development-Goals-Report-2020.pdf Last assessed 20/08/2023.

3. Richard Fuller, Philip J. Landrigan, Kalpana Balakrishnan, Glynda Bathan, Stephen Bose –O" Reilly and Michael Brauer (2022). Pollution and Health: A progress update. *The Lancet*, 6(6), E535-E547.

4. Sampath P. and Swaminathan R. on behalf of the TNCRP Study Group (2021). Cancer incidence and mortality (Year 2017), incidence trend (2012-2017) and estimates (2018-2021) for Tamil Nadu state. Tamil Nadu Cancer Registry Project, Cancer Institute (W.I.A.), Chennai, Tamil Nadu, India.

5. World Health Organisation. (2022). IARC list of carcinogens. IARC Monographs. Volumes 1-132. https://monographs.iarc.who.int/list-of-classifications/ Last assessed 23/09/2023.

6. World Health Organisation (2022). List of classifications by cancer sites with sufficient or limited evidence in humans. IARC Monographs Volumes 1-132

7. Sujitha, S., Prabu, D., Dinesh Dhamodhar., Rajmohan, M. and Sindhu, R. (2023). An analysis of cancer causing agents and its association with the prevalence of cancer cases in Noyyal river basin, Tamil Nadu, India - an explorative study based on scientific evidences. *Int J Health Sci Res*., 13(9), 215-224.

8. Saubhagya Ranjan Mahapatra and Nimmy, P.M. (2021). Groundwater contamination with heavy metals in Chennai city, India – A threat to the human population. *IOP Conf. Series: Earth and Environmental Science*., 889,012037

9. Sridhar, S. G. D., Sakthivel, A. M., Sangunathan, U., Balasubramanian, M., Jenefer, S., Mohamed Rafik, M. G. and Kanagaraj. (2017). Heavy metal concentrationin groundwater from Besant Nagar to Sathankuppam, South Chennai, Tamil Nadu, India. *Appl Water Sci*., 7, 4651–4662

10. Silambarasan, K., Senthilkumaar, P. and Velmurugan, K. (2012). Studies on the distribution of heavy metal concentrations in River Adyar, Chennai, Tamil Nadu.

European Journal of Experimental Biology, 2(6), 2192-2198.

11. Chandrasekar. V., Shaik Mahamad, Latha, G. and Imrana Banu. (2018). Heavy metal concentrations in groundwater: An analytical study of coastal taluks in Tiruvallur district – Tamil Nadu. *International Journal for research in applied science and engineering technology*., 6(III),1863-1866.
12. Jayashree, R. and Vasudevan, N. (2007). Organochlorine pesticide residues in groundwater of Thiruvallur district, India. *Environ Monit Assess*., 128, 209-215.
13. Meenakshi, P. and Sriram, G. (2020). Heavy metals assessment of temple ponds in Kanchipuram, Tamil Nadu, India. *IOP Conf. Series: Materials Science and Engineering*., 954, 012043.
14. Prabhu Dass Batvari, B. and Surendran, A. (2015). Assessment of heavy metal contamination in Chembarambakkam lake water, Chennai, Tamil Nadu, India. *Journal of Chemical and Pharmaceutical Research*., 7(3), 865-869.
15. Uma, T., Saravanan, N. and Jothi Narendiran, N. (2016). Comparative analysis of physio-chemical characters and heavy metals in dye industry effluent and sugarcane industry effluent along with lake water. *International Journal of Fauna and Biological Studies*., 3(3), 81-83.
16. Mohana, P., Velmurugan, P.M. and Jayaprakash, M. (2020). Assessment of heavy metal pollution index of groundwater in Arani taluk of Tamil Nadu, South India. *Ecological environment and Conservation*., 26(Suppl. Issue), S213-S218.
17. Kistan Andiyappan, Vijaya Anandan Veerasamy Alagarsamy and Thaminum Ansari Abubacker (2017). Contemporary status of heavy metal contamination in soils affected by tannery activites, Ranipet, South India. *Orient J Chem*., 33(6), 3092-3100.
18. Ambedkar, G. and Muniyan, M. (2012). Analysis of heavy metals in water, sediments and selected freshwater fish collected from Gadilam river, Tamilnadu, India. *International Journal of Toxicology and Applied Pharmacology*., 2(2), 25-30.
19. Times of India (2023). It's official: Chennai's rivers are 'dead'. Read more at: http://timesofindia.indiatimes.com/articleshow/97076908.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst
20. Padmaja J. (2023). Buckingham Canal full of antibiotics: Study. The Times of India. Read more at:http://timesofindia.indiatimes.com/articleshow/102867270.cms?from=mdr&utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst 2023, August 23
21. Surya Rajeev Nair, Shreelakshmi, Bharathwaj, Sindhu, R., Rajmohan, Prabu, D., and Dinesh (2021). Systematic review on the use of Indian Gooseberry in improvement of oral hygiene. *Drug and Cell Therapies in Hematology*, 10(1), 2611–2620.
22. Toxicology profiles (2023). Agency for Toxic Substances and Disease Registry. U.S. Department of Health & Human Services. Last Reviewed: May 3, 2023