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IMPACT OF INDUSTRIAL POLLUTION ON LAND, WATER AND AGRICULTURAL PRODUCTION IN SIPCOT INDUSTRIAL REGION IN TAMILNADU

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Abstract

This paper deals with impact of industrial pollution on land, water and agricultural production in Cuddalore SIPCOT industrial region in Tamil Nadu. It outlines the impact of water pollution and land pollution on crop yield. This study makes an experimental analysis of crop yield in SIPCOT industrial region and non industrial region. In this study, impact of industrial activities on land and water quality has been examined on the basis of appropriate scientific method. The crop yield decline is explained with the help of soil and water test. This paper concludes with some interesting findings along with policy suggestions.

Introduction

Industrial pollution is the contamination of the environment by businesses, particularly plants and factories that dump waste products into the air and water. Industrial waste is one of the largest contributors to the global pollution problem endangering people and the environment. Many dangerous pollutants, by-products of manufacturing, enter the air and water, risking health and lives. Common pollutants include carbon monoxide, formaldehyde, mercury and lead. Waste released into the water systems, including medical waste, kills river and ocean life. Cities are particularly at risk for the direct effects of industrial pollution, but the ultimate results filter down throughout the environment. Industrial pollution can negatively affect public health by distributing harmful chemicals into water, the air and the soil. The quality of the environment is also at risk, as industrial pollution can impact climate change, hinder the growth of natural plants and grasses, cause the loss of species and aid in the erosion of buildings. The health of humans and animals is a primary concern with industrial pollution. Air pollution that impacts the ground-level ozone can weaken respiratory systems, reduce lung function and increase respiratory inflammation in humans and animals alike. When exposed to air pollution, people may experience nausea, pulmonary congestion and chest pains.

Industrial pollution affects the growth of plants, crops and animals, thus reducing natural resources. When air quality is low due to industrial pollution, the ozone damages the forest ecosystems and crops. Bodies of water that are polluted by industrial chemicals can infect drinking water and also the natural habitats of aquatic species. Industrial pollution events such as fires, radioactive material leaks and oil spills directly affect the level of pollution within water, the soil and the air. Natural habitats, such as forests and oceans, remain polluted, which has a negative impact on the species that live within the habitats.

This study aims at analysis environmental impact of SIPCOT Industrial Complex (State Industries Promotion Corporation, Tamilnadu) of the Cuddalore region. The cause, nature and extent of environmental degradation in India have been whichever upon before the statement of the objectives, aims and scope of the present study. Environmental degradation expressed as the pollution of the natural resources and eroding the capacity of the eco-system support healthy living in the wake of the proliferation of industries in residential neighborhood is a significant indicator of the suffering that industrialization imposes on generations of people to come. Industrialization associated with technological progress is itself a major cause of environmental pollution even as technological progress and innovation could also be part of the solution. Usually land pollution occurs in various forms such as loss of soil fertility, ground water pollution, accumulation of chemical pollutants, changes in the structure of soil and so on. Land pollution results in ground water pollution and crop yield decline in the industrial region. In order to study the effect of industrial pollution on agricultural development, a comparative study can be preferred. In general Agro eco system in industrial region is highly polluted with the accumulation of pollutants in water and land contrastingly agro eco system in non-industrial region is free from pollutants. Hence undertaking a comparative study on crop yield in village situated in industrial region and villages situated in non industrial region is desired to analyze the status of land degradation and water pollution in SIPCOT industrial region by taking non industrial region as control group.

Review on the Subject

The study of review of literature is an important aspect of any research. It aims at analyzing the past trends in research output of any subject. This study deals with industrial pollution. Hence there is a need to identify the area coverage, subject coverage, content coverage and objective coverage in research on industrial pollution with the help of review of literature. Hence, there is a need to review a few works for the purpose of present study.

Vasisht A-K; Singh,-R-P; and Mathur,-V-C (2003) estimate the land degradation in the country. Widely accepted estimates indicate that nearly 57% of the geographical area or 187.8 million hectares of land are degraded to different intensities.

Sharma,-S-K; and Chandel,-C-P-S (2004) evaluate the groundwater samples from Jaipur, Rajasthan, India for their structural and functional attributes, both quantitatively and qualitatively, in order to determine their suitability for irrigation and drinking purposes.

Randall,-C-W (2004) study highlights that nutrient pollution of estuaries and coastal waters has resulted in the impairment of ecosystems and major reductions and collapse of fisheries at numerous sites around the world, resulting in major socio-economic implications.

Alka-Tangri (2005) study on river Pandu highlights that about 200000 gallon wastes per day the effluents of various industries, like thermal power station, fertilizer plant, Panki industrial estate, dyes, Chemical and others industries, Small Arms factory, and Ordinance factory.

Kolotov,-B-A; Demidov,-V-V; Volkov,-S-N (2003) have observed that chlorophyll content can be a primary indicator of environment degradation due to heavy metal contamination. Most pollutants decrease chlorophyll content, was evident when environmental pollution was monitored in the areas of heavy metal contamination.

Venkatachalam,-L (2004) study has identified certain specific sources of government failure that are potentially affecting the groundwater quality in the state of Tamil Nadu, India.

Kaplay,-R-D and Patode,-H-S (2004) analysis of the 67 samples collected from 25 borewells and 42 dug wells in the basaltic aquifer at Tuppa, New Nanded, Maharashtra, India over a period of three years reveal that groundwater from this region shows higher content of pollutants like TDS, Cl, TH, Ca, Mg and SO4 The geochemical characteristic of groundwater is related to pollution.

The study by Antil,-R-S and others (2004) highlight that land degradation in Haryana has been due to soil erosion, soil salinity and sodicity, water logging, sewer water and industrial effluents, and agrochemicals.

Umamaheswari,-S (2004) has made an attempt to assess the water quality of river Thamirabarani at Ambasamudram, Tamil Nadu, India, by selecting two sites, one beneath the railway bridge (Up stream site) and the other beneath the highway bridge (Down stream site). Physico-chemical and microbial analysis of water was made from June 2001 to February 2002 at an intermittent period of four months. pH, alkalinity, BOD, and COD, were found to be greater in the order of 8-3-8.5, 140, 250-320 and 2411.0 mg/l respectively in the downstream site of the river water, whereas the dissolved oxygen analyzed varied from 2.05-2.50 mg/l in the downstream site of the river.

Kannan,-V; Ramesh,-R; Sasikumar,-C (2005) have investigated the physio-chemical characteristics of groundwater samples mixed with effluents discharged from the textile industries at Chellandipalayam (Site-I), Senaparatti (Site-II) and Pasupathipalayam (Sites-III and IV) in Karur District, Tamil Nadu, India. Results reveal the very high levels of Ca, Mg, Na, Cr, K, Ni, Cu, Zn, CO3, SO4, NO3 and Cl. The concentrations of these ions exceed the limit prescribed by ISI.

Paudel, K. P, H. Zapata and D. Susano (2005) have investigated the Environmental Kuznets Curve (EKC) on water pollution with both semi parametric and parametric models using watershed level data for the state of Louisiana, USA.

Abdalla, C. W., B. A. Roach and D. J. Epp. (1992) have reported that pollution from nonpoint sources is the single largest remaining source of water quality impairments in the United States.

Thus many studies have been conducted on industrial pollution in different parts of the world and also in India. However there is no specific study on industrial pollution consequent upon establishment of SIPCOT industrial complex in Tamil Nadu. It is a research gap. In order to fulfill this gap, the present Project is being undertaken.

Methods and Materials

A comparative analysis of SIPCOT industrial region and non-industrial region with respect to economics of crop cultivation based on land and water quality test has been made. This type of analysis is preferred to analyze the impact of industrial pollution in SIPCOT industrial region on crop yield and economics of cultivation. The extent to which the crop yield has been affected in the industrial region could be learnt from the situation in non industrial region which has pollution free environment along with supplementary data from the results of soil and water tests. In this study six villages are selected. Out of them three villages are selected in and around the SIPCOT industrial region and another three villages are selected 10 km away from the SIPCOT industrial region. From each village 20 farm households are selected sample under sampling method.

Totally 12 groundwater and soil samples have been collected from 6 different villages in and around the SIPCOT industrial area. In SIPCOT industrial region, 6 ground water and soil samples have been collected from the three villages, viz., Kudikadu, Nainarkuppam and Kayalpattu. From each village, samples have been collected from two locations. In the non-industrial region, 6 ground water and soil samples have been collected from three villages, viz., Panchaiyankuppam, Thaikkal and Sangolikuppam. From each village, samples are collected from two locations. The water samples were collected in clean two-litre polythene bottles. Analysis is carried out for pH, turbidity colour, odour, electrical conductivity, total dissolved solids, total hardness, calcium, magnesium, sodium, potassium, iron, nitrate, chloride, fluoride and solids, total hardness, calcium, magnesium, sodium, potassium, iron, nitrate, chloride, fluoride and sulphate as per APHA (1995) and Trivedy & Goel (1986). The soil samples are collected in polyethylene bags. Analysis is carried out for PH value electric conductivity, soil organic carbon, density of microorganisms and soil porosity.

Results and discussion

This section deals with primary data analysis. The impact of industrial pollution on crop yield has been analyzed on the basis of control group and experimental group method. The experimental group is the SIPCOT industrial region particularly villages situated around the 2km radius of the industrial agglomeration and control group covers the villages, situated above 10km away from the industrial region. Further the impact of industrial pollution can be assessed on the basis of land quality and water quality both in the control group region and in the experimental group region.

A study of data in table 1 indicates the economics of crop cultivation in the industrial region and non-industrial region. The data relating to industrial area are collected from three villages Kudikadu, Nainarkuppam and Kayalpattu. The data relating to non industrial area are collected from three villages viz., panchaiyankuppam, Thaikkal and Sangolikuppam and these villages are located about 10 km away from the industrial location. The selected villages around the industrial area are located withier the radius of 2 – 3 kms from the industrial area. This type of analysis is made to assess the impact of land pollution in consequent upon establishment of SIPCOT industrial region.

Table 1

Economics of Crop Cultivation in Industrial Region and Non Industrial Region

Crop	Industrial region				Non-Industrial region			
	Yield	Total cost	Crop revenue	B/c	Yield	Total cost	Crop revenue	B/c
Paddy	2505	8415	16815	1.99	3146	7645	20291	2.65
Cholam	882	3105	4267	1.37	1525	2768	6862	2.47
Cumbu	856	3015	5615	1.86	1938	2417	9690	4.00
Ragi	784	3490	10882	3.11	3000	3419	12690	3.71
Maize	675	3712	5115	1.37	1125	3475	6850	1.97
Blackgram	345	3026	7125	2.35	652	2518	9815	3.89
Green gram	426	3217	6105	1.89	596	2452	7896	3.22
Red gram	422	2145	5215	2.43	625	1965	9750	4.96
Groundnut	925	5418	8166	1.50	1985	4505	9965	2.21
Gingelli	512	6025	8415	1.39	819	5965	13466	2.25
Sunflower	331	5252	10655	2.02	665	4816	16177	3.35
Turmeric	2000	2815	14650	5.20	3715	2618	16860	6.44
Onion	2715	3445	10568	3.06	4506	1996	13518	6.77
Vegetables	512	3965	5632	1.42	676	3576	7436	2.07
Cotton	241	4050	5425	1.33	482	4553	6968	1.53
Sugar cane	65	14902	55250	3.70	96	12905	81600	6.32
Banana	33013	6128	11415	1.86	42149	5676	14174	2.49

Source Computed:

'T' Statistics Summary Result

	Yield	Total cost	Crop revenue
T value	2.317	3.78	3.02
Df	16	16	16
T-test	2.12	2.12	2.12

It is observed that the yield per hectare of paddy in industrial region is worked out to 2505 kg/hectare and non-industrial region records 20.37 per cent of higher yield. Though yield is more in the case of non-industrial region, the cost of cultivation is low. In the industrial region land degradation is quite common. As a result farmers spend more for the cost of cultivation and at the same time low yield of crop due to decline in the fertility of soil consequent upon industrial pollution. In the case of Cholam, there is a 42.16 per cent of increase in the yield of Cholam in non-industrial region compared to industrial region.

The yield of Cumbu in industrial region works out to 856 kg/hectare and it is 1938 kg/hectare in the case of non-industrial region, showing 55.83 per cent of higher yield. The higher yield of Cumbu in non industrial region is attributed to fertility of soil. The yield of Ragi shows 73.86 per cent of increasing trend in the case of non industrial region along with low cost of production and maize yield records a 40 per cent higher in the non industrial region.

The yield of black gram in industrial region works out to 345 kg/hectare and it is 682 kg/hectare in the case of non-industrial region, showing 47.08 per cent of higher yield. The higher yield of black gram in non-industrial region is attributed to the fertility of soil. It is observed that 28.52 per cent of higher yield of green gram is observed in the non-industrial region and it is 32.48 per cent increase in the case of red gram. The yield of groundnut in industrial region is worked out to 925 kg/hectare and it is 1985 kg/hectare in the case of non industrial region, showing 53.40 per cent of higher yield.

It is seen that there is 37.48 per cent increase in the yield of gingelly in non industrial region and it is 50.22 per cent in the case of yield of sunflower compared to the industrial region. The yield of turmeric in industrial region works out to 2000 kg/hectare and it is 3715 kg/hectare in the case of non industrial region, showing 46.16 per cent of higher yield. It is observed that 39.74 per cent of higher yield of onion is observed in the non industrial region and it is 24.26 per cent of increase in the case of vegetables. The yield of cotton in industrial region works out to 241 kg/hectare and it is 482 kg/hectare in the case of non industrial region, showing 55.60 per cent of higher yield. It is observed that 32.29 per cent of higher yield of sugarcane is observed in the non industrial region and it is 21.67 per cent increase in the case of banana. It is observed that the cost of cultivation is quite high in the case of industrial region due to decline in soil fertility and it results in low productivity of all crops. Ultimately, low income and low benefit are found in the cost ratio. The non industrial region is free from land pollution as it is located 10 kilometers away from the industrial site. It is the reason for higher yield of crops with less cost and ultimately farmers get more benefits with less cost.

The t-test is applied for further discussion. The computed t-value is 2.31, which is greater than its tabulated value at 5 per cent level of significance. Hence, there is significant difference between yield of crops in industrial region and non-industrial region. A similar result has been observed with respect to cost of cultivation and crop revenue between industrial region and non-industrial region.

The reason for low yield of crops in industrial region is attributed to the following facts. The effluents produced from the existing units in SIPCOT are acidic or neutral. The TDS content is high, in addition to the levels of Total Suspended Solids, Chemical Oxygen Demand, Biological Oxygen Demand, Chlorides and Sulphates. Fluoride content is in the effluents discharged from the chemical manufacturing units.

It is observed that in the absence of any facilities to deal with poisonous wastewater or toxic wastes, companies have resorted to indiscriminate discharge of their wastes. Besides directly affecting the fertility of the land, such practices also poison the groundwater used for irrigation. Farmers in the region report that yields have plummeted even while costs of extracting water have increased because new or deeper borewells have to be dug as an alternative to the contaminated groundwater in the existing wells.

The ability of plants to absorb nutrients can be altered by changes in TDS. Discharge of effluents on land, as has been and continues to be the practice in many SIPCOT industries, alters the soil's organic matter content and hampers the ability of soil organisms to replenish the organic content. The wastewater has affected the water springs, and therefore, agriculture. Coconut, mango, tamarind and cashew yields are affected right at the flowering stage due to air pollution." Farm workers complain of sores on their limbs because of contact with contaminated water and sludge. Those working in fields close to factories also face the threat of injury due to gas leaks or other such mishaps.

Land Quality Assessment

This section is devoted to analyze the soil quality in two different types of farming locations. Soil fertility is the main factor for determining agriculture yield. This study has monitered the soil characteristics in the SIPCOT industrial region and non industrial region. The industrial region denotes the three villages, situated with the 2 kilometers radius of the SIPCOT industrial region. The non industrial region comprises three villages. Soil samples are collected from both regions. From each region soil samples are collected from six locations. In order to compare the soil fertility between the lands in SIPCOT industrial region and non industrial region, soil testing has been carried out to know the parameters: pH, EC, organic carbon, porosity, and maximum water holding capacity and available nutrients. On the basis of soil testing is the following observations have been made during the period of analysis.

Table 2

Soil pH value in SIPCOT industrial region and non industrial region

Location	Location (Name of the village	Industrial region	Location	Location (Name of the village	Non - Industrial region
S_1	Kudikadu	8.23	S_7	Panchaiyankuppam	7.12
S_2	Kudikadu	8.15	S_8	Panchaiyankuppam	7.09
S_3	Nainarkuppam	8.96	S_9	Thaikkal	7.05
S_4	Nainarkuppam	8.52	S_{10}	Thaikkal	7.01
S_5	Kayalpattu	7.68	S_{11}	Sangolikuppam	7.02
S_6	Kayalpattu	8.25	S_{12}	Sangolikuppam	7.03

Source Computed:

A study of data in table 2 indicates the pH level in soil of both SIPCOT regions. The SIPCOT industrial region has high level of soil ph value and it is above eight. The prevalence of high soil ph value in SIPCOT industrial region is due to land pollution and accumulation of alkaline substances in soil. This is due to toxic nature of effluents discharged into the cropland situated around the industrial complex. All the six locations in the industrial region have high soil ph value. On the other hand, all the six locations in the non-industrial region have more or less neutral soil ph value. This is because of non-pollution of land and such regions are located away from the industrial region.

Table 3 Soil Electrical Conductivity Between SIPCOT Industrial Region and Non Industrial Region

Location	Location (Name of the village	Industrial region	Location	Location (Name of the village	Non - Industrial region
S_1	Kudikadu	1.35	S_7	Panchaiyankuppam	2.59
S_2	Kudikadu	0.96	S_8	Panchaiyankuppam	2.52
S_3	Nainarkuppam	0.85	S_9	Thaikkal	2.65
S_4	Nainarkuppam	0.77	S_{10}	Thaikkal	2.90
S_5	Kayalpattu	0.65	S_{11}	Sangolikuppam	2.95
S_6	Kayalpattu	0.33	S_{12}	Sangolikuppam	2.97

Source Computed:

Table 3 presents data on the electric conductivity of soil in SIPCOT industrial region and non industrial region. It is observed that soil electric conductivity is relatively high in non industrial region. Contrastingly, soil electric conductivity level is quite low in SIPCOT industrial region. The declining soil electric conductivity in SIPCOT industrial region is due to land pollution along with accumulation of pollutants on the surface of soil. The non industrial region is free from pollution, so the soil of the region is rich in organic content and it leads to high level of electric conductivity.

Organic Carbon

Organic matter content of soil is the chief medium in which it enhances the availability of nutrients for crop growth and development. Building up of organic matter in a soil is a slow and tedious process, but application of more organic manure's over the years may sustain and enhance organic content in the soil. But in tropical climate, due to hygroscopic nature of constituents of organic matter, its carbon content is very meager. The soil organic carbon level is declined in consequence of industrial pollution. Hence there is a need to analyse the extent of soil organic carbon level in SIPCOT industrial region and non industrial region.

Table 4
Soil Organic Carbon Level in SIPCOT Industrial Region and Non Industrial Region

Location	Location (Name of the village	Industrial region	Location	Location (Name of the village	Non - Industrial region
S_1	Kudikadu	0.71	S_7	Panchaiyankuppam	1.12
S_2	Kudikadu	0.77	S_8	Panchaiyankuppam	1.26
S_3	Nainarkuppam	0.65	S_9	Thaikkal	1.18
S_4	Nainarkuppam	0.52	S_{10}	Thaikkal	1.25
S_5	Kayalpattu	0.64	S_{11}	Sangolikuppam	1.33
S_6	Kayalpattu	0.50	S_{12}	Sangolikuppam	1.42

Source Computed:

Data presented in table 4 indicate the soil organic carbon level. It could be noted that the non industrial region has the highest level of 1.42 per cent of soil organic carbon level and the lowest 1.12 per cent of soil organic carbon level. The present of high level of soil organic carbon level in non industrial region is due to its location in the pollution free environment. Contrastingly, the SIPCOT industrial region has low level of soil organic carbon and it is due to its location in the industrial complex region.

Table 5
Population Density of Selective Microorganisms in SIPCOT Industrial Region and Non Industrial Region

Location	Bacteria THC x 10^5		Actinomycetes CFU x 10^4		Fungi CFUU x 10^3	
	Industrial region	Non - Industrial region	Industrial region	Non - Industrial region	Industrial region	Non - Industrial region
1	45	95	10	42	45	80
2	46	90	16	45	50	85
3	40	96	18	40	55	70
4	50	85	22	38	40	76
5	52	87	24	43	35	60
6	55	84	22	35	37	65

Source Computed:

Table 5 presents data in the Population Density of Selective Microorganisms in SIPCOT industrial region and non industrial region. The farming system in the non industrial region has high level of bacteria actinomycetes and fungi population. On the other hand, farming system in SIPCOT industrial region has lesser number of microbial population. This is due to industrial pollution and pollutants destroy the soil microbial population.

Table 6
Soil Porosity in SIPCOT Industrial Region and Non Industrial Region

Location	Name of the village	SIPCOT Industrial region	Location	Name of the village	SIPCOT Non industrial region
S_1	Kudikadu	44.26	S_7	Panchaiyankuppam	50.87
S_2	Kudikadu	42.05	S_8	Panchaiyankuppam	55.05
S_3	Nainarkuppam	46.32	S_9	Thaikkal	50.46
S_4	Nainarkuppam	48.05	S_{10}	Thaikkal	56.05
S_5	Kayalpattu	49.06	S_{11}	Sangolikuppam	57.05
S_6	Kayalpattu	45.06	S_{12}	Sangolikuppam	54.07

Source Computed:

1. Porosity

Porosity is the percentage of pore space present in the soil; higher the pore space more will be the aeration, this helps in better root growth; ultimately better absorption of nutrients and water.

It is observed from the data in table 6 that soil porosity is relatively low in SIPCOT industrial region in all locations. On the other hand, the soil porosity is relatively high in the case of non-SIPCOT industrial region.

T-Test Summary Result

Variable	t-value	Df	t-critical value
Soil pH value	7.15	5	2.01
Soil Electric conductivity	9.30	5	2.01
Soil Organic Carbon	8.21	5	2.01
Population Density of Selective Microorganisms	9.87	5	2.01
	7.21	4	2.13
	8.69	5	2.01
Soil porosity	6.80	4	2.13

Source Computed:

T-test is applied for further discussion. The computed t-value is 7.15, which is greater than its tabulated value at 5 per cent level of significance. Hence, there is a significance difference in soil pH value between SIPCOT industrial region and non industrial region.

Table 7
Water Sampling Locations.

Code	Location (Name of the village)	Distance from the site (km)	Direction w. r to site
S_1	Kudikadu	0.5	N
S_2	Kudikadu	1.5	SW
S_3	Nainarkuppam	1	NW
S_4	Nainarkuppam	1.7	N
S_5	Venkatapuram	1.53	SE
S_6	Venkatapuram	1.84	E
S_7	Panchaiyankuppam	10.35	W
S_8	Panchaiyankuppam	10.5	NE
S_9	Thaikkal	12	NW
S_{10}	Thaikkal	11.5	S
S_{11}	Sangolikuppam	12.5	SW
S_{12}	Sangolikuppam	11.25	SW

Source Computed:

A similar result has been observed with respect to soil electric conductivity level, soil organic carbon level, population density, selected microbial organisms, and soil porosity. The significant difference is due to variation in soil quality and soil fertility. Land quality is quite low in industrial region. This is due to discharge of pollutants in the soil.

The SIPCOT industrial area is located among the villages of. Therefore, environmental monitoring study is needed for the surroundings of SIPCOT, realty Kudikadu, Nainarkuppam, Kayalpattu, Panchaiyankuppam, Thaikkal, and Sangolikuppam

Water Quality Assessment

This section deals with water quality assessment on the basis of standard parameters. An analysis of water quality assessment enables one to understand the deviation of water quality from the universally prescribed standard. The industrial pollution can alter the water quality consequent upon discharge of solid waste storm water and effluents.

Table 8

Physico- Chemical Analysis of ground waters of the Selected Villages

	Industrial Region						Non-Industrial Region					
Parameters	**S_1**	**S_2**	**S_3**	**S_4**	**S_5**	**S_6**	**S_7**	**S_8**	**S_9**	**S_{10}**	**S_{11}**	**S_{12}**
PH	8.02	8.05	8.86	8.56	7.59	7.69	7	7.01	7.03	7	7.01	7.02
Turbidity	5	3	7	8	6	6	5	3	4	3	5	5
Colour	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Odour	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
EC	3560	2370	2940	4020	2870	1880	1450	1475	1488	1380	1500	1499
TDS	2000	2050	2058	2814	2009	2336	1050	966	1092	1134	856	1218
TH	756	880	872	1120	840	416	556	472	480	500	496	496
Ca	104	112	176	240	176	93	65	70	72	73	74	69
Mg	60	66	103	124	96	54	28	27	29	25	27	25
Na	155	150	210	520	220	180	102	76	120	121	130	135
K	32	43	45	140	58	42	85	24	30	30	40	40
Fe	0	0.12	0.12	0.14	0.1	0	0	0.1	0	0	0.01	0.02
NO_3	62	67	72	110	63	86	30	32	39	40	37	35
CI	720	540	512	880	528	288	164	172	172	180	224	224
F	0.2	0.8	1.4	0.4	0.4	0.2	1.2	0.4	0.4	1	1	1
SO_4	252	97	70	26	185	70	52	56	64	84	134	134

Source Computed:

Classification of water on the basis of EC values (Wilcox 1995).

EC (μmhos/cm)	Class	No. of samples
<250	Excellent	Nil
250-750	Good	Nil
750-2000	Permissible	6
2000-3000	Doubtful	3
>3000	Unsuitable	2

The results of water analysis are given in table 8. The results compared with standards for drinking water as per IS: 10500-1983 specifications for drinking ground water and WHO. In the industrial region the pH value of water has been observed range from 7.59 to 8.86. All the sites in the industrial region have a high level of pH value showing alkaline nature of soil in consequence of industrial pollution. In the case of non-industrial region the pH value of water has been observed range from 7 to 7.03. Almost all the sites show that pH is slightly neutral in the non-industrial region which is within the permissible limits. If pH values are higher than the permissible limits; this will affect adversely alkalinity of soils, microbial life and corrosion rate. The turbidity ranges from 3 to 8 NTU and these values are found to be within the limits in the case of industrial region. The turbidity level is above the tolerable limits in four of the non-industrial locations.

Electrical conductivity values are found to vary from 1380 to 4020 μmhos/cm, which are quite higher than the limits of the prescribed standard (1500 μmhos/cm) as recommended by WHO[1]. The electric conductivity level is quite normal in the case of non-industrial region. The electrical

[1] WHO, 1997. Regoinal publication, South East Asia Series No: 14, WHOm New Delhi.

conductivity values are quite high in the six locations of industrial region. The higher EC and TDS values reflect greater salinity of water and it is not suitable for drinking and irrigation in ordinary conditions, but may be used occasionally under special circumstances. By using only EC values Wilcox (1995)[2] has classified the limits of EC for irrigational water. According to Wilcox, classification of more than 40% of samples for the study area are found to be doubtful and belong to unsuitable classes.

Total dissolved solids are observed in the range of 966 to 2841 mg/L and these values exceed the limits as prescribed by IS: 10500-1983. The samples which have high values of TDS are unsuitable for drinking and irrigation. These samples may affect the soil porosity. In general, the total dissolved solids are quite high in the water samples of industrial region and it is low in the case of water samples of non-industrial region. Total hardness of the samples ranges from 416 to 1120 mg/L. On the basis of total hardness, water samples analysed can be classified either as soft (0 to 70 mg/L), moderately hard (75 to 150 mg/L), hard (150 to 300 mg/L) and very hard (above 300 mg/L) (Gawas et al. 2006). Hence, it is observed that the samples are very hard. Calcium ranges from 65 to 240,g/L and these values are above the desirable limit of 75 mg/L. Magnesium values range from 25 to 124 mg/L in all the samples. Magnesium vales are higher than the prescribed standard value of 30 mg/L in all locations in SIPCOT industrial region. In the case of non-SIPCOT industrial region the Magnesium level in water is within permits table limit.

All the values are in mg/ L, except pH, turbidity (NTU) and electrical conductivity (μmhos/cm).

Sodium values vary form 76 to520 mg/L. The samples in SIPCOT industrial region are with higher Na value than the standard value (200 mg/L) as recommended by WHO. Potassium ranges from 24 to 140 mg/L. These minerals, however, are insoluble so that potassium levels in groundwaters normally are much lower than sodium concentration. The concentration of iron ranges from 0.1 to 0.14 mg/L and the values are within the limits except in samples S_2, S_3 and S_4 in the SIPCOT industrial region as prescribed by IS: 10500-1983. Presence of iron leads to the growth of some microorganisms. Excess iron causes indigestion and constipation in human beings.

Nitrate of the samples ranges from 30 to 110 mg/L. Much of the nitrate in the groundwater reaches with the percolating water through the soil. Nitrates are very loosely bound with the soil particles and easily leak out. Six samples in the present study in the SIPCOT industrial region (S_1, S_2, S_3, S_4, S_5, S_6,) have abnormal by high value of nitrate exceeding 45 mg/L. The high concentration of nitrate in drinking water is toxic and causes blue body disease/methaemoglobinaemia in children and gastric carcinomas.

Chloride values vary from 164 to 880 mg/L. Among the 12 water samples, six water samples in the SIPCOT industrial region (S_1,S_2, S_3, S_4, S_5, and S_6,) have high concentration of chloride which exceed the permissible limit of 250 mg/L. Chlorides in drinking water do not cause harmful effects on public health, but high concentration can cause salty taste that most people find objectionable, and it may increase the corrosivity of water.

In this study, the fluoride concentration is found between 0.2 and 1.4 mg/L. It has a dual effect on the physiology. Concentration less than 0.7 mg/Land and more than 1.5 mg/L are injurious. Approximately 1 mg/L of fluoride ion is desirable in public water for optimal dental health. Sulphate

[2] Wilcox, L.V., 1995. Classification and Use of Irrigation Water, US Dept. of Agriculture. 969: 19.

ranges from 26 to 252 mg/L and these values are within the limits except sample S_1 in SIPCOT industrial region. Higher concentrations of sulphate in drinking water may produce objectionable taste or unwanted laxative effects, but there is no significant danger to public health from sulphate.

Conclusion

The findings of the economics of crop cultivation in SIPCOT industrial region and non-industrial region bring out the following facts. The yield of all crops is quite low in SIPCOT industrial region compared to non-industrial region. The cost of cultivation is quite high in SIPCOT industrial region than with non industrial region. Similarly income generation through crop cultivation is quite high in non industrial region than in the SIPCOT industrial region.

The reason for low yield of crops in industrial region is attributed to the following facts. The effluents produced from the existing units in SIPCOT are acidic or neutral. The TDS content is high, in addition to the levels of Total Suspended Solids, Chemical Oxygen Demand, Biological Oxygen Demand, Chlorides and Sulphates. Fluoride content is in the high range for effluents discharged from the chemical manufacturing units.

It is observed that the absence of any facility to deal with poisonous wastewater or toxic wastes, companies have resorted to indiscriminate by discharge their wastes. Besides directly affecting the fertility of the land, such practices also poison the groundwater used for irrigation. Farmers in the region report that yields have plummeted even while costs of extracting water have increased because new or deeper borewells have to be dug as an alternative to the contaminated groundwater in the existing wells.

The ability of plants to absorb nutrients can be altered by changes in TDS. Discharge of effluents on land, as has been and continues to be the practice in many SIPCOT industries, alters the soil's organic matter content and hampers the ability of soil organisms to replenish the organic content. The wastewater has affected the water springs, and therefore, agriculture. Coconut, mango, tamarind and cashew yields are affected right at the flowering stage due to air pollution." Farm workers complain of sores on their limbs because of contact with contaminated water and sludge. Those working in fields close to factories also face the threat of injury due to gas leaks or other such mishaps.

The findings of soil test between SIPCOT industrial region and non industrial region reveal the following facts. The yield of crops is quite low in SIPCOT industrial region in addition to high cost of production. This is due to land degradation; it has been proved with high soil ph value, low soil electric conductivity level, low density of microbial population and low soil porosity. On the other hand, the yield of crops is high in non-industrial region along with low cost of production. The non-industrial region is free from land degradation and such areas are located faraway from the SIPCOT industrial region.

The findings of ground water quality test between SIPCOT industrial region indicate the following facts. On the basis of physico-chemical studies, it may be concluded that the quality of groundwater near the SIPCOT region is affected and the groundwater from these sites are not fit for human consumption. However, in the non-industrial region groundnut water quality is good in terms of present permissible limits of pH value, electrical conductivity value, total hardness and other mineral compositions. The groundwater source, once get polluted, the effects of pollutants, may persist for longer durations. Therefore, proper disposal of industrial effluents with periodical monitoring of groundwater in the industrial area is necessary; otherwise alarming situations will arise soon.

Suggestions

The following suggestions are made on the basis of findings of the study.

1. The Government must initiate steps to identify the extent and nature of environmental degradation, and begin remediation of the land and water at the expense of the polluting factories in SIPCOT.
2. Illegal units, including a majority of factories operating with out valid licences, should be shut down and the Pollution Control Board should set right the in institutional inadequacies that led to inaction despite knowledge of the illegalities. Industries must be allowed to continue only if they function in full compliance with the existing regulations. The suggestion is to issue a lawyer's notice calling upon the Tamilnadu Pollution Control Board to direct closure of defaulting industries and call upon all industries to get consent within a period of one month from the notice. If the notice is not complied with, a PIL may be file in the High Court, Chennai seeking relief.
3. SIPCOT should be restricted to non-polluting industries which are not water-intensive. Such industries must commit to providing employment locally, beginning with people who may have lost their lands to SIPCOT.
4. Statewide, industries must be required to implement a time-bound program towards clean production and pollution prevention, rather than pollution control.
5. The Tamilnadu Government should ban the extraction of groundwater from coastal aquifers for industrial purposes, and launch an aggressive groundwater regulatory regime based on scientific assessments of groundwater capacity, and the prioritised needs of drinking water for communities and agriculture.

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