Nature Environment and Pollution Technology
An International Quarterly Scientific Journal

ISSN: 0972-6268	Vol. 12	No. 2	pp. 363-366	2013

Original Research Paper

Effect of Urbanization on Groundwater Quality of Tirumangalam Taluk, Madurai

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Nat. Env. & Poll. Tech.
Website: www.neptjournal.com

Received: 18-11-2012
Accepted: 13-12-2012

Key Words:
Water Quality Index
Groundwater quality
Urbanization
Land use/land cover
Tirumangalam taluk

ABSTRACT

Urban expansion is a major driving force altering local and regional hydrology. During the past several decades, groundwater quality has emerged as one of the most important and confronting environmental issues and it plays a significant role in the national economy through satisfying various water needs. It has special significance and needs greater attention of all concerned since it is a major alternate source of domestic, industrial and drinking water supply. In this paper, groundwater quality of water samples of eleven locations situated in Tirumangalam Taluk have been compared with respect to land use land change between 2002 and 2011. Groundwater samples were tested for nine physico-chemical parameters following the standard methods and procedures. BIS drinking water quality standards were adopted for calculation of Water Quality Index (WQI) to find suitability of water for drinking purpose. The overall view of the water quality index of the samples from the present study area reveals that the groundwater quality is getting deteriorated over a period of nine years and it creates negative impact on environmental quality.

INTRODUCTION

Rapid urbanization brings with it many problems as it places huge demands on land, water, housing, transport, health, education etc. Freshwater is one of the basic amenities for sustenance of life; the human race through ages has striven to locate and develop it. Water is vital for life and in its natural state is free from pollution. But when man tampers the water body it loses its natural conditions. Groundwater has become an essential resource over the past few decades due to increase in its usage for drinking, irrigation and industrial uses. The quality of groundwater is equally important as that of the quantity (Asadi et al. 2007). One of the major direct environmental impacts of development is the degradation of water resources and water quality. Conversion of agriculture, forest, grass and wetlands to urban areas usually comes with a vast increase in impervious surface which can alter the natural hydrologic conditions (Tang et al. 2005). The problem of drinking water contamination, water conservation and water quality management has assumed very complex shape. Attention of water contamination and its management have become imperative because of far-reaching impact on human health (Sinha & Srivastava 1995). Groundwater pollution not only affects the water quality, but also threats human health, economic development and social prosperity (Priti Singh & Khan 2011). The urban areas are fast getting densely populated and are expanding rapidly to adjoining areas putting unwanted stress on the natural resources (Pradeep et al. 2008). House & Newsome (1989) stated that the Water Quality Index (WQI) allows 'good' and 'bad' water quality to be quantified by reducing a large quantity of data on a range of physico-chemical variables to be a single number in a simple, objective and reproducible manner (Liou et al. 2004). The WQI concept is based on the comparison of the water quality parameter with respective regulatory standards (Khan et al. 2003) and provides a single number that express overall water quality at certain locations based on several water quality parameters (Yogendra & Puttaiah 2008). WQI improves understanding of water quality issues by integrating complex data and generating a score that describes water quality status and evaluates water quality trends (Boyacioglu 2007). The quality of water is generally defined in terms of its physical, chemical and biological parameters and measured as water quality index to assess whether water is potable or not. Deeper groundwater tapped by bore well can still be used for drinking purposes with caution.

STUDY AREA

The latitude and longitude extension of the Tirumangalam Taluk (Fig. 1) is 9°37'32.89"N to 9°57'55.95" N and 77°48' 55.17"E to 78°57'18.52" E respectively and its altitude range from 52 to 353m above mean sea level. The climate is dry and hot, with rains during October-December. Temperatures during summer reach a maximum of 40°C and a minimum of 26.3°C. Winter temperature ranges between 29.6°C and 18°C. The average annual rainfall is about 85 cm. As of the 2001 India census, Tirumangalam taluk has a population of 1,96,642. Males constitute 98,877, and females 97,765 of the population. Eleven different locations under Tirumangalam taluk are taken up for the water quality research (Table 1).

Table 1: Locations of groundwater quality study.

Well No	Block	Village	Latitude	Longitude
W-1	Tirumangalam	Chinna Ulagani	09°46'25"	78°03'08"
W-2	Tirumangalam	Sengapadai	09°46'55"	77°57'00"
W-3	Tirumangalam	Thangalacheri	09°50'10"	77°52'08"
W-4	Tirumangalam	Kappalur	09°50'25"	78°01'00"
W-5	Tirumangalam	Chokkanathanpatti	09°56'17"	77°57'55"
W-6	Tirumangalam	Sathangudi-1	09°50'21"	77°56'23"
W-7	Tirumangalam	Sathangudi-2	09°50'18"	77°56'29"
W-8	Kallikudi	Peikulam	09°38'44"	77°59'25"
W-9	Kallikudi	Puliankulam	09°39'06"	77°54'33"
W-10	Kallikudi	Kallikudi	09°41'38"	77°58'16"
W-11	Kallikudi	Kurayur	09°41'40"	78°01'30"

MATERIALS AND METHODS

Water samples were collected from the eleven locations under Tirumangalam taluk to study the physico-chemical characteristics of groundwaters. The data on water quality parameters provided by Institute of Water Studies, Government of Tamilnadu, Taramani, Chennai were utilized for the study. Water quality index (WQI) was calculated by weighted index method to determine the suitability of groundwater for drinking purposes. The standard methods and procedures were used for quantitative estimation of water quality parameters. The indices have been calculated for nine water quality physico-chemical parameters.

In the present study for Tirumangalam taluk, the WQI has been calculated by adopting weighted index method developed by Tiwari & Mishra (1985) and Asadi et al. (2007) to determine the suitability of groundwater for drinking purposes and using standards of drinking water quality recommended by the Bureau of Indian standards (BIS). The physico-chemical parameters consisted of pH, TDS, total hardness, calcium, magnesium, chloride, sulphate, nitrate and sodium were used for computing WQI using the following formula.

WQI = Antilog [$\sum_{i=1}^{n}$ Wi log10 Qi]

Where,

W (Weightage factor) is computed using the following equation (Table 2).

$W_i = K/S_i$

Where,

K, Proportionality constant is derived from,

$K = 1/\sum_{i=1}^{n} 1 / Si$

Where,

S_i is the BIS standards value for the water quality parameter.

Table 2: Weightage factor of water quality parameters.

Parameter	Standard (S_i)	$1/(S_i)$	K	Weightage Factor (W_i)
pH	8.5	0.118	4.857	0.571
TDS, mg/L	500	0.002	4.857	0.010
Total hardness, mg/L	300	0.003	4.857	0.016
Calcium, mg/L	75	0.013	4.857	0.065
Magnesium, mg/L	30	0.033	4.857	0.162
Chloride, mg/L	250	0.004	4.857	0.019
Sulphate, mg/L	200	0.005	4.857	0.024
Nitrate, mg/L	45	0.022	4.857	0.108
Sodium, mg/L	200	0.005	4.857	0.024
~		0.206		1.000

And,

Quality rating (Q_i) is calculated using the formula,

Q_i = $[(C_i - C_{id}) / (C_s - C_{id})] \times 100$

Q_i = Quality rating for i^{th} parameter

C_i = Measured value for i^{th} parameter which is estimated value

C_{id} = Ideal value for i^{th} parameter in pure water (7 for pH and 0 for all other parameters)

C_s = Standard value for i^{th} parameter recommended by standards

The suitability of WQI values for human consumption are rated as follows 0-25 = Excellent, 26-50 = Good, 51-75 = Bad, 76-100 = Very bad and above 100 = Unfit.

RESULTS AND DISCUSSION

Water Quality Index range observed during the year 2002 was from 40.69 to 99.07 whereas during the year 2011 it ranged from 66.46 to 123.59. All the study locations show increase in WQI resulting in degradation of water quality over the period of nine years. Water quality index of the eleven locations under Tirumangalam taluk for the year 2002 and 2011 and their category are calculated (Table 3). The priority area for attention is identified from 1 to 11 (Table 4).

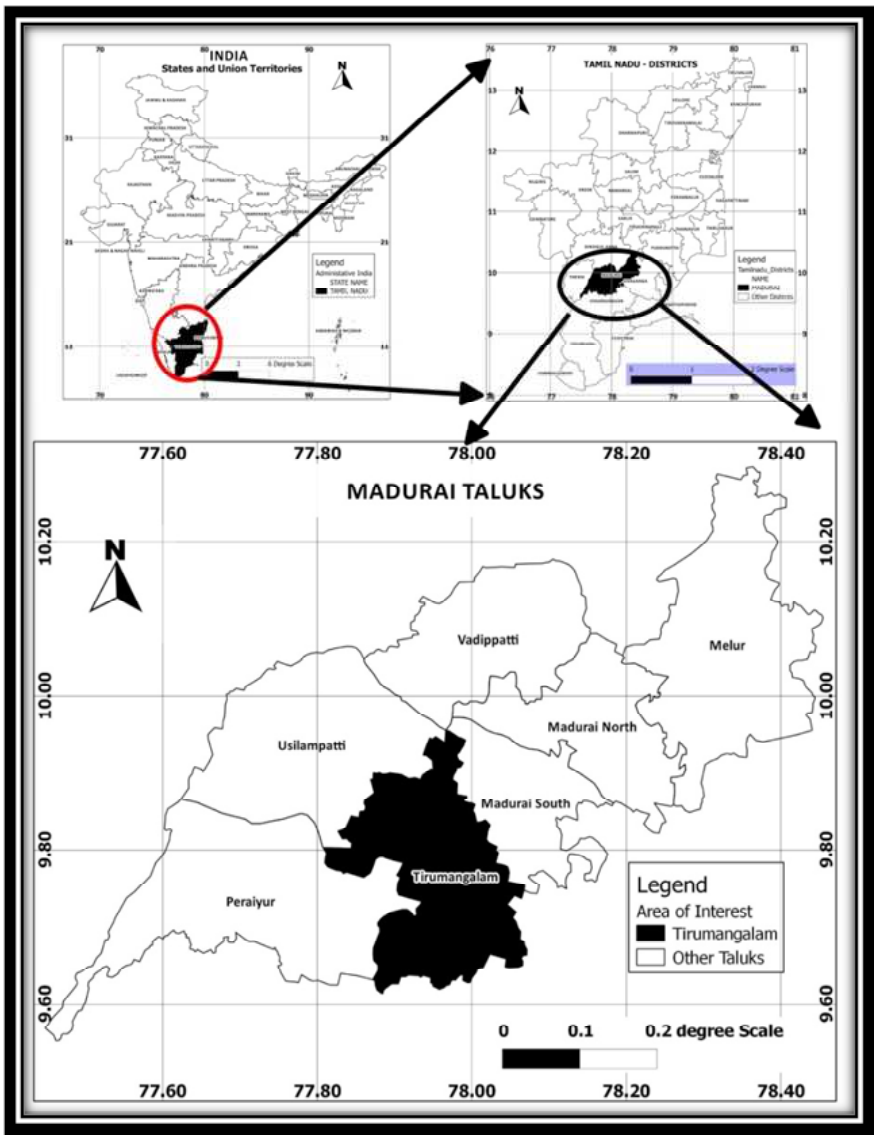

Fig. 1: Study area.

As per the water quality data for 2011, water quality index of three locations is categorized as unfit, six locations as very bad and two locations as bad. Groundwater quality has deteriorated at eight locations over the period from 2002. Deterioration of water quality is very significant over the last nine years where rapid urbanization has taken place in Madurai district particularity towards Tirumangalam taluk. These land use changes cause negative impact on environmental quality like degradation in soil, water quality, natural ecosystem, and socioeconomic cultures. Due to this LULC (landuse/landcover), it gives a negative impact particularly on the groundwater quality. Therefore, understanding the process of urban growth and exploring its effects on natural ecosystems for sustainable land management is more essential to prevent the exploitation of environmental quality. Local planning authority must take care for the urban expansion areas. Land degradation results mainly due to population pressure which leads to intense land use without proper management practices. Urban expansion limits should be standardised and should not affect the natural resources. Urban renewal programme should be implemented by Madurai local planning authority and Madurai Corporation. National Water Resource Council (NWRC) must give special attention on change of boundary such as water bodies and agricultural lands. In addition to Master plan and Regional plan, Zonal development plan (planning for urban expansion) should be prepared by the authorities. The results from the study would provide

Table 3: Water quality based on WQI value.

Well No	Year	pH	TDS	TH	Ca	Mg	Cl	SO_4	NO_3	Na	WQI	Category
W-1	2002	8.2	1222	250	72	90	291	311	20	99	78.35	Very bad
	2011	8.2	1250	250	72	264	291	321	25	99	85.41	Very bad
W-2	2002	8.6	586	160	42	62	124	60	2	106	96.32	Very bad
	2011	7.7	600	160	184	62	150	52	21	106	117.57	Unfit
W-3	2002	8.1	1139	760	28	168	432	134	35	149	102.79	Unfit
	2011	7.9	674	760	194	328	624	24	73	428	123.59	Unfit
W-4	2002	8.1	344	220	26	38	78	115	1	357	52.25	Bad
	2011	8.1	1037	220	160	61	78	58	39	285	93.17	Very bad
W-5	2002	7.9	383	120	26	150	78	96	3	32	78.81	Very bad
	2011	8.1	955	120	96	41	277	16	28	285	77.75	Very bad
W-6	2002	8.3	776	430	40	96	6	86	56	104	75.12	Bad
	2011	8.1	924	430	60	60	156	212	28	104	66.46	Bad
W-7	2002	8.5	438	250	32	41	174	248	4	632	99.07	Very bad
	2011	7.7	3669	250	460	328	174	264	4	423	86.72	Very bad
W-8	2002	8.7	836	270	16	56	223	82	3	219	82.87	Very bad
	2011	7.9	677	270	94	112	199	36	13	139	108.24	Unfit
W-9	2002	8.6	453	320	40	44	50	6	14	18	40.69	Good
	2011	8.6	550	320	56	44	251	26	40	18	67.07	Bad
W-10	2002	7.5	652	205	54	55	96	144	3	69	78.45	Very bad
	2011	8.1	685	205	46	73	709	14	4	69	96.20	Very bad
W-11	2002	8.3	261	180	6	180	942	41	6	330	60.98	Bad
	2011	7.8	1981	180	184	200	942	192	60	330	80.16	Very bad

Table 4: Priority areas based on water quality index.

Village	Well No.	WQI/ Category	Year 2002	2011	Priority
Thangalacheri	W-1	WQI	102.79	123.59	1
		Category	Unfit	Unfit	
Sengapadai	W-2	WQI	96.32	117.57	2
		Category	Very bad	Unfit	
Peikulam	W-8	WQI	82.87	108.24	3
		Category	Very bad	Unfit	
Kallikudi	W-10	WQI	78.45	96.20	4
		Category	Very bad	Very bad	
Kappalur	W-4	WQI	52.25	93.17	5
		Category	Bad	Very bad	
Sathangudi-2	W-7	WQI	99.07	86.72	6
		Category	Very bad	Very bad	
Chinna-Ulagani	W-1	WQI	78.35	85.	7
		Category	Very bad	Very bad	
Kurayur	W-11	WQI	60.98	80.16	8
		Category	Bad	Very bad	
Chokkana-thanpatti	W-5	WQI	78.81	77.75	9
		Category	Very bad	Very bad	
Sathangudi-1	W-6	WQI	75.12	66.46	10
		Category	Bad	Bad	
Puliankulam	W-9	WQI	40.69	67.07	11
		Category	Good	Bad	

comprehensive and reliable information which may serve as a guideline for the development of Tirumangalam taluk. This research can be extended in future for soil investigation (permeability), impact on surface run-off, impact on agricultural product and climate for the study area.

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