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Hazards of Onsite Sanitation System on Groundwater - A Case Study of Suburban Area in Bangalore Rural District, Karnataka, India

SHIVENDRA B T[1], SANJEEV T P[1] AND RAMARAJU H K[2]

Dayananda Sagar College of Engineering, Bangalore, Karnataka State, India

Department of Civil Engineering, SJBIT, Bangalore, Karnataka State, India

Email: shivubts@yahoo.com, hkramaraju@gmail.com

Abstract: *Practice of onsite sanitation in majority of peri urban areas in India is responsible for deterioration of surface and groundwater resources. Due to inadequate sanitation and practice of onsite sanitation like pit latrines and septic tanks , the contaminant levels are exceeding permissible levels in ground water drinking sources resulting in water borne diseases, causing widespread morbidity and mortality. A field study carried out for one year in a peri urban areas of Bangalore rural district indicates that ground water sampling collected at twelve sampling stations near onsite sanitation systems are unfit for drinking purpose. Higher concentration of nitrates and chlorides in bore well water samples show that ground water is getting contaminated with onsite sanitation.*

Keywords: *On-site sanitation, Ground water contamination, Nitrate, Total coli forms*

1. Introduction

In Peri urban areas most of the population is not connected to a central water supply. Peri urban areas in India are depended on groundwater for drinking purpose. The groundwater is extracted by bore wells either by owner at their sites or by municipal bore wells in and around the peri urban areas. The groundwater is used for drinking purpose without any treatment. The groundwater is contaminated by untreated domestic wastewater, industrial wastewater disposal into open drains, landfill sites, leakages from underground storage tanks and from onsite sanitation systems.

The close location of groundwater sources and onsite sanitation is common in densely populated periurban areas. The septic tank/cesspools/pit latrines are used as an onsite sanitation system by the people. Septic tanks, and pit latrines without lining permits the leaching of effluents to surrounding soil. The effluents like chloride, pathogens and nitrate percolate to the surrounding soil may cause groundwater contamination, and water borne diseases. This type of onsite sanitation has potential danger of polluting groundwater sources, which is common in many under developed and developing countries.

People in densely populated peri urban areas and rural areas are most vulnerable by consumption of untreated water from bore wells. The septic system contributes an average of 13 kg of nitrogen per household per year to groundwater. The nitrogen leaching out from leach pit latrines could raise the nitrogen concentrations from negligible levels to dangerous levels may cause serious health hazards. Potential healths hazards due to excess consumption of nitrate are methemoglobinaemia in children, esophageal and gastric cancer. Nitrates were found to have direct affects on central nervous system and vasodilator cardio-vascular system. The human body reduces the nitrate to nitrite, which in turn oxidizes iron in hemoglobin. The resulting mathaemoglobin reduces the ability of blood to carry oxygen to different parts of body leading to cyanosis. Nitrites can react with amines and amides to form nitrosamines and nitrosamides. Most nitroso-compounds were tested to be carcinogenic in wide range of animal species.

The practice of onsite sanitation is not limited to developing and underdeveloped countries, but it is under practice in developed countries like U.S.A. Most of the studies [1] related to onsite sanitation are used nitrate, chloride and feacal coli forms/E-coli as indicator parameters to assess the effect of onsite sanitation systems on groundwater. Out of above indicators the health hazards due nitrate and feacal coli forms/E-coli are highlighted in many studies. The health hazards of nitrate concentration above W.H.O. limit is reported by many researchers.[1, 2,3,4,5]. The health hazards of feacal coli forms/E-coli are highlighted in many researchers' studies. [6, 7, 8]. In India elevated levels of nitrate hazards due to nitrate contaminant from onsite sanitation is reported by [4, 5]. The hazards due to feacal coli forms/E-coli from onsite sanitation are reported by [8]. Hence at locations of onsite sanitation practices data management of water quality monitoring along with health studies will be useful in mitigating the impacts due to onsite sanitation on groundwater.

In the present study Hosakote area is selected to monitor the contaminants levels in water samples of

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bore well located near onsite sanitation systems. The contaminants like nitrate, chloride, total dissolved solids, total count and E-coli are monitored to predict the impact of low cost on site sanitation system on ground water. In addition, to establish safe distance between on-site sanitation systems and groundwater supply sources and to suggest remedial measures for prevention of contamination of groundwater, this study was carried out.

2. Study Area

Hosakote is a peri urban area in Bangalore rural district in the Indian state of Karnataka. The town is approximately 27 km from Bangalore city. Hosakote is located at latitude 77°32′34.8″ E and 13°17′31.2″ N longitude. The elevation of the area is 891 m above mean sea level (MSL). The city has a population of 56,613 as per the census 2011. The geographical area is 18.25 square kilometers. The surface geology is gneisses and laterite. The soil of Hosakote town consists of laterite gravelly clay, sandy clay loam, and sandy loam. The average annual rainfall is 768mm. The average temperature during summer is 32°C and winter temperature is 27°C.

The sources of water are bore wells and Chikkamanakere tank, tankers (50%) and municipal water supply (47%). At present the water is supplied from borewells. Water table is very deep and the depth of the well varies from 400-800 feet. The groundwater occurs in open spaces of weathered zone, under semi-confined conditions. The Geophysical resistivity survey indicates fractures at 14, 108,110,123,134 and 138m depth and yield is 0.10 to 9.13 litres per second and transmissibility is 7.4 to 535.72 m^2/day[9]. Demand of water is about 2.7 in MLD. Most of houses in the areas have septic tanks. No sewerage facility exits in the town and wastewater of town is diverted through major storm water drains to Chikkamanakere tank.

People are dependent on their own or on public bore wells installed by the municipal corporation at many places in the locality. The public bore wells are close to the open drains, which carry the sullage as well as effluent from the toilets. The bore well sampling locations were decided on the basis of visits to different localities. Reconnaissance survey is carried out in selected layouts of study areas by visiting the houses. Details regarding sources of water supply, sanitation and health related diseases are collected by questionnaire. After reconnaissance survey, bore well sampling points are selected close to community toilets near police quarters, near bus stands and residential areas. 12 (Twelve) bore well water sampling locations are selected in the old kote area, Brahman street and Sir. M.V.Layout. The distance between onsite sanitation systems and bore wells varies from 10 to 150 feet. All the houses in the localities are having onsite sanitation systems and disposal of sullage in open drain is common.

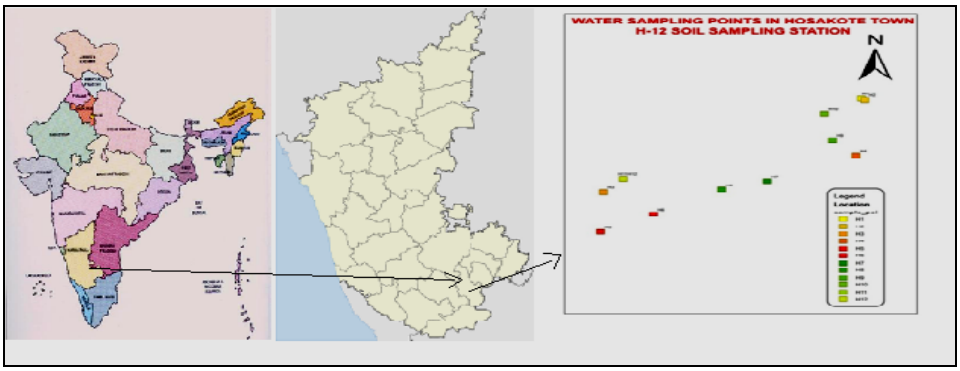

Fig.1. *Study area map depicting water sampling stations (Survey of India)*

3. Materials and Methodology

Reconnaissance survey was carried out in selected layout of Hosakote town to select bore wells sampling points. Details regarding sources of water supply, sanitation and health related diseases are collected via questionnaire by visiting the houses. Details of septic tanks, drainage system and solid waste disposal collection, disposal and agricultural activities are collected.12 bore well water sampling stations (Fig.1) were selected near onsite sanitation systems and water samples are collected monthly from Feb 2014 to Jan 2015. Water samples are collected as per standard methods [10] in 2 Litre plastic cans for physico-chemical analysis and 300 ml capacity BOD sterilized bottle for bacteriological studies.

4. Results and discussions

The bore wells water samples were analyzed for onsite sanitation indicatior parameters like Total dissolved solids, chloride, nitrate, total coli forms and E-coli for three seasons, as per standard methods [10]. Table.2. Presents results of analysis of bore wells water samples for onsite sanitation indicator parameters.

Total dissolved solids: The value of total dissolved solids varies from 387.50 to 1959.5 mg/l in pre-monsoon season, 432 to 2049 mg/l in monsoon season and 441.75 to 2312.5 mg/l, in post monsoon season. The variations of Total dissolved solids in different seasons are shown in Fig.2 and in Table.2. In study

area 41% of borewells water samples in post monsoon, 50% in monsoon and 50% in post monsoon are having maximum values of total dissolved solids and are exceeding WHO Guideline of 1000mg/l. Except at H1 to H5, all other sampling stations borewells water sample's total dissolved solids are beyond drinking water standards. In old kote area, Brahman street the bore well water is not good for drinking purpose and is unpalatable. In Sir. M.V.Layout the TDS values of borewells water samples are within drinking water standards. The high values of TDS can be attributed to the local geo-chemical characteristics.

Chloride: The value of chloride varies from 120 to 790.5 mg/l in pre-monsoon season, 115 to 773.25 mg/l in monsoon season and 155 to 748.75 mg/l in post monsoon season. The variations of Chloride in different seasons are shown in Fig. 3 and Table2. In study area 75% of borewells water samples in post monsoon, 67% in monsoon and 67% in post monsoon are having maximum values of chloride and are exceeding drinking water standards of 250mg/l. Except at H1 to H4 all other sampling stations borewells water samples have chloride concentration beyond drinking water standards. All water samples in kote area, Brahman street are not good for drinking purpose and are unpalatable. In Sir.M.V.Layout the chloride values of borewells water samples of sampling station H1 to H4 are within drinking water standards.

Nitrate: The Nitrate values are in the range of 17 to 54.95 mg/L in pre-monsoon season, 14.7 to 49.78 mg/L in monsoon season and 11.5 to 43.5 mg/L in post monsoon. The variations of nitrate in different seasons are shown in Fig .4 and Table2. The nitrate values of borewells water samples in stations H1, H9, H11 and H12 are exceeded the desirable limit of 45 mg/L. In study area 17 % of samples in post monsoon are having more than 45mg/l of nitrate. 100% of bore well samples are having greater than 20 mg/l of nitrate in monsoon season and in post monsoon season. Except at stations H11 and H12 all other sampling station borewells water samples are having nitrate concentration within drinking water standards. All water samples in old kote area, Brahman street and in Sir.M.V.Layout are having greater than 20mg/l values of Nitrate. Nitrate concentration is more in pre monsoon. The decrease in nitrate concentration in summer season can be attributed to the lowering of the groundwater table wherein anaerobic condition is created and nitrate is partially converted to nitrogen [2].

Total coli forms count: The Total coli forms count varies from 02 to 7.25/100 ml in pre-monsoon season, 3.75 to 6.25 /100 ml in monsoon season and 4 to 5.5/1oo ml in post monsoon season. The variations of Total coli forms count in different seasons are shown in Fig.5 and Table 2. The presence of total coli form is observed in the all bore well samples during three seasons. Total coli forms are present in bore water samples located at a considerable distance from the onsite sanitation systems. The presence of total coli forms in bore water samples may be due to infiltration of leachate from the onsite sanitation systems. The total count is more in monsoon season compared to other seasons. The total count is more in case of Sir.M.V.Layout compared to old kote area and Brahman street. The high total count in monsoon season in new layouts may be due to the short distance between borewells and onsite sanitation systems. The infiltration and recharge in the monsoon season can lead to faster movement of the pathogens in the groundwater compared to summer season. This is responsible for increase in the survival rate of pathogens and thereby increasing the total coli form count in monsoon season.[4]. The presence of Escherichia-coli is not observed in any of the bore wells water samples during all seasons.

5. Conclusions

The results of analysis of bore well water samples located close to onsite sanitation systems indicate the presence of high values of nitrate and chloride. It is due to closeness of soak pits, septic tank and borewells. The nitrate to chloride ratio is greater than one indicates the contamination of feacal origin in these groundwater sources. The study reveals that nitrate contamination in most of the bore well water samples. The increase in nitrate concentration in post monsoon season indicates leaching of nitrogen to groundwater source. The percolation of wastewater from stagnant open unlined drainage system may be also responsible for leaching of pollutants into groundwater source. Up to 30 m from onsite sanitation system the bore wells are contaminated with high concentration of chloride and nitrate. The concentration of TDS and chloride is less in monsoon season compared to others seasons. This may be due to recharge of aquifers and dilution effects. Up to 30 m from onsite sanitation system distance all bore wells are contaminated with total count. Onsite sanitation systems are poorly constructed which provides pathways for movement of contaminants.

It is also observed that high concentration of nitrate is observed in both old and newly developed layout areas. More chloride and TDS is observed in old residential areas compared to new layout. The TDS concentration in Sir. M.V.Layout is low and is within permissible limit. TDS concentration is exceeding the permissible limit in old kote area at station S11 and S12. The Total coli forms count is more in Sir.M.V.Layout compared to old kote and other areas.

Table 1. *Study area details*

Study site location	Density of population Sq./km	Average annual rainfall (mm)	Surface Geology	Soil type	Sampling points monitored	No's of users families in the		Age of the tank yrs.		Type of construction	Distance of tank		
						Max	Min	Max	Min		From drinking water source (m) MaxMin.		From agricultural field (m)
Hosakote (Sir.M.V.Layout, old kote area, Brahmin street)	3102	768	Gneisses And laterite	sandy clay loam, sandy loam laterite gravelly clay	12	100	04	20	02	Size stone masonry/ rubble dry masonry/Rcc circular rings)	30	05	30

Table 2. *Concentration of Indicator parameters of bore well water sample from Hosakote, Bangalore Rural District.*

Parameters	Seasons	Stations H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12
Total Dissolved Solids (mg/l)	Pre monsoon	421.00	387.50	530.25	641.25	887.50	914.00	1940.75	1761.00	1959.75	1796.25	1459.00	1595.50
	Monsoon	432.00	432.25	507.75	545.50	647.00	872.00	2049.00	1734.00	1945.00	1764.25	1448.75	1390.75
	Post monsoon	489.75	441.75	539.50	544.25	862.75	1005.75	2312.25	1712.50	1925.75	1759.75	1496.50	1316.25
Chloride (mg/l)	Pre monsoon	148.75	120.00	177.50	230.00	257.50	448.50	653.25	790.25	654.75	725.00	561.25	550.00
	Monsoon	122.50	115.00	157.50	195.00	203.75	387.50	721.25	773.75	703.75	622.50	427.50	482.50
	Post monsoon	187.50	155.00	205.00	218.75	251.25	325.00	748.75	658.75	725.00	658.75	507.50	520.00
Nitrates (mg/l)	Pre monsoon	46.48	17.03	36.35	32.00	30.60	36.38	44.53	42.53	46.03	32.48	49.05	54.95
	Monsoon	20.63	14.70	20.00	27.50	28.33	33.75	31.08	37.25	43.53	39.33	37.63	49.78
	Post monsoon	23.75	11.50	27.35	26.25	28.25	26.38	46.00	37.25	36.23	33.75	40.05	43.50
Total coli forms M.P.N.per 100ml	Pre monsoon	4.00	2.00	5.50	4.00	4.00	4.75	5.25	6.50	4.00	4.75	4.50	7.25
	Monsoon	3.75	3.75	5.25	4.00	5.50	4.00	4.75	4.00	4.00	4.00	4.75	6.25
	Post monsoon	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	5.50
E-coli	Pre monsoon	AB	AB	AB	AB	AB	AB	P	AB	AB	AB	P	AB
	Monsoon	AB	AB	AB	AB	AB	AB	P	AB	P	P	AB	AB
	Post monsoon	AB	AB	AB	AB	AB	AB	P	P	AB	AB	P	AB

P=Present, AB= absent

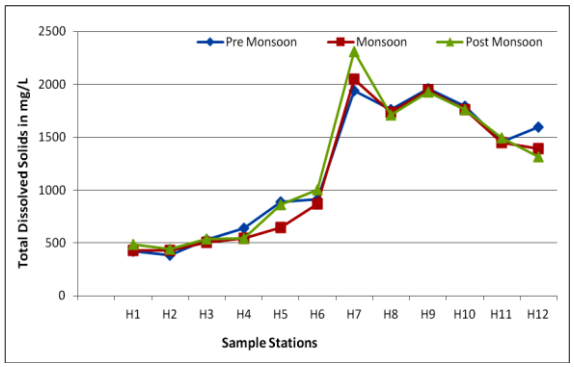

Fig 2.*Total dissolved solids variation among the sampling stations*

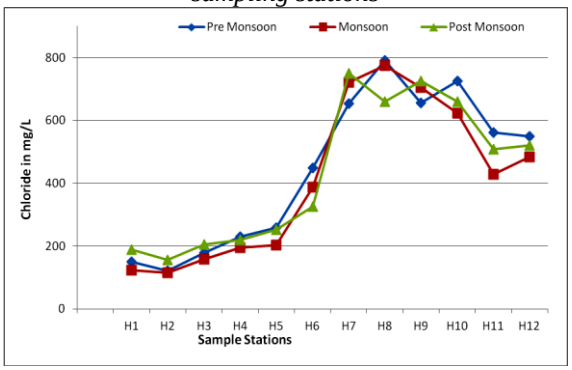

Fig.3*.Chloride variations among the sampling stations*

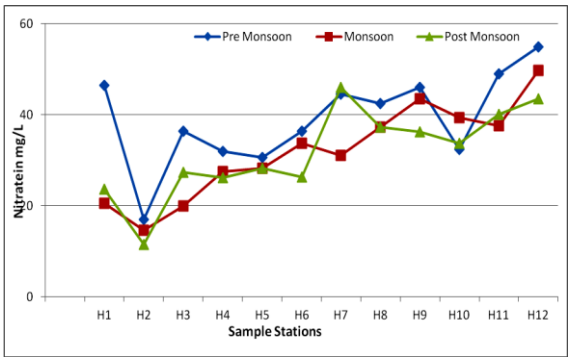

Fig.4. *Nitrate variation among the sampling stations*

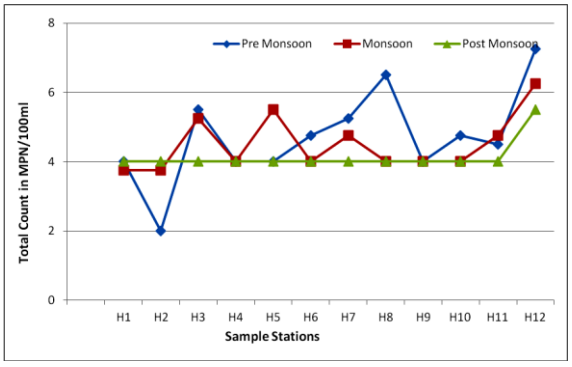

Fig. 5. *Total Coli form variation among the sampling stations*

This may be due to the short distance between groundwater source and onsite sanitation systems. The attenuation of pollutants due to die-off or adsorption will be less. The presence of fracture in underlying rocks at different depth is indicated by geophysical resistivity survey conducted by [9]. This provides pathways for movement of contaminants. The study concludes that fracture rocks aquifers are impacted by onsite sanitation systems. This study results are similar with study conducted by [4] at Indore city having deep bore well with basaltic rocks. The present study also concludes that the present distance between bore wells and onsite sanitation system (latrines) with hygienic conditions are insufficient to prevent groundwater contamination. Establishment of settings standards by concerned authority for siting of bore well from onsite sanitation is necessary in the study area.

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