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Study of Movement of Pollutants in Soils around the Onsite Sanitation Systems - A Case Study of Periurban area in Karnataka, India

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ABSTRACT

Sitting onsite sanitation systems near ground water sources without following any Indian national building organization, guideline is common in the peri urban areas in India. Due to close location of them the contaminants infiltrates from onsite sanitation systems and causes contamination of groundwater sources. Contamination of groundwater sources by pathogenic bacteria and nitrate are two major public health risks due to onsite sanitation systems. Sufficient depths of unsaturated soil and adequate horizontal separation distances between an onsite system and water sources are required to protect public health from aquifer contamination. In the present study the assessment of movement of pollutants in sandy soils around the onsite sanitation systems has been carried out to study the impact of septic tank on nearby borewell groundwater. Soil samples were collected around the septic tank in five directions. In each direction, soil samples were collected at 1 m interval longitudinally up to 2 m from septic tank edge at 0.3 m and 0.5 m depth. The soil samples are analyzed for sulphates, chlorides, phosphates, nitrates. The soil samples for bacterial analysis (*E. coli*) were collected in both monsoon and non-monsoon seasons upto 10 m from septic tank edge. From analysis of soil samples it can be concluded that concentration of nitrate, chloride, phosphate and sulphates leached from septic tank are not able to effect quality of bore well water located downstream of septic tank. The *E. coli* movement in the soil is observed upto 5 meters from the edge of the septic tank. The study concludes that the present distance between public borewell and septic tank is sufficient to prevent groundwater contamination.

***Key words**: Onsite sanitation system, Movement of Pollutant, Nitrate, Chloride, E-coli.*

Introduction

In India under Swachh Bharat Mission, 2.5 lakhs community toilets and 2.6 lakhs public toilets are constructed in various towns with a focus on elimination of open defection. The toilets are connected to septic tanks/soak pit. When these toilets are constructed in different types of soils, soil and water pollution may occur from unlined and malfunctioning septic tanks in areas having onsite sanitation. To protect and safeguard the quality of water supplies, knowledge and characteristics of soil contamination and application are required. Factors affecting the movement of microorganisms and pollutants in soil are soil physical characteristics like texture, particle size distribution, clay type, organic matter, pH , bulk density and soil environment like temperature, soil water content, microbial factors like type and den-

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sity of microorganisms, presence of larger organisms. Extensive use of onsite sanitation in densely populated periurban area may cause environmental and human health impacts. Contaminants identified by leaching from onsite sanitation system includes bacteria, viruses, ammonia, nitrates chlorides and phosphates because of their potential health hazard, i.e., incidence of blue baby disease (methaemoglobineamia) and bacteriological contamination may result in water borne diseases like diarrhea, cholera, dysentery, etc. Contamination of surface and groundwater sources by pathogenic bacteria and nitrate are two major public health risks due to onsite sanitation systems. Sufficient depths of unsaturated soil and adequate horizontal separation distances between an onsite system and water supply wells or water bodies are required to protect public health from pathogen contamination. When the pollutant infiltrate from a unlined septic tank, its movement depends on the soil type, permeability and distance between septic tank and groundwater source. The soil acts as a line of defensive in arresting pollutants in filtered from septic tank to surrounding area. In the soil like a coarse gravel sand pollutant are move faster in lateral and longitudinal directions compared to clayey soils. The unsaturated zone is most important line of defense against pollution of soil. It arrests the fecal microorganisms, nitrates, chlorides and sulphates. Under saturated condition of soil the movement of bacteria and chemical is more in longitudinal and lateral directions.

When the pollutants such as sulphates, chlorides, phosphates, nitrates, and fecal microorganisms start moving from the septic tank, its flow path will be disturbed by presence of some obstruction, after some time due to build up of pollutants the enclosed area itself may be act as a source of pollution. When pollutant are liberated from septic tank and enters to soil subsurface, there will be a tendency of it to move downwards depending on the amount of moisture. If the water table is at higher level and soil is having more porous media then the pollutants will move quickly to contaminate the groundwater. The objective of present study is to study the movement of pollutant in sandy soils around the onsite sanitation system and its impacts on nearby borewells in Periurban area in Karnataka.

Literature Review

Nadeshwara Rao and Hallapa Gowda (1996) conducted studies on movement of pollutant near soak pit in Mysore district. In their studies they found that concentration of nitrate, chloride, phosphate are exceeded the permissible limit in the soil samples collected near onsite sanitation system and they have effected quality of bore well water of surrounding areas.

The movement and survival of bacterial varies with type of soil under different climate conditions, infiltration soil characteristics, bacterial characteristics, soil moisture conditions is worked out by various researchers all over the world.

The travel distance of pathogens should be sufficient to till they come inactive. The various researchers suggested the travel distance and presence of coliform from onsite sanitation system (Dyer, 1941 and Banerjee, 2011). They suggested travel distance of coliform pit varies from 1 to 25m depending upon soil type seasons of year, and geo environmental conditions.

Dyer (1941) in his study on microbial impact of onsite sanitation system on groundwater constructed and installed a test well near a latrine pit placed in an alkaline alluvium soil under saturated and unsaturated condition. He observed that the movement of total coliform was within 7 m from the pit during December to September month. Nichols *et al*. (1983) in their study in USA used totally 8 no of lined and unlined latrines to compare the movement of faecalcoli forms in soil samples collected near the pits. In his studies during June and August 1975-1979, he observed only one peat lined pit located in shallow and rocky soil in saturated condition was contaminated with fecal coli forms. They concluded that peat lined pits are effective in preventing migration of fecal coliform. Banerjee (2011) conducted studies on 12 pour-flush latrines, analysed total and fecal coliform as indicator parameter and found that increased concentration during the monsoon season in different soils. He concluded that the migration of bacteria is upto 10 m only from pits during monsoon season.

Study Area

Doddaballapura Periurban town (Figure 1) of Bangalore rural district is selected for field observation. The peri urban town is 40 Km from Bangalore City. Doddaballapura is located at latitude 77° 322 34.83 E and longitude. 13° 172 31.23N. The area is characterized by undulating topography with dendritic to subdendritic drainage system. The elevation of the area ranges from 917 to 1175 above Mean sea level (MSL). The city has a population of 85,000 as per the census of 2011. The geographical area is 7.2 square kilometers. The surface geology is Tonalitic Gneisses and Gneisses. The soil is Sandy loamy, Clay and Loamy sandy. The average Annual rainfall is 768 mm. Doddaballapura is depended on ground water, with municipal and private water supply. The major source of potable water is tankers (50%) and Municipal water (47%). The town has very limited sewer connection and is under construction. Most of houses in the areas have septic tanks. 25% of people has access to private toilets, 76% own toilets and 09% shared toilets. 15% of population does not access to private toilet.7% community toilet and 8% open toilet. The main reason for not having toilet is financial constraints (61%) and space (65%) (ASHWA). Water table is very deep in the city and tube wells are the common water sources.

The depth of the well varies from 400 to 800 ft and distance of sanitation systems from bore wells varies from 10 to 150 feet. People are dependent on the public bore wells installed by the Municipal Corporation at many localities in the town. The public tube wells are also close to the open drains, which carry the sullage as well as effluent from the toilets.

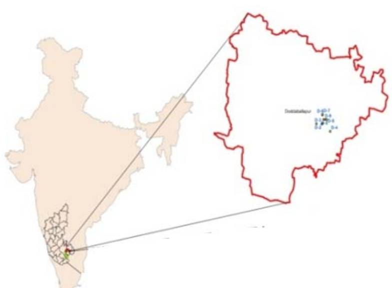

Fig. 1. Study area map

Disposal of sullage in open drain is commonly observed. A septic tank in this town is selected for study purpose. Fig. 2 shows the location of community toilets with septic tank in D-cross, Doddaballapura Periurban town. The septic tank is in the centre place of the town and it is constructed near police station, which is being used by around 100 public people per day from the past ten years. The septic tank is 10 × 5 meters, 2.4 m depth and is unlined at sides and bottom. There is one public borewell situated at 30m (150 feet) distance in the downstream of septic tank. The public bore well is 200 meters depth and about 10 years old.

Methodology

The collections of soil samples have been carried out at site according to the methodologies given by Padmasiri, 1992. Auger boring is used to collect the soil samples, for which post hole augers were used. This method has the advantages of being inexpensive, with no drilling fluid is to be introduced into bore hole and no possibility of diluting formation water, and it can be used quickly for shallow depths. At the point where the samples are required, the auger was advanced by rotating and pressing manually into the soil. While advancing the auger, bore holes have to be maintained dry to remove easily. These holes were bored up to required depth and of 20 to 25 cm diameter. For analysis of nitrate, chloride, sulphate and phosphate soil samples were collected around the septic tank in five directions. A, B, C, D and E as shown in Fig. 4. In each direction, samples were taken at 1 m interval longitudinally up to 2 m and depth wise at 0.3 m and 0.5 m. Thus, in each direction 4 soil samples were collected and totally 20 soil samples were collected around the pit. The soil samples for bacterial analysis were collected in both monsoon and non-monsoon seasons upto 10m from septic tank edge. The collected samples were taken to Geotechnical laboratory of Dayananda Sagar College of Engineering in air tight polythene bags for analysis. The analysis of soil samples was carried out according to the manual prepared and recommended by NEERI (National Environmental engineering Research Institute, 1994.) and BIS codes of soil mechanics.

Fig. 2. Location of community toilets with septic tank in D-cross. Doddaballapura town

Results and Discussion

The results of physical properties, Bacteriological analysis and pollutants analysis of soil samples collected near septic tank of study area is tabulated in Tables 1,2,3,4,5 and 6. Table 1 shows the physical properties of soil. The soil red in colour and sandy in nature. Table 2 shows the density and movement of *E-coli* in different distances at 1.0m depth in five directions. The Tables 3, 4, 5 and 6 shows the movements of chlorides, nitrates, sulphates and phosphates leached from onsite sanitation system. The concentration and directional movement of chlorides, nitrates, sulphates, phosphates and E-coli in the soil are discussed below.

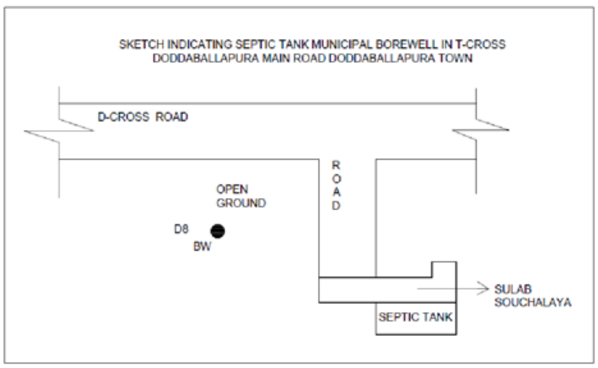

Fig. 3. Sketch indicating Septic Tank and Public bore well in D-cross, Doddaballapura Town

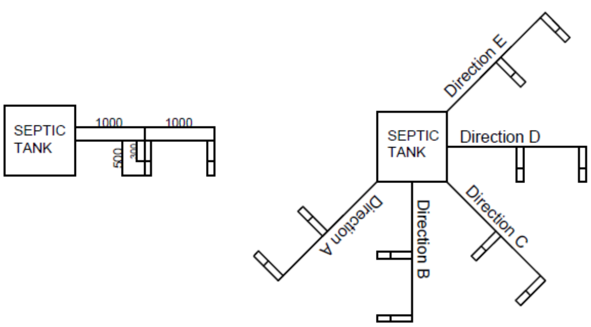

Fig. 4. Scheme of soil sampling points around septic tank, community toilet, D-cross Doddaballapura

Chloride: Table 3 shows the chloride concentrations from the soil samples collected in five directions around septic tank, at different depth and calculated depth average concentrations. From the table it can be observed that depth wise the concentration is increasing in all the directions. It was also observed that chloride concentrations movement in soil in A-direction is more. The concentration movement in A-direction (Downstream direction from septic tank) is between 354.50 and 407.67 Meq/l at 0.3m depth and it is between 443.12and 460.85 Meq/l at 0.5m depth.

Nitrate: From the Table 4 it can be observed that depth wise it is increasing gradually as distance increases up to 0.5m. From data it can be observed that, the nitrate concentration in soil is moving in all direction, but its movement is more towards direction-B (Downstream direction from septic tank) and it is between 32 and 47.5 mg/kg soil at 0.3 m depth and at 0.5m depth it is between 33 and 46.5 mg/kg soil.

Phosphate: Table 5 shows the phosphate concentration and calculated average depth concentration around the pit. The phosphate concentration is increasing depth wise as distance increases. From the table it was also observed that pollutant transport is more towards direction-A and it is between 71 and 60 mg/kg soil at 0.3m depth and it's between 83 and 50 mg/kg soil at 0.5m depth.

Sulphate: Table 6 shows sulphate concentration in soil around pit and the concentration is increasing depth wise. From the Table it can be observed that the concentration movement is between 110 and 75 mg/l at 0.5 m depth and between 95 and 75 at 0.3 m depth toward direction-A. The unit for chloride concentration obtained from soil is Meq/l. whereas the

Table 1. Physical properties of soil collected near septic tank of study area

Sl. No.	Location	Season	Moisture content% KN/m^3	Bulk density KN/m^3	Dry density	Specific gravity	Void ratio %	Degree of saturation	Porosity %	Permeability m/Day
1	Community toilet with septic tank near D-cross Doddaballapura	Non monsoon	11.65	16.70	14.90	2.40	0.61	45.83	37.89	0.022
		Monsoon	11.80	18.90	16.90	2.36	0.41	67.26	29.27	0.024

Table 2. Bacteriological analysis of soil near community toilet with septic tank.
Location; Community toilet with septic tank near D-cross Doddaballapura, Monsoon and non-monsoon season April and September

Sl. No.	Sample point	Horizontal distance in meters	Depthin meters M)	*E-coli* CFU/100ml (Colony Forming Unit).	
				Non-Season Monsoon	Monsoon season
1.	A-DirectionD11	1.00	1.0	$0.2x10^4$	$0.5x10^4$
2.	D12	3.00	1.0	AB	$0.4x10^4$
3.	D13	5.00	1.0	$0.1x10^4$	$0.2x10^3$
4.	D14	7.00	1.0	AB	AB
5.	D15	10	1.0	AB	AB
6.	B-DirectionD21	1.00	1.0	$0.3x10^4$	0.4x104
7.	D22	3.00	1.0	AB	$0.2x10^3$
8.	D23	5.00	1.0	AB	AB
9.	D24	7.00	1.0	AB	AB
10.	D-DirectionD31	1.00	1.0	AB	AB
11.	D32	3.00	1.0	AB	AB
12.	D33	5.00	1.0	AB	AB
13.	D34	7.00	1.0	AB	AB
14.	C-DirectionD41	1.00	1.0	$0.2x10^3$	$1.6x10^3$
15.	D42	3.00	1.0	AB	$1.1x10^3$
16.	D43	5.00	1.0	AB	AB
17.	D44	7.00	1.0	AB	AB
18.	D45	10.00	1.0	AB	AB
19.	E-DirectionD51	1.00	1.0	AB	AB
20.	D52	3.00	1.0	AB	AB
21.	D53	5.00	1.0	AB	AB

Table 3. Chloride concentration in soil collected near on site sanitation system.

Depth(m)	Longitudinal distance (m)	
	1	2
A Direction		
0.3	354.5	407.67
0.5	443.12	460.85
Depth averaged value	398.81	434.26
B Direction		
0.3	106.35	106.35
0.5	80.65	70.9
Depth averaged value	93.5	86.62
C Direction		
0.3	240.15	496.3
0.5	70.9	212.7
Depth averaged value	155.52	354.5
D Direction		
0.3	212.7	202.7
0.5	360.5	202.7
Depth averaged value	286.6	202.7
E Direction		
0.3	177.25	124.07
0.5	159.52	80.62
Depth averaged value	168.38	106.63

All concentration in (Mg/kg) soil

Table 4. Nitrate concentration in soil collected near onsite sanitation system.

Depth (m)	Longitudinal distance (m)	
	1	2
A Direction		
0.3	30.5	33
0.5	32.5	33
Depth averaged value	31.5	33
B Direction		
0.3	32	47.5
0.5	33	46.5
Depth averaged value	32.5	47
C Direction		
0.3	33.5	50
0.5	36	35
Depth averaged value	34.75	42.5
D Direction		
0.3	31.5	35
0.5	31	36
Depth averaged value	31.25	35.5
E Direction		
0.3	41	36
0.5	42	37
Depth averaged value	41.5	36.5

All concentration in (Mg/kg) soil

Table 5. Phosphate Concentration in soil collected near onsite sanitation system.

Depth (m)	Longitudinal distance (m)	
	1.0	2.0
A Direction		
0.3	71	60
0.5	83	50
Depth averaged value	77	55
B Direction		
0.3	69.50	41
0.5	71.50	52
Depth averaged value	70.5	46.5
C Direction		
0.3	55	33
0.5	66	58
Depth averaged value	60.5	45.5
D Direction		
0.3	50	41
0.5	69	33
Depth averaged value	59.5	37
E Direction		
0.3	52	35
0.5	56	40
Depth averaged value	54.0	37.5

All concentration in (Mg/kg) soil

Table 6. Sulphate concentration in soil collected near onsite sanitation system.

Depth(m)	Longitudinal distance (m)	
	1.0	2.0
A Direction		
0.3	95	75
0.5	110	75
Depth averaged value	102.5	75
B Direction		
0.3	85	65
0.5	95	70
Depth averaged value	90	67.5
C Direction		
0.3	95	45
0.5	95	55
Depth averaged value	95	50
D Direction		
0.3	60	55
0.5	65	50
Depth averaged value	62.5	52.5
E Direction		
0.3	40	60
0.5	45	45
Depth averaged value	42.5	52.5

All concentration in (Mg/kg) soil

unit for chloride concentration in drinking water sample is mg/l. since equivalent weight of chlorine ion is equivalent to molecular weight of chloride. Meq/l=ppm=mg/l. In case of nitrate, phosphate, sulphate, concentration is extracted in 1 kg of soil in 1 litre of distilled water.

Hence mg/kg soil –mg/l

E-coli (CFU/100 ml): The density of *E. coli* varies from $0.2x10^4$ to $0.5x10^4$(CFU/100 ml) in the soil near onsite sanitation during non-monsoon and monsoon seasons. It can be observed that the movement of *E.coli* (CFU/100ml) is toward direction-A in both monsoon and non monsoon season. The *E. coli* presence may be due to infiltration of leachate from onsite sanitation system. The *E. coli* travels up to 3 m and 5 m respectively, during non monsoon and monsoon seasons in soil near onsite sanitation system. These findings are similar to the studies conducted by Dyer (1941), Banerjee (2011) on microbial movement in soil near onsite sanitation system in India.

Conclusion

It can be concluded that the movement of pollutants leached from onsite sanitation system is more towards downstream direction compared to other directions. Since public borewell is located in the downstream of septic tank and the pollutant movement towards bore well will not causing any groundwater contamination. The study also concludes that the present distance between wells and latrines with hygienic conditions are sufficient to prevent groundwater contamination. Vertical distance of 2 m between bottom of pit and water table is found to be sufficient as water table is well below the ground surface in the study areas. As per Indian national building organization, Government of India, New Delhi (1989), a horizontal distance of 10 m distance between onsite sanitation and groundwater source and vertical distance of 2m between bottom of pit and water table is found to be sufficient.

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