Groundwater quality impairment due to mismanagement of biodegradable waste

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Abstract — **unplanned rapid urbanization during the post globalization period has led to the spread of many urban pockets without appropriate infrastructure such as sanitation, waste management facilities, etc. Most of the wastewater generated is discharged to storm water drains with partial or no treatment and this water ultimately gets discharged to water bodies due to interconnected network of lakes in Bangalore. The city generates 3000-4000 tonnes of solid waste and the government has identified waste disposal or landfill sites at outskirts. However due to lack of appropriate regulatory mechanism the waste collected from respective wards are being dumped in drains, lake beds or open area. Indiscriminate and continuous disposal of solid and liquid waste has affected the natural resources – land and water. The current study focuses on the assessment of impacts of waste mismanagement in the city. Groundwater quality assessment has been done in the buffer zones of water bodies as well as illegal solid waste dumps. Overlay of environmental parameters along with water sources reveal higher levels of nitrates due to the sustained inflow of wastewater to the water bodies and also due to transport of leachate (with nutrients) from dump sites. The groundwater wells closer to sewage fed water bodies or illegal waste dump has higher levels of nitrates pointing to the contamination of water due to mismanagement of waste in the city. Flooding in the city at some pockets is due to dumping of solid waste and resultant clogging of drains.**

Index Terms— **Solid waste, liquid waste, unscientific disposal of solid waste, water bodies, Groundwater**

I. INTRODUCTION

Bangalore has been experiencing rapid urbanisation evident from the concentrated growth of core region and sprawl at outskirts. Temporal land use analyses show 584% growth in built-up area during the last four decades with the decline of vegetation by 66% and water bodies by 74% [1]. Analyses of the temporal data reveals an increase in urban built up area of 342.83% (during 1973 to 1992), 129.56% (during 1992 to 1999), 106.7% (1999 to 2002), 114.51% (2002 to 2006) and 126.19% from 2006 to 2010.

The city is located on a ridge and the natural water courses along the three directions are Vrishabhavathi, Koramangala-Challaghatta (K&C) and Hebbal-Nagavara valley systems. These water courses are today being used for the transport and disposal of the city's sewage. Most of the sewage and wastewater generated is discharged directly into these storm water drains that ultimately link to water bodies. The shortfall or lack of sewage treatment facilities has contaminated the majority of water bodies [2].

The city generates around 3000-4000 t/d of USW and organic component constituent >70% [3, 4, 5]. The existing solid waste treatment system in the city is not very effective resulting in large scale disposal of biodegradable organic waste at open dump sites. Waste generated in the city has increased significantly and most wastes are being openly dumped at about 60 known dumping sites and many unrecorded sites [4, 6]. Open dumping has become a common practice of waste disposal. It generally occurs near accessible public and private open land, fallow agricultural land, road sides, at the foot of hilly regions and near water bodies or open sewer channels [7, 8]. It mainly consists of household waste and in some cases construction debris.

Biodegradation of organic wastes in open dumps through the breaking down of simple compounds by aerobic and anaerobic microorganisms releases gas and leachate. The leachate accumulates at the bottom of the dumpsite and starts percolating through soil as rain water infiltrates through the piled waste. Leachate generated from these open dumps consists of inorganic ions, organic constituents apart from trace metals, etc. Generated leachate quantum and characteristics is dependent on the age and composition of waste and quantum of rain [9]. Thus, improper management of solid waste is a serious environmental concern as it contaminates groundwater, surface water and soil.

Household waste with both inorganic and organic constituents is heterogeneous in nature and requires longer degradation time leading to a longer period of contact of leachate with soil or water bodies. The sustained dumping of wastes without any treatment, leads to the contamination of groundwater resources [10, 11]. The impact of leachate generated from solid waste has been studied in recent years [12, 13, 14, 15, 16, 17, 18]. Solid wastes are also dumped near

or into the water channels or drainage channels which causes clogging of drains due to non-degradable inorganic wastes. Lack of appropriate treatment facilities for treating wastes (solid and liquid) has contaminated surface water resources. This is evident from higher instances of disease vectors and occurrence of water borne diseases, profuse growth of invasive water weeds, which necessitates regular monitoring of water quality for public health and environment.

The present communication assesses the implication of mismanagement of organic fractions of waste (solid and liquid) on the other natural resources. The study involves spatial analyses of water quality in and around i) water bodies receiving untreated or partially treated sewage and ii) in the region proximate to unauthorized dumps of solid waste..

II. MATERIALS AND METHODS

A. Study area

Bangalore city is situated within the latitudes 12°39'00'' to 13°13'00'' N and longitudes 77°22'00'' to 77°52'00'' E covering an area of 741 km^2. Bangalore city population has increased enormously from 65,37,124 (in 2001) to 95,88,910 (in 2011), accounting for 46.68 % growth in a decade. Population density has increased from as 10732 (in 2001) to 13392 (in 2011) persons per sq. km [1]. Rapid urbanization in recent times has led to 632% increase in builtup area (from 1973 to 2010) and the loss of 78% water bodies and 76% vegetation cover [1]. Sewage generated in the city is either untreated or partially treated that finally gets into these water bodies leading to the enrichment of nutrients due to the sustained inflow. Bangalore city, one among the five metros in India. About 60% of the MSW collected was dumped at unauthorized dumpsites located around Bangalore. A 10km buffer was considered around the city to account peri-urban area with illegal open dumps (Fig 1).
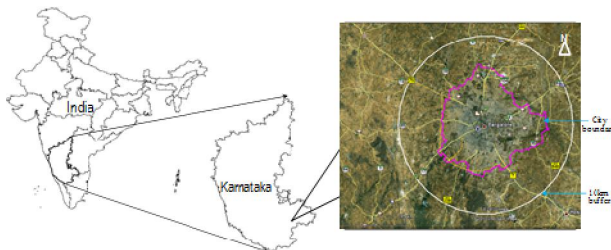

Figure 1. Study area Bangalore city boundary

B. Data collection and sources

The work involved collection of data through experiments, government agencies, spatial analysis of compiled data using geographic information system (GIS). Field survey was conducted in the year 2011-2012 to i) find open dumpsites and ii) check the drainage blockages due to clogging of waste. GPS (Global Positioning System) was used to capture the dumpsite locations.

A random sampling method was used for field observations of solid waste dumps. A total 62 open dumpsites and 93 locations of drainage channels were surveyed. These open dumpsites were located at peri-urban areas in the peripheral area of the city (Fig 2). Simultaneously, each of the sites was photographed using a digital camera apart from quantification of organic fraction of waste. These dumpsite locations were spatially analysed using GIS [19]. 33 water bodies were chosen for the current analysed and most of them have been receiving sewage since long time (Fig 3). Water quality values of groundwater wells located in the close proximity (<250m) of sewage fed lake or open dumpsites were assessed. Nitrate level for water bodies located closer to open dumpsites were compiled from various literatures [20, 21, 22]. All spatial analyses were performed with Mapinfo software 7.4.

III. RESULTS AND DISCUSSION

A. Survey of illegal dumping of waste

A total 62 open dumpsites were surveyed near the major water bodies of the city. These locations was spatially distributed in all the four zones i.e. NE (North-East), SE (South-East), SW (South-West) and NW (North-West) of the city. There were 21, 28, 11 and 2 dumpsite locations which were located in NE, SE, SW and NW, respectively (Fig 2).

These sites were classified into seven categories based on their predominant composition of waste. These categories were identified as plastic, organic, construction debris, indeterminate (mixed up fresh wastes making segregation difficult), old (older waste where organic waste components are already degraded), and other (non-household wastes from industry, hospital, etc.). These predominant categories are based on the percentage of waste volume at the dumpsites. At 47% of the locations, construction debris was predominant in the wastes, as many construction activities were happening in nearby areas. Organic waste, plastic waste and rejects from recycling units were located at 26%, 24% and 3% of open dumpsites. These locations were spread in 2.6 ha of land area and the average dump height was 0.6 m.

Wastes are also dumped in drainage network. A total of 95 locations of drainage channels were observed during the rainy season of year 2011. Among these locations, 37 were slow flowing, 47 had a moderate flow and only 9 locations had a rapid flow. Presence of solid waste in drainage channels is very common in all slow to fast flowing drainage channels; almost 95% of the locations had the presence of solid waste. Generally, a large number of locations had plastics and cloths that clogged the flow path or the channels under the various bridges. However, at few places styrofoam, building debris and organic wastes along with plastic and cloth were also observed to choke the flow path [8].

B. Water qualities of water bodies and ground water

A number of studies show that most of Bangalore's lakes are polluted [2, 20, 22, 23, 24]. Dumping of solid waste in the lake bed and in catchment has contributed to the contamination of water bodies. Disposal practices of direct discharge of sewage and waste water into water bodies are major reasons for contamination of surface water in the Bangalore. In anthropogenically modified, weed-infested streams from upper reaches, deoxygenated water (DO = 0-0.3ppm) arrives for most part of the day, due to high flow rates of water through extensive weed mats. The influx of hypoxic, nutrient rich wastewaters during the day is more stressful to aquatic biota as fish and invertebrates that undergo higher metabolic rates during the day require a higher DO than in the night.

A physico-chemical and biological analysis of sewage-fed Varthur lake in Bangalore highlight of prevailing anaerobic conditions (0mg/L) at the inlet. The profuse growth of floating macrophytes was observed in summer and winter seasons. Alkalinity, TDS, conductivity and hardness values were higher when compared to earlier studies. Enrichment of nutrients in sampled lakes has contributed to eutrophic status. The entry of untreated industrial pollutants in Bangalore's lakes has been documented [20, 25, 26, 27]. Ammoniacal N was reported in urban lakes such as the Hosur lake (16-30mg/l), Varthur lake (>3mg/l) and Bellandur lake (31mg/l) [22, 28, 29].

Ammoniacal nitrogen is often found in sewage, waste water and leachate generated from solid waste unscientific disposal. Ammoniacal N gets converted to ammonium ions and ammonium ions are nitrified and are converted into nitrate. Nitrate level is measured in six lakes and given in Table 1, which shows that at outlet of most of these lake's nitrate concentration ranges from 5 to 7.4mg/l.

C. Linkages between surface water bodies and ground water resources

Temporal analyses indicate the decline of 34.48% during 1973-1992, 56.90% during 1973-2002 and 70.69% during 1973-2007 in the erstwhile Bangalore city limits. Similar analyses done for Greater Bangalore (i.e. Bangalore city with surrounding 8 municipalities) indicate the decline of 32.47% during 1973-1992, 53.76% during 1973-2002 and 60.83% during 1973-2007. This is correlated with the increase in built-up area from the concentrated growth model focusing on Bangalore, adopted by the state machinery, affecting severely open spaces and in particular water bodies. Some of the lakes have been restored by the city corporation and the concerned authorities in recent times. These lakes have a well defined boundary, clean water and are maintained by the neighbourhood people. These lakes are used for recreational purposes. They are home to migratory birds and also add aesthetic beauty to the surroundings. Disappearance of water bodies and a sharp decline in the number of water bodies in

Bangalore is mainly due to intense urbanization and urban sprawl. Many lakes were encroached for illegal buildings (54%). Field surveys (during July-August 2007) show that nearly 66% of lakes are sewage fed, 14% surrounded by slums and 72% showed loss of catchment area. Also, lake catchments were used as dumping yards for either municipal solid waste or building debris. The areas surrounding these lakes have illegal constructions of buildings and most of the time slum dwellers occupy the adjoining areas [6].

Assessment of groundwater table highlights the decline of groundwater table to 200-250m with the removal of lakes as against 30-40m before removal of water bodies. Some localities with intense urbanisation the groundwater table has dipped to 300-400m. This highlights the linkage of groundwater sources with surface water bodies.

Groundwater quality in the vicinity of water bodies and solid waste open dump were assessed by considering the wells in the buffer of 250m of water body/open dump. Higher nitrate levels in the immediate vicinity of contaminated water bodies and open dumps corroborate the ground water quality linkage with other natural resources (soil and surface water bodies). The ground water quality in the catchment of nineteen sites closer to unauthorized dumpsites are more than the desirable limit (<45mg/l) as shown in Fig 4.

The nitrate content in Bangalore's groundwater was varying from less than 1mg/l to 554mg/l with an average of 38.34mg/l [21]. Also nitrate level in ground water is more than the contaminated surface water bodies due to longer residential time (ammonia available in surface water converted into nitrate) and sustained inflow of sewage concentrates nitrate levels in ground water. This highlights the need for immediate interventions in solid and liquid waste treatment to prevent further contamination of ground water.

TABLE I: WATER BODIES NITRATE CONTENT AND NEARBY LOCATED NUMBER OF UNAUTHORIZED DUMPSITES

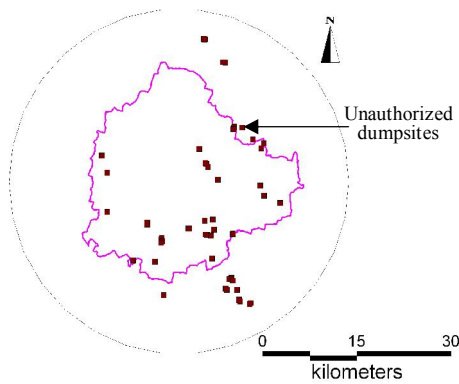| Water body	Number of dumpsite locations	Nitrate content (mg/l)	Reference
Gaudankere	1	6.71	[21]
Herohalli	1	6.35	[21]
Madivala	2	I=15.83, O=5.06; I=0.62, O=0.62	[20, 21]
Varthur	1	I=8.02, O=7.43; I=1.74, O1=1.57, O2=1.7	[20, 21]
Veerasandra	2	6.29	[21]
Yellamallappachetty	2	I=6.43, O=5.78; I=2.57, O=0.39	[20, 21]

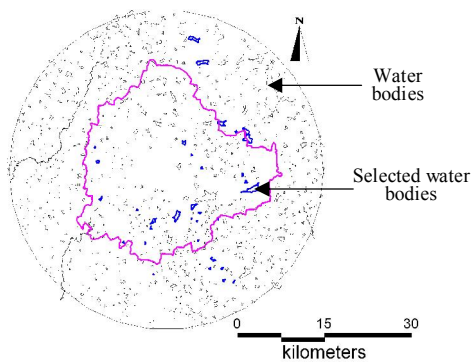Figure 2. Bangalore with unauthorized dumpsites

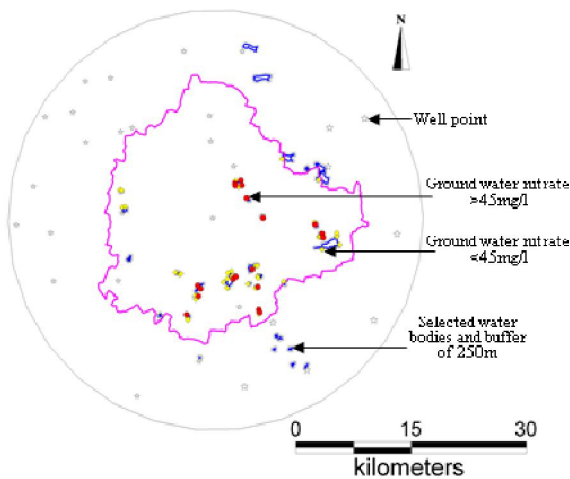Figure 3. Bangalore with selected water bodies

Figure 4. Ground water nitrate concentration range [21], well points and selected water bodies near to illegal dumpsites

IV. CONCLUSION

The existing practice of waste discharge and disposal near water bodies are creating nuisance in the environment. Nitrate level in ground water and surface water are assessed to check the impacts of waste mismanagement in urban area. At 19 locations near to unauthorized dumpsite and water bodies show higher levels of nitrate in ground water. Reason could be related to continuously increasing load of direct inflow of sewage, waste water and leachate in water bodies. As there are no other possible reasons for increasing level of nitrate in ground water, so, mismanagement of waste has significant impact on water quality parameters. This highlights the need for immediate interventions for waste treatment to avoid further contamination of ground water.

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