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Assessment of solid wastes choking open sewers and vulnerability to urban flooding

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Abstract

This paper describes the extent of urban flooding caused by solid waste disposed in open urban sewers within city corporation area. The typical locations where USW is discharged and the locations most vulnerable to disposal /floods as well as the conditions favoring choking /blocking and subsequent flooding has been studied along with the impacts of solid waste on drainage network in Bangalore city during the rainy season of the year 2011. Random surveys were conducted in flood prone areas to determine locations where floods occur due to solid wastes blocking sewage and storm water flow. Around 50% of main drainage locations were checked. Survey was initiated based on available local information and literature. Flooding indicators were clear and enabled us to delineate this from non flooding area. Three flooding areas were selected based on the level of flooding and waste accretion. Interviews were also conducted in all the three locations to know flood associated damage. The results showed that waste was present at almost 90% of total visited flood locations and were the likely cause of open sewer choking and temporary floods during peak discharge. Drainage channels were either narrow or partially to completely blocked with solid wastes. Plastics and clothes were the main constituents of solid waste present in such choked waterways - sewers. Understanding of such choking events also helps to determine the patterns and characteristics of drainage streams where solid waste can accumulate and cause urban flooding.

Key Words: solid waste, drainage, field survey

Introduction

As cities grow and develop, the urban landscape undergoes a high degree of change. Most often the natural water courses and waterways maintained in the past suffer encroachment both planned and unplanned – legally and illegally. As a result the flow cross section is rapidly reduced resulting in frequent flooding in wet weather. Secondly, as cities develop and expand, the once fringe areas with lots of open land is converted to concreted surfaces or built up area. As a result of this the level of infiltration of rain water is greatly reduced and the volume of run-off greatly increased. The narrowing of natural water courses as well as increased run-off contributes to urban flooding. In addition, in many developing country cities such as India, flooding in metropolitan cities has become a common problem largely due to reduction of passage for natural drains due to illegal or poorly planned developmental efforts (Gupta and Nair, 2011; Gupta and Nair, 2010; Ramachandra and Mujumdar, 2006; ENVIS Report, 2005). The causes of such urban flooding are therefore significantly different from other types of flooding like river flooding or coastal flooding that occur as one time events. The consequences of such urban flooding can be classified into three categories: a) direct consequences (material damages), b) indirect consequences (traffic detours) and c) social and economic consequences (Konig *et al*., 2002).

In many of urban areas in India after a short length of flow of sewage underground (200mm to 1200mm dia pipes), the sewage pipes are no longer able to take the large flow. The combined sewage from these large pipes generally flows in open sewers – sewers that were originally storm water courses. These now carry sewage continuously and occasionally storm water from intense weather events. When these are choked or encroached to a point of being too narrow, the water flow spills over its banks into nearby settlements. This occurs generally following high intensity rainfall wherein the sewer /open storm drain can no longer take the large combined water flow. Among the many reasons which cause urban flooding in such water courses / open sewers are a) encroachment of drain and reduction of flow area, b) improper maintenance of drainage /sewer system, c) blockages of drainage channels by USW dumped along its flow path upstream of these sensitive points. The most common reasons found for such blockages are a) accumulation of silt or dumped debris or b) disposal of solid waste in the channel.

Poor and unplanned solid waste management and insensitive attitude among the upstream residents results in USW being dumped into the open sewers (Figure 4). Such dumped USW cannot be transported through these narrow streams and results in sewer blockages (Kolsky and Butler, 2000). Solid wastes which enter the drain comprise mainly of fermentables, cloth, plastic and paper. Fermentable organic wastes of the dumped USW (e.g. food and garden wastes) as well as paper are rapidly degraded under such wet conditions leaving behind a predominantly non biodegradable complex of wastes that occasionally flows in the sewers or remains stuck at vulnerable points along the water course. These non biodegradable wastes flow along with sewage in these drainage channels and gradually accumulate at shallow regions in the path where the flow rates are very low or the wastes encounter physical obstruction due to a shallow nature – especially when the only sewage is flowing in these streams. The extent of such mass accumulating at specific points along the flow gradually increases with increasing quantities of USW being discharged into the streams. Following high intensity rains that lead to a large runoff, the water level in these drains rise and releasing all the obstructed USW components especially accumulated plastics and cloth that do not undergo rapid degradation. The sudden influx of water as runoff carrying with it a large volume of non-degradable materials (cloths and plastics) results in the narrow sections of the sewers /flow channel becoming choked with these wastes and concomitant rise is water levels to create a local flood. As such flows are ephemeral the occurrence of flooding is also short lived. Therefore it is not easy to delineate areas where floods had occurred after the event. As most of such events occur very late in the evening – cloudbursts, the floods are also generally later in the evening or at night and are difficult to record. Only traces of the flood events are recordable from visible traces of waste accretion. Water mark on house walls, compound walls, fences or electricity poles remain the sole indicators of flooding and the water level reached. Pieces of wastes hanging on fences or adhering to drainage walls, bridge railings or water and drainage pipes crossing the water stream or found hanging on nearby vegetation indicate that clogging of the flow by solid wastes could be one of the reasons for the flood. Typically it is found that the flow path under the bridges built over these drains also carry water supply pipes, communication network pipes, electricity cables, etc. all of which also significantly obstruct the flow when the water levels are high. These also act as filters for a large quantity of cloth and plastics that can potentially block the flow when water levels are high and result in flooding. In this paper we examine the instances of such cases and record the vulnerability of the drainage system to such events of choking and flooding.

Bangalore city generates around 3600 tons of urban waste daily (Chanakya *et al*., 2009). There are three waste treatment and disposal facilities; Mandur, Mavallipura and KCDC (Karnataka Compost Development Corporation, now not working). Mavallipura and Mandur have capacity to treat 600 tpd and 1000 tpd of waste (BBMP report, 2010). City has both type of collection facilities; door-to-door as well as community bin collection. The door to door collection system is either incomplete or not easily accessible to many in slums depending upon the layout and placement of common bins. Generally a large number of slums have come up in these low lying areas surrounding these storm water drains. In all such cases solid wastes are dumped near or into the water channels – and sometimes on land but very close to the eater channel. Sometimes the collection facility is not regular. In all such cases solid wastes are dumped into the drainage network – even if there is a high fence to prevent such events. USW dumped in various parts of the storm channel /open sewers is gradually carried to locations of shallow and slow flow where they tend to accumulate till a storm event carries this large mass away. Such large floating mass easily chokes the narrow path below road bridges and results in flooding. In this paper we examine patterns of such choking in order to determine if there exist alternatives that could avoid such choking and flooding. However, controlling such flooding may not be very straightforward as USW deposition occurs all along the course while these could cause flooding only in specific locations. Marking of such vulnerable points, anticipation of peak rainfall events and preventive activities could greatly arrest or avoid flooding in areas where solid wastes is the major cause. This article focuses on flood prone locations of the city and develops indicators to identify the flooding region due to poor solid waste management.

Material and Methods

A digital elevation model (DEM) was created for Bangalore city using ASTER image of 30m resolution to analyze water catchment areas and drainage basins within the boundary of the city. There are three water catchments and drainage paths in the city namely Vrishabhavathi, Hebbal, Koramangala and Challaghatta valley systems (Fig 3).

Figure 1: Details of channel flow.

Figure 2: Details of the three study sites subject to urban flooding. Photo insets indicate the choked area while stagnant water in larger photo shows blockage of regular flow.

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2c. Near Cox Town

Table 1: Details about three major flooding area

Sr. No.	Area	Type of flow	Duration of flood (hrs)	Average flood height (m)	Waste details
1	Near Anjanapura temple (Bapuji Nagar, Byatarayanapura and Kavika layout)	Mixed pockets of slow & fast	3	0.9	Plastic, paper and construction waste (Fig 2a)
2	Near National Games Village (Anepalya, Dr. Ambedkar Nagar and Yellar Nagar)	Slow	3.5	0.9	Plastic, paper and organic waste (Fig. 2b)
3	Near Cox town (Assaye Road and Kenchappa Road)	Slow	2.5	0.8	Plastic and cloth (Fig. 2c)

There are four methods to check the drainage performance; resident survey, direct observations during floods, chalk gauges and electronic sensors (Kolsky and Butler, 2002). Electronic sensors are costly and require protection from vandalism where as Chalk gauges are low cost and require frequent visits to site. In this study we adopted direct observations post flooding along with verification by interviews with selected residents of the area. Water marks and wet patches after flooding were used as indicators of the levels to which water had risen. The duration of the flooding was determined as an average from interviews with residents. The residual blockages and materials causing blockages were firstly observed visually and detailed photographs were taken. From the visual estimate of the blocking material as well as from the photographs the composition of the blocking material was estimated (Sathiskumar et al., 2005).

Field survey was conducted for three months in 2011. It was divided into two phases. Survey was initiated based on local information, news of flooding in newspapers and other available literature that recorded past events of flood prone areas. The first survey was conducted in rainy season (in the month of Jun-July) to determine the exact locations, the points most vulnerable and typical causes that could be measured. This helped arriving at a suitable methodology to monitor and record such events including causal factors. Among the identified vulnerable sites, three segments representing around 50% of major drainage flooding locations were monitored. About 1-4km upstream of these locations were also observed to understand the sources, extent and types of USW disposal into the water channels. A total of 97 points around the path of the drain were observed along with a hand held global position system (GPS, Garmin 60/72). All drainage locations recorded were classified into three categories of flow, namely, *slow* flowing (<0.5m/sec), *moderately* fast flowing (0.5-2m/sec) and *very rapidly* flowing (>2m/sec) regions of the drain. These are put out in Table 1 and Figure 1. Drainage channels were monitored starting from their origin in the upper reaches within the city up to locations where they merge to form very large flow type of drainages /sewers carrying more than 100 MLD of sewage. These smaller drains /sewers finally drain in to the Vrishabhavathi stream (valley) to the South-West direction (400 MLD), to the north east into the Hebbal valley (north east direction) and third into the Koramangala and Challaghatta valley (400 MLD) in the South-East direction.

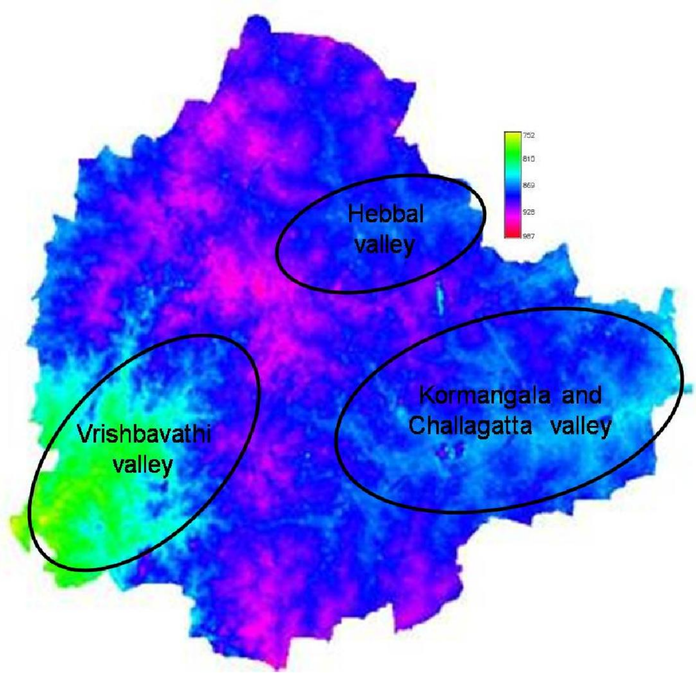

Fig 3: Digital elevation model (DEM) with drainage valley area of the city

Direct observations during floods gave a detailed understanding of the extent, type and frequency of urban flood pockets. Flooding indicators were easy to delineate from non flooding area. Chain link and masonry fences around the drains provided various signatures of past flooding and thereby the levels to which the water had risen during these flood events. As mentioned earlier, chain link and barbed wire fences and stone masonry walls in the flood zone trap various objects from the floating USW in the flood event that is discernible immediately after the flood event. Similarly wet patches or USW objects hanging around the trees, bushes or other plants close to drainage as well as extensive scattering of drifted USW indicated that such large quantities of USW could be the causal agents of flooding in that specific area. From this survey, three flooding areas were selected based on the level of flooding and waste accretion. In all these locations drainages were either narrow or partially blocked with solid waste.

The second survey was conducted in the selected flooding region of the city. The selected areas were Anjanapura temple, National Games Village and Cox Town. These have been identified flood prone areas of Bangalore (Gupta and Nair, 2011). In these localities watermarks of the flood were very clear on the walls of houses or commercial places. We conducted interviews with at least three local residents in each location to find out the flood level within houses, frequency of flood and duration of flood. The flooding frequency, extent, depth and duration were recorded in interviews and from the abovementioned water marks (Kolsky and butler, 2002). We also measured the depth of water flowing in all the three locations to know the general water depth in drainage. GPS were used to find the elevation of drainage channels. All the GPS points were taken at less than 1 meter distance from channel to avoid the associated errors.

Results and discussion

Fig 3 shows the drainage path along which the sewers flow out of the city. This image was generated with the help of DEM, which ensure the real existing catchment boundary of the city. Table 1 and Figures 1 give details about sewage flow pattern observed in the surveys. Among the study locations 37 was slow flowing, 47 were moderate flow and only 9 locations had rapid flow patterns. The slow and moderate flow streams observed were all encroached upon and were substantially silted and observably littered with solid wastes (Figure 4). Presence of waste in drainage channels is very common in all slow to very fast drainage channels, almost at 95% locations waste was present. Generally large number of locations had plastics and clothes that clogged the flow path or the channels under the various bridges. However at a few places Styrofoam, building debris and organic wastes along with plastic and cloth were also observed to choke the flow path (Figure 4-5).

Fig 4: Drains littered with solid waste. Picture on left shows clear signs of flooding

Fig 5: Solid wastes in storm water drains which can choke the water flow under peak conditions.

The presence of undecomposed organic wastes showed firstly the origin (namely house holds, hotels or commercial establishments) and second that this heap was of recent origin. The presence of unfermented food and leaf wastes indicates that these decomposable materials did not have adequate time to degrade and therefore is of recent origin. From observing a few marker species, cabbage, onion, potato etc. we could determine the age of wastes and by various toys as to where these originated China, etc. Most of the fresh wastes were observed only on the banks of the streams and not actually in the stream. As much of the components of domestic wastes is of food origin in Bangalore, it is expected that all fermentables suffer a rapid degradation and become indistinguishable in a very short time. Typically, organic waste takes around 5-30 days to degrade. Therefore ultimately only non biodegradable materials like plastic and clothes are left undecomposed in the stream. Usually, construction waste or debris settle in drainage channel and decrease the depth of the drainage network. When present in large quantities it gets accumulated near the edge of the channels and making the flow path narrow. Generally, the habit of many residents who throw garbage in channel has made the stream slow and narrow. All these prevent the free flow of water (Oriola, 1994). Most people who use the sewer as a USW disposal location generally believe that these wastes will flow away with water without causing any harm downstream. In urban area drainage encroachment starts with disposal of construction waste near the edge of these drains or water body. Initially it will be temporary later on with its continuous disposal will cause permanent encroachment of channel or water body. Presently, with the scarcity of land area or due to lack of proper waste management, waste disposal near drains has become a very common phenomenon in urban city.

Urban flooding has become an annual event in Bangalore city. The city has quasi centralized collection system with 75-90% of waste collection efficiency, which is satisfactory and make the city clean (Chanakya *et al*., 2009). Yet when drains pass by slum areas, a lot of USW is disposed in or around these drains. This suggests that the USW collection system is either absent, inaccessible or inconvenient to these users. This prompts them to throw their USW into the storm water channels /sewers nearby. Similarly, many commercial places also have an inadequate daily collection system and a lot of commercial wastes end up near these drainage channels /sewers. The composition of commercial waste is different from household waste and is characterized by a high content of plastics and paper and a lower content of fermentable matter (Chanakya and Sharatchandra, 2005). To avoid such wastes entering drains it requires providing very efficient collection system in such sensitive areas compared to the rest of the city.

Table 2 and Figure 2 give detailed views about the three main flooding areas studied (near Anjanapura Temple, Yellar Nagar near National Games Village (NGV) and near Cox Town; 2a,b&c respectively). All the three areas have a problem of annual flooding. Near NGV heaps of wastes were observed in this slum. This suggested that the waste collection system was not efficient and regular. It was found from interviews that all the three study locations flooded after 4h of continuous rainfall. All three locations had USW disposed off on their banks firstly reducing the width of the channel and secondly permitting a lot of USW to fall into the sewer and obstruct immediate flow and third provide a very large mass of USW to be carried along during storm flow and choke the channel under the road bridge and thereby causing floods as well as to spread the USW in the flooded area. Fig 6 presents details about locations at which observations were recorded at the three study locations.

Conclusion

Urban flooding has become an annual event in the Bangalore city although it is situated on a very high ground and slopes in all directions. Much of the flood marks leaves behind a lot of USW in its wake and it is often suspected that the presence of a large load of USW chokes the water flow under road bridges, especially in low lying areas and causes water levels to rise and inundate the houses nearby. Three key locations of flooding were studied in detail and commonalities of flooding were observed. Firstly it is clear that being a low lying area and poor drainage caused by encroached drainages makes the location quite prone to flooding. Second, a large load of USW disposed into this drain upstream aggravates the situation by partially choking the water course under these road bridges to cause a temporary flooding. Third the presence of other pipes across the flow path provides barriers on which solid waste particles can adhere and allow the drainage path to be choked.

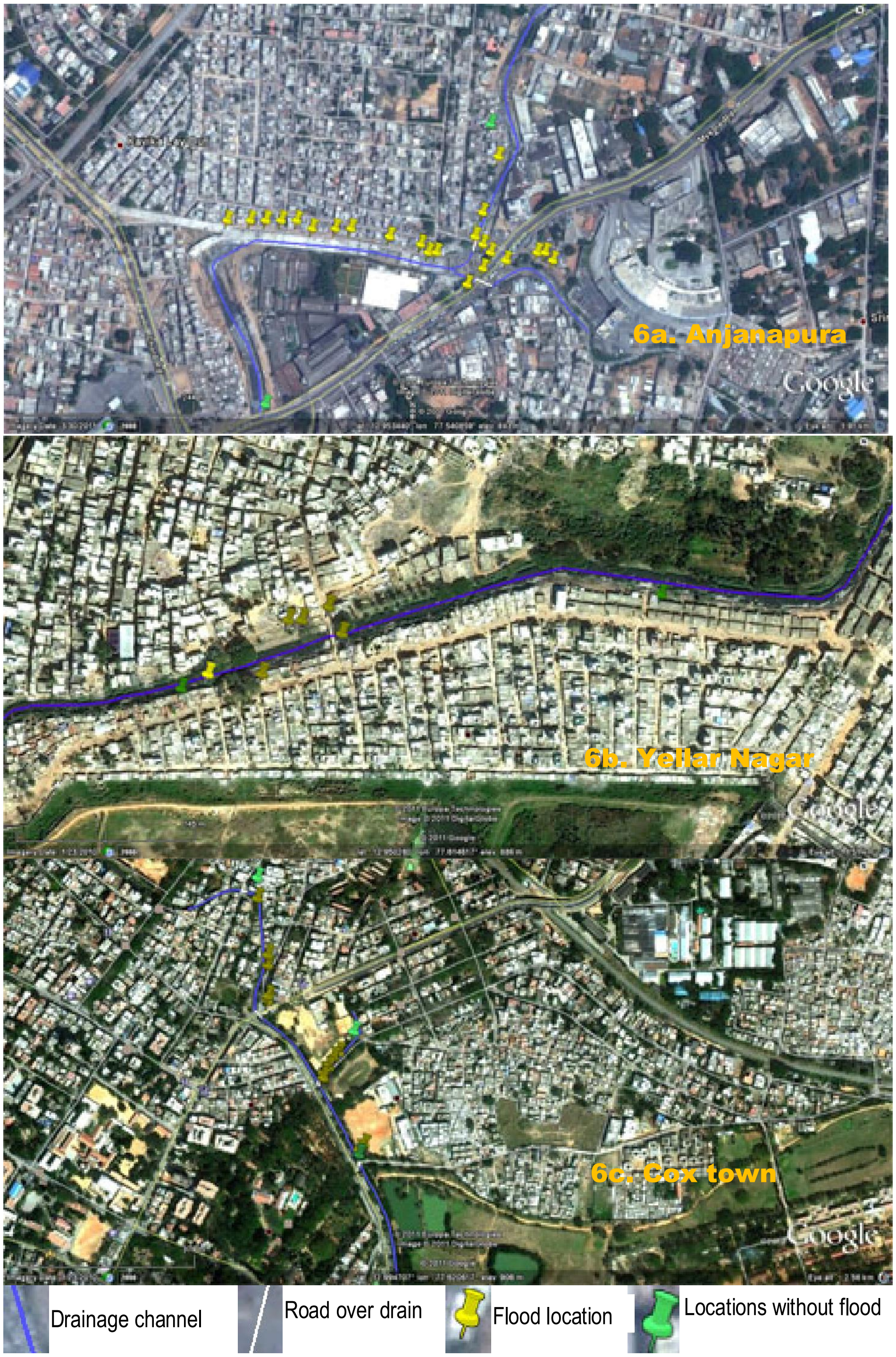

Fig 6: Details about three main flood areas taken up for study.

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