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OCCURRENCE AND GENERAL CHARACTERISTICS OF DEPOSITS IN THE ATHENS STORM SEWERS

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Abstract

The sewer system of the city of Athens is composed of a separate network at the most part and of a very minor segment of combined network serving the oldest part of the city. The maintenance of the network is inadequate. Therefore, no information is available about the deposits of sewer sediments within the network. A recent pilot investigation is summarised here, which showed that: (1) Deposits do exist in the Athens storm sewer system and may constitute a serious problem for the proper hydraulic function of the network. (2) The sediment discharge capacity of the network during moderate storm events seems to be modest, as deposits of very fine material were traced at certain locations. (3) The finer deposits have high organic loads (due to illegal connections and accidental spills of industrial sewerage in the storm sewers). These deposits are likely to develop some kind of cohesiveness because dry periods are usually long for the Athens climate.

Introduction

The sewer system of the city of Athens is composed of a separate network at the most part and of a very minor segment of combined network serving the oldest part of the city. The maintenance of the network is inadequate. Therefore, no information is available about the deposits of sewer sediments within the network. A recent investigation (Zarris, 1995) showed that there is a considerable problem with the deposits of the sewer sediments, which may affect seriously the proper hydraulic function of the network.

Sewer sediments are not yet considered as an important factor for designing sewers in Greece. The existing design guidance for avoiding sewer sediment deposits is very simple and most probably inadequate. It relies on a safe minimum slope for ensuring self-cleansing conditions, which is determined in such a way that the flow velocity for the 10% of the full-bore capacity ($Q/Q_0 = 0.10$) exceeds 0.3 m/s for foul water sewers and 0.6 m/s for storm sewers.

Today, new methods for a more realistic and efficient design of sewer networks have to be developed. This study is a preliminary investigation towards this direction, aiming at the identification of the related problems in current sewer networks in Greece. It examines the presence of the deposits in the sewers of Athens, their locations and general characteristics.

Objectives and study area

The study outlined here is concerned with the Athens storm sewer network and has the following objectives:

- Preliminary investigation of the network in order to get a clear picture of the situation of the network and to assess the problems caused by deposits.
- Sampling of the existing deposits and laboratory analysis in order to determine the properties of deposits (granulometry, organic load, etc.).
- Identification of the deposit characteristics and the locations of the network where deposits are most likely to occur.
- Explanation of the reasons of the formation of the deposits within the network by applying the appropriate hydraulic considerations.

The study area is a subcatchment of the Kifissos River, the main watercourse of Athens. The topography of the subcatchment is ideal for the purposes of this study (small surface slope) and the mixed land uses allow a more representative approach of the quality of the sediments.

Table 1 Characteristics of the study area

Subcatchment	Area (ha)	Population	Land uses	Runoff Coefficient
K27	920	200 000	Residential, Commercial and Industrial	0.70 (at average)

Four particular locations of the network have been investigated thoroughly twice in a two month period. The study area and the four locations are shown in Figure 1 below.

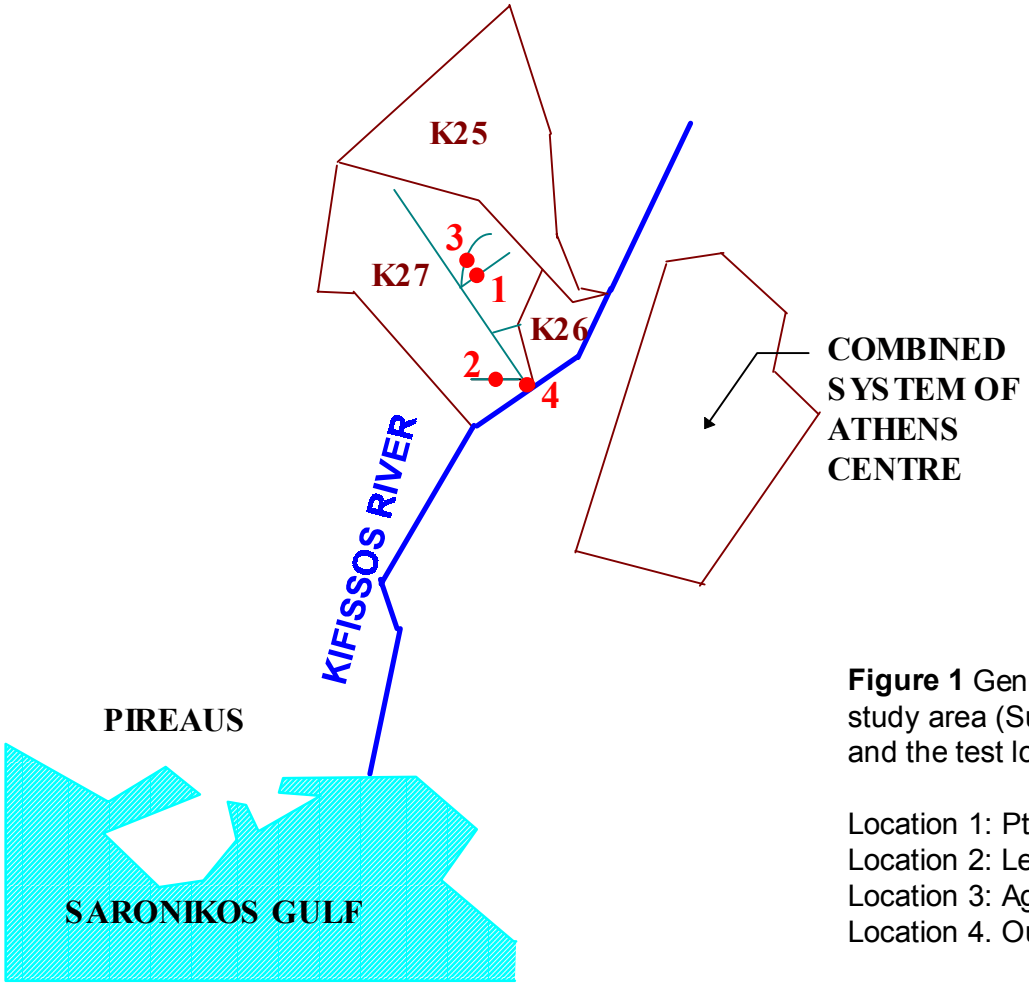

Figure 1 General location of the study area (Sub-catchment K27) and the test locations.

Location 1: Ptolemaidos St.
Location 2: Leventi St.
Location 3: Agias Lavras St.
Location 4. Outlet to Kifissos River

Results

The in situ investigation has shown that deposits are very serious as their depths in large interceptor sewers exceed 50 cm in depth. Four cases of deposits have been sampled and analysed in laboratory. The properties of the solids of the deposits are given in the Table 2 below. The results of the granulometric sieving are given in Figure 5.

Table 2 General properties of deposits

Location	Cross section shape and dimensions (cm)	d_{10} (mm)	d_{50} (mm)	d_{90} (mm)	Organic load (%)	Deposit depth (cm)
Ptolemaidos St. (1)	Egg Shape (130/195)	0.46	3.3	9.6	-	20-25
Ptolemaidos St. (2)	As above	0.26	4.3	12.6	-	20-25
Leventi St. (1)	Circular (70)	0.0168	0.155	2.0	30.3	8-10
Leventi St. (2)	As above	0.28	1.48	3.7	6.0	8-10
Agias Lavras	Egg Shape (105/225)	0.012	0.06	0.6	7.0	5-10
Outlet	Rectangular (2x200x250)	0.038	0.148	1.5	9.0	45-55

(1) First survey on 22 March 1995 (2) Second survey on 25 May 1995

Figure 2 Deposit in the circular sewer at Leventi St., upstream of a sewer bend. Survey on 25/05/96.

Figure 3 Coarse granular deposit in the egg shaped sewer at Ptolemaidos St., upstream of a sewer bend. Survey on 25/05/96.

Figure 4 Fine thick (50 cm) deposit in the outlet of the K27 sewer to the Kifissos River. Survey on 25/05/96. The outlet is submerged during intense floods of the Kifissos River.

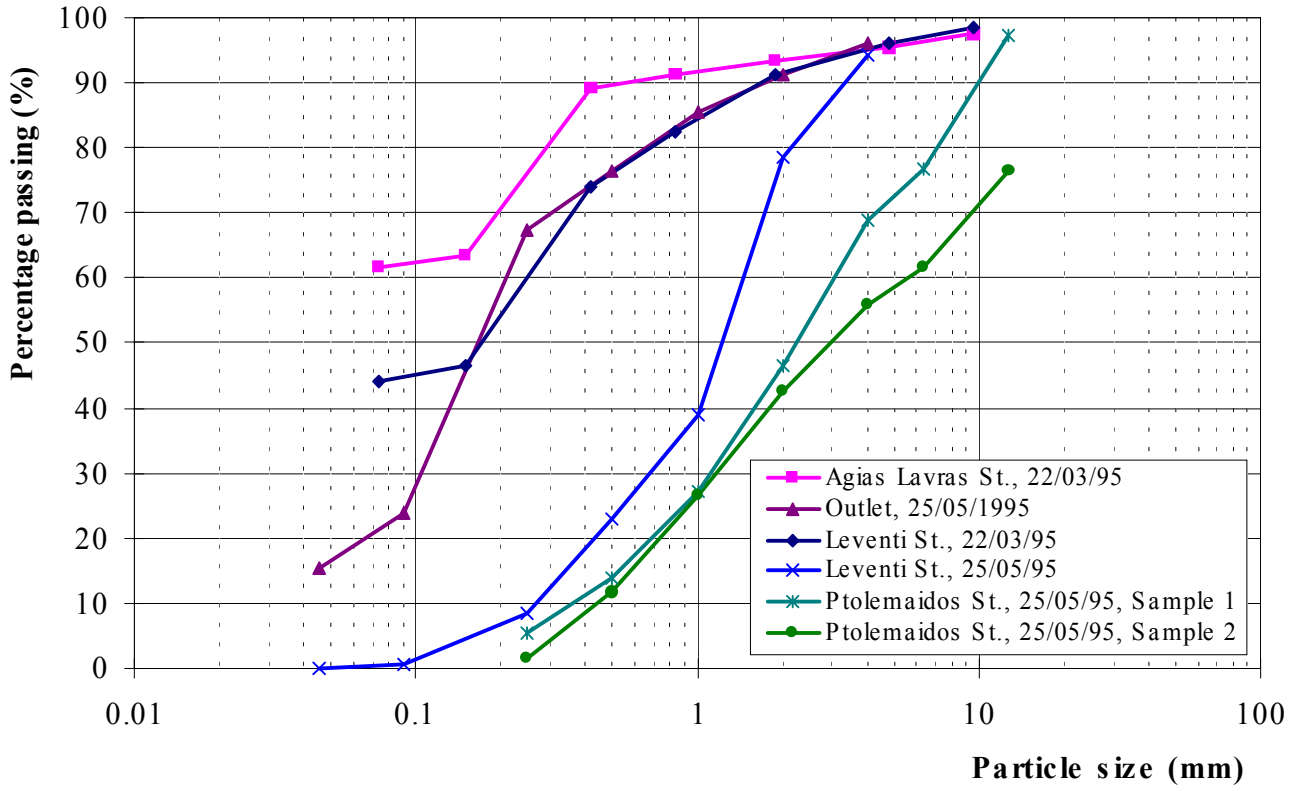

Figure 5 Granulometric analysis of the deposit samples. Notable is the existence of two categories, coarse-granular and fine. Also notable is the change of the deposit characteristics at Leventi St. from fine to coarse during a two month interval. Sample 1 of Ptolemaidos St. comes from the upper part of the deposit near the surface, while Sample 2 is from the lower part near the invert.

Interpretation of results

The results indicate that the following two categories of deposits typically occur in the Athens storm sewers:

- *Deposits from coarse and granular material at the upstream parts of the network* (more than 95% of the total mass consists of sand and gravel). As shown in Figure 5 there is no apparent stratification of the particle sizes on the entire depth of the deposit. After an intense rainfall the deposit surface was rough with a random appearance (without any regular form such as ripples or dunes). After a period of two months from the first survey when the preceding rainfall was modest this surface became plain.
- D*eposits from fine material at the downstream parts of the network* (30% of the total mass pass the 74 μm sieve). In two of the examined cases (Leventi St. and Agias Lavras St.) the deposits have impressively fine fractions (44 and 61.6% of the total mass respectively pass the 74 μm sieve). These deposits most likely have properties quite similar to the material known as “heavy fluid layer”. While the organic load of these deposits is generally high for storm sewers (more than 10% on average), the environmental damage at the start of a storm event (first flush) would be quite serious for the receiving waters, especially after a long preceding dry period.

Hydraulic considerations

Deposits occur at locations where there exist irregularities of the flow. Deposits are generally found at the following locations:

- Upstream of sewer bends without the proper fitting to eliminate form energy losses.
- Upstream of locations where the sewer cross section widens downstream.
- Upstream of locations where the sewer slope decreases downstream.
- At the outlets where there is no a hydraulic drop of the outlet sewer to the receiving waters.
- Upstream of a confluence with a more significant flow such as a major urban watercourse.
- Under low sewer slopes (generally less than 4 m/km).

Generally, the deposits are formed under subcritical gradually varied flow with more than one of the above factors occurring at the same time. The average bed shear strength of the deposits is not tested in laboratory but it seems to be higher than that estimated from the Shields criterion. The average shear stress of the surface organic layer of the fine deposits seems to be close to the value given by Nalluri and Alvarez (1992), i.e., about 2.5 Nt/m^2.

General conclusions

1. Deposits do exist in the Athens storm sewer system and may constitute a serious problem for the proper hydraulic function of the network.
2. The sediment discharge capacity of the network during moderate storm events seems to be modest, as deposits of very fine material were traced at certain locations.
3. The finer deposits have high organic loads (due to illegal connections and accidental spills of industrial sewerage in the storm sewers). These deposits are likely to develop some kind of cohesive shear stress because dry periods are usually long for the Athens climate.

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