3d printed pills to investigate mis-connections

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Abstract
Separate sewers are more and more preferred over combined ones but are sensitive to misconnections. Several inspection techniques (time consuming and expensive) are specifically devoted to detecting such misconnections: smoking test and dye tracing are the most popular. This paper presents a new, low-cost and easy to apply method based on 3D printed pills. Numbered (with a unique code) and coloured (blue or red) pills are thrown in toilets, washbowls etc. and then collected in sewers. After an automatic treatment of the collected pills in both the wastewater and the storm water system, the comparison between the sent and collected pill databases allows the identification and the location (inside the building itself) of the misconnections present. Pill and pill analyser designs, analysis methods and on-line tools are described on this paper. Social acceptability and legal issues are briefly discussed.

Keywords
3d printing, illicit connections, inspection technique, low-cost, separate sewers

INTRODUCTION

For sewer systems, the following general assumption is made: misconnections can come from inside one apartment or one house. Misconnections lead to several problems. In order to identify potential misconnections after the construction of a new sewer or for diagnosing of an existing one, there are several inspection techniques (Panasiuk *et al.*, 2015): the authors highlight the need of low-cost and simple techniques. Recently, 3D printing techniques have been developed and the creativity of researchers. This paper presents an application of 3D printing techniques for sewer inspection. The main idea is unsophisticated and obvious is summarized in this paper.

MATERIALS AND METHODS

Pills and the pill analyser

The specifications of the pills are: *i)* the pills must be cheap to be used by the everyone, *ii)* the pills must be eco-friendly because they might be lost during the exchange between the staff in charge of the diagnostic and the inhabitants or cannot be retrieved from the sewer system , *iii)* the pills must float to be easily caught downstream, and *iv)* the pills must pass most of the siphons (in e.g. washbowls) in order to have an easy insertion process (no need to dismount the facilities). Pills (Figure 1) made with PLA (Garlotta, 2001) having a relative density of 0.95 and is biodegradable. After the collection and cleaning, pills can be analysed manually or automatically with a smartphone connected to a laptop.

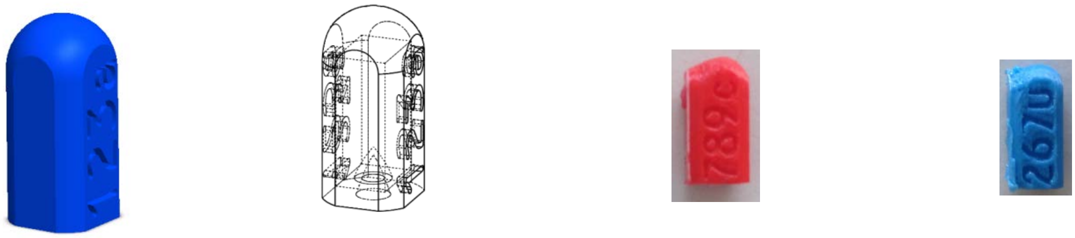

Figure 1. From left to right: 3d drawings (solid and line representations); red and blue pills.

A code has been written to analyse the pictures: Optical Character and Colour Recognition (OCCR) is done. Depending to the recognition, when positively identified the automatic pill analyser manages the spread of the pills to result buckets or, when not cleaning one with a system a pipe and seven solenoid valves. The system is controlled by Matlab®, a chassis and a control card for the valve and the stirrer below the cleaning bucket.

Method

Step 1. Distribution of the pills. Due to the low weight of the pills (0.2 gram per pill), some dozens of pills can be easily send by mail to every postal address connected to the sewer to inspect with instructions about the way to insert them.

Step 2. On-line tool and app to validate the expected database. A database needs to be constructed in order to know which pill has been inserted where. Inhabitants can choose two tools: i) a paper form, sent by mail with the pills and ii) a on-line tool accessible with Internet.

Step 3. Collection of the pills. Pills need to be collected in sewer or in surface water. The collecting device is under development.

Step 4: Colour and number recognition to identify misconnections. By comparison to the thrown pill database and the sewer where the pills were collected, the misconnection are identified.

RESULTS, DISCUSSION, CONCLUSION AND FURTHER WORKS

Two tests have been performed to ensure the reliability of the project. For the first one, pills have been spread to volunteers in our department to test the flush through siphons. The pills have been able to pass all the tested siphons. A second one has confirmed the robustness of the OCCR code. There are still two important questions linked to this new method. The first one is dealing with the collection of the pills in sewer of surface water: some appropriate nets, ideally positioned in sewers, still need to be tested *in situ*. The second one is linked to the social acceptability: inhabitants are supposed to fill in the database, while giving some personal details. The technique presented in this paper seems promising and technically feasible. This method will allow for an accurate a cheap identification of the misconnections, detect the scale of the misconnection (a full building or more local errors).

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