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Raja-Louisa Mitchell (raja-louisa.mitchell@tu-berlin.de)
Paul Uwe Thamsen
Chair of Fluid System Dynamics, Department of Fluid Dynamics and Technical Acoustics, Technische Universität Berlin

Michel Gunkel
Jan Waschnewski
Berliner Wasserbetriebe, Berlin, Germany

Investigations into wastewater composition focusing on nonwoven wet wipes

Badanie składu ścieków ze szczególnym uwzględnieniem chusteczek nawilżanych z włókniny

Abstract
This paper summarizes the problems caused for wastewater systems by changing wastewater composition, especially the increasing use of nonwoven wet wipes and their disposal via the toilet. The nonwoven wet wipes do not disintegrate in the sewer system as paper-based toilet does, but accumulate to large agglomerations that can block the system and clog pumps. This not only reduces the operational safety and stability of the wastewater system, but also costs the operator a lot of money. The paper introduces an approach to estimate the composition of wastewater and presents first results for the city of Berlin.
Keywords: wastewater composition, solids, wet wipes, clogging

Streszczenie
W artykule omówiono problemy występujące w sieciach kanalizacyjnych związane ze zmieniającym się składem ścieków, a zwłaszcza obecnością w ściekach chusteczek nawilżanych z włókniny wrzucanych do toalety. Chusteczki nawilżane wykonane z włókniny nie rozpadają się w kanalizacji tak jak papier toaletowy, ale tworzą skupiska, które mogą powodować niedrożność instalacji i rur, zagrażając bezpieczeństwu i stabilności eksploatacji sieci kanalizacyjnej i zwiększając koszty eksploatacyjne ponoszone przez operatora. W artykule przedstawiono metodę analizy składu ścieków i pierwsze wyniki uzyskane podczas badań przeprowadzonych w Berlinie.
Słowa kluczowe: skład ścieków, ciała stałe, chusteczki nawilżane, niedrożność

1. Introduction

1.1. Project KURAS – Concepts for urban stormwater management and wastewater systems

Urban water infrastructures are increasingly facing challenges resulting from climate change and demographic developments. Using Berlin as an example, the project KURAS (concepts for urban stormwater management and wastewater systems), which is supported by the Federal German Ministry for Education and Research, aims at demonstrating how future wastewater disposal, water quality, urban climate, and quality of life in the city can be improved through intelligently combined stormwater and wastewater management. The project consists of a network of partners from research, industry and public authorities as well as one public utility responsible for drinking water supply and wastewater disposal.

The KURAS project focusses on two main research areas: *Stormwater management* and *wastewater systems*.

Based on specific selection criteria (population, type of sewer system, pumping station etc.), the Berlin district Wilmersdorf (~260,000 inhabitants and 40,000 m^3 dry weather flow) was chosen as a model area for the focus *wastewater system* (shown in Figure 1). The wastewater in Wilmersdorf is collected partly in a combined sewer system and partly in a separate sewer system. This means measures in both sewer system types can be examined. The model area belongs to the catchment area of the main wastewater pumping station Wilmersdorf, which pumps the greatest part of the wastewater to the wastewater treatment plant (WWTP) Ruhleben.

The focus in the research area wastewater systems lies on operational and constructive measures in the sewage network to counter problems resulting from overload and underload in the system, using the model area Wilmersdorf as an example. Expected changes in demography, water consumption and climate until 2050 were defined for the model area, as they can result in an increase or reduction of the extent and frequency of overload and underload in the wastewater system.

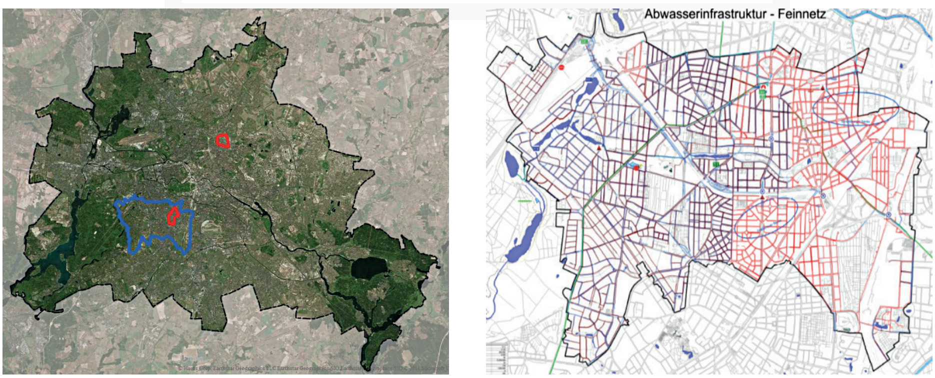

Fig. 1. Left: City of Berlin with the model catchment area "Wilmersdorf", used in the project KURAS, depicted in blue outline. Right: Detailed map of model area "Wilmesdorf" showing the sewers

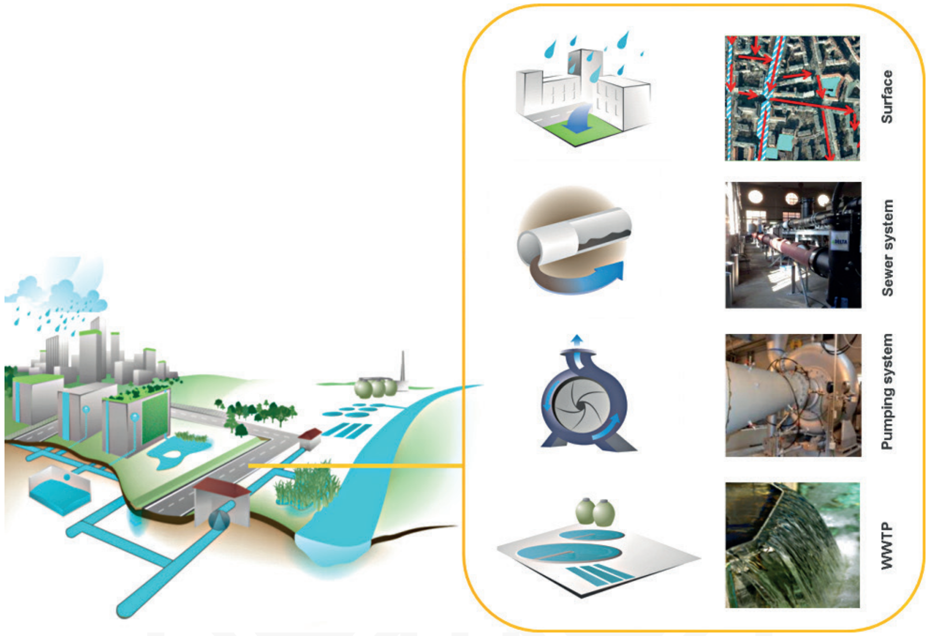

Fig. 2. Research focus areas in KURAS [picture: KURAS]

To systematically examine and identify the most effective measures for the sewage network (from the discharger to the WWTP) the system was divided into four research clusters: Surface, sewers, pumping system and wastewater treatment plant (as seen in Figure 2).

Currently, there are two main challenges confronting operators of wastewater systems. On the one hand, the growing gap between overload in the system due to extreme weather events and underload due to generally reduced wastewater amounts makes it hard to handle the large variations in flow. On the other hand, the use of toilets for the disposal of various products increasingly leads to problems in the wastewater system (e.g. blockages). Both challenges are explored in the research project KURAS. This paper will present an approach to investigate the composition of the solid fraction of wastewater, thereby providing valuable information for the operation of the wastewater infrastructure, especially the pumping systems.

1.2. Wastewater composition

The characteristic wastewater composition is well described from a chemical point of view. However, from a physical point of view, a description of wastewater, or its solid components, is lacking. To date, no description or standardisation regarding the physical properties of wastewater exists, let alone an approximation of the amount, type and composition of flushed products in the wastewater.

Nonetheless, wastewater operators throughout the world have seen a change in wastewater composition over the last years, due to a growing amount of wet wipes in the wastewater (some examples: [1–4]). These disposable wipes (baby wipes, cosmetic wipes and wet toilet paper wipes, examples are shown in Figure 3) are made of synthetic nonwoven textiles and thus do not tear or disintegrate in the sewer system as toilet paper does. This means they can become knotted during the wastewater transport to form large conglomerates of textile materials which can cause system blockage, clogging and operational problems in the wastewater system. Sydney Water, e.g., removed about 1 million kilograms of wet wipes from its wastewater systems over the past two years [1].

On the one hand this disrupts operation and reduces the operational stability of the whole wastewater system. On the other hand, these blockages are a growing expense factor for wastewater operators (New York City, e.g., claims that more than $18 million have been spent during the past five years to remedy wipe-related problems in their 14 wastewater treatment plants [2]).

This problem has been discussed in the media in recent years, as the literature shows ([1–4]) but has hardly been researched scientifically yet. Due to this, scientific literature is still greatly lacking. An example are Karadagli et al. and Eren et al. [5, 6, 7] who researched the physical disintegration of wet wipes in the sewer system.

Fig. 3. Examples for wet wipes (wet toilet paper wipes, baby wipes, cosmetic wipes, hand wipes)

2. Methods

In Berlin, wet wipes are increasingly found in the wastewater system, too, for example in the sewers, in the layer of scum in the pump suction chambers and in the pumps themselves. For this reason, together with the Berliner Wasserbetriebe (the Berlin water utilities) the Department of Fluid System Dynamics at TU Berlin conducted a series of field studies in the KURAS model area Wilmersdorf to better assess the nature and amount of flushed materials.

Fig. 4. Impressions of wet wipes in the Berlin sewer system [pictures from TUB-FSD and BWB]

2.1. Field measurements

An extensive field measurement campaign was designed and samples were collected at two points (combined sewer system) within the KURAS model area Wilmersdorf.

To gain a representative overview of the constituents per m^3 wastewater, composite samples of wastewater (~2.8 m^3) were taken three times a day (morning, noon and afternoon) with a suction vehicle. Flaps on the nozzle of the suction hose ensured that all of the incoming wastewater was collected. The samples remained in the suction vehicle until the end of the day, so that the total mixed sample amounted to 8.3 m^3 (8.3 m^3 is the total volume of the suction vehicle). The total sample was then discharged into the sewer through a basket screen (mesh size ~ 5 mm^2). The basket screen retained all the solids contained in 8.3 m^3 wastewater. The solids were weighed and then a random grab sample was extracted from the total solids. The constituents of the random sample were analysed by a textile laboratory. Figure 5 and Figure 6 show the process of sampling.

In total 13 composite samples were collected over the course of one year, whereof 12 samples could be analysed using their weight in comparison to the total weight of the sample (one sample was not weighed in total. Therefore for this sample it was only possible to determine a percentage distribution of the different fractions, but not determine the specific weights). A more extensive measuring campaign with a greater amount of samples would have given a broader picture. However, due to financial and scheduling conflicts, the measuring campaign could not be continued in the project. A possible continuation is planned for the future.

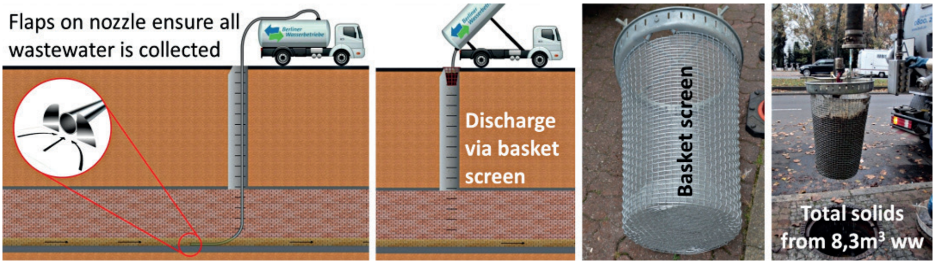

Fig. 5. From left to right: Wastewater being collected with the suction vehicle, wastewater being discharged into the sewers through the basket screen, basket screen, basket screen with solids captured from 8.3 m^3 of wastewater

Fig. 6. From left to right: Suction vehicle, wastewater being discharged into the basket screen, basket screen retaining the solid

The textile laboratory dried the samples and determined the dry weight of the total sample and each specific fraction (after separating the fractions by hand). The following fractions (dry weight) were analysed: plastics (foils and other plastics), textiles (fibres, threads, areas, nonwovens (drylaid nonwovens and spunbound nonwovens), composite materials, knitted fabrics, woven fabrics), paper (lumps, strands and areas), wood/leaves, rest (e.g. hair. cigarette butts etc.). Sediments were also analysed, however, as they are not in the focus of this investigation (they don't have the potential to clog pumps or screens), they were disregarded. An overview of the analysed fractions with their respective subcateogires is given in Table 1.

Table 1. Solid fractions anaylsed by the textile laboratory (with respective subcategories)

<table>
<tr><td colspan="5">Textiles</td><td colspan="3">Paper</td><td colspan="2">Plastics</td><td rowspan="6">Wood. leaves</td><td rowspan="6">Rest</td></tr>
<tr><td colspan="5">Fibres</td><td rowspan="5">Lumps</td><td rowspan="5">Strands</td><td rowspan="5">Areas</td><td rowspan="5">Foils</td><td rowspan="5">Others</td></tr>
<tr><td colspan="5">Threads</td></tr>
<tr><td colspan="5">Areas</td></tr>
<tr><td colspan="2">Nonwovens</td><td rowspan="2">Composite materials</td><td rowspan="2">Knitted fabrics</td><td rowspan="2">Woven fabrics</td></tr>
<tr><td>Dry-laid</td><td>Spun-bound</td></tr>
</table>

3. Initial results

The composition of the solids in the wastewater varies much more than initially thought. The samples were taken from May 2014 to June 2015 (not in the very cold winter months), always on Mondays. It was expected that the solid fractions would be somewhat similar (due to same day of the week and same time of day of sampling), perhaps varying with the weather (rain events) and annual seasons. However, the compisition of the solids differed strongly and no correlation with weather or seasons could be inferred. Figure 7 shows the specific amount of solids for the 12 samples found per m^3 wastewater, divided into the analysed fractions (plastics, textiles, paper, wood/leaves and rest). The total amount of solids varies from 57.7 g/m^3 to 1109.3 g/m^3, with an average total amount of solids of 319 g/m^3 wastewater (as seen in Figure 8). The composition of the total solids (the amount of the individual fractions) also varies strongly. Paper (this fraction also includes wetlaid nonwoven fabrics, e.g. kitchen roll), is the fraction which has the largest range (from 0 g/m^3 to 886 g/m^3). The textiles, which were in the focus of this investigation, also show a large range, varying from 0 g/m^3 to 155 g/m^3.

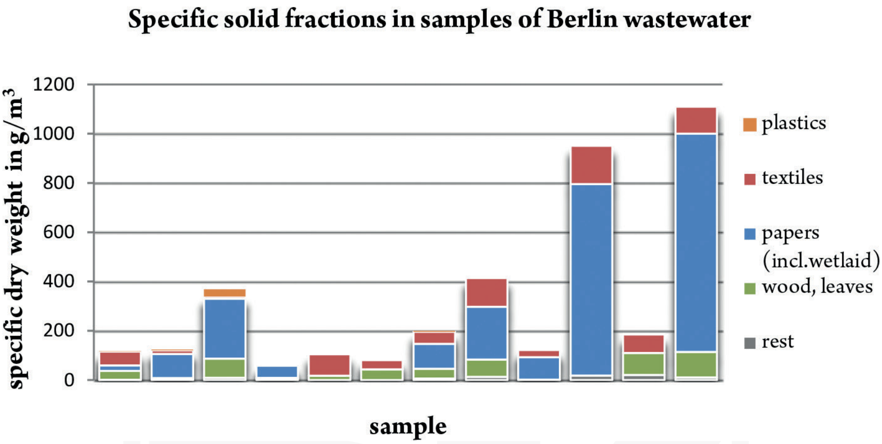

Fig. 7. Specific amount of solids per m^3 wastewater in samples of Berlin wastewater (based on 12 samples from two wastewater catchment areas. sampled from May 2014 to June 2015).

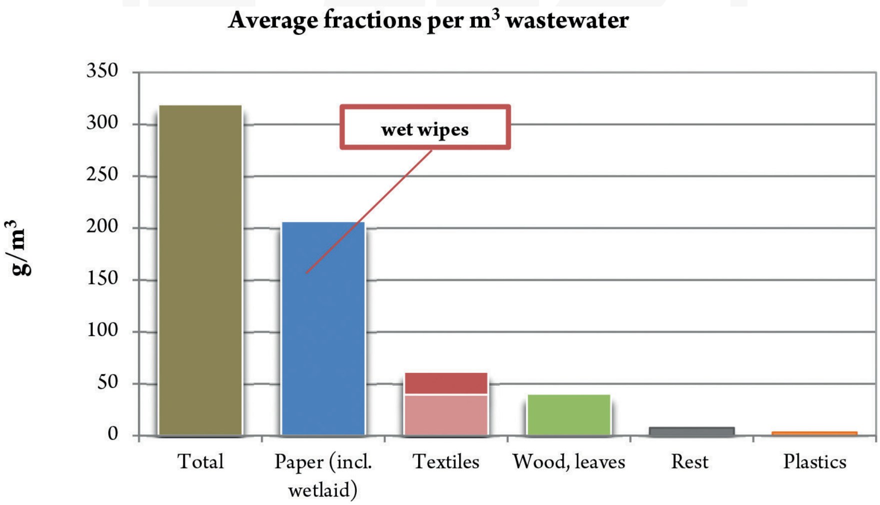

Fig. 8. Average fractions of solids per m^3 wastewater (based on 12 samples from two wastewater catchment areas, sampled from May 2014 to June 2015).

Figure 8 shows the average fractions of solids to be found in one m³ of wastewater. As can be seen in Figure 7, it is hard to determine a meaningful average, as the total amount of samples is very small and the individual samples differ so much (and partly do not follow a clear normal distribution). Nonetheless, for the purpose of getting an idea of wastewater physical constituents, average values were calculated. Based on the existing samples, analyses and type of catchment (combined sewer system in residential urban area), it can be stated that on average one m^3 wastewater has a total amount of 319 g of solids per m^3 wastewater. These total solids are made up of 207 g of paper per m^3, 62 g of textiles per m^3 (of which 40 g are nonwoven wet wipes), 40 g of wood and leaves per m^3, 7.5 g of rests (e.g. cigarette butts or hair) and, finally, the smallest fraction are the plastics with an average of 3 g/m^3 wastewater.

Figure 9 shows the average percentage distributions of the solids. As can be seen, paper makes up the largest fraction with 45%, followed by the textile fraction (33%), the wood/ /leaves fraction (18%), the rests (3%) and finally the plastics with 1%. While paper is the largest fraction, it can be seen that the textiles are a relevant fraction as they make up a third of total wastewater solids. In the textile fraction, the nonwoven wet wipes make up the largest share (14% of total solids), followed by fibres (10% of total solids), composite materials, e.g. tampons or incontinence articles (8% of total solids) and finally threads with 1% of total solids.

A hotspot for pump clogging material to collect, is the layer of scum in suction chambers of pumping stations. After the routine flushing of the suction chamber (in most large Berlin pumping stations, e.g., at least once a day), this layer is broken up and the concentrated floating solids (paper, textiles) have to be pumped away. To get an impression of the solids collected in the layer of scum, a random sample was taken and analysed. The composition of this sample is pictured in Figure 10. As only one sample was taken in one pumping station, no general conclusions regarding the composition of the scum layer can be made. However, this example can be used to illustrate the possible constituents. As expected, the scum layer

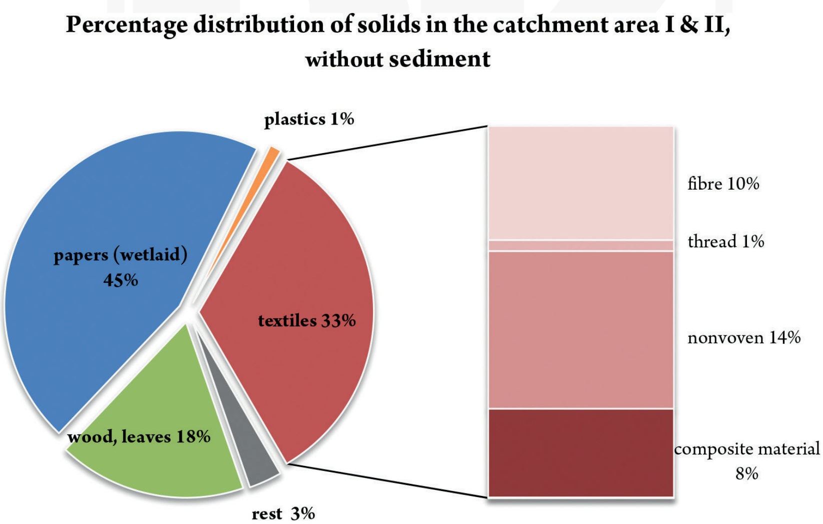

Fig. 9. Percentage distribution of solids (based on 12 samples from two wastewater catchment areas, sampled from May 2014 to June 2015)

comprises only floating solids. Paper made up the largest fraction (76%), which was mostly due to large amounts of wetlaid nonwovens (i.e. household kitchen roll), which is a paper, but not as soluble and readily degradable as toilet paper. Aside from minor amounts of plastic (1%) and some rests (1.8%), the textiles made up the remaining solids (21%). This textile portion was made up of 11% composite materials (e.g. incontinence articles, pictured in Figure 11), 8% nonwoven wet wipes (different sizes and types, e.g. spunbound nonwovens and drylaid nonwovens, examples shown in Figure 11), as well as minor amounts of other fabrics.

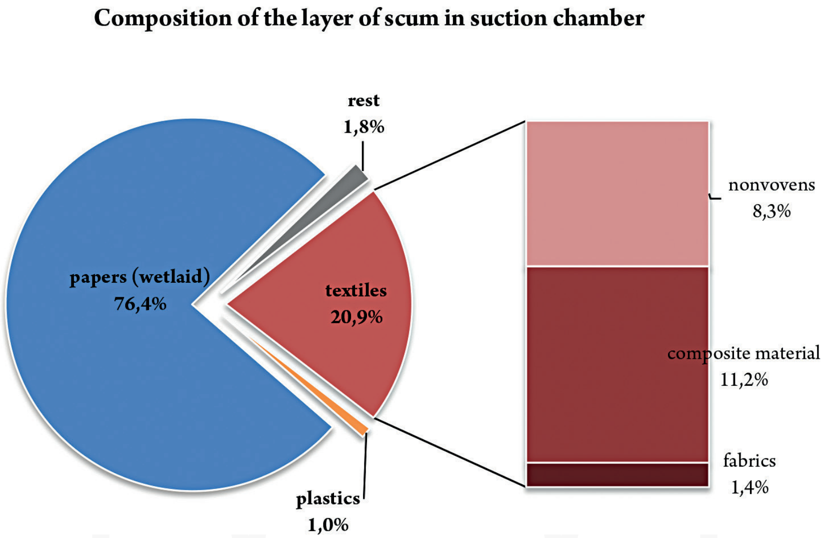

Fig. 10. Composition of the scum layer in a suction chambr of a pumping station (based on one random sample)

Fig. 11. Example constituents of scum layer in pumping station (based on one random sample), from top left to bottom right: paper lumps (paper), incontinence articles (composite materials), gauze (composite materials), wet wipes (different types, category nonwovens)

4. Conclusions

Based on the present data, it could be shown that textiles, and among them the wet wipes, which are currently causing so many problems in the wastewater system, are definitely a relevant category of wastewater solids. To be able to draw more general conclusions, further samples will be taken and analysed.

Furthermore it could be shown that the amount and composition of solids in wastewater vary immensely. To be able to correlate influencing factors with the wastewater solids, further field measurements are necessary.

4.1. Outlook

The field measurement campaign will be continued to collect further data. In addition to further samples taken from the sewers directly, "system hotspots" will be sampled. These include suction chambers of pumping stations, the screenings of wastewater treatment plants and the material clogging the pumps. This will give an insight into which wastewater constituents are the most damaging for our wastewater systems.

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