Transportation and surface runoff treatment

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Abstract. Surface water runoff are characterized by specific physicochemical composition, which depends on the area of water disposal. Surface runoff in Russia and other foreign countries characterized by high concentration of suspended solids, petroleum products, high chemical oxygen demand and etc. This article provides data about foreign and Russian compact filters. Filters are installed in the water receiving sumps of the storm sewage system. Analysis of efficiency of different filter construction has been conducted. As a result of this analysis it is determined, that its efficiency, purification capacities and resource are highly limited, while its operating costs are quite high. Stationary surface runoff treatment plants are more reliable, and allow to reach purification level, which is required to dispose surface runoff into water objects. Composition of treatment plants depends on amount of surface runoff and transportation conditions. This article provides results of visual observation of sewer collectors condition, which are used to transport surface runoff to treatment plants, and its common defects. This article also provides results of study of structure and composition of sediment, which is found inside the sewage collector. It is determined, that size of sediment particles equals to 3-4 mm and its density – 2.3 g/sm³. Main elements of the sediment are silicon and oxygen, but there are aluminum, calcium and sodium additives.

1. Introduction

Provision untreated surface water runoff are one of the main pollutants of water objects. The amount of impurities, which they bring to water objects, equals to 8…15% of impurities of domestic sewage. Physicochemical composition of surface water runoff depends on a couple of factors [1] and significantly varies on different areas of sewage disposal.

The main contaminants of the surface runoff from urban areas are suspended solids, petroleum products, COD, chlorides, etc. Furthermore, recently there has been a significant pollution of surface runoff with heavy metals, deicing and surface-active agents [1-13]. Its concentration changes across different territories. For example, concentration of suspended solids in surface runoff in Russia fluctuates from 50 to 1450 mg/l. As for petroleum products, concentration varies from 0.46 to 475 mg/l. Chemical oxygen demand (COD) varies between 50 and 446 mg/l. Biochemical oxygen consumption (BOC₅) can reach up to 136 mg/l. Dry residue can be as high as 5718 mg/l, chlorides can reach up to 850 mg/l, sulfates – up to 792 mg/l, pH of surface runoff varies from 7.41 mg/l to 9.4 mg/l. Alkalinity of water fluctuates between 2 and 9 mmol/l, general water hardness - between 2.5 and 13 mg/l [1, 14, 15, 21].
Similar pollution composition can be observed in urban areas of other countries [1, 8]. For example, concentration of suspended solids in Washington is 11280 mg/l. Also, for most Chinese cities standard chemical oxygen demand is 1950 mg/l. Surface runoff contains not just mineral impurities, dissolved and undissolved organic impurities, but also salts of heavy metals (zinc, copper, iron, cadmium, chrome, etc.). Physicochemical composition of industrial surface runoff depends on the technological process, sanitary technical condition of the factory and other factors [1]. Concentration of suspended solids and petroleum products in such sewage is 1.8…2 times higher, then that in domestic sewage.

Surface water runoff disposal from urban areas organized through storm sewage. It consists of separate elements, connected to each other: sewer wells (Figure 1a), drainage network and sewer collectors. Through sewer collectors, water runoff in disposed to rivers and other water objects, or to sewage treatment works (Figure 1c).

![Figure 1](image)

**Figure 1.** Storm sewage: a – sewer wells; b - sewer collectors; c - sewage treatment facilities.

Sewer wells are placed around roadways, lawns and courtyards. Special grids prevent debris, trash and leaves from getting into the sewer well. Surface runoff drift into drainage network under the influence of gravitational powers. Drainage network consists of PVC, ceramic or reinforced concrete pipes of 300-1200 mm diameter.

To reduce pollution load in the surface runoff, different filters are used (Ultra-Urban Filter, Jellyfish™ Filter, Enviro Trap Catch Basin Insert, Storm Basin, etc.). Filters are installed specifically into the water receiving sewer wells and are often compact. Depending on the construction and operation principle they can purify surface runoff from suspended solids, petroleum products and heavy metals. It is possible to replace worn-out filtering elements. On the Figure 2 constructions of some filters are provided.

The efficiency of filters is provided in Table 1, in which presents data from producers. As seen from the table, among the observed filters, efficiency of purification of surface runoff from suspended solids differs from 30 % (Enviro Trap Catch Basin Insert) to 98% (Jellyfish™ Filter), from oil and grease - 90 % (Ultra-Urban Filter), from heavy metals (zinc) – from 20% (Enviro Trap Catch Basin Insert) to 95% (Bio Clean Grate Inlet Skimmer Box). It should be noted, however, that concentration of pollutants in the analyzed water differs, so comparable analysis is difficult.
Figure 2. General appearance of some filters: a – Ultra-Urban Filter; b – Jellyfish™ Filter; c - Enviro Trap Catch Basin Insert.

Table 1. Producers data about filters efficiency [16].

| Removed substances | Ultra-Urban Filter | Jellyfish™ Filter | Enviro Trap Catch Basin Insert | Bio Clean Grate Inlet Skimmer Box | Storm Basin |
|--------------------|--------------------|-------------------|-------------------------------|-----------------------------------|-------------|
| TSS mg/L           | -                  | 112               | 250                           | 978                               | 112         |
| %                  | 80                 | 98                | 30                            | 66                                | 98          |
| TPH mg/L           | >100               | -                 | -                             | -                                 | -           |
| %                  | 90                 | -                 | -                             | -                                 | -           |
| Oil and Grease mg/L| >100               | 59.5              | -                             | 189                               | 59.5        |
| %                  | -                  | 90                | -                             | 95                                | 90          |
| Total Copper mg/L  | -                  | 78                | 0.08                          | 1.9                               | -           |
| %                  | -                  | 99                | 9                             | 95                                | -           |
| Total Lead mg/L    | -                  | 35                | 0.79                          | 1.5                               | 0.018       |
| %                  | -                  | 86                | 4                             | 87                                | 73          |
| Total Zinc mg/L    | -                  | 1.45              | 0.3                           | 13.7                              | 0.335       |
| %                  | -                  | 59                | 20                            | 95                                | 48          |
| Phosphorus mg/L    | 85                 | 50                | -                             | 64                                | 47          |

In Russia filters of purification of surface runoff FOPS® are used. There are different types of such filters (FOPS®-MU, FOPS®-U, FOPS®-C and etc.) and they have different load, which depends on the purified pollutants (Table 2).

Table 2. Load of FOPS® filters [17].

| Filter type | Load                                      |
|-------------|-------------------------------------------|
| FOPS®-MU    | Carbon granular (higher then 75%), filtering |
| FOPS®-U     | Carbon granular (higher then 95%)          |
| FOPS®-C     | Carbon-zeolyte granular                   |

Filters are used as an individual element to remove specific pollutant (or group of pollutants), and can be used as a combination of filters for serially connected sumps. This allows for more complex
and deep purification of surface runoff [17]. By the developer’s information, FOPS® type filter provides higher level of surface runoff purification in contrast to foreign filters (Table 3).

It should be taken into consideration that the filter’s resource is highly limited, and filtering load should be replaced from time to time, which leads to high operating cost. Thus, stationary treatment plants are considered most reliable.

Technological scheme and composition of treatment plants depend on the quality of surface runoff in the area, and purification requirement [18-20]. Treatment plants designed for mechanical cleansing, sedimentation and sorption cleaning. They consist of grids, sand catchers, accumulative tank sumps, reagent farms, sumps or flotators, filters with inert of sorption load, plants for disinfection of purified water.

**Table 3. Efficiency of surface runoff purification for different substances (mg/l) [17].**

| Removed substances     | Filters          |
|------------------------|------------------|
|                        | FOPS®-MU | FOPS®-U | FOPS®-C |
| Suspended soils        | 2000° /5b | 2000° /5b | -      |
| Petroleum products     | 50° /0.05b | 100° /0.05-5b | -      |
| COD                    | 650°/30b | 1500° /30b | -      |
| Copper                 | -       | -       | 0.54 /0.001b |
| Zinc                   | -       | -       | 1.04 /0.01b |
| Lead                   | -       | -       | 0.54 /0.006b |
| Ammonium nitrate       | -       | -       | 10° /0.4b |

*a* concentration of pollutant in untreated water.

*b* concentration of pollutant in treated water.

Technological schemes, plants composition and rational sphere of usage are provided in [18, 19]. For surface runoff treatment it’s possible to use biotechnologies, with bioengineering plants: biofilter channels and slopes, bioplateau, biopounds and fitofilters [21].

Surface runoff gets to the sewage treatment works through sewer collectors, which are connected to the drainage network. Diameter of collectors can vary from 1200 mm to 4000 mm and even higher. Sewer collectors consist of huge concrete and reinforced concrete blocks. If the sewer collector is not operational, city areas will be flooded during long rains, huge amounts of solid matter will be brought to the treatment plants, pollutants level in surface runoff will increase. Therefore the load on the treatment plants will increase. Thus, preventive control, cleansing of the sewer collectors, defect detection is very important technical task, because collectors must always be in working condition.

2. **Materials and methods**

For defect detection, visual inspection of sewer collectors, (diameter 1200-3500 mm) was conducted and list of deficiencies was created.

Study of chemical composition and structure of the sample of sediment was conducted on the laboratory equipment of Water Supply and Sewerage department of the Moscow State (National Research) University of Civil Engineering. Scanning electron microscope Quanta (Figure 3a) was used for the research. Microscope consists of a number of blocks: electron gun; lens systems; spray aperture; vacuum pump; deflection coils; electron detectors. Blocks created the image of the object during the simultaneous work. Sediment weight was measured on electronic scales VICON (Figure 3b). Sediment for the test for taken from the collector during the autumn period.
3. Results

Visual observation of sewer collectors of different diameter, which receive and dispose surface runoff from different city areas showed the following defects: gapping; disruption of construction, siltation; overlapping the flow section; concentration of debris etc. (Figure 4). These defects contribute to siltation, flow section decrease, and leads to flooding of city territories.

Microscopic analysis of sediment sample (3 mm size) (Figure 5) and its particles provided the following results: main elements of the sediment are oxygen (38.01…46.51 %) and silicon (20.72…23.35 %), which means that sediment is mostly sand with small additives of sodium (1.58…6.75 %), calcium (1.62…7.76 %) and aluminum (4.55…8.40 %). Concentration of carbon-based organic substances is between 13.04 % and 20.19 %.

There is no fundamental difference between sample and it’s particles in chemical composition. In both cases silicon was main element. However, amount of sodium and aluminum is higher in particles, while in the sample iron (3.04 %), aluminum (4.55 %) and calcium (4.93 %) was detected. Besides, density of sediment was determined. Weight of the sediment (volume 2.8 cm$^3$) equals to 6,445 g, density $\sim 2.3$ g/cm$^3$, which is almost equal to silicon density.
Figure 5. Sample and microscope photos of sediment.

4. Conclusions
Main pollutants of the surface runoff and its concentration range were observed. Storm sewerage and its main elements were described. Analysis of construction and efficiency of Russian and foreign filters for water receiving sewer wells was conducted. 

It is shown, that condition of collectors impacts its capacity and quality of surface runoff, which are going to the treatment facilities. Visual observation is conducted. Determined, that almost all collectors have similar defects: gapping, concentration of debris, siltation, and disruption of construction. 

As a result of microscopic research of sediment, it was determined, that it consists of mineral particles with the prevalence of silicon.

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