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THE POSSIBILITIES OF LOCAL STORMWATER MANAGEMENT IN THE CONTEXT OF ITS QUALITY AND QUANTITY

MOŻLIWOŚCI MIEJSCOWEGO ZAGOSPODAROWANIA ŚCIEKÓW OPADOWYCH W KONTEKŚCIE JAKOŚCIOWYM I ILOŚCIOWYM

Abstract: On account of the previous attitude to urban land use by means of substantial building development and fast rainwater disposal the quantity of rainwater constitute increasing threat in the form of urban flooding. It results in financial loss connected with the removal of damage caused by cellar flooding in residential and office buildings in city centres. Also climate changes reveals appearing more frequent torrential rainfalls cause an increased frequency of flooding events. The local management of rainwater on site of its occurrence gives the possibility of reducing the amount of storm water discharged to the most overloaded storm and combined sewerage system, therefore the potential effects of flooding in urban areas can be reduced. The most important element in reducing the amount of stormwater from relevant area is the reduction of impervious surface in relation to permeable surface. Nowadays, due to land prices in urban areas, available building area is normally used in one hundred percent. At this point, so called alternative ways of rainwater management may be used. Very important for the selection of an appropriate solution for a given catchment area are soil and water conditions, terrain slope, but also the quality of rainwater that can be used for sanitary purposes and the maintenance of green areas. The surface from which rainwater is collected for its re-use can be contaminated with different types of substances. Water drops are already contaminated in the atmosphere by dust suspended in the air. Then, depending on the surface, metals or petroleum substances may get into rainwater, but mainly pollution in the form of suspended solids is observed. Rainwater runoff may require a preliminary treatment before its re-using or introducing into the ground. All of the methods of stormwater treatment should not be overused due to the fact that it increases the cost of equipment, but also this equipment should not cause a negative impact on humans and the environment. The local management of stormwater can be a way to reduce the amount of waste water discharged from the catchment area. It can cause the reduction of consumption of potable water for sanitary purposes. Therefore, the selection of equipment and care to surface, from which rain water is managed, is very important. Without the change of attitude to the management of rainwater the effects of precipitation will become more severe and costly.

Keywords: management of rainwater, rainwater quality

Introduction

Nowadays urban areas are extensively built over by impervious surfaces. The local management of rainwater on site of its occurrence gives the possibility of reducing the amount of storm water discharged to the mostly overloaded storm and combined sewerage system, therefore the potential effects of flooding in urban areas can be reduced. The essence of suitable benefits is the correct selection of facilities for local rainwater management from the solutions available and possible to use. Important for the selection of an appropriate solution for a given catchment area are soil and water conditions, surface slope, but also the quality of rainwater that can be used for sanitary purposes and the maintenance of green areas. There are also guidelines for the use of rainwater instead of potable water for other purposes. The surface from which rainwater is collected for its

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re-use can contaminate it with different types of substances. Mixing the runoff from various types of surfaces can show both negative and positive effects, which also depends on its final use. Rainwater runoff may require a preliminary treatment before its re-using or introducing into the ground.

The quality of wastewater

The composition of rainwater undergoes the largest change during its contact with the surface. In urban areas a large part of the impervious surface belong to roofs and streets. The concentration of pollutants in runoff water from the roof and road surface may range greatly. In the literature the series of research results concerning selected pollutants: pH, suspended solids, COD, BOD, ammonia nitrogen, heavy metals (cadmium, zinc, copper, lead, nickel, chromium), PAHs, petroleum hydrocarbons, and bacteria are presented. Most of the literature data can be divided into the results from the roof surfaces and the road surfaces. But there are also the papers in which results from other surfaces such as pavements are presented. These articles constitute much smaller part.

The quality of wastewater from roofs

In case of roofs material from which the roof and the elements of gutters supplying are madet has a significant impact on the run-off quality. Also the roof slope, the location, the direction and intensity of wind have influence on the observed pollution concentration. The main reason for the increase in pollutant concentrations are in the case of roofing materials the substances that accumulate on the surface of the roof like bird droppings and plant particles and corrosion products. The literature data on this type of surface is divided into types of materials which roofs are made or because of the surrounding in which they are located. The diversity in index of pollutants in case of the specified surface includes, in some cases, only the suspended solids, and COD and in others a large number of other compounds including, for example, magnesium and sodium. For the purpose of current paper, the key indicators including pH, suspensions solids, COD, BOD, ammonia nitrogen, heavy metals, or in some cases petroleum substances known as PAHs and hydrocarbons of petroleum were selected.

Göbel [1] in his publication presents the results of 22 pollutants from 12 different areas and the runoff from roofs covered with tiles, concrete, fiber cement, bitumen, glass with zinc gutters. Selected average values amount: pH 5.7, suspended solids 43 mg/dm³, BOD₆ 12 mg/dm³, COD 66 mg/dm³, heavy metals, cadmium (Cd) 0.8, zinc (Zn) 1851, copper (Cu) 153, lead (Pb) 69, nickel (Ni) 4, chromium (Cr) 4 µg/dm³ ammonium nitrogen 3.39 mg/dm³, PAHs 0.39 µg/dm³, petroleum hydrocarbons, 0.70 mg/dm³. At the same time the mean values for identical roofing discharge runoff from roofs without zinc gutters are shown. In this case, the only difference in the average values is for zinc, where the average is 370 µg/dm³. In the publication the roofs covered with copper, aluminum and zinc are distinguished. The only difference concerns the heavy metals and in the reference to roofs: with zinc gutter the values amount for the copper roof suitably copper 2600 µg/dm³, for the zinc roof zinc 600 µg/dm³. For aluminium roof mean values of selected indicators have the same value.

The data from Spain [2] from the four selected roofs that are located on the university campus and in the city of Barcelona with a variety of catchments from clay tiles, metal sheet, polycarbonate plastic and the catchment covered with gravel, the following results were obtained: pH 7.59, TSS 5.98 mg/dm³ and ammonium nitrogen 0.50 mg/dm³.

The confirmation of importance of determining the quality of rainwater from the roof is conducting the research in this subject around the world. In the Southwest China rainwater runoff from the roof of a university building covered with concrete and from roof covered with tiles located in a residential area was analyzed. The average concentration of TSS was 69 and 43 mg/dm³ whereas COD 83 and 52 mg/dm³. At the same time the runoff from roof that was located on the campus area was analyzed regarding heavy metals: copper 0.05, zinc 0.33, lead 0.54, cadmium 0.053 and iron 2.7 mg/dm³ [3].

In Poland considerable interest in the subject area can be seen too. In the paper [4] the results of the runoff composition from the roof located in Czestochowa are shown. TSS was in the range of 20.5-62.3 mg/dm³, BOD₅ 9.0-16.0 mg/dm³ and COD from 12.1 to 24.8 mg/dm³. In turn in one of the review articles [5] runoff from roofs was characterized by concentration in the range of pH 6.0-6.9, TSS 2.1-79 mg/dm³, COD 6-230 mg/dm³, petroleum substances 0.4-2.4 mg/dm³. In the publication [6] hydrocarbon concentration of the three roofs located along the major transportation routes of Gdańsk was presented. The concentration range of petroleum hydrocarbons from these three facilities amounted from 24.98 to 64.42 µg/dm³.

The number of available data and their diversity confirm the interest in the quality of stormwater. Based on the available data, it can be remarked additionally that the first flush of runoff brings the biggest pollution, so it is good to separate the first flush portion of runoff and stormwater prior to its release a management system. In the next portion of runoff in most cases low pollutant concentration occur, other than heavy metals, which is connected with the roof covering.

The quality of wastewater from roads

Runoff from roads as well as from roofs constitute significant share of total precipitation runoff. For safety reasons devoted to the receivers the rainwater from the lanes should be removed as soon as possible. Regarding roads, surrounding areas (city, industrial and green area) and density of traffic constitute the major factors to the quality.

One of German research on runoff from roads with annual daily traffic load of 57.000 vehicles/day in surrounding of residential housing, office buildings and a park showed the pH in the range 6.2-8.3, suspended solids 18.3-3165 mg/dm³, COD 3.6-81 mg/dm³, heavy metals cadmium <0.5-4.8 µg/dm³, copper 24-604 µg/dm³, zinc 128-3470 µg/dm³, lead <0.5-405 µg/dm³, nickel 4.2-403 µg/dm³ [7].

In the paper [1] track records of runoff from road are divided into road area on the service road, main roads and motorways. The characteristics of pollution from road service were: pH 7.4, TSS 150 mg/dm³, BOD₆ 11 mg/dm³, COD 70 mg/dm³, ammonium nitrogen 0.1 mg/dm³, cadmium 1.6 µg/dm³, zinc 400 µg/dm³, copper 86 µg/dm³, lead 137 µg/dm³, nickel 14 µg/dm³, chrome 10 µg/dm³, PAHs 4.5 µg/dm³, petroleum substances 0.16 mg/dm³. Characteristics of pollution from main road: pH 7.4, TSS 163 mg/dm³, BOD₆ 11 mg/dm³, COD 105 mg/dm³, ammonium nitrogen 0.9 mg/dm³, cadmium 1.9 µg/dm³, zinc

407 $\mu\text{g}/\text{dm}^3$, copper 97 $\mu\text{g}/\text{dm}^3$, lead 170 $\mu\text{g}/\text{dm}^3$, nickel 11 $\mu\text{g}/\text{dm}^3$, chrome 11 $\mu\text{g}/\text{dm}^3$, PAHs 1.65 $\mu\text{g}/\text{dm}^3$, petroleum substances 4.17 mg/dm^3 . For the motorway data are formed pH 7.4, TSS 153 mg/dm^3 , BOD₆ 32 mg/dm^3 , COD 107 mg/dm^3 , ammonium nitrogen 0.5 mg/dm^3 , cadmium 3.7 $\mu\text{g}/\text{dm}^3$, zinc 345 $\mu\text{g}/\text{dm}^3$, copper 65 $\mu\text{g}/\text{dm}^3$, lead 224 $\mu\text{g}/\text{dm}^3$, nickel 27 $\mu\text{g}/\text{dm}^3$, chrome 13 $\mu\text{g}/\text{dm}^3$, PAHs 2.61 $\mu\text{g}/\text{dm}^3$, petroleum substances 4.76 mg/dm^3 .

The results of runoff from roads in the Polish area of Czestochowa contain: pH, COD, BOD₅, TSS and heavy metals [4, 8]. The scope of the particular indicators amounted: pH 5.6-6.9, COD 22.8-215.0 mg/dm^3 , 10-150 BOD₅ mg/dm^3 , TSS 11-864.5 mg/dm^3 , heavy metals suitably: copper 3.37-7.99 $\mu\text{g}/\text{dm}^3$, cadmium 0.47-0.77 $\mu\text{g}/\text{dm}^3$, lead 21.0-63.0 $\mu\text{g}/\text{dm}^3$, nickel 17.08-32.12 $\mu\text{g}/\text{dm}^3$, arsenic 11.97-28.24 $\mu\text{g}/\text{dm}^3$.

Other results from the road catchment area of Polish roads given in the collection of publications are summarized in the paper [5]. The roads are listed separately as expressways and city roads. In the case of expressways COD was 157 mg/dm^3 , TSS 200 mg/dm^3 . In the runoff from city roads COD amounted 270 mg/dm^3 , TSS 320 mg/dm^3 , petroleum substances 1.2 mg/dm^3 . The list also presents results from residential roads where the value amounts pH 6.9-7.9, COD 161-247 mg/dm^3 , TSS 61-292 mg/dm^3 , petroleum substances 0.6-2.4 mg/dm^3 .

The literature data show stormwater runoff from roads as mostly polluted. This is especially visible with reference to rainwater from the roofs. Runoff from roads is also characterized by higher levels of pollution concentration. Most of the pollution indicators (TSS, COD, metals) are observed in both types of runoff. However some pollutants are studied primarily in runoff from roads, but not in all. It is worth mentioning that petroleum substances whose origin results from flushing products is based on crude oil from road surface. The presence of these substances should be lower in runoff from roofs, as confirmed by the available data (0.02-2.4 mg/dm^3). In the runoff from roads scope of the presented results amounts 0.16-4.76 mg/dm^3 .

The amount of stormwater

The location in the climatic zone and local conditions have the greatest impact on the occurrence of heavy rainfall events [9]. However, heavy rains in terms of daily total rainfall are barely differ in Poland and neighbouring countries [10].

The amount of stormwater is mainly connected with the intensity of precipitation, its duration, and surface runoff (surface impervious, pervious). The catchments with a high surface impervious generate greater amounts of rainwater due to a little opportunity for infiltration. Unfortunately, in urban areas, where rainwater can cause considerable damage, the ratio of the impervious surface and pervious ones is high. The management of rainwater runoff for each parcel individually would result in the stopping of the total runoff from small rainfall events, while the amount of stormwater from heavy rains would be reduced by the possibility of precipitation in collection systems. It should be noted that in the case of designing the facilities to stormwater management, the attention is mostly places on the quantitative balance. An important aspect is to create a balance of quality of stormwater due to the fact that the contamination the ground and ground water through stormwater are possible.

Systems for rainwater management

Before the cities rapidly developed it was common to use methods of rainwater management through the collection and using rainwater during dry weather as well as the surface disposal and infiltration into the ground. While the traditional approach to rainwater sewerage system designing based on the fastest disposal of rainwater out of the city is replaced by retention of excess rain water or management of rainwater in the site of precipitation, the earlier described methods are used again, but objects are optimized for maximum the appropriate use of storage capacity and the surface area for infiltration.

It should be remarked that the reasons for choosing a stormwater management system are miscellaneous and depend on the availability of drinking water, reflected in the price of water supply, environmental awareness, fees for discharge of stormwater into sewerage system, as well as the technical possibilities of the location and operation of facilities for each building object.

The principle of sustainable development extorts out of designers applying of the local devices and facilities for the management of rainwater. Through the processes which are involved in them the devices can be divided:

- Processes using detention:
 - Open detention tanks (currently implement they have also the function of create landscaping)
 - Closed detention tanks (usually installed in the existing sewerage system in order to relieve the overloaded part of a system and a in new sewerage system in order to optimize the sewer diameters and reduce the maximum flow discharged into a receiver)
- Processes using detention and ground infiltration:
 - Lawns, surfaces of gardens, parks, green areas with the right kind of soil, that is pervious and has suitable level of ground water. A portion of the rainwater is evaporated in the process of evapotranspiration, which depends on the type and size of the flora covering green area.
 - Car park areas, roadways with little road traffic, pavements, paved recreation areas
 - using perforated modules made of concrete - the percentage parts of biologically active surface up to 50% of the total paved surface,
 - using perforated elements made of plastic - the percentage parts of biologically active surface up to 95% of the total paved surface,
 - using concrete, granite or paving blocks that are laid on the foundation with permeable substructure for example on a sand ballast without cement - a disadvantage of the solutions is the low degree of infiltration,
 - using permeable asphaltic concrete on sand or gravel ballast - a disadvantage of the solution is silting-up process which makes the surface loses its conductivity properties.
 - Absorptive tanks of the structure similar to the trough characterize by greater depth. The tanks are used for larger areas > 1 ha. Commonly used for drainage of motorways and expressways.
- Processes using deretention and underground infiltration:

- Receptive manholes, so far mainly been made from concrete. The diameter of wells is depended on flow and type of soil below the wells. Currently, the receptive manholes are made of plastic of various constructions depending on the manufacturer.
- Drainage boxes and chambers are mainly used for rainwater removal from large objects. They should be used in areas where there is a low level of groundwater. Due to the modularity and good strength they can be used to produce large retention-infiltration tanks. These devices are successfully used for rainwater removal from airports, industrial plants, sports facilities.
- Draining systems are used in good soil and water conditions - for small objects (eg detached house).
Above division was created on the basis of [11, 12].

The results of research

The research on the determination of the quality of storm runoff in urban areas was based on the small selected surface on roads. In the runoff of rainwater from definite surface the pollutants indicators as COD, TSS, petroleum hydrocarbons were determined. Sampling sites were located in the city of Lodz in a residential area and a residential area near the petrol station. Analyzed wastewater came from ten different rainfall events during 2012 and 2013.

Table 1

The ranges of pollutants concentrations (COD, TSS petroleum substances)
occurred in stormwater runoff from roads

Type of surface	COD [mg O ₂ /dm ³]	TSS [mg/dm ³]	Petroleum hydrocarbons [mg/dm ³]
Urban roads	93-1000	40-1866	0.15-3.15

Table 1 shows the concentration of pollutants with the minimum and maximum values, which occurred in the effluent of the three collection points in the analyzed rainfalls. The results of the concentration of TSS and petroleum hydrocarbons correspond to the ranges found in the literature on the quality of rainwater runoff from roads. The only indication above the scope from literature is COD, the maximum value of the samples of the analyzed rainfall was 1000 mg/dm³. Regarding for road surfaces as high COD value was not an exception. Therefore the analyzed surface is recognized as very polluted and the first flush runoff should be separated or the collected rainwater should be preliminarily removed before their reuse in order to ensure the proper sanitation and the comfort of retention devices.

The quality of sewerage has an influence on the proper selection of facility to stormwater management related to the exclusion of some of the solutions due to environmental contamination, clogging, contamination of soil and groundwater and increase investment and operating costs.

Conclusions

- The basis for the proper management of storm water is a sustainable strategy of development supported by properly accordant devices.

- Local stormwater management can distinctly reduce the amount of storm water brought to the sewerage systems.
- Local systems accordant to prevailing conditions can bring economic and social benefits.
- The quality of stormwater runoff is a major factor that may adversely affect on the facilities to rainwater management.
- The first flush of rainwater should be separated and treated.
- Further research on the quality of rainwater in order to control and prevent the accumulation of large amounts of harmful substances in environment should be carried out.

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MOŻLIWOŚCI MIEJSCOWEGO ZAGOSPODAROWANIA ŚCIEKÓW OPADOWYCH W KONTEKŚCIE JAKOŚCIOWYM I ILOŚCIOWYM

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Abstrakt: Ze względu na dotychczasowe podejście do zagospodarowania terenu poprzez znaczną zabudowę powierzchni i systemy szybkiego odprowadzania wód opadowych z obszarów zurbanizowanych ilość ścieków opadowych stanowi coraz większe zagrożenie objawiające się tzw. powodziami miejskimi. Skutkiem tego są straty materialne związane z usuwaniem szkód wyrządzonych przez np. podtopienia piwnic budynków mieszkalnych czy biurowych w centrach miast. Jednocześnie zmiany klimatu objawiające się coraz częściej

występującymi opadami ulewnymi powodują zwiększoną częstotliwość takich zdarzeń. Zagospodarowanie opadu w miejscu jego wystąpienia daje możliwości zmniejszenia ilości odprowadzanych ścieków deszczowych do (najczęściej przeciążonej) sieci kanalizacji deszczowej i ogólnospławnej, zatem zmniejsza ewentualne skutki zalewania obszarów zurbanizowanych. Najważniejszym elementem zmniejszającym ilość ścieków opadowych z danego terenu jest ograniczanie powierzchni przeznaczonej do zabudowy w odniesieniu do powierzchni nieuszczelnionej. Obecnie ze względu na ceny działek na terenach zurbanizowanych dostępna powierzchnia zabudowy zazwyczaj wykorzystywana jest w stu procentach. Znajdują tutaj zatem swoje zastosowanie tzw. alternatywne sposoby zagospodarowania wód opadowych. Bardzo istotne z punktu widzenia doboru odpowiedniego rozwiązania dla danej zlewni są występujące warunki gruntowo-wodne, spadek terenu, ale również jakość zbieranej wody opadowej, która może zostać wykorzystana do celów sanitarnych oraz utrzymania zieleni. Powierzchnie, z których woda opadowa zbierana jest do ponownego wykorzystania, mogą ją zanieczyszczać różnego typu związkami. Już w atmosferze krople wody zostają zanieczyszczone pyłami zawieszonymi w powietrzu. Następnie w zależności od powierzchni mogą być zanieczyszczone metalami lub substancjami ropopochodnymi, głównie jednak zanieczyszczenia występują w postaci zawiesin. Ścieki opadowe mogą wymagać pewnego podczyszczania przed ich ponownym wykorzystaniem lub wprowadzeniem do ziemi. Miejscowe zagospodarowanie wód opadowych powinno w jak najmniejszym stopniu wykorzystywać systemy oczyszczania, żeby nie powodować dodatkowego wzrostu kosztów urządzeń, ale jednocześnie nie wpływać negatywnie na człowieka i środowisko. Miejscowe zagospodarowanie wód opadowych może być sposobem na zmniejszenie ilości ścieków odprowadzanych z obszaru zlewni. Jednocześnie może pozwalać na zmniejszenie ilości zużywanej wody wodociągowej do celów sanitarnych. Istotny jest dobór urządzenia i dbałość o nawierzchnie, z których woda opadowa zostaje zagospodarowana. Bez zmiany podejścia zarządzania wodami opadowymi skutki opadów będą coraz bardziej dotkliwe i kosztowne.

Słowa kluczowe: zagospodarowanie wód opadowych, jakość ścieków deszczowych