STUDY OF THE CHEMICAL COMPOSITION OF URBAN SURFACE RUNOFF OF MINSK CITY (BELARUS)

V.Khomich, A.Aucharova, V.Chuduk, G.Bokaja

Institute for Problems of Natural Resources Use & Ecology
National Academy of Sciences of Belarus
Staroborisovsky tract., 10; 220 114 Minsk, Belarus
Phone: (375 17) 264 23 12; Fax: (375 17) 264 24 13;
e-mail: Lena_Ovch@rambler.ru

Abstract

In Belarus up to now only 10 per cent of urban surface runoff are purified mainly from suspended solids and oil products. Not purified urban surface runoff is a reason of numerous adverse impacts, especially on receiving waters. At that time very limited data on this issue are available. So we have started a project devoted to chemical composition of the surface runoff and its impacts study in cities. In the paper the results of spring and summer surveys of urban runoff are described. Water samples were collected at the locations where urban runoff formed: roofs, roadways, shopping plaza, pavements, etc. Besides, the samples of snow, water from the Svisloch river and from the stormwater storage pond were also collected. The chemical composition of runoff has been determined for such water quality constituents as suspended solids, pH and main ions. Samples of flux collected from the roadways and pavements showed severe contamination of urban surface runoff. Chlorides are indicator compounds; its concentration in such water samples 8–50 times exceeded the concentration of chlorides in the receiving water. The increased concentrations of suspended solids, natrium and nitrites were also noted.

Introduction

The urban surface runoff is one of the sources of environment contamination. The surface runoff from the natural landscapes accounts 6–10 per cent and the share of underground runoff is about 90 per cent (1). There are two types of surfaces on the urban territories: impervious (roofs, roadways, pavements, etc.) and pervious (parks, grass-plots, etc.). These surfaces have different runoff coefficients and contribute to various formation of surface runoff. The impervious territories reduce infiltration of rainwater into the ground, and thereby increases the generation of surface runoff. The surface runoff increases 3 times on the city territory.

There is a growing interest in the urban surface runoff, its impacts and the different system of control and treatment strategies designed to mitigate such impacts either fully or partly. Also the discharges of urban stormwater may cause numerous adverse effects on receiving waters, including flooding, erosion, sedimentation, temperature rise and species succession, dissolved oxygen depletion, nutrient enrichment and eutrophication, toxicity, reduced biodiversity, and the associated impacts on beneficial water uses (2). Loads and concentration of pollutants in the urban surface runoff depend on rainfall characteristics, local atmospheric deposition, drainage design, type of functional zone, traffic density, etc.

In European countries, Canada and USA urban drainage infrastructures are significantly changing from the older systems with pipes only, to new, more environmentally friendly systems (green infrastructures) encompassing attractively landscaped ponds, wetlands, infiltration sites and swales (2).

There is a traditional drainage system in Minsk. The snowmelting water and rainwater of runoff is drained via a stormwater collection system to the receiving water (the Svisloch river). This system has some main collectors (the first order collectors), which catch surface runoff and carry off it in the stormwater storage pond. In this pond the urban surface runoff is purified, mainly from suspended solids and oil products. Also there are a second and third order collectors which have self-dependent discharges in the Svisloch river and inflows. The water from such collectors is not purified, because the urban surface runoff water is related, as a rule, to the normative clean water. At the same time, the data of foreign measures show, that the urban runoff conveys such pollutants as solids, hydrocarbons, heavy metals, nutrients, deicing agents, phenols and herbicides (3, 4). At that time in our country very limited data on this issue are available. So we have started a project devoted to chemical composition of the surface runoff and its impacts study in cities.

Objects and methods

Two seasonal field surveys were undertaken reflecting a period of snowmelting and a period of rainfalls. In this initial surveys four different types of functional zones (transport zone, housing and residential zones and zone of “green plants”) on the territory of Minsk, the stormwater storage pond and the lake of Lebjazhe located near the shopping plaza Zhdanovichy were sampled. The Drozdy reservoir located in the upper courses of the Svisloch higher of the Minsk city and the Svislosh river below the Minsk were surveyed too. All samples were collected in March 2003 (the snowmelting period) and in May, June and July 2003 (rainfall period).

Water samples of surface runoff were collected at the locations of their formation. Besides, the samples of snow, atmospheric rainfalls, water from the Svisloch river and from the stormwater storage pond were collected. The chemical composition of water samples has been determined for such water quality constituents as suspended solids, pH and main ions. An accredited chemical laboratory of Institute for Problems of Natural Resources Use and Ecology following standard methods performed all analyses.

Results

<u>Runoff from different functional zones</u>

The data of the chemical composition of atmospheric rainfalls and urban stormwater runoff are summarized in Table 1.

Table 1: The chemical composition of atmospheric rainfalls and urban stormwater runoff from the territory of Minsk city, mg/L

Type of water	Season	pH	HCO_3^-	Cl^-	SO_4^{2-}	NO_3^-	NO_2^-	Ca^{2+}	Mg^{2+}	Na^+	K^+	$NH4^+$	Total mineralization
Atmospheric rainfalls	spr	6.6	4.6	1.4	3.7	0.07	0.05	0.9	0.6	1.0	1.3	1.36	15.0
	sum	6.2	6.0	–	1.1	1.95	–	–	–	0.3	0.2	0.09	–
Snow water	win	7.1	12.2	1.7	1.3	1.80	0.05	0.8	0.4	1.5	0.3	0.48	20.5
Snow from the snowdump	win	7.2	132.2	2836.8	15.6	–	–	20.0	3.6	986	5.72	–	3999.9
Stormwater runoff from roads and pavements	spr	7.7	94.3	3863.2	38.1	3.13	0.93	39.3	6.5	2447.5	20.1	1.90	6515.1
	sum	7.3	73.2	17.7	9.3	1.00	0.91	16.0	3.6	12.2	2.2	3.84	140.1
Stormwater runoff from shopping plaza	spr	7.6	68.6	52.5	3.7	0.71	0.11	17.6	3.5	38.4	5.8	0.90	192.7
	sum	7.8	88.5	11.5	20.0	1.15	0.31	16.8	4.2	9.1	6.5	0.21	130.4
Stormwater runoff from “green zone”	spr	7.7	39.6	15.6	2.7	2.3	0.09	9.5	3.4	7.8	7.3	0.07	88.4
	sum	7.2	30.5	7.2	0.68	0.92	0.02	4.14	1.26	4.3	1.3	0.08	50.3
The maximum permissibal concentration	–	–	–	300.0	100.0	9.0	0.02	180.0	40.0	120.0	50.0	0.39	1000

The data in Table 1 show, the fluxes from roads and pavements have been most contaminated. We can see the same results not only in spring but also in summer. During the snowmelting period such water samples contain a lot of chlorides (805.1–5659.4 mg/L) and natrium (610.0–3580.0 mg/L). Also the increased concentration of suspended solids (1944.9–2570.0 mg/L) and nitrites (0.2–1.4 mg/L) is noted. The total mineralization varies from 1070.4 to 9432.9 mg/L. The samples collected in the same places in the rainfall period are less contaminated. The total mineralization decreases 50 times generally due to reduce of chlorides and natrium concentrations. Fluxes collected from housing, residential and "green zone" contain substantially less quantity of chlorides, natrium, nitrites and suspended

The stormwater storage pond

The data of the chemical composition of water from the reservoir Drozdy, the Svisloch river and the stormwater storage pond "Drazhnja" are summarized in Table 2.

Table 2. The chemical composition of water in the Drozdy reservoir, the Svisloch river and the stormwater storage pond "Drazhnja", mg/L (the spring survey)

Place of samples collection	pH	HCO_3^-	Cl^-	SO_4^{2-}	NO_3^-	NO_2^-	Ca^{2+}	Mg^{2+}	Na^+	K^+	$NH4^+$	Total mineralization
The reservoir Drozdy	7.1	245.5	14.5	38.0	3.55	0.06	58.2	17.4	10.4	2.0	0.20	389.7
The Svisloch river below the Minsk city, before the stormwater storage pond outlet	7.9	250.1	88.7	34.8	5.35	0.14	62.9	19.1	57.6	5.4	1.54	525.7
The stormwater storage pond inlet	8.0	82.34	253.2	14.8	4.40	0.35	22.9	2.9	175.0	7.0	3.10	840.3
The stormwater storage pond outlet at the Svisloch river	7.6	210.5	488.3	26.4	4.40	0.45	63.0	10.4	320.0	10.6	3.50	1137.6
The Svisloch river below the stormwater storage pond outlet	7.8	236.4	285.7	34.4	5.20	0.32	59.1	17.4	192.0	7.0	2.50	840.3

The results in Table 2 show, that the Svisloch river is undergone by the severe antrohogenic load due to influence of surface runoff. The concentration of some main ions in the river water increases not after outlet of the stormwater storage pond but also after Minsk city before this outlet. The highest increase is noted for chlorides (20 times) and natrium (19 times), as well as, for amonium (12 times) and nitrites (6 times). The concentration of the other ions stays on the same levels.

The Lebjazhe lake, near the shopping plaza

The data of the chemical composition of water from the Lebjazhe lake and the stormwater runoff from the shopping plaza are summarized in Table 3.

The data in Table 3 show, the stormwater runoff from shopping plaza is less polluted. But in water samples from this territory increased concentrations of amonium and nitrites are detected. We can note seasonal fluctuations of main ion concentration. So total water mineralization of the Lebjazhe lake decreases from 708.5 to 362.1 mg/L, it probably takes place because of rainfall water dilution. The surface runoffs is less contaminated in the rainfall period. We can see, the Lebjazhe lake and surrounding swales intercept runoff and clean it from suspended solids. In other words these swales are a barrier for penetration suspended solids into the Drozdy reservoir.

Table 3. The chemical composition of water from the Lebjazhe lake and the stormwater runoff from the shopping plaza, mg/L

Place of samples collection	Date	pH	HCO_3^-	Cl^-	SO_4^{2-}	NO_3^-	NO_2^-	Ca^{2+}	Mg^{2+}	Na^+	K^+	$NH4^+$	Total mineralization
The Lebjazhe lake	12.03.03	7.41	341.6	101.3	78.0	3.95	0.42	106.8	28.9	42.4	3.4	1.70	708.5
	06.06.03	7.51	142.0	106.4	37.1	0.70	0.06	38.9	19.4	50.0	2.4	0.42	397.5
	07.07.03	7.80	128.1	101.3	23.8	1.25	0.01	39.3	17.6	48.1	2.5	0.29	362.1
The center of the shopping plaza	06.06.03	7.41	85.4	7.1	9.7	1.20	0.32	11.4	6.8	7.2	8.0	3.70	140.9
	07.07.03	8.72	67.1	7.2	2.3	1.54	0.11	16.5	1.3	4.9	7.2	0.10	109.7
The border of the shopping plaza (no asphalt)	12.03.03	7.81	70.1	54.2	3.8	0.70	0.10	15.3	3.5	40.0	5.6	0.70	194.8
	06.06.03	7.70	115.9	15.9	31.2	0.50	0.54	19.2	12.0	14.0	9.2	0.90	219.5
	07.07.03	7.74	109.8	21.7	19.3	3.95	0.39	26.9	5.0	11.0	4.9	0.37	203.4

Discussion

The runoff water polluted level varies in the large ranges for different functional zones. Also these fluxes have a different suspended solids concentration. We determine an increased concentration of ammonium in surface runoff water from different functional zones in compersion with the runoff from "green zone". This evidence about the week oxidant process and the results are in good agreement with Barymovoj and Chernyschova (5).

In the snowmelting period concentration of suspended solids in water samples from surfaces of roads and pavements increases 65–85 times the maximum permissible concentrations (MPC), nitrites – 45–49, natrium – 11–30, chlorides – 7–19, ammonium – 5 times.

The concentration of chlorides in water samples from the stormwater storage pond increases 1.6 times MPC. The concentration of chlorides in water of the Svisloch river before and after outlet from the stormwater storage pond changes from 0.3 to 1 MPC. The same relation we can see for natrium. The concentration of this element at the outlet is 2.6 MPC and increases from 0.5 MPC (before the outlet) to 1.6 MPC (after the outlet), for nitrites – from 7 to 16 times and ammonium – from 4 to 6 times. The concentration of suspended solids in water of the Svisloch after the stormwater storage pond outlet increases 1.5 times MPC (6).

The summer stormwater runoff is significantly cleaner than the spring fluxes. The total mineralization decreases due to decrease generally of chlorides and natrium concentrations. But there is an increased concentration of ammonium and nitrites.

There is no high level of chlorides and natrium concentrations in water sampled from shopping plaza, but is marked the high concentration of nitrites (4–6 MPC) in the snowmelting period and (3–20 MPC) in the rainfall period. There is an increased concentration of ammonium (2 MPC) in spring and (10 MPC) in summer too.

The urban surface runoff, especially in spring, impacts on the Svisloch and inflows and have to purify.

Conclusions

These data provide a preliminary assessment of runoff contamination from the territory of Minsk. The results of spring survey show, the urban territories with high traffic and pedestrian density contribute to severe contamination of urban surface runoff. Application of deicing agents in a winter period (mixture of salt and sand) is the main source of high concentration of chlorides, natrium and suspended solids in water samples. The storm runoff from urban territory and especially fluxes from the roads and pavements in a snowmelting period increase the chemical load on receiving waters and contribute to contamination of chlorides, natrium and nitrites. The surface runoff has a high concentration of suspended solids and high total mineralization in this period.

The outlet from the stormwater storage pond has an impact on the Svisloch river too and contribute to water quality deterioration.

Runoff samples from roofs, shopping plaza and mixed land use are substantially less contaminated, as well as, samples collected in May, June and July during the rainfall period. The summer stormwater runoff is cleaner than spring fluxes.

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