Carpathian Journal of Earth and Environmental Sciences, May 2012, Vol. 7, No. 2, p. 5 - 12

FLOATING DEBRIS FROM THE DRINA RIVER

Danica ZUPANSKI[1] & Ratko RISTIC[2]
[1]*Institute for Development of Water Resources "Jaroslav Cerni" Belgrade, Jaroslav Cerni Street 80, Serbia,*
E-mail: dzupanski@gmail.com
[2]*Faculty of Forestry, University of Belgrade, Kneza Viseslava 1, Belgrade, Serbia*

Abstract. Floating debris accumulation in storage reservoirs of three dam sites in the river Drina catchment area in Serbia have been causing difficulties in operations and occasional loss of electricity. In the previous research it was suggested that the origin of floating debris could be related to landfills near the riverbanks. This paper attempts to strengthen the apparent connection between landfills and floating debris. As a first step, an inventory of landfills in the Drina River catchment area was assembled. It was found that all municipal landfills in the catchment area are uncontrolled, with mixed, partly hazardous waste. Most of the landfills were located at the riverbanks or in the floodplain. Much of the wastes in contact with the surface water became floating debris. The landfills identified as potential sources of floating debris were potentially the sources of water pollution and could have a profound impact on the river environment. It appears that the most affected water body is the last downstream reservoir of the Drina River due to a cumulative effect of the upstream landfill activities, as well as due to other anthropogenic pressures. The international watershed of the Drina River includes three countries: Bosnia and Herzegovina, Montenegro, and Serbia, thus the problem of floating debris is a regional ecological problem. In order to address this problem and find solutions, it was proposed to identify floating debris as a common and urgent problem in this area, and furthermore to develop a comprehensive plan for future actions.

Keywords: floating debris, surface water, uncontrolled landfills

1. INTRODUCTION

There is about $2.2x10^6$ tons of waste produced in Serbia every year. Public waste management companies collect waste from approximately 60% of the Serbia's territory, eventually depositing them in landfills. There are no waste collection containers in rural areas, however, resulting in illegal depositing by riverbanks or in uncontrolled burning (Ilic et al., 2003).

Legislations that exist in four surrounding countries that share river Drina's catchment area are very similar, and commonly do not require local authorities to sample and monitor activities at uncontrolled landfills (Waste Management Strategy, Serbia, 2010; Zupanski & Gavrilovic, 2006). As a consequence, the problem of pollution has been generally ignored.

According to the serbian Regulations for ecological parameters for surface water, (Official Gazette of Republic of Serbia, 2011) there are four water bodies identified in the Drina River, all heavily modified. As a member of the International Commission for the Protection of the Danube River (ISPDR), Serbia has an obligation to provide, by year 2015 (Slodczyk, 2010), a satisfactory ecological condition of the River Drina, which is a major tributary to the Sava River and eventually to Danube.

The River Drina has been experiencing a growing problem of floating debris (Vukosavljevic, 2000). It has been estimated that Drina River gets contaminated by 45,000 m^3 of floating wastes per year from Serbian part of watershed, approximately 10% of the total produced wastes (Zupanski & Gavrilovic, 2006). Similar content of floating debris, with hazardous industrial and/or medical waste, has been also found in the Ligurian Sea (Aliani et al., 2003), and on beaches in the southeast Pacific (Bravo et al., 2009), and in open oceans, on shorelines or even the most remote island in global environment (Barnes et al., 2011).

Floating debris comes from many sources such as: storm water discharge, combined sewer overflows (Nakada et al., 2004), beachgoers and other nonpoint sources, ships and other vessels (Derrick, 2002), solid waste disposal, landfills, and illegal dumping (Araujo & Costa, 2006), offshore mineral, oil and gas exploration, industrial activities (Moore et al., 2011).

The most buoyant types of floatable debris are plastic (Barnes et al., 2011; Teuten et al., 2011) and some types of rubber (Araujo & Costa, 2006). Paper, wood, and cloth items initially float but then sink once they become saturated with water. Glass, metal, and some types of rubber sink (Ryan et al., 2009).

Although quantities vary between countries, approximately 10% of solid waste is plastic, and up to 80% of waste accumulates on land, rivers, shorelines, the ocean surface or seabed is plastic (Barnes et al., 2011).

Plastic debris contain organic contaminants POPs, PAH, PCBs, SOM-sorbent organic matter that is released and/or transported to terrestrial and aquatic systems (Teuten et al., 2011; Ogata et al., 2009). Plastic, as a part of floating debris were identified in several rivers and lakes in Serbia and suggested that it is similar to municipal waste (Zupanski & Gavrilovic, 2006).

Floating debris can be produced from natural materials, such as tree trunks and branches (Bocchiola et al., 2002). For small rivers and creeks, large amounts of such debris can impact flow direction and flooding (Abbe & Montgomery, 1996; Bocchiola et al., 2002). In addition, a presence of strong winds can cause a steady transport of surface debris with possible beaching (Aliani et al., 2003).

Bio-chemical decomposing of municipal biodegradable wastes produces leachates and landfills gases that could cause both organic and inorganic pollution (Jahic, 1980; Kalyuzhnyi et al., 2003). According to Covich et al., (1999) organic pollution of surface waters creates changes in water temperature, dissolved oxygen concentration, depth, pH-factor, salinity etc.

These changes create a disturbance and consequently impact the population of benthic invertebrates, suggesting that in some cases the presence or absence of a single species can dramatically alter ecological processes. Inorganic nutrient enrichment, in particular by phosphorous and nitrogen, can lead to an increase of algae and higher plant growth (Clarke & Warton, 2001), known as a process of eutrophication (Crossley et al., 2002).

In densely populated regions, river basins are considered to be the most degraded ecosystems (Qicai, 2011). Some authors (Poff & Hart, 2002; Hart et al., 2002), suggest that the most important aspect of restoration is re-establishment of aquatic environment, impacted by a presence and condition of dams and by stream flows.

In this paper we address the problem of floating debris and their relation to uncontrolled landfills. In addition we suggest a foundation for a regional comprehensive action plan. In section 2 we give the characteristics of the river basin, and in section 3 we describe the methodology. Results of our investigation are shown in section 4, and conclusions are drawn in section 5.

2. STUDY AREA

The basin of river Drina (Fig. 1), occupies an area of 19,570 km^2 with the stream length of 346 km. In the upstream part of the basin the annual precipitation is 3,000 mm, with an overall average of 1,100 mm. The basin includes two eco-regions: Dinaric western Balkans and Pannonian lowland. The annual flow volume at the Sava river confluence is 13.4x109 m^3.

There are five tributaries to the River Drina: Lim, Uvac, Cehotina, Tara and Piva. The largest tributary is the River Lim with an area of 5780 km^2 and the smallest tributary is the River Cehotina with basin area of 1,400 km^2.

The River Drina is an international river and there are 16 counties in the watershed of Serbia (Fig. 1), with 666,700 citizens (Table 1). The status of the Drina River water bodies, have been identified only in the territory of Serbia. According to the Water Framework Directives, the artificial lakes should be defined as heavily modified. This suggests that the presence of the hydropower facilities in the watershed of the river Drina were the dominant influences for heavily modified water bodies definitions. An average Drina river flow flux at the Sava river confluence is 436 m^3/s, two times larger than an average for all of Serbia (Rasic, 2002).

3. MATERIALS AND METHODS

The accumulated floating debris found in reservoirs has been transported from upstream regions by rivers and creeks.

Field investigations include collecting data related to: (i) waste management practice and landfill locations available from local authorities, (ii) site inspections of the landfills, (iii) other known dump sites and walkovers to the nearest surface water for detection of floating debris, and (iv) quantification of amount and type of floating debris available from hydroelectric facilities operators (observation period were March-September, 2009-2011).

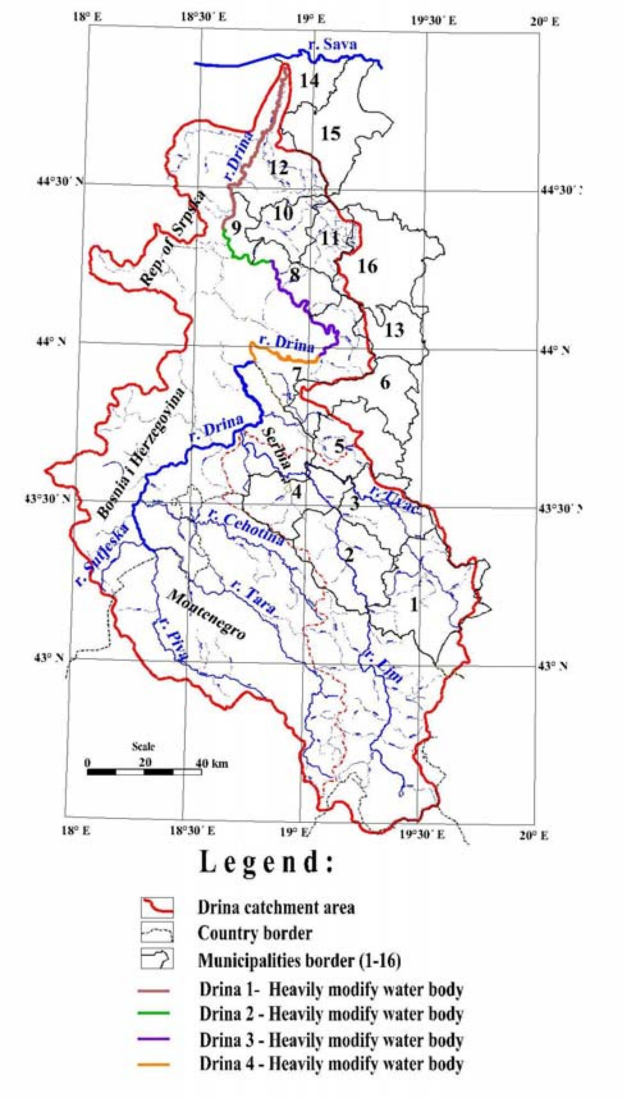

Figure 1. Drina river catchment area

Floating debris was collected from the water surface periodically, after events from each reservoir. Waste collection was organized by local community (volunteer).

At the riverbank all waste (anthropogenic origin) were separated on plastic waste (bottles, glasses, films, containers, bags, etc.) organic waste (cloth, paper, animal carcasses, small branches, leafs, mud), auto-gum, metal waste, and woody waste (manmade). Plastic waste were packed in PVC sheet (1.20x0.8m) and transported for recycling. Metal waste and auto-gum wastes were transported for recycling also, and organic waste were transported by plastic containers of 1m^3, to the nearest landfill. Woody wastes (manmade) were given to local farmers for fuel.

Main goal of our investigation was to expose the problem of uncontrolled landfills and to define uncontrolled landfills as permanent diffuse sources of pollution via floating debris. In the past, the investigations have been focused on the interactions between landfills and underground water and soils, generally due to pollution from leachates, as well as on the interactions between landfills and atmospheric gasses, related to the greenhouse effect. Only by identifying floating debris it was possible to make a connection between landfills and surface water.

4. RESULTS AND DISCUSSIONS

We found that floating debris in the river Drina basin consist of plastic bags, bottles and glasses, plastic packages, tires, dead branches, aluminum waste, carcasses, and other mud and organic materials (Zupanski, 2000; Zupanski & Gavrilovic, 2006). We noticed that some components of the debris were different from the natural river debris and woody debris. On the other hand, it appears that floating debris is a new category of debris with main characteristics (i) anthropogenic origin, and (ii) heterogeneous content. Floating debris first appears on water surface where they float for some time, until they sink, partially or all the way to the bottom. According to the location, floating debris can be: (i) surface floating debris, (ii) suspended debris (between the surface and the riverbed bottom), and (iii) settled debris (at the riverbed bottom). In order to distinguish floating debris from municipal waste, we use the distance from landfill to surface water to derive its origin.

Data from local authorities have shown that all municipal wastes have been disposed without a permit, thus they have been identified as uncontrolled landfills. In order to establish which landfills are responsible for creating more floating debris than others, a preliminary evaluation of the risk of floating debris reaching surface water has been done. The main criterion used is: if the landfill is located in the riparian zone of the river, it is of potentially high risk. The size of riparian area and the related interaction between land and water are critical for maintaining the ecological health of an aquatic environment (Bolton & Shellberg, 2001).

This area varies with the size of the stream or the river. Riparian of 200 m could influenced aquatic environment (Sponseller et al., 2001), 100 m buffer predict biointegrity (Lammert & Allan 1999) and for references sites of stream type riparian buffer zone greater o r equal to 3x channel wide is proposed (Hering et al., 2003).

Unfortunately, the field data for the Drina River are practically non-existent. In order to make quantitative estimates, we define a constant value of 100 m for the width of the riparian area of River Drina, based on general terrain and soil characteristics of the area. The riparian zones of river Drina are strongly affected by geology (Quaternary sediments), by alluvial soils (Dedier et. al., 2007) and climaregional forests (e.g., phytocenosis Populeto-Salicetum, Quercetum-farnetto cerris, Abieto-fagetum and Picetum mugii, Jovanovic, 1971). The streams in these inundation areas have the gravel in their sediments and groundwater seeps through porous soils to feed the river. Any pollution entering this contact medias has great influence to aquatic environment.

We found that 12 main landfills with potentially high risk are in the riparian area. For other landfills more research is needed in order to obtain a reliable estimate of the risk level. Another important criterion is the risk of surface water pollution due to floating debris, in which case the disposed waste type is analyzed. This criteria, however, has not been included since the data from local authorities show that all landfills have a similar content of mixed wastes, organic and inert, municipal solid and hazardous wastes.

For high and moderate risk landfills we propose a detailed quantitative analysis by sampling of water, air, soil and biota, which would direct further actions related to moving the waste or landfill remediation. For low risk landfills we propose introducing a monitoring system based on observations of the ground water quality. Preliminary calculation of the amount of filtrates and gases has been based on data collected from local communities.

This information is important because it shows that both small and large landfills are the sources of leachates and landfill gases. They can be absorbed by surrounding wastes, eventually becoming floating debris.

Although the Drina river basin covers two eco-regions, Dinaric western Balkans and Pannonian lowlands, there is no regional management control of resources, rather an administrative overseeing only. Since the counties are basic units of waste management in this area, our analysis covers somewhat larger area than the actual river basin. Geographical coverage of the Drina river basin with participating counties is shown in figure 1.

Each county has one main, official landfill and several illegal landfills (Table 1). Counties of Nova Varos and Priboj share one main landfill, located in Priboj County. Columns 1-6 of table 1 contain data collected by Ilic et al., (2003). Average annual precipitation data for the period 1955-1995 (column 7) are available from the Republic Hydro-meteorological Service of Serbia. The columns 8-10 (Jahic, 1980), are obtained using typical subjective practice for landfill calculations in Serbia at the time.

4.1. Preliminary calculation of the annual volume of filtrates

Under the assumption that landfill is not covered, the daily amount of filtrates Qf is:

$$Qf = K(P+Q) \quad (1)$$

where K is the absorption coefficient, P is the annual precipitation for landfill area (m^3), and Q is the total water amount from other sources (m^3) (e.g., car washing, landscaping, etc.).

Table 1. Inventory of municipal waste landfills in the municipalities of the Drina catchment area in Serbia

	Municipality	Popul. (thousands)	Main Landfill	Dist. Surface Water (m)	Landf. Area (ha)	Waste Vol. ($10^3 m^3$)	Precipitation (mm/yr)	Absorp. Coef	Leach. Vol. ($10^3 m^3$/yr)	Landfill Gas Volume ($10^3 m^3$)	Risk
	1	2	3	4	5	6	7	8	9	10	11
1.	Sjenica	28.0	Sjenica	0	2.7	53.9	695	1.5	2.8	21.6	H
2.	Prijepolje	41.2	Brodarevo	50	2.0	54.1	765	1.5	2.3	21.6	H
3.	N. Varos	20.0	Drugulic	100	1.7	(400.0)	990	1.5	(2.0)	(160.0)	H
4.	Priboj	30.4	Drugulic	100	1.7	400.0	780	1.5	2.0	160.0	H
5.	Cajetina	15.6	Bregovi	›1000	2.2	236.0	936	1.0	3.1	94.4	L
6.	Uzice	83.0	Sarica O.	0	7.6	1531.7	758	1.0	5.8	612.7	H
7.	B. Basta	29.0	Okucje	0	2.1	64.1	765	1.0	1.6	25.6	H
8.	Ljubovija	17.0	Sljunkara	0	0.2	23.0	893	1.0	0.2	9.2	H
9.	M. Zvornik	14.1	Brasina	50	0.1	0.7	925	1.0	0.1	0.3	H
10.	Krupanj	20.2	Kosevine	100	1.2	17.3	900	1.5	1.6	6.9	H
11.	Osecina	15.1	Belotic	200	1.4	25.0	870	1.0	1.2	10.0	M
12.	Loznica	86.4	Loznica	0	7.9	182.0	797	1.0	6.3	72.8	H
13.	Kosjeric	14.0	Glavna	0	0.6	12.8	776	1.5	0.7	5.1	H
14.	Bogatic	33.0	Nisno P.	›1000	7.0	280.0	675	1.0	4.7	112.0	L
15.	Sabac	122.9	Glavna	50	17.8	713.9	678	1.0	12.1	285.2	H
16.	Valjevo	96.8	Goric	50	6.9	570.0	769	1.0	4.7	228.0	H
	Total	666.7			63.1	4164.0			49.2	1665.4	

Risk: H-high, M-moderate, L-low

The absorption coefficient varies from K=0.1 for landfills on flat terrain and K=0.15 for sloped terrain. Experience suggests that 70% of precipitation evaporates due to drying, and 25% due to biothermal processes. The remaining precipitation settles as leachate seepage at the bottom of the landfill, 15% for sloped landfills and 10% for flat landfills.

Given that these are non-sanitary landfills, there is no inflow from other waters, making Q=0. We also assume that the amount of filtrates is same for the two counties sharing one landfill, the Nova Varos and Priboj counties.

4.2. The volume of landfill gases

Landfill gases consist mostly of methane (CH_4) and carbon-dioxide (CO_2), about 90% of all gases. The remaining part consist of carbon-monoxide (CO), ammonia (NH_3), hydrogen-sulfide (H_2S), nitrogen (N) and oxygen (O), as well as many other compounds dangerous for the environment and for the people. According to empirical data used in Serbia, one cubic meter of mixed municipal solid waste produces about 0.4-0.5 m^3 of gas. The column 10 of Table 1, that gives the cumulative volume of produced gases, has been calculated using a typical value of 0.4 m^3 over an average age of landfills of 25 years.

4.3. Amount and type of debris

River flow is important for debris to enter a reservoir, but the wind is a primary transport mechanism for dispersing debris on the surface. By increasing and decreasing the water level, a dam operator could have an influence to debris transport mechanism.

Floating debris quantity is affected by several factors: equipment issue, diffuse or concentrate surface debris, distance between offload, area, direction of winds, etc. So the amount of debris could vary from year to year. Total amount of floating debris from Los Angeles basin via two main rivers, San Gabriel and Los Angeles, in 2004 was 30,438.52 kg or 30 metric tones (Moore et al., 2011).

Overflows dams generally accumulate the floating debris until a period of higher water level occurs whereby the debris is passed downstream, because of flood protection. All of the three dams (e.g., Zvornik, Bajina Basta and Potpec) have an overflow, and the amount of floating debris from the water surface is not valid for calculation and comparison to facilities with different operation mode and practice.

For example, total amount of removed floating debris from the reservoir of HPP Zvornik (river Drina) were 2,508m^3, in 2009. Debris was separated as: plastic waste (bottles, glasses, PVC bags, films) 1839m^3, auto-gum 10m^3, organic waste 100m^3, metal waste 5m^3 and woody waste 454m^3.

At 2010, total amount were about 1,900m^3 and in 2011, it have been collected from until now 2,220m^3. The total amount of floating debris from the reservoir of HPP Bajina Basta (r. Drina) was 19,112m^3, in 2009, 8,162m^3 in 2010 and 9142 m^3 in 2011. Debris amount from reservoir of HPP Potpec (r.Lim) were 1,200m^3, but until now all debris are passed downstream.

Plastic debris is contributor of chemical pollutants to the environment. Absorption of polychlorinated biphenyls (PCBs) from ingested plastic could cause failure or death to birds, fish or invertebrates (Derrick, 2002). Phthalate plasticizers and brominated flame retardants are associated with carcinogenic and endocrine disrupting effect.

Also, landfill leaching is the source of water pollution via soluble contaminants from plastic: monomer bisphenol A (BRA) and polymers of PVC. Concentration of BRA in leachate ranged from 10 to ten thousand $\mu g\ l^{-1}$ and is much higher than detected in sewage effluents (Teuten et al., 2011). Small fragments of pellet resin (> 5mm) could also be ingested by aquatic animals, and may present physical hazard by clogging feeding (Barnes et al., 2011).

4.4. General assessment

The landfill risk assessment is calculated for main landfills only. Old landfills that are not in use are not identified or included. In addition, it was established that all landfills are uncontrolled. Out of 15 main landfills presented in Table 1 (column 11), 12 are estimated to be high risk (H) one moderate (M) and two low risk (L).

Note that three main landfills (numbered 5, 15, and 16 in Table 1) do not belong to the proper Drina river basin, rather to the surrounding river basins. However, they have been included due to their similarity with landfills in the Drina river basin. Their high risk status indirectly suggests that floating debris in other river basins in the region can be of similar origin.

Landfill legislation that was active in Serbia until 5 December 2010 did not enforce sampling and monitoring of landfills. The new landfill legislation active today is addressing sanitary landfills only. Given that all active landfills in Serbia are uncontrolled and non-sanitary, they are effectively not covered by these legislations.

They fall into a legislative loophole, implying that there is no enforced control of landfills and no assessment of the risk to the environment and to human health. In addition to uncontrolled landfills as sources of diffuse contamination, we are also interested in understanding other human activities that caused the existing ecological status of the Drina River.

Such an analysis is shown in figure 2, through a schematic of the Drina river basin. There are 17 towns, 3 protected areas and 8 hydropower plants with 9 reservoirs in the Drina river basin. According to the Ilic et al., (2003), there are no facilities for processing and filtering of the municipal and industrial water.

Consequently, all municipalities and industrial facilities freely dump wastewater into the river, without any filtering. Before the end of 2010, only 17 companies reported contaminating the river with wastewaters, however without specifying the amounts and type of pollutants.

There are three national parks (Durmitor, Sutjeska, and wetlands Zasavica), and the world heritage Tara river canyon, supporting rare and relict species, that can be further endangered or even become extinct due to present human activities.

The regimes of operations of hydropower plants on Drina River are dependent on each other, since coordination is required in dam overflow situations in order to prevent flooding. At the same time, however, large volumes of water overflow carries floating debris from upstream areas, eventually polluting downstream areas.

The last downstream dam, hydropower Zvornik, has a fish passage that would normally allow a free circulation of fish. Due to debris blocking the passage, however, the diversity of fish population can be endangered. Investigation of difficulties of operation of the hydropower plant Bajina Basta (Zupanski & Gavrilovic, 2006) indicates that shell colonies on the griders were responsible, decreasing the water inflow and thus hindering the production of electric energy. Uncontrolled increase of population of one invertebrate species at the nutrient inflow point implies an ecological disturbance caused by organic pollution that requires future research.

The improvement of the river ecological status begins with planning. The actions following the Water Framework Directive (WFD), in particular the Guidance No. 11 – planning process, have shown positive impacts elsewhere, and can probably be used for river Drina.

A proposal for making a Plan for Regional Environmental Protection (PREP) of the river Drina consists of several steps: (1) Identifying the leading problem common to all countries in the Drina river catchment area (i.e., the problem of floating debris), (2) Forming a Steering Committee with members from all participating countries, that will be responsible for overseeing the situation and informing the public, (3) Making the plan that will be voted on and enforced, (4) Implementation of the plan, and (5) Monitoring of the progress.

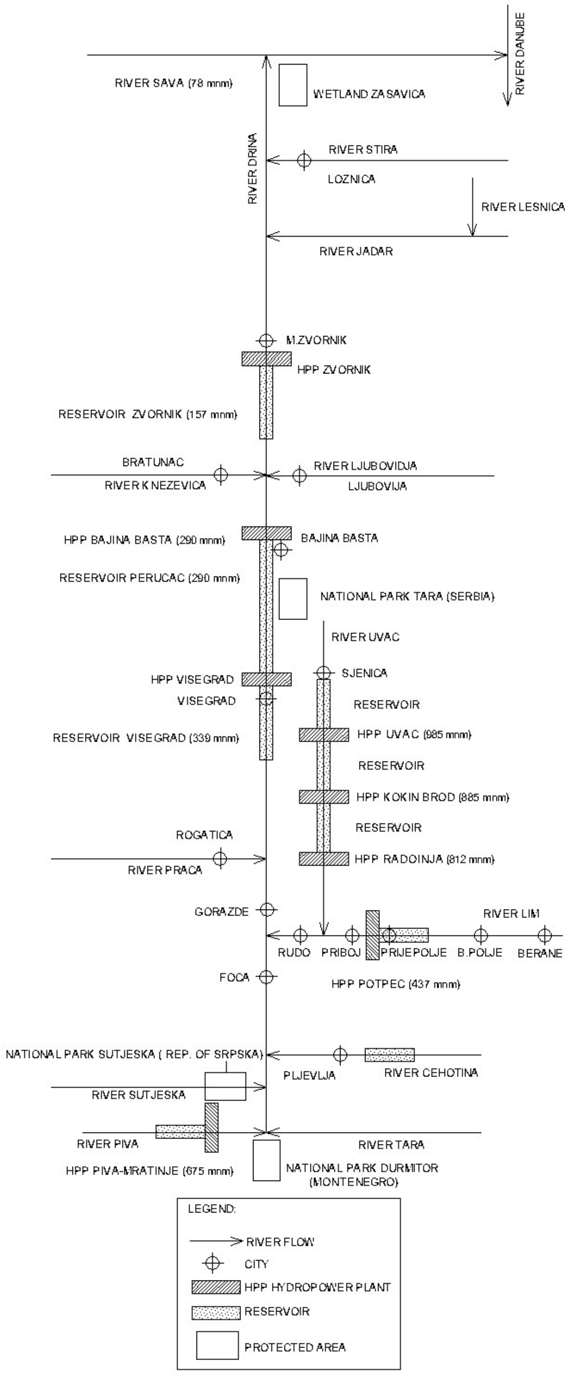

Figure 2. Schematic of the Drina River Basin

5. CONCLUSIONS

In this paper the problem of floating debris in river Drina has been examined. This is a major problem in three countries in the Drina river basin, Bosnia and Herzegovina, Montenegro, and Serbia, which impacts the ecology of the region, population health, as well as the performance of hydropower plants. We establish a connection between floating debris and uncontrolled landfills in the area from an assembled inventory of landfills. Our data suggest that all municipal landfills in the Drina river catchment area are uncontrolled, with an additional hazard due to the location of landfills at the riverbanks or in the floodplain. In contact with surface water much of the wastes become floating debris.

Comparing between different type of floating debris, we conclude that the plastic debris have the greatest percent, 60-80, in total amount of floating debris in all observed reservoirs, from river Drina and tributary, river Lim.

We believe that landfills we identified as potential sources of floating debris are also the sources of water pollution and can have a profound impact on the river environment. The calculated volume of filtrates, the content of floating debris, and the vicinity the streams and river to the landfills to the streams and the river, they all suggest that floating debris could have a regional impact in decreasing the aquatic environment quality and influenced the human health. In addition, floating debris can cause a disruption of the hydropower production on river Drina. It appears that the most affected water body is the last downstream reservoir of the Drina River due to a cumulative effect of the upstream landfill activities, as well as due to other anthropogenic pressures.

The problem of floating debris in Drina River originating from uncontrolled landfills is a regional ecological problem. In order to address this problem and find solutions, we propose to identify floating debris as a common and urgent problem in this area, and furthermore to develop a comprehensive regional plan for ecological protection of the river Drina, that can be used as a foundation for future actions.

ACKNOWLEDGEMENTS

This research is a part of the study under contract No.11191/2004 from Electro Resources Management Company of Serbia and Institute for Water Resources „Jaroslav Cerni“ and under contract 817/11 from 16.07.2009, between Hydropower Plant „Zvornik“ and Institute for water resources „Jaroslav Cerni“ Belgrade, Serbia. We hereby express our sincerest gratitude for financial support. We would like to thank Eng. Misko Sretenovic from HPP Djerdap, Belgrade office, for his help in understanding the dam sites operating systems. We acknowledge Prof. Slobodan Petkovic, from Forest faculty, Belgrade, for his consultations. We also would like to acknowledge Marko Orescanin, Ph.D, from University of Illinois USA, and Mara Orescanin, Ph.D student at MIT USA, for help with manuscript translations and scientific terms.

REFERENCES

Abbe, T.B. & Montgomery, D.R., 1996, *Large woody debris jams, channel hydraulics and habitat formation in large rivers*. Res. Management 12, p.201-221.

Aliani, S., Griffa, A. & Molcard, A., 2003, *Floating debris in the Ligurian Sea, northwestern Mediterranean*. Marine Pollution Bull., 46, p.1142-1149.

Araujo M. & Costa M. 2006, *The significance of solid wastes with land-based sources for a tourist beach: Pernambuco, Brasil,* Pan. American Journal of Aquatic Sci. 1,p.28-34.

Barnes, D., Galgani F., Thomson R. & Barlaz M., 2011, *Accumulation and fragmentation of plastic debris in the global environment*, Phil. Trans. of Royal Soc. 364, p.1985-1998.

Bocchiola, D., Catalano, F., Menduni, G. & Passoni. G., 2002, *An analytical-numerical approach to the hydraulics of floating debris in river channels*. J. Hydrology, 269(1-2),p.65-78.

Bolton, S. & Shellberg, J., 2001, *Ecological issues in floodplains and riparian corridors*. White paper prepared for Washington Department of Fish and Wildlife, University of Washington, Center for Streamside Studies, p.154.

Bravo, M., Angeles, G., Luna-Jorquera G., Nunez P., Vasquez N. & Thiel M. 2009, *Anthropogenic debris on beaches in the SE Pacific (Chile), Results from a national survey supported by volunteers*, Marine Pollution Bulletin 58, p.1718-1726.

Clarke, S. & Warton, G., 2001, *Sediment nutrient characteristics and aquatic macrophytes in lowland English rivers*, Science of the total Environment, 266(1-3), p.103-112.

Covich, A., Palmer, M. & Crowl, T., 1999, *The role of bentic invertebrate species in freshwater ecosystem*, BioScience, 49(2), p.119-127.

Crossley, M.N., Dennison, W.C., Williams R.R. & Wearing A.H. 2002, *The interaction of waterflow and nutrient on aquatic plant growth*, Hydrobiologia, 489(1-3), p.63-70.

Derrick, J. 2002, *The pollution of the marine environment by plastic debris: a review*, Marine Pollution Bulletin, 44, p.842-852.

Dedier, A., **Mitrovic-Josipovic, M., Radulovic, E., Dimic, B., Maric, L. & Krunic-Lazic M.** 2007, *Environment in Serbia: An Indicators Based Review*, Publisher: Serbian Environmental Protection Agency (SEPA), Ed: Cicero, Belgrade, Serbia, ISBN: 978-86-84163-34-1, p.168.

Hart, D., Johnson, T,. Bushaw-Newton L., Horwitz, R., Bednarek, A., Charles, D., Kreeger, D. &Velinsky, D. 2002, *Dam removal: Challenges and opportunities for ecological research and river restoration*, Bioscience, Vol. 52, No. 8, p.669-681.

Hering, D., Buffagni A., Moog, O., Sandin, L., Sommerthouser, M., Strubauer, I., Feld, C. & Jonson, R., et al., 2003, *The Development of a System to Assess the Ecological Quality of Stream based on Macroinvertebrates*-Design of the Sampling Programme within the AQEM Project, Internat. Rev. Hydrobiology 88(3-4), p.345-361.

Ilic M., Stevanovic-Carapina K., Mladenovic A., Milovanovic D., Todorovic M., Gavric I. & Petkovic, G. 2003**,** *Municipal Solid Waste Management Plan,* Ed. Regional Centar for Environmental Protection (REC) for Central and Eastern Europe, Standard 2, Belgrade, ISBN 86-7550-007-6, p.133.

Jahic, M., 1980, *Landfills and water protection*, Publ.: Institute for human health and environment protection, Sarajevo, ISBN 86-81669-02-8, p.174.

Jovanovic, B., 1971, Dendrology and Principles of Plant Sociology, Publisher: Scientific Book, Belgrade, Serbia, p.536.

Gouvernemont of Serbia, 2010, *National Waste Management Strategy*, Publ. Official Gazette of Republic of Serbia, No.8/10, p.122, (in Serbian).

Gouvernemont of Serbia, 2011, Regulations for ecological and chemical parametars for surface water and status of groundwater, Publ. Official Gazette of Republic of Serbia. No..74/11, p.13, (in Serbian).

Kalyuzhnyi S., Epov A., Sormunen, K., Kettunen, R., Rintala, J., Privalenko, V., Nozhevnikova, A., Pender, S. & Colleran, E. 2003, *Evaluation of the current status of operating and closed landfills in Russia, Finland and Ireland with regards to water pollution and methane emision*, Water Science and Technology, 48(4) p.37-44.

Lammert, M. & Allan J.D., 1999, *Assessing biotic integrity of stream: effects of scale in measuring the influence of land use cover and habitat structure on fish and macroinvertebrates*, Environmental Management 23(2), p.257-270.

Moore J., Lattin L. & Zellers F., 2011, *Quantity and type of plastic debris flowing from two urban rivers to coastal waters and beaches of southern California*, Journal of Integrated Coastal Zone Management, 11(1), p.65-73.

Nakada, N., Nyunoya, H., Nakamura, M., Hara A., Iguchi, T. & Takada, H. 2004, *Identification of estrogenic compounds in wastewater effluent*, Environ. Toxicol. Chem. 23, p2807-2815.

Ogata Y. et al., 2009, *International Pellet Watch: Global Monitoring of persistant Organic Pollution (POPs) in coastal waters*, Marine Pollution Bulletin, 58, p.1437-1446.

Poff L. & Hart D. 2002, How *Dams Vary and Why It Matters for the Emerging Science of Dam Removal***,** BioScience, Vol. 52. No. 8,p.659-668.

Qicai L., 2011, *Influence of Dams on River Ecosystem and Its Countermeasures,* Journal of Water Resource and Protection, 3, p.60-66.

Rasic, M., 2002, *Master plan for the catchment area of the Drina river project of the Drina river watershead*, Proceedings: Scientific Meeting, HYDRO 2002 (In Serbian), Ed. Energoproject-Hydroengineering Co., Belgrade, Vol. 1, p.1-13.

Ryan, P., Moore, C., van Franecer, J. & Moloney, C. 2009, *Monitoring the abundance of plastic debris in the marine environment*, Philosophical Transaction of the Royal Society, 364, p.1990-2012.

Slodczyk K., 2010, *Transeuropean Transport Network in the Context of the Implementation of Sustainable Development – A case study of the Danube river regulation project*, Economic and Environmental Studies, Vol. 10, No.4, p.399-413.

Sponseller, R.A., Benfield E.F. & Valett, H.M., 2001, *Relationship between land use, spatial scale and stream macro invertebrate communities*, Freshwater Biology, 46, p.1409-1424.

Teuten, E., Saquing, J., Knappe, D., Barlaz, M., Jonsson, S., Bjorn, A., Rowland, S., et al., 2011, *Transport and release of chemicals from plastic to the environment and to wildlife*, Philosophical Transaction of the Royal Society, 364, p.2027-2045.

Vukosavljevic S. (2000), *Problems in operations of the HPP Potpec by the floating debris and river debris influence,* Journal of Electrical Resources Management (in Serbian), Belgrade, Vol. 53, p.57-63.

Zupanski, D., 2000, *Biological closure of the municipal solid waste landfilsl in Serbia*, International Conference Proceedings: Waste waters, municipal solid wastes, and hazardous wastes, Kopaonik. Publisher: Society for Water Technology and sanitary engineering, Belgrade, Serbia, p.243-247.

Zupanski, D. & Gavrilovic Z., 2006, *Hydroelectric power plant protection from floating debris accumulation*, International Conference Proceedings, “Elektra VI”, Tara, Serbia, Vol.1, p.244-249.

Received at: 28. 06. 2011
Revised at: 04. 01. 2012
Accepted for publication at: 14. 01. 2012
Published online at: 20. 01. 2012