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Garbage in Rivers and the Problems of Its Transportation to the Ocean

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Abstract: This project proposes to evaluate the transport capacity of plastic waste to receiving bodies in urban watersheds because most of the plastics found in the oceans are produced in these. These are an important factor in the problem of litter in the oceans. The oceans have become gigantic waste dumps. The widespread mismanagement of urban waste is polluting the seas to unimaginable levels. In particular, and analyzing the situation in Argentina, the case of the Dupuy sub-basin in the Riachuelo-Matanza basin was considered the river that is most polluted and is usually called the Chernobyl of Argentina, hence the importance of its study. For this, hydrological modeling was carried out and the flow rates and flood levels were determined.

Key words: SUW, solid urban waste in rivers, solid waste in oceans, flood levels

1. Introduction

Sustainable Development is that which “satisfies the needs of the present without compromising the capacities of future generations to satisfy their own needs” according to the World Commission on Environment and Development (established by the United Nations in 1983). That is, the process by which the requirements of today’s society are met must not negatively affect the quality of life of future society.

On July 20, 2016, the first report of the Sustainable Development Goals (SDGs) was presented, which accounts for the road travelled, where we are and how much more is needed to achieve the 2030 Development Agenda. Each goal has specific targets that must be achieved in the next years.

The Argentine State, together with the rest of the UN Member States, adhered in September 2015 at the World Summit on Sustainable Development in New York to the 2030 Agenda “Transform our world”.

Objective 14 raises the protection of the oceans and underwater life. Because the world's oceans — their temperature, chemistry, currents, and life — drive global systems that make Earth habitable for humanity. The prudent management of this essential global resource is a key feature of a sustainable future. (UNDP).

Currently, the oceans have become gigantic landfills. The widespread mismanagement of urban waste is polluting the seas to unimaginable levels.

Marine litter, according to the United Nations Environment Program (UNEP) is any solid and persistent material manufactured or processed, disposed of, or abandoned on the coast or in the sea. It is estimated that between 6.4 and 8 million tons of marine litter, mainly plastic, reach the ocean [1].

Main sources of marine litter are Land-based: land-fills and littering of beaches and coastal areas (tourism), rivers and floodwaters, industrial emissions discharge from storm water drains, untreated municipal sewerage; and Sea-based: fishing and aquaculture, illegal or accidental dumping at sea from shipping (e.g., transport, tourism), offshore mining and extraction [2].

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They come in various types such as glass, paper, cardboard, metal, cloth, fishing-related waste, ammunition, wood, cigarette filters, sanitary waste from sewage, ropes, toys, etc. Plastics represent 80% of marine litter [3]. Plastics in the marine environment have become of great concern due to their persistence in the ocean and the adverse consequences for marine life and to human health [4].

It is estimated that 1.15 to 2.14 million tons of plastic enter the ocean each year from rivers. More than half of that plastic is less dense than water, meaning it won't sink once it hits the sea [5]. When it is introduced into the marine environment, the floating plastic can be transported by surface currents and winds, recaptured by the coasts, and degraded into smaller pieces by the action of the sun, temperature variations, waves, and life marina, or lose buoyancy and sink [6]. Being resistant, they persist on the sea surface as they make their way out to sea, transported by converging currents and finally accumulating on garbage islands [5].

There are currently 5 documented garbage islands in our oceans, although there are other smaller ones such as the one that is forming in the Mediterranean (the largest measures approximately 3.4 million square kilometres). These plastic agglomerations have been formed by the action of currents and winds, together with the uncontrolled dumping of garbage [7].

This panorama presents us with a complex scenario in the face of environmental paradigms and raises the need to evaluate the transport capacity of plastic waste to receiving bodies in urban basins since most of the plastics found in the oceans are produced in these.

Fig. 1 Micro and Macro plastics on the coast.

In this article, an approach is made to the problems that arise in the Dupuy stream basin, which belongs to the great Riachuelo basin in the province of Buenos Aires. This basin is considered one of the twenty most polluted basins in the world.

The Matanza Riachuelo Basin covers some 2,000 km^2 and is in the Metropolitan Area of Buenos Aires, a place with a high population density. The contamination of this basin affects and diminishes the quality of life of people.

ACUMAR (Matanza Riachuelo Basin Authority) monthly removed more than 230 tons of waste from the Matanza Riachuelo water mirror, which is sent for final disposal at CEAMSE (State Society Metropolitan Area Ecological Coordination) together with what is cleaned from dump points, dumps, corridors, and margins. [8].

2. Material and Methods

The objective of the study was to make an approximation to the problem of garbage management and its transport in the basin under analysis.

This basin has numerous works and studies carried out by ACUMAR (Matanza-Riachuelo Basin Authority) where the waste in the basin is sampled, allowing the existing situation to be visualized.

The analysis consisted of:

- Compilation and analysis of hydrological information of the site, Matanza Riachuelo basin.
- Study of the urban basins of the Arroyo Dupuy, tracing them and application of hydrological/hydraulic models to determine the flow, EPASWMM
- Analysis of the relationship between flow and entrainment of urban solid waste.

3. River Source of Garbage Entry Into the Oceans

The sources of plastic entering the oceans are many and diverse, including fluvial and atmospheric transport, garbage on beaches, as well as transport, and activities directly carried out at sea.

An important source of contamination to the aquatic environment is caused by garbage present in urban streets and open-air dumps, exposed to runoff during precipitation events. This garbage is then discharged to the final receptors of the runoff (rivers, lakes, and seas) and transported by them. In highly industrialized areas or areas with a high population density, water contamination with solid waste often becomes critical and it is expected that this situation will worsen with the increase in precipitation, and expected situation in many places, because of climate change [9].

Rivers in densely populated urban basins present the problem that they become true garbage rivers when there are floods and transport all the garbage from the banks.

4. Transport of Plastic Through the Fluvial System

Plastic debris transport by rivers is a crucial, but complex component of the global plastic pollution, transport mechanisms, measurement methods and modelling approaches, and providing and outlook for future research. Riverine plastic debris transport is an emerging science and important knowledge has been developed in recent years. However, what becomes clear that there are still many scientific questions to answer and methodological challenges to overcome [10].

The route of macroplastic debris through a fluvial system (or its given part, e.g., subcatchment or river reach) can divide into five phases: input, transport, storage, remobilization, and output [11]. Each phase is controlled by natural o anthropogenic factors. Input of microplastic is mainly controlled by anthropogenic factors, phase 2-4 (transport and remobilization) by natural ones, and phase 5 (output) by both types of factors.

This conceptual model helps us understand that the river is not only a mere transport of plastic to the ocean but also stores it.

5. Matanza-Riachuelo Basin

The Matanza-Riachuelo River is a tributary of the Río de la Plata, and this in turn flows into the Atlantic Ocean. Its channel runs a total of 64 km in a southwest-northwest direction. It is a collector of 66 tributaries. The main course of the Basin is called Matanza in its first segments and Riachuelo in its final section until its mouth where it discharges its waters into the Río de la Plata.

It is a plain basin. Due to its low slope and low flow, there is a slow movement of its waters, hindering its aeration process. The territory of the basin includes the northeast of the Province of Buenos Aires (Argentina), covering part of 14 of its municipalities.

Approximately 6,000,000 people live in this basin, according to estimates by the Matanza-Riachuelo Basin Authority (ACUMAR) for 2016[1]. Within this basin is the sub-basin of the Dupuy stream.

It is estimated that there are more than 4,000 industrial establishments located in the middle and

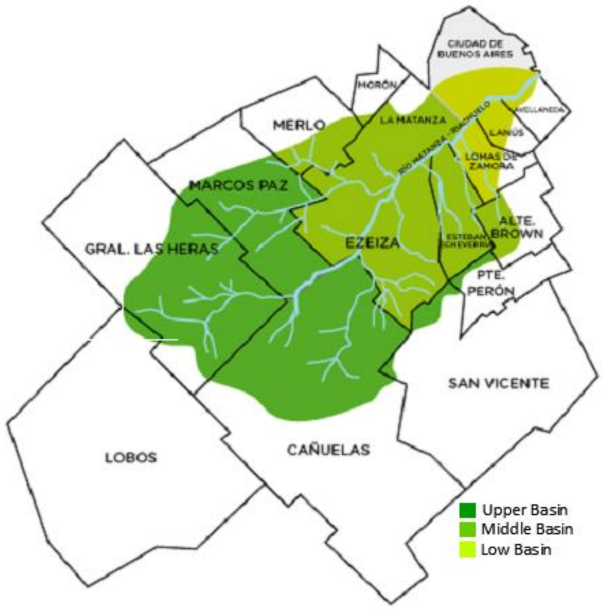

Fig. 2 Matanza – Riachuelo Basin[2].

[1] https://www.acumar.gob.ar/caracteristicas-cuenca-matanza-riachuelo.

[2] https://es.wikipedia.org/wiki/R%C3%ADo_Matanza-Riachuelo.

lower sections of the basin. Within the industries are chemical, petrochemical, food, tanneries, metallurgical and refrigerators, among others. Many of these industries discharge raw effluents into the drainage system or directly into the river. In addition to high levels of organic pollution, these discharges provide toxic pollutants such as heavy metals.

The Matanza-Riachuelo River is one of the most polluted bodies of water, fundamentally due to the industrial and residential discharges it has received throughout its history. The Riachuelo, being a plain river, without a large flow, does not facilitate the effective runoff of fluids and lacks self-purification capacity.

The management of Urban Solid Waste (RSU) in our country is of municipal competence. The governments of these jurisdictions are responsible for managing the waste generated in their territories. The inadequate, inefficient, and insufficient management of MSW has as one of the main consequences of the presence of open dumps.

In general, the Buenos Aires municipalities included in the Basin have serious problems in dealing with waste management in a sustainable manner. A first limitation is that most of them have financing problems because of the insufficient collection, which must be supplemented by provincial and, on occasion, national funds. This reality places them in a situation of economic instability that prevents them from autonomously managing their operations and having a clear horizon to carry out their programs [12].

Regarding the management of the RSU, it represents on average between 15% and 30% of the annual budget. Added to this is a relative disorder and disintegration in accounting, financial and budgetary matters of the entire municipality, in general, and of RSU management. This is framed in a situation of structural income problems and low collection capacity of municipal rates. Hence, the municipality finds itself in deep difficulties when it comes to paying for infrastructure works necessary to carry out environmentally sound management of waste. This often leads to limiting waste management to systems with few environmental controls and the consequent risks to health and the environment. Another limitation that local governments have is that rarely in the municipal structure is there an area responsible for solid waste management endowed with resources, tools, and technical capacity to face the efforts required to prepare and develop comprehensive MSW management plans. In many cases, the lack of sufficient information, and the lack of uniform and widespread criteria, make it difficult to design and implement management plans, programs, and projects related to MSW at the municipal level [12].

5.1 Dupuy Stream Sub-Basin

Due to the large area of the Matanza Riachuelo basin, the Dupuy stream basin was selected to develop the study. The basin is in the locality of Laferrere (La Matanza) in the Metropolitan region of Buenos Aires.

The town has 248,362 inhabitants according to the 2010 census, it is the most populous in the district and one of the most populated in the suburbs of Buenos Aires. It is located 24 km from the center of the City of Buenos Aires.

The locality of Laferrere is crisscrossed by the Don Mario, Susana, and Dupuy streams, which after traveling from north to south discharge their waters into the Matanza-Riachuelo river. The Dupuy stream probably does not have interventions and in most of its course, it is in the open.

In the Arroyo Dupuy basin, 26 dumps have been detected between dump points and micro dumps. This data was obtained from a survey of middens in the Matanza-Riachuelo basin carried out by ACUMAR.

6. Characterization of Solid Waste Generated in the AMBA

For proper comprehensive waste management, it is necessary to know their composition, which will depend on the country, the city, the socioeconomic level, the culture, and the economy of the place. This information allows strategic decisions to be made to define how to dispose of waste in the best way, either by recovering it to the value chain or proper final disposal.

Specifically for this study, the values of plastic that are generated and the percentage that they represent will be considered, as well as the subcomponents. Analyzing and knowing the percentages of plastics allows estimating how much of the plastic that is generated and that does not go to the formal circuit, would be reaching the receiving bodies.

According to a study of the characterization of solid waste generated in the Metropolitan Area of Buenos Aires (AMBA), carried out in 2010/2011 by the Sanitary and Environmental Engineering Institute through the technical assistance agreement entered between the Metropolitan Ecological Coordination (CEAMSE), the largest amount of waste is a domestic waste with 37.65%. Plastics are in second place, they represent 15.22%, of which PEAD are the ones with the highest percentage with 2.02%. It is followed by paper and cardboard with 13.8%. Those that represent the least amount are medicines.

Where Polyethylene Terephthalate (PET) corresponds to 13% of the total Plastics that made up the waste analysed; High-Density Polyethylene (PEAD) 13%; Low-Density Polyethylene (PEBD) 41%; Polypropylene (PP) 19% and Polystyrene (PS) 10%.

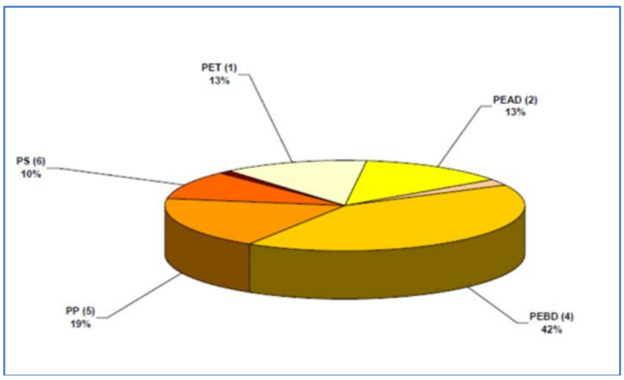

Fig. 3 Subcomponents of the plastics components of the AMBA 2011. Source: CEAMSE.

7. Hydrological Modeling

7.1 Digital Terrain Model

To quantify and visualize the ground conditions in three dimensions (3D), a numerical data structure is generated that represents the spatial distribution of the elevation of the ground surface, that is, a digital elevation model (DEM) from a variety of resources listed below.

For the preparation of the MDE, the raster images of the SRTM project were downloaded from the Nasa ftp, which consists of a specially modified radar system to acquire stereoscopic topographic elevation data. The technique used combines interferometric software with SAR radars with “synthetic” widths in their reflector antennas.

ASTER (Advanced Satellite Thermal Emissions and Reflection Radiometer) images were acquired from NASA. The ASTER instrument, provided by the Japanese Ministry of Industry and Commerce and built by NEC, Mitsubishi Electronics Company, and Fujitsu, Ltd., measures cloud properties, catalogues vegetation, surface mineralogy, soil properties, the temperature of the soil, and surface topography of specific regions of the Earth. ASTER’s high spatial resolution makes it possible to observe minute details. The main accidents, structures, and geoforms are clearly visible. On the other hand, and about the generation of DEMs, having two sensors at different angles allows obtaining, at very close times, different images of the same sector suitable for stereoscopic reconstructions.

The images obtained during the topographic survey carried out at the place where the fenders were installed were digitized and referenced. This information was integrated into the generated MDE. With the help of the images and photographs of the area, singular points were identified in the channels and within the basin (ridges, trough lines, crests, ravines, etc.) prioritizing the runoff lines and significant accidents within the area of flood.

The set of information was completed and contrasted with data extracted from images taken from Google Earth Pro.

An inspection of the area was carried out to identify singular points (ridges, watercourse lines, crests, ravines, etc.) prioritizing runoff lines and significant accidents within the contribution area.

7.2 Supply Basin

With the generated model, the basin, the sub-basins, and their associated parameters were determined.

The discretization in sub-basins used for the analysis is presented in Fig. 4.

7.3 Hydrological Modeling

A hydrological model was made to obtain the values of flows and volumes of surface runoff water from the basin, through a simulation of the rain-flow transformation process. For this purpose, the storms corresponding to the recurrence periods of interest were determined in the first instance.

For the rain-flow transformation model, the EPA SWWMM program was used, which is widely used and widely accepted.

8. Flood Levels Based on Modeling Results

From the flows calculated with EPASWMM, the tension rods and the speeds in the streets were calculated considering a section composed of the roadway and typical sidewalk. Haestad Methods Flowmaster software was used for this purpose.

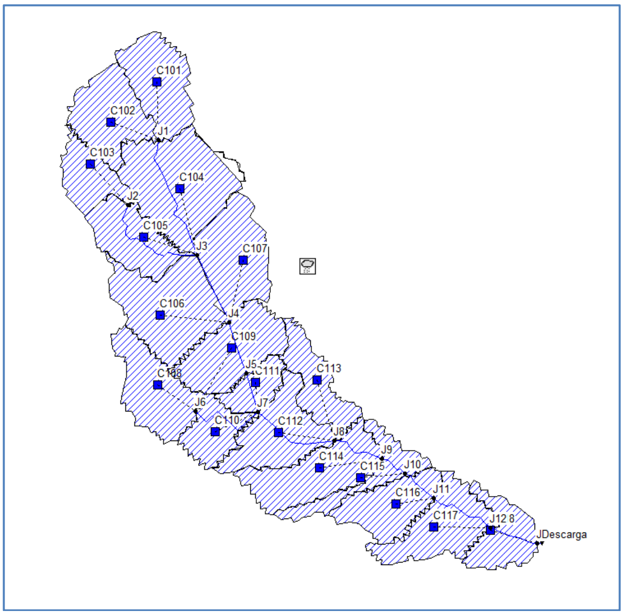

Fig. 4 Sub-basins considered in the modelling of the dupuy basin.

For the analysis of the levels of flood danger in homes based on various criteria [13], a table was made presenting the lowest and highest depth values (based on the flows obtained in the modelling) for the recurrence times of 25, 50 and 100 years as well as the associated speed values (Table 1).

Table 1 Analysis of Flooding, According to Different Criteria

			Cuenca	OFEE	FEMA	Gales	IMTA
TR 25 years	Lower tie rod (m)	0.18	C101	Low level	Medium level	Low level	Nil level
	Speed of the lower tie rod (m/s)	1.77					
	High tie rod (m)	0.34	C104	Medium level	Medium level	Low level	Low level
	Speed of the high tie rod (m/s)	1.68					
TR 50 years	Lower tie rod (m)	0.2	C100	Low level	Medium level	Low level	Nil level
	Speed of the lower tie rod (m/s)	1.89					
	High tie rod (m)	0.383	C104	Low level	Medium level	Low level	Low level
	Speed of the high tie rod (m/s)	1.523					
TR 100 years	Lower tie rod (m)	0.21	C105	Low level	Medium level	High level	Nil level
	Speed of the lower tie rod (m/s)	2.01					
	High tie rod (m)	0.4	C105	Medium level	High level	Transition level	Low level

The biggest problem generated in the basin is the dragging of garbage bags that are deposited on the sidewalks. When the tie rod of the streets reaches approximately 20 cm (considering a sidewalk height of 15 cm), the bags would be already moved because they float.

With the value of the garbage generation rate of the basin of 1.29 kg/day/inhabitant, the population of 2024, the percentage of waste that goes to the informal circuit, and the percentage of plastic waste; the number of plastics that would go to the receiving bodies in the year 2024 would be 4.5 tons/day (Table 2).

Table 2 Quantity of Plastics Reaching the Dupuy Stream - 2024

	Generation rate kg/inhabitant/day	Population 2024	Waste kg/day	Informal circuit 10.1% kg/day	Informal Circuit tn/day	Plastic tn/day
Dupuy	1.29	231860	299099	30209	30.21	4.5

This implies that they are almost always dragged and reach very far distances from the drop point, which is why plastics reach the oceans if they are not intercepted on their way. Given the characteristic of the density of these and that they travel long distances, it is possible that plastic islands are formed, and their accumulation occurs.

An additional comment should be made about those materials with a higher density than water (greater than 1000 kg/m^3) they would not present the same buoyancy and could be analysed from the Shields abacus, for which the diameter should be considered. of the macroplastics, the tie, and the slope.

9. Conclusion

So far, attention has been directed at thermal warming and sea-level rise. And not much progress has been made on the issue of how much solid waste dumps from cities contribute to the environmental deterioration of the oceans. Existing studies of waste in oceans and seas do not link their quantity with the responsibility and transport capacity of rivers as conduction elements. In addition, there are notable advances in the study of the consequences in the distribution of rainfall, and in the risk of more episodes, and more intense, of droughts and floods.

The need to evaluate the amount of waste that is dragged in urban basins towards the streams that flow into the oceans was raised. These constitute an important factor in the problem of garbage in the oceans.

The benefits of plastic are undeniable. The material is inexpensive, lightweight, and easy to produce. These qualities have led to a boom in plastics production over the past century. The world is no longer able to deal with the amount of plastic waste that is generated, the ways in which it is manufactured, used, and disposed of as waste must be rethought. This requires an analysis of the life cycle of this element.

In Argentina, the Matanza-Riachuelo Basin in the Province of Buenos Aires is one of the most polluted in the world. The waste generated because of the activities carried out in its basins constitute a source of pollution that is aggravated by the incorrect disposal and management of urban solid waste.

When considering the sustainable development of a society, it is essential to face the protection of our bodies of water not only from the human point of view but also from our responsibility as protectors of the planet. In this context, to understand the seriousness of the situation, it is necessary to address management models where the importance of adequate watershed management can be assessed. For this, it is crucial to promote the dissemination of the problem of the deterioration of water bodies due to the presence of waste and to achieve social awareness on the subject.

Regarding the basin that was analysed, it was possible to evidence by the results obtained through the EPASWMM software, that all the nodes of the basin, from the return period of 25 years, manifest overflows. This circumstance added to the fact that around the main channel there are dumps with the presence of plastics in large quantities, the vast majority of these would be transported.

As previously calculated, by 2024, 4.5 tons of plastic would arrive per day due to the large amount generated in homes and their poor management. The overflow and dragging of waste from the banks of the canal, links a problem of hydraulic capacity with a sanitary one, evidencing the multidimensionality of the problems that are addressed by environmental engineering.

Another result obtained from the analysis of the density of plastics is that the bottles if they are discarded empty and covered since they are much less dense than water, can be transported for hundreds of kilometres with greater ease. This situation makes it important that the bottles that are discarded are crushed or compacted so that their density increases, and they do not reach the oceans.

It is of great importance, due to the density of the garbage bags that are placed on the sidewalks with household waste, that you consider placing them in elevated garbage baskets so that they are not dragged. This would also benefit that the animals do not break the bags and spread the waste.

This study highlights the importance of analysing the processes of plastic transport in urban basins, which are the largest sources of pollution in the oceans. Little is known about this transport and it itself involves and requires all the actors of society, to reverse the environmental problems linked to plastic pollution in the oceans.

The challenge is to involve the entire population in this issue as necessary participants to obtain sustainable development.

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