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Solid Waste and Sediments in The Urban Drainage of The City of Recife-Pe

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Moacyr Magalhães Cavalcanti Neto*[1], Wrias Elmom Firmino Lino[1], Agostinho Gomes Marinho[1], Kalinny Patricia Vaz Lafayette[1], Luciana Cássia Lima da Silva[1], Simone Rosa da Silva[1], Jaime Joaquim da Silva Pereira Cabral[1], Jonas da Silva Bezerra[2]

[1] Recife, PE Universidade de Pernambuco, Brazil

[2]Recife, PE Universidade Federal de Pernambuco, Brazil

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ABSTRACT

The generation of waste becomes a problem when part of it reaches the drainage systems and the watercourses, degrading the environment. Due to this, it is necessary to quantify waste that reaches the urban drainage. The survey of the amount of solid waste in the urban drainage network is indispensable for adequate management of urban waters and environmental sustainability. In this way, this article aims to measure the amount of solid waste existing in the drainage systems of the city of Recife, through direct and indirect methods that aim to estimate waste loads. The correlation between rainfall and solid waste data found in the drainage system is also evaluated through the forecast curve of drained solid waste. For the city of Recife an index of 112.90 $kg.ha^{-1}.ano^{-1}$ was obtained, an expressive value to cities in developed countries, which is probably caused by the deficiency of collection measures and lack of awareness of the population from a hydro-environmental point of view. With regards to the forecast of drained waste, it was verified that rainfall has a deciding character in the quantity of solid waste circulating in the urban drainage system.

INTRODUCTION

The flood, among all-natural disasters, is the most common recurring risk event and causes losses by altering the socio-spatial configurations of the affected cities. Several factors cause urban rainwater drainage problems, such as structural, hydrological, socioeconomic, and climatic [22]. As well, there are several significant factors caused by anthropic action that trigger the frequent occurrence of floods, such as the high concentration of waste in the drainage system that obstructs the pipelines [18,22].

In developed and densely populated countries, much of the urban infrastructure investment is directed towards urban drainage, aiming at an integrated approach to urban water management as well as raising public awareness of urban effluent pollution, which compromises urban areas themselves as well as the water bodies that receive these effluents [15].

The combination of unplanned urbanization and solid waste dumped at random makes drainage a complicated issue for cities. Urban drainage systems in densely populated cities are often filled with garbage and sediment, as people still use the micro drainage system for solid waste disposal [14,7].

Waste, besides obstructing the drainage system and increasing the frequency of flooding, contributes to the deterioration of water systems due to the long lifespan of some debris. For the proper management of water sources and the reduction of solid waste on the water system, it is necessary to quantify the existing solid material [20]. A suitably designed urban drainage infrastructure linked to a regular maintenance plan of the drainage system is essential to ensure the continuous operation of the drainage system [16].

Although most cities have urban sanitation services, they are often unable to collect all solid waste contained in urban drainage systems, resulting in the accumulation of debris in canals and galleries. These systems, often already affected by poor conduction capacity at the current level of urbanization, become solid waste transport agents, and consequently obstruct the flow [21,3]. And since they are unable to retain this solid waste, a good part of this garbage reaches the coast through the drainage system, generating environmental impacts [23].

In the city of Recife, the urban drainage system is not very efficient, due to the disordered occupation process (waterproofing of previously infiltrate areas and increase of surface flow), the characteristics of its landscape (plains with quotas close to 0), and its location in the

Northeastern coastal area of Brazil (direct influence of the tide). It is further aggravated by low environmental awareness, with the deposition of waste by the population in this system, leading to more flooding problems, especially in periods of intense and prolonged rainfall [28].

Data on qualitative and quantitative aspects of solid waste in the drainage system, as well as the characterization and identification of the sources of origin, could serve as a basis for the implementation of mitigation measures, besides constituting important information aimed at contributing to the integrated management of resources in the urban environment [31,30].

The objective of this work is to quantify the existing waste in the drainage systems of the city of Recife through a direct and indirect method of estimating waste loads, as well as to evaluate the possibility of a correlation between precipitation and solid waste data found in the drainage system, through a statistical tool. Importantly, some research correlates precipitation and solid waste as generators of problems in urban drainage systems [29,28,32,17].

MATERIAL AND METHODS

Study area

The city of Recife is located in the northeastern region of Brazil, at the eastern end of the State of Pernambuco, latitude 8°3'14" S and longitude 34°52'51" W. According to estimates by the Brazilian Institute of Geography and Statistics [11], Recife has an estimated population of approximately 1.537.704 inhabitants. Its demographic density is about 7.039,64hab/km², with an area of 218,435 km². Figure 1 shows the location of the city of Recife/PE.

Figure No. 1: Location of the area investigated.

The urban space of Recife is composed of six Administrative Political Regions (RPA): RPA1-Center, RPA2-North, RPA3-Northwest, RPA4-West, RPA5-Southwest, and RPA6-South (Figure 2). The RPAs were defined for the formulation, execution, and permanent evaluation of government policies and plans.

The landscape is formed by two topographic groups: the plains located in the Center-East portion and the coastal strip of the southern part (with dimensions varying from 0 to 5m, reaching slightly higher and even negative values) and the adjacent hills in the portions North, West and South (with dimensions varying between 30 and 100m) [4].

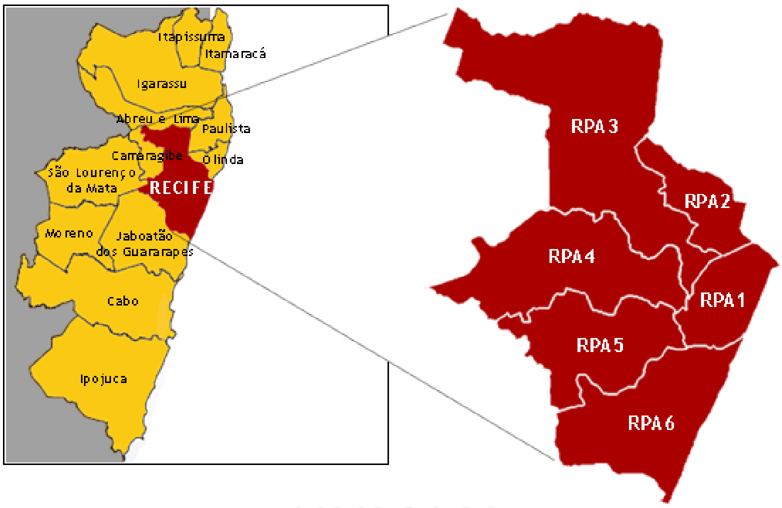

Figure No. 2: AdministrativePoliticalRegionsof Recife (RPA).

The geological site on which Recife was implanted is formed by a plain of fluvial-marine origin, the result of millions of years of sedimentary accumulation. The annual average precipitation is 2.263 mm and evaporation is 1.099 mm. According to the classification of Köppen, the Climate is Asi - Tropical rainy dry summer, with an average annual temperature of 25,9°C and average air humidity of 78,30% [6].

The city of Recife is located in an estuarine region, formed by an alluvial plain, including islands and mangroves as geographic features, surrounded by low-lying hills.

Macrodrainage: Recife is confined between the sea and the hills, and the main rivers are Capibaribe, Beberibe, and Tejipió, which have a shared estuary. The Jaboatão river has some tributaries that are located in Recife although the estuary is in another municipality. Also part of this macro-drainage are the larger streams Morno, Vasco da Gama (Arruda), Camaragibe, Cavouco, Jiquiá, Jordão. And in addition 99 channels totaling 132.787 km of extension (Table 1).

Table No. 1: Macrodrainage of the city of Recife.

Rivers	No. of watercourses	Length (km)	
		Coated	Uncoated
Capibaribe	33	29,005	10,240
Beberibe	25	18,057	12,103
Tejipió	14	5,500	11,735
Jordão	3	12,705	0,435
Jiquiá	18	15,601	9,826
Jaboatão	6	2,535	5,045
TOTAL	**99**	**83,403**	**49,384**

Microdrainage: The network consists of galleries and gutters, with an extension of 1.558 km [26]. Many segments are undersized.

Solid Waste: Solid waste, when improperly dumped on the surface of urban areas, can reach drainage nets. They accumulate in the existing drainage surrounding neighborhoods of commerce, parking lots, road and rail stations, roads, schools, public parks, etc. And in these places, they continue until they are removed by the public collection system, or are carried away by the surface flow, reaching the drainage system. This waste is formed by materials such as plastic bottles, cans, paper, residential furniture, construction debris, and old mattresses [2].

Once inside the drainage system, solid waste can be carried by the conduits, streams, channels, and rivers, reaching the estuaries and occasionally reaching the sea, in coastal cities. Possibly, the form of conduit used in the drainage system can influence the number of solid waste destined in this system, as it is easier to have access to the channels, as they are open than to the galleries, as they are underground[17].

Along the way, however, they are often entangled by vegetation along the banks of channels, lakes or rivers, or scattered along the beaches. Most are probably buried by the sediments of lakes, rivers, or beaches [2].

The problem of solid waste in drainage networks can be seen in the largest Brazilian cities. According to [7], these problems of lack of cleaning of solid waste, as well as the poor finishing of the galleries, can cause the drainage system to malfunction. Waste is improperly disposed of, reaching the drainage system (Figure 3), reaching larger bodies of water such as beaches, seas, and lakes, and damaging the hydraulic efficiency of structures such as pump wells, holding basins, etc.

Figure No. 3: Execution of works to remove obstructions in the drainage network.

Quantification of waste in the drainage system

In the first step, the solid waste index (I) was calculated from the raw channel and gallery cleaning data, which contains a large amount of sediment, referred to as direct quantification. Then the calculation of the value of I was made from a method called indirect quantification. Soon after, the solid waste prediction was carried out in the drainage system by applying simple linear regression. Finally, a qualitative-quantitative analysis of the solid waste/sediment removed in the drainage system was carried out.

Direct Quantification

It was performed based on the cleaning data of channels and galleries, and since the data used contained only the wet weight of the waste, a percentage of the moisture content obtained in literature was applied to these weights, resulting in the dry weight of waste being removed, as seen in Equation 1.

It should be noted that, in the city of Recife, the material removed from the cleaning of canals and galleries from the years 2012 to 2016 was weighed in the scale of the landfill site and this material was composed of domestic waste and many sediments carried by the heavy rains.

$$\mu_{rr} = u.\mu_{ru} \tag{1}$$

Where:

μ_{rr} is the mean of the dry waste removed (ton/year);

u is the moisture content (%);

μ_{ru} is the mean of the wet waste removed (ton/year).

The cleaning data was consolidated using a spreadsheet, and from this information, the value of I was calculated by Equation 2 below:

$$I = \frac{\mu_{rr}}{A}.1000 \tag{2}$$

Where:

I is the solid waste index ($kg.ha^{-1}.year^{-1}$);

μ_{rr} is the mean of the dry waste removed (ton/year);

A is the total contribution area of the basins (ha).

Indirect Quantification

For this quantification, the indirect method proposed by [1] was used. This method allows estimating the potential load of solid waste in urban drainage from the information and characterization of the census tracts and urban waste collection data (Figure 4).

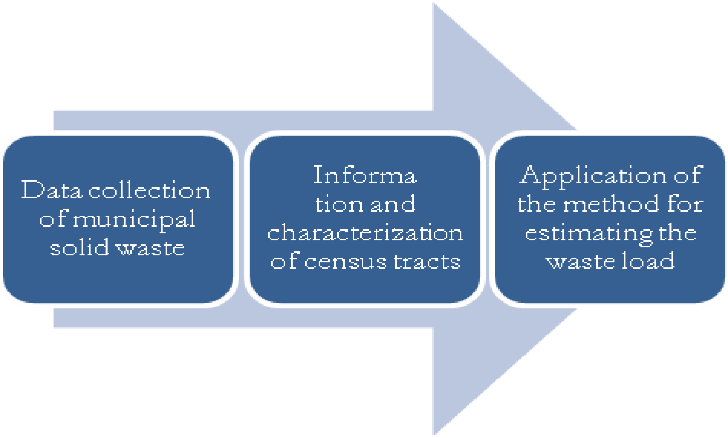

Figure No. 4: Flowchart of the indirect method.

The proposed method can be equated from Equation 3.

$$Q_r = G.N_{habpd}.D_{lcd} \quad (3)$$

Where:

Q_r is the estimated waste load (kg/day);

G is the per capita production of waste (kg/hab/day);

N_{habpd} is the rate of inhabitants per household (hab/dom);

D_{lcd} is the number of households that throw waste into the water body (dom).

By dividing the value $Q_r$by the total contribution area of the basins (A) and multiplying by the number of days per year, we will have the solid waste index (I).

Solid waste prediction

To investigate the variation of the amount of waste in the drainage systems during rainfall events, a forecast curve was drawn using the simple linear regression method, which relates the precipitation height with the amount of waste removed from the canals and galleries.

The objective of the curve is to assess the possibility or lack of feasibility of a correlation between the total precipitate and the solid waste accumulation per precipitation event [27]. It is a tool to help municipal managers simulate drainage volumes and assess the effectiveness of measures used to minimize the problem.

Quanti-Qualitative Analysis

For this analysis, 5 different collection points were selected from the city of Recife (Figure 5) to estimate the percentage of sediment to the solid waste of the material removed from the cleanings performed in the drainage system.

With the help of the cleaning team of the Urban Maintenance and Cleaning Company - EMLURB, all the material was collected from the STORM DRAIN of the 5 sites chosen, the solid waste was separated from the sediments and the weighing was done. Once the weights were known, the percentages of each point were then calculated.

Figure No. 5: Collection sites in the city of Recife

RESULTS AND DISCUSSION

Table 2 shows the amount of raw waste that was removed from the canals and galleries of the city of Recife between the years 2012 to 2016 [8].

The average moisture content for new waste of 70% was adopted in the city of Recife [9]. This parameter of humidity was adopted for the calculation of the dry waste since the data of the EMLURB only contemplates the weight information of the waste still wet. Table 3 shows the amount of dry waste and the respective precipitations of the same period.

Table No. 2: Quantitative raw waste taken from Recife's canals and galleries from 2012 to 2016.

MONTH	YEAR				
	2012	2013	2014	2015	2016
	Wetweight(ton)	Wetweight(ton)	Wetweight(ton)	Wetweight(ton)	Wetweight(ton)
January	12.690,27	15.108,77	7.791,74	19.107,37	3.614,86
February	9.313,71	9.637,39	7.355,71	13.663,25	2.018,06
March	12.096,36	8.888,51	9.074,47	17.062,78	3.905,95
April	7.588,65	11.030,49	25.461,63	8.281,28	11.284,48
May	6.127,64	4.118,11	22.345,71	7.706,58	10.502,92
June	4.425,54	5.054,82	12.870,05	4.773,87	13.912,87
July	2.727,11	5.998,45	12.815,10	6.829,58	10.373,24
August	185,02	4.350,27	6.927,23	6.213,87	11.290,36
September	351,63	4.746,04	6.012,01	10.990,04	7.079,92
October	181,97	9.456,38	5.767,89	11.059,12	3.100,61
November	306,80	12.546,56	4.031,94	9.776,68	1.868,23
December	174,72	8.121,02	2.341,74	4.216,18	367,82
TOTAL	**56.169,42**	**99.056,81**	**122.795,22**	**119.680,60**	**79.319,32**

Table No. 3: Quantitative of dry waste removed in the city of Recife and rainfall data of the Curado-PE station.

MONTH	YEAR									
	2012		2013		2014		2015		2016	
	Dry weight (ton)	Rainfall (mm)	Dry weight (ton)	Rainfall (mm)	Dry weight (ton)	Rainfall (mm)	Dry weight (ton)	Rainfall (mm)	Dry weight (ton)	Rainfall (mm)
January	3.807,08	208,55	4.532,63	70,30	2.337,52	97,85	5.732,21	59,15	1.084,46	101,30
February	2.794,11	152,25	2.891,22	37,00	2.206,71	139,45	4.098,98	54,60	605,42	52,60
March	3.628,91	146,60	2.666,55	85,00	2.722,34	203,80	5.118,83	312,70	1.171,79	230,55
April	2.276,60	45,50	3.309,15	199,40	7.638,49	263,60	2.484,38	28,90	3.385,34	255,10
May	1.838,29	152,30	1.235,43	309,45	6.703,71	295,10	2.311,97	173,40	3.150,88	483,40
June	1.327,66	292,10	1.516,45	424,10	3.861,02	335,45	1.432,16	418,15	4.173,86	160,40
July	818,13	250,65	1.799,54	253,00	3.844,53	252,50	2.048,87	458,35	3.111,97	110,30
August	55,51	148,45	1.305,08	189,90	2.078,17	156,55	1.864,16	96,55	3.387,11	50,35
September	105,49	15,30	1.423,81	144,65	1.803,60	215,45	3.297,01	30,95	2.123,98	52,55
October	54,59	45,30	2.836,91	97,75	1.730,37	111,15	3.317,74	13,70	930,18	14,10
November	92,04	9,70	3.763,97	65,05	1.209,58	32,95	2.933,00	21,25	560,47	15,35
December	52,42	21,95	2.436,31	137,40	702,52	82,15	1.264,85	78,35	110,35	68,00
TOTAL	**16.850,83**	**1.488,65**	**29.717,04**	**2.013,00**	**36.838,57**	**2.186,00**	**35.904,18**	**1.746,05**	**23.795,80**	**1.594,00**

For rainfall, data from the Curado rainfall station, nº 834007, were obtained from the meteorological database for teaching and research of the National Institute of Meteorology – INMET [13].

Figure 6 shows more clearly the variation of the amount of dry waste over time. The city of Recife presents a rainier period that runs from March to August (six months), with maximum value in July, and a drier period, from September to February (six months) with the minimum value in November [5].

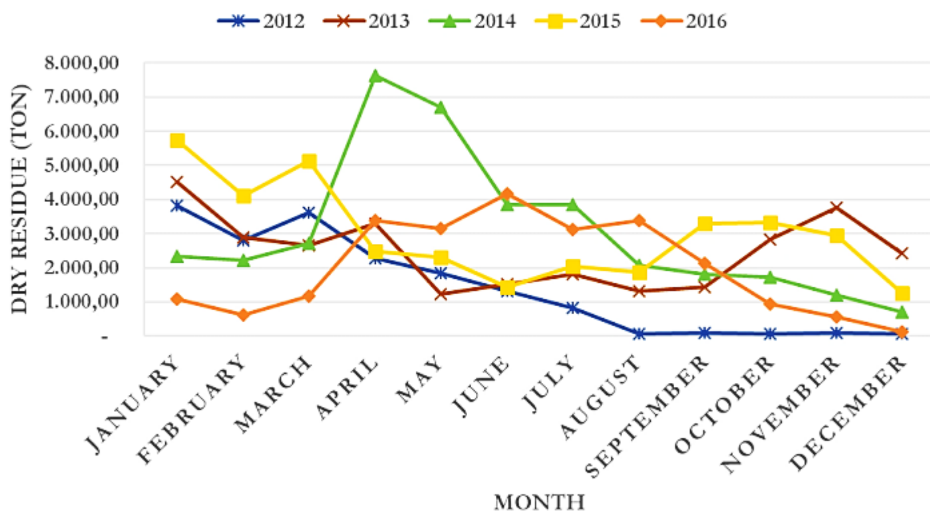

Figure No. 6: Dry waste collected from the Recife drainage system.

It can be hypothesized that there is no regularity in the removal of waste from rainy periods. Such an event may be related to the type of clean-up of the canals and galleries by [8], when there were years (2012, 2013, and 2015) in which waste removal was anticipated to prepare for the rainy season and in others (2014 and 2016) it happened during the rainy season.

The highest total volumes of waste removed were in the years 2013, 2014, and 2015 that coincide with the rainier years (Figure 7). A relationship between the precipitated volume and the amount of dry waste removed, where this relation is positive, the greater the volume of precipitation, the greater the amount of waste removed from the canals and galleries.

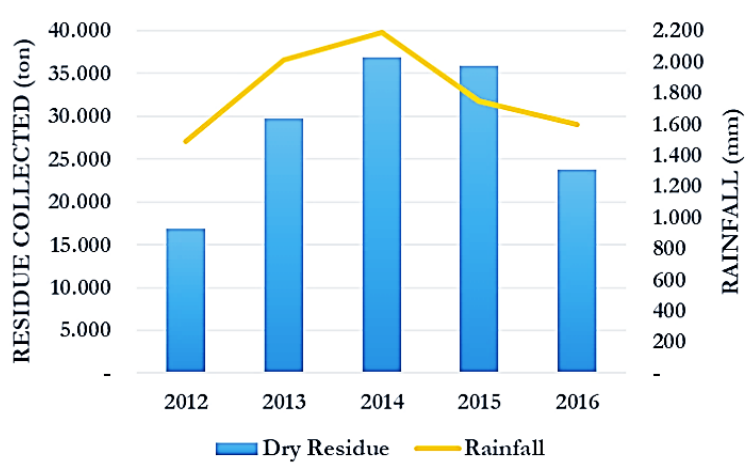

Figure No. 7: Waste collected and Rainfall in Recife.

With the application of the direct method for the calculation of the solid waste index released in the watercourse per hectare per year, the results described in Table 4 were obtained.

Table No. 4: Results of the direct method for calculating *I*.

Year	Dry waste removed (ton/ano)	Total basin contribution area (ha)	*I* ($kg.ha^{-1}.ano^{-1}$)
2012	16.850,83	21.843,50	771,43
2013	29.717,04	21.843,50	1.360,45
2014	36.838,57	21.843,50	1.686,48
2015	35.904,18	21.843,50	1.643,70
2016	23.795,80	21.843,50	1.089,38
AVERAGE	**28.621,28**	**21.843,50**	**1.310,29**

The value found is quite high when compared to other cities. [19] presented values of 82 $kg.ha^{-1}.year^{-1}$ for the city of Springs, and 48 $kg.ha^{-1}.year^{-1}$ for the city of Johannesburg, both cities in South Africa. It is perceived that the collection of waste, in the methods found in literature, does not consider them part of the sediment carried to the drainage systems, because in its applied methodologies, the collected waste is the floating one, whereas, in the cleaning data used in this work, the waste is raw and has a large portion of sediment.

The qualitative and quantitative analysis of the material removed from the collection sites confirmed this large amount of sediment to the solid waste in the drainage system of the city of Recife. Table 5 shows the values found for each point.

Table No. 5: Quantitative sediment and the solid waste removed at collection points.

Collection Site	Sediment (kg)	Solid Waste (kg)	Sediment (%)	Solid Waste (%)
1	661,00	1,44	99,78%	0,22%
2	363,80	1,36	99,63%	0,37%
3	133,10	0,46	99,66%	0,34%
4	45,70	8,50	84,32%	15,68%
5	548,80	97,90	84,86%	15,14%
TOTAL	**1.752,40**	**109,66**	**94,11%**	**5,89%**

Collection sites 1, 2, and 3 show a predominance of sediments which can be explained by the fact that these points are located in a strictly residential area with a regular collection of garbage, while points 4 and 5 are in a large commercial flow region where the population still insists on incorrect disposal of garbage in the roads and that end up being carried into the drainage system during heavy rains.

The information about the values of the variables used in the indirect method was obtained from the census [12] and the Metropolitan Program of Solid Waste (PMRS) of the Metropolitan Region of Recife [24]. From the survey data of the census tracts of the city of Recife, the population size, the number of households, and the destination of waste from these households were obtained, which can be observed in Table 6.

Table No. 6: Number of households regarding the destination of waste.

Waste disposal	**NumberofDomiciles (dom)**
Collectedbymaidservice	445.779
Collected on cleaning service bucket	14.900
Burned (on property)	687
Buried (on property)	54
Discarded in vacant lot or backyard	7.358
Discarded in waterbody	1.310
Anotherdestination	666
Total Collected	**460.679**

From these values it is possible to determine the rate of inhabitants per household (N_{habpd}) and the number of households that throw waste in water bodies (D_{lcd}). The per capita production of waste (G) was obtained from the PMRS of the Metropolitan Region of Recife with a value of 1.579 kg.hab^{-1}.day^{-1}.

Thus, the value of the drainage waste load (Q_r) can be estimated according to Equation 3 and the results are presented in Table 7.

Table 7. Estimated waste load in urban drainage.

G (kg.hab^{-1}.day^{-1})	1.579
N_{habpd}(hab/dom)	3.266
D_{lcd} (dom)	1.310
Q_r(kg/day)	6.756.66

The value Q_r can also be expressed as 2.446.181,38 kg/year. This data would be a minimum estimated waste load since we have hypotheses that impact the method. In the application of the method, [1] considers the hypotheses:

- Waste discarded on land is not carried by bodies of water by rainfall and therefore will not be retained in the drainage system;

- The households that have the final destination classified as "others", can be burned, buried, thrown into the ground, or bodies of water. However, there is no way to quantify these categories of waste disposal and therefore it will be considered that it does not have the drainage system as a final destination;

- The waste released into the water bodies of these basins is retained in the urban drainage system. But in reality, this does not occur immediately because some of the waste can be retained on the banks of streams and also in drainage structures.

In the literature, it is quite common to present this quantification of waste in the urban drainage in the form of kg.ha^{-1}.year^{-1}, as presented in Table 8. Thus we have for the city of Recife an estimated load of 112,90 kg.ha^{-1}.year^{-1}. This result is found by dividing the value Q_r by the total area of basin contribution (21.843,50 ha).

Table 8. Waste quantification in urban drainage.

Location	Load ($kg.ha^{-1}.year^{-1}$)
Springs, South Africa	82,00
Johannesburg, South Africa	48,00
Auckland, New Zealand	2,76
Cape Town, South Africa	18,00
Melbourne, Australia	6,00
Maceió, Brazil	103,83
Recife, Brazil	112,90

According to [19] the average loads of solid waste vary greatly with the use of the soil. It can be seen that the estimated load for Recife (112,90 $kg.ha^{-1}.year^{-1}$) is close to the cities of Maceió (103,83 $kg.ha^{-1}.year^{-1}$) and Springs (82,00$kg.ha^{-1}.year^{-1}$), which are located in developing countries. The cities of developed countries, which have efficient collection systems, implementation of self-cleaning structures, and investment in hydro-environmental education, have much lower load indexes, such as the cities of Melbourne in Australia and Auckland in New Zealand, which already have management systems of improved solid waste.

When comparing waste load values of the direct and indirect methods, a considerable disparity is observed. The value obtained by the direct method is 11 times greater than that of the indirect method. This fact can be attributed to the fact that the data used in the direct method has a large amount of sediment, whereas in the indirect method sediments are not considered.

Data analysis allowed us to verify that in the years of 2012, 2013, and 2015 there are collection peaks in months considered less rainy. This is due to the cleaning efforts carried out by the city council that aims to combat floodwaters and prepare the municipality for the rainy season. Thus, in the rainy season, the quantity of waste in the drainage system decreases considerably, whereas in the years 2014 and 2016 the highest values of waste removed occur in the months of greater rainfall since they were not contemplated in the early withdrawal of waste.

For the drainage solid waste prediction, the years 2014 and 2016 were chosen because they show a relation between the largest quantities of waste removed and higher pluviometric volumes. The data of solid waste found within the drainage system was averaged over a month, and this data was compared with the precipitation data in the same period to obtain the linear regression line. Figure 8 shows the relationship between rainfall and solid waste generated in the network and the respective equation.

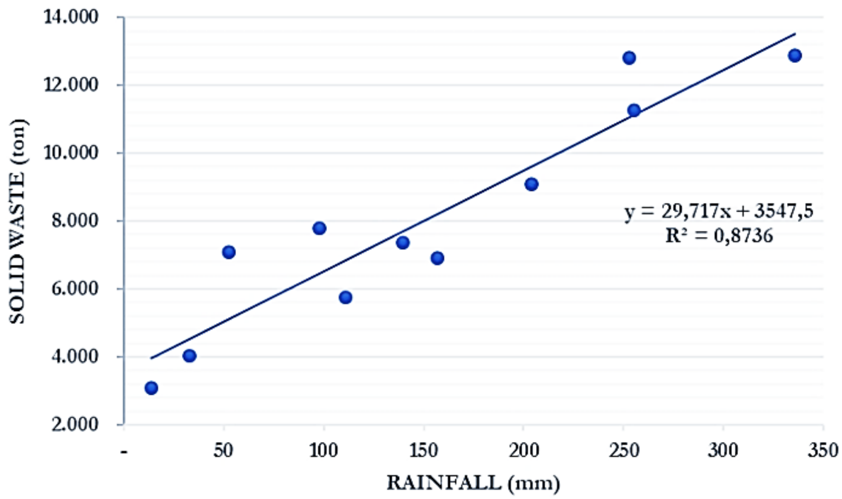

Figure No. 8: Correlation between Precipitation x Solid Waste in the Recife Drainage System in the years 2014 and 2016.

The equation $y = 29{,}717x + 3547{,}5$ corresponds to the relationship between rainfall and the amount of solid waste within the drainage system of the city of Recife, which indicates that for each monthly millimeter of rainfall, the drainage will have an increase of 29,717 tons, where 87,36% of the solid waste found in the drainage system can be explained by rainfall.

The value of the correlation between the rainfall and the amount of solid waste found in the drainage system was also studied by other authors, finding the following results: 63% by [20], when analyzing the urban region of Porto Alegre, RS, 74% by [10], in the urban perimeter of Rio do Meio in Florianópolis-SC and [32] the value of 76.36%, in the municipality of Santa Maria-RS. These values can vary due to the occupation of the soil, the population that integrates the region, and the capacity of waste transport of the watercourse.

The influence of the precipitation on the amount of waste in the drainage system can also be observed in its variation to the average number of dry days in the analyzed period [19]. On dry days, sweeping and garbage collection are done more efficiently, and less solid waste is available on the streets to be carried by the rains. Figure 9 shows that the amount of waste in the drainage system has a negative relationship, the more dry days, the less solid waste in the drainage system. Both equations corroborate the thesis that precipitation is determinant in the quantity of solid waste that accumulates in the urban drainage system.

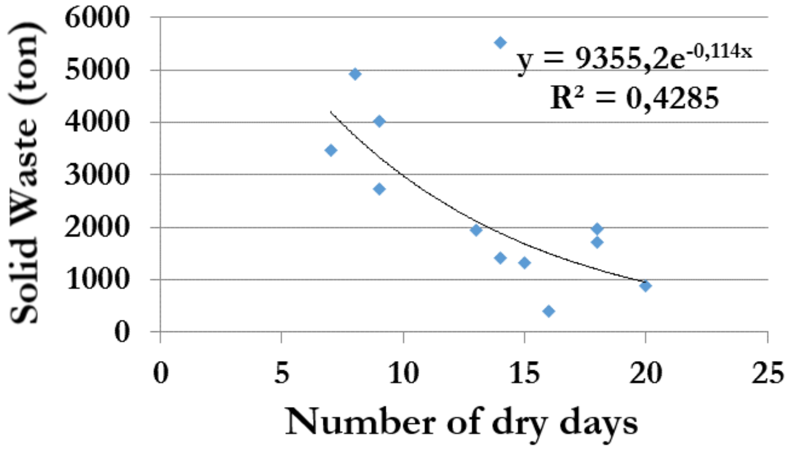

Figure No. 9: Correlation between dry days x Solid Waste in the Recife Drainage System in the years 2014 and 2016.

CONCLUSION

From the analysis of the available dry waste data collected by EMLURB in the city of Recife, it can be noted that the wetter years, 2013, 2014, and 2015 were the years with the largest amount of dry waste removed, showing that the relation between volume precipitate and the amount of dry waste removed has a positive relationship, ie, the greater the volume of precipitation, the greater the amount of waste removed from the canals and galleries.

Through the method of indirect quantification of the estimated potential of solid waste in urban drainage, the high value of the load in the city of Recife can be noted (112,90 $kg.ha^{-1}.year^{-1}$), when compared to city loads in developed countries such as Auckland, New Zealand, which has a load of 2,76 $kg.ha^{-1}.year^{-1}$, and highlights the need for investment in hydro-environmental education and efficient collection systems.

Rainfall precipitation is determinant in the quantity of solid waste circulating in the urban drainage system of Recife, as expected. The linear regression indicates that for each monthly millimeter of rainfall, the drainage will have an increase of 29,717 tons.

The municipal government of the city of Recife must continue the monitoring of the quantification of solid waste in urban drainage in the next years, in addition to the appreciation of neighborhoods where there is awareness of the population (hydro environmental education) to assess the reduction of impacts in the watercourses and the expenses related to cleaning them with this measure.

REFERENCES

1.ARMELIN LF. 2005. A questão do acúmulo de resíduos sólidos em bacias de detenção urbanas na região metropolitana de São Paulo. Dissertação de Mestrado, Universidade de São Paulo, São Paulo, SP, Brasil.

2.ARMITAGE N, ROOSEBOOM S. 2000. The Removal of Litter from Stormwater Conduits and Streams: Paper 1 – The Quantities Involved and Catchment Litter Management Options. Water S. A. 26(2): 181-187.

3.BLUMENSAAT F, et al. 2012. Water quality-based assessment of urban drainage impacts in Europe – where do we stand today?.Water Science Technology. 66: 304-318.

4.CABRAL JJSP, SILVA TC, QUEIROGA T, MELO F, PIRES N, MONTENEGRO SMGL. 2001. A Problemática da Drenagem Urbana em Áreas Planas Costeiras no Nordeste Brasileiro. In: Adolfo Vilanueva; Joel Goldenfun; André Silveira. (Org.). Soluções para a drenagem urbana em países da America Latina. 1ed. Porto Alegre: ABRH. 1:18-34.

5.CABRAL JJSP, ALENCAR AV. 2005. Recife e a Convivência com as Águas. In: Hydroaid (Itália), PMSS/ Ministério das Cidades. (Org.). Gestão do Território e Manejo Integrado das Águas Urbanas. Brasília: Ministério das Cidades. 111-130.

6.CONDEPE/FIDEM - Agência Estadual de Planejamento e Pesquisas de Pernambuco. Os Morros da Região Metropolitana do Recife. Disponível em: <http://www2.condepefidem.pe.gov.br/web/condepe-fidem/biblioteca-virtual-download1>. Acesso em: 02 jun 2018.

7.DIBALA WT. 2018. A review of sustainability of urban drainage system: traits and consequences. Journal of Sedimentary Environments. 3(3):131-137. doi: 10.12957/jse.2018.37825.

8.EMLURB. Portal de transparência. Recife, PE. Disponívelem:<http://dados.recife.pe.gov.br/dataset/pesagem-de-coletas-de-residuos>. Acesso em: 26 mai 2018.

9.FIRMO ALB. 2013. Estudo numérico e experimental da geração de biogás a partir da biodegradação de resíduos sólidos urbanos. Tese de Doutorado, Universidade Federal de Pernambuco, Recife, Pernambuco.

10.GAVA T, FINOTTI AR. 2012. Resíduos sólidos urbanos na rede de drenagem da bacia hidrográfica do rio do meio, Florianópolis/SC. Revista de Gestão Ambiental e Sustentabilidade. 1 (2):80-102.

11.IBGE – Instituto Brasileiro de Geografia e Estatística. 2018ª. Estimativas populacionais para os municípios e para as Unidades da Federação brasileiros. Disponível em: <https://ww2.ibge.gov.br/home/estatistica/populacao/estimativa2017/estimativa_dou.shtm>. Acesso em: 16 abr 2018.

12.IBGE – Instituto Brasileiro de Geografia e Estatística. 2018b. Página institucional. Disponível em: <https://cidades.ibge.gov.br/brasil/pe/recife/panorama>. Acesso em: 26 mai 2018.

13.INMET - Instituto Nacional de Meteorologia. 2018. Página institucional. Disponível em: <http://www.inmet.gov.br/portal/index.php?r=estacoes/estacoesautomaticas>. Acessoem: 26 mai 2018.

14.LAMOND J, BHATTACHARYA N, BLOCH R. 2012. The role of solid waste management as a response to urban flood risk in developing countries, a case study analysis. WIT Transactions on Ecology and the Environment. 159:193–204.
15.MAKSIMOVIĆ Č. 2001. General Overview of urban drainage principles and practice. In: TUCCI; Carlos E. M. Urban drainage specific climates: urban drainage in humid tropics. Paris: UNESCO. IHP-V. Technical Documents in Hydrology. 1(40):1-23.
16.MAKSIMOVIĆ Č, PRODANOVIĆ D, BOONYA-AROONNET S, LEITAO JP, DJORDJEVIĆ S, ALLITT R. 2009. Overland Flow And Pathway Analysis For Modelling Of Urban Pluvial Flooding. Journal of Hydraulic Research. 47: 512-523.
17.MESQUITA JBF, PEREIRA SP, NETO IEL. 2020. Modelagem da drenagem urbana e avaliação das cargas bacteriológicas na Vertente Marítima de Fortaleza, Ceará. Engenharia Sanitária Ambiental. 25 (1) 205-216. https://doi.org/10.1590/S1413-41522020189161
18.NADEESHA D C, et al. 2015. A THEORETICAL DISCUSSION AND CASE STUDY ON THE DEVELOPMENT OF SMART STORM DRAINAGE UNIT FOR COMPACT CITIES. JurnalTeknologi. 5: 29–34.
19.NEVES MGFP, TUCCI CEM. 2003. Gerenciamento integrado em drenagem urbana: quantificação e controle de resíduos sólidos. XV Simpósio Brasileiro de Recursos Hídricos.
20.NEVES MGFP, TUCCI CEM. 2008. Resíduos Sólidos na Drenagem Urbana: Estudo de Caso. Revista Brasileira de Recursos Hídricos. 13: 43-53.
21.NEVES MGFP, TUCCI CEM. 2011. Composição de resíduos de varrição e resíduos carreados pela rede de drenagem, em uma bacia hidrográfica urbana. Engenharia Sanitária e Ambiental. 16: 331-336.
22.PERVIN IA, RAHMAN SMM, NEPAL M, HAQUE AKE, KARIM H, DHAKAL G, KALAM A. 2020 Adapting to urban flooding: A case of two cities in South Asia. Water Policy. 22: 162-188. http://dx.doi. org/ 10.2166/wp.2019.174
23.RAMIREZ MMB, CAAMAL RD, OSTEN JRV. 2019. Occurrence and seasonal distribution of microplastics and phthalates in sediments from the urban channel of the Ria and coast of Campeche, Mexico. Science of the Total Environment. 672(1): 97-105. https://doi.org/ 10.1016/j.scitotenv.2019.03.472
24.RECIFE. 2018a. Programa metropolitano de resíduos sólidos. Disponível em: http://www2.recife.pe.gov.br/servico/programa-metropolitano-de-residuos-solidos-0>. Acesso em: 26 mai 2018.
26.RECIFE. 2018b. Plano diretor de drenagem e manejo de águas pluviais da cidade de Recife.
27.SALLES A, WOLFF DB, SILVEIRA GL. 2012. Solid wastes drained in an urban river sub-basin. Urban Water Journal. 9(1): 21-28.
28.SILVA JUNIOR MAB, SILVA SR. 2016. Impacts of urbanization and climate change in the drainage system of Recife-PE. Revista Brasileira de Geografia Física. 9: 2034-2053.
29.SILVA AS, SILVEIRA SL, WOLFF DB, CRUZ JC. 2011. Captura de Resíduos Sólidos Drenados em uma Bacia Hidrográfica Urbana. Revista Brasileira de Recursos Hídricos. 16 (4): 149-155. http://dx.doi. org/10.21168/rbrh.v16n4.p149-155
30.SILVA AS. 2010. Resíduos sólidos drenados em sub-bacia hidrográfica urbana em Santa Maria - RS. Dissertação de Mestrado, Universidade Federal de Santa Maria, Santa Maria, RS, Brasil.
31.TUCCI CEM. 2003. Águas urbanas In: TUCCI, C. E. M.; BERTONI, J. C. (Org.). Inundações urbanas na América do Sul. Associação Brasileira de Recursos Hídricos. Porto Alegre.
32.WOLFF DB, GONÇALVES IH, GASTOLDINI MCC, SOUZA MM. 2016. Resíduos sólidos em um sistema de drenagem urbana no município de Santa Maria (RS). Engenharia Sanitária e Ambiental. 21 (1):151-158.