

Environmental and Social Impacts of Urban and Rural Water areas intercepting the BR 277 (Km 493 to 730) Concerning the Transport of Hazardous Products

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Abstract— The BR-277 is one of the main routes for several products, including hazardous products, causing great concern due to the problems they can cause to the population and the environment in case of an accident. The section of the highway that connects Guaraniaçu to Foz do Iguaçu is in an essential hydrographic region with three main watersheds for the state: the Piquiri, Lower Iguazu and Paraná 3 basins. The study was a survey from 2013 to 2017 of traffic and accidents involving the transportation of hazardous products in 209 kilometers, in the stretch from km 493 to 730 of BR-277 (Guaraniaçu to Foz do Iguaçu), highlighting the socio-environmental impacts to the urban and rural sources that they can cause in the event of accidents. The data was qualitatively analyzed and presented in graphs. The road administrators provided the traffic data, classes, and collisions with hazardous products. The percent of hazardous cargoes was 27 in 2013; 21 in 2014; 15 in 2015; 19 in 2016; and 18 in 2017 — Summing 27501 hazardous cargoes for the period. The most transported products were flammable liquids, gases, hazardous, and corrosive substances. There were nine accidents with dangerous products in the stretch, the km 584 showed the highest accident record, with 414 accidents in 5 years. Due to high road haulage, traffic, and the number of accidents in the region, preventive and mitigating measures must be taken. Such as accident risk training for public and private managers and employees working with this type of transportation and reinforcement of the signaling of critical and water source areas.

Keywords— Accidents prevention, Contamination of Water Resources, Hazardous loads.

I. INTRODUCTION

One of the main highways in Brazil and the state of Paraná is BR-277, which, together with BR 369 and 467, are strategic routes for the transfer of products and grains to other states and countries (Der, 2019). It has a length of 730 km, beginning at the Port of Paranaguá and ending at the Friendship Bridge, in Foz do Iguaçu. It is of high

strategic relevance as it connects Brazil with the Argentine and Paraguayan border.

Thus, constituting a vital route of connection between Mercosur countries and playing a significant role in the flow of agricultural products produced in the state of Paraná and directed to exports and imports (Balbo et al., 2011).

For this reason, the highway has heavy traffic of the road, being the most used means for the transportation of both passenger and cargo vehicles, and maybe products and inputs for agricultural, livestock, commercial, and industrial activities.

The state of Paraná presented a gross domestic product (GDP) value in 2013 of R \$ 333,481 million, an increase of 17% five years later. Thus, in 2017 was recorded a GDP of 421,914 R \$ million and of these, 22% corresponds to agricultural and agricultural activities (Ipardes, 2018).

In 2017 in the state, 19,829,990 tons (tons) of soybeans, 18,225,121 tons of corn, and 2,225,344 tons of wheat were produced (Ipardes, 2019). One of the regions of the state that stands out in the production of these grains is the western region, which due to the growth and modernization of these agricultural activities, in recent years has intensified the production and marketing of these grains (Reis, 2017). In 2017, production in the region was 3,788,757 tons of soybeans, 4,748,065 tons of corn, and 231,429 tons of wheat.

Thus, the demand for agricultural and agricultural products increased significantly, to meet the structure of the region's agro-industrial production matrix, leading to the growth of infrastructure and urbanization, contributing to the expansion and offer of services associated with the transportation of these products (Corrêa, 2009).

BR-277 has become a strategic route from an economic point of view, is one of the main ways for the flow and distribution of agricultural inputs such as fertilizers, fungicides, pesticides, and herbicides used in plantations (Reis, 2017).

In addition to the transportation of agricultural products, another demand in the region is chemicals, due to its industrial expansion, contributing to regional development, it is estimated that 26% of Paraná's GDP originates from its industrial activities (Wongtschowski, 2012; Ipardes, 2018). Thus, as the demand for these products increases, so does their transportation traffic, which, due to their physical and chemical characteristics, may be considered dangerous.

According to the resolution of the National Land Transportation Agency (ANTT) No. 420/04, it is called dangerous products, all substances, or articles found in nature or produced by any process that, due to their physical and chemical characteristics, pose a health risk, for public safety or the environment.

Thus, a product is classified as dangerous because of its characteristics and its transport. The United Nations (UN) has adopted technical criteria for its classification based on its physical, chemical, and toxicological properties, such as pressure, temperature, toxicity, corrosivity, radioactivity, flammability, explosiveness, infectives. These aspects also help in identification at the moment of transportation (Teixeira, 2010).

The transport of these substances cannot be treated as any other goods, since in the event of accidents or collisions with vehicles carrying hazardous cargo, in addition to the loss of life and material damage that usually occurs, this extends to severe environmental damage, such as contamination of water bodies and soil (Rechkoska, Rechoski; Georgioska, 2012).

The highways are intercepted by water bodies, permanent preservation areas, and legal reserves, as well as surrounding rural, indigenous, and riverside communities. Thus, rivers near highways are generally used for public supply. Accidents with hazardous products near waterways can cause severe environmental damage and may have several effects, spreading through the contamination of these water bodies, compromising their natural characteristics and surroundings, and harming individuals who depend in some way on this resource (Canto, 2014).

Thus, there is a concern regarding the social and environmental impacts that accidents with dangerous products can cause, on ecological and social risks and vulnerabilities of water resources, which are presented in studies by Martínez-Alegría; Ordóñez; Taboada(2003), Bubbico; Di Cave and Mazzarotta (2004), Nardocci and Leal (2006), Pedro and Costa (2009), Souza (2009), Teixeira (2010), Balbo et al. (2011), Beltrami; Freitas et al. (2013), Andrade (2016), Cordeiro et al.(2016), Tinoco; Nodari and Pereira (2016), Machado et al. (2017), Siqueira et al. (2017), Machado et al. (2018), Troglio et al. (2018).

The BR 277 stretch from kilometer (km) 493 (Guaraniaçu) to km 730 (Foz do Iguazu), is a crucial hydrographic region known as the watershed of three relevant watersheds of the Paraná state, the Piquiri basin, do Baixo Iguazu and Paraná 3, where they have water sources close to the highway, which has intense road traffic. Therefore, the objective of this study was to conduct a survey of traffic and accidents that occurred with the transportation of dangerous products along the BR 277 (Guaraniaçu to Foz do Iguazu) stretch, highlighting the social and environmental impacts that can cause, in case of accidents, to urban and rural springs.

II. METHODOLOGY

2.1 Area of study

It contemplated the stretch of the survey, from Km 493 to 730 of BR-277, between the cities of Guaraniaçu to Foz do Iguacu, located in western Paraná. We considered 209 km and the coverage of 11 municipalities, namely: Guaraniaçu, Ibema, Catanduvas, Rattlesnake, Santa Tereza do Oeste, Blue Sky, Matelândia, Medianeira, São Miguel do Iguacu, Santa Terezinha de Itaipu and Foz do Iguacu. The chosen route was due to the vast and vital hydrographic region, which is close to the BR-277 highway, as shown in figure 1 — Area of water dividers between three critical watersheds: Paraná 3, Baixo Iguacu and Piquiri (Covatti, 2006), (Figure 1).

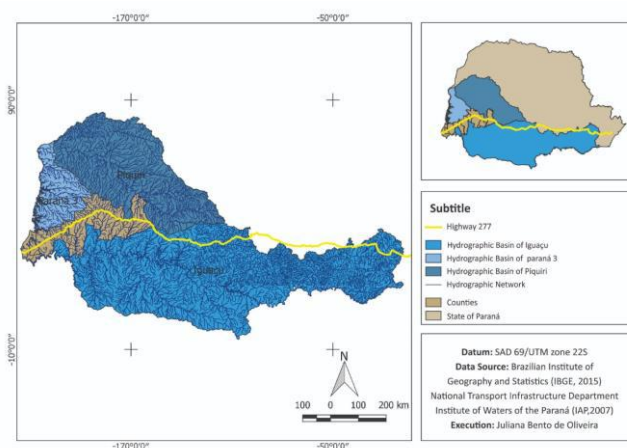


Fig. 1: Study area excerpt KM 493 A 730 from BR 277 (Guaraniaçu to Foz do Iguacu, Paraná)

SOURCE: The authors 2018.

2.2 Data Analysis

Data for all vehicles that circulated, transporting hazardous products, through the three toll plazas along the study stretch, referring to the two-way (east/west) and (west/east) of the state, were acquired through of the concessionaire that manages the road. Thus, the traffic of hazardous products during the period from 2013 to 2017 then, analyzed qualitatively and presented through graphs, for a better understanding of the results.

Thus, the main classes of hazardous products that had the most circulation in the stretch and those with low traffic were listed, such as 1 (explosives), 4 (flammable solids), 5 (oxidizing substances and organic peroxide) and 6 (toxic and infectious substances), which have been grouped and presented in others. There were no records of classes 7 and 8. These classes are defined by the United Nations (UN) (based on their physical and chemical characteristics that can cause damage to the environment and the health of the

population. According to ANTT 420/04, a product or article is considered to be hazardous to transport when it falls within at least one of the new hazardous product classes.

Thus, it was possible to identify four of the nine classes presented above, which refer to class 2 (gases), class 3 (flammable liquids), class 8 (corrosive substances), and class 9 (miscellaneous hazardous substances).

For the composition of the mapping of the critical points of the stretch, in which a more significant number of general accidents were registered, the database of the Superintendence of Water Resources Development and Environment Sanitation (2007) was used to delimit the watersheds and their hydrographic network; for the limit of the municipalities, the Brazilian Institute of Geography and Statistics (2015); For the delimitation of the highway, the base of the National Department of Transport Infrastructure (2015) was used.

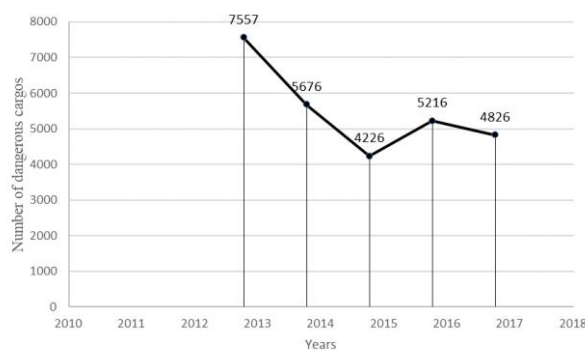
Thus, it was possible to identify four of the nine classes presented above, which refer to class 2 (gases), class 3 (flammable liquids), class 8 (corrosive substances), and class 9 (miscellaneous hazardous substances).

In the QGIS Software 2.18, the map was prepared, which through the coordinates and the accident numbers, it was possible to highlight the critical points with the highest occurrences of accidents and mark the locations, where there were accidents with dangerous products. With the help of bibliographic references, the possible social and environmental impacts were listed

III. RESULTS AND DISCUSSION

3.1 Dangerous Cargo Traffic

From traffic data, we observed that from 2013 to 2017, a total of 27,501 hazardous cargoes were trafficked in the analyzed segment (Graph 1).



Graph 1: Dangerous cargo flow 2013-2017 from KM 493 to 730 of BR-277(Guaraniaçu to Foz do Iguacu,Paraná).

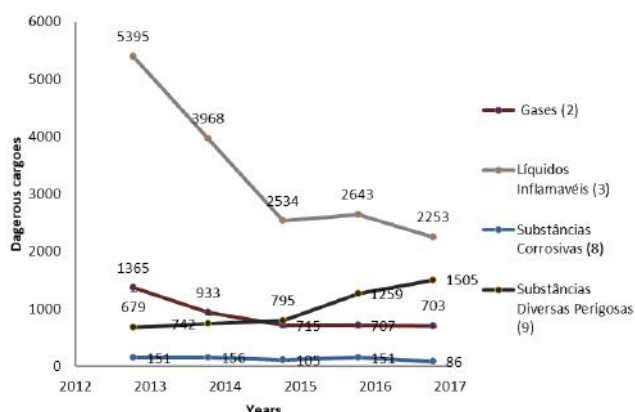
Source: The Authors (2018)

Graph 1 shows that in 2013 about 27% of the total value was registered; in 2014, 21% were recorded, in 2015 (15%), in 2016 (19%), and 2017 (18%).

The reduction from 2013 to 2014 is due to the installation of the automatic payment gate service at the tolls, as these automatic gateways do not register the vehicle and its cargo, and only record the monetary value of its passage at the toll booth. This type of system failure, which does not record the license plate, description, and types of loads they carry, leads to underreporting of the actual number of vehicles carrying dangerous goods, which may be much higher. Therefore, it is estimated that the values shown in the graph could be higher.

Another point raised was that the year 2015 had a low value compared to other years, this is probably due to the economic crisis that Brazil has been experiencing in recent years, according to the National Transport Confederation (CNT) (2017). The 2015 crisis impacted all productive activities, in which investments in both infrastructure and sectors were reduced. In that year, Gross Domestic Product (GDP) fell by 3.8%, and in 2016 there was another decrease of -3.6%. Thus, all segments of the economy (agriculture, industry, and services) had negative records in this period. Barbosa Filho (2017) demonstrates in his study that in 2015 Brazil went through what is called the "sustainability crisis" due to the series of shocks between supply and demand, caused mostly by errors of public management. Thus affecting the GDP and directly affecting the economic sectors.

Graph 2 shows traffic related to the transportation of various hazardous products, which are conducted daily on the stretch of BR-277 that connects Guaraniçu to Foz do Iguaçu.



Graphic 2: Classes of Dangerous Goods Transported from KM 493 to 730 of BR-277 (Guaraniçu to Foz do Iguaçu, Paraná).

Source: The Authors (2018)

Thus, it was possible to identify four of the nine classes presented above, which refer to class 2 (gases), class 3 (flammable liquids), class 8 (corrosive substances), and class 9 (miscellaneous hazardous substances).

The most transported class was 3, which refers to flammable liquids, i.e., fuels such as gasoline, ethanol, and diesel oil. Over the five years analyzed, a total of 16,793 hazardous cargoes were obtained. In 2013 they were 32%, 2014 (24%), 2015 (15%), 2016 (16%) and 2017 (13%). This frequency is due to the great demand for numerous activities that this type of product has, such as the supply of cars, trucks, and other equipment, as well as its use in industrial and agricultural activities (Pedro; Costa, 2009).

The second most transported class was 9, which refers to hazardous substances totaling 4980 loads. In 2013 there was 14%; in 2014 (15%), in 2015 (16%), in 2016, there was an increase to 26%, and in 2017 the record was 30%. Pesticides such as herbicides, fungicides, among others, fall into this class. Data released by the Parana State Pesticides Trade and Use Monitoring System (SIAGRO, 2019) showed that the total pesticides marketed in 2013 was 7,214,300 tons and in 2017, 5,067,300 tons in the 11 municipalities covering the study area.

These data, in comparison to the transport of class 9, contradict, since observing figure 3, it can be noticed that there was a smaller flow of dangerous cargoes in 2013 and more significant in 2017. However, it is worth mentioning BR-277 is used as a corridor for the neighboring countries of Mercosul, so these numbers of increased class 9 flow, should refer to imports of these types of products.

Class 2 was the third class with the most transport, which corresponds to gases that are substances that, due to their physical state, move freely, thus expanding indefinitely, occupying the entire environment, even when having different air densities and may present hazards such as being flammable, toxic and corrosive (Cetesb, 2018).

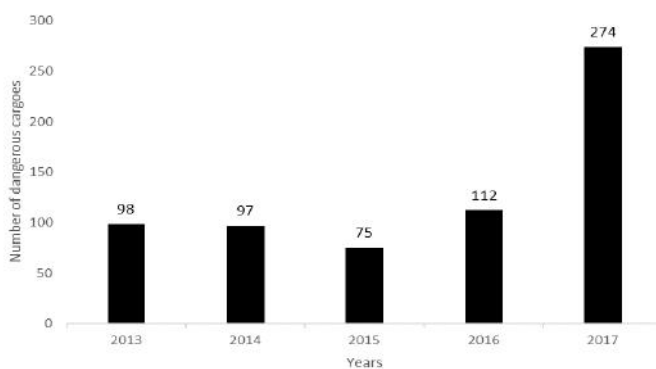
One of the most traded is Liquefied Petroleum Gas (LPG), which is used as a raw material in various segments, such as domestic (cooking gas), as fuel, commercial, and industrial use. 4,423 cargoes were transported during the five years. In 2013 there were 31%, in 2014 (21%), for the period from 2015 to 2017 maintained 16% each year.

Class 8 includes corrosive substances, which have properties known as acids and bases, such as sulfuric acid, hydrochloric acid, nitric acid, sodium hydroxide, potassium hydroxide, among others. Occurrences involving acids or bases that reach water bodies may cause changes in pH and conductivity. Besides, contact with these products causes burns, damage to living tissue, and death of aquatic

organisms, depending on the severity of contamination (Gouveia et al. 2014; Cetesb, 2018).

However, it was the class that had the lowest number of records compared to the others, totaling 649 loads in five years. It is that in 2013 was 23% in 2014 (25%) 2015 (16%) 2016 (23%) and 2017 (13%) of the product transported loads.

However, the other “classes 1 (explosives), 4 (flammable solids), 5 (oxidizing substances and organic peroxide) and 6 (toxic and infecting substances)”, which had lower traffic were grouped into others. Thus, represented in graph 3, the total record of the five years was 656 loads. Of the total in 2013 and 2014, 15% were transported, in 2015 (11%), in 2016 (17%) and in 2017 there was a 42% increase, due to neighboring countries, especially Paraguay, where Foz do Iguacu border region has been developing an industrial hub, thus increasing the demand for chemicals.



Graph 3. The flow of the other classes carried in the stretch of KM 493 A 730 of BR-277 (Guaraniçãu to Foz do Iguacu, Paraná).

SOURCE: The authors (2018)

3.2 Accidents with dangerous goods transport

The analysis of the general accidents showed that in the surveyed segment, 7,233 records occurred from January 2013 to December 2017. In Table 3, it is possible to observe the kilometers that can be considered critical points, because it shows a higher number of occurrences

Table 3: Points of higher occurrence of accidents in the study stretch.

KM	2013	2014	2015	2016	2017	Total
584	91	93	90	60	80	414
725	58	57	35	55	40	245
723	46	50	31	43	34	204
726	38	47	30	38	34	187

586	36	38	28	31	34	167
TOTAL	269	285	214	227	222	1217

Source: Ecocatarates, 2019.

According to statistics released by the State Coordination of Protection and Civil Defense of Paraná (2019) from 2013 to 2017, there were 111 occurrences of accidents with dangerous products in the state. There were nine registrations with vehicles that transported dangerous products during the period in the study stretch.

The km 584 where the clover catarracts are located is a vital connecting corridor between BRs - 163, 467, 369, and 277. In addition to giving access to the municipality of Cascavel, in the five years were reported 414 incidents in the place. With hazardous products in this location, had a record in 2013, with diesel.

In 2014 there was a record in km 602, according to the service agencies, were approximately 30 thousand liters of spilled diesel oil, whose area of influence is the São Francisco River basin, which is not part of the Cascavel water abstraction. Thus, the water supply was not affected, even though the product reached 25 km away from the accident site and could have contaminated other rivers, which are part of the Paraná basin 3; however, there were no reports after it occurred. The responsible environmental agency fined the fuel network.

In light of Law No. 9,605 of February 12, 1998 (Brasil, 1998), which provides for criminal and administrative sanctions arising from conduct and activities that are harmful to the environment, Article 54 states that, to cause pollution of any kind at such levels as to result or damage to human health or causing the death of animals or significant destruction of the flora, will have a detention sentence of six months to a year and a fine if the crime causes water pollution that makes it necessary to interrupt public supply of water from a community.

Thus, diesel oil, due to its molecular weight and its constituents, presents itself as less volatile and less water-soluble, with reduced mobility, different from gasoline and its components (Finotti; Caicedo; Rodriguez, 2001). The impacts that this product can cause was demonstrated by Freitas et al. (2013), with the changes that *Danio rerio* fish suffered when exposed to high concentrations of diesel and gasoline, showing changes in their physiology as aneurysm, respiratory epithelial cell necrosis and consequently other lesions, demonstrating the high toxicity of these fuels — Exposing the risks of these substances to human and animal health and the environment.

Another accident happened in 2017, at km 587, where it is a point that has springs near the BR, besides the presence

of Paulo Gorski Ecological Park. The transported product was characterized as batteries containing liquid acid. This type of material is part of class 8 - corrosive substances, ie, corrosive liquids, including soluble ones, can alter water conditions and can significantly decrease or increase its pH, thus making it difficult for many organisms to survive (Lew, 2008; RAO, 2008).

At km 645, near Blue Sky, in 2013, the truck transported about 16 thousand liters of gasoline, whose three thousand liters of fuel spilled on the highway. Already in 2014, at km 546 in Catanduvas, there was an accident with aviation kerosene, both products are included in class 3 of flammable liquids.

Finotti; Caicedo; Rodriguez (2001) presented in their research the effects of gasoline constituents, namely: Benzene, Toluene, Ethylbenzene, and Xylene, known as BTEX, which are monoaromatic hydrocarbons classified as hazardous. The author classifies benzene as carcinogenic, while toluene, ethylbenzene, and xylene are classified as toxic. These gasoline constituents have higher water solubility, so in case of accidents near water bodies, besides contaminating the surface part, it can also reach the water table easily.

Arcuri et al. (2012) demonstrated in their study the consequences that gasoline constituents can have on human health and contact with the substance or inhalation causes several short to long term damages. It highlights some, such as central nervous system depression and neurobehavioral, hematological, neoplastic, and mutagenic changes.

Also, two pesticide accidents were recorded in 2017; one was at km 697 located near the municipality of São Miguel do Iguaçu, which product was Poison Megaxan 75 wg powder and the other was with ethyl dichlorophosphate at km 659, in the urban area of Matelândia. Vehicles transporting these products in urban areas, agricultural areas, or near environmental preservation areas were found to be susceptible to accidents, and, depending on the product being transported, leakage may occur.

Once spilled, this product can be carried into water resources, contaminating them, thereby disrupting public supply to the population. This problem is intensified in municipalities that have only a source of water supply, because in case of leakage of such hazardous products, this will lead to water scarcity to the population, bringing with it various social and environmental problems and health, as well as, losses in industry, commerce, and agriculture, either due to lack of water or contamination (Siqueira, 2016).

In this sense, Scucato (2008) mentions that pesticides can be persistent, mobile, and toxic in soil, water, and air. In addition to being accumulators in the ground and biota, whose residues can reach surface waters, runoff, and groundwater by leaching. Thus, an accident with this type of product can cause damage to the health of the population, such as contact poisoning or the consumption of food contaminated by pesticide residues that are difficult to measure. In the case of chronic intoxication, it can manifest itself through paralytic diseases and neoplasms.

In 2014, besides the accidents already presented, there were two more, one in km 543, near the city of Ibema with explosive product, but it was not specified what type of product and in km 526 in Guaraniáçu, with a vehicle that carried asphalt emulsion, which is considered a hazardous substance as it is a mixture of various compounds and usually has kerosene in its composition. Thus, the spillage of this product can lead to reduced dissolved oxygen levels in water resources, with the possibility of a film-forming on the water surface, causing the death of aquatic organisms (Petrobras, 2019).

Therefore, water bodies are more susceptible to environmental damage, as it is complicated to control the risks and impossible to predict the place and time of these accidents (Viana, 2009). These accidents have serious consequences, such as injuries and deaths, high property damage, traffic stoppage, environmental impact on soil, air, and water, as well as damage to fauna and flora, which can last for years (Santos; Góis, 2011).

3.3 Critical points of the study excerpt

In figure 2, we observe the critical aspects, which were considered places that had the highest incidence of general accidents and are indicated by the red circle. They are located at intersections of the highways with other BR or marginal roads. Thus, of the five points, two are located in the municipality of Cascavel, km 584, where is located the Clover Falls, with a record of 414 accidents and km 586, which is the intersection of Bairro Cascavel Velho, with 167 accidents. The other critical points are located in the municipality of Foz do Iguaçu, in the following locations: km 725 (245 accidents), 723 (204 accidents), and 726 (187 accidents). Hazardous product incidents were recorded at five critical points and one near km 586.

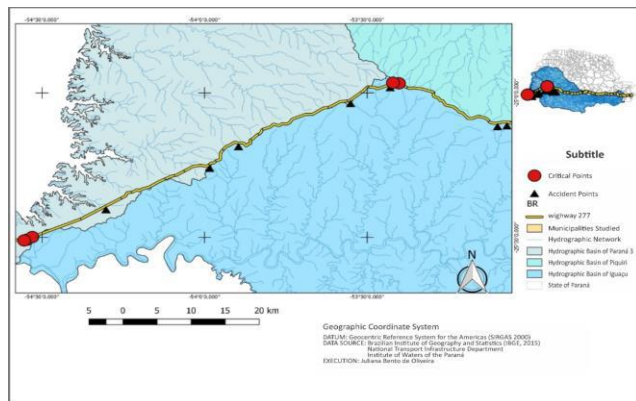


Fig.2: Area of occurrence of accidents with dangerous loads of km 493 to 730 of BR-277 (Guaraniaçu to Foz do Iguaçu, Paraná).

Source: The authors, 2019

Beltrami, Freitas and Machado (2012) analyzed data from the sectors of the National Secretariat of Civil Defense, the Ministry of Environment and the Ministry of Health on accidents with hazardous products, from 2006 to 2009. Thus, reported that the total number of occurrences in four years was 3,601, resulting in an average of 900 hazardous product accidents per year and 75 per month. In the state of Paraná alone, there were 275 occurrences in this same period.

The author also points out that even a state that has an organized Civil Defense structure, in case of accidents with dangerous products, does not have the data registered in the national system.

The Brazilian Institute of Environment and Renewable Natural Resources (IBAMA) has a system on environmental accidents; however, the last report was issued in 2014, and in nine years, 4713 environmental disasters were registered in the Brazilian transport matrix, which predominates by road (this includes the transport of dangerous goods). Thus, accidents with dangerous products on Brazilian highways had their highest number of registrations in 2013, which were 195, totaling 27% and in 2014, whose records were 205, making 28.3% of occurrences (Ibama, 2015).

IV. CONCLUSION

This study demonstrated the need to implement risk management since, in five years, nine accidents caused considerable environmental and social damage.

Thus, conducting studies on vulnerabilities and preventive actions on the highways can help reduce accidents, as well as promote training on the subject, for the companies that perform these transports and also for the

managers of the interests, such as the municipal one, environmental and federal, and the strengthening of information and educational campaigns for people who work in the area, especially the carriers that perform this activity.

Finally, there is the need to encourage preventive and mitigating measures such as the improvement of signs and delimitation of the most critical areas, such as those near water sources, proposing structural measures on the highway, for the preservation of watercourses and the restoration of the riparian forest environment.

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