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Development of a microplastic retention mechanism in water treatment plants (WTPs)

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ACKNOWLEDGMENT

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SUMMARY

The concern with the contamination of different environments by microplastics is growing, given the ubiquity of plastic materials in the daily life of our society. Microplastics derived from the weathering and the wear and tear of larger materials or personal use products such as cosmetics, for example, have already been found in human tissue in alarming concentrations. Studies have found these microparticles in water treatment plants that do not have a specific mechanism for removing this pollutant, which results in their presence in the water that reaches the population's homes. Having as a goal the solution of this demand, this project has developed a microplastics filtration mechanism to be used in treatment plants, with easily accessible, low-priced materials. Based on data from a specific treatment plant, the mechanism was built and tested reproducing the conditions of this environment. The simulations demonstrated the effectiveness of the designed filter. During the tests, different water flows were generated in order to assess the influence of flow input on filter efficiency. This parameter proved to be an essential factor for the quality of filtration, that is, the greater the flow of water, the higher the filtration rate. The results show that addition of an effective filter has the characteristic of being easily adapted, and it is expected, therefore, to be eventually applied in water treatment plants for quantification microplastic studies as well as studies aimed at implementation as a step-in water treatment.

Keywords: Microplastic, Water Treatment Plant, Filtration

TABLE OF CONTENTS

1. INTRODUCTION

The concern around plastic contamination has been growing, and these residues are one of the main contaminants that must be tackled as a priority in the 21st century.

Plastic items come in all shapes and sizes, with the smallest sizes (<5mm) being considered "microplastics". These primary particles are produced in the form of small granules, which will be used as raw material for the manufacture of plastic products. In addition to this raw material, microspheres are added to cosmetics and other personal care products (HORTON; DIXON, 2018). In relation to the latter, its wide use by the pharmaceutical industry is justified by the advantage in relation to price, when compared to the use of seeds as exfoliating agents.

These particles have taken on a dangerous role in aquatic environments, bringing potential health risks to various living beings, including humans. According to a study by the University of Victoria, Canada, a person can consume from 74 to 121,000 microplastic particles per year, considering the microplastic present in the air and in the food we consume. This study becomes more alarming when considering the ability of these microplastics to adsorb toxic substances such as mercury, for example (VEDOLIN et al., 2018; LOPES et al., 2020).

When considering the processes that water goes through during its treatment in Water Treatment Plants (WTPs), it is difficult to imagine the presence of contaminants, however, as shown in the University of Victoria study, we constantly consume microplastic, and this particle is present in treated water (TEOTÔNIO, 2020).

When studying filtering methods in conventional WTPs, it is possible to notice the lack of filters dedicated to the retention of microparticles with a density lower than that of water. This explains the presence of microplastic in the water we consume, as in addition to their capacity to float in water, this particle has a nonpolar characteristic, which gives this fragment the difficulty in adhering to other substances in flocculators, thus passing through filtration systems.

Teotônio (2020) identified the presence of microplastics in all tap water samples in the "*Plano Piloto (central region of the city)*" region in Brasília, showing the inadequate disposal of this waste and the lack of strategies to remove this pollutant in water treatment plants. Another study carried out in four different Portuguese WTPs demonstrated that the effluent generated by these stations contains significant amounts of microplastics, even with the presence of different removal methods (GOUVEIA, 2018).

In Porto Alegre, water samples from five different WTPs were collected, and plastic-like polymers were identified in all water samples (LOPES et al., 2020). Given the above, the ubiquity of microplastics in all environments is indisputable, as well as their interaction with organisms, including humans.

Schwab et al. (2019) found, on average, 20 microplastic particles, with sizes ranging from 50 to 500µm, for every 10g of human feces collected. A recent study reported the presence of microplastics in human placental samples (RAGUSA et al., 2021) and alerted the scientific community to the importance of improving studies in this direction.

Thus, considering the danger of this pollutant for human beings, it is increasingly necessary to develop a methodology for retaining these microparticles in water treatment plants throughout Brazil, aiming at solving this serious problem.

The objective of this project is to develop a microplastic retention method in water treatment plants (WTPs), which has specific features such as low cost and easy installation or adaptation in different WTPs.

2. METHODOLOGY

To develop an easy-to-apply and reproducible microplastic retention method, the steps involved in the water treatment process in a conventional treatment plant were identified and analyzed.

To obtain a reliable scale for testing the methodology, data such as water flow and the size of tanks and gutters were obtained from the São Roque Treatment Station, located in the city of Itajaí in the state of Santa Catarina. Due to sanitary regulations and the current Covid-19 pandemic context, we did not obtain authorization from appropriate agencies for on-site testing, therefore, it was not possible to apply the filter prototype in a WTP. Thus, the prototype testing was performed by simulation, reproducing the parameters found in the WTP.

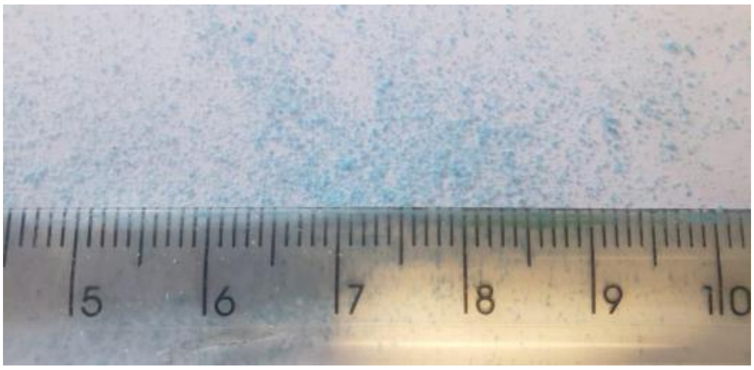
Based on the idea of reproducibility of the method in different WTPs, easy access and adaptation materials were used to develop the filtration mechanism (Table 1).

Table 1. Materials used in the construction of the filter and structure for simulation.

100mm PVC pipe
PVC gloves and knees
plastic pot
Automotive horn (14 cm high and 18.5 cm wide)
Nylon mesh with 300 µm opening
Cylindrical shaped glass
Submerged aquarium pumps with capacities of 120l/h and 1000l/h.
bolts and nuts
Silicone glue
Glass aquarium (20cm wide and 50cm high).

Obtaining microplastics for filter testing followed the simulation of weathering processes that plastic materials suffer in the environment. Various plastic materials (pen lids, plastic pot lids, plastic bottles) were sanded to obtain particles smaller than 1mm (Figure 1). The choice of these materials was based on the type of plastic, that is, low-density materials (which float in water) were chosen.

Figure 1: Microplastics obtained manually.



Assessing the difference in filtration in relation to water flow, two pumps with different capacities were tested. The first with a flow of 120l/h and the other with a capacity of 1000l/h.

After the simulation, three samples of the material retained in the filter were submitted to microscopic analysis, to obtain a qualification of the microplastics in terms of shape and size.

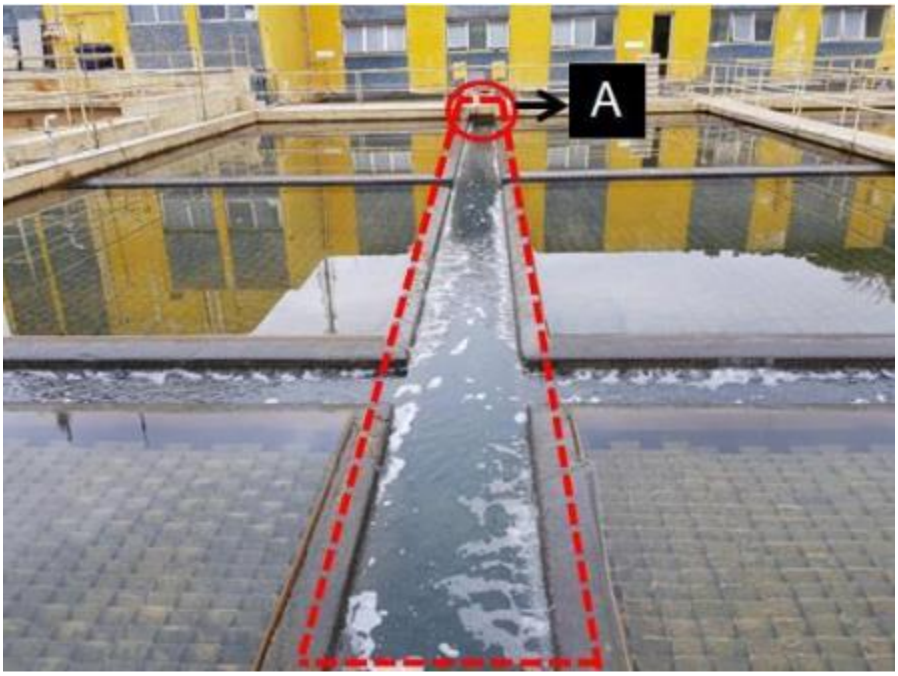
3. RESULTS

3.1 Choosing the location for the filter installation

After analyzing the steps that take place during the water treatment in WTPs, the location for installing the filtration mechanism was chosen. Several factors were taken into consideration during this choice such as the level of organic material present in the water, the size of the site and the flow of water.

The chosen location (Figure 2) consists of a gutter that directs the water from the settling tank to the filtration tank. This location is ideal for installing the filter, because after the settling process, the larger impurities such as organic materials in suspension are removed, thus avoiding a possible obstruction of the filter.

Figure 2: Representation of part of the São Roque Water Treatment Plant (Itajaí-in the state Santa Catarina). In the dotted detail, the gutter positioned between the settling tank and the filtration tank. In A, the selected location for installing the filtration mechanism.



Another relevant factor for choosing this location is its dimensions. With 60 cm wide and 120 cm of water depth, this place does not require a large structure to filter all surface water that passes through the mechanism. Most plastics are less dense than water (RYAN et al., 2009), therefore, depth is not relevant in the design of the mechanism, with no need for the entire volume of water to pass through the filter element, but only the surface water.

This chosen congruence point has 275 l/s of flow. The continuous flow is an important factor, as it guarantees a fast and efficient filtration of all suspended material and allows for the continuous control of particles captured by the filter and its maintenance. Furthermore, the constant filtration facilitates future filtration and quantification studies.

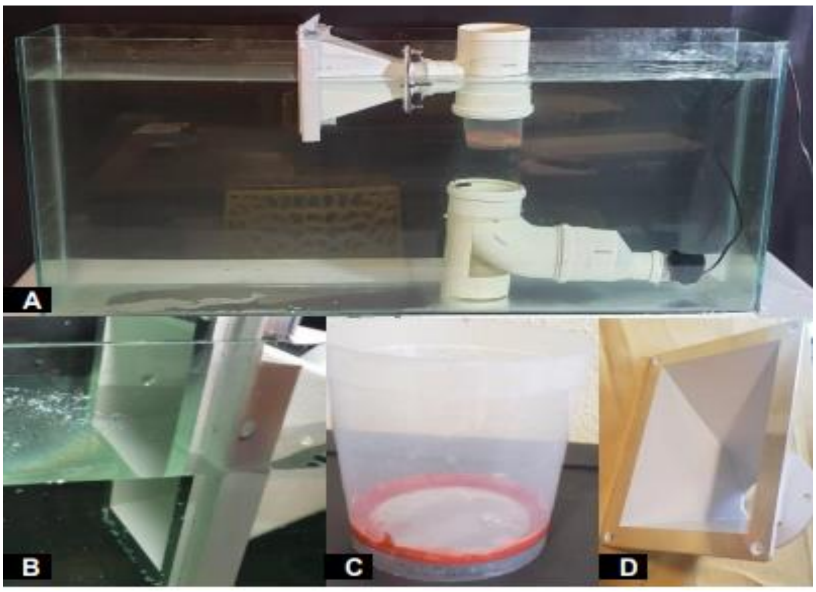
3.2 Construction of the filter

The materials used in the construction of the filter were chosen considering the low cost and easy access, always aiming at reproducibility and adaptation in any WTP.

The Figure 3 shows schematically the component parts of the filter. A rectangular piece with tapered ends (automotive horn) was connected to a PVC pipe. Inside this pipe, in the middle portion of the filter, a filtering element was placed, which consists of a plastic cylinder whose bottom is composed of a nylon mesh with an opening of 300 µ.

Angles brackets were adapted on the sides of the initial rectangular structure with the aim of prevent water from escaping through the sides of the filter. For simulation and testing purposes, a submerged pump was attached to the end of this structure for creating the existing flow in the WTP environment.

Figure 3: Representation of the filter prototype (A). Detail of the rectangular treble horn with the adapted angles brackets (B). Cylinder with 300µ nylon mesh at the bottom (C). Rectangular structure with tapered ends (automotive treble horn) (D).

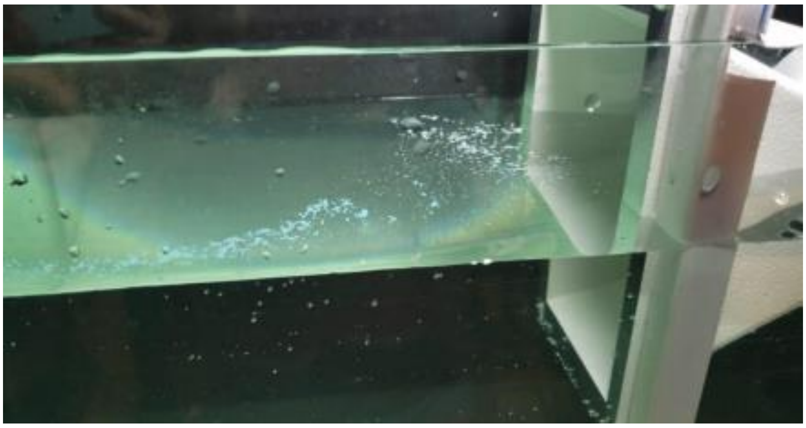


3.3 Simulation and testing of the filtration mechanism

The simulation and testing of the prototype was performed by reducing both the medium and the filter to a scale of 1/3 in relation to the measurements of the São Roque WTP, used as a reference in this study. This scale reduction allowed for a demonstration of the WTP environment.

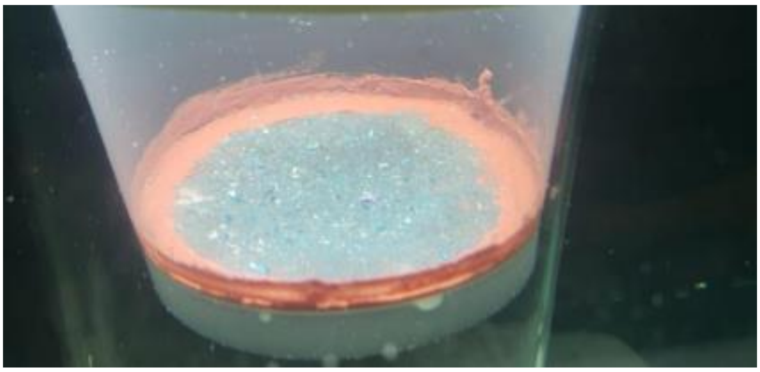
For the two simulations carried out, with the intention of respect the predefined scale, 40 cm of the aquarium were filled with water. With the filter in place and the submerged pump turned on, the microplastics were added in the initial portion of the aquarium, simulating a path until reaching the filter (Figure 4).

Figure 4: Microplastics added to the aquarium at the beginning of the simulation



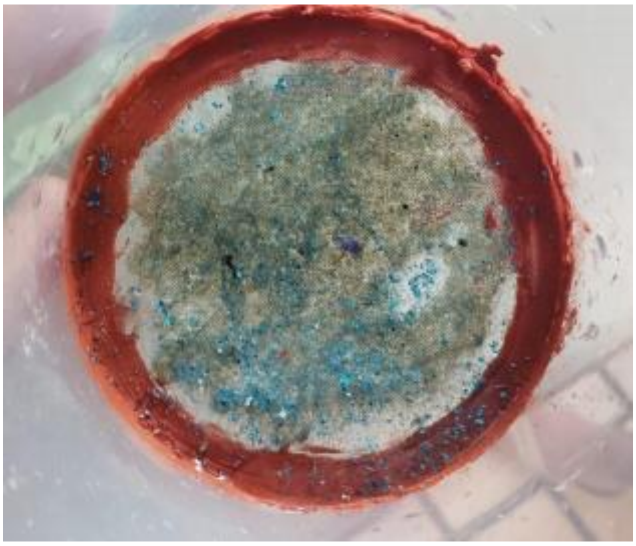
Through this simulation, it was noticed a directly proportional relationship between the retention of microplastic in the mesh and the water flow. Testing two pumps with different flows, it is concluded that when we use the submerged pump with the capacity to produce a water flow of 120l/h, the larger microplastics were floating above the filter element, that is, without contact with the mesh but even so they are still filtered out. By increasing the flow, using a pump with a capacity of 1000l/h, the amount of microplastic retained in the mesh (Figure 5) is greater and filtration occurs faster.

Figure 5: Microplastics being retained in the filter during the simulation.



However, the filter proved to be efficient, since almost all microparticles with a size equal to or greater than 300µ were retained in the filter element in all simulations (Figure 6).

Figure 6: Microplastics retained in the mesh after the simulation.



Considering that the simulated flow is equivalent to approximately 0.07% of the flow at the São Roque WTP, it is concluded that the filter operation in conventional WTPs would be enhanced.

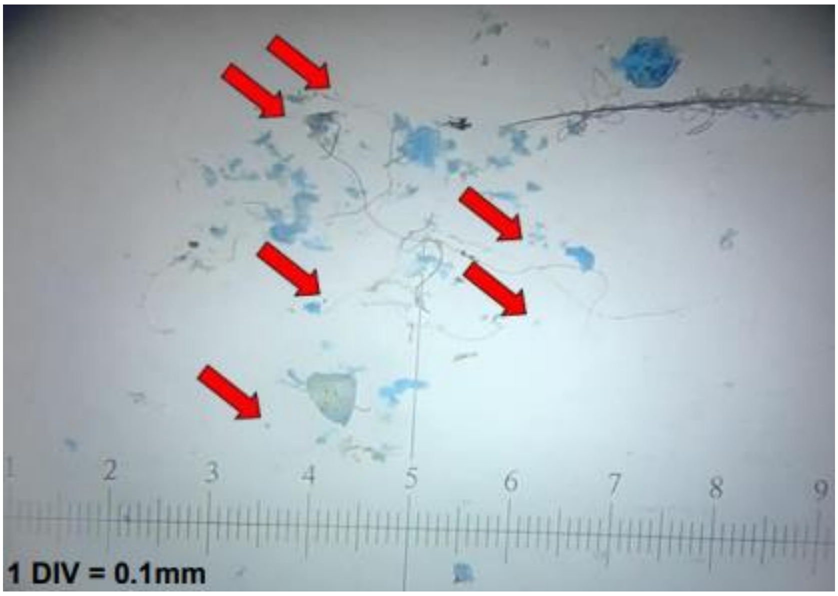
It should be noted that the dimensions of the treble horn located at the beginning of the filter were positioned so that half of it was submerged, equivalent to 7 cm of water. This adaptation is essential for filtering microplastics from denser materials, such as polyethylene terephthalate (PET) and polyvinyl chloride (PVC), for example.

3.4 Granulometry of the filtered material

The particle size evaluation revealed the qualitative variety of the filtered microplastics, being possible to notice a clear difference in size and shapes, confirming the similarity between these particles and those found in nature.

This microscopic analysis also allowed for a discussion about the size of the filtered particles. The results showed the presence of many particles whose size was smaller than the opening of the nylon mesh used (300µ), as highlighted in figure 7. This result can be explained by the chemical characteristics of these particles, which tend to cluster, due to the surface tension of the water and static energy.

Figure 7: Granulometry of a sample of the material retained in the mesh, each division = 0.1mm (40x magnification) 1 DIV = 0.1mm



This effectiveness in filtering exceedingly small particles is extremely relevant, given the findings of studies on microplastics in humans. Ragusa et al. (2021) found, in human placentas, microplastic fragments ranging from 5 to 10 μm (compatible with a possible transport through the bloodstream), with spherical or irregular shape, which corroborates the fragments retained during this study.

An important reflection was obtained by this study, assuming that these microparticles are present in abundance in the environment and that their ingestion is already reported. Much of this problem could be solved with inspection and surveillance of environmental agencies, however, the Brazilian legislation itself, such as Consolidation Ordinance No. 5, of September 28, 2017, of the Ministry of Health, which deals with the drinkability standards of the water, has no specifications regarding the presence of microplastics in water.

4. CONCLUSIONS

The prototype elaborated in this project cost around R$ 450.00 (four hundred and fifty reals – around US$ 90.00), a value that can vary according to the adaptations that can be made due to the different dimensions of the ETAs. This low cost contributes to the replication of this method between the stages of water treatment, as the method was also not very invasive and therefore will not interfere with the other stages of treatment.

For the next stage of the project, the aim is to apply the filter model proposed at the São Roque WTP, in the city of Itajaí, in the state of Santa Catarina, to quantify and qualify the microplastics collected according to the seasons, analyzing the effectiveness of the mechanism under variables such as rainfall, salinity, turbidity, as well as comparing water samples after passing through decanters with and without the filter.

Since studies on the presence of microplastic in water treatment plants are recent and scarce, it is expected that, in addition to its use from the sanitary point of view, this project will be a potential driver for future research work on the presence of this pollutant in these locations.

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ANNEX A. QUESTIONS ABOUT THE PROJECT

1. **What are the greatest contributions expected from the implementation of this project with a view to society, the economy, the environment and, in particular, water resources?**

   The implementation of this mechanism in the Water Treatment Plants (WTPs) would bring several benefits to society, as well as to the environment, given the omnipresence of microplastics in the environment and even in the water we drink. This problem, in addition to involving the pollution of water resources, is, from a sanitary point of view, a potential risk to human health. The retention of microplastics in WTPs will prevent the ingestion of these particles by humans and, consequently, will prevent their retention in the body, as well as the passage of pollutants adsorbed on them. In addition, a wide use of this filter will provide quantitative data related to the presence of these contaminants in water bodies, and from this data, preventive, and control measures for this type of pollution may be taken.

2. **What innovation is being proposed? How does it relate to existing solutions?**

   The proposed innovation is the installation of a microplastic filter for Water Treatment Plants, since conventional WTPs do not have a specific filter for this contaminant and that the common filtration system is sometimes not able to retain these particles, given their specific characteristics. Considering that the presence of microplastic in treated water is a problem of global scale, this project could be the solution to one of the biggest environmental problems of the present. Studies related to microplastic pollution focus on detection and diagnosis rather than solution.

3. **For which region or situation does the project apply? Can it be replicated? Does it serve developing and developed countries?**

   The project does not depend on the region, the structure of the project, together with its low cost, provides a filtration mechanism that can be incorporated in several ETAs around the world, even in underdeveloped countries, due to its low cost.

4. **What is the project implementation cost?**

   The cost of the prototype was R$ 450.00 (US$ 90.00). The full-scale filter will cost approximately R$500.00 (US$100.00), since installation and maintenance have no additional costs, which facilitates the application of the project.

5. **What would be or were the biggest difficulties for the development and implementation of the project?**

   The biggest challenge was to develop this project during a period of COVID-19 pandemic. The contact between the student and the advisor was sometimes restricted to online calls, as well as the inaccessibility of the city's treatment plant, chosen as the basis for the design and construction of the filter. Due to this context, the installation at the WTP itself was unfeasible, requiring the production of a prototype, as well as an environment for simulation, which would represent all the real variables of the actual installation site at the WTP.

6. **Which Sustainable Development Objectives (SDOs) and goals does your work most relate to?**

   The project fits into Sustainable Development Goal 6, Drinking Water and Sanitation for All, within this goal, the project fits into goal 6.3, as the application of the filter would collaborate with cleaner water (goal 6.3).

7. **What moved you to choose this theme?**

   The concern with the ingestion of microplastics and their presence already confirmed in the human body was the main motivator of the project, since this particle is already present in human organs, tissues, placenta and even feces. One of the most alarming data was the University of Victoria research that warns that a person can ingest up to 121,000 microplastic particles in a period of one year. In addition to these data, the presence of microplastic in treated water and its property of adsorbing toxic substances to the body were motivating factors for choosing the topic and carrying out the project.

ANEXX B. DOCUMENTATION OF PARTICIPANTS

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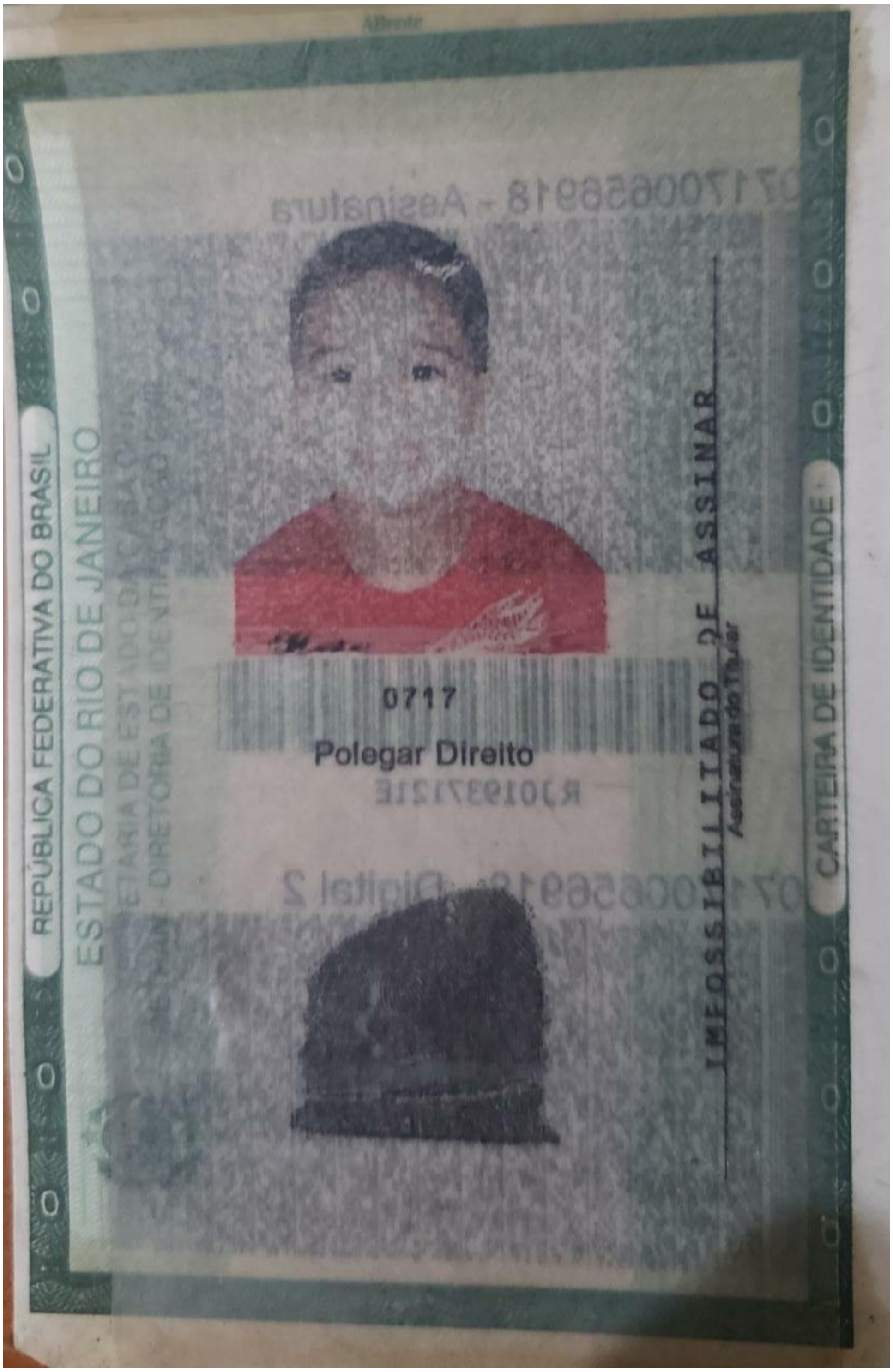
- Identification Document of ALL authors
- Proof of enrollment in high school OR proof of completion of high school for ALL authors



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