

# Qualitative Evaluation of the Basic Sanitation System with Fuzzy Logic in the Colonia Antônio Aleixo and Puraquequara Neighborhood in Manaus-AM, Brazil

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**Abstract**— *The present work is justified by the problems that exist in the municipality of Manaus in relation to basic sanitation, where it is one of the worst in Brazil, considering the neighborhoods of Colonia Antônio Aleixo and Puraquequara, which have rarely had popular participation in their planning, has unleashed over the years a continuous process of invasions that lasts until the present day, which ends up degrading the environment and calls on the government to intervene in order to provide these places with urban infrastructure. In this disregard for the population of the city of Manaus at a certain time ago, in relation to basic sanitation, it was interesting to evaluate the situation of some districts of Manaus by means of some data to verify through the technique of artificial intelligence called logic fuzzy, how good is the quality of basic sanitation in the days in two specific neighborhoods. The definition of the modeling was done and the results obtained with an artificial intelligence technique made it possible, through some data, to generate another very important data, which is the quality of basic sanitation in the neighborhoods analyzed in the course of all the work presented.*

**Keywords**— *Basic sanitation, Free Zone of Manaus, Fuzzy Logic, public policy on basic sanitation.*

## I. INTRODUCTION

The Free Zone of Manaus was conceived in the year of 1957, in an original idea of the Federal Deputy, by the state of Amazonas Francisco Pereira da Silva and implanted in the year of 1967, in the military government. It aimed to implant an industrial district, a commercial

center and an agricultural district in the center of the Western Amazon, exactly to foster activities of the three (3) sectors of the economy: Primary Sector (agricultural district); Secondary Sector (Industrial District); and, Tertiary Sector (Shopping Center). But besides these economic goals, it also had social objectives, such as deploying high-quality services in the center of Western Amazonia in all areas of State activity [1].

Among these services, there was the basic sanitation plan, developed in the administration of the municipal mayor of Manaus Paulo Nery, since the city was expanding and there was no basic sanitation, other than that left by the British during the rubber period [2].

Manaus at that time had few neighborhoods, still, and practically ended up in the neighborhood of Flores. But its expansion began with the construction of four (4) residential complexes, the famous COABS: one (1) in Flores; one (1) in Park 10; one (1) in the Root; and one (1) in Japan. All with the purpose of receiving the population that was growing, in function of the Free Zone of Manaus. Within these proposals for the construction of housing projects, there was clearly the inclusion of basic sanitation. It was done, but in a timid way [1].

In the period of the implantation of the Franca area of Manaus, the neighborhood Colônia Antônio Aleixo, already existed in the infrastructure of the city of Manaus. But it was a place with no connection, land route to the city, since there lived those affected by leprosy, disease, which since biblical times proves awe in the population and their sufferers, are removed from the city. It was only in 1972 that the first access road was built, by land, being

paved during the management of Jorge Teixeira, in the city of Manaus [3].

Beginning in the early 1980s, people without the disease's prevalence began to fix housing on the site. This place is very close to the meeting of the waters and, as they were a place to treat a disease, never suffered intervention of the public power in the structural part of basic sanitation. With the increase of residences and the settlement of areas near the Amazon River, it would be necessary to intervene to prevent human debris from being dumped directly into the river. But initiatives so far are flimsy [3].

In this disregard for the population of the city of Manaus at a certain time ago, in relation to basic sanitation, it was interesting to evaluate the situation of some districts of Manaus by means of some data to verify through the technique of artificial intelligence called logic fuzzy, how good is the quality of basic sanitation in the days in two specific neighborhoods.

The objective of this article is to qualitatively define the situation of the Basic Sanitation System with the Fuzzy Logic in the neighborhoods of Colonia Antônio Aleixo and Puraquequara in Manaus-AM.

## II. JUSTIFICATION

This work is then justified by the problems that exist in the municipality of Manaus in relation to basic sanitation, where it is one of the worst in Brazil, considering the neighborhoods of Colonia Antônio Aleixo and Puraquequara, which in general have never had popular participation in their planning, has unleashed over the years a continuous process of invasions that lasts until the present day, which ends up degrading the environment and calls on the government to intervene in order to provide these places with urban infrastructure.

## III. LITERATURE REVIEW

### 3.1 . BASIC SANITATION

Concerns about a centralized water distribution system were born from growing health concerns. In the ancient world, there was already this concern about the existence of water distribution systems in Egypt, Palestine, Persia, Phenicia, etc., as [4] point out: "Egypt, India, Sumeria, Mesopotamia and Greece are pioneers in the construction of wells, fountains, dams and aqueducts. In Mesopotamia irrigation systems were already used (4,000 BC). The first sewer galleries (3,200 BCE) date from India. The Sumerians (5,000-4,000 BC) constructed irrigation canals, galleries, settlements, cisterns, reservoirs, wells, tunnels and aqueducts".

As can be observed, every people had its peculiarities in relation to water. While some associated their

importance with deities, others were concerned with the better use of water resources. In Egypt, for example, the use of a product for the treatment of water (aluminum sulphate in water clarification) was considered to be inappropriate for consumption [5].

In ancient Greece, this thought arose out of concern for health, since Tales of Miletus claimed that water was the origin of the whole universe and, since origin was the most important thing for human beings, as [4]: "In classical Greece, the cradle of philosophy, it had an intrinsic relationship with medicine. And as water was the source of life, according to philosophy, medicine used this precept to defend the preservation of this good, since the disease originates from external causes such as water quality".

Thus, from a concern with health, it began to establish the need for a water distribution system for the population based on the polis (public city), that is, this would be attribution of the State. [4]: "In order to achieve this, it is important to note that, in Rome, this process consecrated as a function of engineering knowledge, which was fundamental to Rome, due to its large engineering constructions that needed underlying elements".

As can be seen, with extreme clarity, in the words of the authors mentioned above. The Roman State became responsible for activities of a purely public nature, such as health, which included water distribution and sanitation and urban hygiene [6].

In the Middle Ages, this system changed profoundly, mainly by the loss of power of the Roman Empire. The cities were practically abandoned and refuges were created around the rivers, which caused a profound change in the water distribution system, which was then collected directly from the rivers. [4]: In England, the first legislation to protect water resources was introduced, as was pointed out by [4]. "In 1388, in England was formatted the first environmental legislation of the world, the so-called "English Act", which dealt with pollution of water and air. This law described prohibitions as the dropping of excrement, litter and debris into cesspits, rivers and other waters".

With this, the presence of the State was instituted as the controller of the conditions of the water, at the same time that the capitalism appeared. The process of capitalist development, intensified by the Trade Revolution of the sixteenth and seventeenth centuries, was, until then, the circulation of commodities [4].

From the second half of the eighteenth century, however, industrial mechanization began in England, diverting the accumulation of capital from commercial activity to the production sector [7].

This fact brought about great changes, both economic and social, that allowed the disappearance of the remnants of still existing feudal relations and practices and the definitive implantation of the capitalist mode of production [7].

At the same time, as mentioned above, campesinos who moved to the cities formed a large contingent of available labor - the so-called reserve industrial army (the first consequence of the Industrial Revolution - the intense rural exodus), which is essential for occurrence of the Industrial Revolution. Because of the scarcity of jobs, this massive, very low-cost labor force met industrial needs, since the cost of the labor force was very small, they could apply large sums of capital to new facilities [8].

It was of great importance for this advance, that is, organization in associations, leading to a vote in 1924 by the English parliament, where the right which was hitherto restricted to the ruling classes, the free association, was won. The trade-unions negotiated with the capitalists to create a scale of wages, forcing their acceptance, and set off strikes whenever these wages were rejected. Thus, these associations were strengthened [9].

From the middle ages, feudalism, to the industrial era, the changes were so profound that they eventually had a definite influence on the migratory process due to the new opportunities that arose from the improvement of life that affected the nomadic nature of man [9].

This intensification of population for the city undoubtedly provoked a complete change in the system of cities, especially in relation to the provision of public services, among them the distribution and treatment of water, which forced the capitalist countries to promote changes in the sanitary areas [10].

This change took place around the so-called 'contagion theory', which was nothing more than the intensification of diseases due to water quality, such as a cholera epidemic that occurred in the mid-nineteenth century [11].

As a result, the European states have stepped up six investments in sanitary aspects with the creation of water distribution and treatment systems for the population and also the establishment of sanitary sewage systems, as well as a major shift in urban waste. These systems demonstrated to the rest of the world the need for treatment and distribution of water by a public system and that had as a consequence an immediate improvement in the public health system of the population as a whole. In Brazil, this concern only began to exist upon arrival of the royal family to Brazil in 1808, since the conditions of sanitation in Brazil were very improper. But with the

arrival of Dom Joao VI, this concern began, as it was necessary to have minimum hygiene conditions for the royal family [12].

But as public policy, these issues began to be concentrated in the field of municipal management, since the central power did not give attributions like this. The Republic, proclaimed in 1889 did not change that vision, which only occurred from 1930 with the arrival of Getúlio Vargas to the power [13].

### 3.2 FUZZY LOGIC

"The theory of fuzzy sets emerged as a tool to respond to problems related to vague information, Inaccurate or ambiguous, usually described in language natural - qualitative terms - to be transcribed into numerical language" [14].

According to Fonseca Júnior:

"Fuzzy logic is an intelligent technique that provides a mechanism for manipulating imprecise information - concepts of small, high, good, very hot, cold. - Allows to infer an approximate answer to a question based on inexact, incomplete or not totally reliable knowledge" [15].

According to [16] fuzzy logic theory, also known as nebulous logic or even fuzzy logic, has been increasingly used in systems that use information that is provided by people to automate any processes, such as decision aid. This theory has been used in applications ranging from the control of household appliances to resources used in medicine and the financial market.

The fuzzy logic can also be used for simulations and treat imprecise concepts such as bad, regular and good, which is the case of the present work.

According to [17]:

"The Fuzzy Logic (Nebula) is the logic that supports the modes of reasoning that are approximate rather than exact. Modeling and fuzzy control of systems are techniques for the treatment of qualitative information in a rigorous way. Based on the concept of fuzzy sets, fuzzy logic is the basis for the development of process modeling and control algorithms and methods, allowing the reduction of design and implementation complexity, making it the solution to control problems that were previously intractable by classical techniques".

According to [17], "fuzzy modeling and control theory deals with the relationship between inputs and outputs, adding several process and control parameters". This allows complex process considerations to be handled in such a way that the resulting result of the fuzzy logic is stable and robust.

**IV. METHODS****4.1 DATA OF THE NEIGHBORHOOD COLONY ANTÔNIO ALEIXO**

In the year 2013, PMM surveyed the area on the situation of basic sanitation in the Colonia Antônio Aleixo neighborhood, where data are contained in tables 1, 2 and 3 below.

*Table.1 - Water supply system in the neighborhood Colonia Antônio Aleixo – Manaus*

Water supply system	Rating of the service provided	Main complaint of the service	Distribution network pressure	Does water analysis in the residence	The depth of the well	Water-borne diseases
Public network 70.23%	Bad 45.14%	Quality 45.10%	Strong 47%	Yes 0%	15 m 16.66%	Yes 53,85%
Alternative source 23.12%	Regular 43.10%	Lack of water 41.18%	Poor 53%	No 100%	20 m 50%	No 46.15%
Public and Well Network 6.65%	Good 11.76%	Quality and lack of water 13.72%	-	-	Others 33.34%	-

Source: PMM (2013).

*Table.2 - Sanitary sewage system in the Colonia Antônio Aleixo neighborhood – Manaus*

Type of Exhaustion System	Individual system, Treatment type	Problems with the pit
Collective 0%	Septic tank 35%	There is not 44,88%
Single 100%	Sink 65%	Bad smell 55.12%
-	Others 0%	Others 0%

Source: PMM (2013).

*Table.3 - Solid Waste System in the Colonia Antônio Aleixo - Manaus neighborhood, according to the diagnosis of the area carried out by PMM*

There is solid waste collection	Frequency of collection	Transportation that carries out the collection	Collection Classification	Quality of Public Cleaning
Yes 97%	Frequency of collection Daily 100%	Truck compactor 90%	Bad 30%	Bad 50%
No 3%	Weekly 0%	Dump Truck 1%	Regular 60%	Regular 49%
-	Others*	Carrots of the garis 9%	Good 10%	Good 1%

\*Refers to collection two (2) to three times per week

Source: PMM (2013).

**4.2 DATA OF THE PURAQUEQUARA DISTRICT**

In the year 2013, PMM also surveyed the area of the Puraquequara neighborhood on the situation of basic

sanitation, the information is found in Tables 4, 5 and 6 below.

*Table 4 - Water supply system in the Puraquequara neighborhood – Manaus*

Water supply system	Rating of the service provided	Main complaint of the service	Distribution network pressure	Does water analysis in the residence	The depth of the well	Water-borne diseases
Public	Bad	Quality	Strong	Yes	15 m	Yes

network 72.13%	46.44%	50.45%	54.00%	0%	20.00%	61,56%
Alternative source 21.03%	Regular 34.56%	Lack of water 43.57%	Poor 46.00%	No 100%	20 m 45.00%	No 38.44%
Public and Well Network 7.65%	Good 19.00%	Quality and lack of water 5.98%	-	-	Others 35.00%	-

Source: PMM (2013).

Table 5 - Sewage system in the Puraquequara neighborhood – Manaus

Type of Exhaustion System	Individual system, Treatment type	Problems with the pit
Collective 0%	Septic tank 45.00%	There is not 48,89%
Single 100%	Sink 55.00%	Bad smell 51.11%
-	Others 0%	Others 0%

Source: PMM (2013).

Table 6 - Solid Waste System in the Puraquequara neighborhood - Manaus, according to the diagnosis of the area carried out by PMM

There is solid waste collection	Frequency of collection	Transportation that carries out the collection	Collection Classification	Quality of Public Cleaning
Yes 95%	Frequency of collection Daily 100%	Truck compactor 85%	Bad 40%	Bad 60%
No 5%	Weekly 0%	Dump Truck 10%	Regular 45%	Regular 35%
-	Others*	Carrots of the garis 5%	Good 15%	Good 5%

\*Refers to collection two (2) to three times per week

Source: PMM (2013).

## V. MODELING FUZZY LOGIC

For the fuzzy logic modeling, InFuzzy software was used, where it allowed all modeling, rule definition and simulation to occur to obtain the basic sanitation quality of the neighborhoods Colônia Antônio Aleixo and Puraquequara, both in the city of Manaus.

Following is the initial screen of the software used to make the whole process using the artificial intelligence technique called fuzzy logic.

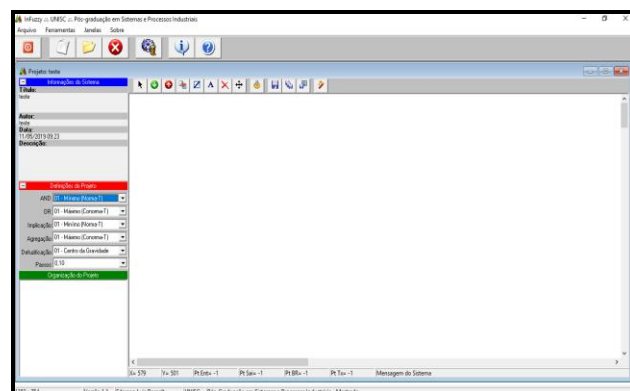


Fig.1 - InFuzzy software environment

Source: Authors (2019).

### 5.1 STRUCTURAL MODELING

Following is the initial modeling with its entire structure, such as the four input variables indicated by a



green background color, the rule engine that is responsible for the conditions of comparisons to generate the result in the output variable, such rule engine is indicated by the yellow background color, and put an end to the output variable indicated by the red background color.

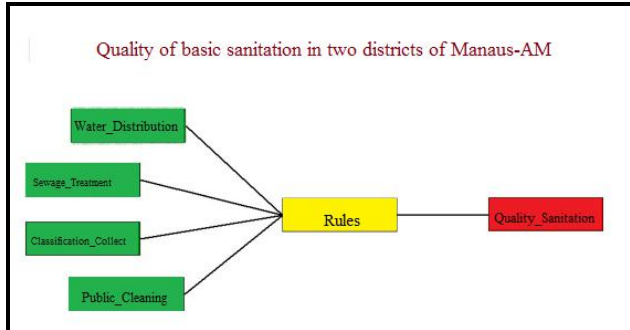


Fig.2 - Structural modeling

Source: Authors (2019).

## V.II. VARIABLES OF ENTRY

Based on the data from the tables presented previously, four fields were used to serve as input variables:

- Classification of the service provided (Table 1 and 2).
- Individual system, type of treatment (Table 3 and 4).
- Classification of the collection (Table 5 and 6).
- Quality of public cleaning (Table 5 and 6).

The following are the graphs of all input variables used, where the blue color symbolizes the poor condition, red the bad condition, green represents regular and purple means good.

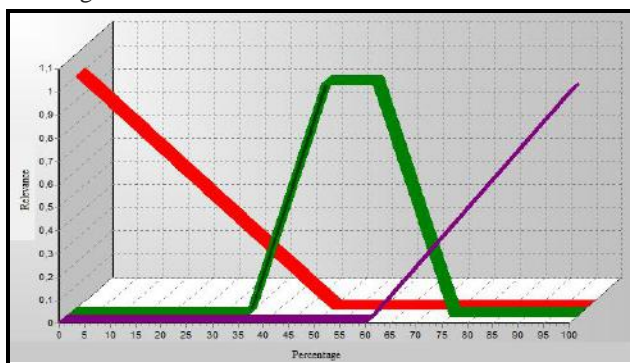


Fig.3 - Variable classification of the service provided

Source: Authors (2019).

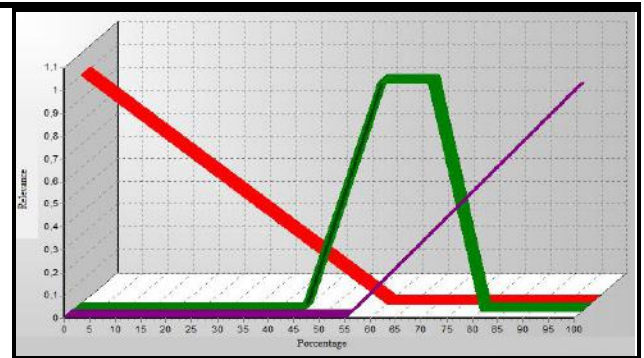


Fig.4 - Individual system variable, type of treatment

Source: Authors (2019).

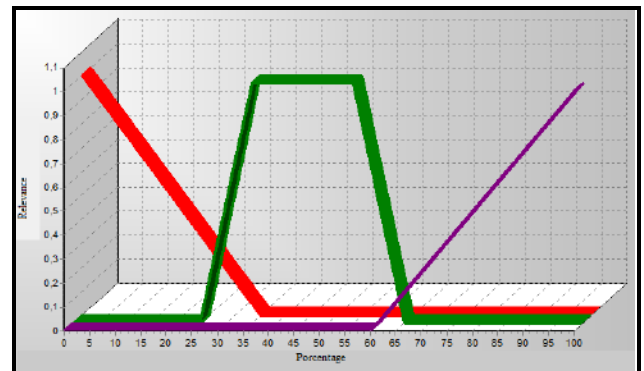


Fig.5 - Collect classification variable

Source: Authors (2019).

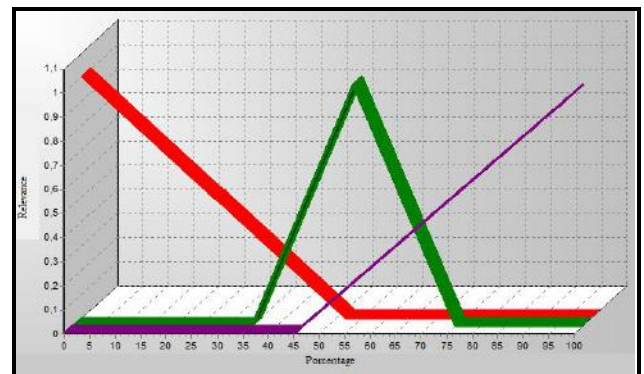


Fig.6 - Variable quality of public cleaning

Source: Authors (2019).

## 5.3 OUTPUT VARIABLE

The output variable represents the satisfaction of the quality of basic sanitation in the neighborhood, where the inserted rules and the input variables have a direct impact on the final result, as well as the pertinence functions used in the modeling of the variables.

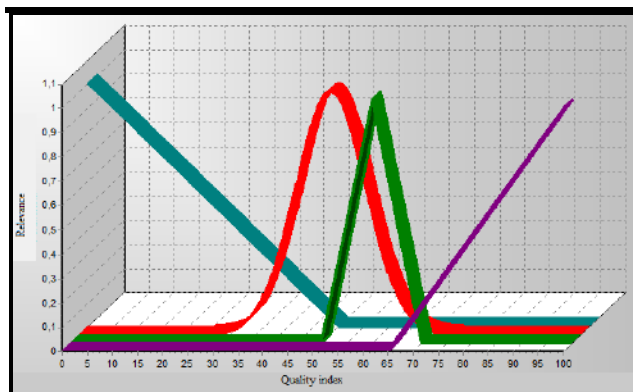


Fig.7 - Output variable (quality of basic sanitation)

Source: Authors (2019).

## VI RESULTS OF DEFUZZIFICATION

In the simulation process the data used for the Colonia Antônio Aleixo neighborhood were indicated in the table below. An important observation to be made is that the data used are the ones with the highest percentage, except the one corresponding to the "Individual system, type of treatment", since the septic tank is more pleasant than the sink, percentage in this case, both for the table below, as for the Puraquequara neighborhood table.

Table.7 - Data used in the Fuzzy Logic (Colônia Antônio Aleixo)

Classification of service provided (Water supply)	45.14
Individual system, type of treatment (Sewage treatment)	35.00
Classification of collection (Waste collection)	60.00
Quality of public cleaning (Garbage collection)	50.00

Source: PMM (2013) adapted by the authors.

The defuzzification is nothing more than the result of all logic, where the graph shown below is the simulation made of the quality of basic sanitation in the neighborhood Colonia Antônio Aleixo.

By analyzing the graph below, observing the quality index obtained, it is noticed that the degree of satisfaction regarding the quality of basic sanitation is poor.

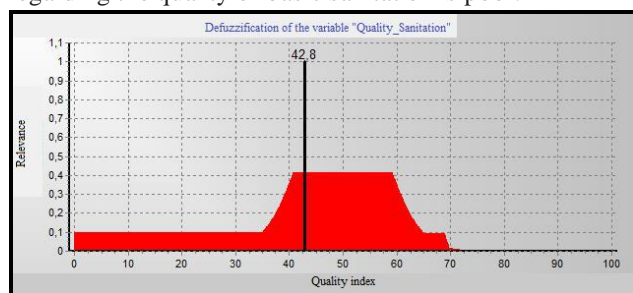


Fig 8 - Defuzzification of the neighborhood Colônia Antônio Aleixo

Source: Authors (2019).

In the Puraquequara neighborhood, the data used for the simulation were the following in the table below.

Table.8 - Data used in the Fuzzy Logic (Puraquequara)

Classification of service provided (Water supply)	46.44
Individual system, type of treatment (Sewage treatment)	45.00
Classification of collection (Waste collection)	45.00
Quality of public cleaning (Garbage collection)	40.00

Source: PMM (2013) adapted by the authors.

Below is a graph of the defuzzification of the Puraquequara neighborhood, where it can be observed that the satisfaction of the quality index of basic sanitation in this neighborhood of Manaus, which is classified as very bad.



Fig.9 - Defuzzification of the Puraquequara neighborhood

Source: Authors (2019).

## VII CONCLUSION

The monographic essay had the specific objectives achieved and evidently the general objective as well.

The first stage of data collection was done through the PMM survey in the districts of Manaus, where the data were extremely important for the development of this course completion work.

The definition of the fuzzy logic modeling was done in an exquisite way, using reliable input variables and establishing agreement with the data taken from the tables.

The definition of the modeling was done and the results obtained with an artificial intelligence technique enabled, through some data, to generate another very important data, which is the quality of basic sanitation in the neighborhoods analyzed during all the work presented, with a final response to poor quality in the neighborhood Puraquequara and bad index in the neighborhood Colonia Antônio Aleixo.

Thus, it was evidenced that in the chaos of the advances the existence of the PMM of a specific diagnosis of the neighborhood in question can foment specific actions in the area of sanitation for the

neighborhood. Regarding the challenges, it is up to the PMM to verify the conditionalities and specificities of the neighborhood so that it has different treatment in the application of the plan. Vulnerabilities are many, mainly in the distribution of water that only reaches 67% of the population. In the sewer network the drama is bigger. With this, the Antônio Aleixo Colony neighborhood has been the same as in many other neighborhoods located on the river banks; the discharge of sanitary sewage into the river caused mainly by invasions of areas on the slopes of the river which constitute one of the main environmental problems of the locality and, consequently, a great challenge for the environmental organs of the public power, because a deep intervention with significant costs to public budgets and the degradation of the exuberant landscape that could become a huge tourist attraction.

The importance of the action of environmental agencies could start from the diagnosis of the problem, propose an alternative solution from the discussion with those involved (the residents) and apply the solution discussed closing the sanitation cycle of the region.

For the permanent process in which individuals and communities become aware of their environment and acquire new knowledge, values, skills and experience are crucial to their ability to act and solve environmental problems, present and future.

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