The Municipal Sanitation Plan for the City of Belo Horizonte

Le plan d'assainissement de la ville de Belo Horizonte

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RÉSUMÉ

Le Plan d'Assainissement de la ville de Belo Horizonte, au Brésil, est un outil du Système Municipal d'Assainissement et a été officialisé par l'adoption de la loi 8.260 du 3 décembre 2001, qui a créé la Politique Municipale d'Assainissement. Cet article présente le processus de création du plan, les indicateurs sectoriels et les critères de priorité des investissements pour la municipalité. Ce papier cherche à amplifier la discussion sur l'importance pour les villes de développer des plans d'assainissement selon la loi fédérale 11.445/07.

ABSTRACT

Belo Horizonte Municipal Sanitation Plan is one of the instruments of the Municipal Sanitation System and was institutionalized upon approval of Law 8.260, of December 3, 2001, which created the Municipal Sanitation Policy. This article intends to introduce the Plan formulation process, as well as the sectoral indicators and the investment priority criteria for the Municipality. Besides that, it seeks to expand the discussion about how important it is for the municipalities to develop their Plans as provided for by Federal Law 11.445/07.

KEYWORDS

Decision making indicators, Law of the National Guidelines for Basic Sanitation (Federal Law 11.445/07), Municipal Sanitation Plan

1 INTRODUCTION

The Municipality of Belo Horizonte presents high rates of sanitation services when compared to the national reality. On the other hand, the situation is not considered satisfactory, since approximately 10 thousand people do not receive treated water yet, 220 thousand do not have their sewage collected, 110 thousand do not have their waste collected, 45 thousand people live in areas subject to landsliding or flood risk, and our environmental reality corresponds to polluted streams and channels.

The Municipal Sanitation Policy was conceived relying on a prospective change to the sectoral, stagnant approach traditionally used to plan and implement sanitation actions and services. The implementation of the Municipal Sanitation Policy, institutionalized by Law 8.260, of December 3, 2001, was one more essential step in the pursuit of the universalization of the environmental sanitation actions and services in the Municipality, having Belo Horizonte Municipal Sanitation Plan (MSP) as one of its instruments.

The Municipal Sanitation Fund – MSF, another instrument composing the System, also created by the same law and later enforced by Decree 11.289, of March 24, 2003, "of accounting nature and with administrative and financial autonomy" is intended for "financing, in an isolated, complementary manner, the instruments of the Municipal Sanitation Policy which programs have been approved by Comusa - Municipal Sanitation Council".

According to the Law, "the Municipal Sanitation Plan is the only suitable disciplinal instrument for application of the Municipal Sanitation Fund's financial resources", and any other destinations are forbidden.

The MSP, quadrennial and updated every two years, intends to establish a local, integrated management system for the environmental sanitation actions and services by means of sanitary, epidemiological and environmental indicators.

2 METHODS

The preparation of the MSP required the definition of a methodology able to diagnose satisfactorily the environmental sanitation scenario in Belo Horizonte and propose actions to be implemented with the purpose of pursuing a gradual, overall solution to the needs of these services.

Firstly and with the purpose of subsidizing the knowledge of the sanitation services in the Municipality, sectoral diagnoses have been prepared based on the data and information available in the several agencies of the Municipal Administration and in the water and sewage concessionaire. Besides these diagnoses, a summary of the priority plans and programs of the Municipal Executive Power has been prepared including the sanitation component, thus allowing a more comprehensive analysis of the municipal reality.

Aiming at a more detailed assessment which allows comparative evaluations of the several realities of the environmental scenario in the Municipality, the elementary subbasins and elementary basins have been defined as territorial analysis units, according to Belo Horizonte Drainage Master Plan.

Both the sectoral indicators and indices and Environmental Health Index (EHI) itself assumed a theoretical variation from zero to one; the closer to the unit, the better is the support provided by a certain action or service, the lesser is the need, the lower is the sanitary risks, and/or more environmentally healthy is the evaluated region.

This way, a comparative analysis was established, expressed by EHI numbers and the "environmental health" among the 98 elementary basins and the 256 subbasins forming the territory of the Municipality.

After obtaining the sectoral indicator and index values and the EHI numbers, the conclusion was that it was necessary to add other aspects to the analysis of priorities of these planning units. It was realized that the pure and simple analysis of the aspects associated with the presence of sanitation services and infrastructure was insufficient for a more coherent definition of the investment priorities.

The second version of the MSP (2008/2011), published in the year of 2008, was guided by four priority axes:

- Environmental Health Index – EHI;
- Demographic density;
- The percentage of population in villages and slums;
- The diarrhea rate in 0-to-5-year-old children.

This latter axis represents a great advance, as it aggregates epidemiological criterion, as established in Federal Law 11.445/07. Besides that, this version has achieved methodological gains regarding the definition of the weights of each indicator and the priority criteria; the creation of a new Drainage Index; the change in the Dengue Indicator; and the establishment of targets for sanitary sewage and garbage collection.

2.1 The Environmental Health Index – EHI

Regarding the definition of the several weights adopted for the sectoral indicators and indices, for the EHI and for the priority criteria of the basins and subbasins, the Hierarchical Analysis Method described below was used. The EHI assumed the following formulation in this second version of the MSP:

EHI = [Iab] x 0.05 + [Ies] x 0.35 + [Irs] x 0.25 + [Idr] x 0.20 + [Icv] x 0.15

Where:

Iab: Water Supply Index

Ies: Sanitary Sewage Index

Irs: Solid Waste Index

Idr: Urban Drainage Index

Icv: Vector Control Index

2.1.1 Water Supply Index (Iab)

The water supply index is represented by the coverage of these services, according to the following equation:

$$\mathbf{Iab} = \frac{\mathbf{Paa}}{\mathbf{Pt}}$$

Where:

Paa: Population of the area at issue provided with water supply

Pt: Total population of the area at issue

The water supply index was admitted as equal to the unit, in view of the current situation of almost universalization of the services. Almost all the population of Belo Horizonte is presently served by the public water supply system, with satisfactory quality and quantity. The areas still subject to intermittence are residual, and those not provided with this service correspond to invaded areas subject to some type of risk.

2.1.2 Sanitary Sewage Index (Ies)

The Sanitary Sewage Index (Ies) is expressed by the composition of the sewage collection indicators (Ice) and sewer collector indicators (Iie), according to the equation below:

$$\mathbf{Ies} = \mathbf{0.40} \times \mathbf{Ice} + \mathbf{0.60} \times \mathbf{Iie}$$

Where:

Ice: Sewage collection indicator

Iie: Sewer collector indicator

Which is:

Sewage collection indicator (Ice)

Expressed by the relation between the population provided with sewage officially connected with the public sewage collection system in a certain area and the total population of the area at issue, as follows.

$$\mathbf{Ice} = \frac{\mathbf{Pae}}{\mathbf{Pt}}$$

Where:

Pae: Population of the area at issue provided with sewage collection

Pt: Total population of the area at issue

Sewer collector indicator (Iie)

Expressed by the relation between the length of sewer collectors implemented in a certain area and the required total length of sewer collectors (existing + estimated) in the area at issue, according to the equation below.

$$\mathbf{Iie} = \frac{\mathbf{Lie}}{\mathbf{Lti}}$$

Where:

Lie: Length of the sewer collectors existing in the area at issue

Lti: Total length of required sewer collectors (existing + estimated) in the area at issue

2.1.3 Solid Waste Index (Irs)

The solid waste index is represented by a single indicator, which expresses the coverage of the residential garbage collection services (Garbage collection indicator – Icl). The garbage collection indicator is expressed by the population provided with door-to-door garbage collection services with relation to the total population of the area at issue, according to the following equation:

$$\mathbf{Irs} = \mathbf{Icl} = \frac{\mathbf{Pcl}}{\mathbf{Pt}}$$

Where:

Pcl: Population of the area at issue provided with door-to-door garbage collection service

Pt: Total population of the area at issue

2.1.4 Drainage Index (Idr)

The drainage index, formerly given little importance due to its fragility, has been changed regarding the reliability of the primary data that generate it. The generated drainage index associates the following aspects:

- Insufficiency of the implemented system due to the increased urbanization and lack of planning in the execution of the works and projects;
- Existence of populations living on the banks of streams, which often occupy fully the chute of streams and where the public power has not made interventions.

Regarding the implemented macrodrainage system, the paper completed in 2008 and named "Mathematical, Hydrological and Hydraulic Modeling of the Macrodrainage System of the Arrudas and Onça River Basins" was used, which is part of the 2nd Phase of Belo Horizonte Drainage Master Plan. Cabc hydrological model and Cliv hydraulic model, developed by Fundação Centro Tecnológico de Hidráulica – FCTH and Escola Politécnica of USP, were employed in this paper, thus allowing the identification of the insufficiency of each channeled section for the flow rates in several recurrence times.

The Drainage Index (Idr) is expressed by the composition of the sufficiency indicators of the existing macrodrainage system (Isdr) and indicator of support by the macrodrainage system (Iadr), according to the following equation:

$$\mathbf{Idr} = \left[(\mathbf{0.50} \times \mathbf{Isdr}) + (\mathbf{0.50} \times \mathbf{Iadr})\right]$$

Where:

Isdr: Sufficiency indicator of the existing macrodrainage system

Iadr: Indicator of support by the macrodrainage system

Which is:

Sufficiency indicator of the existing macrodrainage system (Isdr)

Expressed by the overflowing length on the channeled stream, for the design recurrence time (Tr), by the total length of channeled streams in the area at issue, deducted from the unit, as follows:

$$\mathbf{Isdr} = \mathbf{1} - \frac{\mathbf{Lex}}{\mathbf{Ltc}}$$

Where:

Lex: Overflowing length on the channeled stream for design Tr

Ltc: Total length of channeled streams in the area at issue

Indicator of support by the macrodrainage system (Iadr)

Expressed by the length of the necessary interventions on the untreated stream, by the total length of untreated streams in the area at issue, deducted from the unit.

$$\mathbf{Iadr} = \mathbf{1} - \frac{\mathbf{Lin}}{\mathbf{Lts}}$$

Where:

Lin: Length of the necessary interventions on the untreated stream

Lts: Total length of untreated streams in the area at issue

2.1.5 Vector Control Index (Icv)

It is essential to include an index that can not only insert the vector control issue in the evaluation of the environmental health in Belo Horizonte, but also enable a work methodology that can definitely approach the sanitation and health sectors, aiming at the planning and execution of integrated actions.

According to the conclusion come, dengue would be the best example, not only because of the direct association with other issues, such as solid waste and urban drainage, and relevance of the levels of occurrence of the disease, but also because of the reliable and updated available data.

The vector control index is represented by a single indicator: the Dengue Indicator (Idg), which was developed from the Egg Density Index (IDO), made available by the Municipal Secretariat of Health for the year of 2007.

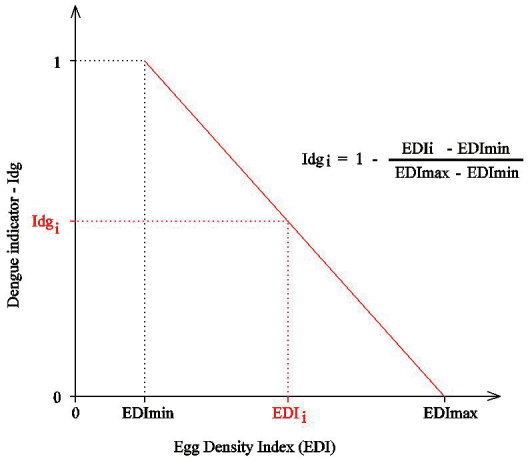
In order to verify and quantify the presence of the dengue vector in the Municipality, the Municipal Secretariat of Health has laid several egg traps throughout the municipal territory. These traps, known as ovitrampas, are examined weekly to check the presence of the vector by the laying of eggs.

The Egg Density Index (EDI) is expressed by the total number of eggs found in an ovitrampa, divided by the number of collection weeks on which eggs were found (positive weeks).

The use of indicators for the creation of other indicators generally requires different measures to be turned into a common scale.

The methodology used in this paper for standardization of the indicators was based on the normalization method (Ott, 1978). The mathematical procedure to calculate the standardized indicators is started from the unification of the scales, that is, the Egg Density Indices for each basin or subbasin are turned into a scale ranging from 0 to 1, resulting in the Dengue Indicator. It is worth of mention that, for this paper, an average value was calculated for all Egg Density Index values in a same area (basin and subbasin), and each basin or subbasin was assigned a single Egg Density Index.

In the data set, the minimum Egg Density Index value (lower density of eggs) corresponds to a dengue indicator equal to 1 (area with the best situation). On the other hand, the maximum Egg Density Index value (higher density of eggs) is assigned a dengue indicator equal to 0 (area with the worst situation). The methodology adopted to calculate the dengue indicator is shown in the figure below.



Procedure to calculate the dengue indicator, according to Ott's normalization method (1978).

After definition of the sectoral indicators and indices related to the five aspects of the environmental sanitation, the EHI was formulated for each elementary basin and each subbasin. The higher the value resulting from the sum of the sectoral indices, the lower the need for sanitation services and, therefore, the higher the EHI.

For the definition of priorities of investments, the Environmental Health Index was given a 40% weight. Grade 40 was adopted for the basin/subbasin with the lowest EHI and proportional grades were assigned to the other basins/subbasins.

2.2 Populational Density

After definition of the EHI values for the basins and subbasins, it was observed that, in some cases, the lowest EHI values corresponded to areas lacking sanitation services, but with low populational density, which did not justify an immediate action with priority of investments. After this sanitary need was identified, it was concluded that a cost-benefit analysis indicating the comprehensiveness of the action was required, for which reason the populational density was incorporated as a second axis in the final definition of priorities of investments.

For the definition of priorities of investments, a 15% weight was assigned to the density of the basin or subbasin. Grade 15 was given to the territorial unit with the highest demographic density, and proportional grades were given to the other units.

2.3 The percentage of population residing in villages and slums

The third analysis axis corresponded to the percentage of population of the basin or subbasin residing in villages and slums with relation to the total population of the territorial unit, aiming at privileging the neediest areas of the city.

As the weight assigned to this criterion was 25%, the basin/subbasin with the highest percentage of population residing in villages and slums was given the highest grade (25), and proportional grades were given to the other territorial units.

2.4 The hospitalization rate due to diarrhea in the 0-to-5-year-old population

At last, the forth axis incorporated into the definition of priorities was the hospitalization rate due to diarrhea in the 0-to-5-year-old population per territorial unit, in order to add an epidemiological criterion to the analysis, according to guidelines provided for in the National Sanitation Policy.

The diarrhea rate is given by the following equation:

$$\mathbf{TXD} = \frac{\mathbf{Pi}_{\mathbf{0-5}}}{\mathbf{Pt}_{\mathbf{0-5}}}$$

Where:

TXD: Hospitalization rate due to diarrhea in the 0-to-5-year-old population in the area at issue

Pi 0-5: 0-to-5-year-old population hospitalized because of diarrhea in the area at issue

Pt 0-5: Total 0-to-5-year-old population in the area at issue

This criterion was assigned a 20% weight. Grade 20 was given to the basin or subbasin with the highest hospitalization rate, and proportional grades were given to the other basins or subbasins.

In summary, the criteria applied for hierarchization of the basins and subbasins, as previously said, consist of the sum of the several grades given to the EHI, to the populational density, to the proportion of population living in villages and slums, and to the hospitalization rate due to diarrhea in the 0-to-5-year-old population.

The area priority criteria in the MSP 2008/2011, for purposes of investments in sanitation services and infrastructure, are, therefore, as follows:

- Lower EHI;
- Higher demographic density;
- Higher percentage of population residing in villages and slums;
- Higher hospitalization rate due to diarrhea in the 0-to-5-year-old population.

The final priority grade corresponds to the sum of all these grades, according to the equation below, and the maximum value is 100.

NOTPRIOR = (NOTISA) + (NOTDENS) + (NOTPOPVI) + (NOTTXD)

Where:

NOTPRIOR: Priority grade (0 to 100)

NOTISA: EHI Grade (0 to 40)

NOTDENS: Grade for demographic density (0 to 15)

NOTPOPVI: Grade for the percentage of population residing in villages and slums (0 to 25)

NOTTXD: Grade for the hospitalization rate due to diarrhea in the 0-to-5-year-old population (0 to 20).

As previously mentioned, the methodology proposed in the MSP for prioritization of investments in the sanitation sector in Belo Horizonte requires the assignment of weights to the several indicators, indices and variables. The Hierarchical Analysis Method (Zambon et al., 2005, and Ceolim, 2005) was

used for definition of these weights in the MSP 2008/2011.

The pair-to-pair comparison method provides a weight vector that expresses the relative importance of the several elements. It deals with a n x n square, pair-to-pair comparison matrix where the rows and columns correspond to the n criteria analyzed for the problem at issue.

The measurement of the judgments can be made by using a three-value scale: more important (+), equal importance (0) or less important (-). As this matrix is reciprocal, only the lower triangular half needs to be evaluated, since the other half derives from this, and the main diagonal assumes values equal to 0 (Zambon et al., 2005, and Ceolim, 2005).

For definition of the weights of the several indicators, indices and prioritization criteria in the MSP 2008/2011, spreadsheets with the criteria to be analyzed have been sent to fifty-eight (58) specialists in sanitation and related segments.

The table below presents the results of the research made for definition of the weights of the several indicators.

INDEX		WEIGHT	SUBINDEX		PERCENTAGE
Iab	Water	0.05	Non-existing		-
Ies	Sewage	0.35	Ice	Collection	0.40
			Iie	Sewer collector	0.60
Irs	Solid waste	0.25	Non-existing		-
Idr	Drainage	0.20	Isdr	Sufficiency	0.50
			Iadr	Provision	0.50
Icv	Vector control	0.15	Non-existing		-

Comparison of the weights of the several indices and subindices

3 RESULTS AND DISCUSSION

3.1 Hierarchization of the river basins

The results achieved from the preparation and implementation of the MSP refer to the capacity this instrument has to evaluate and characterize the environmental health of the Municipality by means of sanitary and epidemiological criteria and indicators.

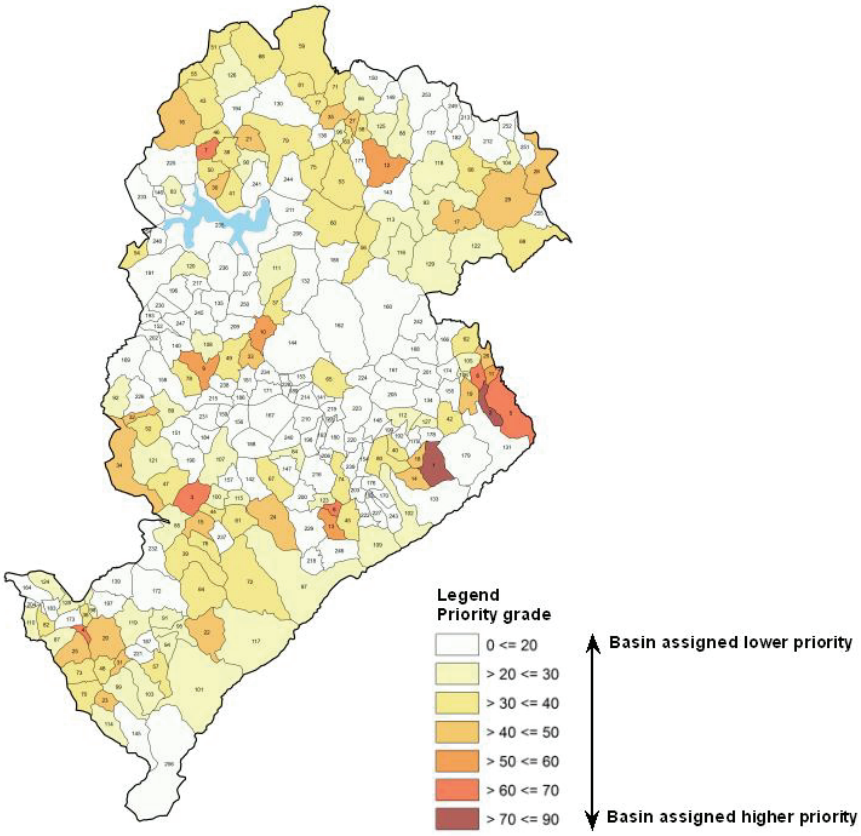
Besides that, the Plan allows the hierarchization of the 256 river basins of the Municipality, indicating the areas which demand higher investments in sanitation. So, the MSP is today an important instrument to guide the investments in the Municipality, besides facilitating the pursuit of resources from financing agencies.

The table below shows the evolution of the several sectoral indices and indicators for the Municipality of Belo Horizonte in the three versions of the Plan.

MSP	Iab	Ice	Iie	Ies	Icl	Iadr	Isdr	Idr	Idg	EHI
2004/2008	1.00	0.86	0.59	0.77	0.95	-	-	0.99	0.61	0.84
2006 (update)	1.00	0.90	0.61	0.80	0.95	-	-	0.99	0.91	0.88
2008/2011	1.00	0.89	0.67	0.76	0.95	0.90	0.86	0.88	0.79	0.85

Evolution of the several sectoral indices and indicators in the three versions of the Plan

The Figure below presents the subbasin prioritization map according to a methodology proposed for the MSP 2008/2011.



Prioritization of the subbasins by the MSP 2008/2011

The results show that the sewage collection index (Ice) was improved between 2004 and 2006, as well as the sanitary sewage index (Ies). However, in the latest version of the Plan, the Ice was slightly reduced in comparison to 2006 because of the stricter definition of the areas unprovided with sewage collection, which is based on the record provided by the concessionaire of this service. The Ies was reduced for the same reason. The sewer collector index (Iie) reflected the investments the Municipality has been making, together with the concessionaire, in the areas lacking this service, which was increased from 0.59 to 0.67 between 2004 and 2008.

The garbage collection index (Icl) was kept stable over the years. This situation can be explained by the characteristics of the areas unprovided with this service, mostly villages and slums. These areas are generally very steep and present a complex highway system. So, although the interventions proposed for the villages and slums present considerable urbanistic changes, they do not contribute much to the conditions required for the expansion of the door-to-door residential garbage collection, with little impact on the Icl values. This service provision reaches a very high index in the regular urbanization areas of the city, being deficient only on some very steep streets and on unpaved streets or without exit on the outskirts of the city.

The drainage index (Idr) was reduced because of the change in its methodology, as previously mentioned, which included the creation of subindices (Iadr and Isdr).

Between 2004 and 2006, the dengue indicator (Idg) was increased from 0.61 to 0.91. In 2008, this value was 0.79, although it is worth of mention that it was based on the amount of larvae found in the several traps spread throughout the municipal territory, while the two former values were achieved from the number of cases of the disease.

The changes described over the work methodology and previously discussed were responsible for the achievement of an EHI equal to 0.85 in 2008, a value lower than that achieved in 2006 (0.88). It is worth of mention that the formulation of the indices/indicators has been responsible for the non-comparability of the results, as well as the change to the weights. But, in spite of that, the quality of the indicators has been significantly improved. The results achieved by the MSP 2008/2011 showed a tendency of improvement of the environmental health in Belo Horizonte, which can be reinforced by the existence of a large number of programs being developed for that purpose.

3.2 Establishment of goals for 2011

The MSP 2008/2011 presented as one of its advances the establishment of goals for expansion of the coverage of these garbage collection and sewer collector services. The introduction of this item in the MSP 2008/2011 is in conformity with the provisions of Municipal Law 8.260, which implemented the Municipal Sanitation Policy and established in its article 21 that the Municipal Sanitation Plan should include short- and medium-term goals. It is worth of mention that this requirement precedes Federal Law 11.445, which establishes, in its article 19, that the municipal sanitation plans shall comprise, among other items, short-, medium- and long-term objectives and goals for universalization of the basic sanitation services, assuming gradual and progressive solutions compatible with the other sectoral plans.

Aware that to minimize the deficiency of the sanitation services it is essential to implement integrated structural actions involving urbanistic and environmental aspects and the participation of the several agencies associated with this issue, the programs, projects and actions that have been implemented by Belo Horizonte City Administration and by the concessionaire of the services, and which resources are already ensured, have been taken into consideration for the establishment of goals for expansion of these services for the 2008-2011 period. The table below presents the goals established for expansion of the coverage of these garbage collection and sewer collector services.

Index/Indicator		**2008**	**2011**
Sanitary Sewage	Ice	0.89	0.92
	Iie	0.67	0.86
	Ies	0.76	0.88
Solid Waste	Icl	0.95	0.96
Environmental Health Index – EHI		**0.85**	**0.89**

Comparison between the present situation and the goals established for 2011

4 CONCLUSIONS

In spite of preceding Federal Law 11.445, Belo Horizonte Municipal Sanitation Plan, certainly a pioneer initiative in our country, is in conformity with its guidelines, incorporating a planning method unprecedented in Brazilian capital cities. The MSP is, in fact, an absolutely dynamic process for planning of the sanitation actions and services in the Municipality.

Thus, the management of sanitation in Belo Horizonte is accomplished through the systematic production and publicity of current, reliable data and information, the consequent generation of sectorial indices and indicators that reflect the local reality and the guarantee of social control and popular participation.

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